RESPONSE OF MANGO (*Mangifera indica* L.) TO CHEMICAL REGULATORS UNDER HIGH DENSITY PLANTING SYSTEM

by

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(2018-12-008)

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
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KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, associate ship, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis **"Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system"** is a record of research work done independently by **Ms. Anju Jayachandran (2018- 12-008)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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We, the under signed members of advisory committee of **Ms. Anju Jayachandran (2018-12-008),** a candidate for the degree of **Master of Science in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system"** may be submitted by **Ms. Anju Jayachandran (2018-12-008),** in partial fulfilment of the requirement for the degree.

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Dedicated to my family and teachers

Introduction

1. INTRODUCTION

Mango (*Mangifera indica* L.), a member of family Anacardiaceae, is amongst the most important fruit crop of India and has been in cultivation in the Indian subcontinent since time immemorial. It is the most acclaimed fruit of India and is considered as the 'National Fruit of India'. The fruit is highly regarded its outstanding flavour, excellent aroma, good taste, desirable colour shades and nutritional value that has attracted the global market. India is the largest producer of mango in the world occupying an area of 22.58 lakh ha with an annual production of 218.22 lakh MT and the average productivity being 9.7 MT/ha (DACFW, 2018).

Mango is not considered as a commercial crop of Kerala, but mango are an inevitable component of every homesteads of Kerala. The total estimated area under mango cultivation in Kerala is 83.12 thousand ha with an annual production of 439.20 T and the average productivity comes to around 5.28 t/ha (DACFW, 2018). Palakkad has the highest area (9942.00 ha) under mango cultivation in Kerala (AGRISTAT, 2018). Low productivity of mango in the state is primarily due to the use of low yielding traditional varieties, poor orchard management practices, irregularity/bienniality of flowering, inadequate technology up gradation, beside the prevalence of climatic conditions, fragmented land holdings, pest and disease *etc*.

Many commercial orchards of mango are being established in Muthalamada panchayat of Palakkad district, which is one of the largest mango production centres in the country, now known as Mango city of Kerala. The mango orchards in Muthalamada takes up nearly 3500 hectares of area with an annual production of 45000 MT and average productivity of 85 t/ha. The hot and humid climatic condition of this area is highly favourable for mango cultivation. The town exports nearly Rs. 200 crore worth mango varieties a year. Muthalamada alone contributes 60 per cent of mango production in Kerala. The main varieties exported include Alphonso, Banganapalli, Sindhuram, Nadashala, Muvandan, Bangalora, Imampasand, Neelum and Prior. These varieties have a great demand in the markets of major cities like

Mumbai, Kolkata, Delhi, Chennai and also in the Gulf countries. The main feature of Muthalamada mango is its earliness, which helps to fetch very high price for the produce due to the huge demand for the fruits in the main markets in other parts of the country.

As in any other crop, process of flowering plays a vital role in mango productivity. The complex pattern of mango flowering is still a great concern to researchers. The nature of irregular/ alternate bearing in mango is one of the major reason for poor yields. Adoption of high density planting makes maximum use of land by accommodation more number of plants per unit area by facilitating easy cultural practices leading to higher productivity by the maintenance of tree size when compared to conventional planting system. Crop regulation through chemicals and plant growth regulators along with the adoption of high density planting system have shown promising results in overcoming irregularity in bearing and thereby improving productivity of mango (Tripathi *et al*., 2006).

Paclobutrazol (PBZ), a triazole derivative is being widely used nowadays for regularity and synchronization in flowering, yield enhancement and for retarding vegetative growth. On the other hand, indiscriminate soil application of this can cause environmental contamination. The residual effect of PBZ can alter the microbial population balance and levels of soil fertility. It is also highly expensive for a normal farmer. There are chemicals such as ethephon, KNO_3 and salicylic acid that have proved effective for the induction of flowering in mango.

The major issues of Muthalamada mango is the indiscriminate use of growth regulators for induction of flowering along with the excessive application of plant protection chemicals for the control of pests like mango hoppers and thrips. Farmers have realized the importance of high density planting system only in the recent past. But they are unaware of the application of growth regulators under HDP system.

In this context, the present study was undertaken in Muthalamada with an objective to evaluate the response of different mango varieties to chemical regulators under high density planting system in the agro climatic conditions of Muthalamada in Palakkad district of Kerala.

Review of Literature

2. REVIEW OF LITERATURE

The complex pattern of mango flowering is of great concern to researchers. The works on mango flowering physiology are still a large area to be explored. The main reasons for low productivity of mango orchards is due to variety of reasons namely the use of low yielding traditional varieties, poor orchard management practices, irregularity/bienniality of flowering, inadequate technology up gradation, beside the prevalence of climatic conditions, fragmented land holdings, pest and disease *etc*.

Irregular or alternate bearing in mango is a serious malady leading to poor yields. Crop regulation is an important cultural practice for mango productivity improvement (Randeep, 2012). Several chemicals such as KNO_3, salicylic acid and plant growth regulators like paclobutrazol (PBZ) and ethephon have been proved effective for the induction of flowering in mango along with adoption of modern approaches of canopy management like high density planting and pruning (Kumar, 2003). Such strategies can help to suppress the vegetative stage leading to advanced blooming, prolonged flowering cycles and quality fruit production.

The work done so far with respect to the response of various chemicals and plant growth regulators on flowering and fruiting in mango varieties grown under high density planting system is reviewed hereunder. Research carried out in other crops has also been reviewed for better clarity at appropriate places in the text. It has been divided under the following heads:

2.1. Effect of paclobutrazol on flowering

The paclobutrazol (PBZ) is a substituted triazole that reduces the vegetative growth by inhibiting gibberellin biosynthesis in plants at kaurene stage and stimulates flower development (Rademacher, 1986).

Kulkarni (1988) reported that PBZ given at 10 g a.i. per tree flowered six to eight weeks earlier in two mango cultivars Dashehari and Banganapalli under Indian conditions.

Burondkar and Gunjate (1991) observed that soil treated trees with paclobutrazol significantly suppressed the vegetative growth, increased the number of bisexual flowers and induced early flowering in two cropping seasons in Alphonso mango than foliar treated trees.

Soil application of PBZ on mangoes at the rate of 6g/tree in July resulted in higher flowering percentage as compared with untreated trees (Tongumpai *et al*., 1991). Paclobutrazol treated trees were found to have smaller canopies with reduced internodal length and induced very profuse flowering (Charnvichit and Tongumpai, 1991).

According to Winston (1992), soil application of PBZ were found to be more effective on flowering and cropping than foliar application and treatments with collar drench more effective than drip line. He reported again that there was an unacceptable compaction of flower panicles at rates greater than 4 ml a.i. per tree of PBZ.

According to Kurian and Iyer (1993), the application of PBZ as soil drench at the rate of 10g / tree narrowed down the sex ratio in Alphonso mango.

Eduard and Oded (1994) studied the effect of PBZ on grafted and auto grafted (grafted on their own stem) seedlings of mango cultivars '13-1' and 'Peach' and found that 64 per cent of non-grafted and 31 per cent of auto grafted seedlings flowered at 20 mg of PBZ per plant. They also reported a reduction in inflorescence size (approximately 4-10 cm) with increased rate of PBZ application.

Tongumpai *et al*. (1997) reported that single and multiple foliar application of paclobutrazol at 1000 and 2000 ppm to mango tree were effective in promoting early and uniform off season flowering. They also found that the length of the shoots and panicles were not affected by these treatments.

Suranant (1999) discovered that the percentage of flowering in mango was highest (51 %) with PBZ as soil drench and lowest with foliar spray (29 %). According to Zora *et al*. (2000), there was a reduced vegetative growth and increased flowering in mango cv. Dashehari during the first week of October at Ludhiana condition.

Reduction in tree height, tree volume and shoot length along with enhanced flowering by the application of paclobutrazol at the rate of 10 g and 5 g a.i/tree in mango cv. Alphonso was reported by Murti *et al*. (2001).

In a work done by Vijayalakshmi and Srinivasan (2002) in Alphonso noted that soil application of PBZ @ 2.5g/tree induced more number of flowers per panicle with higher intensity of bisexual flowers (30.59 %).

Karki and Dhakal (2003) reported that application of PBZ as soil drench in September was highly effective in flowering when compared with August and October treatments. Yeshitala *et al*. (2004) reported that soil application of PBZ had significantly higher percentage of hermaphrodite flowers per panicle than sprayed trees.

Singh and Ranganath (2006) reported the effectiveness of paclobutrazol for induction of regular, prolific and early bearing in mango cv. Banganapalli grown under tropical and humid conditions.

Silva *et al*. (2010) indicated that paclobutrazol application enhanced the flowering shoots due to lesser vegetative growth and increased food reserves in the tree in mango cv. Kent.

Shinde *et al*. (2015) found that soil drenching of PBZ based on crown diameter at second fortnightly interval of July resulted in early panicle emergence in mango cv. Alphonso.

In an experiment reported by Wongsrisakulkaew *et al*. (2017) to study the effect of PBZ concentration on flowering of mango cv. Namdokmai- sitong under Thailand conditions found that the trees which received PBZ at 1,000 mg/l had the highest percentage of flowering shoots than the control trees. They also reported that the trees which received PBZ at 2,000 mg/l resulted in stunting of flushes and panicle malformation.

Kumar *et al*. (2019) reported that those plants that received paclobutrazol as soil drench at 5000 ppm was observed with maximum panicle length and more number of secondary branches per panicle.

2.2. Effect of paclobutrazol on fruit set, fruit yield and quality

Singh and Dhillon (1992) reported that soil application of PBZ recorded higher fruit yield and high TSS: acid ratio in mango cv. Dashehari when compared to foliar application.

According to Winston (1992), collar drench of paclobutrazol had a significant effect on fruit number, fruit weight as well as yield of mango cv. Kensington Pride when compared with the control trees. They also found that different quantities of paclobutrazol application did not affect the TSS and fruit weight of mango.

An improvement in flowering, fruit set and fruit retention by soil application of PBZ was observed by Burondkar and Gunjate (1993).

In a study conducted by Shinde *et al*. (2000) on the effect of dose and time of application of paclobutrazol on Alphonso mango reported that different doses of PBZ have a significant effect in increasing the fruit set when compared to control trees. Soil drenching of paclobutrazol at 20-40 g/tree to mango cv. Dashehari during October resulted in increased percentage of hermaphrodite flowers, fruit set and yield (Singh, 2000).

An increase in the number of flowering shoot, fruit set, fruit retention and yield was noticed by the soil application of PBZ at 5 g a.i/tree in mango cv. Langra during the off year (Hoda *et al*., 2001).

A significant improvement in fruit quality in terms of TSS, total chlorophyll and total carotenoids by soil application of paclobutrazol @ 6 g a.i/tree in mango cv. Langra was reported by Singh and Saini (2001).

According to Vijayalakshmi and Srinivasan (2002), soil application of paclobutrazol showed a significant increase in TSS, total sugar, reducing sugar and reduced titrable acidity in treated ‘Alphonso’ tree.

An improvement in percentage of flowering shoot, yield and fruit quality by the soil application of PBZ was reported by Yeshitala *et al.* (2004) in ‘Tommy Atkins’ mango.

Benjawan *et al*. (2006) reported that foliar application of paclobutrazol at the rate of 1,000 ppm/tree exhibited in increased panicle length, fruit set and yield of Kaew mango variety of Thailand. Improvement in fruit set and fruit retention as well as highest yield were recorded by Singh and Singh (2006) by soil application of paclobutrazol at the rate of 5 g a.i/ tree in mango cv. Gulab Khas during off year.

Trees treated with paclobutrazol at 7.5 g a.i/tree produced highest number of fruits and yield in mango cv. Langra (Karuna *et al*., 2007). Karuna and Mankar (2007) observed that PBZ treated Langra variety exhibited an increased proportion of fruit set per panicle and reduced fruit drop.

Nafees *et al*. (2010) reported that soil drenching with various doses of paclobutrazol showed significant increase in fruit set than control trees. In a work done by Tandel and Patel (2011), an increase in flowering, fruit set and fruit retention at marble and maturity phases per panicle were observed with paclobutrazol treatments in cvs. Alphonso, Kesar and Rajapuri.

Soil drenching of PBZ at 5 g/tree during September resulted in abundant flowering, increased fruit set and higher yield in mango cvs. Alphonso and Prior was reported by Randeep (2012). Soil application of paclobutrazol at 3 ml/m^2 of canopy diameter applied during third week of August in mango cv. Totapuri enhanced fruit weight, total soluble solids, ascorbic acid and reduced titrable acidity when compared to untreated trees (Reddy *et al*., 2013).

Studies of Narvariya *et al*. (2015) showed that paclobutrazol treated trees produced more bisexual flowers, maximum number of fruits per tree, fruit size and yield when compared with control trees.

Kumar *et al*. (2019) reported that soil drenching of paclobutrazol at 5000 ppm gave highest yield, heaviest fruit and showed improved fruit quality in mango cv. Amrapali when compared with control trees.

In a work conducted by Sagar *et al*. (2019) on the effect of high density planting and paclobutrazol on quality and bio chemical parameters of mango (*Mangifera indica*

L.) cv. Alphonso reported that PBZ at 2 ml/l/m^2 of canopy recorded maximum titrable acidity, TSS, ascorbic acid and total sugar.

2.3. Effect of potassium nitrate on flowering

Potassium nitrate (KNO_3) stimulate early panicle emergence and increase the number of inflorescence in tropical and subtropical regions, thus enabling increased and regular production (Adam, 1974).

Erez and Lavee (1976) reported that potassium nitrate is a universal rest-breaking agent that may simply hasten flower emergence of a differentiated, but dormant mango bud.

According to Bondad *et al*. (1978), single foliar spraying of KNO_3 up to 160g/litre and double spraying of up to 80g/litre were reported to be safe and recorded maximum panicle size in 'Pahutan' mango. They also speculated that KNO_3 may play a vital role in floral differentiation via nitrate assimilatory pathway.

Bonard and Linsangan (1979) reported 100 per cent flowering in mango cvs. Pico and Carabao within 7-14 days when sprayed with KNO_3 at 10, 20, 40, 80 or 160g/litre. According to Nunez (1985), a single spray of KNO_3 at the rate of 80g/litre enhanced the percentage of flowering shoot in mango cvs. 'Haden' and 'Manila'.

Mass (1989) studied that two per cent foliar spray of KNO_3 in November on mango cv. Keitt and Tommy Atkins resulted in 100 per cent flowering.

Rojas *et al*. (1993) studied the effect of KNO_3 on flower characters in mango cv. Haden and found maximum percentage of flowering shoots and panicle length with KNO_3 spray at 6 per cent.

Ferrari and Sergent (1996) observed a significant increase in the percentage of reproductive shoots with triple foliar spray of KNO_3 at 12 g/litre on 'Haden' mango trees during September, October and November.

In a work done by Vijayalakshmi and Srinivasan (2002), an improvement in sex ratio was observed by the application of KNO_3 at 1 per cent during the 'off' year in mango cv. Alphonso.

Kumar *et al*. (2004) observed that potassium nitrate induced early panicle emergence and maximum number of bisexual flowers. Yeshitela *et al*. (2004a) noted that spraying KNO_3 at 3 per cent on 'Tommy Atkins' resulted in longer inflorescence and longer flushes. They also reported that the minimum inductive period for complete floral induction and development in Tommy Atkins to be 35 days.

Dalal *et al*. (2005) observed early and regular flowering in mango var. Pariya with 1.5 per cent KNO_3 when compared with control trees. They also reported maximum number of panicles by the application of KNO_3.

Hima (2007) reported that foliar spray of KNO_3 at 1 and 2 per cent concentration could result in flowering of shoot within 10 and 9 days after application in Prior variety when compared to 24 days gap in control trees. She also observed greater intensity of flowering and panicle size in the same treatment.

A higher concentration of KNO_3 was found favourable to induce early emergence of panicles and significantly increased the percentage of bisexual flowers in mango (Muhammad *et al*., 2007).

Nahar *et al*. (2010) reported that foliar application of KNO_3 at 4 per cent induced early emergence of panicles and maximum number of panicles per tree in mango variety Amrapali.

An increased number of flowering shoots and number of bisexual flowers were reported with foliar application of KNO_3 at 2 per cent in mango cv. Alphonso (Sudha *et al*., 2012). Babul and Rahim (2013) investigated to know the effect of foliar spray of KNO_3 in mango cv. Amrapali and found that KNO_3 (4 %) was found to be the best in in increasing the length and width of panicle when compared to control.

An early induction of flowering with higher flowering percentage in mango cv. Alphonso with potassium nitrate spray at 3 per cent was reported by Patil *et al*. (2013).

Afiqah *et al*. (2014) reported that tree age and shoot maturity may have an effect on the flowering response to KNO_3 application. They also added that treatment with 2 per cent KNO_3 spray produced longer panicles and induced early panicle emergence in 5-year-old 'Chok Anan' mango trees.

Amarcholi *et al*. (2015) undertook a study on the influence of various chemical regulators on flowering in mango cv. 'Kesar' and found that foliar application of KNO_3 (1 %) gave maximum flowering percentage.

Tin (2016) noticed that application of KNO_3 at 3 per cent is suitable for Sentalone mango off season flower production.

Maloba *et al*. (2017) reported that foliar spraying of KNO_3 (4 %) increased the percentage of flowering, number of panicles and induced early flowering in 'Apple' and Ngowe' mango trees when compared to untreated trees.

Malshe *et al*. (2020) investigated to know the response of foliar application of various nutrients on hastening maturity and yield in mango cv. Alphonso and found that two sprays of KNO_3 at 3 per cent induced early flowering, maximum panicle length, breadth and highest hermaphrodite flower.

2.4. Effect of potassium nitrate on fruit set, fruit yield and quality

Oosthuyse (1997) observed highest fruit set and fruit retention in mango cv. Tommy Atkins with single spraying of KNO_3 at 4 per cent. Foliar application of high doses of KNO_3 at 3.6 and 4.6 per cent significantly increased number of fruits per tree, yield and apparently reduced alternate bearing in mango cv. Haden (Sergent *et al*., 1997).

An increment in number of fruits per tree, fruit weight and yield was observed with foliar spray of KNO_3 (3 %) at different time intervals in mango cv. Tommy Atkins (Ataide *et al*., 2000).

Gupta and Brahmachari (2004) indicated that mango cv. Bombai recorded maximum weight and yield/tree when sprayed with KNO_3 at 4 per cent.

Foliar spraying of potassium nitrate gave maximum number of fruits per panicle and highest yield in mango cv. Baneshan (Kumar *et al*., 2005). Dalal *et al*. (2005) observed maximum fruit set and yield in mango cv. Pariya with foliar spraying of potassium nitrate at 1.5 per cent.

Kumari (2006) reported that foliar spray of potassium nitrate (2 %) recorded significant reduction in acidity and increased the TSS and reducing sugars in mango cv. Langra.

Azam *et al*. (2007) studied that KNO_3 at three per cent spray applied during last week of January before blooming gave highest fruit set and reduced incidence of mango malformation. Similar findings were reported by Astudillo and Bondad (1978).

In mango, foliar application of KNO_3 at four per cent produced maximum number of fruits, increased fruit set and yield in mango variety Amrapali (Nahar *et al*., 2010).

An increased fruit number, higher fruit set and yield were obtained with foliar spray of potassium nitrate at (2 %) in mango cv. Alphonso (Sudha *et al*., 2012).

In a study conducted by Patil *et al*. (2013) showed significantly higher number of fruits per panicle, increased fruit set and yield with foliar spray of potassium nitrate at 3 per cent. Similar results were obtained by Khattab *et al*. (2006) who claimed that KNO_3 at 4 per cent had increased fruiting and yield in mango cultivars.

In a work done by Sarkar and Rahim (2013) reported that plants treated with KNO_3 at 4 per cent gave the highest number of fruits/plant, biggest fruit and maximum yield.

Afiqah *et al*. (2014) noted higher fruit set and yield with foliar spray of potassium nitrate at 2 per cent followed by 5 per cent in Chok Anan' mango trees.

Baiea *et al*. (2015) noted an increased number of fruits per tree, fruit weight, yield and quality in terms of TSS, total sugar and ascorbic acid content with KNO_3 at 2 per cent as foliar spray for four times in mango cv. Hindi.

An improvement in fruit set percentage, fruit retention, number of fruits per panicle, number of fruits per tree and yield were reported with two sprays of KNO_3 (1%) during flower bud differentiation and full bloom stage in 'Kesar' mango (Amarcholi *et al*., 2016).

Maloba *et al*. (2017) conducted an experiment to study offseason flower induction in mango using ethephon and potassium nitrate and observed that foliar spray of potassium nitrate at 4 per cent produced maximum number of fruits per tree and increased fruit set in 'Ngowe' and 'Apple' mango varieties.

Patolia *et al*. (2017) reported that two sprays of KNO_3 at 2 per cent during October and November gave maximum number of fruits per tree and higher fruit quality in terms of TSS, total sugar and reducing sugar in 'Dashehari' mango.

Disha *et al*. (2018) conducted a study on the impact of KNO_3 in major fruit crops and found that aerial spray of KNO_3 applied twice improves yield, fruit retention, quality attributes and organoleptic parameters of all the fruits.

In a study conducted by Malshe *et al*. (2020), reported that two sprays of KNO_3 at 3 per cent resulted in maximum fruit set and retention, biggest fruit and highest yield in Alphonso mango when compared with control trees.

2.5. Effect of ethephon on flowering in mango

According to Dutcher (1972), foliar application of ethephon at the rate of 125-200 ppm resulted in early flowering in mango cv. Carabao within six weeks after treatment.

Pandey *et al*. (1973) showed the effect of ethrel on flowering in mango and observed flowering in previous year fruited branches and accelerated flowering branches. Sen *et al*. (1973) observed an increased flowering in mango during 'on' years, but failed to induce flowering during 'off' years.

Chacko *et al*. (1974) reported that foliar applications of ethephon (200 ppm) during September for four to five times at an interval of 15-20 days induce heavy flowering in mango cv. Langra. They also noticed that single application of ethephon at high concentrations *viz*., 1000 and 2000 ppm would induce abscission of leaf and epinasty on sprayed trees.

Rath (1974) reported that foliar application of ethrel (200, 400 and 600 ppm) stimulate off season flowering in mango cv. Langra. Contradictory to this, a finding by Rameshwar and Kulkarni (1979) noticed that ethrel application at 200 ppm during

October – November was less effective for flower induction in ‘Langra’ during ‘off’ year.

Das and Rath (1978) reported that exogenous application of ethrel during bud differentiation would inhibit vegetative growth and put forth flowering in mango cv. Langra. Ravishankar (1978) obtained enormous flowering in Alphonso mango when ethrel (250 ppm) was applied at 15 days interval during ‘on’ year. Production of multiple axillary panicles was also the result of the same treatment.

In an experiment conducted by Manival *et al*. (1979) to study the effect of ethrel on flowering in mango cv. Pairi found that 300-400 ppm of ethrel induce flowering in treated trees, while the untreated trees showed only vegetative growth. They also stated that ethrel application up to 500 ppm did not show any symptoms of leaf scorching or abscission.

In 10 year old mango cv. ‘Haden’, 500-1000 ppm ethephon spraying increased the early flowering by 40-55 per cent than usual flowering (Nunez-Elisea *et al*., 1980). It was contradictory to the findings of Pal *et al*.(1979), who observed ethephon treatment to be ineffective for five consecutive years.

Shuzeng and Zongwei (1981) obtained an increased number of panicles with ethrel spray at 200 ppm in mango cv. Qingpi.

Rao and Ramarao (1983) reported that consecutive application of 200 ppm of ethrel elevated the percentage of flowering shoots in mango cvs. Baneshan and Alphonso. Rawash *et al*. (1983) noticed significant increase in the percentage of flowering with ethrel spray at 500 ppm applied for six times between September and November.

The ethylene-generating agent, ethephon, has been reported to successfully induce flowering in different mango varieties in the Philippines and India (Chanda and Pal, 1986). In a work done by Singh and Dhillon (1986) who observed that ethrel sprayed at 300 ppm produced highest percentage of hermaphrodite flowers when compared with control trees. According to Hoda (1986), foliar application of ethrel advanced flowering during ‘on’ and ‘off’ year in mango.

Ethephon sprayed at 200 ppm for three times at weekly intervals was found to be the best concentration to induce early flowering and maximum number of inflorescence in mango (Suma, 1987).

Foliar application of ethrel at 200 ppm to mango cv. Chausa during March promoted early flowering by rising peroxidase and α amylase activities for flower induction (Yamdagni and Khangia, 1989).

In an experiment conducted by Sauco *et al*. (1991) to study the effect of ethephon on mango flowering in mango cvs. Haden, Sensation and Zill found out that there was an early emergence of panicles in 2-5 weeks when ethephon was applied as foliar spray. They also reported that the effectiveness of mango flowering depends on its dosage, application date and cultivar.

An increment in flowering duration and flowering shoot was observed with ethrel application at 100 and 200 ppm, respectively in mango cv. Langra (Kumari, 2006). Karim *et al*. (2007) observed that ethrel application at 1 % produced greater number of panicles when compared with ethrel at 0.5 per cent and 1.5 per cent of juvenile mango trees.

In an experiment conducted by Chaudhari *et al*. (2014) to study the effect of foliar spray of growth retardants on flowering and fruiting in mango cv. Kesar found out that ethrel spray at 200 ppm was effective to induce earlier flowering.

Maloba *et al*. (2017) noted that ethephon at 1000 ppm induced early flowering and increased flowering percentage in 'Ngowe' and 'Apple' mango trees grown in Kenya. Similar results were confirmed by Chacko *et al*. (1972) who found out that ethephon increased flowering percentage in 'Langra' and 'Dashehari' during 'off' years.

2.6. Effect of ethephon on fruit set, fruit yield and quality

Chacko *et al*. (1972) reported that the fruit set and yield was considered satisfactory by ethephon application during 'off' season in mango.

Chacko *et al*. (1974) observed that consecutive applications of ethephon spray at 200 ppm for a period of three years did not show any reduction in vigour and yield in treated mango cv. 'Langra'.

Shanmugavelu *et al*. (1976) noted an improved TSS content with the application of ethrel in mango. Similar result was confirmed by Soni *et al*. (1981) in Sapota. Ravishankar (1978) noticed that spraying ethrel at 250 ppm at 15 days interval during August in the 'on' year gave superior yield in the 'off' year.

Bhullar (1982) reported maximum reducing sugars, total sugars and ascorbic acid in mango cv. Langra by ethrel treatment at 800 ppm. Singh and Dhillon (1986) observed a decline in the incidence of floral malformation in mango with different growth regulators and also found highest TSS: acid ratio with ethrel at 250 ppm.

According to Kumar and Singh (1993) an increased content of reducing, non-reducing, total sugar and ascorbic acid was recorded in Amrapali mango with ethrel application at 250, 500 and 700 ppm.

Yah *et al*. (1998) observed that ethephon applied at 1500 ppm had lower TSS, but higher reducing sugar content in mango cv. Kent. However, ascorbic acid and carotenoid content was maximum in fruits treated with 2500 ppm of ethephon.

Shyamal *et al*. (2010) conducted a study to determine the effect of plant growth substances on vegetative characters, flowering and fruit quality of papaya and revealed that ethrel (200 and 300 ppm) was found to be best for improving the fruit quality.

Maloba *et al*. (2017) reported that foliar application of ethephon at the rate of 600 to 1000 ppm resulted in highest fruit set in 'Ngowe' and 'Apple' mango varieties. They also observed that ethephon spray at 600 ppm helps to minimize the negative effect of fruit drop on the trees and spraying ethephon at 600 ppm is more cost effective than spraying at 1000 ppm.

2.7. Effect of salicylic acid on flowering

Salicylic acid is a phenolic phytohormone that has shown to influence a number of physiological processes like plant growth and development, flowering, photosynthetic rate and stomatal conductance (Raskin, 1992).

Kumar and Reddy (2008) reported that foliar spray of salicylic acid at 100 ppm induced early emergence of panicle, increased the panicle length and percentage of hermaphrodite flowers in mango cv. Baneshan.

Foliar application of salicylic acid at 100 ppm was found effective in increasing the percentage and length of healthy inflorescences in mango cv. Keitt (Ahmed *et al*., 2014).

In a work done by Ngullie *et al*. (2014) who observed that foliar application of 2000 ppm salicylic acid resulted in more number of male and hermaphrodite flowers per panicle and highest sex ratio.

2.8. Effect of salicylic acid on fruit set, fruit yield and quality

Naqvi *et al*. (1998) noticed improved fruit retention with foliar application of salicylic acid at 5 mg/l in mango cvs. Dashehari, Langra and Sindhri.

Foliar spray of salicylic acid (2000 ppm) at flower bud differentiation stage in October increased the fruit set and yield in mango cvs. Amrapali and Dashehari. Substantial improvement in fruit quality in terms of TSS, reducing sugar and total sugar was also noted with the same treatment (Singh *et al*., 2001).

Kumar and Reddy (2008) observed that foliar application of salicylic acid at 100 ppm showed increased TSS and minimized titratable acidity in mango cv. Baneshan.

Saied (2011) observed that foliar application of salicylic acid (200 ppm) increased finger, hand and bunch weight as well as increased TSS, total sugar and reduced acidity on 'Williams' banana.

Masoud and Osama (2012) observed that four sprays of salicylic acid at 100 ppm increased fruit retention in Washington Navel Orange when compared to untreated trees.

An increment in fruit weight, TSS, total sugar, reducing sugar, ascorbic acid and decreased acidity was observed with four sprays of salicylic acid (100 ppm) in mango cv. Hindybisinnara mango trees (Ahmed *et al*., 2013).

Ngullie *et al*. (2014) reported that foliar application of 2000 ppm salicylic acid produced more number of fruits per tree, highest fruit retention per panicle and improved quality parameters like TSS and sugar in mango cv. Kesar.

Ahmed *et al*. (2015) reported that two foliar sprays of salicylic acid at 100 ppm at the beginning and after fruit set improved yield and fruit quality in Sukkary mango trees.

Application of salicylic acid at 2000 ppm gave maximum fruit retention, highest fruit yield and induced better sized fruits in mango cv. Kesar (Rahmani *et al*., 2017).

According to Ahmed *et al*. (2018), trees treated three times with salicylic acid (100 ppm) resulted in increased yield and both physical (fruit weight, thickness, diameter, pulp and peel weight) and chemical (TSS, sugars, acidity, ascorbic acid) characteristics of mango cvs. Fagri Kalan, Zebda and Alphonso.

2.9. High density planting

The effect of pruning intensity of mango cvs. Amrapali, Mallika and Dashehari grown under high density planting system were studied and observed that severely pruned trees showed the highest number of sprouted shoots with highest net photosynthetic rate and light interception when compared to unpruned trees (Singh *et al*., 2009).

A study conducted by Dalvi *et al*. (2010) to standardise spacing for high density planting system in mango cv. Alphonso over the normal spacing of 10 m x 10m concluded that the highest yield/unit area and B: C ratio was obtained by adopting a spacing of 5m x 5m under HDP in Alphonso.

A study conducted by Gaikwad *et al*. (2017) on the effect of spacing on growth, yield and quality of mango observed that trees planted at a spacing of 10m x 10m increased fruit characters like fruit length and fruit breadth, whereas the highest fruit yield and B: C ratio was observed under the spacing of 5m x 5m.

A study on the effect of different pruning levels and pruning time along with chemical regulation in mango cvs. Mallika and Ratna was conducted and it was observed that pruning at 20 cm with paclobutrazol application during June and

September was the best for chemical regulation of mango varieties under HDP (Manohar, 2019).

Methods and Materials

3. MATERIALS AND METHODS

The research work entitled "Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system" was carried out in the Muthalamada region of Palakkad district of Kerala during 2019-2020.The materials used and methodology adopted for the studies are presented in this chapter.

3.1. Geographical location of the site

The experimental site is located at 10º 61' N and 76º 69' E and at an elevation of 103 meters above MSL. The area is situated to the mid–upland zone and is characterized by moderate to steep sloping lands.

3.2. Climate

The area experiences a hot and humid climate. The weather parameters recorded during the period of observation are presented in Appendix 1.

3.3. Experimental details

3.3.1. Soil

It was found that the soil type of the experimental field had sandy loam surface soils and sandy clay sub soils.

3.3.2. Varieties

The age group of the selected observational trees were eight years old. The following are the varieties selected for study.

Table 1. Varietal characteristics

Sl. No	Varieties	Characters
1	Alphonso	It is a leading commercial variety of Ratnagiri district of Maharashtra and is commonly known as the 'King of mangoes'. It is medium in size, oblique in shape and orange yellow in colour. The fruit quality is excellent and has a good keeping quality
2	Banganapalli	It is a commercial variety of Andhra Pradesh and Tamilnadu. It is a mid-season variety which is good for canning. The fruit size is large and oval in shape
3	Sindhuram	It is also known as Bennet Alphonso. As the name suggest, this variety has a bright red colour on top and it changes to yellow colour towards the bottom
4	Nadashala	It is also known by the name Peter or Pether. It is a regular bearer, dual purpose variety. The fruits are medium sized with excellent taste and pleasant aroma when ripe

3.3.3. Planting

The experimental area is of 1.5 acres of land. The grafts are planted under high density planting system with 6m x 2m spacing during the year 2010.

3.3.4. Design of the experiment

The experiment was laid out in Completely Randomized Design (CRD) with five treatments and four replications with three observational trees for each replication under high density planting system with a spacing of 6mx2 m. The experiment was conducted separately in eight year old mango varieties in a standing crop where the planting has already been done in

block constituting a single variety.

3.3.4.1. Treatments

i. **Varieties** – Alphonso, Banganapalli, Sindhuram and Nadashala

ii. Chemical regulators

Sl. No.	Notation	Name of chemical regulators	Rate of application
1	T_1	Paclobutrazol	Soil drenching @ 8ml in 10 litres of water/tree
2	T_2	KNO_3	4 %
3	T_3	Ethephon	200 ppm
4	T_4	Salicylic acid	2000 ppm
5	T_5	Control (No chemical regulator)	-

All these chemicals other than PBZ was applied as foliar spray one month after pruning (July) and the spray was applied two times at 15 days interval

Plate 1. Field view of experimental field

Plate 2. Field board

3.4. Preparation of chemicals and method of application

3.4.1. Paclobutrazol – Paclobutrazol is available as a liquid formulation under various trade names, and the most common being 'Cultar' with the active ingredient paclobutrazol (23%W/W) and manufactured by Syngenta Crop Protection Private Limited. The recommended dose of Cultar for a grown up tree (>15years old) is 20ml/tree as per POP of KAU.The application of paclobutrazol as soil drench around the tree trunk is the most effective method as it ensures maximum uptake by trees. Paclobutrazol was applied as a single soil application. As the age of experimental trees were of eight years, 8 ml of cultar was dissolved in 10 litres of water and poured in 20 cm deep pits taken 60 cm away from the tree trunk on all four sides.

3.4.2. KNO_3–Potassium nitrate (KNO_3) is available in powder form with N-13% and K-45% and marketed by MV Agro chemicals. For the preparation of KNO_3 at 4% solution, 40 g of KNO_3 was dissolved in 1litre of water and applied as foliar spray using portable power sprayer as per treatment details.

3.4.3. Ethephon – Ethrel is available in liquid formulation with ethephon (39 % SL) as active ingredient. It is marketed by Tropical Agrosystem Pvt. Ltd. For the preparation of ethephon at 200ppm, 0.2ml of ethrel was dissolved in 1litre of water and the volume was made to required quantity. Foliar application was given with the help of portable power sprayer.

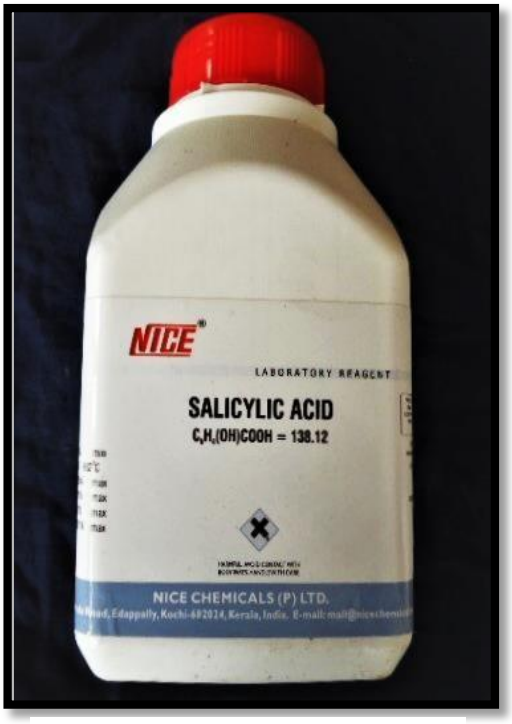
3.4.4. Salicylic acid–Salicylic acid is available in powder form (99%) and marketed by NICE Chemicals Pvt. Ltd. For the preparation of salicylic acid at 2000 ppm, 2.0 g of salicylic acid was dissolved in 1 litre of water and the volume was made to required quantity. It was applied as foliar spray with the help of portable power sprayer.

The sprayer was washed thoroughly with water after each spraying to remove the residue of chemicals.

3a. Paclobutrazol (T_1)

3b. Potassium nitrate (T_2)

3c. Ethephon (T_3)



3d. Salicylic acid (T_4)

4a **4b**

Plate 4a and 4b. Addition and mixing of chemicals for foliar spray

Plate 5. Application of foliar spray

6a

6b

Plate 6a and 6b. Paclobutrazol soil drenching @ 8ml in 10 litres of water/tree

3.5. Observations recorded

In each variety, observations were recorded in sixty plants. The parameters recorded are as follows.

3.5.1. Tree characters

Observations of tree characters such as age of tree, height of mature tree, trunk circumference, crown diameter, crown shape, tree growth habit and foliage density. The height of mature tree was recorded before and two months the treatment imposition.

3.3.1.1. Age of tree

Age of the tree was recorded by noting the year of planting up to the year at present and expressed in years.

3.3.1.2. Height of mature tree

Tree height was recorded by measuring from ground level to the top of the tree using a measuring tape and expressed in meter.

3.3.1.3. Trunk circumference

Trunk circumference was measured by measuring the girth of the tree at 50 cm from the ground level using a measuring tape and expressed in centimeter.

3.3.1.4. Crown diameter

Crown diameter was recorded by measuring the horizontal distance from one end to another end of the canopy in two directions *viz.,* North-South and East-West with the help of a measuring tape and the average values were calculated and expressed in meter.

3.3.1.5. Crown shape

The crown shape was noted as oblong, broadly pyramidal, semi-circular or spherical by visual observations.

3.3.1.6. Tree growth habit

Tree growth habit was noted as erect, spreading or drooping by visual observations.

3.3.1.7. Foliage density

Foliage density was noted as sparse, intermediate or dense by visual observations.

3.3.2. Leaf characters

Leaf characters like leaf blade length, leaf blade width, colour of young and fully developed leaf were recorded. The length and width of leaf blade before and two months after treatment imposition were recorded.

3.3.2.1. Leaf blade length

Leaf blade length was recorded by taking the average of 10 mature leaves measured from the base to the tip of leaf blade with the help of a measuring scale.

3.3.2.2. Leaf blade width

Leaf blade width was recorded by taking the average of 10 mature leaves measured at the widest point using a measuring scale.

3.3.2.3. Colour of young leaf

Colour of young leaf was noted as light green, light green with brownish tinge, light brick red, reddish brown or deep coppery tan colour on 5-10 days old leaves by visual observations.

3.3.2.4. Colour of fully developed leaf

Colour of fully developed leaf was noted as pale green, green or dark green colour by visual observations.

3.3.3. Inflorescence characters

Inflorescence characters such as days for first flowering, flowering duration, inflorescence position, length, width, sex ratio and density of flowers in the inflorescence were recorded for various treatments.

3.3.3.1. Days for first flowering

Number of days taken for first flowering was recorded for each treatment.

3.3.3.2. Flowering duration

Number of days from first flower opening until the end of flowering for each tree under different treatments in Alphonso, Banganapalli, Sindhuram and Nadashala were recorded.

3.3.3.3. Inflorescence position

Inflorescence position was noted as terminal or axillary for each treatment.

3.3.3.4. Length of inflorescence

Length of 10 randomly selected inflorescence from all the four directions were measured and average was calculated for each treatment.

3.3.3.5. Width of inflorescence

Width of 10 randomly selected inflorescence from four directions were measured and average was calculated for each treatment.

3.3.3.6. Sex ratio

Sex ratio is defined as the ratio of number of hermaphrodite flowers to the number of male flowers in an inflorescence. It is calculated as

$$\text{Sex ratio} = \frac{\text{Number of hermaphrodite flowers}}{\text{Number of male flowers}} \times 100$$

3.3.3.7. Density of flowers in the inflorescence

Density of flowers in inflorescence was noted as sparse, medium or dense for each treatment by visual observations.

3.3.4. Fruit and stone characters

Fruit and stone characters *viz.*, time taken from flowering and fruit set and fruit set to fruit maturity, fruiting duration, fruit bearing intensity, fruit length, diameter,

fruit weight, pulp to peel ratio, pulp to stone ratio, yield per tree and shelf life were recorded by collecting ten fully matured fruits per replication from each treatment.

3.3.4.1. Time taken from flowering and fruit set

Number of days taken from flowering to fruit set under each treatment in Alphonso, Banganapalli, Sindhuram and Nadashala were recorded.

3.3.4.2. Time taken from fruit set to fruit maturity

Number of days taken from fruit set to fruit maturity for each tree under different treatments in four mango varieties *viz.,* Alphonso, Banganapalli, Sindhuram and Nadashala were recorded.

3.3.4.3. Fruiting duration

Fruiting duration is the number of days from initial fruit set until final harvest. It was expressed in days.

3.3.4.4. Fruit bearing intensity

Visual observation was done to measure the fruit bearing intensity and was noted as low, medium or high.

3.3.4.5. Fruit length

Fruit length was measured from the base to the tip of the fruit using a measuring scale for each replication and expressed in centimeter.

3.3.4.6. Fruit diameter

Fruit diameter was recorded by measuring at the widest point using a measuring scale and expressed in centimeter.

3.3.4.7. Fruit weight

Weight of individual fruits were recorded with the help of a weighing balance. The average was worked out for each treatment and expressed in grams.

3.3.4.8. Pulp to peel ratio

Pulp to peel ratio is obtained by dividing the pulp weight to peel weight of individual fruits from each replication and average was worked out.

3.3.4.9. Pulp to stone ratio

Ratio of pulp weight to stone weight of individual fruits gave the pulp to stone ratio.

3.3.4.10. Yield per tree

The total yield of fruits per tree was calculated and expressed in kg/tree.

3.3.4.11. Shelf life

The shelf life of fruits was determined by keeping the fruits at room temperature and noted the number of days taken from harvesting up to the appearance of any spoilage symptoms and expressed in days.

3.3.5. Quality attributes of fruit

Quality attributes like TSS, acidity, ascorbic acid, total carotenoids, reducing sugar and total sugar were estimated.

3.3.5.1. Total Soluble Solids (TSS)

TSS of fruit was recorded with the help of a digital hand refractometer using the juice extracted from the pulp and expressed in ^{o} Brix.

3.3.5.2. Acidity

Acidity was determined by titration method given by A. O. A. C. (1984). Ten gram of the sample was blended with distilled water and volume was made up to 100 ml. This was filtered and 10 ml of the filtrate was titrated against 0.1 N NaOH solution, using phenolphthalein as indicator. The appearance of light pink colour was marked as the end point. The acidity was expressed in terms of per cent citric acid of the fruit and was calculated using the formula

$$\text{Titrable acidity (\%)} = \frac{\text{Titre value x Volume made up x 0.064}}{\text{Weight of sample x Volume of sample}}$$

3.3.5.3. Ascorbic acid

Ascorbic acid was estimated by titration method given by A.O.A.C. (1984). Five gram of sample was grinded with oxalic acid and volume was made up to 100 ml with oxalic acid. This was filtered and 10 ml of the aliquot was titrated against 2,6-Dichloro phenol indophenol dye till light pink colour appears. The ascorbic acid was expressed as milligram of ascorbic acid per 100 gram of fruit pulp.

3.3.5.4. Total carotenoids

Total carotenoids was analysed as per the method given by Roy (1973). The carotenoid pigments were extracted by taking a known quantity of sample using a mixture of petroleum ether and acetone in the ratio of 3:1. The known volume was made up with the same mixture of petroleum ether and acetone. The total carotenoid content was determined by reading OD at 452 nm using UV-Vis spectrophotometer. The amount of total carotenoid was expressed as µg/100 g of fruit pulp and was calculated using the following formula

$$\text{Total carotenoid (µg/100 g of pulp)} = \frac{\text{3.87 X OD x Final volume}}{\text{Weight of sample}} \text{ x 100}$$

3.3.5.5. **Total sugars**

Total sugar was analyzed by boiling 50 ml of clarified solution (filtrate of reducing sugar) after the addition of citric acid and distilled water. It was neutralized with 1N NaOH after cooling and volume was made upto 250ml. This solution was titrated against the mixture of Fehling A and Fehling B until it shows a brick red colour. The total sugar was expressed in percentage (Ranganna, 1986) and calculated as

$$\text{Total sugar (\%)} = \frac{\text{0.05 x Volume made up x Dilution}}{\text{Titre value x Weight of sample x Volume of titrat}} \text{ x 100}$$

3.3.5.6. Reducing sugars

Reducing sugar content was determined using the method given by Lane and Eynon (Ranganna, 1986). Ten gram of fruit sample was blended with distilled water and clarified using neutral lead acetate. It was further neutralized by Potassium oxalate to remove excess lead acetate and volume was made upto 250 ml. The solution was filtered using filter paper and the filtrate was titrated against mixture of Fehling A and Fehling B using methylene blue as indicator. The appearance of brick red colour marks the end point. Reducing sugars was expressed in percentage and calculated as

$$\text{Reducing sugar (\%)} = \frac{0.05 \times \text{Volume made up}}{\text{Titre value} \times \text{Weight of sample}} \times 100$$

3.3.6. Physiological characters

Physiological characters such as stomatal index, stomatal frequency, stomatal conductance, photosynthetic and transpiration rate as well as leaf area index were recorded.

3.3.6.1. Stomatal index

Stomatal index was determined by dividing the number of stomata per square millimetre by the number of stomata plus number of epidermal cells per square millimetre multiplied by 100. Stomatal index was calculated using the formula described by Salisbury (1972) as,

$$\text{Stomatal Index} = \frac{S}{E + S} \times 100$$

'S' denotes the number of stomata per unit area and 'E' the number of epidermal cells in the same unit area.

3.3.6.2. Stomatal frequency

Stomatal frequency was determined by counting the number of stomata present per unit area of leaf.

Abaxial leaf epidermal peels were prepared by spreading thin layer of a suitable replica fluid (quick fix) and allowing the replica to dry. The peeled replica was viewed under a light microscope (40X magnification).

3.3.6.3. Stomatal conductance

Stomatal conductance of the leaves of each treated tree were determined at harvest stage by taking third or fourth mature leaves from the apical end using a portable photosynthesis system (IRGA) – LICOR 6400 and expressed as µS.

3.3.6.4. Photosynthetic rate

Photosynthetic rate of the leaves were measured at harvest stage by taking third or fourth mature leaves from the apical end using a portable photosynthesis system (IRGA) – LICOR 6400 and expressed as µ mol m^{-2} s^{-1}.

3.3.6.5.Transpiration rate

Transpiration rate of the leaves were measured at harvest stage by taking third or fourth mature leaves from the apical end using a portable photosynthesis system (IRGA) – LICOR 6400 and expressed as m mol m^{-2} s^{-1}

All the above physiological parameters were estimated by using the natural light source during 8.00 am to 11.00 am by taking the third or fourth mature leaves from the apical end.

3.3.6.6.Leaf area index

For the estimation of leaf area, third or fourth mature leaves from the apical end of the shoot were measured using the formula suggested by Ahmed and Morsy (1999). The area was expressed in centimeter square (cm^2). Leaf area index was calculated using the following formula,

$$LAI = \frac{\text{Total leaf area}}{\text{Total ground area occupied per plant}}$$

3.3.7. Biochemical analysis

Biochemical analysis like leaf nutrient status (C/N ratio), ascorbic acid and chlorophyll content were recorded.

3.3.7.1. Leaf nutrient status (C/N ratio)

As per the sampling technique given by Bhargava and Chadha (1993), leaf samples were collected. Twenty well matured leaves from all the four sides of the tree were taken. First sampling was done at flowering stage and the next one during harvesting stage. Collected leaf samples were used for the estimation of total carbohydrate and nitrogen.

Total carbohydrate in the sample were estimated using Anthrone reagent method as per Sadasivam and Manickam (1991) and was expressed in percentage.

$$\text{Carbohydrate (\%)} = \frac{\text{OD (sample) x Standard concentration x Total volume}}{\text{OD (standard) x Volume taken x Weight of sample}}$$

Total nitrogen of the leaf sample was determined by micro-kjeldahl method as per Sadasivam and Manickam (1991) and expressed in percentage.

$$\text{Nitrogen (\%)} = \frac{\text{Normality x Titre value x 0.014 x 100}}{\text{Weight of sample}}$$

3.3.7.2. Ascorbic acid

Ascorbic acid was estimated by titration method given by A.O.A.C. (1984). Five gram of sample was grinded with oxalic acid and volume was made up to 100 ml with oxalic acid. This was filtered and 10 ml of the aliquot was titrated against 2, 6-Dichlorophenolindophenol dye till light pink colour appears. The ascorbic acid was expressed as milligram of ascorbic acid per 100 gram of leaf sample and calculated as

$$\text{Ascorbic acid (mg/100 g of leaf)} = \frac{\text{Titre value x Dye factor x Volume made up x 100}}{\text{Weight of sample x Volume of sample}}$$

3.3.7.3. Chlorophyll content

Leaf chlorophyll content was estimated by the method given by Hiscox and Israelstam (1979). Weighed 100 mg of leaf sample was immersed in 10 ml of dimethyl sulphoxide (DMSO) and the sample was incubated at 65 ℃. The volume of the extract was made up to 10 ml with DMSO and sample was read UV-Vis spectrophotometer at 645 and 663 nm using pure DMSO as blank. Chlorophyll a, chlorophyll b and total chlorophyll were calculated as per the following formula.

$$\text{Chlorophyll a (mg/g} \quad \frac{(12.7 \times OD_{663}) - (2.69 \times OD_{645}) \times \text{dilution} \times \text{volume}}{1000 \times \text{Weight of sample}}$$

$$\text{Chlorophyll b (mg/g)} = \frac{(22.9 \times OD_{645}) - (4.68 \times OD_{663}) \times \text{dilution} \times \text{volume}}{1000 \times \text{Weight of sample}}$$

$$\text{Total chlorophyll (mg/g)} = \frac{(20.7 \times OD_{645}) + (8.02 \times OD_{663}) \times \text{dilution} \times \text{volume}}{1000 \times \text{Weight of sample}}$$

3.3.8. Economic analysis

For economic analysis, total returns (TR) and total cost (TC) were estimated in Alphonso, Banganapalli and Sindhuram. Total variable cost was calculated by the addition of cost incurred on inputs, labour charges, intercultural operations and harvesting. Total returns was calculated by the yield obtained after the final harvest. Later, Benefit cost ratio (BCR) was obtained by dividing the total returns (TR) by the total cost (TC) (Khan *et al*., 2017).

3.3.9. Incidence of pest and diseases

Pest and disease incidence like per cent incidence/severity index of pest and diseases were recorded.

PDI is the percentage of diseased plants or parts in the sample or population of plants. It was calculated from the following formula

$$PDI = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

The intensity rating of mango thrips per panicle was categorized as free/resistant, less susceptible, moderately susceptible and highly susceptible. It is presented in the table below.

Category of susceptibility	**Thrips (Population/panicle)**	**Ratings**
Free/Resistant	0	-
Less susceptible (Low)	1	Up to 5 nymphs or adults or both
Moderately susceptible (Medium)	2	6 – 15
Highly susceptible (High)	3	>15

3.3.10. Statistical analysis

The data were subjected to analysis of variance based on the method of Panse and Sukhatme (1978). Wasp 2.0. and MS- Excel software were used for computation and analysis.

Results

4. RESULTS

The results of the study entitled "Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system" are furnished in this chapter. The influence of various chemical treatments of paclobutrazol, KNO_3, ethephon and salicylic acid on morphological, physiological, biochemical and economic attributes of mango were studied. The results of the study conducted on four mango varieties Alphonso, Banganapalli, Sindhuram and Nadashala are presented under the following heads.

1. Tree characters
2. Leaf characters
3. Inflorescence characters
4. Fruit and stone characters
5. Physiological characters
6. Biochemical analysis
7. Economic analysis
8. Incidence of pest and disease

4.1. Tree characters

Different observations on tree characters are height of mature tree, trunk circumference and crown diameter of Alphonso, Banganapalli, Sindhuram and Nadashala are recorded as per the IPGRI crop descriptor (2006) before and after the treatment imposition are presented in Table 1 to 6.

4.1.1. Age of tree

The age group of the selected mango varieties were eight years old.

4.1.2. Height of mature tree

The effect of different chemical treatments on tree height of four mango varieties before and two months after treatment application are presented in Table 2.

In Alphonso, height of mature tree before the treatment ranged from 3.32 m to 3.74 m, whereas it ranged from 3.46 m and 3.91m after the treatment. The tree height recorded in Banganapalli before the treatment was ranged from 4.63 m to 5.29 m,

whereas it was (include this) ranged from 4.78m to 5.66 m after the treatment. In Sindhuram, the tree height recorded before the treatment ranged from 3.61 m to 4.16, whereas it ranged from 3.78 m to 4.34 m after the treatment. In Nadashala, tree height recorded before the treatment ranged from 4.13 m to 4.81 m, whereas it ranged from 4.30 m to 4.95 m after the treatment.

However, application of different chemical regulators had no significant effect on tree height of mango varieties.

4.1.3. Trunk circumference

The effect of different treatments on trunk circumference recorded before and two months after treatment are presented in Table 3.

In Alphonso, the trunk circumference recorded before the treatment ranged from 33.8 cm to 35.3 m, whereas it ranged from 36.8 cm to 39.2 cm after the treatment. In Banganapalli, trunk circumference recorded before the treatment ranged from 43.6 cm to 47.6 cm, whereas it ranged from 46.0 cm to 49.7 cm after the treatment. In Sindhuram, the trunk circumference recorded before the treatment ranged from 33.1 cm to 41.7 cm, whereas it ranged from 35.6 cm to 44.1 cm after the treatment. In Nadashala, trunk circumference noted before the treatment ranged from 37.2 cm to 50.2 cm, whereas it ranged from 39.6 cm to 49.6 cm after the treatment.

However, application of different chemicals had no significant effect on trunk circumference in the varieties.

4.1.4. Crown diameter

Data showing on the effect of different treatments on crown diameter before and two months after treatment imposition are presented in Table 4.

In Alphonso, the crown diameter measured before the treatment ranged from 3.21 m to 3.81 m, whereas it ranged from 3.34 m to 3.99 m after the treatment. In Banganapalli, crown diameter measured before the treatment ranged from 3.70 m to 4.76 m, whereas it ranged from 3.79 m to 4.91 m after the treatment. In Sindhuram, the crown diameter measured before the treatment ranged from 3.06 m to 3.97 m, whereas it ranged from 3.20 m to 4.13 m after the treatment. In Nadashala, the crown diameter

recorded before the treatment ranged from 4.15 m to 5.38 m, whereas it ranged from 4.32 m to 5.32 m after the treatment.

Data indicated that there was no significant effect on crown diameter on four mango varieties

4.1.5. Crown shape

Data relating to crown shape are presented in Table 5.

In Alphonso and Banganapalli, all the treatments were found to have a semi-circular crown. Broadly pyramidal shaped crown were observed in all the treatments of Sindhuram and Nadashala varieties.

4.1.6. Tree growth habit

Data pertaining to the tree growth habit are furnished in Table 6.

With respect to the tree growth habit in Alphonso, Banganapalli, Sindhuram and Nadashala were found to have spreading type of tree growth in all the treatments.

4.1.7. Foliage density

Data on the influence of different treatments on foliage density are tabulated in Table 7.

In Alphonso, all the treatments were observed to have a dense foliage density. All the treatments in Banganapalli, Sindhuram and Nadashala were found to have an intermediate foliage density.

4.2. Leaf characters

Different observations on leaf characters *viz.*, leaf blade length, leaf blade width, colour of young leaf and fully developed leaf of Alphonso, Banganapalli, Sindhuram and Nadashala under various chemical treatments were recorded as per the IPGRI crop descriptor (2006), and the results are furnished below.

Table 2. Response of different chemical regulators on tree height (m) of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	3.54	3.64	5.29	5.52	3.61	3.78	4.34	4.54
T_2	3.74	3.91	5.05	5.24	4.12	4.27	4.77	4.92
T_3	3.35	3.52	4.63	4.78	3.97	4.12	4.13	4.30
T_4	3.32	3.46	5.14	5.37	3.99	4.19	4.67	4.84
T_5	3.60	3.76	5.17	5.66	4.16	4.34	4.81	4.95
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 3. Response of different chemical regulators on trunk circumference (cm) of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	35.3	39.2	47.0	49.5	33.1	35.6	37.2	39.6
T_2	34.2	37.6	43.6	46.0	40.0	42.2	47.8	50.7
T_3	35.0	39.2	46.7	49.2	36.6	38.6	41.1	44.0
T_4	34.6	37.1	47.1	49.6	39.7	41.7	50.2	52.6
T_5	33.8	36.8	47.6	49.7	41.7	44.1	47.2	49.6
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 4. Response of different chemical regulators on crown diameter (m) of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	3.21	3.34	4.27	4.40	3.10	3.24	4.15	4.32
T_2	3.23	3.42	4.76	4.91	3.47	3.63	5.38	5.55
T_3	3.33	3.48	3.70	3.79	3.06	3.20	4.69	4.86
T_4	3.81	3.99	4.25	4.40	3.97	4.13	4.92	5.09
T_5	3.28	3.41	4.52	4.65	3.67	3.85	5.144.	5.32
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 5. Response of different chemical regulators on crown shape of mango varieties

Crown shape				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Semi circular	Semi circular	Broadly pyramidal	Broadly pyramidal
T_2	Semi circular	Semi circular	Broadly pyramidal	Broadly pyramidal
T_3	Semi circular	Semi circular	Broadly pyramidal	Broadly pyramidal
T_4	Semi circular	Semi circular	Broadly pyramidal	Broadly pyramidal
T_5	Semi circular	Semi circular	Broadly pyramidal	Broadly pyramidal

Table 6. Response of different chemical regulators on tree growth habit of mango varieties

Tree growth habit				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Spreading	Spreading	Spreading	Spreading
T_2	Spreading	Spreading	Spreading	Spreading
T_3	Spreading	Spreading	Spreading	Spreading
T_4	Spreading	Spreading	Spreading	Spreading
T_5	Spreading	Spreading	Spreading	Spreading

Table 7. Response of different chemical regulators on foliage density of mango varieties

Foliage density				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Dense	Intermediate	Intermediate	Intermediate
T_2	Dense	Intermediate	Intermediate	Intermediate
T_3	Dense	Intermediate	Intermediate	Intermediate
T_4	Dense	Intermediate	Intermediate	Intermediate
T_5	Dense	Intermediate	Intermediate	Intermediate

4.2.1. Leaf blade length

Data showing the effect of different treatments on leaf blade length before and two months after treatment imposition are presented in Table 8.

In Alphonso, leaf blade length recorded before the treatment was ranged from 24.6 cm to 30.3 cm, whereas it was ranged from 26.6 cm to 31.7 cm after the treatment. In Banganapalli, the leaf blade length recorded before the treatment was ranged from 20.7 cm to 21.7 cm, whereas it was ranged from 21.9 cm to 23.1 cm after the treatment. In Sindhuram, the leaf blade length measured before the treatment was ranged from 22.5 cm to 25.1 cm, whereas 24.2 cm to 27.2 cm after the treatment. In Nadashala, the leaf blade length recorded before the treatment was ranged from 24.8 cm to 26.3 cm, whereas it was ranged from 25.6 cm to 27.1 cm after the treatment.

However, application of different treatments had no significant effect on leaf blade length in all the four varieties before and after the treatment imposition.

4.2.2. Leaf blade width

Data pertaining to leaf blade width by different treatments before and two months after the treatment imposition are presented in Table 9.

In Alphonso, the leaf blade width recorded before the treatment was ranged from 5.72 cm to 6.53 cm, whereas it was ranged from 5.79 cm to 6.58 cm after the treatment. In Banganapalli, leaf blade width recorded before the treatment was ranged from 4.77 cm to 5.23 cm, whereas it was ranged from 4.83 cm to 5.28 cm after the treatment. In Sindhuram, the leaf blade width measured before the treatment varied from 5.68 cm to 6.12 cm, whereas it was ranged from 6.31 cm to 6.82 cm after the treatment. In Nadashala, the leaf blade width recorded before the treatment was ranged from 6.31 cm to 6.82 cm, whereas it was ranged from 6.38 cm to 6.89 cm after the treatment.

However, the treatments had no significant effect on leaf blade width on four mango varieties.

Table 8. Response of different chemical regulators on length of leaf blade (cm) of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	24.6	26.6	21.7	23.1	25.1	27.2	25.4	26.7
T_2	29.0	30.7	21.2	22.7	24.2	26.2	25.1	26.4
T_3	30.3	31.7	20.7	21.9	23.6	25.4	24.8	25.6
T_4	27.0	28.5	21.1	22.5	22.5	24.2	26.3	27.1
T_5	28.9	30.3	21.5	23.1	23.4	24.7	24.9	26.0
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 9. Response of different chemical regulators on width of leaf blade (cm) of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	5.72	5.79	5.03	5.10	6.12	6.19	6.38	6.45
T_2	6.30	6.34	5.12	5.19	5.86	5.92	6.63	6.70
T_3	6.25	6.30	4.77	4.83	5.68	5.75	6.82	6.89
T_4	6.20	6.25	5.01	5.06	5.92	6.00	6.71	6.78
T_5	6.53	6.58	5.23	5.28	5.81	5.89	6.31	6.38
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 10. Response of different chemical regulators on colour of young leaf of mango varieties

Colour of young leaf				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Light green with brownish tinge	Light green	Light green	Light green with brownish tinge
T_2	Light green with brownish tinge	Light green	Light green	Light green with brownish tinge
T_3	Light green with brownish tinge	Light green	Light green	Light green with brownish tinge
T_4	Light green with brownish tinge	Light green	Light green	Light green with brownish tinge
T_5	Light green with brownish tinge	Light green	Light green	Light green with brownish tinge

Table 11. Response of different chemical regulators on colour of fully developed leaf of mango varieties

Colour of fully developed leaf				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Green	Green	Green	Dark Green
T_2	Green	Green	Green	Dark Green
T_3	Green	Green	Green	Dark Green
T_4	Green	Green	Green	Dark Green
T_5	Green	Green	Green	Dark Green

4.2.3. Colour of young leaf

Data showing the colour of young leaf recorded as per the IPGRI crop descriptor (2006) and are furnished in Table 10.

In Alphonso, all the treatments were found to have a light green with brownish tinge coloured young leaf. A light green coloured young leaf was observed for all the treatments in Banganapalli, Sindhuram and Nadashala.

4.2.4. Colour of fully developed leaf

Data on the influence of various treatments on colour of fully developed leaf are tabulated in Table 11.

In Alphonso, Banganapalli and Sindhuram all the treatments were found to have green coloured fully developed leaves. In Nadashala, all the treatments were observed with dark green coloured fully matured leaf.

4.3. Inflorescence characters

Different parameters of inflorescence characters *viz.,* days for first flowering, flowering duration, inflorescence position, length, width, sex ratio and density of flower in the inflorescence of Alphonso, Banganapalli, Sindhuram and Nadashala were recorded and the results are furnished below.

4.3.1. Days for first flowering

Data on the days for first flowering as influenced by different treatments are furnished in Table 12.

The treatments had a significant influence on days for first flowering. In Alphonso, the effect of chemical regulators on days for first flowering ranged from 67.0 days to 87.0 days. In Alphonso, the treatment T_4 recorded minimum days for first flowering (67.0 days) followed by T_2 (69.8 days), T_3 (77.6 days), T_1 (86.0 days) and T_5 (87.0 days). The days for first flowering recorded in Banganapalli ranged from 56.8 days to 69.7 days. In Banganapalli, the minimum days for first flowering was recorded in T_2 (56.8 days) followed by T_3 (59.5 days), T_4 (64.0 days), T_1 (69.1 days) and T_5 (69.7 days). In Sindhuram, the days for first flowering recorded varied from 52.8 days to 68.0

days. The minimum days for first flowering in Sindhuram was observed in T_2 (52.8 days) and which was followed by T_3 (59.5 days), T_4 (61.2 days), T_5 (68.0 days) and T_1 (73.8 days). The days for first flowering in Nadashala ranged from 74.3 days to 93.5 days. In Nadashala, T_2 recorded the minimum days of (74.3 days) which was followed by T_3 (79.0 days), T_4 (89.6 days), T_1 (91.7 days) and T_5 (93.5 days).

4.3.2. Flowering duration

Data on the response of different treatments on flowering duration are presented in Table 13.

The treatments showed a significant effect on flowering duration. In Alphonso, the flowering duration recorded after the treatment ranged from 20.7 days to 25.8 days. The minimum flowering duration in Alphonso was recorded in T_4 (20.7 days) and which was followed by T_3 (23.3 days), T_2 (24.8 days), T_1 (25.4 days) and T_5 (25.8 days). The duration of flowering recorded in Banganapalli ranged from 16.9 days to 26.2 days. The minimum flowering duration was recorded in T_2 (16.9 days) and which was followed by T_3 (20.1 days), T_4 (24.7 days), T_5 (26.0 days) and T_1 (26.2 days). In Sindhuram, the ranges of flowering duration recorded were 16.2 days to 27.2 days. The minimum flowering duration in Sindhuram was observed in T_2 (16.2 days) and which was followed by T_3 (20.4 days), T_4 (22.6 days), T_1 (27.0 days) and T_5 (27.2 days). The duration of flowering recorded in Nadashala varied from 21.3 days to 28.7 days. In Nadashala, the minimum flowering duration was observed with T_2 (21.3 days) and which was followed by T_3 (24.4 days), T_4 (26.8 days), T_5 (28.2 days) and T_1 (28.7 days).

4.3.3. Inflorescence position

Data pertaining to the position of inflorescence recorded as per IPGRI crop descriptor (2006) is presented in Table 14.

With respect to the inflorescence position, the varieties Alphonso, Banganapalli and Nadashala were found to have inflorescence at the terminal end in all the treatments. In Sindhuram, all the treatments had inflorescence at the terminal and axillary position.

Table 12. Response of different chemical regulators on days for first flowering of mango varieties

Days for first flowering (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	86.0	69.1	73.8	91.7
T_2	69.8	56.8	52.8	74.3
T_3	77.6	59.5	57.0	79.0
T_4	67.0	64.0	61.2	89.6
T_5	87.0	69.7	68.0	93.5
CD (0.05)	1.25	1.38	0.88	0.96

Table 13. Response of different chemical regulators on flowering duration of mango varieties

Flowering duration (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	25.43	26.25	27.00	28.75
T_2	24.81	16.93	16.25	21.37
T_3	23.37	20.18	20.43	24.43
T_4	20.75	24.75	22.62	26.87
T_5	25.87	26.00	27.25	28.25
CD (0.05)	0.85	0.10	1.14	0.81

Table 14. Response of different chemical regulators on inflorescence position of mango varieties

Inflorescence position				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Terminal	Terminal	Terminal and Axillary	Terminal
T_2	Terminal	Terminal	Terminal and Axillary	Terminal
T_3	Terminal	Terminal	Terminal and Axillary	Terminal
T_4	Terminal	Terminal	Terminal and Axillary	Terminal
T_5	Terminal	Terminal	Terminal and Axillary	Terminal

Table 15. Response of different chemical regulators on length of inflorescence of mango varieties

Length of inflorescence (cm)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	24.25	22.21	27.5	22.51
T_2	32.57	33.52	36.28	28.72
T_3	29.73	29.18	32.41	26.17
T_4	35.58	31.67	29.37	24.83
T_5	25.45	24.65	24.15	23.65
CD (0.05)	0.73	0.85	0.67	1.00

Table 16. Response of different chemical regulators on width of inflorescence of mango varieties

Width of inflorescence (cm)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	13.30	13.33	18.53	16.32
T_2	30.32	25.50	28.10	24.51
T_3	25.15	23.46	25.30	18.11
T_4	21.18	24.35	31.11	21.32
T_5	15.08	11.20	22.50	12.90
CD (0.05)	0.64	0.48	0.58	0.99

Table 17. Response of different chemical regulators on sex ratio of mango varieties

Sex ratio				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	27.50	25.53	27.62	20.37
T_2	34.50	33.62	36.05	26.83
T_3	28.75	28.45	38.25	23.34
T_4	41.62	37.75	42.75	35.12
T_5	21.62	21.87	22.64	21.62
CD (0.05)	1.07	0.82	1.25	1.45

Table 18. Response of different chemical regulators on density of flowers in the inflorescence of mango varieties

Density of flowers in the inflorescence				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Medium	Medium	Medium	Medium
T_2	Medium	Medium	Dense	Medium
T_3	Medium	Medium	Dense	Medium
T_4	Dense	Medium	Dense	Medium
T_5	Medium	Sparse	Medium	Sparse

4.3.4. Length of inflorescence

Data on inflorescence length as affected by various treatments are tabulated in Table 15.

The treatments had a significant influence on the length of inflorescence. In Alphonso, the length of inflorescence recorded after the treatment was ranged from 24.25 cm to 35.58 cm. The maximum length of inflorescence in Alphonso was observed in T_4 (35.58 cm) which was followed by T_2 (32.57 cm), T_3 (29.73 cm), T_5 (25.45 cm) and T_1 (24.25 cm).The length of inflorescence recorded in Banganapalli varied from 22.21 cm to 33.52 cm. The maximum length of inflorescence in Banganapalli was observed in T_2 (33.52 cm) and which was followed by T_4 (31.67 cm), T_3 (29.18 cm), T_5 (24.65 cm) and T_1 (22.21 cm). In Sindhuram, the ranges for inflorescence length recorded were 24.15 cm to 36.28 cm. The maximum length of inflorescence in Sindhuram was recorded in T_2 (36.28 cm) and which was followed by T_3 (32.41 cm), T_4 (29.37 cm), T_1 (27.50 cm) and T_5 (24.15 cm). The length of inflorescence recorded in Nadashala was ranged from 22.51 cm to 28.72 cm. The maximum length of inflorescence in Nadashala was recorded in T_2 (28.72 cm) and which was followed by T_3 (26.17 cm), T_4 (24.83 cm), T_5 (23.65 cm) and T_1 (22.51 cm).

4.3.5. Width of inflorescence

Data pertaining to width of inflorescence as influenced by the treatments are given in Table 16.

The treatments showed significant effect on width of inflorescence. In Alphonso, the width of inflorescence measured was ranged from 13.30 cm to 30.32 cm. The maximum width of inflorescence in Alphonso was observed in T_2 (30.32 cm) which was followed by T_3 (25.15 cm), T_4 (21.18 cm), T_5 (15.08 cm) and T_1 (13.30 cm). The width of inflorescence recorded in Banganapalli was ranged from 11.20 cm to 25.50 cm. The maximum width of inflorescence in Banganapalli was recorded in T_2 (25.50 cm) and which was followed by T_4 (24.35 cm), T_3 (23.46 cm), T_1 (13.33 cm) and T_5 (11.20 cm). In Sindhuram, the panicle width recorded was ranged from 18.53 cm to 31.11 cm. The maximum width of inflorescence in Sindhuram was recorded in T_4 (31.11 cm) and which was followed by T_2 (28.10 cm), T_3 (25.30 cm), T_5 (22.50 cm)

and T_1 (18.53 cm). The width of inflorescence recorded in Nadashala ranged from 16.32 cm to 24.51 cm. The maximum width of inflorescence in Nadashala was recorded in T_2 (24.51 cm) which was followed by T_4 (21.32 cm), T_3 (18.11 cm), T_1 (16.32 cm) and T_5 (12.90 cm).

4.3.6. Sex ratio

Data on the influence of various treatments on sex ratio are furnished in Table 17.

The treatments had a significant influence on sex ratio. In Alphonso, the sex ratio recorded was ranged from 21.62 to 41.62. The highest sex ratio in Alphonso was recorded in T_4 (41.62) which was followed by T_2 (34.50), T_3 (28.75), T_1 (27.50) and T_5 (21.62). The sex ratio recorded in Banganapalli was ranged from 21.87 to 37.75. The highest sex ratio in Banganapalli was observed by T_4 (37.75) which was followed by T_2 (33.62), T_3 (28.45), T_1 (25.53) and T_5 (21.87). In Sindhuram, the sex ratio recorded varied from 21.64 to 42.75. The highest sex ratio in Sindhuram was recorded in T_4 (42.75) which was followed by T_3 (38.25), T_2 (36.05), T_1 (27.62) and T_5 (22.64). Sex ratio recorded in Nadashala was ranged from 20.37 to 35.12. The highest sex ratio in Nadashala was recorded in T_4 (35.12) and which was followed by T_2 (26.83), T_3 (23.34), T_5 (21.62) and T_1 (20.37).

4.3.7. Density of flowers in the inflorescence

Data related to the density of flowers in the inflorescence as influenced by various treatments are tabulated in Table 18.

In Alphonso, all the treatments were found to have medium density of flowers except T_4 with dense flowers in the inflorescence. In Banganapalli, the treatments differed significantly with respect to density of flowers in the inflorescence. All the treatments in Banganapalli were observed to have medium flower density except the treatment T_5 with sparse density of flowers. The treatments T_2 to T_4 were found to have dense inflorescence and medium flower density was observed in T_1 and T_5 in the case of Sindhuram. In Nadashala, treatments T_1 to T_4 were found to have medium flower density in the inflorescence, whereas T_5 had sparse flowering density.

7a

7b

7c

7d

7e

7f

7g

7h

Plate 7a – buds closed and covered with green scales; 7b – scales begin to separate; 7c – first floral primordial just visible; 7d – panicle axis begins to elongate and leaves are visible in mixed panicle; 7e – flowers are visibly separated and secondary axes begins to elongate; 7f – secondary axes elongated and flower buds swollen; 7g – 10 % of panicle flowers opened; 7h – more than 50 % of panicle flowers open

T_1 T_2

T_3 T_4

T_5

Plate 8. Effect of chemical regulators on flowering in Alphonso

T_1 T_2

T_3 T_4

T_5

Plate 9. Effect of chemical regulators on flowering in Banganapalli

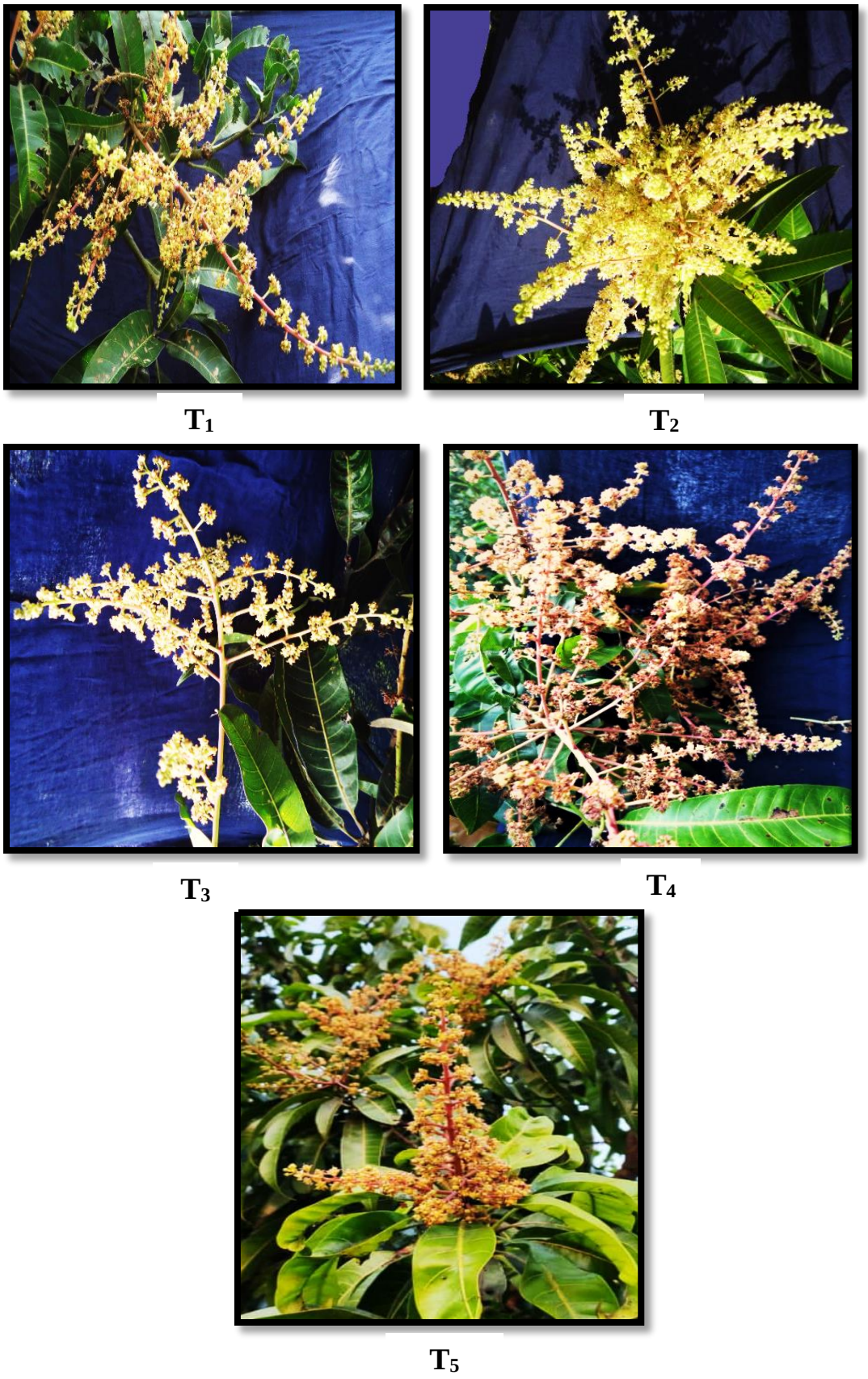


Plate 10. Effect of chemical regulators on flowering in Sindhuram

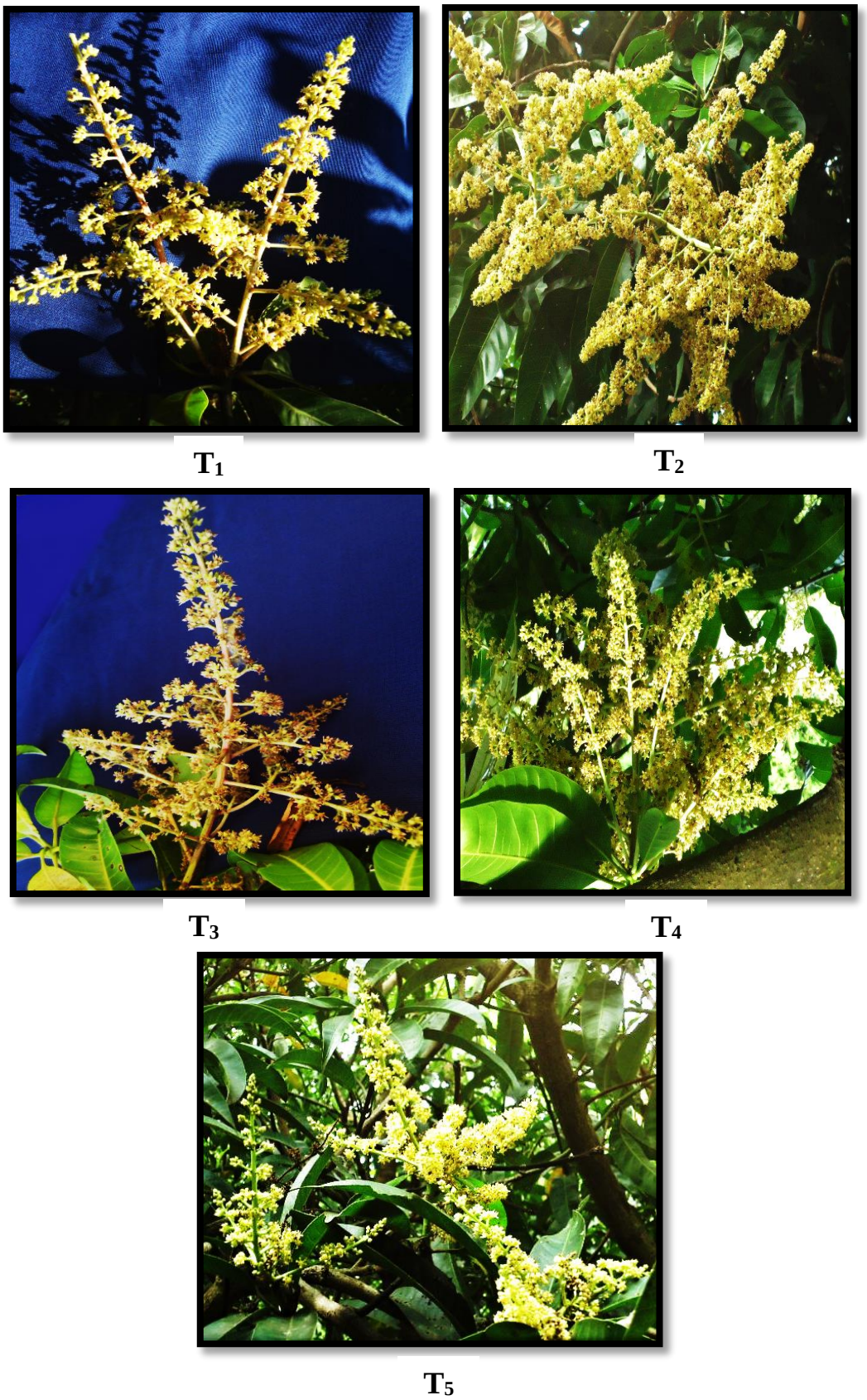


Plate 11. Effect of chemical regulators on flowering in Nadashala

4.4. Fruit and stone characters

Various observations on fruit and stone characters *viz.,* time taken from flowering and fruit set and fruit set to fruit maturity, fruiting duration, fruit bearing intensity, fruit length, diameter, fruit weight, pulp to peel ratio, pulp to stone ratio, yield per tree and shelf life of mango with respect to different chemical treatments were recorded, analyzed and results are presented.

4.4.1. Time taken from flowering to fruit set

Data on the effect of different treatments on time taken from flowering to fruit set are given in Table 19.

The treatments showed significant influence on time taken from flowering to fruit set. In Alphonso, the time taken from flowering to fruit set recorded was ranged from 28.25 days to 33.12 days. The minimum time taken from flowering to fruit set in Alphonso was observed in T_2 (28.25 days) and it was on par with T_3 (28.87 days) followed by T_4 (28.87 days), T_5 (32.62 days) and T_1 (33.12 days). The time taken from flowering to fruit set in Banganapalli varied from 24.00 days to 31.87 days. The minimum time taken from flowering to fruit set in Banganapalli was observed by T_3 (24.00 days) and which was followed by T_2 (28.50 days), T_4 (30.00 days), T_1 (30.62 days) and T_5 (31.87 days). In Sindhuram, the time taken for the above parameter was ranged from 23.75 days to 31.12 days. The minimum time taken from flowering to fruit set was recorded in T_3 (23.75 days) and which was followed by T_2 (25.50 days), T_4 (30.00 days), T_1 (30.62 days) and T_5 (31.12 days). In Nadashala, fruit set has not occurred.

4.4.2. Time taken from fruit set to fruit maturity

Data on the influence of different treatments on the time taken from fruit set to fruit maturity are furnished in Table 20.

The treatments had a significant influence on time taken from fruit set to fruit maturity. In Alphonso, the time taken from fruit set and fruit maturity recorded was ranged from 118.62 days to 126.12 days. The minimum time taken from fruit set to fruit

maturity in Alphonso was recorded in T_2 (118.62 days) which was significantly superior and followed by T_3 (120.12 days), T_4 (124.50 days), T_5 (125.50 days) and T_1 (126.12days). The time taken for the above parameter recorded in Banganapalli varied from 103.87 days to 109.12 days. The minimum time taken from fruit set to fruit maturity in Banganapalli was recorded in T_3 (103.87 days) which was followed by T_2 (105.62 days), T_4 (106.62 days), T_1 (107.75 days) and T_5 (107.75 days). In Sindhuram, the time taken from fruit set to fruit maturity was ranged from 102.87 days to 107.62 days. The minimum time taken from fruit set to fruit maturity in Sindhuram was observed by T_2 (102.87 todays) and which was followed by T_3 (104.50 days), T_4 (105.23 days), T_1 (106.12 days) and T_5 (107.62 days). In Nadashala, fruit set has not occurred.

4.4.3. Fruiting duration

Data pertaining to fruiting duration as influenced by the different treatments are furnished in Table 21.

The treatments had a significant influence on fruiting duration. In Alphonso, the fruiting duration recorded was ranged from 111.50 days to 122.00 days. The minimum duration for fruiting in Alphonso was recorded in T_2 (111.50 days) and which was followed by T_3 (114.62 days), T_4 (118.00 days), T_1 (118.37 days) and T_5 (122.00 days). The fruiting duration recorded in Banganapalli varied from 91.25 days to 100.75 days. The minimum fruiting duration in Banganapalli was recorded in T_3 (91.25 days) and which was followed by T_2 (94.75 days), T_3 (95.50 days), T_5 (100.62 days) and T_1 (100.75 days). In Sindhuram, the fruiting duration ranged from 92.12 days to 98.93 days. The minimum fruiting duration in Sindhuram was recorded in T_2 (92.12 days) and which was followed by T_3 (94.87 days), T_1 (95.50 days), T_4 (96.50 days) and T_5 (98.93 days). In Nadashala, no fruit set has occurred.

4.4.4. Fruit bearing intensity

Data relating to fruit bearing intensity as influenced by different treatments are presented in Table 22.

The treatments differed significantly with respect to fruit bearing intensity in Alphonso. All the treatments in Alphonso were observed to have low fruit bearing intensity except T_2 and T_4 with medium fruit bearing intensity. In Banganapalli, the fruit bearing intensity was medium for all the treatments except the treatment T_5 which recorded a low fruit bearing intensity. In the case of Sindhuram, all the treatments recorded medium fruit bearing intensity except the treatment T_1 which was found to have low fruit bearing intensity. In Nadashala, no fruit set has occurred.

4.4.5. Fruit length

Data pertaining to the effect of different treatments on fruit length is presented in Table 23.

The treatments had a significant effect on fruit length. The fruit length recorded in Alphonso was ranged from 7.90 cm to 9.29 cm. The maximum fruit length in Alphonso was recorded in T_4 (9.29 cm) and which was followed by T_3 (8.73 cm), T_2 (8.25 cm), T_1 (8.15 cm) and T_5 (7.90 cm). In Banganapalli, the fruit length measured was varied from 8.65 cm to 11.65 cm. The maximum fruit length in Banganapalli was recorded by T_4 (11.65 cm) and which was followed by T_2 (11.41 cm), T_3 (11.18 cm), T_1 (9.97 cm) and T_5 (8.65 cm). The fruit length in Sindhuram was ranged from 7.66 cm to 8.48 cm. The maximum fruit length in Sindhuram was observed by T_4 (8.48 cm) and which was followed by T_1 (8.26 cm), T_2 (8.18 cm), T_3 (8.05 cm) and T_5 (7.66 cm). In Nadashala, fruit set has not occurred.

4.4.6. Fruit diameter

Data relating to fruit diameter as influenced by the treatments are given in Table 24.

Application of treatment had a significant influence on fruit diameter. The fruit diameter recorded in Alphonso was ranged from 18.15 cm to 26.97 cm. The maximum fruit diameter in Alphonso was reported in T_4 (26.97 cm) which is significantly superior and was followed by T_2 (23.03 cm), T_1 (22.16 cm), T_3 (20.91 cm) and T_5 (18.15 cm). In Banganapalli, the fruit diameter measured was ranged from 17.87 cm to 26.52 cm. The maximum fruit diameter in Banganapalli was obtained by T_4 (26.52 cm) and which

was followed by T_3 (24.54 cm), T_2 (23.96 cm), T_1 (20.78 cm) and T_5 (17.87 cm). In Sindhuram, the fruit diameter varied from 8.25 cm to 9.35 cm. The maximum fruit diameter in Sindhuram was recorded in T_4 (9.35 cm) and which was followed by T_2 (9.15 cm), T_3 (9.12 cm), T_1 (8.57 cm) and T_5 (8.25 cm). In Nadashala, fruit set has not occurred.

4.4.7. Fruit weight

Data relating to the fruit weight as affected by different treatments are presented in Table 25.

The treatments had a significant influence on fruit weight. The fruit weight measured in Alphonso was ranged from 178.12 g to 336.85g. The highest fruit weight in Alphonso was recorded in T_4 (336.85 g) and which was followed by T_2 (298.97 g), T_3 (244.87 g), T_1 (233.91 g) and T_5 (178.12 g). In Banganapalli, the fruit weight recorded was ranged from 159.87 g to 408.81 g. The maximum fruit weight in Banganapalli was recorded in T_4 (408.81 g) which was followed by T_3 (360.80 g), T_2 (355.97 g), T_1 (245.86 g) and T_5 (159.87 g). In Sindhuram, the fruit weight was ranged from 197.92 g to 242.41 g. The highest fruit weight in Sindhuram was observed in T_4 (242.41 g) and which was followed by T_3 (234.75 g), T_1 (208.46 g), T_5 (197.92 g) and T_2 (182.22 g). In Nadashala, fruit set has not occurred.

4.4.8. Pulp to peel ratio

Data pertaining to the effect of various treatments on pulp to peel ratio are presented in Table 26.

The treatments had a significant effect on pulp to peel ratio. The pulp to peel ratio recorded in Alphonso was ranged from 4.70 to 12.33. The maximum pulp to peel ratio in Alphonso was observed in T_4 (12.33) and which was followed by T_2 (9.30), T_3 (6.17), T_1 (5.60) and T_5 (4.70). In Banganapalli, pulp to peel ratio was ranged from 3.61 to 7.32. The highest pulp to peel ratio in Banganapalli was recorded in T_4 (7.32) and which was followed by T_5 (5.90), T_3 (5.09), T_2 (4.92) and T_1 (3.61).

Table 19. Response of different chemical regulators on time taken from flowering to fruit set of mango varieties

Time taken from flowering to fruit set (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	33.12	30.62	30.62	No fruit set
T_2	28.25	28.50	25.50	No fruit set
T_3	28.87	24.00	23.75	No fruit set
T_4	30.87	30.00	30.00	No fruit set
T_5	32.62	31.87	31.12	No fruit set
CD (0.05)	1.16	0.98	1.13	-

Table 20. Response of different chemical regulators on time taken from fruit set to fruit maturity of mango varieties

Time taken from fruit set to fruit maturity (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	126.12	107.75	106.12	No fruit set
T_2	118.62	105.62	102.87	No fruit set
T_3	120.13	103.87	104.50	No fruit set
T_4	124.50	106.62	105.23	No fruit set
T_5	125.5	109.12	107.62	No fruit set
CD (0.05)	0.78	0.72	0.99	-

Table 21. Response of different chemical regulators on fruiting duration of mango varieties

Fruiting duration (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	118.37	100.75	95.50	No fruit set
T_2	111.50	94.75	92.12	No fruit set
T_3	114.62	91.25	94.87	No fruit set
T_4	118.00	95.50	96.50	No fruit set
T_5	122.00	100.62	98.93	No fruit set
CD (0.05)	1.10	0.94	1.02	-

Table 22. Response of different chemical regulators on fruit bearing intensity of mango varieties

Fruit bearing intensity				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	Low	Medium	Low	No fruit set
T_2	Medium	Medium	Medium	No fruit set
T_3	Low	Medium	Medium	No fruit set
T_4	Medium	Medium	Medium	No fruit set
T_5	Low	Low	Medium	No fruit set

Table 23. Response of different chemical regulators on fruit length of mango varieties

Fruit length (cm)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	8.15	9.97	8.26	No fruit set
T_2	8.25	11.41	8.18	No fruit set
T_3	8.73	11.18	8.05	No fruit set
T_4	9.29	11.65	8.48	No fruit set
T_5	7.90	8.65	7.66	No fruit set
CD (0.05)	0.08	0.09	0.11	-

Table 24. Response of different chemical regulators on fruit diameter of mango varieties

Fruit diameter (cm)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	22.16	20.78	8.57	No fruit set
T_2	23.03	23.96	9.15	No fruit set
T_3	20.91	24.54	9.12	No fruit set
T_4	26.97	26.52	9.35	No fruit set
T_5	18.15	17.87	8.25	No fruit set
CD (0.05)	0.66	0.88	0.14	-

Pulp to peel ratio recorded for Sindhuram was ranged from 2.53 to 4.69. The maximum pulp to peel ratio was observed in T_4 (4.69) and which was followed by T_3 (2.98), T_2 (2.89), T_1 (2.68) and T_1 (2.53). In Nadashala, fruit set has not occurred.

4.4.9. Pulp to stone ratio

The effect of various treatments on pulp to stone ratio are tabulated in Table 27.

The treatments had significant influence on pulp to stone ratio. Pulp to stone ratio recorded in Alphonso was ranged from 2.60 to 6.23. The highest pulp to stone ratio in Alphonso was recorded in T_4 (6.23) and which was followed by T_3 (4.32), T_2 (4.04), T_5 (3.81) and T_1 (2.60). In Banganapalli, the pulp to stone ratio recorded was varied from 3.50 to 6.93. The highest pulp to stone ratio in Banganapalli was recorded in T_4 (6.93) which was followed by T_3 (4.68), T_2 (4.28), T_1 (4.10) and T_5 (3.50). In Sindhuram, pulp to stone ratio recorded was ranged from 2.39 to 4.00. The highest pulp to stone ratio in Sindhuram was recorded in T_4 (4.00) and which was followed by T_1 (2.92), T_5 (2.87), T_3 (2.83) and T_2 (2.39). In Nadashala, fruit set has not occurred.

4.4.10. Yield per tree

Data corresponding to the yield per tree are presented in Table 28.

The treatments had a significant influence on yield per tree. The yield per tree recorded in Alphonso was ranged from 5.40 kg/year to 14.62 kg/tree. The maximum yield in Alphonso was recorded in T_4 (14.62 kg/year) and which was followed by T_2 (13.53 kg/year), T_3 (13.15 kg/year), T_1 (11.06 kg/year) and T_5 (5.40 kg/year). In Banganapalli, the yield per tree was ranged from 6.64 kg/tree to 15.53 kg/tree. The maximum yield in Banganapalli was recorded in T_2 (15.53 kg/year) followed by T_3 (13.90 kg/year) and was on par with T_4 (13.68 kg/year), followed by T_1 (8.00 kg/year) and T_5 (6.64 kg/year).The yield per tree recorded in Sindhuram was varied from 6.00 kg/tree to 20.50 kg/tree. The maximum yield in Sindhuram was observed in T_2 (20.50 kg/year) and which was followed by T_4 (17.06 kg/year), T_3 (15.09 kg/year), T_1 (13.87 kg/year) and T_5 (6.00 kg/year). In Nadashala, fruit set has not occurred.

4.4.11. Shelf life

The data relating to effect of different treatments on shelf life are presented in Table 29.

The shelf life recorded in Alphonso was ranged from 5.0 days to 9.0 days. The maximum shelf life in Alphonso was recorded in T_4 (9.0 days) and which was followed by T_2 (7.7 days), T_3 (7.0 days), T_5 (5.1 days) and T_1 (5.0 days). In Banganapalli, the shelf life recorded was varied from 4.8 days to 5.7 days. However, the treatments had no significant influence over the shelf life in Banganapalli. The shelf life in Sindhuram was ranged from 5.0 days to 7.0 days. The highest shelf life in Sindhuram was observed in T_2 (7.0 days) which was followed by T_4 (4.7 days), T_5 (5.0 days), T_1 (5.0 days) and T_3 (4.7 days).

4.5. Quality attributes of fruit

Various observations on quality parameters *viz.*, TSS, acidity, ascorbic acid, total carotenoids, total sugar and reducing sugar of Alphonso, Banganapalli and Sindhuram under different chemical treatments were recorded and presented below.

4.5.1. TSS

Data pertaining to the effect of different treatments on TSS are furnished in Table 30.

Application of treatments had significant effect on TSS (º Brix). The TSS recorded in Alphonso was ranged from 13.50 º Brix to 21.12 º Brix. The highest value of TSS in Alphonso was recorded in T_2 (21.12 º Brix) and which was followed by T_4 (19.12 º Brix), T_3 (17.62 º Brix), T_1 (15.50 º Brix) and T_5 (13.50 º Brix). In Banganapalli, the TSS recorded was varied from 16.37 º Brix to 22.62 º Brix. The highest TSS in Banganapalli was recorded in T_2 (22.62 º Brix) and which was followed by T_4 (21.37 º Brix), T_1 (19.37 º Brix), T_3 (18.12 º Brix), and T_5 (16.37 º Brix). In the case of Sindhuram, the TSS was ranged from 14.75 º Brix to 22.37. The highest TSS in Sindhuram was recorded in T_4 (22.37 º Brix) which was significantly superior and which was followed by T_2 (19.37 º Brix), T_3 (18.12 º Brix), T_1 (16.25 º Brix) and T_5 (14.75 º Brix).

Table 25. Response of different chemical regulators on fruit weight of mango varieties

Fruit weight (g)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	233.91	245.86	208.46	No fruit set
T_2	298.97	355.97	182.22	No fruit set
T_3	244.87	360.80	234.75	No fruit set
T_4	336.85	408.81	242.41	No fruit set
T_5	178.12	159.87	197.92	No fruit set
CD (0.05)	0.95	0.68	0.83	-

Table 26. Response of different chemical regulators on pulp to peel ratio of mango varieties

Pulp to peel ratio				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	5.60	3.61	2.53	No fruit set
T_2	9.30	4.92	2.89	No fruit set
T_3	6.17	5.09	2.98	No fruit set
T_4	12.33	7.32	4.69	No fruit set
T_5	4.70	5.90	2.68	No fruit set
CD (0.05)	0.10	0.18	0.09	-

Table 27. Response of different chemical regulators on pulp to stone ratio of mango varieties

Pulp to stone ratio				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	2.60	4.10	2.92	No fruit set
T_2	4.04	4.28	2.39	No fruit set
T_3	4.32	4.68	2.83	No fruit set
T_4	6.23	6.93	4.00	No fruit set
T_5	3.81	3.50	2.87	No fruit set
CD (0.05)	0.09	0.10	0.12	-

Table 28. Response of different chemical regulators on yield per tree of mango varieties

Yield per tree (kg/year)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	11.06	13.00	13.87	No fruit set
T_2	13.53	15.53	20.50	No fruit set
T_3	13.15	13.90	15.09	No fruit set
T_4	14.62	13.68	17.06	No fruit set
T_5	5.40	6.64	6.00	No fruit set
CD (0.05)	0.43	0.58	0.79	-

Table 29. Response of different chemical regulators on shelf life of mango varieties

Shelf life (days)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	5.0	4.8	5.0	No fruit set
T_2	7.7	5.7	7.0	No fruit set
T_3	7.0	4.7	4.7	No fruit set
T_4	9.0	5.2	5.5	No fruit set
T_5	5.1	5.2	5.0	No fruit set
CD (0.05)	0.77	NS	0.64	-

Table 30. Response of different chemical regulators on total soluble solids (TSS) of mango varieties

TSS (^{0} Brix)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	15.50	19.37	16.25	No fruit set
T_2	21.12	22.62	19.37	No fruit set
T_3	17.62	18.12	18.12	No fruit set
T_4	19.12	21.37	22.37	No fruit set
T_5	13.50	16.37	14.75	No fruit set
CD (0.05)	1.27	1.20	1.10	-

KNO_3 – 4 % **Salicylic acid – 2000 ppm**

Plate 12a. Response of different chemical regulators on fruiting in Alphonso

KNO_3 – 4 % **Ethephon – 200 ppm**

Plate 12b. Response of different chemical regulators on fruiting in Banganapalli

KNO_3 – 4 % **Control**

Plate 12c. Response of different chemical regulators on fruiting in Sindhuram

Plate 13. Harvested fruits of Alphonso, Banganapalli and Sindhuram from different treatments

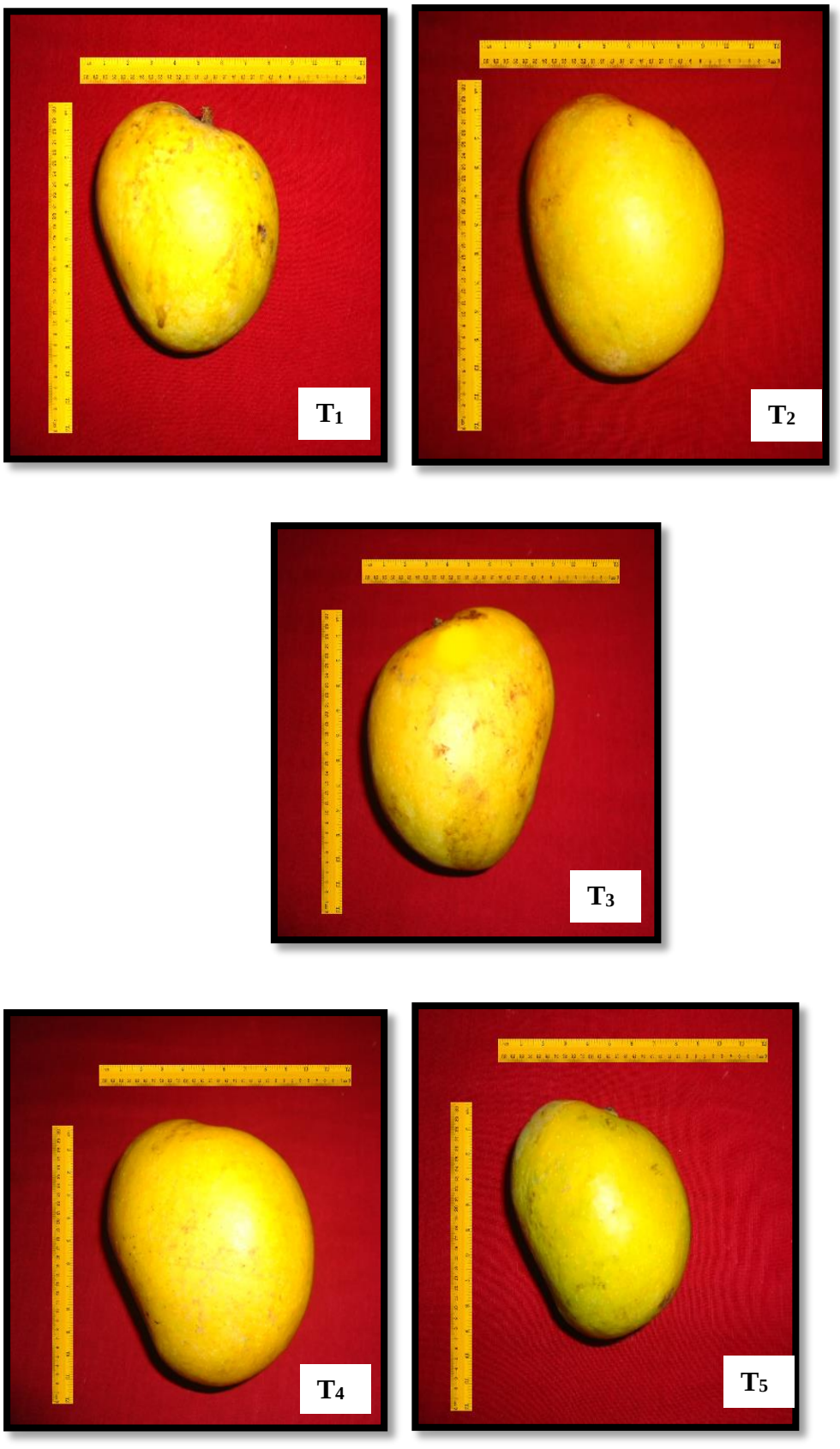


Plate 14. Response of different chemical regulators on fruit size in Alphonso

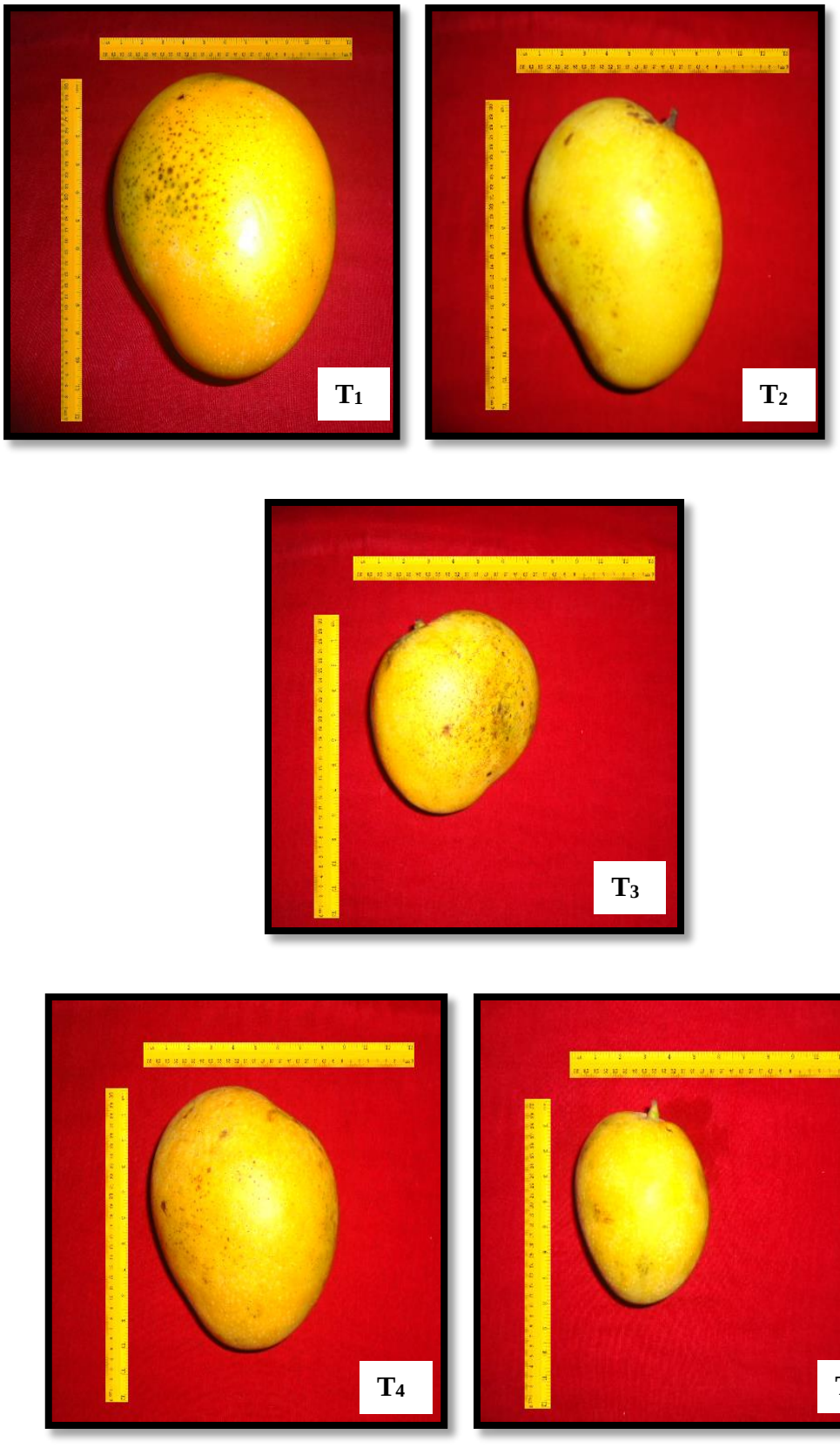


Plate 15. Response of different chemical regulators on fruit size in Banganapalli

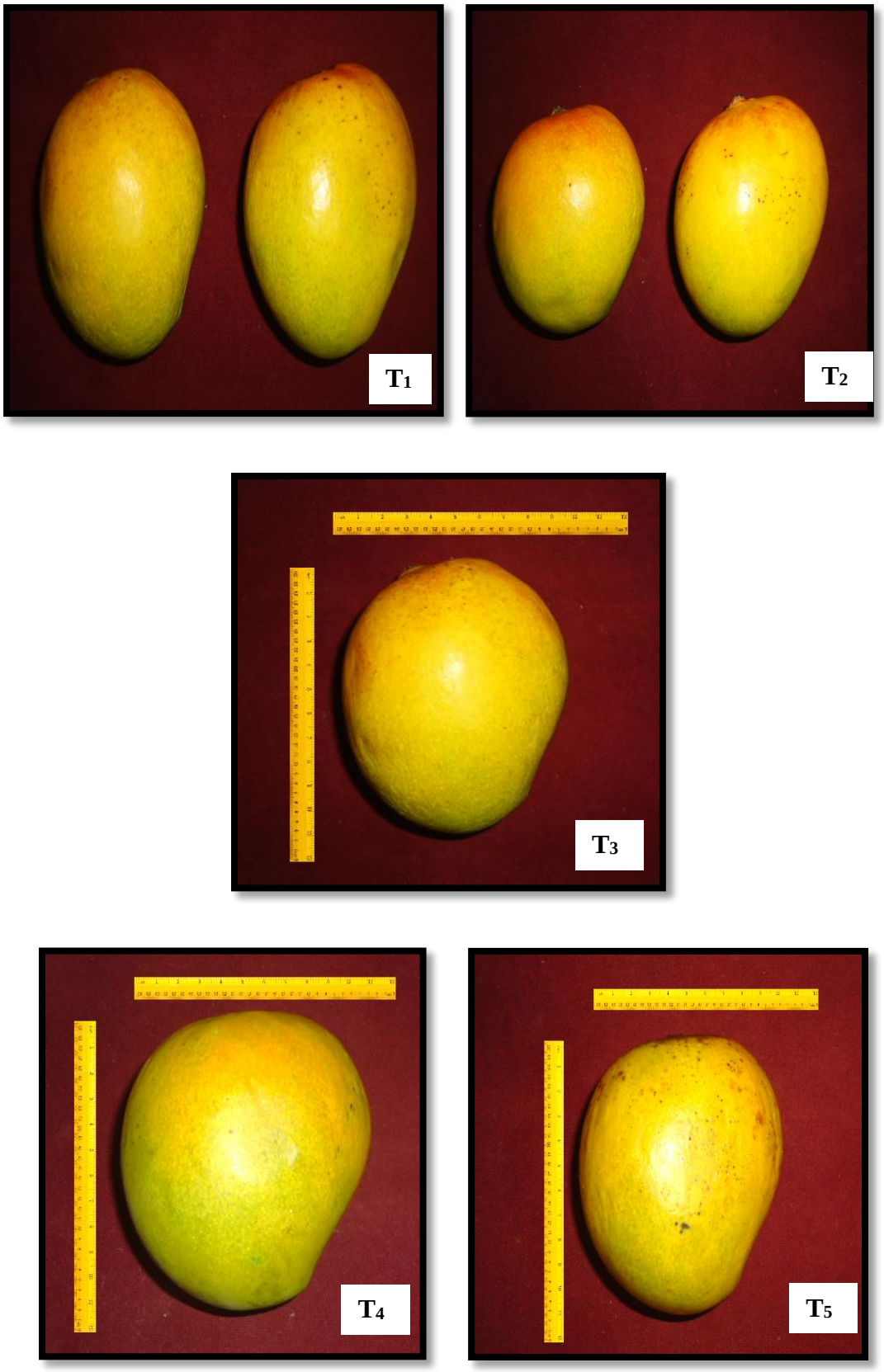


Plate 16. Response of different chemical regulators on fruit size in Sindhuram

4.5.2. Acidity

Data with respect to the effect of different treatments on acidity are presented in Table 31.

The treatments had a significant effect on acidity. The acidity in Alphonso was ranged from 0.189 % to 0.294 %. The minimum acidity in Alphonso was observed in T_2 (0.18 %) and which was followed by T_4 (0.21 %), T_3 (0.24 %), T_1 (0.26 %) and T_5 (0.29 %). In Banganapalli, the acidity was ranged from 0.219 % to 0.301 %. The minimum acidity in Banganapalli was recorded in T_4 (0.21 %) and which was followed by T_2 (0.24 %), T_1 (0.26 %), T_3 (0.28 %) and T_5 (0.30 %). In Sindhuram, the estimated acidity was varied from 0.235 % to 0.390 %. The minimum acidity in Sindhuram was recorded in T_2 (0.23 %) and which was followed by T_3 (0.31 %), T_1 (0.33 %), T_4 (0.35 %) and T_5 (0.39 %).

4.5.3. Ascorbic acid

The data on the effect of various treatments on ascorbic acid are presented in Table 32.

The ascorbic acid content of the fruits in Alphonso ranged from 25.5 mg/100g to 44.37 mg/100g. The highest ascorbic acid in Alphonso was reported in T_4 (44.37 mg/100g) which was followed by T_2 (41.37 mg/100g), T_3 (37.00 mg/100g), T_1 (30.75 mg/100g) and T_5 (25.50 mg/100g).

However, in Banganapalli and Sindhuram, the ascorbic acid content showed no significant difference among the treatments.

4.5.4. Total carotenoids

There was no significant effect on total carotenoids of fruits due to the application of different treatments as shown in Table 33.

4.5.5. Total sugar

Data pertaining to the influence of different treatments on total sugar are given in Table 34.

Application of different chemical regulators had significant effect on total sugar. The total sugar content in Alphonso was ranged from 10.25 % to 18.81 %. The highest total sugar in Alphonso was reported in T_4 (18.81 %) and which was followed by T_2 (16.32 %), T_3 (13.20 %), T_1 (12.02 %) and T_5 (10.25 %). In Banganapalli, the value for total sugar was ranged from 11.50 % to 17.91 %. The highest total sugar in Banganapalli was reported in T_2 (17.91 %) and which was followed by T_3 (16.17 %), T_4 (15.66 %), T_1 (11.50 %) and T_5 (11.50 %). In Sindhuram, the total sugar estimated was varied from 11.28 % to 16.22 %. The highest total sugar in Sindhuram was reported in T_2 (16.22 %) and which was followed by T_4 (16.08 %), T_3 (15.08 %), T_1 (13.43 %) and T_5 (11.28 %).

4.5.6. Reducing sugar

Data relating to the effect of different treatments on reducing sugar are presented in Table 35.

The treatments had a significant effect on reducing sugar. The reducing sugar content in Alphonso ranged from 2.56 % to 5.21 %. The highest reducing sugar in Alphonso was reported in T_4 (5.21 %) which was on par with T_2 (5.16 %), followed by T_1 (4.21 %), T_3 (4.18 %) and T_5 (2.56 %). In Banganapalli, the reducing sugar estimated varied from 4.03 % to 6.58 %. The highest reducing sugar in Banganapalli was reported in T_2 (6.58 %) which is on par with T_4 (6.50 %) and is followed by T_1 (5.08 %), T_3 (4.49 %) and T_5 (4.03 %). In Sindhuram, it was ranged from 2.58 % to 4.30 %. The highest reducing sugar in Sindhuram was reported in T_2 (4.30 %) which is on par with T_4 (3.99 %), T_1 (3.52 %) and T_5 (2.58 %).

4.6.2. Stomatal frequency

Data on the effect of different treatments on stomatal frequency are presented in Table 37.

The treatments had a significant influence on stomatal frequency. In Alphonso, the stomatal frequency recorded ranged from 647.46 stomata/mm^2 to 901.34 stomata /mm^2. The highest stomatal frequency in Alphonso was recorded in T_4 (901.34 stomata /$mm^{2)}$ which was significantly superior and was followed by T_3 (880.98

stomata /mm$^{2)}$, T_2 (743.90 stomata /mm$^{2)}$, T_1 (715.29 stomata /mm^2) and T_5 (647.46 stomata /mm^2). The stomatal frequency in Banganapalli ranged from 595.25 stomata/mm^2 to 937.93 stomata /mm^2. The highest stomatal frequency in Banganapalli was reported in T_4 (937.93 stomata /mm^2) and which was followed by T_2 (849.47 stomata /mm^2), T_3 (830.71 stomata /mm^2), T_5 (673.81/mm^2) and T_1 (595.25/mm^2). In Sindhuram, the values for stomatal frequency ranged from 524.79 stomata /mm^2 to 691.44 stomata /mm^2. The highest stomatal frequency in Sindhuram was observed in T_3 (691.44 stomata / mm^2) and which was followed by T_2 (641.25 stomata /mm^2), T_4 (610.56 stomata /mm^2), T_1 (545.90 stomata /mm^2) and T_5 (524.79 stomata /mm^2).In Nadashala, the stomatal count ranged from 535.22 stomata /mm^2 to 759.85 stomata /mm^2. The highest stomatal frequency in Nadashala was obtained by T_4 (759.85 stomata /mm^2), which was significantly superior and was followed by T_3 (743.78 stomata /mm^2), T_2 (709.56 stomata /mm^2), T_5 (691.42/mm^2) and T_1 (535.22/mm^2).

4.6.3. Stomatal conductance

Data pertaining to the effect of different treatments on stomatal conductance are given in Table 38.

With regard to stomatal conductance, applications of different treatments had no significant effect in Alphonso and Banganapalli. In the case of Sindhuram, the stomatal conductance estimated was varied from 0.059 mol m^{-2} s^{-1} to 0.134 mol m^{-2} s^{-1}. The highest stomatal conductance in Sindhuram was reported in T_4 (0.134 mol m^{-2} s^{-1}) and which was on par with T_2 (0.113 mol m^{-2} s^{-1}) and T_3 (0.093 mol m^{-2} s^{-1}) and T_5 (0.059 mol m^{-2} s^{-1}). In Nadashala, it was ranged from 0.046 mol m^{-2} s^{-1} to 0.069 mol m^{-2} s^{-1}. The highest stomatal conductance in Nadashala was obtained by T_5 (0.069 mol m^{-2} s^{-1}) and which was on par with T_3 (0.061 mol m^{-2} s^{-1}), T_4 (0.048 mol m^{-2} s^{-1}), T_1 (0.048 mol m^{-2} s^{-1}) T_2 (0.046 mol m^{-2} s^{-1}).

4.6.4. Photosynthetic rate

Data relating to the photosynthetic rate as affected by different treatments are presented in Table 39.

Table 31. Response of different chemical regulators on acidity of mango varieties

Acidity (%)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	0.26	0.26	0.33	No fruit set
T_2	0.18	0.24	0.23	No fruit set
T_3	0.24	0.28	0.31	No fruit set
T_4	0.21	0.21	0.35	No fruit set
T_5	0.29	0.30	0.39	No fruit set
CD (0.05)	0.01	0.02	0.01	-

Table 32. Response of different chemical regulators on ascorbic acid of mango varieties

Ascorbic acid (mg/100g)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	30.75	22.37	30.12	No fruit set
T_2	41.37	24.25	29.37	No fruit set
T_3	37.00	26.81	25.50	No fruit set
T_4	44.37	30.31	25.62	No fruit set
T_5	25.50	30.25	27.06	No fruit set
CD (0.05)	1.63	NS	NS	-

NS – Non significant

Table 33. Response of different chemical regulators on total carotenoids of mango varieties

Total carotenoids (mg/100g)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	3.94	0.93	2.53	No fruit set
T_2	3.83	1.03	3.69	No fruit set
T_3	2.77	1.55	3.18	No fruit set
T_4	1.74	1.38	2.34	No fruit set
T_5	1.54	1.17	1.58	No fruit set
CD (0.05)	NS	NS	NS	-

NS – Non significant

Table 34. Response of different chemical regulators on total sugar of mango varieties

Total sugar (%)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	12.02	13.40	13.43	No fruit set
T_2	16.32	17.91	16.22	No fruit set
T_3	13.20	16.17	15.08	No fruit set
T_4	18.81	15.66	16.08	No fruit set
T_5	10.25	11.50	11.28	No fruit set
CD (0.05)	0.65	1.13	0.77	-

Table 35. Response of different chemical regulators on reducing sugar of mango varieties

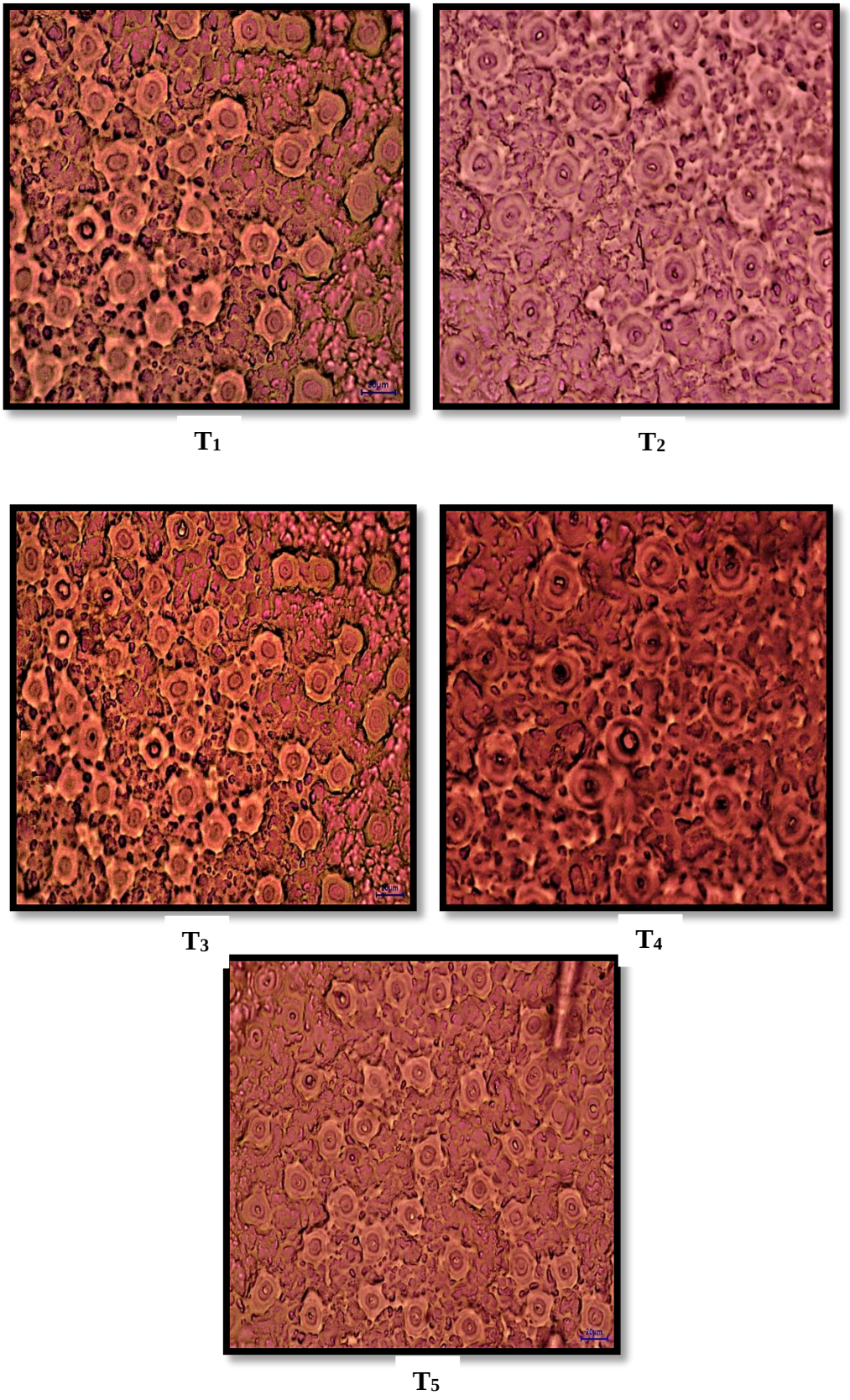
Reducing sugar (%)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	4.21	5.08	3.52	No fruit set
T_2	5.16	6.58	4.30	No fruit set
T_3	4.18	4.49	2.96	No fruit set
T_4	5.21	6.50	3.99	No fruit set
T_5	2.56	4.03	2.58	No fruit set
CD (0.05)	0.35	0.27	0.57	-

Table 36. Response of different chemical regulators on stomatal index of mango varieties

Stomatal index (%)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	21.20	18.82	19.02	12.73
T_2	21.57	20.02	19.73	20.95
T_3	18.66	20.78	20.15	31.73
T_4	18.56	19.66	20.12	20.87
T_5	19.35	19.73	21.22	12.75
CD (0.05)	NS	NS	NS	1.175

NS – Non significant

Abaxial section of leaves of mango varieties (at 40 X magnification using light microscope)

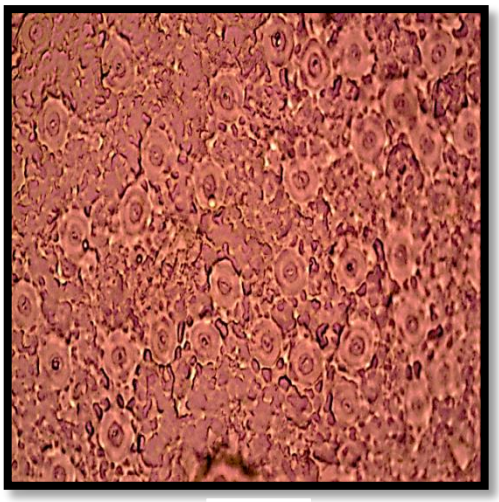


T_1 **T_2**

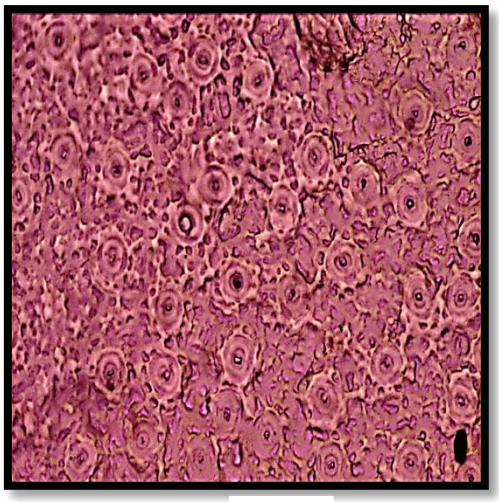
T_3 **T_4**

T_5

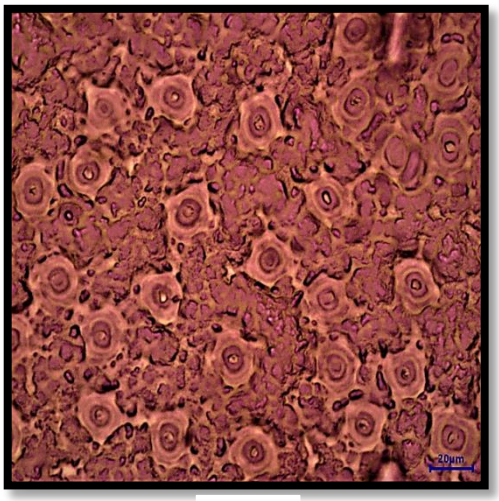
Plate 17a. Response of different chemical regulators on stomatal frequency in Alphonso



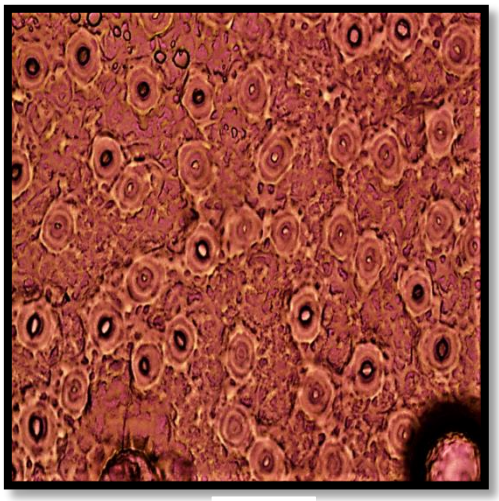
T_1



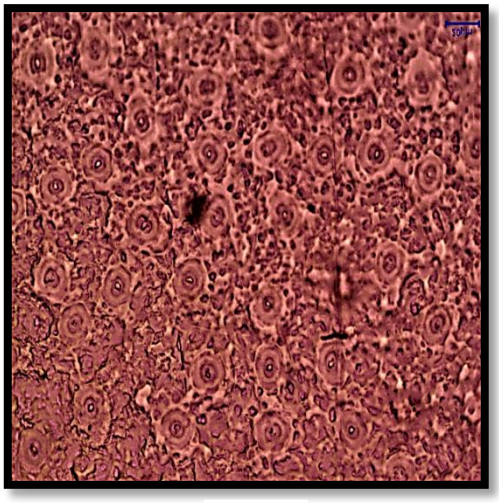
T_2



T_3

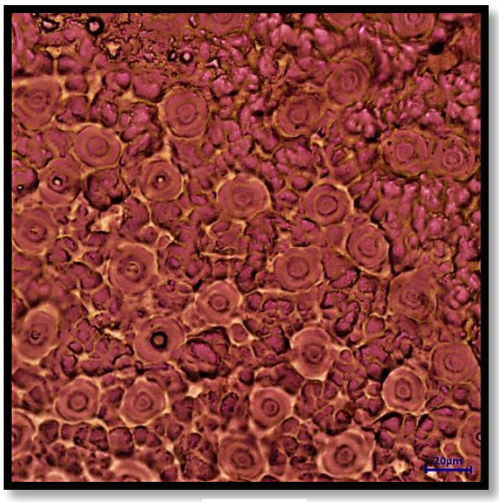


T_4

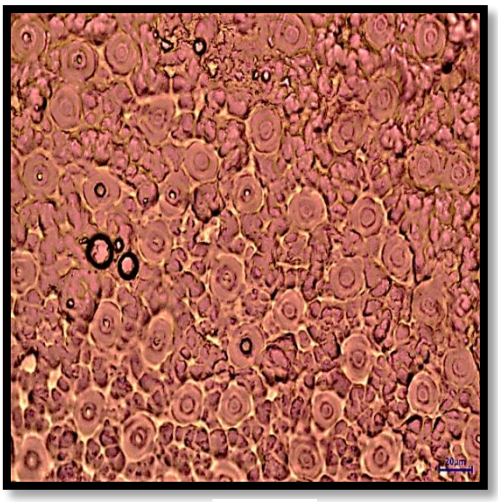


T_5

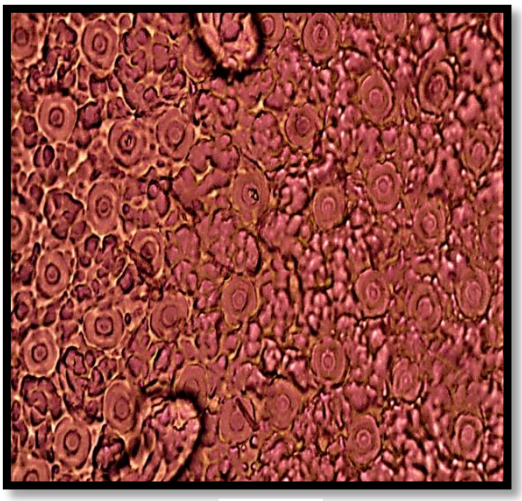
Plate 17b. Response of different chemical regulators on stomatal frequency in Banganapalli



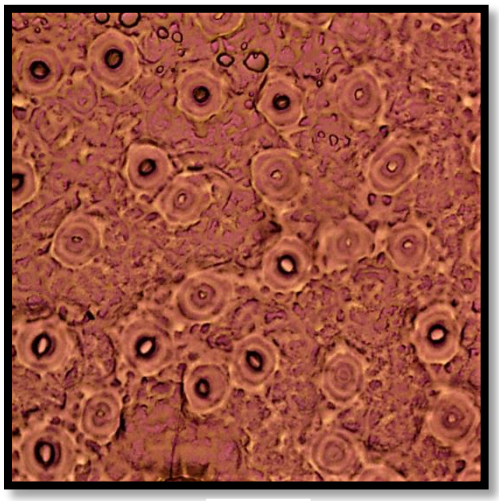
T_1



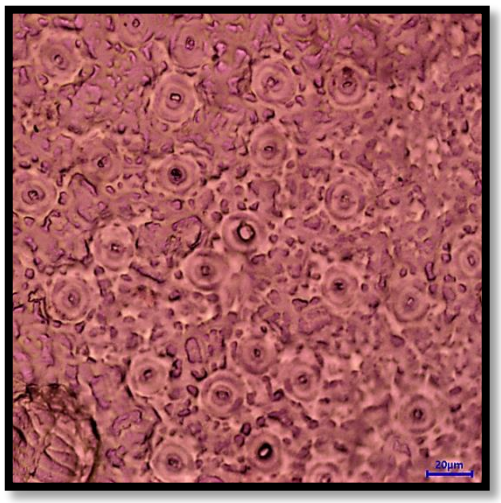
T_2



T_3

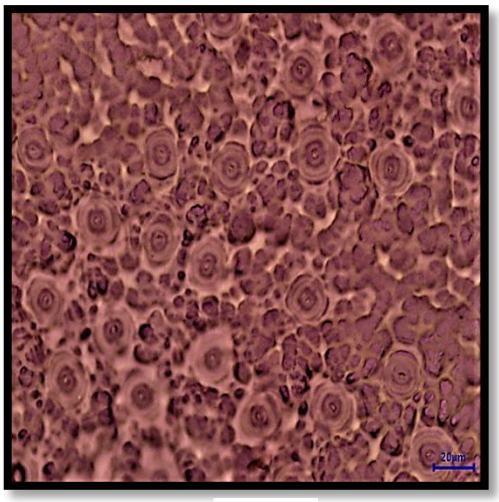


T_4

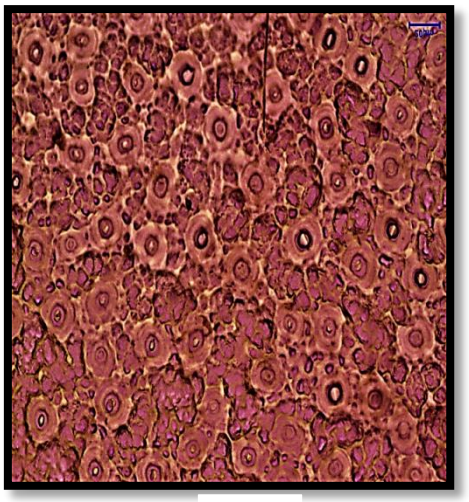


T_5

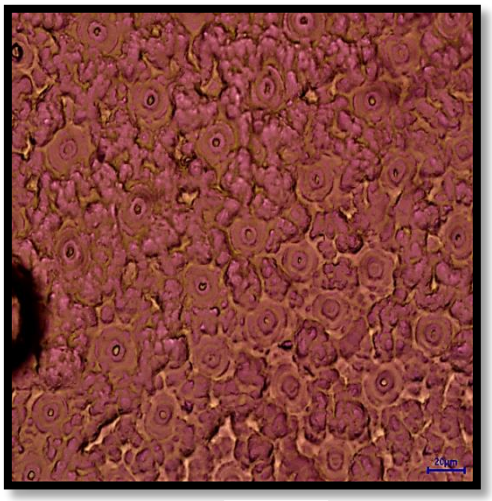
Plate 17c. Response of different chemical regulators on stomatal frequency in Sindhuram



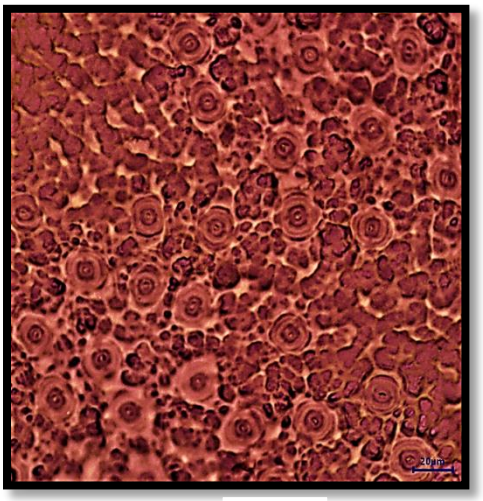
T_1



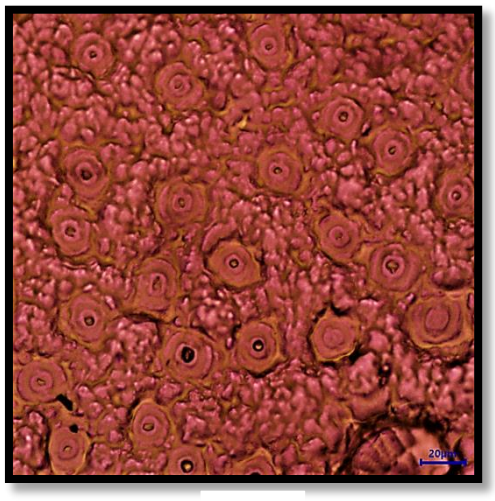
T_2



T_3



T_4



T_5

Plate 17d. Response of different chemical regulators on stomatal frequency in Nadashala

Plate 18. Observations on stomatal conductance, photosynthetic and transpiration rate using IRGA

In Alphonso, the photosynthetic rate was ranged from 1.10 µ mol m^{-2} s^{-1} to 2.30 µ mol m^{-2} s^{-1}. The photosynthetic rate in Banganapalli was ranged from 0.78 µ mol m^{-2} s^{-1} to 2.37 µ mol m^{-2} s^{-1}. In the case of Sindhuram, the photosynthetic rate was ranged from 0.16 µ mol m^{-2} s^{-1} to 0.26 µ mol m^{-2} s^{-1} and in Nadashala, it was ranged from 0.18 µ mol m^{-2} s^{-1} to 0.34 µ mol m^{-2} s^{-1}.

However, the data indicated that there was no significant difference among the treatments with respect to photosynthetic rate.

4.6.5. Transpiration rate

Data on the influence of various treatments on transpiration rate are presented in Table 40.

In Alphonso, the transpiration rate was ranged from 2.41 µ mol m^{-2} s^{-1} to 3.88 µ mol m^{-2} s^{-1}. The transpiration rate in Banganapalli was ranged from 2.47 µ mol m^{-2} s^{-1} to 3.06 µ mol m^{-2} s^{-1}. In the case of Sindhuram, the transpiration rate was ranged from 1.78 µ mol m^{-2} s^{-1} to 2.24 µ mol m^{-2} s^{-1} and in Nadashala, it was ranged from 1.69 µ mol m^{-2} s^{-1} to 2.22 µ mol m^{-2} s^{-1}.

With respect to the transpiration rate, there was no significant difference between the treatments.

4.6.7. Leaf area index (LAI)

The effect of different treatments on leaf area index estimated before and two months after treatment imposition are presented in Table 41.

In Alphonso, the leaf area index recorded before the treatment was ranged from 2.22 to 2.93, whereas it was ranged from 2.26 to 2.98 after the treatment. The leaf area index in Banganapalli recorded before the treatment was ranged from 2.32 to 2.95, whereas it was ranged from 2.41 to 3.05 after the treatment. In Sindhuram, the leaf area index recorded before the treatment was ranged from 2.65 to 2.89, whereas it was ranged from 2.71 to 2.99 after the treatment. In Nadashala, the leaf area index before the treatment was ranged from 2.57 to 3.16, whereas it was ranged from 2.68 to 3.39 after the treatment.

Table 37. Response of different chemical regulators on stomatal frequency of mango varieties

Stomatal frequency (No. of stomata/mm^2)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	715.29	595.25	545.90	535.22
T_2	743.90	849.47	641.25	709.56
T_3	880.98	830.71	691.44	743.78
T_4	901.34	937.93	610.56	759.85
T_5	647.46	673.81	524.79	691.42
CD (0.05)	1.06	0.50	0.64	0.89

Table 38. Response of different chemical regulators on stomatal conductance of mango varieties

Stomatal conductance (mol m^{-2} s^{-1})				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	0.103	0.105	0.068	0.048
T_2	0.116	0.198	0.113	0.046
T_3	0.184	0.187	0.093	0.061
T_4	0.196	0.203	0.134	0.048
T_5	0.065	0.132	0.059	0.069
CD (0.05)	NS	NS	0.041	1.175

NS – Non significant

Table 39. Response of different chemical regulators on photosynthetic rate of mango varieties

Photosynthetic rate (μ $molm^{-2}$ s^{-1})				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	1.12	0.78	0.17	0.22
T_2	1.10	2.18	0.21	0.28
T_3	1.88	1.76	0.26	0.34
T_4	2.30	2.37	0.16	0.25
T_5	0.23	1.18	0.22	0.18
CD (0.05)	NS	NS	NS	NS

NS – Non significant

Table 40. Response of different chemical regulators on transpiration rate of mango varieties

Transpiration rate (m mol m^{-2} s^{-1})				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	2.50	2.53	2.03	1.81
T_2	2.43	2.81	2.13	1.69
T_3	3.02	2.47	2.24	2.22
T_4	3.88	3.02	2.21	2.12
T_5	2.41	3.06	1.78	2.05
CD (0.05)	NS	NS	NS	NS

NS – Non significant

Table 41. Response of different chemical regulators on leaf area index of mango varieties

Treatments	Alphonso		Banganapalli		Sindhuram		Nadashala	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
T_1	2.41	2.45	2.71	2.76	2.68	2.78	2.57	2.68
T_2	2.61	2.65	2.64	2.70	2.89	2.99	2.89	3.26
T_3	2.93	2.98	2.79	2.89	2.65	2.74	3.16	3.39
T_4	2.22	2.26	2.95	3.05	2.72	2.77	2.82	2.92
T_5	2.36	2.40	2.32	2.41	2.65	2.71	2.63	2.73
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

However, application of different treatments had no significant effect on leaf area index.

4.7. Biochemical analysis

Observations on biochemical parameters *viz.*, leaf nutrient status (C/N ratio), ascorbic acid and chlorophyll content of Alphonso, Banganapalli, Sindhuram and Nadashala under various treatments were recorded and the results are presented below.

4.7.1. Leaf nutrient status (C/N ratio)

Data on the influence of leaf nutrient status as affected by different chemical regulators during and two months after flowering are given in Tables 42 and 43.

4.7.1.1. Carbohydrate content during flowering

Application of treatments had a significant influence on carbohydrate content during flowering. In Alphonso, the carbohydrate content during flowering varied from 11.86 % to 14.35 %. The highest carbohydrate content during flowering in Alphonso was observed in T_4 (14.35 %) which was on par with T_2 (14.06 %) and was followed by T_3 (13.35 %), T_1 (12.93 %) and T_5 (11.86 %). The carbohydrate content in Banganapalli during flowering was ranged from 11.31 % to 13.40 %. In Banganapalli, the highest carbohydrate content was recorded in T_3 (13.40 %) and which was followed by T_2 (12.70 %), T_4 (12.57 %), T_1 (11.78 %) and T_5 (11.31 %). In case of Sindhuram, the content of carbohydrate during flowering was ranged from 11.40 % to 13.08 %. The highest carbohydrate content in Sindhuram was recorded in T_2 (13.08 %) and was on par with T_3 (12.61 %), followed by T_4 (12.23 %), T_1 (11.56 %) and (10.97 %). In Nadashala, the carbohydrate content during flowering was varied from 11.26 % to 14.08 %. The highest carbohydrate content in Nadashala was recorded in T_2 (14.08 %) and was on par with T_4 (13.47 %), followed by T_3 (13.01 %), T_1 (11.71 %) and T_5 (11.26 %).

4.7.1.2. Nitrogen content during flowering

The treatments had a significant effect on nitrogen content during flowering. In Alphonso, the nitrogen content during flowering was ranged from 0.91 % to 1.08 %. In Alphonso, the lowest nitrogen content was recorded in T_4 (0.91 %) and which was followed by T_2 (0.98 %), T_5 (0.99 %), T_3 (1.03 %) and T_1 (1.08 %). The nitrogen content during flowering in Banganapalli was varied from 0.89 % to 0.97 %. The lowest nitrogen content in Banganapalli was recorded in T_3 (0.89 %) and was on par with T_2 (0.92 %) and T_4 (0.94 %), followed by T_5 (0.95 %) and T_1 (0.97 %). In Sindhuram, the nitrogen content varied from 0.88 % to 0.99 %. The lowest nitrogen in Sindhuram was recorded in T_2 (0.88 %) and which was followed by T_3 (0.94 %), T_4 (0.98 %), T_1 (0.99 %) and T_5 (0.99 %). In Nadashala, the nitrogen content during flowering ranged from 0.93 % to 0.98 %. The lowest nitrogen content during flowering in Nadashala was recorded in T_2 (0.93 %) and was on par with T_4 (0.95 %), which was followed by T_1 (0.97 %), T_3 (0.97 %) and T_5 (0.98 %) during flowering.

4.7.1.3. C/N ratio during flowering

The treatments had a significant influence on C/N ratio during flowering. The C/N ratio in Alphonso during flowering ranged from 11.87 to 15.63. The highest C/N ratio in Alphonso was recorded in T_4 (15.63) and which was followed by T_2 (14.31), T_3 (12.82), T_5 (11.90) and T_1 (11.87). In Banganapalli, the ratio ranged from 11.78 to 15. The highest C/N ratio during flowering in Banganapalli was observed in T_3 (15.00) and which was followed by T_2 (13.72), T_4 (13.30), T_1 (12.01) and T_5 (11.78). In Sindhuram, the C/N ratio during flowering varied from 11.45 to 14.73. The highest C/N ratio in Sindhuram was recorded in T_2 (14.73) and which was on par with T_3 (13.25), T_4 (12.37), T_1 (11.65) and T_5 (11.45). In Nadashala, the ranges are from 11.37 to 15.00. The highest C/N ratio in Nadashala was recorded in T_2 (15.00) and which was on par with T_4 (14.48), T_3 (13.26), T_1 (11.98) and T_5 (11.37).

Table 42. Response of different chemical regulators on C/N ratio of mango varieties during flowering

Treatments	Carbohydrate (%)				Nitrogen (%)				C/N ratio			
	Alphonso	Banganapalli	Sindhuram	Nadashala	Alphonso	Banganapalli	Sindhuram	Nadashala	Alphonso	Banganapalli	Sindhuram	Nadashala
T_1	12.93	11.78	11.56	11.71	1.08	0.97	0.99	0.97	11.87	12.01	11.65	11.98
T_2	14.06	12.70	13.08	14.08	0.98	0.92	0.888	0.93	14.31	13.72	14.73	15.00
T_3	13.35	13.40	12.61	13.01	1.03	0.89	0.949	0.97	12.82	15.00	13.25	13.26
T_4	14.35	12.57	12.23	13.77	0.91	0.94	0.986	0.95	15.63	13.30	12.37	14.48
T_5	11.86	11.31	10.97	11.26	0.99	0.95	0.995	0.98	11.90	11.78	11.45	11.37
CD (0.05 %)	0.965	0.475	0.719	0.634	0.083	0.053	0.046	0.038	0.684	0.814	0.475	0.506

Table 43. Response of different chemical regulators on C/N ratio of mango varieties at two months after flowering

Treatments	Carbohydrate (%)				Nitrogen (%)				C/N ratio			
	Alphonso	Banganapalli	Sindhuram	Nadashala	Alphonso	Banganapalli	Sindhuram	Nadashala	Alphonso	Banganapalli	Sindhuram	Nadashala
T_1	12.43	11.31	11.13	11.33	1.12	0.99	1.01	0.99	11.08	11.31	10.93	11.36
T_2	13.33	12.31	12.66	12.31	1.01	0.95	0.91	0.95	13.15	12.88	13.82	13.18
T_3	12.70	13.03	12.21	12.53	1.05	0.92	0.97	1.00	11.96	14.12	12.46	12.42
T_4	13.73	12.25	11.87	12.87	0.95	1.01	1.01	0.97	14.37	12.03	11.71	12.85
T_5	11.37	10.98	10.57	10.27	1.03	0.99	1.02	1.01	10.97	11.08	10.30	10.10
CD (0.05 %)	0.71	1.30	1.06	0.68	0.07	0.04	0.04	0.03	0.62	0.46	0.47	0.95

Table 44. Response of different chemical regulators on ascorbic acid of mango varieties

Ascorbic acid (mg/100g)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	28.22	25.05	24.22	25.70
T_2	26.49	26.70	21.82	29.24
T_3	27.55	26.94	23.15	23.92
T_4	24.25	27.40	19.82	25.85
T_5	25.84	28.23	21.86	26.15
CD (0.05)	NS	NS	NS	NS

NS – Non significant

Table 45. Response of different chemical regulators on total chlorophyll content of mango varieties

Total chlorophyll content (mg/g)				
Treatments	**Alphonso**	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	1.04	1.23	0.41	1.12
T_2	1.94	2.23	1.95	1.85
T_3	0.96	1.20	1.64	0.80
T_4	2.04	2.15	1.56	1.54
T_5	0.60	0.87	0.82	0.84
CD (0.05)	0.009	0.010	0.037	0.098

4.7.1.4. Carbohydrate content at two months after flowering

The treatments showed significant effect on carbohydrate content at two months after flowering. In Alphonso, the carbohydrate content at two months after flowering was ranged from 11.37 % to 13.73 %. The highest carbohydrate content in Alphonso was recorded in T_4 (13.73 %) and was on par with T_2 (13.33 %), followed by T_3 (12.70 %), T_1 (12.43 %) and T_5 (11.37 %). The carbohydrate content at two months after flowering in Banganapalli was ranged from 10.98 % to 13.03 %. The highest carbohydrate content in Banganapalli was observed in T_3 (13.03 %) and was on par with T_2 (12.31 %), T_4 (12.25 %), followed by T_1 (11.31 %) and T_5 (10.98 %). In the case of Sindhuram, the values varied from 10.57 % to 12.66 %. The highest value of carbohydrate content at two months after flowering in Sindhuram was obtained by T_2 (12.66 %) and was on par with T_3 (12.21 %), T_4 (11.87 %), followed by T_1 (11.13 %) and T_5 (10.57 %). In Nadashala, the carbohydrate content ranged from 10.27 % to 12.87 %. The highest value of carbohydrate content at two months after flowering in Nadashala was recorded in T_4 (12.87 %) and was on par with T_3 (12.53 %), T_2 (12.31 %), followed by T_1 (11.33 %) and T_5 (10.27 %).

4.7.1.5. Nitrogen content at two months after flowering

The treatments had a significant effect on nitrogen content at two months after flowering. In Alphonso, the nitrogen content ranged from 0.95 % to 1.12 %. The lowest nitrogen content in Alphonso was recorded in T_4 (0.95 %) and was on par with T_2 (1.01 %), followed by T_5 (1.03 %), T_3 (1.05 %) and T_1 (1.12 %). The nitrogen content in Banganapalli at two months after flowering ranged from 0.92 % to 1.01 %. The lowest nitrogen content in Banganapalli was recorded by T_3 (0.92 %) which was on par with T_2 (0.95 %), followed by T_1 (0.99 %), T_5 (0.99 %) and T_4 (1.01 %). In case of Sindhuram, the nitrogen content estimated at two months after flowering varied from 0.91 % to 1.02 %. The lowest nitrogen content in Sindhuram was observed in T_2 (0.91 %) and which was followed by T_3 (0.97 %), T_4 (1.01 %), T_1 (1.01 %) and T_5 (1.02 %). In Nadashala, it was ranged from 0.95 % to 1.01 %. The lowest nitrogen content in Nadashala at two months after flowering was recorded by T_2 (0.95 %) and which was on par with T_4 (0.97 %), followed by T_1 (0.99 %), T_3 (1.00 %) and T_5 (1.01 %).

4.7.1.6. C/N ratio at two months after flowering

The treatments had shown significant effect on C/N ratio at two months after flowering. In Alphonso, the C/N ratio at two months after flowering ranged from 10.97 to 14.37. The highest C/N ratio at two months after flowering in Alphonso was recorded in T_4 (14.37) which was followed by T_2 (13.15), T_3 (11.96), T_1 (11.08) and T_5 (10.97). The C/N ratio in Banganapalli ranged from 11.08 to 14.12. The highest C/N ratio in Banganapalli at two months after flowering was recorded by T_3 (14.12) and which was followed by T_2 (12.88), T_4 (12.03), T_1 (11.31) and T_5 (11.08). In Sindhuram, it was varied from 10.30 to 13.82. The highest C/N ratio was recorded in T_2 (13.82) which was followed by T_3 (12.46), T_4 (11.71), T_1 (10.93) and T_5 (10.30). In Nadashala, the C/N ratio estimated at two months after flowering varied from 10.10 to 13.18. The highest C/N ratio in Nadashala at two months after flowering was obtained by T_2 (13.18) which was on par with T_4 (12.85), T_3 (12.42) followed by T_1 (11.36) and T_5 (10.10).

4.7.2. Ascorbic acid

Data pertaining to the influence of different treatments on ascorbic acid are furnished in Table 44.

Ascorbic acid content estimated in Alphonso ranged from 24.25 mg/100g to 28.22 mg/100g. In Banganapalli, the ascorbic acid value varied from 25.05 mg/100g to 28.23 mg/100g. The ascorbic acid content in Sindhuram ranged from 19.82 mg/100g to 24.22 mg/100g. In Nadashala, the ascorbic acid value estimated ranged from 23.92 mg/100g to 29.24 mg/100g.

However, application of different treatments had no significant effect on ascorbic acid content.

4.7.3. Chlorophyll content (mg/g)

The data corresponding to **t**he effect of various treatments on chlorophyll content are presented in Table 45.

The treatments had a significant effect on chlorophyll content. The chlorophyll content estimated in was Alphonso ranged from 0.96 mg/g to 2.04 mg/g. The highest

chlorophyll content in Alphonso was reported in T_4 (2.04 mg/g) which was significantly superior to other treatments and followed by T_2 (1.94 mg/g), T_1 (1.04 mg/g), T_3 (0.96 mg/g) and T_5 recorded the lowest chlorophyll content of (0.60 mg/g). In Banganapalli, the chlorophyll content varied from 0.87 to 2.23 mg/g. The maximum chlorophyll content in Banganapalli was observed in T_2 (2.23 mg/g) and which was followed by T_4 (2.15 mg/g), T_1 (1.23 mg/g), T_3 (1.20 mg/g) and the lowest chlorophyll content was recorded in T_5 (0.87 mg/g). In Sindhuram, the chlorophyll content ranged from 0.41 mg/g to 1.95 mg/g. The highest chlorophyll content in Sindhuram was obtained by T_2 (1.95 mg/g) and which was followed by T_3 (1.64 mg/g), T_4 (1.56 mg/g), T_5 (0.82 mg/g) and T_1 recorded the least chlorophyll content (0.41 mg/g).

In Nadashala, the chlorophyll content was ranged from 0.80 mg/g to 1.85 mg/g. The highest chlorophyll content in Nadashala was observed in T_2 (1.85 mg/g) and which was followed by T_4 (1.54 mg/g), T_1 (1.12 mg/g), T_5 (0.85 mg/g) and T_3 (0.80 mg/g).

4.8. Economic analysis

Benefit cost was worked out (Table 46, 47 and 48). It was calculated by taking into account the cost of inputs, labour costs for the application of chemical regulators as well as for intercultural and harvesting operations in Alphonso, Banganapalli and Sindhuram. So, by the calculation of total cost and total returns, benefit cost ratio was worked out. The highest B: C ratio in Alphonso was recorded in T_4 (2.26) and was followed by T_3 (2.18), T_2 (1.61), T_5 (1.44) and T_1 (1.03). In Banganapalli, the highest B: C ratio was recorded in T_3 (2.31) and which was followed by T_4 (2.11), T_2 (1.84), T_5 (1.77) and T_1 (1.22). The highest B: C ratio in Sindhuram was recorded in T_4 (2.64) and was followed by T_3 (2.50), T_2 (2.44), T_5 (1.60) and T_1 (1.30).

Table 46. Response of different chemical regulators on B: C ratio of Alphonso

Treatments	Cost of cultivation excluding treatments (Rs./ha)	Additional cost due to treatments (Rs./ha)	Total cost of cultivation (Rs./ha)	Total returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
PBZ (T_1)	31267.5	57940	89207.5	92351.0	3143.5	1.03
KNO_3 (T_2)	31267.5	39000	70267.5	112985.9	42718.4	1.61
Ethephon (T_3)	31267.5	18980	50247.5	109802.5	59555.0	2.18
Salicylic acid (T_4)	31267.5	22782.5	54050.0	122077.0	68027.0	2.26
Control (T_5)	31267.5	-	31267.5	45090.0	13822.5	1.44

Table 47. Response of different chemical regulators on B: C ratio of Banganapalli

Treatments	Cost of cultivation excluding treatments (Rs./ha)	Additional cost due to treatments (Rs./ha)	Total cost of cultivation (Rs./ha)	Total returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
PBZ (T_1)	31267.5	57940	89207.5	108550.0	19342.5	1.22
KNO_3 (T_2)	31267.5	39000	70267.5	129675.5	59408.0	1.84
Ethephon (T_3)	31267.5	18980	50247.5	116065.0	65817.5	2.31
Salicylic acid (T_4)	31267.5	22782.5	54050.0	114228.0	60178.0	2.11
Control (T_5)	31267.5	-	31267.5	55444.0	24176.5	1.77

Table 48. Response of different chemical regulators on B: C ratio of Sindhuram

Treatments	Cost of cultivation excluding treatments (Rs./ha)	Additional cost due to treatments (Rs./ha)	Total cost of cultivation (Rs./ha)	Total returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
PBZ	31267.5	57940	89207.5	115814.5	26607.0	1.30
KNO_3	31267.5	39000	70267.5	171175.0	100908.0	2.44
Ethephon	31267.5	18980	50247.5	126001.5	75754.0	2.50
Salicylic acid	31267.5	22782.5	54050.0	142451.0	88401.0	2.64
Control	31267.5	-	31267.5	50100.0	18832.5	1.60

Table 49. Response of different chemical regulators on per cent disease incidence of sooty mould of mango varieties

Treatments	Per cent disease incidence (%) of sooty mould			
	Alphonso	**Banganapalli**	**Sindhuram**	**Nadashala**
T_1	25	25	37.5	50
T_2	37.5	12.5	12.5	62.5
T_3	50	25	25	50
T_4	37.5	37.5	25	25
T_5	50	25	37.5	37.5

Table 50. Response of different chemical regulators on severity/intensity rating of thrips of mango varieties

Treatments	Thrips (Population/panicle)				Ratings			
	Alphonso	Banganapalli	Sindhuram	Nadashala	Alphonso	Banganapalli	Sindhuram	Nadashala
T_1	17.75	13.00	11.00	7.00	3	2	2	2
T_2	11.55	4.75	4.50	17.50	2	1	1	3
T_3	19.75	8.50	10.00	18.50	3	2	2	3
T_4	11.25	10.75	9.50	21.00	2	2	2	3
T_5	15.75	12.75	8.75	20.50	3	2	2	3

Category of susceptibility	Thrips (Population/panicle)	Ratings
Free/Resistant	0	-
Less susceptible (Low)	1	Up to 5 nymphs or adults or both
Moderately susceptible (Medium)	2	6 – 15
Highly susceptible (High)	3	>15

4.9. Incidence of pest and diseases

The details on the causal agent, damage caused, symptoms and management of major pest are given below.

4.9.1. Pest incidence

a. Mango thrips (*Scirtothrips* spp)

Nymphs and adults were found to suck the sap of the inflorescence and caused drying and withering of panicle severely. The excretions of these insect led to the infestation of sooty mould that covered the lamina and reduced the photosynthetic efficiency. For controlling thrips, Spinosad 45 % @ 3.0 ml was mixed in 10 litres of water and sprayed using a rocker sprayer on the affected trees. Severity rating of thrips in mango varieties were worked out and presented in Table 50.

b. Mango leaf hopper (*Idioscopus clypealis*)

Adults and nymphs were found to suck the sap of leaves. The affected part was crinkled and dried. The development of sooty mould due to the excretion of these insect were noticed. Confidor 350 SC @ 0.5 ml/tree mixed in two litres of water was sprayed on the affected trees.

c. Mealy bug (*Drosicha mangiferae*)

Heavy clustering of mealy bug adults were found sucking the sap of fruit and fruit stalk. This caused the drying of fruit and ultimately fruit drop. For the control of mango mealy bug, malathion at 0.05 % was sprayed on the affected trees.

4.9.2. Disease incidence

a. Sooty mould (*Capnodium mangiferae*)

Development of black velvety thin covering on the surface of leaves were observed due to the excretions of the sucking pests. The trees were observed to be black from distance. Control of sooty mould was done by managing the sucking pests

using insecticide as listed above. The percentage disease incidence (PDI) of sooty mould in mango varieties were worked out in Table 49.

Mango mealy bug (*Drosicha mangiferae*)

Mango thrips (*Scirtothrips* spp) incidence

Sooty mould (*Capnodium mangiferae*)

Plate 19. Pest and disease incidence

Discussion

5. DISCUSSION

An experiment entitled 'Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system' was conducted to study the response of different mango varieties (Alphonso, Banganapalli, Sindhuram and Nadashala) under high density planting system in the agro climatic conditions of Muthalamada. The results of the experiment are discussed as follows; tree and leaf characters, inflorescence characters, fruit and stone characters, quality attributes, physiological characters and biochemical characters.

5.1. Tree and leaf characters

The height of mature tree, trunk circumference and crown diameter were not significantly influenced by the application of different chemical regulators. This was contrary to the finding of Khader (1991) and Ram *et al*. (1993) where there was a reduction in tree height, trunk circumference and crown diameter with paclobutrazol drench in mango cv. Dashehari. Singh *et al*. (2010) reported restriction of vegetative growth with the application of KNO_3 at 1 per cent. Exogenous application of ethrel were found to inhibit vegetative growth in mango (Das and Rath, 1978).

The crown shape of Alphonso and Banganapalli was semi circular and broadly pyramidal shape in Sindhuram and Nadashala. Alphonso, Banganapalli, Sindhuram and Nadashala had spreading tree growth habit. The foliage density of Alphonso was dense, whereas it was intermediate in Banganapalli, Sindhuram and Nadashala. The observations of the above parameters were in line with the Mango Database.

The leaf characters *viz.*, leaf blade length and leaf blade width were not influenced significantly by the application of different chemical treatments before and two months after the treatment imposition. This could be due to the fact that the application of different chemicals did not produce any significant effect on length and width of the leaves at any stage of the plant growth.

Colour of young leaf observed in Alphonso and Nadashala were light green with brown tinge and light green coloured young leaves in Banganapalli and Sindhuram. Similar finding was observed in the Mango Database.

5.2. Inflorescence characters

In this study, application of different chemical treatments was found to have significant effect on the flowering characters (Fig 1).

The number of days for first flowering is an important phenomena for all perennial fruit crops as it controls either delay or rapidity of a crop. In Alphonso, the treatment T_4 (salicylic acid at 2000 ppm) recorded minimum days for first flowering (67.0 days) and T_5 (control) recorded maximum days (87.0 days). Use of salicylic acid resulted in minimum number of days for panicle emergence in mango cv. Baneshan (Kumar and Reddy, 2008). Similar findings were reported by Kalarani *et al.* (2002) and Singh *et al*. (2001) in mango. In Banganapalli (56.8 days), Sindhuram (52.8 days) and Nadashala (74.3 days) recorded minimum days for first flowering in treatment T_2 (KNO_3 at 4 %). The maximum days for first flowering in Banganapalli (69.7 days), Sindhuram (68.0 days) and Nadashala (93.5 days) were recorded in T_5 (control). Early emergence of panicles with higher flowering percentage was reported by (Kumar *et al*., 2004; Nahar *et al*., 2010; Patil *et al*., 2013) with the application of KNO_3. This may be due to the direct action of nitrate in breaking the dormancy of flower buds, thus triggering the bud to initiate flowering (Trewasvas, 1983).

Application of different chemical regulators influenced the flowering duration (Fig 2) in which the minimum flowering duration in Alphonso was recorded in T_4 (20.75 days) with salicylic acid at 2000 ppm and which was followed by T_3 (23.37 days) with ethephon at 200 ppm. Application of salicylic acid had a significant effect in minimizing flowering duration (Ngullie *et al.*, 2014). The maximum duration of flowering was observed in T_5 (25.87 days), which was on par with the treatment T_1 (25.43 days) with paclobutrazol application at 8 ml. In Banganapalli (16.93 days), Sindhuram (16.25 days) and Nadashala (21.37 days) recorded minimum flowering duration in T_2 with KNO_3 at 4 %.

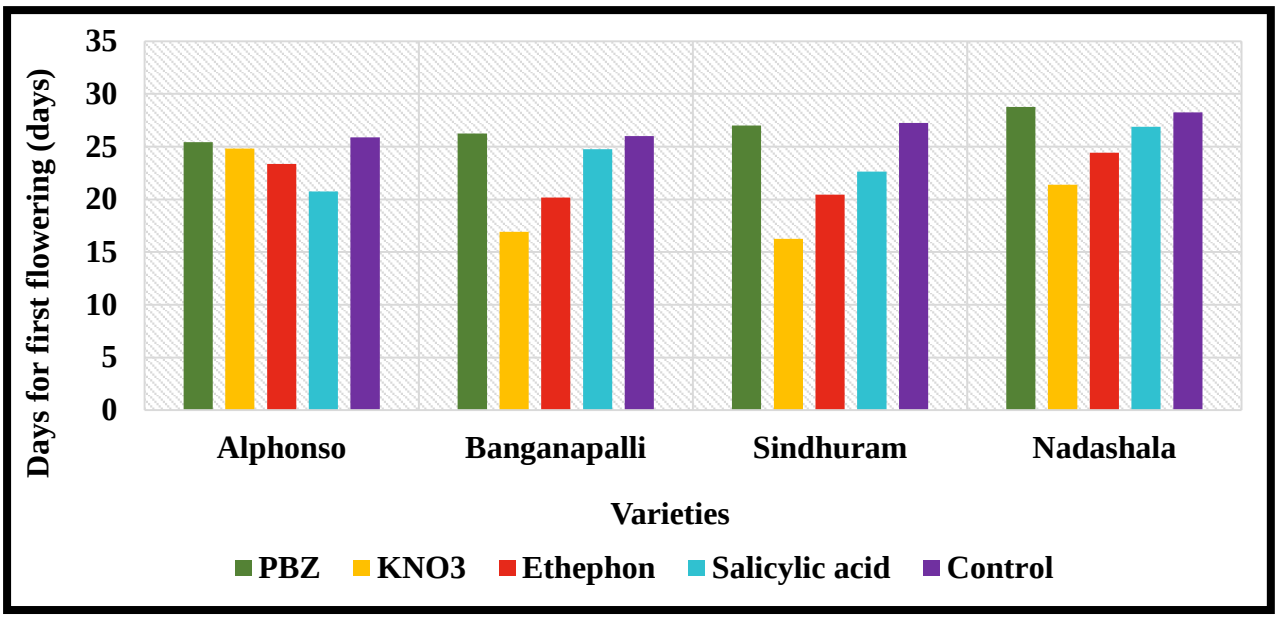


Fig 1. Response of chemical regulators on days for first flowering of mango varieties

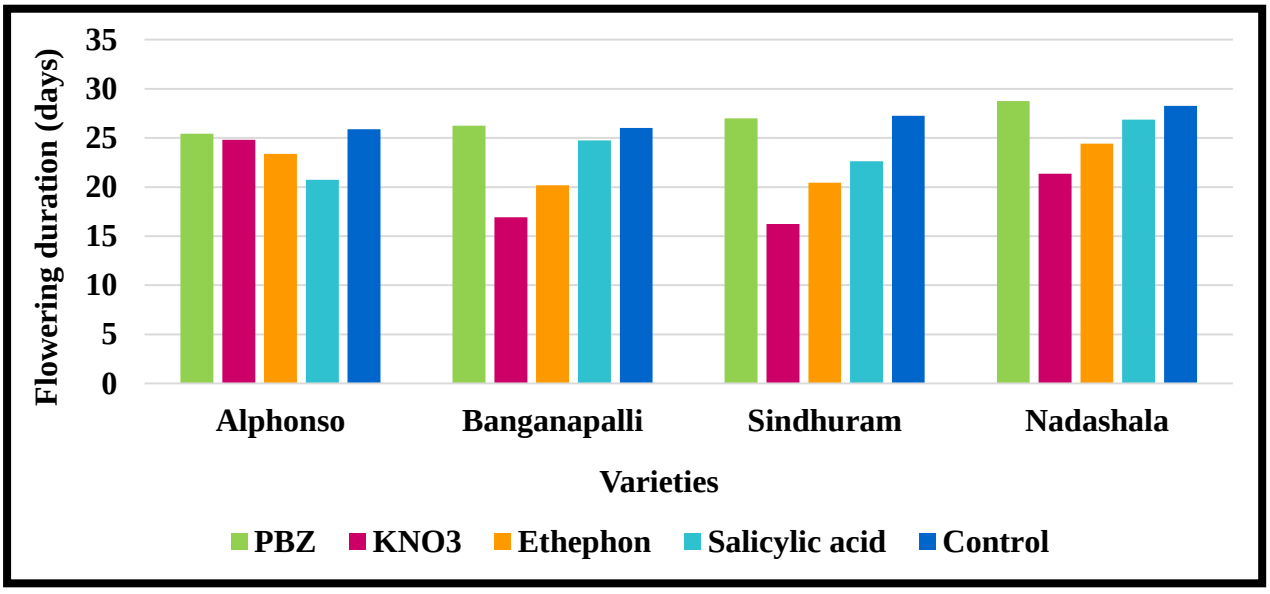


Fig 2. Response of chemical regulators on flowering duration of mango varieties

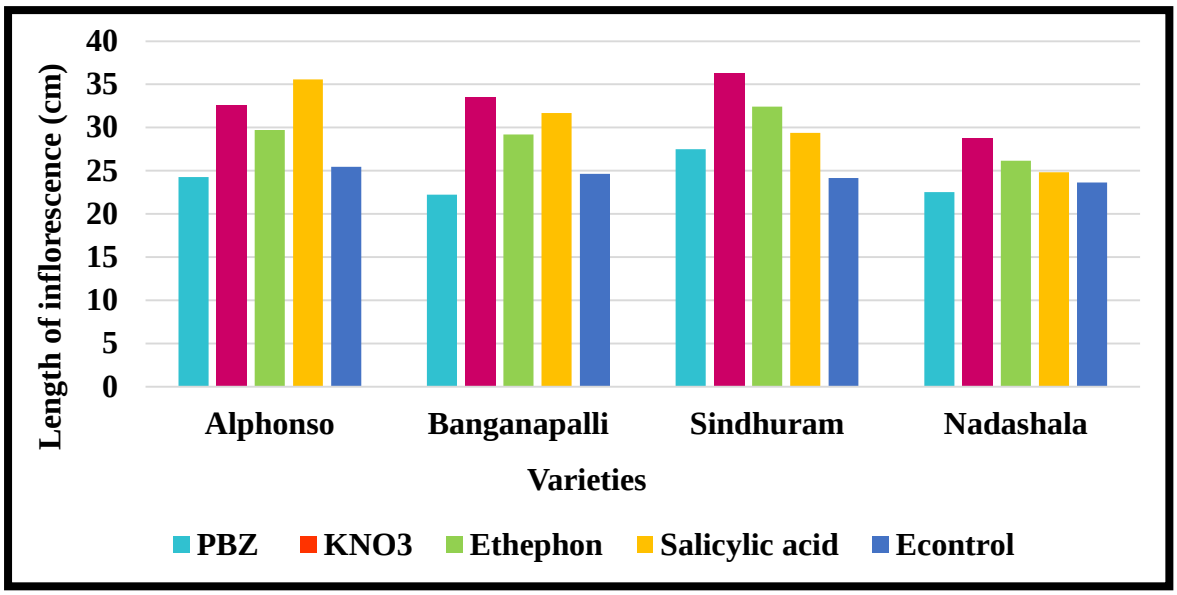


Fig 3. Response of chemical regulators on length of inflorescence of mango varieties

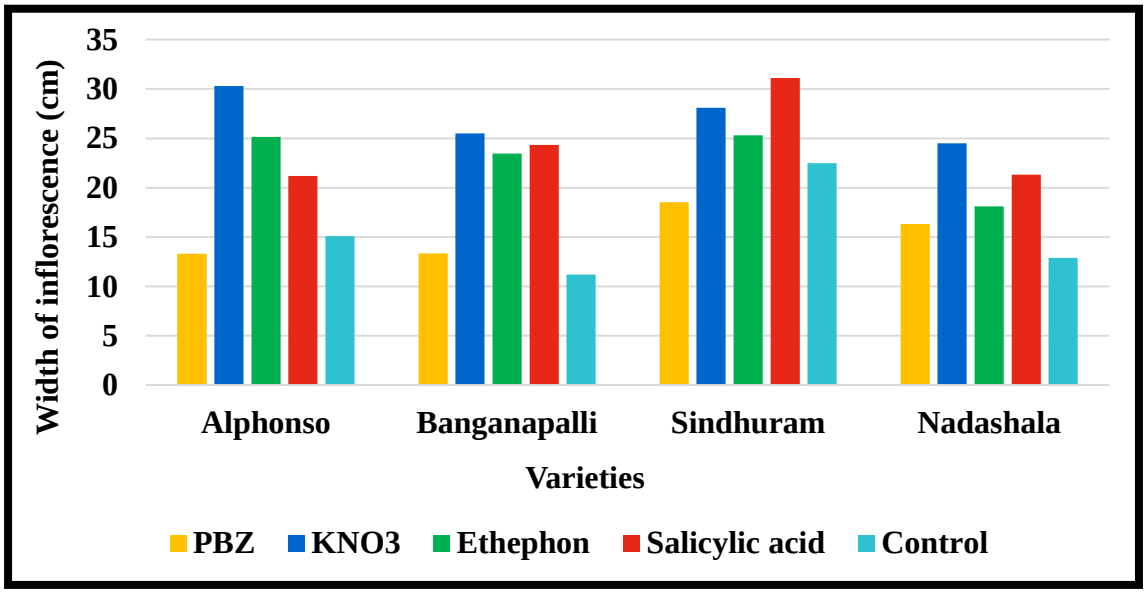


Fig 4. Response of chemical regulators on width of inflorescence of mango varieties

Minimum flowering duration with the application of KNO_3 in mango cv. Bombay Green was reported by Singh *et al*. (2019). Similar result was also reported in mango by Ubale and Banik (2017). The maximum flowering duration in Banganapalli (26.25 days) and Nadashala (28.75 days) were recorded in T_1 with paclobutrazol application at 8 ml. In Sindhuram, the treatment T_5 (27.25 days) took the maximum duration for flowering and was on par with T_1 (27.00 days).

The results clearly showed that the length of inflorescence was significantly influenced by the application of different chemical regulators (Fig 3). The maximum length of inflorescence in Alphonso was observed in T_4 (35.58 cm) with salicylic acid at 2000 ppm and which was followed by T_2 (32.57 cm) with KNO_3 at 4 %. Use of salicylic acid regulates the synthesis of auxin and / or cytokinin, which involves in cell division, cell expansion and cell differentiation resulting in maximum inflorescence length (Snow, 1935). In Banganapalli (33.52 cm), Sindhuram (36.28 cm) and Nadashala (28.72 cm), the maximum length of inflorescence was recorded in treatment T_2 with KNO_3 at 4 %. It was also reported that application of KNO_3 influenced panicle length in mango (Dalal *et al*., 2005; Babul and Rahim, 2013; Shongwe *et al*., 1997; Afiqah *et al*., 2014). The treatment T_1 (PBZ @ 8 ml) recorded minimum length in Alphonso (24.25 cm), Banganapalli (22.21 cm) and Nadashala (22.51 cm). In Sindhuram, minimum length of (24.15 cm) was recorded in T_5 (control).

Applications of different chemical regulators influenced width of inflorescence (Fig 4). Data showed that in Alphonso (30.32 cm), Banganapalli (25.50 cm) and Nadashala (24.51 cm) recorded maximum width of inflorescence in T_2 with KNO_3 at 4 %. In Sindhuram, T_4 (31.11 cm) recorded maximum width with salicylic acid at 2000 ppm. The treatments T_1 (PBZ at 8 ml) recorded minimum width in Alphonso (13.30 cm) and Sindhuram (18.53 cm), whereas T_5 (control) showed minimum width of (11.20 cm) in Banganapalli and (12.90 cm) in Nadashala. The favourable effect of KNO_3 application on panicle width in mango cv. Alphonso was reported by (Malshe *et al*., 2019; Yeshitela *et al*., 2004).

The sex ratio exhibited a significant influence by the application of different chemical regulators (Fig 5). The data showed that the highest sex ratio in Alphonso (41.62), Banganapalli (37.75), Sindhuram (42.75) and Nadashala (35.12) were recorded in treatment T_4 (salicylic acid). The lowest sex ratio (21.62) in Alphonso, (21.87) in Banganapalli and (21.64) in Sindhuram were recorded in T_5 (control). In case of Nadashala, the lowest sex ratio of (20.37) was recorded T_1 (PBZ at 8 ml) which was on par with T_5 (21.62). This could be due to the increased synthesis of floral stimulus by salicylic acid (Singh *et al*., 2001). Sex ratio was increased by the application of salicylic acid in mango cv. Kesar (Ngullie *et al*., 2014). Salicylic acid triggered flowering by acting as a chelating agent (Pieterse and Muller, 1977; Watanable *et al.*, 1981).

5.3. Fruit and stone characters

Fruit is the economically important part, the main objective of any research is to improve its size, yield and quality of the fruit. In this study, application of different chemical treatments were found to have a marked effect on fruit and stone characters.

The results showed that time taken from flowering to fruit set reported significant effect by the application of chemical regulators (Fig 6). The minimum time taken from flowering to fruit set in Alphonso was observed in T_2 (28.25 days) with KNO_3 at 4 % and it was on par with T_3 (28.87 days) with ethephon at 200 ppm. It concludes that the minimum time taken from flowering to fruit set in Alphonso by the application of KNO_3 may be due to the fact that KNO_3 induced early panicle emergence as reported by Nahar *et al*. (2010) and Muhammad *et al*. (2007). The maximum time taken from flowering to fruit set in Alphonso was observed in T_1 (33.12 days) with soil application of paclobutrazol at 8 ml, which was on par with T_5 (32.62 days). In Banganapalli (24.00 days) and Sindhuram (23.75 days), the minimum time taken was recorded in T_3. Ethrel application also promoted early flowering by rising peroxidase and α amylase activities for flower induction (Yamdagni and Khangia, 1989) and thus minimized the time taken from flowering and fruit set in Sindhuram and Banganapalli. Treatment T_5 recorded the maximum time

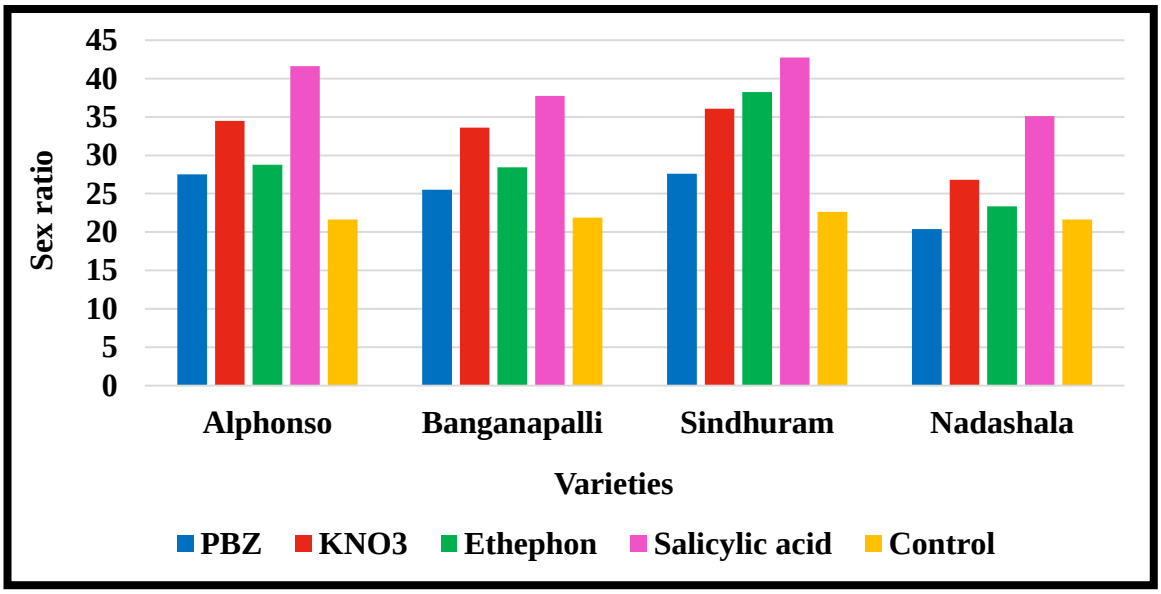


Fig 5. Response of chemical regulators on sex ratio of mango varieties

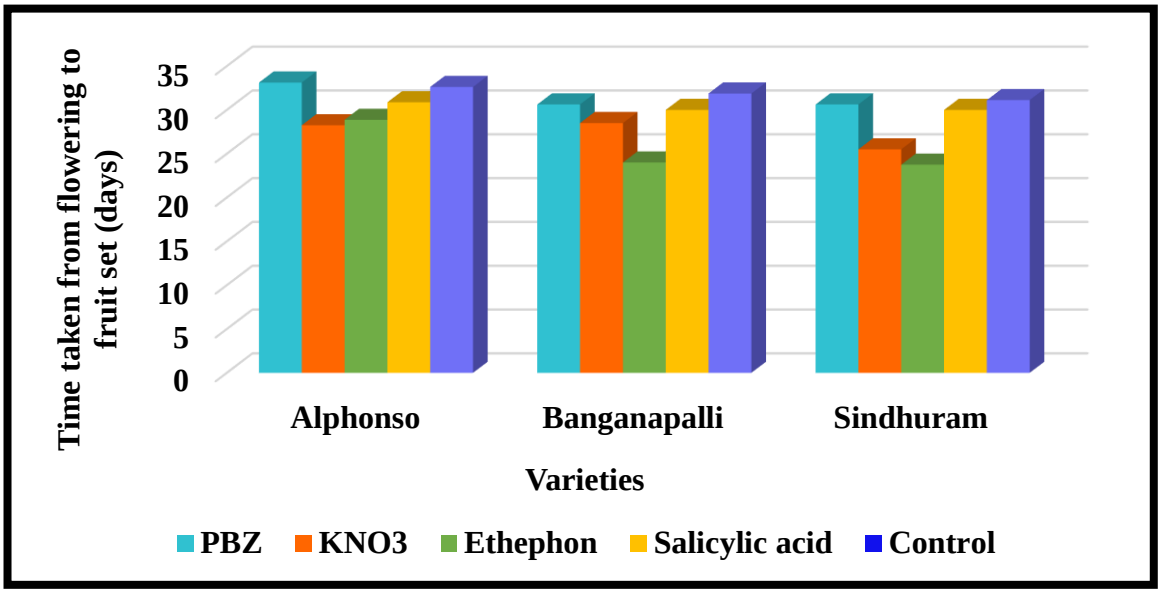


Fig 6. Response of chemical regulators on time taken from flowering to fruit set of mango varieties

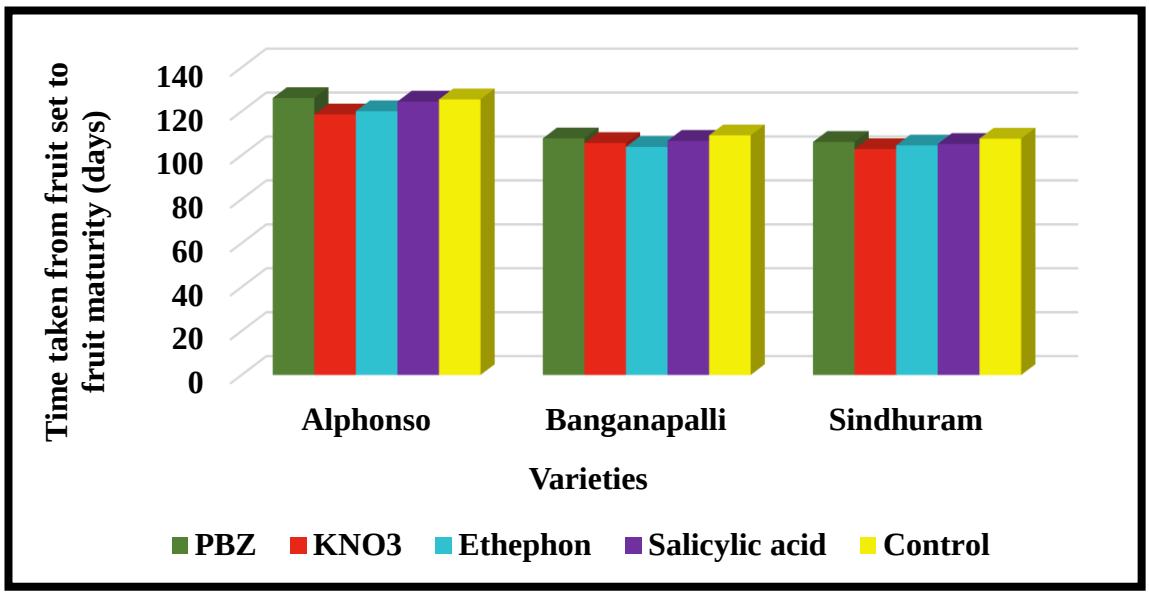


Fig 7. Response of chemical regulators on time taken from fruit set to fruit maturity of mango varieties

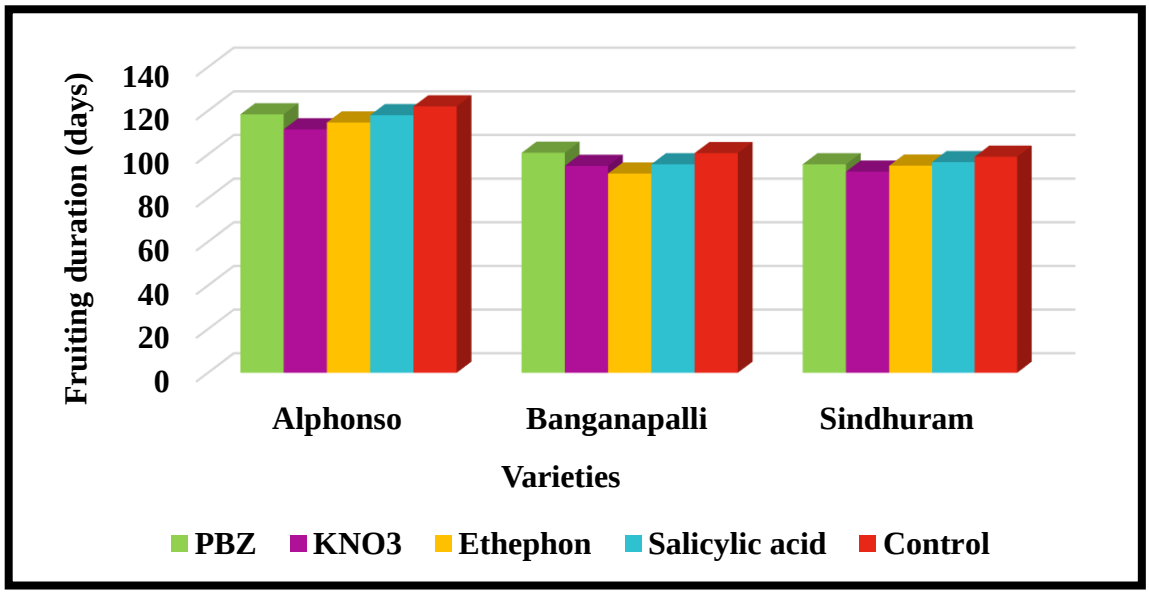


Fig 8. Response of chemical regulators on fruiting duration of mango varieties

taken from flowering to fruit set in Banganapalli (31.87 days) and Sindhuram (31.12 days). In Nadashala, fruit set has not occurred. In Nadashala, flowering commenced in the last week of November and during this month, there was a peak in the maximum temperature (33.96 ^{0}C) which could have dried the stigmatic surface and thus resulting in no fruit set.

A similar effect was observed for the time taken from fruit set to fruit maturity. In the present study, the time taken from fruit set to fruit maturity was influenced significantly by different chemical treatments (Fig 7). The data indicated that in Alphonso (118.62 days) and Sindhuram (102.87 days), the minimum time taken from fruit set and fruit maturity were recorded in T_2 (KNO_3 at 4 %) which was significantly superior and followed by T_3 (120.12 days) with ethephon at 200 ppm. In Banganapalli, the minimum time taken from fruit set and fruit maturity of (103.87 days) was recorded in T_3 (ethephon at 200 ppm) and followed by T_2 (105.62 days) with KNO_3 at 4 %. The maximum time taken in Alphonso (126.12 days) was recorded in T_1 and was on par with T_5 (125.50 days). The treatment T_5 (control) gave the maximum time of (109.12 days) in Banganapalli and (107.62 days) in Sindhuram. The reason for minimum time taken for fruit set to fruit maturity may be due the early induction of flowering by KNO_3 and ethephon as reported by (Nahar *et al*., 2010; Yamdagni and Khangia, 1989).

In the present study, fruiting duration was significantly influenced by the application of different chemical treatments (Fig 8). As per recorded data, T_2 (KNO_3 at 4 %) showed the minimum duration for fruiting in Alphonso (111.50 days) and Sindhuram (92.12 days). In Banganapalli, T_3 (ethephon at 200 ppm) was recorded with minimum fruiting duration of (91.25 days). The treatment T_5 (control) recorded the maximum duration for fruiting in Alphonso (122.00 days) and Sindhuram (98.93 days). In Banganapalli, the maximum fruiting duration of (100.75 days) was recorded in T_1 (PBZ at 8 ml). Early panicle emergence in Alphonso and Sindhuram with KNO_3 and ethephon in Banganapalli would have minimized the fruiting duration (Nahar *et al*., 2010; Yamdagni and Khangia, 1989).

The present investigation have clearly shown that fruit length, fruit diameter and fruit weight were significantly influenced by the application of chemical regulators. Data reveals that treatment T_4 (salicylic acid at 2000 ppm) gave the maximum fruit length of (9.29 cm) in Alphonso, (11.65 cm) in Banganapalli and (8.48 cm) in Sindhuram. The treatment T_5 (control) showed the minimum fruit length in Alphonso (7.90 cm), Banganapalli (8.65 cm) and Sindhuram (8.65 cm).

The treatment T_4 (salicylic acid at 2000 ppm) produced maximum fruit diameter of (26.97 cm) in Alphonso, (26.52 cm) in Banganapalli and (9.35 cm) in Sindhuram. The minimum fruit diameter in Alphonso (18.15 cm), Banganapalli (17.87 cm) and Sindhuram (8.25 cm) were observed in treatment T_5.

Data showed that in Alphonso (336.85 g), Banganapalli (408.80 g) and Sindhuram (242.41 g), higher values of fruit weight was recorded by T_4 (salicylic acid at 2000 ppm). The lowest value of (178.12 g) in Alphonso and (159.87 g) in Banganapalli were observed in T_5 whereas T_2 (KNO_3 at 4 %) showed lowest fruit weight of (182.22 g) in Sindhuram.

It concludes that enhanced fruit length with the application of salicylic acid may be due to increased nutrient uptake (Ngullie *et al*., 2014). Improvement of fruit weight and size with the application of plant growth regulators was reported by (Eman *et al*., 2007; Raskin 1992; Lee *et al*., 1995; Faissal *et al*., 2014).

The pulp to peel ratio and pulp to stone ratio were significantly influenced by the application of different chemical treatments (Fig 12). The treatment T_4 (salicylic acid at 2000 ppm) gave the maximum value for pulp to peel ratio of (12.33) in Alphonso, (7.32) in Banganapalli and (4.69) in Sindhuram. The minimum pulp to peel ratio in Alphonso (4.70) was recorded in T_5 (control).

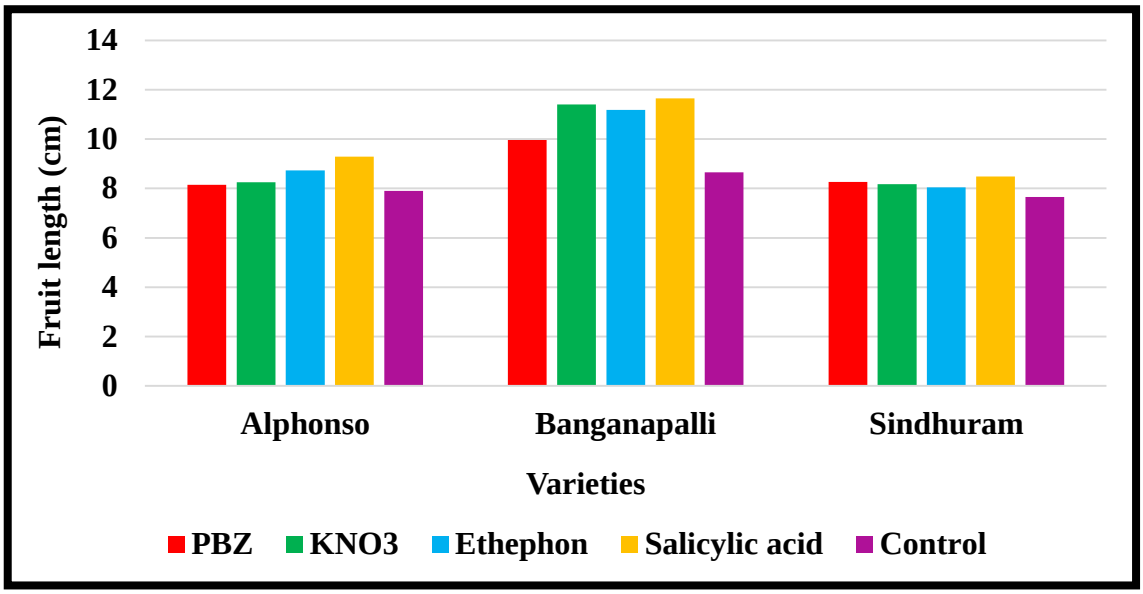


Fig 9. Response of chemical regulators on fruit length of mango varieties

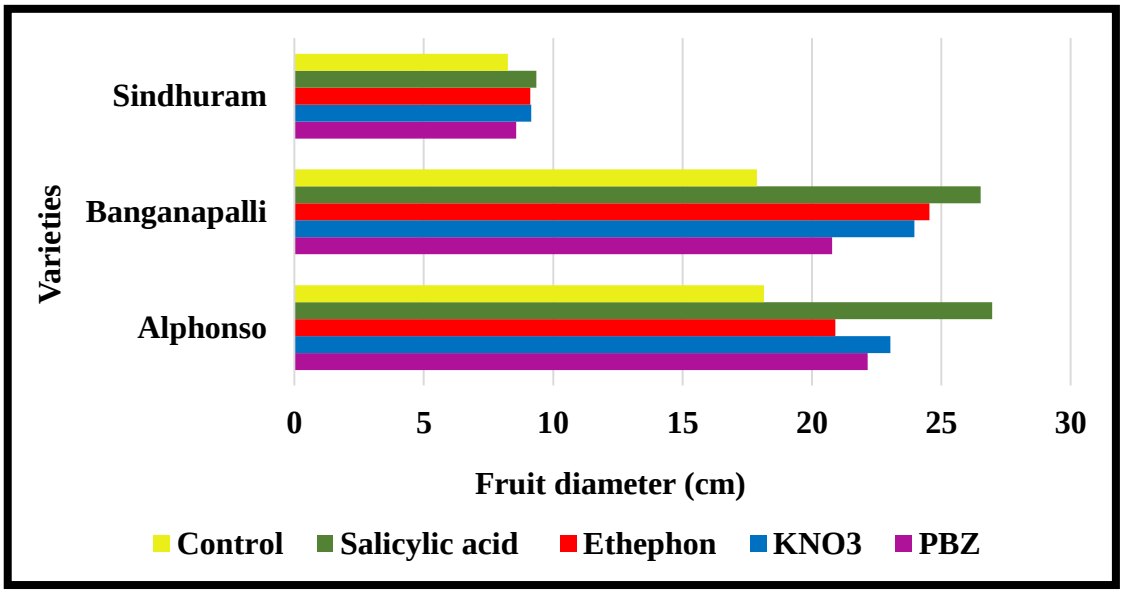


Fig 10. Response of chemical regulators on fruit diameter of mango varieties

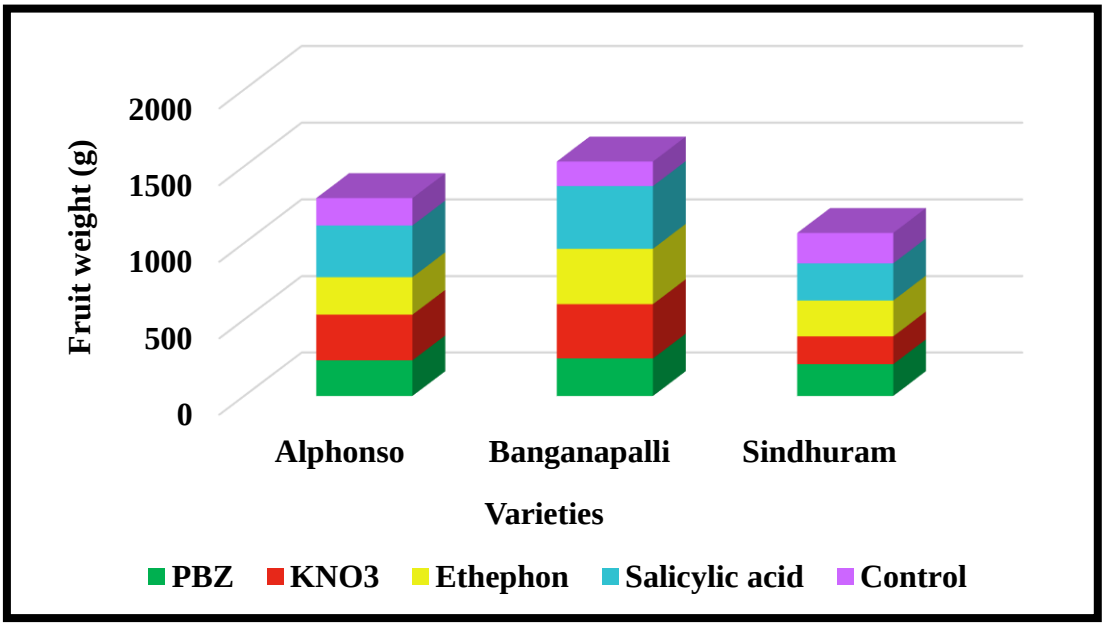


Fig 11. Response of chemical regulators on fruit weight of mango varieties

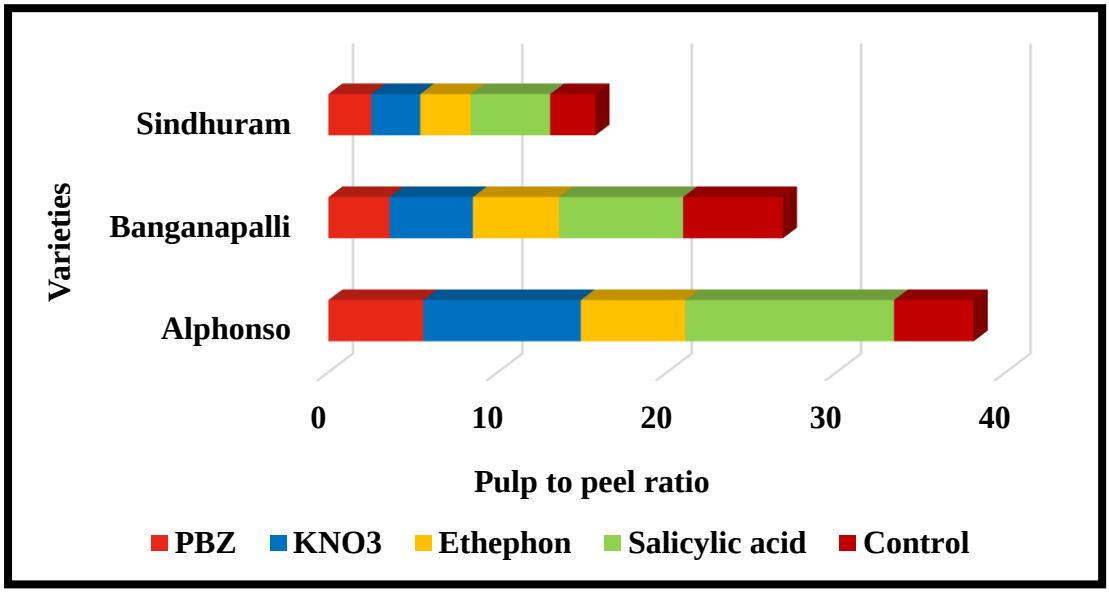


Fig 12. Response of chemical regulators on pulp to peel ratio of mango varieties

In Banganapalli (3.61) and Sindhuram (2.53), the minimum pulp to peel ratio were recorded in T_1.

In the present study, application of different treatments influenced the pulp to stone ratio (Fig 13). The data showed that in Alphonso (6.23), Banganapalli (6.93) and Sindhuram (4.00), higher values for pulp to stone ratio were recorded in T_4 (salicylic acid at 2000 ppm). In Alphonso, the lowest pulp to stone ratio of (2.60) was recorded in treatment T_1 (PBZ at 8 ml), whereas in Banganapalli, the treatment T_5 (control) recorded the least value of (3.50) for pulp to stone ratio. The minimum pulp to stone ratio in Sindhuram was observed in treatment T_2 (2.39).

The increase in pulp weight could have been associated with increase in pulp to peel ratio and pulp to stone ratio. Rapid cell division and cell enlargement along with the accumulation of balanced assimilates to the developing fruit increases the pulp weight and volume (Mandal *et al*., 2015). This finding is in harmony with those obtained by Ahmed *et al*. (2018) in mango cvs. Fagrikalan, Zebda and Alphonso with application of increasing concentrations of salicylic acid.

The yield per tree in the present study was significantly influenced by the application of different chemical treatments (Fig 14). With respect to the yield per tree, maximum value in Alphonso (14.62 kg/year) was recorded by treatment T_4 (salicylic acid at 2000 ppm) which was significantly superior to other treatments and followed by T_2 (13.53 kg/year) with KNO_3 at 4 %. In the present investigation, the rise in yield parameters with the application of salicylic acid may be associated with the elevated photosynthetic activity in leaves and photo assimilates translocation to fruit (Ngullie *et al*., 2014). Increase in yield due to salicylic acid by increasing fruit set percentage was also reported by Martin-Mex *et al.* (2005). The treatment T_2 (KNO_3 at 4 %) recorded the maximum yield in Banganapalli (15.53 kg/year) and was on par with T_4 (20.50 kg/year) in Sindhuram. The applied nutrients (N and K) in KNO_3 might have stimulated the activity of number of enzymes which in turn leads to the mobilization and translocation of photosynthates towards the developing sink,

resulting in more fruits and fruit yield (Barun, 2006). The rise in fruit yield with potassium nitrate application was reported by Sarker and Rahim (2013). The results of the present study was in line with the observations of Gupta and Brahmachari (2004) and Oosthuyse (1997). The minimum value of (5.40 kg/year) in Alphonso, (6.64 kg/year) in Banganapalli and (6.00 kg/year) in Sindhuram was recorded in T_5 (control).

The present study has clearly shown that shelf life was significantly influenced by the application of different chemical treatments in Alphonso and Sindhuram, whereas in Banganapalli, the treatments did not significantly influenced the shelf life. The maximum shelf life of (9.0 days) in Alphonso was recorded by treatment T_4 (salicylic acid at 2000 ppm) and which was followed by T_2 (7.7 days) with KNO_3 at 4 %. Role of salicylic acid in increasing shelf life may be attributed by enhancing fruit firmness by decreasing the activity of cell wall degrading enzymes (Srivatsava and Dwivedi, 2000). Zainuri *et al*. (2001) reported the suppression of postharvest disease in mango caused by *Collectotrichum gloeosporioides* by salicylic acid thereby increasing postharvest life. Similar trend was reported by Ngullie *et al*. (2014) and Reddy and Sharma (2016) in mango. In Sindhuram, the treatment T_2 (KNO_3 at 4 %) was found to have the maximum shelf life of (7.0 days) and which was followed by T_4 (5.5 days). Potassium reduces respiration, blocks energy losses by maintaining turgor pressure and minimizes water loss in fruits and thereby improves shelf life of fruits (Amarcholi *et al*., 2016).

Increase in shelf life in mango cv. Amrapali with potassium nitrate was reported by Sarker and Rahim (2013). Similar findings were noticed by Sergent *et al.* (1997). The lowest shelf life in Alphonso (5.0 days) was reported in T_1 whereas in Sindhuram, the lowest shelf life of (4.7 days) was observed in T_3. In Banganapalli, the treatments had no significant effect on shelf life.

5.4. Quality attributes of fruit

In the present study, the application of different chemical treatments showed a significant influence on TSS. The highest value of TSS of (21.12

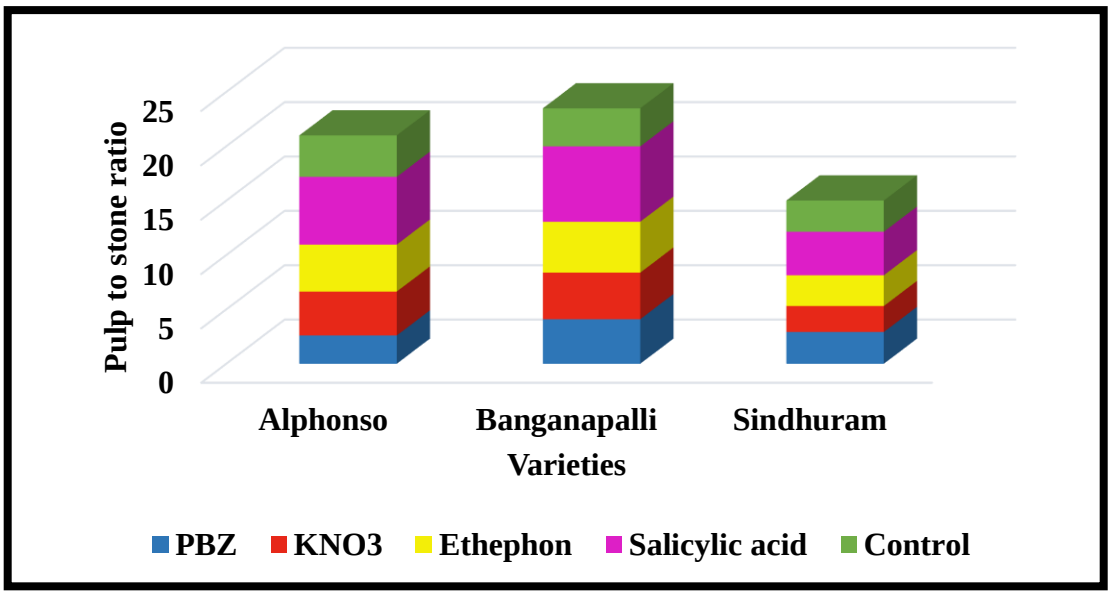


Fig 13. Response of chemical regulators on pulp to stone ratio of mango varieties

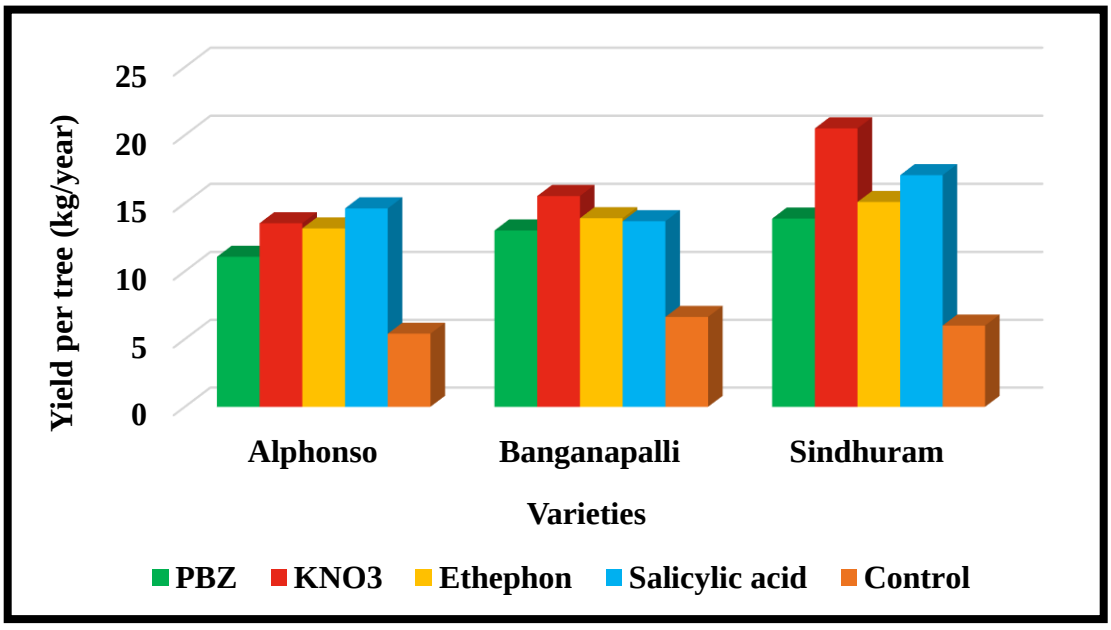


Fig 14. Response of chemical regulators on yield per tree of mango varieties

º Brix) in Alphonso and (22.62 º Brix) in Banganapalli were recorded by treatment T_2 (KNO_3 at 4 %). The role of potassium nitrate on higher TSS content is attributed to the translocation of sugars and organic acids from the leaves to fruits, resulting in quality fruits (Jawandha *et al*., 2017). Similar trend was reported by Sarker and Rahim (2013), Khayyat *et al*. (2012), Yadav *et al*. (2014) and Patolia *et al*. (2017) in mango. The treatment T_4 (salicylic acid at 2000 ppm) recorded the highest TSS of (22.37 º Brix) in Sindhuram. The promotive effect of salicylic acid on TSS could be associated with regulating the metabolism of carbohydrate metabolism in both source and sink tissue (Raskin, 1992). Role of salicylic acid in the hydrolysis of sucrose by invertase have been reported by LeClere *et al*. (2003). Similar finding was obtained by Singh *et al*. (2001) in mango cvs. Amrapali and Dashehari. The lowest value of TSS was recorded by treatment T_5 (control) in Alphonso (13.50 º Brix), Banganapalli (16.37 º Brix) and Sindhuram (14.75 º Brix).

In the present study, acidity in fruits was found significantly influenced with the application of different chemicals. The minimum acidity of (0.18 %) in Alphonso and (0.23 %) in Sindhuram were recorded in T_2 (KNO_3). The increased TSS with potassium nitrate treatment would have resulted in reduced titrable acidity (Prasad *et al*., 2015). The results are in accordance with Kumari (2006) and Baiea *et al*. (2015), who observed significant reduction in acidity with potassium nitrate application in mango. In Banganapalli, the minimum value of (0.21 %) was recorded in T_4 (salicylic acid at 2000 ppm) and which was followed by T_2 (KNO_3 at 4 %). Application of salicylic acid in mango cv. Kesar minimized the acidity (Noorullah, 2017). The maximum values for acidity in Alphonso (0.29 %), Banganapalli (0.30 %) and Sindhuram (0.39 %) were recorded in treatment T_5 (control).

In the present study, the ascorbic acid content in Alphonso was significantly influenced by application of different chemical treatments, whereas Banganapalli and Sindhuram were not influenced significantly. The highest ascorbic acid content in Alphonso (44.37 mg/100g) was recorded in treatment T_4 (salicylic acid at 2000 ppm) which was followed by T_2 (KNO_3 at

4 %). Increase in ascorbic acid with the application of salicylic acid was reported by Ngullie *et al*. (2014). The results are in conformity with those obtained by Ahmed *et al*. (2018) and Rahmani *et al.* (2017). In Banganapalli and Sindhuram, the ascorbic acid content showed no significant difference among the treatments.

There was no significant effect on total carotenoids of fruits in the present investigation with the application of different chemical treatments. Contrary to this was obtained by Dutta *et al*. (2011) on total carotenoid.

The effect of different chemical treatments on total sugar was significantly influenced in the present study. The highest value for total sugar in Alphonso (18.81 %) was recorded by treatment T_4 (salicylic acid at 2000 ppm) and which was followed by T_2 (KNO_3 at 4 %). Increase in total sugar in ripe mango fruits by salicylic acid at 2000 ppm was reported by (Singh *et al*., 2001). Similar finding was obtained by Ahmed *et al*. (2013) and Ngullie *et al.* (2014) in mango. The highest total sugar content in Banganapalli (17.91 %) and Sindhuram (16.22 %) was recorded by treatment T_2 (KNO_3 at 4 %). Potassium treatment enhances photosynthetic efficiency of the leaves and increases the translocation of assimilates into the fruit, which might be the possible reason for increased total sugar content (Singh *et al*., 1982). The findings are in line with the reports of (Dutta *et al*., 2011; Singh *et al.*, 2019; Baiea *et al.*, 2015; Elkhishen, 2015 and Singh and Kaur, 2018) in mango. The lowest total sugar content in Alphonso (10.25 %), Banganapalli (11.50 %) and Sindhuram (11.28 %) was recorded by treatment T_5 (control).

The effect of treatments on reducing sugar was significantly influenced in the present study. In Alphonso, the highest reducing sugar content of (5.21 %) was recorded by treatment T_4 (salicylic acid at 2000 ppm) and which was followed by T_2 (KNO_3 at 4 %). It concludes that application of salicylic acid results in the translocation of more photo assimilates to the developing sink and the breakdown of starch during ripening (LeClere *et al*., 2003). This finding is in accordance with Singh *et al.* (2001) and Kumar and Reddy (2008)

in mango. The highest reducing sugar content in Banganapalli (6.58 %) and Sindhuram (4.30 %) were recorded in T_2 (KNO_3 at 4 %). Sarker and Babul (2013) reported that KNO_3 recorded higher reducing sugar content in mango. The results lend support to the findings of Kumari (2006) and Baiea *et al*. (2015) who reported higher reducing sugar content in mango. The minimum value for reducing sugar was recorded in Alphonso (2.56 %), Banganapalli (4.03 %) and Sindhuram (2.58 %).

5.5. Physiological characters

Leaf epidermal anatomy with special reference to stomatal index is a very useful tool for estimating the level of atmospheric CO_2. In the present study, stomatal index did not show significant influence by the application of different treatments in Alphonso, Banganapalli and Sindhuram, whereas in Nadashala, the treatments had a significant influence on stomatal index. The highest stomatal index value in Nadashala (31.73 %) was recorded in T_3 (ethephon at 200 ppm), which was superior to all other treatments. The second best treatment for highest stomatal index value of (20.95 %) was recorded in T_2 (KNO_3 at 4 %). The lowest stomatal index of (12.73 %) in Nadashala was recorded in T_1 (PBZ at 8 ml). Higher stomatal index is produced when the number of stomata is more than the epidermis cell (Qosim *et al*., 2007). Increased leaf area may be attributed to increased stomatal count, thereby increasing the stomatal index (Cahyanto *et al*., 2017).

In the present study, stomatal frequency was influenced significantly with the application of different treatments. The highest stomatal frequency in Alphonso (901.34 stomata/mm^2), Banganapalli (937.93 stomata / mm^2) and Nadashala (759.85 stomata /mm^2) were recorded in T_4 (salicylic acid at 2000 ppm). In Sindhuram, the highest stomatal frequency of (691.44 stomata / mm^2) was obtained from T_3 (ethephon at 200 ppm) and which was followed by T_2 (KNO_3 at 4 %). The lowest values for stomatal frequency in Alphonso (647.46 stomata /mm^2) and Sindhuram (524.79 stomata /mm^2) were observed in T_5 (control). In the case of Banganapalli (595.25 stomata /mm^2) and Nadashala (535.22 /mm^2) were recorded in T_1 (PBZ at 8 ml). Increased leaf area coupled

with growth regulator spray may be the possible reason for increased stomatal frequency (Lakshmipathi *et al*., 2017).

The effect of different treatments on stomatal conductance was not influenced significantly in Alphonso, Banganapalli and Nadashala, whereas in Sindhuram, the treatments had shown effect on stomatal conductance in the present investigation. In Nadashala, the highest stomatal conductance of (0.134 µ S) was observed in T_4 and is considered superior to all other treatments. The minimum value was recorded in T_5 (0.059 µ S). Increased leaf area may be associated with increased stomatal conductance (Ahmad *et al*., 2016). Larger leaf surface enables the tree to capture maximum light for biochemical processes.

However, application of different chemical treatments did not significantly influence the photosynthetic and transpiration rate. It is contradictory from the finding of Singh *et al.* (2001), where they found out enhanced rate of photosynthetic rate and reduced transpiration level with the application of salicylic acid in mango.

Application of different chemical regulators did not have any significant effect on leaf area index.

5.6. Biochemical analysis

The C/N ratio of shoots during flowering and two months after flowering were analysed from all the treatments and was found to influence significantly with the application of different treatments.

In Alphonso, the highest C/N ratio of (15.63) was recorded in T_4 (salicylic acid at 2000 ppm) and which was on par with T_2 (KNO_3 at 4 %). The highest C/N ratio during flowering in Banganapalli (15.00) was observed in T_3 (ethephon at 200 ppm). In Sindhuram, the highest C/N ratio of (14.73) and (15.00) in Nadashala were recorded in T_2 (KNO_3 at 4 %). The minimum C/N ratio during flowering in Alphonso (11.87) was observed in T_1 (PBZ at 8 ml).

The lowest C/N ratio during flowering in Banganapalli (11.78), Sindhuram (11.45) and Nadashala (11.37) were recorded in T_5 (control).

The highest C/N ratio at two months after flowering in Alphonso (14.37) and Nadashala (13.18) were recorded in T_4 (salicylic acid at 2000 ppm). In Banganapalli, the highest C/N ratio of (14.12) was observed in T_3 (ethephon at 200 ppm). The highest C/N ratio of (13.82) in Sindhuram was recorded in T_2 (KNO_3 at 4 %). The minimum value for C/N ratio in Alphonso (10.97), Banganapalli (11.08), Sindhuram (10.30) and Nadashala (10.10) were observed in treatment T_5 (control).

It was observed that the carbohydrate content continued to increase till flowering and then decreased rapidly in all the varieties (Suma, 1987). There are also reports that indicated decreased C/N ratio at latter stages in mango (Sen and Mallick, 1941).

The C/N ratio plays a vital role in mango flowering and foliar spray of chemicals influence the C and N contents in the shoot (Malshe *et al*., 2020). This was in agreement with the findings of Singh (2002), who reported that the initiation of flowering is based on higher C/N ratio. The syntheses of floral stimulus in mango trees are associated with the accumulation of carbohydrate in the leaves and shoot apex (Kumar *et al*., 2013). A higher content of total nitrogen in stems and leaves was observed just before flower bud initiation (Chacko and Singh, 1969). Generally, the flowering shoots have much higher levels of carbohydrates and nitrogen content than in non-flowering shoots (Singh, 1959; Sen *et al*., 1965). The high endogenous ratio of C and N in plants stimulates flowering, whereas a low C/N ratio favours vegetative growth was reported by (Corbesier *et al*., 2002).

Highest carbohydrate content and C/N ratio with the application of KNO_3 was described by Sudha *et al*. (2012). This may be due to the elevation of nitrogen concentration over a threshold nitrogen level due to action of KNO_3, thereby synchronizing bud break and initiating floral induction which is

mediated by ethylene (Protacio, 2000). A similar finding with potassium nitrate over C/N ratio was reported by Malshe *et al*. (2020).

Highest C/N ratio with the application of ethrel increased the ability of buds to produce more panicles than vegetative shoots (Elkhishen, 2015). Bhattacharyya (1975) observed an increased carbohydrate content in papaya with the application of ethylene. Thus in the present investigation, increased carbohydrate and C/N ratio of shoots in mango would have resulted with the application of ethephon.

The ascorbic acid content in leaves had no significant effect with the application of various treatments.

Chlorophyll contents is very important for photosynthesis and the food produced during photosynthesis is required for normal activity of plants. In the present investigation, chlorophyll content showed a significant effect with the application of different treatments.

With regard to chlorophyll content in Alphonso, the highest chlorophyll content of (2.04 mg/g) was reported in T_4 (salicylic acid at 2000 ppm) which was significantly superior to other treatments and followed by T_2 (1.94 mg/g) with KNO_3 at 4 %. The treatment T_2 (KNO_3 at 4 %) recorded the maximum chlorophyll content in Banganapalli (2.23 mg/g), Sindhuram (1.95 mg/g) and Nadashala (1.95 mg/g). The least chlorophyll content of (0.60 mg/g) in Alphonso and (0.87 mg/g) in Banganapalli was observed in T_5 (control). In Sindhuram (0.41 mg/g) and Nadashala (0.80 mg/g), the lowest chlorophyll content was found in treatment T_1 (PBZ at 8 ml) and T_3 (ethephon at 200 ppm) respectively.

Increase in photosynthetic rate with increasing chlorophyll content in matured mango leaves was reported by Nii *et al.* (1995). A relationship between leaf area and chlorophyll contents in mango varieties was reported by (Jyothi *et al.*, 1998). In contrast to the above conclusion, in our study there was no relationship between photosynthetic rate, leaf area and chlorophyll content.

Sudha *et al.* (2012) registered an increased chlorophyll content with KNO_3 in mango. The maximum values for chlorophyll content in mango leaves was reported with the application of salicylic acid by Ahmed *et al*. (2015). Thus in the present study also application of plant growth regulators would be the possible reason for increased chlorophyll content.

5.7. Economic analysis

Benefit cost ratio is an important factor that decides the optimum concentration of various inputs to be used for maximization of production and returns from any crop. The different treatments and operations in Alphonso, Banganapalli and Sindhuram were identified and the cost and benefit were worked out. The analysis revealed that the highest B: C ratio in Alphonso (2.26) and Sindhuram (2.64) were reported with T_4 (salicylic acid at 2000 ppm. In Banganapalli, the highest B: C ratio of (2.31) was reported with T_3 (ethephon at 200 ppm). The lowest B: C ratio in Alphonso (1.03), Banganapalli (1.22) and Sindhuram (1.30) were reported with T_1 (paclobutrazol at 8 ml). When comparing the yield per tree, T_2 (KNO_3 at 4 %) gave the highest yield in Banganapalli (15.53 kg/year) and was followed by ethephon (200 ppm) with (13.90 kg/year), which was on par with T_4 (salicylic acid at 2000 ppm) with (13.68 kg/year). In the case of Sindhuram, the highest yield per tree was recorded with KNO_3 (4 %) with (20.50 kg/year) and was followed by salicylic acid (2000 ppm) with (17.06 kg/year). In Banganapalli and Sindhuram, the highest yield per tree was observed with the application of KNO_3 (4 %) and followed by the application of salicylic acid (2000 ppm). But when the economic returns were compared, trees treated with salicylic acid (2000 ppm) was found to be economically feasible, as the total cost of cultivation was found to be 30 per cent lower than that of KNO_3.

Summary

6. SUMMARY

The present experiment "Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system was conducted to evaluate the response of different mango varieties *viz.*, Alphonso, Banganapalli, Sindhuram and Nadashala to chemical regulators under high density planting system in the agro climatic conditions of Muthalamada and also to study the cost effectiveness. The study was undertaken in the Muthalamada region of Palakkad district of Kerala during 2019-2020. The experiment was laid out in Completely Randomized Design (CRD) with five treatments and four replications. The treatments comprised of paclobutrazol (soil drenching @ 8 ml in 10 litres of water/tree), KNO_3 (4 % foliar spray), ethephon (200 ppm foliar spray), salicylic acid (2000 ppm foliar spray) and control with no chemical regulator.

The effect of different chemical regulators on growth, flowering, fruiting, quality, physiological and biochemical characters were studied in detail and important findings are summarized below.

1. Application of different chemical regulators had no significant effect on tree height, trunk circumference, crown diameter, leaf blade length and leaf blade width in mango varieties Alphonso, Banganapalli, Sindhuram and Nadashala.
2. The crown shape was found to be semi circular in Alphonso and Banganapalli, whereas it was broadly pyramidal in Sindhuram and Nadashala.
3. The tree growth habit in all the four varieties was found to be spreading.
4. The foliage density was observed to be intermediate in Banganapalli, Sindhuram and Nadashala, whereas it was dense in Alphonso.
5. The colour of young leaf in Alphonso and Nadashala were found to be light green with brownish tinge, whereas it was light green in Banganapalli and Sindhuram.
6. The colour of fully developed leaf in Alphonso, Banganapalli and Sindhuram were found to be green coloured, whereas in Nadashala it was observed to be dark green coloured.

7. Minimum days for first flowering and minimum flowering duration were observed with salicylic acid (2000 ppm) in Alphonso, whereas KNO_3 (4 %) recorded minimum days for both first flowering and flowering duration in Banganapalli, Sindhuram and Nadashala.

8. Maximum length of inflorescence in Alphonso was observed with salicylic acid, whereas KNO_3 (4 %) recorded maximum length of inflorescence in Banganapalli, Sindhuram and Nadashala.

9. Maximum width of inflorescence in Alphonso, Banganapalli and Nadashala was observed with KNO_3 (4 %), whereas it was the salicylic acid (2000 ppm) treatment in Sindhuram.

10. The highest sex ratio in all the four varieties were observed with the salicylic acid (2000 ppm).

11. In Alphonso, dense inflorescence was observed with the application of salicylic acid (2000 ppm) and medium density in all other treatments. In Banganapalli and Nadashala, application of paclobutrazol (8 ml), KNO_3 (4 %), ethephon (200 ppm) and salicylic acid (2000 ppm) were found to have medium density of inflorescence except in control with sparse inflorescence. In Sindhuram, KNO_3 (4 %), ethephon (200 ppm) and salicylic acid (2000 ppm) treated trees were found to have dense inflorescence, except in control with a medium density of flowers.

12. The minimum time taken from flowering to fruit set was observed with KNO_3 (4 %) treatment in Alphonso and whereas ethephon (200 ppm) in Banganapalli and Sindhuram.

13. The minimum time taken from fruit set to fruit maturity was observed with foliar spraying of KNO_3 (4 %) in Alphonso and Sindhuram, whereas it was ethephon (200 ppm) in Banganapalli.

14. Minimum fruiting duration in Alphonso and Sindhuram was recorded with the application of KNO_3 (4 %), whereas it was the ethephon (200 ppm) foliar spray that recorded minimum fruiting duration in Banganapalli.

15. The fruit bearing intensity was medium with the application of salicylic acid (2000 ppm) in Alphonso, whereas in Banganapalli, it was medium with KNO_3 (4 %), ethephon (200 ppm) and salicylic acid (2000 ppm). The fruit bearing intensity

was found to be medium with KNO_3 (4 %), ethephon (200 ppm), salicylic acid (2000 ppm) and control in Sindhuram.

16. Physical parameters of the fruit like fruit length, fruit diameter, fruit weight, pulp to peel ratio, pulp to stone ratio were significantly influenced by salicylic acid (2000 ppm) foliar spray in all the varieties.
17. Maximum yield was recorded with salicylic acid (2000 ppm) foliar spray in Alphonso, maximum yield in Banganapalli and Sindhuram was recorded with the application of KNO_3 (4 %).
18. Maximum shelf life was recorded with salicylic acid (2000 ppm) treatment in Alphonso, whereas it was in the treatment KNO_3 (4 %) in Sindhuram. The treatments had no significant effect on shelf life in Banganapalli.
19. Highest TSS in Alphonso and Banganapalli were recorded by the application of KNO_3 (4 %), whereas it was salicylic acid (2000 ppm) application in Sindhuram.
20. Minimum acidity in Alphonso and Sindhuram were recorded with the application of KNO_3 (4 %) and whereas in Banganapalli it was salicylic acid (2000 ppm).
21. Highest ascorbic acid in Alphonso was recorded with the application of salicylic acid (2000 ppm), whereas the treatments did not show any significant effect on ascorbic acid content in Banganapalli and Sindhuram.
22. Application of different chemical regulators did not significantly influence on total carotenoids in all the varieties.
23. Total sugar and reducing sugar were maximum with salicylic acid (2000 ppm) in Alphonso, whereas in Banganapalli and Sindhuram, the application of KNO_3 (4 %) was found to be effective.
24. Highest stomatal index was observed with the application of ethephon (200 ppm) in Nadashala. Applications of different chemical regulators did not show significant effect on stomatal index in Alphonso, Banganapalli and Sindhuram.
25. Highest stomatal frequency in Alphonso, Banganapalli and Nadashala were recorded in salicylic acid (2000 ppm), whereas it was with ethephon (200 ppm) in Sindhuram.
26. Highest stomatal conductance was observed with the application of salicylic acid (2000 ppm) in Sindhuram and control showed highest stomatal conductance in

Nadashala. However, application of different chemical regulators did not show any significant effect on stomatal conductance in Alphonso and Banganapalli.

27. Photosynthetic rate, transpiration rate and leaf area index were not significantly influenced by the application of different chemical regulators.
28. The C/N ratio during flowering was maximum with salicylic acid (2000 ppm) in Alphonso, ethephon (200 ppm) in Banganapalli and KNO_3 (4 %) in Sindhuram and Nadashala. A similar trend was observed in all the varieties with C/N ratio at two months after flowering.
29. Application of different chemical regulators did not show significant effect on ascorbic acid of leaves in all the varieties.
30. The highest chlorophyll content was observed with salicylic acid (2000 ppm) in Alphonso, KNO_3 (4 %) in Banganapalli, Sindhuram and Nadashala.
31. The highest B: C ratio in Alphonso and Sindhuram was observed with salicylic acid (2000 ppm), whereas it was observed with ethephon (200 ppm) in Banganapalli.
32. The major pests like mango hoppers, thrips, mealy bug and diseases like sooty mould were observed during the study. Less susceptibility of thrips population/panicle was observed with KNO_3 (4 %) in Banganapalli and Sindhuram. The lowest PDI was observed with Paclobutrazol (8 ml) in Alphonso, whereas it was KNO_3 (4 %) in Banganapalli and Sindhuram and salicylic acid in Nadashala.

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Appendix

Appendix 1

Weather data 2019-2020 - Muthalamada

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Mean maximum temperature (℃)												
2019	31.83	30.13	29.13	30.40	30.81	33.96	32.74					
2020								32.39	33.03	34.03	36.77	37.13
Mean minimum temperature (℃)												
2019	27.50	24.26	23.71	24.47	24.00	27.83	26.52					
2020								24.35	24.93	25.77	27.07	25.71
Rainfall (mm)												
2019	2.25	168.8	304.0	104.5	194.5	266.6	11.4					
2020								0	0	26.6	133.2	66.2
Soil temperature at 15 cm (℃)												
2019	20.33	20.52	20.71	19.50	20.19	21.17	21.32					
2020								22.26	22.34	22.45	22.67	22.97
Soil temperature at 30 cm (℃)												
2019	19.00	18.32	18.62	14.33	15.48	19.13	19.29					
2020								19.58	20.03	20.06	20.50	20.55

RESPONSE OF MANGO (*Mangifera indica* L.) TO CHEMICAL REGULATORS UNDER HIGH DENSITY PLANTING SYSTEM

by

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Abstract of the Thesis

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ABSTRACT

The experiment on "Response of mango (*Mangifera indica* L.) to chemical regulators under high density planting system" was conducted to evaluate the response of different mango varieties (Alphonso, Banganapalli, Sindhuram and Nadashala) to chemical regulators under high density planting system in the agro climatic conditions of Muthalamada and also to study the cost effectiveness. The study was undertaken in the farmers' field in the Muthalamada region of Palakkad district of Kerala during 2019-2020. The experiment was laid out in Completely Randomized Design (CRD) with five treatments and four replications. The treatments comprised of T_1 - paclobutrazol (soil drenching @ 8 ml in 10 litres of water/tree), T_2 - KNO_3 (4 % foliar spray), T_3 - ethephon (200 ppm foliar spray), T_4 - salicylic acid (2000 ppm foliar spray) and T_5 - control.

Application of KNO_3 (4 %) had significant influence on growth, flowering, yield and quality of four mango varieties under study. In Banganapalli, Sindhuram and Nadashala, the days for first flowering and flowering duration was found to be minimum. The maximum inflorescence length and width was observed in Banganapalli and Nadashala. The maximum density of flowers in the inflorescence was observed in Sindhuram. In Alphonso, the time taken from flowering to fruit set and fruit set to fruit maturity was observed to be minimum. The fruit bearing intensity was found to be medium in Alphonso, Banganapalli and Sindhuram and shelf life observed was maximum in Sindhuram (7.0 days). The highest TSS (22.62 ° Brix) was observed in Banganapalli with minimum acidity in Alphonso (0.18 %). Total sugars and reducing sugars were found to be maximum in Banganapalli and Sindhuram. When the C/N ratio during flowering and two months after flowering were compared, it was found to be maximum in Sindhuram and Nadashala. The total chlorophyll content was found to be maximum in Banganapalli, Sindhuram and Nadashala.

With the application of ethephon (200 ppm), the density of flowers in the inflorescence was found to be medium in Alphonso, Banganapalli and Nadashala. In Banganapalli, the time taken from flowering to fruit set, fruit set to fruit maturity and fruiting duration was found to be minimum. The fruit bearing intensity was found to be medium in Banganapalli and Sindhuram. The highest stomatal index and stomatal frequency were observed in Nadashala and Sindhuram respectively. In Sindhuram and Nadashala, stomatal conductance was found to be the maximum. The highest C/N ratio during flowering and two months after flowering were found to be maximum in Banganapalli.

With the application of salicylic acid (2000 ppm), it was observed that in Alphonso, the number of days for first flowering and flowering duration were minimum and inflorescence length was found to be maximum. The highest sex ratio was observed for this treatment in Alphonso (41.62), Banganapalli (37.75), Sindhuram (42.75) and Nadashala (35.12). The maximum density of flowers in inflorescence were observed in Alphonso and Sindhuram. Fruit characters like fruit length, fruit diameter, fruit weight, pulp to stone ratio and pulp to peel ratio were found to be maximum. Maximum shelf life was observed in Alphonso (9.0 days). The highest TSS (22.37 ° Brix) was observed in Sindhuram and minimum acidity (0.21 %) in Banganapalli. Maximum ascorbic acid, total sugars and reducing sugars were observed in Alphonso. The stomatal frequency was highest in Alphonso, Banganapalli and Nadashala, whereas highest stomatal conductance was observed in Sindhuram and Nadashala. The highest C/N ratio during flowering and two months after flowering and also maximum chlorophyll content were recorded in Alphonso.

When compared to control, soil application of paclobutrazol (8 ml) recorded minimum number days for first flowering in Alphonso, Banganapalli and Nadashala. The density of flowers in the inflorescence and fruit bearing intensity were found to be medium in Banganapalli.

Application of KNO_3 (4%) gave maximum yield per tree in Banganapalli (15.53 kg/year) and Sindhuram (20.50 kg/year), whereas it was salicylic acid (2000 ppm) in Alphonso (14.62 kg/year). The yield per tree was lowest in Alphonso (11.06 kg/year), Banganapalli (13.00 kg/year) and Sindhuram (13.87 kg/year) with soil application of paclobutrazol (8 ml). The highest B: C ratio were recorded in Alphonso (1.98) and Sindhuram (1.32) with salicylic acid (2000 ppm), whereas in Banganapalli (1.88), it was highest with ethephon (200 ppm).

In Banganapalli and Sindhuram, the yield per tree was higher with KNO_3 (4 %) application followed by salicylic acid (2000 ppm) application. But when the economic returns were compared, the trees sprayed with salicylic acid (2000 ppm) was found to be economically feasible as the total cost of cultivation was found to be 30 per cent lower than that of KNO_3. So, it can be concluded that foliar application of salicylic acid (2000 ppm) is the best for chemical regulation of mango under high density planting system in Muthalamada.