Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)

by

BHAGYA D. KARTHA

(2020-12-035)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

2023

Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)

By

BHAGYA D. KARTHA

(2020-12-035)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(FRUIT SCIENCE)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

2023

DECLARATION

I, Bhagya D. Kartha (2020-12-035) hereby declare that the thesis entitled **Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)** is a bonafide record of research done by me during the course of study and the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
Date: 26/5/23

Bhagya D. Kartha
(2020-12-035)

CERTIFICATE

Certified that this thesis entitled **Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)** is a record of research work done independently by **Bhagya D. Kartha** (2020-12-035) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara
Date: 26/5/23

Dr. Aswini A.
Assistant Professor
Department of Fruit Science
College of Agriculture, Vellanikkara
(Chairperson Advisory Committee)

CERTIFICATE

We, the undersigned members of the advisory committee of **Bhagya D. Kartha (2020-12-035),** a candidate for the degree of **Master of Science in Horticulture**, with major field in **Fruit Science**, agree that this thesis entitled **Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)** may be submitted by **Bhagya D. Kartha (2020-12-035)**, in partial fulfilment of the requirement for the degree.

Dr. Aswini A.

Chairman, Advisory committee
Assistant Professor
Department of Fruit Science
College of Agriculture, Vellanikkara

Dr. Jyothi Bhaskar

(Member, Advisory committeee)
Professor and Head
Department of Fruit Science
College of Agriculture,
Vellanikkara

Dr. Anu G Krishnan

(Member, Advisory committee)
Professor,
Regional Agricultural
Research Station,
Kumarakom

Dr. Parvathi M. Sreekumar

(Member, Advisory committee)
Assistant Professor and Head
Department of Plant Physiology
College of Agriculture,
Vellanikkara

ACKNOWLEDGEMENT

*First and foremost, praise and thanks to the **Almighty**, for everything that happens to me.*

*With great respect and devotion, I would like to record my deep sense of gratitude and indebtedness to my major advisor **Dr. Aswini A**., Assistant Professor, Department of Fruit Science for her valuable guidance, constant inspiration, abundant encouragement and valuable suggestions which render me to accomplish the research work successfully. I extend my sincere gratitude for the care affection on me throughout the study period.*

*It is my pleasure to express my gratitude **Dr. Jyothi Bhaskar**, Professor and Head, Department of Fruit Science and member of the advisory committee for her unfailing support and guidance which help me in the successful completion of my research work and preparation of the thesis.*

*I express my heartfelt gratitude and indebtedness to **Dr. Anu G Krishnan**, Professor, Regional Agricultural Research Station Kumarakom, and member of the advisory committee for timely support and critical evaluation during the course of this investigation*

*Words are inadequate to express my sincere gratitude to **Dr. Parvathi M. Sreekumar**, Assistant Professor and Head, Department of Plant Physiology member of my advisory committee for the timely support, critical evaluation valuable suggestions during the journey at different stages.*

*I am grateful to Mrs**. Zahida P. M.**, Assistant Professor, Department of Fruit Science and **Mrs. Sapheera C. P**., Assistant Professor, Fruit crops Research Station for their encouragement and moral support during the course of study.*

*I express my sincere thanks to **Jincy chechi** for timely guidance and support, which is surely a reason for the timely completion of my research work. A special thanks to **Sami chettan, Manju chechi, Ancy chechi and Nishad chettan,** for all help and support during my research work.*

I take this opportunity to express my obligation to ***Sharon chechi, Aswathychechi, Hilal, Saleem and Rajini chechi*** *for their cooperation and assistance rendered during the course of investigation.*

No choice of words will suffice to express thanks to my loving friend ***Vishnu priya*** *and* ***Pooja*** *for being with me from beginning of course study till now and played a big part in completion of the research programme. Without their persistent help, thiswould not have been possible. I am greatly lucky with the best and supportive friends,* ***Jayalakshmi T, Amrutha Lakshmi, Mintu, for*** *their judicious and timely support and encouragement.*

A special thanks are due to my seniors ***Ms. Amrita Manohar, Ms. Anju Jayachandran, Ms. Keerthana Sethunath, Mr. Rajendra B.N. and Ms. S. Alekya Naidu*** *for their support and help. I am thankful to my juniors* ***Billal, Sneha, Anjana, Chetan and Aarthi*** *for their whole-hearted cooperation.*

I am thankful to ***Kerala Agricultural University*** *for the technical and financial support offered during the study period. I would like to express my thanks to staffs of library and computer club of College of Agriculture, Vellanuikkara for their cooperation and assistance during study period.*

I am grateful to my dear friend ***Gopika K.*** *for her love and moral support given to me during my study period.*

I shall remain ever indebted and affectionately cherish the blessings and good wishes of my beloved ***Amma, Achan, Ammama,*** *my brother* ***Biswas, Chechi and Siddhu*** *who were a constant inspiration. I express my gratitude to my mother in law,* ***Ally*** *for her constant encouragement and moral support. I am in dearth of words to express my gratitude towards my Partner* ***Gokul*** *who is a constant source of inspiration. I shall be eternally indebted to him for his support.*

Bhagya D. Kartha

Dedicated to my Parents,

Ettan

Major advisor

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Figure No.	Title
1	Meteorological data during the period of observations (Nov 2021 to Sep 2022)
2.	B:C ratio

Introduction

1. INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is an, evergreen tropical fruit tree considered to be a native to Southeast Asia, particularly in the Sunda Islands and the Malay Peninsula (Yaacob and Subhadrabandhu, 1995). Mangosteen is known as "Queen of Tropical Fruits" due to its characteristic taste and flavor (Diczbalis and Westerhuis, 2005).

The tree grows well in low lands as well as in higher altitudes. The best growth of trees is achieved in areas of altitudes of about 500-600 m from mean sea level. It requires high humidity and an annual rainfall of minimum 1200 mm, without prolonged dry periods. Mangosteen requires an uninterrupted water supply of 15 to 30 days, with a short dry period that initiates flowering (Nakasone and Paull, 1998).

The mangosteen is mainly cultivated in Indonesia, Malaysia, Philippines and Thailand. Mature mangosteen trees attain a height of about 6 to 25 m. Trees take about 10 or more years for fruiting and yield around 400 fruits per tree. Fruits are round, dark purple or reddish, and has a white juicy pulp possessing a slight acidic and sweet flavor.

The pericarp of mangosteen also contains many important beneficial constituents like antioxidants and has got anti-inflammatory activities (Husen *et al.,* 2017, Ansori *et al.,* 2020). Mangosteen fruit contains bioactive compounds such as xanthones, terpenes, anthocyanins, tannins, phenols, and some vitamins (Chin *et al*., 2008). Many studies have shown that these xanthones present in pericarp of mangosteen fruits possess anti-oxidant, anti-proliferative, pro-apoptotic, anti-inflammatory and anti-carcinogenic activities. Due to its health promoting benefits mangosteen is classified as a "superfruit". (Gutierrez-Orozco and Failla, 2013)

Mangosteen is rich in potent bioactive compounds, such as xanthones, and contains pharmacologically important anti-inflammatory and anti-tumor compounds; and it is utilized for various purposes, ranging from usage in industrially important products to applications in advanced technologies and biomedical innovations (Aizat *et al*., 2019).

The pericarp of mangosteen fruit has been used in traditional medicine in Southeast Asia for centuries to treat infection, wounds, inflammation and diarrhea (Pedraza-Chaverri *et al.,* 2008).

The Kerala State enjoys a warm humid tropical condition, which is congenial for successful cultivation of many tropical fruits. Popular fruits traditionally grown in Kerala include mango, banana, jack, pineapple etc. Recently farmers have shown interest to cultivate new exotic tropical fruits. Mangosteen is one of the important exotic fruits acclimatized to Kerala and is gaining vast popularity in the last decade. It is popular in Thrissur district and in central parts of Kerala and in high ranges like Wayanad district.

However, the long pre bearing or juvenile period (about 8-10 years) of seedlings and irregular bearing habit are the drawbacks in expansion of this crop. Use of plant growth regulators like Paclobutazol (PBZ) has been successful in many fruit crops to induce flowering and regulate fruiting; and it is commercially used in mango in India (Singh, 2000; Patel *et al.* 2016). A few similar reports of induction of flowering in mangosteen are also available elsewhere. However the use of PBZ is not common or popular in mangosteen. If the suitable dose of PBZ is standardized for successful induction of flowering and fruiting it will be a boon for the mangosteen farmers, and hence this study was taken up with the following objective:

To study the influence of Paclobutrazol, and its optimum doze for induction of flowering and fruiting in mangosteen.

Review of literature

2. REVIEW OF LITERATURE

Mangosteen in one among the exotic fruits getting popularity in Kerala. Many farmers of Thrissur district and central parts of Kerala, and of high range zones cultivate mangosteen and it is well acclimatized to Kerala conditions and is gaining vast popularity in the last decade. It is popular in Thrissur district and in central parts of Kerala and in high ranges like Wayanad district. However, the long pre bearing or juvenile period (about 8-10 years) of seedlings and irregular or erratic bearing habits are the problems faced for expansion of this crop. Treatment with plant growth regulators are effective to induce flowering and regular cropping in many fruit crops and information available on these aspects are reviewed here under.

Paclobutrazol (PBZ) was first announced as a new bio- regulator in 1986, and it was introduced to the market by ICI Agrochemicals, now part of Syngenta. (Rademacher, 2016).

The mode of action of PBZ is framed as part of the terpene pathway. It inhibits the biosynthesis of gibberellins by inactivating the enzyme ent-kaurene oxidase, which catalysis their oxidation to ent-kaurenoic acid. This favors the activation of the enzymes geranylgeranyl reductase and phytoene synthase for chlorophyll and abscisic acid biosynthesis, respectively (Hedden and Sponsel, 2015; Grant *et al.,* 2018). As a result, it decreases vigour and promotes floral induction and development (Wongsrisakulkaew *et al.,* 2017; Mog *et al.,* 2019). Paclobutrazol is classified under triazole family of plant growth regulators and has been found to protect several crops from various environmental stresses, including drought, chilling and heat radiation. It impedes gibberellin biosynthesis which leads to reduction in stem elongation (Orabi *et al.,* 2010).

Application of plant growth regulators in crops modifies the hormonal balance, growth and physiology leading to increased yield, enhanced crop tolerance against abiotic stress and improved physiological trait of crops. The growth regulating properties of PBZ are induced by changes in the levels of plant hormones like gibberellins (GAs), abscisic acid (ABA) and cytokinins (CK).The isoprenoid pathway is impacted by PBZ, which also inhibits

the production of gibberellin, raises levels of cytokinins, and reduces stem elongation as a result. More terpenoid pathway precursors build up when gibberellin synthesis is suppressed, which triggers the creation of abscisic acid (Desta and Amare, 2021).

2.1 Vegetative characters

Various types of plant growth regulators are widely used in fruit crops for induction of regulation of growth, flowering, control fruit drop, increase fruit set, improving fruit set, hastening ripening etc. (Suman *et al.,* 2017, and Sebastian *et al.,* 2019). Among these, Paclobutrazol is commercially used in crops like mango for induction of flowering. Hoffmann (1992) opined that the action of plant growth regulators is highly specific to plant species, cultivar and stage of development, and strongly dependent on its rate of application and environmental conditions.

Yaacob and Tindall (1995) and Sdoodee and Chiarawipa (2005) reported that a short spell of drought period is required for mangosteen trees to induce flowering. Paclobutrazol, a gibberellins inhibitor, has been effectively used in reducing canopy volume and increasing flower intensity in peach (Allan *et al.* 1993). It is reported that PBZ application on the growing medium is more effective than foliar application. The application of PBZ to crops can reduce plant height and prevent lodging. It also reduces evapotranspiration and decreases plant moisture stress by enhancing the relative water content of leaf area and develops resistance in the plants against biotic and abiotic stresses. In addition, it acts as highly active systemic fungicide and used against several economically important fungal diseases (Desta and Amare, 2021).Paclobutrazol has been proven to protect plants against abiotic stresses. Studies on the optimization of paclobutrazol dose for mitigation of wager deficit stress in rice shown that the highest augmentation of relative water content (RWC), membrane stability index (MSI), total chlorophyll, chlorophyll stability index (CSI), and abscisic acid (ABA) was observed at 90 ppm of PBZ. Based on a curve-fitting analysis of the physiological responses of three rice cultivars to PBZ, the optimum dose was estimated to be around 100 ppm. (Maheswari *et al.,* 2023)

Shoot growth reduction was the most striking growth response observed in different species treated with PBZ (Pinto *et al.,* 2005) and this response was attributed primarily due to decreased inter nodel length. PBZ was also found to effectively inhibit plant height and leaf expansion in *Syzygium campanulatum* (Nazarudin *et al.,* 2007).

The PBZ effectively suppressed growth in a wide range of plant species, where treated plants tend to be smaller and more compact in appearance and had darker green leaves (Esmaielpour *et al*; 2011; Brito *et al;* 2016; Rahman *et al;* 2016; Hamdani *et al;* 2018). Terri and Millie (2000) and Banon *et al.,*(2002) also reported that PBZ-treated plants tend to be dark green, shorter and more compact in appearance.

PBZ induced various morphological modifications depending on plant species, growth stage, rate and method of application (Yeshitela *et al.,* 2004). Vijayalakshim and Srinivasan (1999) found that application of PBZ in mango resulted in increasing the leaf area compared to other treatments like potassium nitrate, urea and ethrel. However, this was found to be contradictory to the finding of Fernandez *et al.,* (2006) who reported a decrease in leaf area with PBZ in *Phillyrea angustifolia*. Although PBZ decreased the surface area of the plants, it improved the durability of leaves; therefore, the decrease in the surface area of leaves was compensated by the lack of leaf falling and by the leaf durability (Tekalign and Hammes., 2005).

Treatment of plants with PBZ resulted in stems with the same numbers of leaves and internodes compressed into a shorter length (Fletcher *et al.,* 2000; Taizand Zeigeer, 2006). A similar trend in reduction of inter nodal length was indicated in tomato in response to PBZ treatment (Rahman *et al.,* 1989).

Results of various research works indicated that PBZ can be effective for obtaining sturdy growth and reducing plant height in several species with- out decreasing flowering quality (Mansuroglu *et al.,* 2009; Currey and Lopez, 2010).Webster and Quinlan (1984) also reported that PBZ has great efficacy in

reducing height of many temperate fruit species and cultivars. Similar reductions in plant height were reported in *Syzygium myrtifolium* (lilly pilly) (Nazarudin *et al.,* 2012) and mango (Yeshitela *et al.,* 2004) in response to PBZ treatment. Paclobutrazol is a systemic plant growth regulator and it is capable to reduce the inter nodal length of new shoots and causes earlier formation of terminal buds and induce flowering Mabvongwe, 2016).

PBZ, a triazole, is an extremely active chemical and give better resultsa in almost all plant species, whether applied as a foliar spray or soil drenching is more effective when applied to the growing media and application on the growing medium would give longer retention and more absorption of active ingredient than foliar spray. It inhibits GA biosynthesis by blocking the oxidation of ent- kaurene. PBZ has been used to provide plant protection against numerous abiotic stresses such as chilling, injury drought, stress, flood and salinity. PBZ inhibit the vegetative growth components, but GA induced vegetative growth components like total shoot length. PBZ application increases the tuber yield, specific gravity, dry matter yield, fruit number, yield, TSS, reducing sugar, total sugar, and decrease in TA. (Desta and Amare, 2021)

The rate of soil application of PBZ is a function of tree size and cultivar. The rate is determined by multiplying the diameter of tree canopy in meters by 1 to 1.5 g of active ingredients of PBZ. Soil type, irrigation systems are the factors included.

Overdose of PBZ may cause undesirable effects such as restricted growth, panicle malformation (too compact) and shoot deformity (Tongumpai *et al.,* 1991). Cultar, the commercial formulation of PBZ reduces vegetative growth, shoot elongation and number of leaves in many fruit trees by interrupting gibberellic acid synthesis at kaurene stage (Burondkar and Gunjate 1991).

The relative concentration of gibberellin and cytokinin decides the fate of the shoot. A significant decline in the GA_3 observed in the shoots of PBZ-treated plants after two months of application in mango and there was no difference in the level of GA3-like

substance between control and treated plants one year after the treatment. This indicates the need for reapplication of PBZ in the next season (Protacio *et al.,* 2000).

Paclobutrazol was found effective in reducing tree vigour and in promoting flowering, fruit set and yield in mango (Singh 2000). Soil application of paclobutrazol around the tree trunk (collar trench) was more effective than foliar application as it ensures proper uptake in inducing flowering and fruiting (Kulkarni *et al.,* 2006)

The application of paclobutrazol before flower bud differentiation ie., three months earlier than anticipated flowering has been effective in inducing flowering in mango without accompanying reduction in shoot length. However higher concentration of PBZ leads to canopy and panicle compaction (Shinde *et al.* 2000, Husen *et al*. 2012,)

PBZ has been characterized as a stable compound in soil and water with half-life of more than a year under both aerobic and anaerobic conditions. However, its residue could not be detected above quantifiable level (0.01 ppm) in soil and in fruit when applied in optimum level. The potential of PBZ to contaminate ground water at optimum concentrations is low however the risk of its exposure to aquatic life is high. PBZ is considered moderately hazardous for human beings with remote chance of being genotoxic and carcinogenic. In view of the above, optimized use of the PBZ to derive maximum benefit with least undesirable impact on food and environmental safety aspects are suggested (Kishore *et al.,* 2015).

The effect of four rates of nitrogen (0, 1, 2, and 3 kg per tree) and four timing of paclobutrazol application (control, three months before flowering, two months before flowering and one and a half months before flowering) were evaluated in Philippines in 22 year old mangosteen trees. It was observed that Paclobutrazol application three months before flowering was the best, resulting in reduced shoot length, earlier flowering, highest yield, highest number and weight of fruits per tree (Nakorn, 1998).

Field experiment was conducted during 2011-12 at Fruit Research Station, Sangareddy to study the influence of flower enhancing plant growth regulators and fruit

improvement in fruit set on mango cv. Banganpalli. Trees applied with paclobutrazol (3 mL/m of canopy diameter) alone significantly reduced the vegetative growth in terms of minimum number of new flushes and internodal length compared to the control trees (Krishna *et al*., 2017)

Singh, (2000) reported that foliar application and soil drenching of Cultar at 0, 10, 20, 40 and 60 g / tree to mango cv. Dusheri prior to flower bud differentiation during the first week of October reduced the tree vigour, promoted flowering and fruit set and increased yield.

Bio efficacy of paclobutrazol on regular bearing of mango cv. Dashehari was investigated by (Kumar *et al.,* 2019). Paclobutrazol was applied as soil drenching around the tree trunk @ 15 mL, 20 mL, 25 ml, 30 mL, 35 ml, 60 mL and 30 mL (ES)/ tree along with control. Significant variations were observed in growth, flowering, fruiting, yield and quality attributes due to different doses of paclobutrazol. Treatment T4 (paclobutrazol 30 mL/tree) was found to reduce vegetative growth All treatments had reduced leaf area in comparison with control. This reduction in shoot length and leaf area has been due to antagonism of gibberellin biosynthesis for which paclobutrazol is known for (Kumar *et al.,* 2019)

2.2 Flowering and fruiting

Many fruit trees, like mango and litchi require a dry period to cease its vegetative phase and initiate flowering and the duration of this dry period for mangosteen is approximately 20 days. This stage of growth and development is very crucial as any kind of at this stage water stress affects the final yield (Salakpetch, 2000).

Yaacob and Tindall (1995) also reported that mangosteen under natural conditions needs a short dry season (15-30 days) to stimulate flowering followed by irrigation or rainfall. Sdoodee and Chiarawipa (2005) also reported that the drought period usually occurred from February to March and a short dry period occurred during July and August in southern Thailand; and confirmed that mangosteen trees need a dry period to induce

flowering. PBZ is effective not only in flower induction but also in early and off season flower induction in mango (Christov *et al.,* 1995, Burondkar *et al.,* 2013).

PBZ, a gibberellin inhibitor, reduces vegetative promoter level and thereby increases florigenic promoter/vegetative promoter ratio which stimulates flowering shoots in weakly inductive shoots of fruit crops (Yeshitela *et a*l., 2004;, Voon *et al.,* 1991).

PBZ can considerably enhance the total phenolic content of terminal buds and alter the phloem to xylem ratio of the stem. Such alterations could be important in restricting vegetative growth and enhancing flowering by altering assimilates partitioning and patterns of nutrient supply for new growth (Kurian and Iyar, 1992).

The response to PBZ varied with cultivar and crop load. The effectiveness of PBZ in promoting flowering in *Citrus* spp. Depends on the crop load. In light to medium fruit loaded trees, PBZ significantly increased the percentage of sprouted buds and floral shoots and reduced the number of vegetative shoots (Martinez- Fuentes *et al.,* 2013).Phenological changes are mostly due to an increase in the number of days in the dry period. Induction of flowering in mangosteen needs a drought period as it causes accumulation of nutrients in shoots. The results of a three years experiment, indicated that the floral induction of mangosteen was influenced by a drought period of approximately 21 days, followed by irrigation or rainfall (Apiratikorn *et al.,* 2012).

Studies involving weather parameters of nearly 30 years conducted in southern Thailand on phenological changes of mangosteen indicated that, the mangosteen trees flowered on getting the required dry period resulted in flowering both in the on-season and off-season. Prolonged drought in summer followed by rain during July–August caused leaf flushing instead of flowering and this resulted in no off-season fruit production. This indicated that climatic variability resulted in a phenological change of mangosteen in Southern Thailand where there is usually off-season production. In addition, climatic variability affected the fruit yield and fruit quality in mangosteen (Apiratikorn *et al.,* 2012).

Paclobutrazol when applied as either a foliar spray or as soil drenching (David and John 1992) regulated the flowering and fruiting on tropical fruits especially in mango (Voon *et al.* 1991), (Omran 2001) and other tropical seasonal fruits such as durian (Chandraparnik, 1992).

The C:N ratio in shoots, leaf water potential (ψ_w) , and ABA content in paclobutrazol-treated and untreated trees all increased gradually as shoots got closer to the bud break stage, according to Upreti *et al* (2013) experiments on mango.With a sharp increase at bud break, PBZ increased the C: N ratio and leaf water potential. The ABA concentration of buds was favorably correlated with the C: N ratio in the shoot. During 30 days prior to bud break to the onset of the floral bud, cytokinins such as zeatin (Z), zeatin riboside (ZR), and dihydrozeatin riboside (DHZR) continuously increased in the buds. Increased ZR and DHZR contents in buds were positively correlated with leaf water potential in PBZ treated trees. The most noticeable GAs in the leaves and buds were GA_4, GA_3, GA_7 and GA_1. These gibberellins exhibited patterns in buds that were the opposite of those of cytokinins.The PBZ treatment reduced the GA_4, GA_3, GA_7 and GA_1 contents in both leaves and buds, with buds being more susceptible to the PBZ treatment. These findings suggested that PBZ, in addition to its effect on gibberellins, also elevated ABA and cytokinin levels along with the C: N ratio and leaf water potential in mango buds to induce flowering responses.

Paclobutrazol alone and in combinations with fruit set improving chemicals significantly minimized the number of days taken for panicle initiation and increased the number of days taken for 50% and 100% flowering, duration of flowering when compares to control trees. Significantly highest fruits.tree-1 and yield was recorded in paclobutrazol (42.17 % over control) alone applied trees compare to control. Among the combination, maximum increase in yield over control was recorded in paclobutrazol application along with spermidine (63.11 %), NAA + spermidine (57.59 %), NAA + boron (60.03 %). Paclobutraol and NAA have significantly minimised the number of new flushes compare to control. Maximum number of fruits was recorded in application of paclobutrazol and

minimum number of fruits per tree was recorded in untreated control. Paclobutrazol significantly reduced the number of days taken for panicle initiation compare to control. Paclobutrazol application has significantly increased the number of fruits per tree compare to control and NAA spray (Krishna *et al.,* 2017).

Paclobutrazol has been found effective in early flower induction in mango. It significantly influenced the pattern of vegetative growth, flowering, yield and fruit quality attributes during normal season of Alphonso, predominantly grown in Konkan region on west coast of India. Use of paclobutrazol in July-August, is a popular and recommended technology widely and regularly practiced since 1992 for induction of regular flowering for producing crop during main season (March 15- May 30); and currently it is used in an area of more than 10,000 ha of mango, with an estimated quantity of paclobutrazol 20,000 L annually (Burondkar *et al.*, 2000).

Trials involving foliar spray and soil drench applications of Cultar at 0, 10, 20, 40 and 60 g / tree to mango cv. Dusheri prior to flower bud differentiation during the first week of October indicated that soil drenching Cultar (20-40 g/tree) was the best treatment to reduce the tree vigour, promote flowering and fruit set and yield enhancement in Dusheri (Singh, 2000).

Investigations conducted by Kumar *et al.,* (2019) on regular bearing of mango cv.Dashehari with Paclobutrazol as soil drenching around the tree trunk at 15 mL, 20 mL, 25 mL, 30 mL, 35 mL, 60 mL and 30 mL (ES)/ tree along with control indicated that there were significant variations in flowering, fruiting, yield and quality attributes due to different doses of paclobutrazol. Treatment T4 (paclobutrazol 30mL/tree) was found superior with respect to yield and quality parameters. It was found to reduce vegetative growth and increase flowering, fruit set, fruit retention, yield attributes, TSS, sugars, ascorbic acid and β carotene content.

In order to allow mango production during the off-season, paclobutrazol was discovered. This was effective in promoting early flowering. Following paclobutrazol

treatment, it was also observed that the hormonal linkages involved with floral induction in mango (Upreti et al., 2013). By encouraging early flowering, the PBZ administered as a soil drench, at 3.0 mL/m canopy diameter during the third week of August increased fruit harvest period (i.e. early harvest) by 22 days as compared to untreated trees.

The female flowers of the mangosteen are solitary and grow singly or sporadically in clusters (2–10 blooms), developing at the terminal buds of new branches. The four sepals and four petals that made up the flower's primary components varied in size and colour. Both male and female flowers have a large number of filamentous and sessile anthers, located in various places (Te-chato, 2007).

Apiratikorn *et .al.,* (2012.), conducted a study in southern Thailand on 18 years old mangosteen during the year 2008-2010. They have observed the flowering during on and off season and also the alternate bearing habit. They have observed that, changes in distribution of rainfall pattern lead to change in flowering, productivity and quality of fruits. On- season flowering commenced on 15 March whereas off season flowering was observed on September 9th and harvesting of on season was on June whereas off season harvest was on December.

Setiawan, (2013) investigated the phenological characteristics of mangosteen and variations in flowering phenology at Bogor, Indonesia. The results indicated that trees tend to flower after vegetative growth flushes, especially after dry weather. This dry period was required to induce flowering in mangosteen. The fruiting season in Bogor is from July to middle August. Bud development to anthesis took 19 days. Fruit development took 115-140 days from anthesis. Fruit developement was observed at 2-10 weeks after anthesis. After 13 weeks the growth of fruits ceased. Harvesting period extended to 44 days from December 7 to January 20. 16-20 week time period was taken for fruit ripening and hand picking was done at 2-3 days interval. Generally, mangosteen fruit take 5 to 6 months to its matuity from fruit set. The pattern of fruit growth followed a single sigmoid curve. The average yield of 50- 100 fruits, it is also indicates that fruit production depend on the canopy size. The yield varied from tree to tree and from season to season.

In Andaman, mangosteen fruit ripening occurred during May to August. (Bohra and Waman, 2019). In this case the flowering might have occurred from January – April. Delayed flowering of fruit due to fluctuations in climatic parameters were also reported from Kerala. Usually crops like mango, nutmeg, cashew commence its flowering from November every year. But in 2020, fruit bearing trees have only started flowering in mid-February, witnessing a change in flowering season. In previous season (2019), most of the fruit bearing trees like mango had flowered to their full capacity. However, soon after the harvest season, the state witnessed another flood in August 2019. There is a chance for an imbalance in the system, owing to the climatic change. Moreover, the trees require time for energy build up and resources. The temperature has not decreased considerably in many areas. All these elements, combined together might have resulted in the change in the flowering pattern of these trees. (Shibu, 2020)

2.3 Yield and quality parameters

Then *et al.,* (2019) reported results of trials conducted at Malaysia involving three doses of paclobutrazol (at 50%, 100% and 125% of the manufacturer's recommended dose) applied by soil drenching surrounding the trunk base and control (untreated). Three years yield after the treatment showed that all the three doses improved the yield of mangosteen by 132-214% and 37-106% in first and second year of harvesting, respectively. They suggested that paclobutrazol at lower dose (50% recommended rate as suggested) applied through soil drenching once in two years will improve the yield performance of mangosteen.

Omran and Semiah (2006) studied fourteen-year-old mangosteen trees at the MARDI Research station in Bukit Tangga in northern Peninsula Malaysia during the 2003–2004 season to ascertain the impact of paclobutrazol (PBZ) application combined with potassium nitrate or Bicomine (a plant growth regulator) on flowering and fruiting of mangosteen (*Garcinia mangostana* L.). Treatments given were; 1) untreated control, 2) PBZ applied as soil drench at 2 g/tree followed by foliar application of Bicomine (at 1 mL in 6 l of water) followed by weekly applications during flowering and fruit development, 3) PBZ applied as foliar spray (at 1000 ppm) followed by weekly foliar application with 2% KNO_3 until

flowering and 4) PBZ applied as foliar application (at 1000 ppm) followed by weekly sprays with bicomine (at 1 mL in 6l of water) during flowering and fruit development. This were all applied on December 18.

There were ten replications for each treatment. The outcomes showed that applying PBZ to the soil along with bicomine did not improve blooming or boost yield. In comparison to the control, paclobutrazol applied through foliar aplication along with potassium nitrate or bicomine promoted mangosteen flowering and fruiting. The treatments had no discernible variations in total yield. Trees treated with foliar PBZ + Bicomine produced fruits that were noticeably smaller than those from the other treatments. This decrease in fruit weight could be due to the higher number of fruits produced by each tree. Regardless of the treatments applied to the trees, other characteristics of fruit quality remained unaffected (Omran and Semiah, 2006).

Preliminary studies on artificial induction of flowering in mangosteen at Kerala Agricultural University, Vellanikkara indicated positive trends (increased yields and low gamboge) with soil drenching of Paclobutrazol @ 2g ai/tree by soil drenching and foliar application of GA 200 ppm + BA 100 ppm and GA 200 ppm + BA 200 ppm (Manoj, 2011) in young mangosteen plants. However the trials were done in young plants and with a combination of other growth regulators.

A soil drenching of Cultar (20–40 g/tree) was found to be the most effective method for reducing tree vigour, promoting flowering and fruit set, and increasing production in Dusheri during trials using foliar spray and soil drenching of Cultar at 0, 10, 20, 40, and 60 g/tree to mango cv (Singh, 2000).

Patel *et al.,* (2016), from their study in Alphonso mango at Anand Agricultural University, Navsari Gujarat reported that, treatment of Paclobutrazol 23% w/w @ 9.2 g a.i./tree as soil drench (i.e. 40 mL commercial formulation /tree) resulted in maximum number of fruits and fruit weight, maximum net profit and benefit-cost ratio.

Rane *et al.,* (2005) reported that the application of paclobutrazol to mango trees results in higher fruit yield and these trees start bearing fruits every year. Accordingly, the mango growers were advised to apply 3 mL of paclobutrazol per metre of tree canopy diameter during 15th July to 15thAugust by diluting the dose with adequate water. This recommendation has been tested on the farmers' field in Hodawade village of Vengurle tehsil, for four years (2000-01 to 2003-04). The cost-benefit ratio of application of paclobutrazol (cultar) has been found as 1.49 whereas in non-application of paclobutrazol, it has been found as 1.13. It has been be concluded the application of Cultar for mango production is highly profitable.

The cultar-treated mango trees have provided an average yield of 39.60 q/ha, whereas the untreated trees have given an average yield of 16.80 q/ha. It has been concluded that paclobutrazol minimizes the risk in obtaining yield as well as income from alphonso mango production in the Sindhudurg district of Maharashtra (Rane *et al.,* 2005)

In the mango cv. Dashehari, paclobutrazol application at 30 mL/tree increased flowering, fruit set, fruit retention, yield characteristics, TSS, sugars, ascorbic acid and carotene content (Kumar *et al.,* 2019).Mango yields normally increase after PBZ treatments, although Voon *et al.,* (1991) stressed the significance of providing sufficient nutrients and irrigation to maintain these high yields. Moreover, PBZ improved the productivity of "Tommy Atkins" in the studies conducted by Medonca et al (2002).PBZ is effective in increasing the number and weight of fruits per tree, in improving the fruit quality in terms of increases in carbohydrates, TSS and decreases acidity (Desta and Amare (2021).

Recent studies conducted in mango The application of PBZ caused earlier flowering by 22 days and harvesting was also done earlier by 18 days compared to the control. Plants subjected to FBP with PBZ reflowered 36 days later and harvesting was delayed by 16 days compared to the control. Moreover, the combination of PBZ 1.5 g with FBP showed significantly higher flowering percentages, number of panicles, total flowers, total fruits and weight of fruit compared to the control. In addition, the application of PBZ 1.5 g with FBP increased the total soluble solids, reducing sugar, non-reducing sugar, total sugar and β-

carotene, while it decreased the vitamin C content. The present findings imply that applying PBZ 1.5 g with FBP to mango can extend the flowering and fruiting time, while the fruit quality was also influenced positively (Rahman *et al.,* 2023).

Materials and methods

3. MATERIALS AND METHODS

The present investigation on "Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)" was conducted on 15 year old mangosteen trees with an objective.

3.1 Experiment site

The location of the experiment was at the College Orchard, Department of Fruit Science College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala during September 2021 to August 2022. Vellanikkara enjoys a warm humid tropical climate, and is situated between longitudes 76.28º and latitude 10.54º with an altitude of 11.12m above sea level.

3.2 Soil

The experiment was conducted in the existing mangosteen orchard of the College. The soil had an average contentment of 1.33% organic carbon (medium), phosphorous 55.36 kg/ha (high), potassium of 369.9 kg/ha (high), calcium of 415.75 mg/kg, magnesium of 111.63 mg/ha (deficient) pH of 5.42 (strongly acidic) and EC of 0.06.

3.3 Season and weather condition

The data on weather parameter during this period is given in Appendix 1.

3.4 Materials

Thirty trees of uniform size were selected for the experiment. The experiment has conducted in the existing mangosteen tree in the orchard of 15 years old planted in 2007

3.5 Methods

3.5.1 Design of experiment

The experiment was conducted in completely randomized design with five treatments, 3 replications and two trees per replication.

Design of experiment: CRD

Treatments-5

Replication- 3

Number of plants per treatment per replications 2

3.5.2 Treatments

T1 Paclobutrazol @ 2.3 g ai/tree (10mL Cultar)

T2 Paclobutrazol @ 4.6 g ai /tree (20mL Cultar)

T3 Paclobutrazol @ 6.9 g ai /tree (30mL Cultar)

T4 Paclobutrazol @ 9.2 g ai /tree (40mL Cultar)

T5 Control - Water alone

The commercial formulation of the chemical "Cultar" with 23%w/w paclobutrazol was dissolved in 10 L of water and applied in 30 cm deep holes around the basin of trees at uniform distance and covered with soil.

3.5.3 Field

The experiment has conducted in the existing mangosteen orchard at a spacing of 7m X 7m. Thirty uniform trees were selected for the trial.

3.5.4 Preparation of PBZ solution (cultar) and its soil drenching

The required quantity of the commercial formulation cultar for each tree was diluted in 10 L of water and applied in four pits of 30 cm depth, 60 cm away from the plant at the four corners of the basins and was covered with soil after application. This is done by soil drenching.

10mL Cultar forT1
20 mL Cultar for T2
30 30 mL Cultar for T3
40 mL Cultar for T4
T5 Control - Water alone for T5

Paclobutrazol is a plant growth regulator which is available in many trade names like katyayani fast - paclobutrazol 23% SC, Syngenta cultar Paclobutrazol 23% w/w. We have used syngenta cultar, commonly called as cultar. This was applied as a single dose to the plant on 29-11-2021 after a dry spell of two weeks.

3.6 Observations recorded

Details of observations recorded are detailed below:

3.6.1 Vegetative characters

The following vegetative characters were recorded at monthly intervals from the time of application of PBZ for nine months.

3.6.1.1 Tree height (m)

Height of the trees was measured using instrument hypsometer from ground level to the top of the tree.

3.6.1.2 Trunk circumference (cm)

Circumference of the trunk was measured using measuring tape by recording the girth at 50 cm above ground level and recorded in centimeters and noted the mean.

3.6.1.3 Number of branches

Number of primary branches was counted and expressed in numbers.

3.6.1.4 Crown diameter (m)

Crown diameter was measured as the mean diameter of canopy in two directions (North-South and East-West) and was expressed the mean diameter in meters.

3.6.1.4 Time taken for bud break and days taken for flushing

Ten branches in each tree were tagged as soon as their buds shown signs of bud differentiation and the day taken for bud break after application of PBZ was noted. The days taken for flushing was also noted in each tree, and mean was calculated. This are calculated from the day of application of paclobutrazol.

3.6.1.5 Growth of shoots and leaf production in unit time

Five shoots from north, south, east and west directions were tagged at random from each tree. Growth of shoots (length in cm) and leaf production (total number of leaves per shoot) were recorded at monthly interval and extension of growth per month was estimated. Increase in shoot length and number of leaves per month are noted from initial length after application.

Plate 3.1 Field view

Plate 3.2 Cultar – the commercial formulation used in the experiment

Plate 3.3 Tagging the trees

Plate 3.4 General overview of the experiment field

Plate 3.5 Preparation of the chemical in 10 L of water

Plate 3.6 Pouring the dissolved chemical into four pits

Plate 3.7 Measuring the shoot length

Plate 3.8 Crown diameter

Plate 3.9 Different stages of flower opening

3.6.2 Flowering characters

3.6.2.1 Days taken for first flowering

Date of first flowering in each tree after application of paclobutrazol was noted, and the days to first flowering was calculated.

3.6.2.2 Days taken for last flowering

Days taken for the last flowering of each tree after application of PBZ in all treatments were noted.

3.6.2.3 Duration of flowering (days)

Period of flowering in days was calculated by noting first and last days of flowering in each tree, counting the duration in days and expressing the average per treatment per replication.

3.6.2.4 Flower clustering habit (number)

Number of flowers per cluster from ten flowering twigs per tree was noted and the average per replication was expressed to describe the flower clustering habit. Observation of flower clustering habit was noted by observing flowers per cluster that is;

- One flower per cluster
- Combination of 1 and 2 flowers per cluster
- Combinations of 1, 2, 3
- Other

We have noting 10 clusters in each tree as per classification mentioned in the IPGRI botanical descriptor for mangosteen (IPGRI, 2003) noted below

3.6.3 Fruit characters

3.6.3.1 Days taken for fruit set

Twenty flowers per tree per replication were tagged on the date of flowering, and days taken for fruit set after application of paclobutrazol was noted.

3.6.3.2 Days taken for harvest

From the day of PBZ application days taken to first harvest was estimated per treatment per replication.

3.6.3.3 Number of days from fruit set to fruit maturity

Days to fruit maturity was calculated from the date of fruit set to maturity from 5 flowers per tree, and the average was expressed in days. On the day of fruit set it was tagged and at maturity, no. of days taken was calculated.

3.6.3.4 Fruit size (cm)

Diameter of 20 mature fruits harvested at random per tree were selected and calculated the average fruit size.

3.6.3.5 Average fruit weight (g)

Average weight of 20 fruits at random per tree were taken. The size of the fruits from the tree were described as large/ medium/ small as per classification mentioned in the IPGRI botanical descriptor for mangosteen (IPGRI, 2003) noted below

Large > 140 g/fruit

Medium- 90-140 g/fruit

Small < 90 g/fruit

3.6.3.6 Fruit colour at maturity

Fruit colour at maturity was noted as suggested by IPGRI (2003), as noted below:

- Green
- Greenish yellow
- Bright yellow
- Orange yellow
- Orange
- Violet
- Purple
- Deep purple
- Pink
- Red
- Others

3.6.3.7 Fruit colour at ripening

Color of fruit at the time of ripening was also noted in 20 fruits per tree.

3.6.3.8 Number of arils/fruit

Number of arils from 20 ripe fruits at random harvested were counted and average number of arils per fruit was estimated.

3.6.3.9 Number of translucent arils/fruit

Number of translucent arils where noted in three fruits from each tree.

3.6.3.10 Number of seeds/fruit

Average number of seeds per fruit was estimated from three fruits selected at random from a tree.

3.6.3.11 Edible portion/aril content in fruit (%)

Weight of three fruits per tree were taken. Fruits were opened, and weight of the outer husk and arils were separated and the percentage of edible portion of the fruits were calculated.

3.6.3.12 Shelf life of fruits

Three uniformly ripe fruits/ tree harvested were kept at ambient condition. Weight of fruits was noted every day and physiological loss in weight was noted. Total duration until the fruits turn to senescence stage from the first day was noted and expressed as shelf life.

3.6.3.13 Number of fruits per tree

Total number of fruits harvested from each tree was noted and total number was estimated.

3.6.3.14 Yield per tree (kg)

Total weight of fruits harvested from all harvests per tree from first to last harvests were noted and total yield per tree was estimated..

3.6.3.15 Gamboge infected fruits (%)

Number of gamboge infected fruits were observed and expressed in percentage for each tree.

3.6.3.16 Marketable fruits (%)

Total weight of fruits harvested and weight of marketable fruits in each harvest per tree was calculated after detecting the damaged fruit weight and expressed as marketable fruits (%)

3.6.4 Quality parameters of fruits

Quality parameters like TSS, acidity, reduced sugar, non-reduced sugar, total sugar, vitamin C were estimated from the fruit of each tree and average per treatment per replication was estimated. Lab analysis was performed as per procedure suggested by Sadasivam and Manicka (2008).

3.6.4.1 TSS (°Brix)

TSS was measured by using digital refractometer by extracting juice from pulp.

3.6.4.2 Acidity (%)

Acidity was measured according to the procedure given by Sadasivam and Manickam (2008).

3.6.4.3 Reducing sugar (%)

Reducing sugar was measured according to the procedure given by Sadasivam and Manickam (2008).

3.6.4.4 Non - reducing sugar (%)

Non - reducing sugar was calculated and analysis was done according to the procedure given by Sadasivam and Manickam, (2008).

3.6.4.5 Titrable sugar

Titrable sugar of the fruit was calculated and analysis was done according to the procedure given by Sadasivam and Manickam, (2008).

3.6.4.6 Total sugar

Total sugar in fruit was also measured according to the procedure given by Sadasivam and Manickam, (2008)

3.6.4.7 Vitamin C (mg/100)

Total sugar in fruit was also measured according to the procedure given by Sadasivam and Manickam, (2008).

3.6.4.7 Statistical analysis

The statistical design adopted for these experiment was completely randomized design (CRD). Procedure prepared by following Panse and Sukhatme (1985). The recorded data was subjected to ANOVA with critical difference values tabulated at 5% level of significance at corresponding degrees of freedom by using GRAPES software (Gopinath *et al*., 2020).

Results

4. RESULTS

The study entitled “Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)” is discussed in this chapter. Observations of various vegetative characters, fruit characters and fruit quality parameters were analyzed statistically and result are furnished below under various headings.

4.1 Vegetative characters

Tree height, number of branch per tree and trunk circumference are presented in Table 4.1 and crown diameter in Table 4.2**.**

4.1.1 Tree height (m)

Height of tree did not show any significant difference. It ranged from 4.35 (T3) to 5.5 m (T1).

4.1.2 Trunk circumference (cm)

It was observed that there was a monthly rate of increase in the trunk circumference. In the control plants (T5) whereas T4 treated showed constant value in the month of April, May and June.

4.1.3 Number of branches

No. of branches per tree does not show any significant difference.

4.1.4 Crown diameter (m)

Crown diameter did not vary significantly among the treatments (Table 4.2).

4.1.5 Time of bud break and days taken for flushing

Days taken for bud break after application of PBZ application differed significantly. This was shown in the Table 4.3. Maximum days taken for bud break was observed in T5

(control). T5 took about 94 days whereas other treatments T1 (74.70 days), T2 (74.30 days), T3 (72.73 days), T4 (70.86 days) were on par with each other. Days taken for flushing differ significantly among the treatments. Minimum days taken for flushing was observed in T4 (167.33 days). The treatments T3 (174.33) and T5 (174.33) where on par with T4. The maximum days taken for flushing was observed in T2 (187.16 days) and was par with treatment T1 (186.50 days).

4.1.6 Growth of shoots and leaf production in unit time

Mean of monthly increase in shoot growth (cm) from December 2021 to June 2022 are furnished in Table 4.3. It was observed that monthly increase in shoot growth of trees differed significantly between treatments. Highest rate of shoot growth was observed in T5 (2.01 cm). Lowest rate of increase in shoot growth was seen in T4 (1.11 cm). Leaf production are furnished in Table 4.4 and it showed no significant difference.

Table 4.1 Effect of paclobutrazol on tree height (m), number of branches and trunk circumference (cm)

Treatment	Tree height (m)	Trunk circumference (cm)							No. of branches
		Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	
T1	5.50	0.25^{b}	0.41^{b}	0.58^{b}	0.58^{c}	0.83^{c}	0.91^{b}	1.50^{ab}	29.33
T2	5.13	0.25^{b}	0.41^{b}	0.50^{b}	0.58^{c}	0.91^{bc}	0.91^{b}	1.08^{bc}	30.83
T3	4.35	0.50^{a}	0.58^{ab}	0.66^{b}	0.83^{b}	0.91^{bc}	0.91^{b}	1.00^{c}	26.16
T4	4.63	0.50^{a}	0.50^{b}	1.00^{a}	1.16^{a}	1.16^{b}	1.16^{b}	1.16^{bc}	26.00
T5	5.10	0.33^{b}	0.75^{a}	0.91^{a}	1.00^{ab}	1.50^{a}	1.66^{a}	1.83^{a}	28.83
CD (0.05)	NS	0.11	0.18	0.20	0.23	0.31	0.38	0.47	NS
CV%	15	17.60	18.75	15.24	15.49	16.01	19.17	19.80	19.72
SE(m) $\pm$	0.42	0.03	0.05	0.06	0.07	0.09	12	15	3.21

Table 4.2 Effect of paclobutrazol on crown diameter (m)

Treatment	Oct N-S	Oct W-E	Nov N-S	Nov E-W	Dec N-S	Dec E-W	Jan N-S	Jan E-W	Feb N-S	Feb E-W	Mar N-S	Mar E-W	Apr N-S	Apr E-W	May N-S	May E-W	Jun N-S	Jun E-W
1	5.62	5.86	5.62	6.01	5.68	5.94	5.70	6.08	5.73	6.08	5.73	6.08	5.73	6.08	5.73	6.08	5.73	6.08
2	5.50	5.41	5.50	13.53	5.60	5.49	5.67	5.56	5.67	5.69	5.69	5.60	5.69	5.60	5.69	5.60	5.69	5.60
3	5.41	5.27	5.43	5.27	5.52	5.39	6.48	5.44	5.81	5.48	5.81	5.48	5.81	5.48	5.81	5.48	5.81	5.48
4	5.25	5.61	5.19	5.61	5.19	5.60	5.25	5.77	5.25	5.77	5.25	5.77	5.25	5.77	5.25	5.77	5.25	5.77
5	4.30	4.20	4.40	4.31	4.43	4.37	4.43	4.51	4.46	4.53	4.46	4.53	4.46	4.53	4.46	4.53	4.46	4.53
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	13.60	16.69	13.14	16.44	13.18	15.24	18.41	15.61	12.69	15.37	12.76	15.67	12.69	15.67	12.76	15.67	12.76	15.67
SE(m) $\pm$	0.41	0.50	0.39	0.71	0.40	0.47	0.58	0.58	0.39	0.48	0.39	0.49	0.39	0.49	0.39	0.49	0.39	0.49

Table 4.3 Effect of paclobutrazol on bud break and season of flushing, growth of shoots in unit time (cm)

Treatment	Time of bud break	Days taken for flushing	Growth of shoot (cm)						
			Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022
T1	74.70[b]	186.50[a]	0.31[cd]	0.45[b]	0.60[b]	0.66[c]	0.82[c]	0.96[b]	1.24[c]
T2	74.30[b]	187.16[a]	0.41[bc]	0.46[b]	0.85[ab]	1.13[ab]	1.22[ab]	1.25[ab]	1.61[b]
T3	72.73[b]	174.33[b]	0.26[d]	0.69[a]	0.91[ab]	0.95[bc]	1.09[bc]	1.31[ab]	1.29[c]
T4	70.86[b]	167.33[b]	0.56[a]	0.67[a]	0.73[b]	0.84[bc]	0.91[bc]	0.98[b]	1.11[c]
T5	94.00[a]	174.33[b]	0.55[ab]	0.68[a]	1.22[a]	1.42[a]	1.54[a]	1.61[a]	2.01[a]
CD (0.05)	7.99	9.22	0.14	0.13	0.37	0.42	0.37	0.37	0.31
CV%	5.68	2.85	18.75	12.22	24.09	0.34	18.40	16.98	12.05
SE(m) ±	2.53	2.92	0.04	0.04	0.12	19.01	0.11	0.11	0.10

Table 4.4 Effect of paclobutrazol on growth of leaf production in unit time

Treatment	Leaf production in unit time							
	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022
T1	7.40	7.00	6.86	6.63	6.63	6.63	6.63	6.96
T2	7.46	7.30	7.00	6.63	6.66	6.40	6.43	6.56
T3	7.26	6.81	6.46	7.00	6.96	6.90	6.90	6.66
T4	7.00	7.00	6.36	6.80	7.20	7.13	7.20	7.40
T5	7.70	7.53	7.16	7.26	7.06	6.96	6.80	6.80
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV%	11.22	10.19	11.48	12.20	12.56	12.57	12.84	18.08
SE(m) ±	0.47	0.41	0.44	0.48	0.50	0.49	0.50	0.71

4.2 Flowering characters

4.2.1 Days taken for first flowering

Days to first flowering after PBZ application showed significant differentce between treatments when compared to untreated control T5 (127.33 days). Earliest flowering was observed in T4 (100.66 days). T4 (100.66 days) which was on par with T3 (107.33 days) and T2 (112 days). Maximum days taken for flowering was observed in T5. T1 (112.66 days), T3 (107.33 days) and T2 (112 days) were also on par with each other. This is furnished on table 4.5.

4.2.2 Days taken for last flowering

Days taken to complete the flowering phase from PBZ application also differed significantly. The maximum duration was observed in T5 (168.33 days) which was at par with T2 (165.16). The flowering phase was completed with minimum days 151.66 in T4

was on par with T3 (155.50). Days taken for last flowering were given on table 4.5.

4.2.3 Duration of flowering (days)

Duration of flowering phase did not show any statistical difference. Duration of flowering is furnished on table 4.5.

4.2.4 Flower clustering habit

The flowers per clusters differed significantly between treatments. Maximum number of flowers per clusters 2.63 was observed in T4 and all other treatments where at par with T1 (1.60), T2 (1.74), T3 (1.34), T5 (1.46). Flower clustering habit also given on table 4.5.

Plate 4.1 Flower cluster

Plate 4.2 First flowering on treated plant

Table 4.5 Flowering characters in days after application of paclobutrazol

Treatment	Days taken for first flowering	Days taken for last flowering	Duration of flowering	Flower clustering habit
T1	112.66[b]	160.00[bc]	47.33	1.60[b]
T2	112.00[bc]	165.16[ab]	53.16	1.74[b]
T3	107.33[bc]	155.50[cd]	48.16	1.34[b]
T4	100.66[c]	151.66[d]	53.66	2.63[a]
T5	127.33[a]	168.33[a]	41.00	1.46[b]
CD (0.05)	11.85	7.82	NS	0.55
CV%	5.81	2.58	17.41	17.49
SE(m) ±	3.76	2.38	4.89	0.17

4.3 Fruit characters

Fruit characters are furnished in table 4.6.

4.3.1 Days taken for fruit set

The statistical analysis showed significant difference for days taken for fruit set and was significantly maximum in control T5 (132.66 days) whereas all other treatments took least time and were statistically on par with each other. T1 (118.16), T2 (118.33), T3 (117) T4 (113 days) were at par with each other.

4.3.2 Days taken for harvest

The days taken for harvest showed significant difference. Earliest harvest was observed seen in T4 which took 189 days. All other treatment were on par (189 days in T4, 191.33 days in T1, and 190.66 days in T2 and 191.33 days for T3) with each other.

4.3.3 Number of days from fruit set to fruit maturity

Days taken from fruit set to maturity did not vary statistically.

4.3.4 Fruit size (cm)

Fruit size also shown statistical difference among treatments significantly maximum was observed in T3 (6.27 cm). Minimum fruit size was observed in T4 (5.07 cm) and was at par with T5 (5.17 cm).

4.3.5 Average fruit weight

Average fruit weight differed significantly between treatments and was maximum in T3 (104.84 g) and all other treatments were at par (80.69g in T5, 89.11g in T4, 88.12g in T2 and T1in 84.60g).

4.3.6 Fruit colour at maturity

Fruits of all treatments had uniform deep purple color and this did not vary between the treatments.

4.3.7 Fruit colour at ripening

Fruits of all treatments had uniform deep purple color and did not vary between the treatments.

4.3.8 Number of arils/ fruit

Number of arils per fruit did not vary significantly between treatments.

4.3.9 Number of translucent arils/fruit

The number of translucent arils varied significantly. Fruits of T2 and T5 had no translucent arils and was on par with each other whereas T1 had maximum number of translucent aril per fruit (0.27).

4.3.10 Number of seeds/fruit

No. of seeds per fruits also differed significantly. T2 had significantly higher number of seeds 2.03 and T3 (1.78) was on par with T2. Lowest number of seeds/fruit recorded was in T5 (1.35) and it was on par with T4 (1.41) and T1 (1.58).

4.3.11 Edible portion in fruits

Percentage of edible portion (aril content) of fruits varied significantly between treatments. Maximum percentage of arils was observed in T2 (35.17g). T3 (32.85g) and T2 were on par with each other. The minimum aril content was observed in T1 (25.26%) was on par with T5 (28.32).

4.3.12 Shelf life of fruits

Effect of treatment on shelf life of fruits was statistically significant. T3 and T4 had significantly longest shelf life of 21.05 and 21.82 days respectively. Shelf life of fruits from T5 control (13.71 days) was the shortest and it was at par with T1 and T2 (16.77 and 16.72 days).

4.3.13 Number of fruits per tree

Total number of fruits per tree differed significantly and it was maximum in T2 (203.50) and T4 (203.70 fruits) and in control T5 produced the minimum number of fruits (143.66 fruits)

4.3.14 Yield per tree (kg)

Total yield of fruits differed significantly between treatments and maximum yield was obtained from T4 (19.27 kg) and lowest from T5 (11.93). Yield of T4, T3, T2 (19.27, 16.79, 16.80) were at par with each other. T1 and T5 were also on par (14.19 and 11.93).

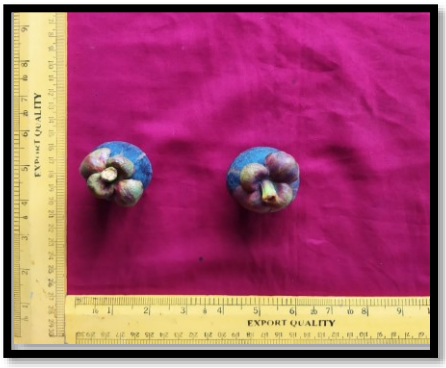
4.3.15 Gamboge infected fruits (%)

Percentage of gamboge infected fruits also varied significantly between treatments. The lowest gamboge infection was observed in T2 (7.45%) and maximum in T5 (41.48%) which was on par with T3 (35.75%).

4.3.16 Marketable fruits (%)

Percentage of marketable fruits in different treatment was statistically significant. The maximum percentage of marketable fruits was obtained from T2 (92.5%) and minimum percentage in control T5 (58.51%)

T1



T2

T3

T4

T5

Plate 4.3 Fruits from different treatments

Plate 4.4 Fruit with translucent arils

Plate 4.5 Mangosteen fruits

Plate 4.6 Gamboge infected fruit

Table 4.6. Effect of paclobutrazol on fruit characters

Treatment	Days@ taken for fruit setting	Days@ taken for harvesting	No. of days from fruit set to fruit maturity	Fruit size (cm)	Average fruit weight (g)	No. of arils/fruit	Number of translucent arils/fruit	Number of seeds/fruit	Edible portion/aril content in fruit (%)	Shelf life of fruits	Number of fruits per tree	Yield per tree (kg)	Gamboge Infected fruits (%)	Marketable fruits (%)
T1	118.16^{b}	191.33^{b}	73.16	5.39^{bc}	84.60^{b}	5.93	0.27^{a}	1.58^{bc}	25.26^{d}	16.77^{bc}	189.33^{b}	14.19^{bc}	24.93^{b}	72.06^{c}
T2	118.33^{b}	190.66^{b}	72.33	5.47^{b}	88.12^{b}	5.99	0.00^{d}	2.03^{a}	35.17^{a}	16.72^{bc}	203.50^{a}	16.81^{ab}	7.45^{c}	92.54^{a}
T3	117.00^{b}	191.33^{b}	74.33	6.27^{a}	104.84^{a}	6.04	0.16^{b}	1.78^{ab}	32.85^{ab}	21.05^{ab}	171.50^{c}	16.79^{ab}	35.75^{a}	64.24^{d}
T4	113.00^{b}	189.00^{b}	76.00	5.078^{d}	89.11^{b}	5.78	0.11^{c}	1.41^{bc}	29.37^{bc}	21.82^{a}	203.70^{a}	19.27^{a}	20.28^{b}	79.71^{b}
T5	132.66^{a}	198.33^{a}	65.66	5.17^{cd}	80.69^{b}	5.80	0.00^{d}	1.35^{c}	28.32^{cd}	13.71^{c}	143.67^{d}	11.93^{c}	41.48^{a}	58.51^{e}
CD (0.05)	11.74	5.29	NS	0.26	8.56	NS	0.03	0.43	4.00	4.80	6.86	2.88	7.61	5.53
CV%	5.38	1.51	8.97	2.67	5.26	2.08	15.03	14.57	7.27	14.64	2.06	10.03	16.11	4.14
SE(m) ±	3.72	1.68	3.74	0.085	2.71	0.07	0.01	0.13	1.27	1.52	2.17	0.91	2.41	1.75

@ Days taken for fruit setting and days taken for harvesting of fruits were counted from the date of application of PBZ

4.4 Quality parameters of fruits

4.4.1 TSS (°Brix)

TSS of fruit pulp was significantly influenced by the treatments. The lowest TSS was observed in T3 (13.67 °Brix) and highest for T1 (14.61°Brix). Treatments T1 (14.61 °Brix), T2 (14.42 °Brix), T4 (14.35 °Brix), T5 (14.31 °Brix) were on par with each other.

4.4.2 Acidity (%)

There was significant difference in acidity of fruit pulp. The lowest acidity was seen in T2 (0.5) and highest in T3 (0.73). Acidity of T1 (0.6), T4 (0.57) and T5 (0.63) were at par with each other.

4.4.3 Reducing sugar (%)

Reducing sugar of fruits pulp was not significantly influenced by the treatments.

4.4.4 Non- reducing sugar (%)

Non reducing sugar of fruit pulp differ significantly between treatments. Lowest reducing sugar was for T4 with 8.70 % and 9.11% in T5 and the treatments were on par with each other. The highest non- reducing sugar was obtained in T2 (10.07%) and were on par with T1 (9.88%).

4.4.5 Total sugar (%)

Total sugar content of fruit pulp varied significantly between treatments. Highest total sugar was obtained in T2 (14.23%) followed by T1 (13.16%) and they were at par with each other. T4 (12.26%) were at par with T5 (12.49) and T3.

4.4.6 Vitamin C (mg/100g)

There was statistical difference in vitamin C content of fruit pulp between treatments. The maximum vitamin c was observed in T4 (17.55 mg/100g) followed by T5 (17.32 mg/100g) and they were at par. The T1 showed the lowest (13.71 mg/100g). T2 and T3 had vitamin C content of 16 mg/100g. Quality parameters are furnished on table 4.7.

Table 4.7 Effect of paclobutrazol on qualitative characters

Treatment	TSS	Acidity	Reducing sugar	Non-reducing sugar	Total sugar	Vitamin C
T1	14.61[a]	0.60[bc]	3.34	9.88[ab]	13.16[ab]	13.71[c]
T2	14.42[a]	0.50[c]	3.31	10.92[a]	14.23[a]	16.00[b]
T3	13.67[b]	0.73[a]	3.04	10.07[ab]	13.10[ab]	16.00[b]
T4	14.35[a]	0.57[bc]	3.54	8.70[c]	12.26[b]	17.55[a]
T5	14.31[a]	0.63[b]	3.37	9.11[bc]	12.49[b]	17.32[a]
CD (0.05)	0.59	0.1	NS	1.14	1.19	1.31
CV%	2.28	9.21	13.37	6.47	5.02	4.49
SE(m) ±	0.18	0.03	0.25	0.36	0.37	0.41

Discussion

5. DISCUSSION

Mangosteen is an important tropical fruit crop gaining popularity and importance in the humid tropical zones of south Indian states like Kerala and western coast of Karnataka. The growth of the crop in the initial stages is very slow and it has a low juvenile period. This greatly affect the flowering and fruiting behavior of the crop. Various types of plant growth regulators are used in fruit crops for induction of growth and flowering and also for altering the fruit drop, increase fruit set, improving fruit set, hastening ripening etc. (Suman *et al*., 2017, and Sebastian *et al.,* 2019). Among these, Paclobutrazol is commercially used in fruit crops like mangoes for the induction of flowering and to regulate the cropping pattern of the tree. (Kurian and Iyer, 1992; Burondkar *et al.,* 2000; Singh, 2000; Upreti *et al.,* 2013; Krishna *et al.,* 2017 and Kumar *et al.,* 2019)

It is with this background, the present investigations were made on the effectiveness of PBZ for induction of flowering in mangosteen at different doses in comparison with a control.

Paclobutrazol was applied to the plants on 29th October 2021. Bud break was observed from January and flowering from February to April. New flush growth and emergence of new leaves were observed from April to May.

The meteorological data was recorded during the period of the study (July 2021 to June 2022) at meteorological observatory of College of Agriculture, Vellanikkara and are furnished in appendix I.

5.1 Vegetative characters

Vegetative characters are observed from the time of PBZ application to seven months after application. It is observed that the vegetative characters of the trees particularly tree height, number of branches, crown diameter, shoot growth and leaf production in unit area did not vary significantly during this period. The highest shoot

growth was observed in T5 (2.01 cm) during June 2022. Suppression of vegetative growth by PBZ has been reported in tomato and in peaches by Allan et *al.,* (1993). The most noticeable growth response seen in the various species treated with PBZ was a reduction in shoot growth Pinto *et al.,* (2005) like *Zinnia elegans* and this response is attributed primarily due to decreased internode length.

In accordance with research done by Brito *et al;* 2016 the PBZ was effective in inhibiting growth in a variety of plant species, while the treated plants tended to be more compact and smaller in size with darker green leaves.

5.2 Bud break and flowering

The earliest bud break was observed in T4 (70.86 days) and it was on par with T1 (74.70 days). Whereas the bud break was delayed in control T5 (94 days). The data revealed that there is a significant effect of paclobutrazol on the bud break, and earliness in flowering.

This was in line with experiments conducted by Singh, (2000) where it was discovered that paclobutrazol was beneficial at lessening tree vigour and increasing mango flowering, fruit set, and yield. Major reason for this is the reduction in glibberellin production was due to the inhibition oxidation of reaction of kaurene to kaurenoic acid in gibberellin acid biosynthesis pathway. The relative concentration of gibberellin and cytokinin decides the fate of the shoot.

Application of PBZ at bud break stage and two weeks prior to anthesis of grapes considerably improved the production, demonstrating that the efficiency of PBZ was depending on stage of development (Christov *et al.,* 1995). The overall assessment of bud break and flowering character in this study showed that PBZ at high doses induced early bud break, delayed flushing and extended the flowering phase in mangosteen.

Season of flushing was first observed in T4 (167.33 days) and it was on par with T3 (174.33) and T5 (174.55 days). T1 (186.50 days) and T2 (187.16 days) were on par

with each other. The research works done on phenology of mangosteen indicate that a short dry spell of 3-4 weeks is required for successful flowering in mangosteen (Yaacob and Tindall, 1995).

Present investigation indicated that early flowering was observed in treatment T4. The metrological data revealed that a dry spell was not experienced during November but an early flower induction was obtained in PBZ treated plants. It is an indication that a dry spell can be compromised with PBZ treatment for the induction of flowering by suppression of the growth and metabolic activities whereas even in the absence of such a drought spell the phenological changes are obtained.

Delayed flowering was observed in control T5 (127.33 days) and days taken for last flowering was also observed in T5 (168.33 days). Earliest days for first flowering T4 (100.66 days) and earliest completion of flowering by T4 (151.66 days). In line with Yeshitela *et al.,*(2004) a gibberellin inhibitor called PBZ lowers the level of vegetative promoter and raises the ratio of florigenic promoter to vegetative promoter, which encourages blooming shoots in fruit crops with weak inductive branches.

According to Mabvongwe, (2016) paclobutrazol is a systemic plant growth regulator and it is capable for the reduction of inter nodal length of new shoots and caused earlier formation of terminal buds and induce flowering. Early and off-season floral induction of mangoes with PBZ was successful (Christov *et al.,* 1995, Burondkar *et al.,* (2013). According to Upreti *et al.,* (2013), paclobutrazol has been proven to be mostly beneficial in the promotion of early flowering, opening the door for mango off-season production. Early flowering was noticed due to increase in C: N ratio with the application of paclobutrazol. The Increase in C: N ratio was due to the increase in cytokinins, ABA and decline in gibberellins, GA_1, GA_4, GA_3 and GA_7 in buds.

Duration of flowering was not significant with each other. The number of flowers per cluster was maximum in Treatment 4 (2.63) where as other treatment T1 (1.60), T2

(1.74), T3 (1.34), T5 (1.46) were on par .This was in agreement with the study of Arzani *et al.,* (2009) which stated that the flower density of peach cultivars showed an increase in flowering density. Here carbohydrate may not have influence on flower initiation while gibberellins level showed to have an inhibitory effect on flower formation.

Recent studies conducted in mango The application of PBZ caused earlier flowering by 22 days and harvesting was also done earlier by 18 days compared to the control. In addition, the application of PBZ 1.5 g with FBP increased the total soluble solids, reducing sugar, non-reducing sugar, total sugar and β-carotene, while it decreased the vitamin C content. The present findings imply that applying PBZ 1.5 g with FBP to mango can extend the flowering and fruiting time, while the fruit quality was also influenced positively (Rahman *et al.,* 2023).

The flowering characters were in agreement with study of Then *et al.,* (2019) pointed out that PBZ at recommended rate (100% and 125%) would induce flowering. Total number of flowers that is about 1,012 and 926 flowers whereas control only having 472 flowers per tree. Here, a decrease in gibberellin acid was seen, resulting in an increase in the mangosteen's C: N ratio. This lead to retardation of vegetative growth. PBZ inhibit the oxidation of kaurene to kaurenoic acid in the gibberellins biosynthesis pathway. As a result, the flower density, fruit set, and total quantity of fruits on PBZ treated plants increased. Effect of PBZ on days taken for flowering characters were illustrated on figure 5.1 and figure 5.2.

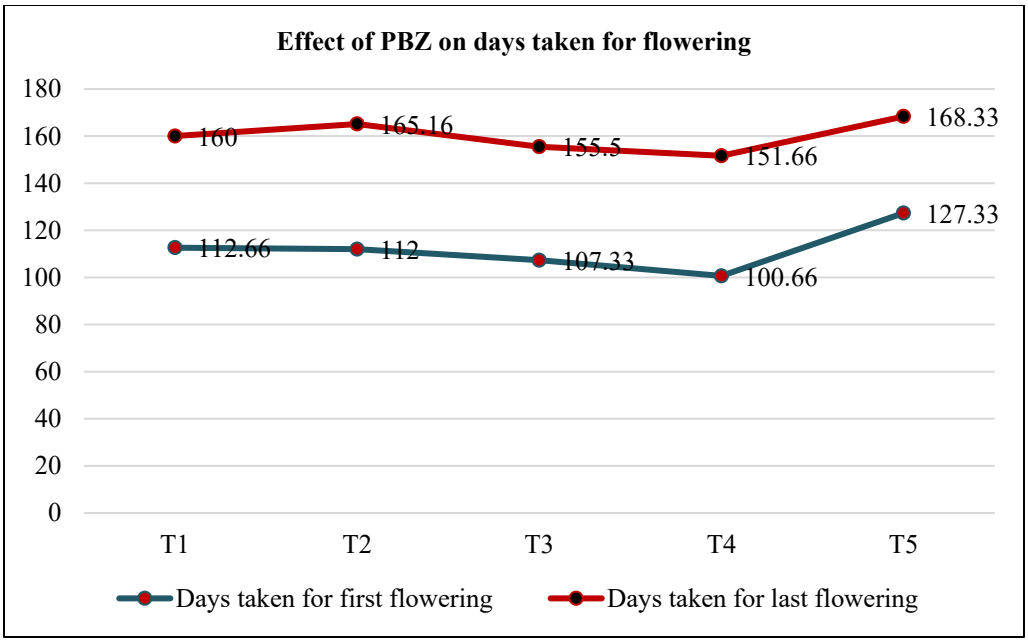


Figure 5.1 Flowering characters influenced by application of PBZ at different concentration.

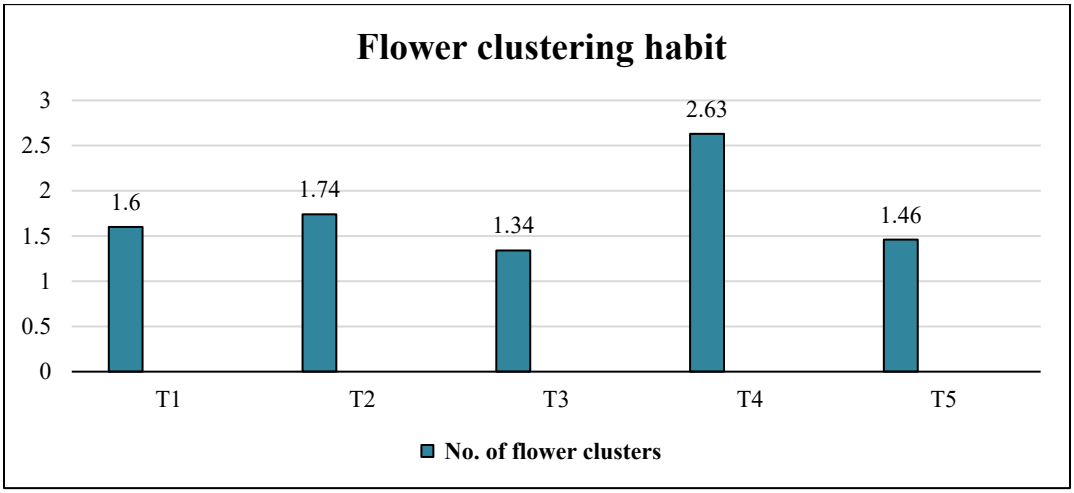


Figure 5.2 Number of flower clusters influenced by application of PBZ at different concentration.

5.3 Fruit and yield parameters

The present study indicated that PBZ treated plants had a significant earliness with respect to days to fruit set and days to first harvest. When the untreated control (T5) took 132.66 days for the first fruit to set, T4 took 113 days, and T1 and T2 (both 118.33 days) were on par with each other.

Days taken for harvest was early in T4 (189.00 days) and it was on par with T1 (191.33 days), T2 (190.66), T3 (191.33). The harvesting was late in control (198.33 days). This was in agreement with observation of Patel *et al.* 2016, who stated that PBZ reduced the vegetative growth by antagonizing the gibberellin action and will be the reason for reduction in duration of mango cv. Alphonso.

Average fruit size and weight of mangosteen fruits were superior in T3 (6.27cm and 104.84 g). The lowest fruit size was found in T5 (control), with 5.17 cm, whereas T1 and T2 were on par with 5.39 cm and 5.47 cm, respectively, and T4 had 50.70 cm. Average fruit weight was maximum for T3 (104.84 g) and other treatments T1 (84.60 g), T2 (88.12 g), T4 (89.11), T5 (80.69 g) were on with each other. . Effect of PBZ of different concentratioon yield, fruit size and average fruit weight is shown in figure 5.3.

Number of translucent arils per fruit was low for T2 and T5 compared to other treatments T1 (0.27), T3 ((0.16), T4 (0.11). Maximum number of seeds per fruit was observed in T2 (2.03) and was on par with T3 (1.78). Minimum number of arils was observed in control (13.71) and was on par with T1 (1.58) and T4 (1.41).

Maximum edible portion in the fruit was observed in T2 and T3 35.17% and 31.85% and minimum in T1 and T5 (25.26% and 28.32%) and these treatments were at the par.

According to investigations conducted by Kumar *et al.,* (2019) on regular bearing of mango with PBZ as soil drenching maximum pulp weight (140.0g) that is edible portion was obtained in treatment applied with PBZ 15 mL/ tree. In all of the treatments compared to the control, the mango cv. Dashehari pulp weight increased.

In accordance with research done by Sarker *et al.,* (2016) a higher rate of photosynthesis and a higher concentration of chlorophyll could be the cause of the enhanced fruit weight in the treatments. By speeding up photosynthesis for a given amount of stomatal conductance or transpiration, paclobutrazol improved leaf water usage efficiency. Several studies using various mango types have found that paclobutrazol improve fruit weight and yield per tree.

Shelf life of fruits was statistically significant. T3 (21.05 days) and T4 (21.82 days) had s highest shelf life of fruits from T5 control, 13.71 days which was the lowest and it was at par with T1 and T2 (16.77 days and 16.72 days).

Maximum no. of fruits were produced by T4 (203.70) which was on par with T2 (203.50) and the lowest number of fruits was observed in T5 (143.66). Total yield was significantly superior in T4 (19.27kg) which was at par with T2 (16.81 kg) and T3 (16.79). This was in accordance with Rane *et al.,* (2005) who reported the application of paclobutrazol in mango trees resulted in higher fruit yield. Effect of PBZ of different concentration on yield is shown in figure 5.4.

Similar results were also indicated by Omran and Semiah, (2006) pointed out that foliar applications of potassium nitrate or bicomine enhanced both flowering and fruiting of mangosteen. Bicomine-treated with foliar application of PBZ had fruit that was noticeably smaller than that from the other treatments. This decrease in fruit weight could be the result of more fruits being produced per tree. Regardless of the treatments, other fruit quality characteristics were unaffected. The overall assessment of fruit set, no. of arils, edible portion and shelf life indicates that T4 was most superior treatment. This indicate the effectiveness of paclobutrazol in increasing the fruit quality.

The minimum percentage of gamboge infected fruit (7.45%) and maximum number of marketable fruits were obtained in T2. Maximum gamboge infection of 41.48% and minimum marketable fruits of 58.50% were reported in control T5. Overall assessment of fruit size and yield indicated that T3 and T4 are the superior treatments similar T5 and T12 were at the par indicating that the lowest dose of PBZ was not effective and it was at par with untreated control. (Rane *et al.,* 2005 and Patel *et al.* 2016),) reported that the application of paclobutrazol in mango trees resulted in higher fruit yield.

In accordance with research done by Then *et al.,* (2019) reported results of trials conducted in mangosteen , which showed that all the three doses of PBZ improved the yield of mangosteen by 132- 214% and 37-106% in first and second year of harvesting, respectively. Increase in yeld of mango by PBZ treatment was reported by (Kumar *et al.,* 2019) also.

According Sarker *et al.,* (2016) a higher rate of photosynthesis and a higher concentration of chlorophyll could be the cause of the enhanced fruit weight in the treatments. By speeding up photosynthesis for a given amount of stomatal conductance or transpiration, paclobutrazol improved leaf water usage efficiency. Several studies using various mango types have found that paclobutrazol , KNO3 and urea, as well as increased fertiliser treatment , all improve fruit weight and yield per tree.

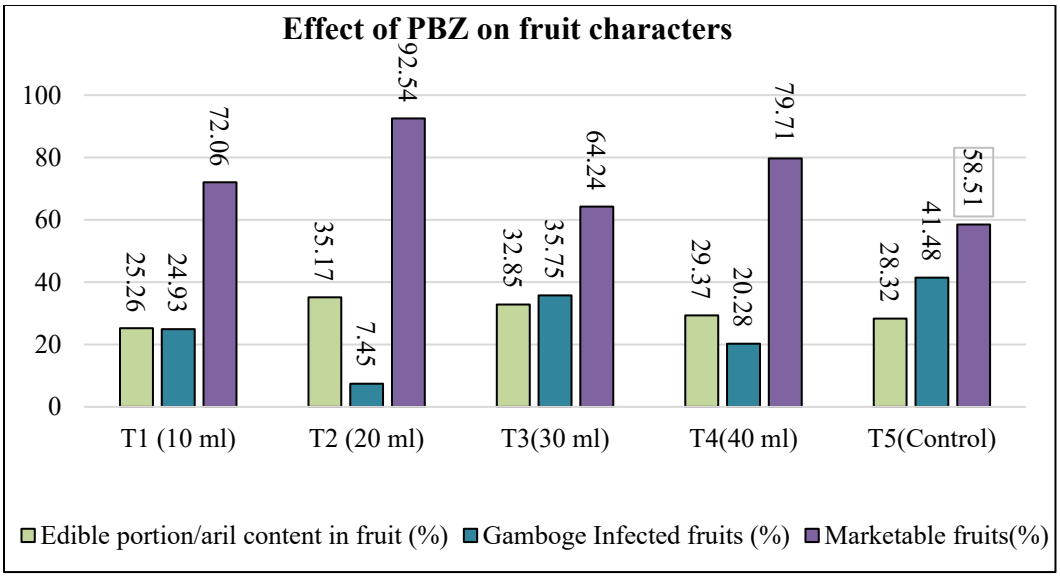


Figure 5.3 Effect of PBZ of different concentration on yield, fruit size and average fruit weight

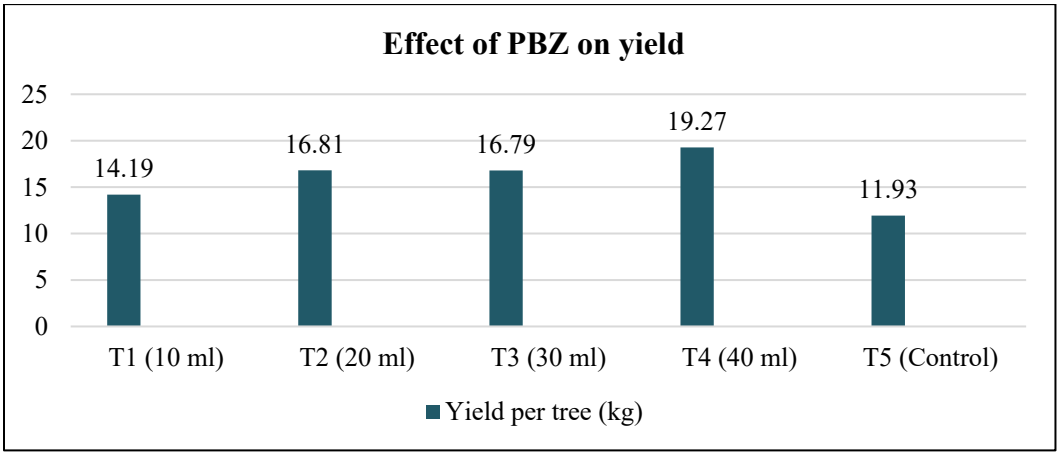


Figure 5.4 Effect of PBZ of different concentration on yield

5.4 Fruit quality parameters

TSS, acidity, reducing sugar, non- reducing sugar, total sugar and vitamin C are the major parameter deciding the quality of fruits.

The maximum TSS was observed in T1 (14.61^0 Brix) which was on par with T2 (14.42^0 Brix), T4 (14.35^0 Brix) and T5 (14.31^0 Brix). T3 recorded the lowest TSS of 13.67^0 Brix.

The results were in accordance with findings of Kumar *et al.,* (2019) the enhancement of TSS was due to rapid hydrolysis of polysaccharides into soluble sugars. Increase in mobilization of carbohydrates from the source to sink under the presence of paclobutrazol influenced TSS.

The lowest acidity was observed in T2 (0.50) followed by T4 (0.57) T1 (0.60), T2 (0.50). Highest acidity was for T3 (0.73). T5 (0.63) was also on par with T1. The reduction in acidity in fruits was mostly due to rapid hydrolysis of polysaccharides into soluble sugars and increase in mobility of carbohydrates from the source to sink under the influence of paclobutrazol by Kumar *et al.,* (2019).

Reducing sugar was non- significant among the treatments. T2 recorded the maximum non- reducing sugar of 10.92% followed by T3 (10.07%). Total sugar maximum in T2 (14.23 %) followed by T1 (13.16%), T3 (13.10%) and T4 (17.55) recorded the highest content of Vitamin C and T2 (16.00), T3 (16.00) was on par with each other. The result indicate the enhanced fruit quality parameters with the application of PBZ. Finding is accordance with report by Kumar *et al.,* (2019)

Vitamin C was lowest for T1 (13.71) and highest for T4 (17.55) and this was on par with T5 (17.32). In accordance with research conducted by Kumar *et al.,* (2019) maximum Vitamin C (16.56 mg/100g) content was found in treatment of PBZ 30 mL/ tree and for paclobutrazol 35 mL/ tree (T5) and minimum (14.43 mg/100g) in control.

The present investigation on “Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)” reveals that paclobutrazol application @ 9.2 g ai /tree (40

mL Cultar 23.00% w/w ai ,T4) was found to be effective to induce early flowering and higher yield. The treatment with Paclobutrazol @ 4.6 g ai /tree ie., 20 mL Cultar 23.00% w/w (T2) was most superior considering the earliness in flowering, yield, and quality attributes of fruits in mangosteen and also considering the cost economics.

Summary

SUMMARY

The present investigation on "Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)" was conducted at the College Orchard of College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur during September 2021 to August 2022 period. The experiment involved testing of five treatments (four doses of paclobutrazol and one untreated control) in three replications in a completely randomised design with two trees / treatment / replication. The treatments were: T1 Paclobutrazol @ 2.3 g ai/tree (10 mL Cultar); T2 Paclobutrazol @ 4.6 g ai /tree (20 mL Cultar); T3 Paclobutrazol @ 6.9 g ai /tree (30 mL Cultar); T4 Paclobutrazol @ 9.2 g ai /tree (40 mL Cultar); and an untreated Control T5 – (Water). Treatments were applied on 29 October 2021. Observations on growth, flowering, fruit set, yield and fruit quality parameters were assessed and the results are summarized below:

- The tree height and number of branches of trees did not vary significantly between treatments. However circumference of trees was maximum in untreated control than that of PBZ treated plants. The treatments had no appreciable impact on the number of branches per tree. Diameter of crown measured in north- south and east - west directions at monthly intervals also did not show significant difference. However there was a slight increase in crown diameter of all trees from October 2021 to June 2022.

- Days taken for bud break after application of PBZ application were significantly influenced by the treatments, and the maximum delayed flowering was observed in untreated control T5 (94 days) where as it was significantly early in treated plants (70.86 days in T4 to 74.7 days in T1) and different doses of PBZ tested were at par with each other for days to bud break.

- Days taken for flushing in shoots after application of PBZ shown significant difference. T1 and T2 where at par with each other (186.5 and 187.16 days

respectively) and they took maximum duration. Days taken for flushing in T3, T4 and untreated control T5 where in statistically at par.

- Days taken for first flowering in trees after PBZ application showed significant difference between treatments when compared to untreated control T5 (127.33 days). PBZ treated plants flowered 15-27 days earlier than the untreated control trees. The earliest flowering was observed in T4 (100.66 days); and the other three PBZ treatments where at par (107.33 days in T3), 112.66 days in T1 and 112 days in T2).

- Days taken to complete the flowering phase from PBZ application also differed significantly. The flowering phase was minimum in T4 (days 151.66) which was significantly lowest when compared to all other treatments. The maximum duration was observed in T5, untreated control (168.33 days), which was closely followed by T2 (165.16).

- The flowers per clusters differed significantly between treatments. T4 had the highest average number of flowers per cluster (2.63), whereas all other treatments were comparable.

- There was significant effect of PBZ viz., earliness for days taken for fruit set (it varied from 113 days in T4 to 118 days T1 andT2; and 117 days in T3) and it was significantly maximum, or delayed in untreated control T5 (132.66 days).

- All PBZ treated trees were statistically at par and early for days to first harvest (189 days in T4 to 191 days in T1 and T3) and the untreated control T5 took significantly maximum days (198.33 days). Days taken for fruit development (from fruit set to maturity) did not vary statistically.

- Fruit size (cm) expressed in terms of diameter also shown statistical difference among treatments significantly maximum diameter of fruits was observed in T3

(6.27cm) and diameter of fruits in T1 (5.39cm) and T2 (5.47cm) were at par; T4 and T5 were also at par with each other (5.07cm and 5.17cm).

- Average fruit weight differed significantly between treatments and was maximum in T3 (104.84 g) and all other treatments where at par (varying from 80.69g in T5 to 89.11g in T4).

- Fruits of all treatments had uniform purple color at maturity and deep purple colour at ripening; this did not vary between the treatments.

- Number of arils in fruits varied from 5.80 control T5 to 6.04 (T3) and it did not vary significantly between treatment.

- The number of translucent arils varied significantly. Fruits of T2 and T5 had no translucent arils were as T1 had 0.27 translucent aril per fruit.

- No. of seeds per fruit also differed significantly T2 and T3 had significantly higher number of seeds (2.03 and 1.78 respectively were as the lowest was T5 (1.35) and it was on par with T4 (1.41) and T1 (1.58).

- Percentage of edible portion (aril content) of fruits varied significantly between treatments ; T2 and T3 had maximum percentage of arils (35.17g and 32.85g) and they were significantly superior and on par with each other. The minimum aril content was observed in T1 (25.26%).

- Effect of treatments on shelf life of fruits was statistically significant. T3 and T4 had significantly highest shelf life of 21.05 and 21.82 days respectively. Shelf life of fruits from T5 control (13.71 days) was the lowest and it was at par with lower dozes of PBZ T1 and T2 (16.77 and 16.72 days).

- Total number of fruits per tree differed significantly and it was maximum in T2 (203.50) and T4 (203.70 fruits) in treated control T5 produced the minimum number of fruits (143.66 fruits)

- Total yield of fruits differed significantly between treatments and maximum yield was obtained from T4 (19.27 kg) and the lowest from T5 (11.93). Yield of T4, T3, T2 (19.27, 16.79, 16.80) were at par with each other. T1 and T5 were on par (14.19 and 11.93).

- Percentage of gamboge infected fruits also varied significantly between treatments. The lowest gamboge was observed in T2 (7.45%) and significantly maximum in T3 and T5 (35.75%, 41.48%) and they were at par with each other.

- Percentage of marketable fruits in different treatment was statistically significant. The maximum percentage of marketable fruits was obtained from T2 (92.5%) and lowest in control T5 (58.51%).

- TSS of fruit pulp was significantly influenced by the treatments and the lowest TSS was observed in T3 (13.67) and T5 and T1 with high TSS were at par (14.31 for T5 and 14.61 for T1).

- There was significant difference in acidity of fruit pulp. The lowest and significant acidity was seen in T2 (0.5%) and highest significant in T3 (0.73).

- Reducing sugar of fruits pulp was not significantly influenced by the treatments and it ranged from 3.04 % (T3) to 3.54% (T4).

- Non reducing sugar of fruit pulp also differed significantly and it was the lowest in T4 (8.7%) followed by 9.11% in T5 and these two treatments were at par. The highest non- reducing sugar was obtained in T2 (10.07%) and in T1 (9.88%) T1 and they were at par with each other.

- Total sugar content of fruit pulp varied significantly between treatments. The highest total sugar content was obtained in T2 (14.23%) followed by T1 (13.16%) and they were at par with each other. T4 (12.26%) had the lowest total sugar content.

- The treatments had significant influence for vitamin C content of fruit pulp. The maximum vitamin C content was observed in T4 (17.55 mg/100g) followed by T5 (17.32 mg/100g) and they were at par while T3 had 16 mg/100g. T1 showed the lowest (13.71 mg/100g).

- The overall effect of PBZ treatments at different doses indicate that PBZ had a suppressing effect on vegetative characters in mangosteen, whereas it was effective to induce early flowering (by 15-27 days) and earliness in first harvest also; the untreated control trees took more time for flowering and first harvest.

- The maximum yield was obtained from T4 (Paclobutrazol @ 9.2 g ai /tree ie., 40 mL Cultar), T3 (Paclobutrazol @ 6.9 g ai/tree ie., 30 mL Cultar), and T2 Paclobutrazol @ 4.6 g ai /tree (20 mL Cultar) ; and they were tat par with each other. T2 and T3 had maximum content of edible portion (arils); and among the quality parameters, T2 had better quality attributes.

- From the study it is concluded that paclobutrazol application @ 9.2 g ai/tree (40 mL Cultar) (T4) is effective to induce early flowering and high yield; and paclobutrazol @ 4.6 g ai/tree ie., 20 mL Cultar (T2) can be recommended considering the early flowering, yield , and quality attributes of fruits in mangosteen.

FUTURE LINE OF WORK

Interaction of weather parameters and soil moisture with PBZ doses on flowering pattern of mangosteen.

References

References

Aizat, W.M., Ahamed- Hashim, F.H. and Jaffar, S.N.S. 2019. Valorization of mangosteen, "The Queen of Fruits" and new advances in postharvest and in food and engineering applications: A review. *J. Adv. Res.* 20: 61-70.

Allan, P., George, A.P., Nissen, R.J., Rasmussen, T.S. and Bunker, M.J.M. 1993. Effects of paclobutrazol on phenological cycling of low-chill 'Florida Prince' peach in subtropical Australia. *Scientia Horticulturae* 53: 73-84.

Ansori, A.M., Fadholly, A., Hayaza S., Susilo, R.J.K., Inayatillah, B., Winarni, D. and Husen, S.A. 2020. A review on medicinal properties of mangosteen (*Garcinia mangostana* L.). *Res. J. Pharm. Tech.* 13(2): 974-982.

Apiratikorn, S., Sdoodee, S., Lerslerwong, L. and Rongsawat, S. 2012. The impact of climatic variability on phenological change, yield and fruit quality of mangosteen in Phatthalung Province, Southern Thailand. *Kasetsart J. Nat. Sci.* 46: 1-9.

Arzani, K., Bahadori, F. and Piri, S. 2009. Paclobutrazol reduces vegetative growth and enhances flowering and fruiting of mature 'J.H. Hale' and 'Red Skin' peach trees. *Hort. Environ. Biotech*. 50: 84-93.

Bañón, S., González, A., Cano, E.A., Franco, J.A. and Fernández, J.A. 2002. Growth, development and colour response of potted *Dianthus caryophyllus* cv. Mondriaan to paclobutrazol treatment. *Scientia Horticulturae 94*(3-4): 371-377.

Bohra, P. and Waman, A.A. 2019. Mangosteen (*Garcinia mangostana* L.): A potential crop for increasing incomes of island farmers. *J. Andaman Sci. Assoc*. 24(1): 9-13.

Brito, C.L.L., Matsumto, S.N., Santos, J.L., Gonecalves, D.N. and Ribeiro, A.F. 2016. Effect paclobutrazol in the development of ornamental sunflower. *J. Agric. Sci.* 39(1): 153- 160.

Burondkar, M.M. 2005. Influence of plant growth regulators, polyamine and nutrients on post flowering physiological behaviour in relation to yield and quality of Alphonso mango (*Mangifera indica* L.). Ph.D. thesis, University of Agricultural Science, Dharward, 271p.

Burondkar, M.M. and Gunjate, R.T. 1991. Regulation of shoot growth and flowering in Alphonso mango with paclobutrazol. *Acta Hortic*. 291: 79-82.

Burondkar, M.M., Gunjate, R.T., Magdum, M.B. and Govekar, M.A. 2000. Rejuvenation of old and over crowded Alphonso mango with pruning and use of paclobutrazol. *Acta Hortic.* 509(2): 681-686.

Burondkar, M.M., Rajan, S., Upreti, K.K., Reddy, Y.T.N., Singh, V.K., Sabale, S.N., Naik M.M., Ngade, P. M. and Saxena, P. 2013. Advancing Alphonso mango harvest season in lateritic rocky soils of Konkan region through manipulation in time of paclobutrazol application. *J. Appl. Hortic*. 15: 178-182.

Chandraparnik, S., Hiranpradit, H., Punnachit, U. and Salakpetch, S. 1992. Paclobutrazol influence flower induction in durian, *Durio zibethinus* Murr. *Acta Hortic.* 321: 282-290.

Chin, Y.W., Jung, H.A., Chai, H., Keller, W.J. and Kinghorn, A.D. 2008. Xanthones with quinone reductase-inducing activity from the fruits of *Garcinia mangostana* (mangosteen). *Phytochemistry.* 69: 754-758.

Christov, C., Tsvetkov, I. and Kovachev, V. 1995. Use of paclobutrazol to control vegetative growth and improve fruiting efficiency of grapevines (*Vitis vinifera* L.). *Bulgarian J. Plant Pysiol.* 21: 64-71.

Currey, C.J. and Lopez, R.G. 2010. Paclobutrazol pre-plant bulb dips effectively control height of 'Nellie White' easter lily. *Hortic. Technol*. 20: 357-360.

Desta, B. and Amare, G. 2021. Review: Paclobutrazol as a plant growth regulator. *Chem. Biol. Technol. Agric.* 8:1.

Esmaielpur, B., Hokmalipour, S., Jalilvand, P. and Salimi, G. 2011. The investigation paclobutrzol effect on growth and yield of two potato (*Solanum tuberosum*) cultivars under different plant density. *J. Food Agric. Environ*. 9(3): 289-294.

Fernandez, J.A., Balenzategui, L., Banon, S. and Franco, J.A. 2006. Induction of drought tolerance by paclobutrazol and irrigation deficit in *Phillyrea angustifolia* during the nursery period. *Scietia Horticulturae* 107: 277-283.

Fletcher, R., Gilley, A., Sankhla, N. and Davis, T.D. 2000. Triazoles as plant growth regulators and stress protectants. *Hortic. Rev.* 24: 55-137.

Gopinath, P.P., Parsad, R., Joseph, B., and Adarsh, V. S. 2020. GRAPES: General Rshiny Based Analysis Platform Empowered by Statics. https://www.kaugrapes.com/home. version 1.0.0. DOI:10.5281/zenodo.4923220.

Grant, G.A., Fisher, P.R., Barrett, J.E. and Wilson, P.C. 2018. Removal of paclobutrazol from irrigation water using granular-activated carbon. *Irrig. Sci*. 36(3): 159-166.

Gutierrez-Orozco, F. and Failla, M.L. 2013. Biological activities and bioavailability of mangosteen xanthones: A critical review of the current evidence. *Nutrients* 5(8): 3163-3183.

Hamdani, J.S., Nurani, A. and Mubarok, S. 2018. The use of paclobutrazol and shading net on growth and yield of potato medians tuber of G_2 in medium land of Indonesia. *J. Agron*. 17: 62-67.

Hedden, P. and Sponsel, V. 2015. A century of gibberellin research. *J. Plant Growth Reg.* 34(4): 740-760.

Hoffmann, G. 1992. Use of plant growth regulators in arable crops: Survey and outlook. In: Karssen C.M, Van L.C and Vreugdenhil D. (eds), *Proceedings of 14th International Conerence on Plant Growth Substances.* Kluwer Academic Publications, London, UK, pp. 798-808.

Husen S.A, Khaleyla, F., Kalqutny, S.H., Ansori, A.N.M., Susilo, R.J.K., Alymahdy, A.D. and Winarni, D. 2017. Antioxidant and antidiabetic activity of *Garcinia mangostana* L. pericarp extract in streptozotocin-induced diabetic mice. *Biosci. Res*. 14(4): 1238-1245.

Husen, S., Kuswanto, S.A. and Basuki, N. 2012. Induction of flowering and yield of mango hybrids using paclobutrazol. *J. Agric. Food Technol*. 2: 153-158.

International plant genetic resources institute. 2003. Descriptors for mangosteen (*Garcinia mangostana*). *Biodivers. Int.* ISBN: 9789290435877.

Kishore, K., Singh, H.S. and Kurian, R.M. 2015. Paclobutrazol use in perennial fruit crops and its residual effects: A review. *Indian J. Agric. Sci*. 85(7): 863-872.

Krishna, G.V., Bhagwan, A., Kumar, M.R. and Shankar, A.S. 2017. Effect of flower enhancing plant growth regulators and fruit set improving chemicals on vegetative growth, early flower initiation and fruit yield of mango (*Mangifera indica* L.) cv. Banganpalli. *Int. J. Pure App*. *Biosci.* 5(3): 667-677.

Kulkarni, V., Hamilton, D. and McMahon, G. 2006. Flowering and fruiting in mangoes in the top end with paclobutrazol. *Crops For. Hortic.* pp.1-3.

Kumar, K., Gora, J.S. and Singh, C.P. 2019. Bio efficacy of paclobutrazol on growth, flowering, fruiting and yield attributes of mango cv. Dashehari under Pantnagar agro-climatic condition. *J. Agric. Ecol*. **7**: 27-37.

Kurian, R.M. and Iyer, C.P.A. 1992. Stem anatomical characters in relation to tree vigour in mango (*Mangifera indica* L.). *Scientia horticulturae* 50(3): 245-253.

Mabvongwe, O., Manenji, B.T., Gwazane, M. and Chandiposha, M. 2016. The effect of paclobutrazol application time and variety on growth, yield and quality of potato (*Solanum tuberosum* L). *Adv. Agric*. 2016: 1-5.

Maheswari, C., Garg, N.K., Singh, A. and Tyagi, A. 2023. Optimization of paclobutrazol dose for mitigation of water deficit stress in rice (*Oryza sativa* L.). *Biochem. Syst. Ecol.* 107: 1045-1096

Manoj, P.S. 2011. Stimulation of growth and induction of variability in mangosteen (*Garcinia mangostana* L.). Ph.D. (Hort) thesis, Kerala Agricultural University, Thrissur, 318p.

Mansuroglu, S., Karaguzel, O., Ortacesme, V. and Sayan, M.S. 2009. Effect of paclobutrazol on flowering, leaf and flower colour of *Consolida orientalis*. *Pak. J. Bot.* 41(5): 2323-2332.

Martinez-Fuentes, A., Mesejo, C., Munoz-Fambuena, N., Reig, C., Gonzalez-Mas, M.C. and Iglesias, D.J. 2013. Fruit load restricts the flowering promotion effect of paclobutrazol in alternate bearing *Citrus* spp. *Scientia Horticulturae* 151: 122-127.

Medonca, V., Neto, S.E.A., Ramos, J.D., Pio, R. and Souza, P.A. 2002. Production and quality of Tommy Atkins mango fruits after application of paclobutrazol. *J. Agric. sci.* 38: 139-149.

Mog, B., Janani, P., Nayak, M., Adiga, J. and Meena, R. 2019. Manipulation of vegetative growth and improvement of yield potential of cashew (*Anacardium occidentale* L.) by paclobutrazol. *Scientia Horticulturae* 257(2): 108-748.

Nakasone, H.Y. and Paull, R.E. 1998. Mangosteen. In: Nakasone, H.Y. and Paull, R.E. (eds), *Tropical Fruits*. CAB International, New York, pp. 359-369.

Nakorn, S.N., Chalumpuk, C. and Chumpa, C. 1998. Effects of rate of nitrogen and timing of paclobutrazol application on flowering, yield and fruit quality of mangosteen (*Garcinia mangostana* L.). In: *15. RIT Annual Conference;* 12-14, February 1998, Chiang Mai (Thailand), pp. 121-141.

Nazarudin, A.M.R., Fauzi, R.M. and Tsan, F.Y. 2007. Effects of paclobutrazol on the growth and anatomy of stems and leaves of *Syzygium campanulatum*. *J. Trop. For. Sci.* 19(2): 86-91.

Nazarudin, A.M.R., Tsan, F.Y. and Mohd, F.R. 2012. Morphological and physiological response of *Syzygium myrtifolium* (Roxb) Walp. to paclobutrazol. *Sains Malays*iana 41(10): 1187-1192.

Omran, H. 2001. Induction of flowering for off-season production in mango cultivation. *Trans. Malaysian Soc. Plant Physiol*. 10: 92-94.

Omran, H. and Semiah, R. 2006. Effect of paclobutrazol application combined with potassium nitrate and Bicomine spray on flowering and fruiting of mangosteen (*Garcinia mangostana* L.). 727: 151-154.

Orabi, S.A., Salman, S.R. and Shalaby, M.A.F. 2010. Increasing resistance to oxidative damage in cucumber (*Cucumis sativus* L.) plants by exogenous application of salicylic acid and paclobutrazol. *World J. Agric. Sci.* 6(3): 252-259.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural research. ICAR, New Delhi, 308-318pp.

Patel, G.D., Patel, B.N., Desai, K.D., Patel, N.K. and Patel, B.B. 2016. Influence of paclobutrazol for earliness in mango cv. Alphonso. *Int. J. Sci. Environ.* 5: 2713-2718

Pedraza-Chaverri, J., Cárdenas-Rodríguez, N., Orozco-Ibarra, M. and Pérez-Rojas, J.M. 2008. Medicinal properties of mangosteen (*Garcinia mangostana*) *Food Chem. Toxicol.* 46: 3227-3239.

Pinto, A.R., Rodrigues, T.D., Leite, I. and Barbosa, J. 2005. Growth retardants on development and ornamental quality of potted 'lilliput' *Zinnia elegans* Jacq. *Scientia Agricola*. 62: 337-345.

Protacio, C.M., Bugante, R.D., Quinto, J., Molinyawe, G. and Paelmo, G. 2000. Regulation of flowering in Carabao mango tree by paclobutrazol. *Philipp. J. Crop Sci.* 25: 27-33.

Rademacher, W. 2016. Chemical regulators of gibberellin status and their application in plant production. *Annu. Plant Rev*. 49: 359-404.

Rahman, H., Khan, M. and Khokhar, M. 1989. Effect of paclobutrazol on growth and yield of tomato. *Pak J Agric Res*. 10: 49-51.

Rahman, M.H., Rahman, B.C., Ahmed, H.M. and Nishi, N.J. 2023. Applying paclobutrazol and flower bud pruning modify the fruiting time and fruit quality of 'Amrapali' mango (*Mangifera indica* L.). *Hortic. J.* doi: 10.2503/hortj.

Rahman, M.N., Shaharuddin, H.A., Wahab, N.A., Wahab, P.E.M., Abdullah, M.O. and Parveez G.K.A. 2016. Impact of paclobutrazol on the growth and development of nursery grown clonal oil palm (*Elaeis guineensis* Jacq.). *J Oil Palm Res.* 28(4): 404-414.

Rane, A.A., Bagade, S.R. and Patil, B.P. 2005. Use of paclobutrazol for minimizing the risk in fruit yield of Alphonso mango in Sindhudurg district. *Agric. Econ. Res. Rev.* 18: 166.

Sadasivam, S. and Manickam, A. 2008. *Biochemical Methods* (3rd Ed.). New Age international (P) Ltd., Publishers, New Delhi, 270p.

Salakpetch, S. 2000. Mangosteen production in Thailand. In: *Proceedings of the Tenth Annual International Tropical Fruit Conference*; 20-22 October, 2000, Hawaii. Tropical Fruit Growers, Hilo, Hawaii, p.39.

Sarker, B.C., Rahim, M.A. and Archbold, D.D. 2016. Combined effects of fertilizer, irrigation, and paclobutrazol on yield and fruit quality of mango. *Horticulturae*, *2*(4): 14.

Sdoodee, S. and Chiarawipa, R. 2005. Regulation irrigation during pre-harvest to avoid the incidence of translucent flesh disorder and gamboge disorder of mangosteen fruits. *Songklanakarin J. Sci. Technol.* 27: 957-965.

Sebastian, K., Arya, M.S., Reshma, U.R., Anaswara, S.J. and Thampi, S. S. 2019. Impact of plant growth regulators on fruit production. *Int. J. Curr. Microbiol. App. Sci*. 8(2): 800-814.

Setiawan, E. 2013. Flowering phenology of mangosteen (*Garcinia mangostana* L.) in Indonesia. *Rekayasa* 6(1): 5.

Shibu, B.S. 2020. Blossom delayed-change in climate impacts flowering of fruit-bearing trees. *The New Indian Express,* 25 Feb. 2020, p.5.

Shinde, A.K., Waghmare, G.M., Wagh, R.G. and Burondkar, M.M. 2000. Effect of dose and time of paclobutrazol application on flowering and yield of mango. *Indian J. Plant Physiol.* 5: 82-84.

Singh, D.K. 2000. Effect of paclobutrazol on yield and quality of different cultivars of ber (*Zizyphus mauritiana*). *Indian J. Agri. Sci.* 70: 20-22.

Singh, Z. 2000. Effect of paclobutrazol on (2RS, 3RS) tree vigour, flowering, fruit set and yield in mango. *Acta Hortic*. 525: 459-462.

Suman, M., Sangma, P.D., Meghawal, D.R. and Sahu, O.P. 2017. Effect of plant growth regulators on fruit crops. *J. Pharmacognosy Phytochemistry.* 6(2): 331-337.

Taiz, L. and Zeiger, E. 2006. *Plant Physiology* (4th Ed.). Sunderland: Sinauer Associates Inc., Publishers, 690p.

Te-chato, S. 2007. Floral and fruit morphology of some species in *Garcinia* spp. *Songklanakarin J. Sci. Technol.*, 29(2) : 245-252.

Tekalign, T. and Hammes, P.S. 2005. Growth and biomass production in potato grown in the hot tropics as influenced by paclobutrazol. *Plant Growth Regul.* 45: 37-46.

Terri, W.S. and Millie, S.W. 2000. Growth retardants affect growth and flowering of Scaevola. *HortSci*ence 35(1): 36-38.

Then, K.H., Norshafiqah, K. and Faiz, O.M. 2019. The effect of paclobutrazol in improving the yield performance of mangosteen (*Garcinia mangostana). Int. J. Agric. Innov. Res.* 8(3): 245-251.

Tongumpai, P., Jutamanee, K. and Subhadrabandhu, S. 1991. Efect of paclobutrazol on fowering of mango cv. 'Khiew Sawoey'. *Acta Hortic.* 291: 67-79.

Upreti, K.K., Reddy, Y.T.N., Shivuprasad, S.R., Bindu, G.V., Jayaram, H.L. and Rajan, S. Hormonal changes in response to paclobutrazol induced early flowering in mango cv. Totapuri. *Scientia Horticulturae*. 150: 414-418.

Vijayalakshmi, D. and Srinivasan, P.S. 1999. Morpho-physiological changes as influenced by chemicals and growth regulators in alternate bearing mango cv. "Alphonso".

Madras Agric. J. 86: 485-487.

Voon, C.H., Pitakpaivan, C. and Tan, S.J. 1991. Mango cropping with cultar. *Acta Hortic.* 291: 219-228.

Webster, A.D. and Quinlan, J.D. 1984. Chemical control of tree growth of plum (*Prunus domestica* L.). *J. Hortic. Sci.* 59: 367-375.

Wongsrisakulkaew, Y., Boonprakob, U., Sethpakdee, R. and Juntawong, N. 2017. Effect of paclobutrazol concentrations and time of foliar application on flowering of 'Namdokmai-Sitong' mango. *Int. J. Geomate* 12(30): 41-45.

Yaacob, O. and Subhadrabandhu, S.1995. Mangosteen (*Garcinia mangostana* L.). In: Yaacob, O. and Subhadrabandhu, S. (eds). *Fruit with a long juvenile period: The production of economic fruits in South-East Asia.* Oxford University Press, Kuala Lumpur, pp. 109-114.

Yaacob, O. and Tindall, H.D. 1995. Mangosteen Cultivation. FAO, Rome, Italy. 100 pp.

Yeshitela, T., Robbertse, P.J. and Stassen, P.J.C. 2004. Effects of various inductive periods and chemicals on flowering and vegetative growth of 'Tommy Atkins' and 'Keitt' mango (*Mangifera indica*) cultivars. *NZ J. Crop Hortic. Sci.* 32: 209-215.

Appendices

Appendix 1

Meteorological data during the period of observation (Oct 2021 to Sep 2022)

Months	Temperature (^{0}C)		Mean RH (%)	Rainfall (days)	Mean sunshine hours (hrs/day)
	Max	Min			
Aug 2021	30.2	23.4	86.00	22.00	02.50
Sep 2021	30.7	23.9	83.00	14.00	04.00
Oct 2021	31.1	23.6	86.00	17.00	03.82
Nov 2021	31.0	23.4	81.00	13.00	03.64
Dec 2021	32.5	23.3	67.00	01.00	08.20
Jan 2022	33.3	22.6	64.00	00.00	09.10
Feb 2022	34.8	23.3	58.00	00.00	08.30
Mar 2022	36.1	24.7	74.00	00.00	06.90
Apr 2022	34.2	25.1	77.00	07.00	05.90
May 2022	31.2	24.0	85.00	23.00	03.00
Jun 2022	31.3	23.6	84.00	19.00	04.50
Jul 2022	29.3	23.5	88.00	21.00	01.80
Aug 2022	29.9	23.6	84.00	15.00	04.30
Sep 2022	31.1	23.7	81.00	12.00	05.40

Appendix 2

B:C ratio

A. CULTIVATION COST for 30 trees

(To the whole experimental plot; common for all plants or treatments)

Particulars	**Rate (Rs)**	**Quantity**	**Cost(Rs)**
Labour charge			
Land preparation	650	5	3250
Weeding	650	2	1300
Spraying	650	2	1300
Harvesting	650	24	15600
Beuveria bassiana spraying	85	5	425
Electricity and water	-	-	1000
Miscellaneous	-	-	500
TOTAL	-	-	23375

Total cost of cultivation for one tree = Rs. 23375 / 30= Rs. 779.16

B. Computation of B: C Ratio (per tree)

SI. No.	Treatments	Cost of Cultar (6 Rs/ ML) P	Common cost of cultivation/ tree Rs. Q	Total variable cost Rs. (P +Q)	Marketable fruits/ tree (kg)	Total Returns/ tree Rs.150 per kg fruits (Rs) R	B:C ratio R / (P+Q)
1	T1 (10 ml cultar)	60	779.16	839.16	10.66	1599	1.90
2	T2 (20 ml Cultar)	120	779.16	899.16	15.60	2349	**2.61**
3	T3(30 ml Cultar)	180	779.16	959.16	10.79	1618.5	1.68
4	T4(40 ml Cultar)	240	779.16	1019.16	15.37	2305.5	2.26
5	T5 (control-water alone)	0	779.16	779.16	6.99	1048.5	**1.34**

Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)

By

BHAGYA D. KARTHA

(2020-12-035)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(FRUIT SCIENCE)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

2023

"Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)"

Abstract

The present investigation on "Induction of flowering and fruiting in mangosteen (*Garcinia mangostana* L.)" was conducted at the College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur during September 2021 to August 2022 period. The experiment involved five treatments, (four doses of PBZ and one control) replicated thrice in a completely randomized design with two trees per treatment per replication. The treatments were, T1 Paclobutrazol (PBZ) @ 2.3 g ai/tree (10ml Cultar); T2 PBZ @ 4.6 g ai /tree (20ml Cultar); T3 PBZ @ 6.9 g ai /tree (30 ml Cultar); T4 PBZ @ 9.2 g ai /tree (40 ml Cultar); and T5 (water alone). Treatments were applied on 29th October 2021. Observations on vegetative characters, flowering characters, fruiting characters and fruit quality parameters were recorded. During the study period, the treatments were not found to influence the height of the tree. However trunk circumference of trees were found to be maximum in the control trees when compared to the trees which were treated with PBZ. It was observed that there was a monthly increase in the trunk circumference in the control plants (0.33 cm to 1.83 cm) whereas trees in T4 showed static growth in the month of April (1.16), May (1.16 cm) and June (1.16 cm). From the findings of the study it was also seen that, PBZ has no influence on the number of branches and crown diameter (m). It was observed that the days taken for bud break was delayed in the control T5 (94 days) where as it was early in T4 (70.86 days) which was on par with T1 (74.70), T2 (74.50), T3 (72.73 days). Minimum days taken for flushing was observed in T4 (167.33 days) which was on par with control (174.33 days) which indicated that PBZ has no effect on days taken for flushing. It was observed that the highest rate of shoot growth was observed in T5 (2.01 cm) and lowest growth in T4 (1.11cm), clearly indicating the effect of PBZ on suppressing the growth of shoot. Days taken for flowering after PBZ application showed significant difference among the treatments. The trees treated with PBZ flowered 15-27 days earlier than the control trees. Though earliest flowering was observed in T4 (100.66 days), T2 (112.00) and T3 (107.33) were found to be on par

with T4. The days taken for last flowering was minimum in T4 (151.66 days) when compared to all other treatments and the maximum duration was observed in control (168.33 days), indicating that PBZ has no influence on duration of flowering. Maximum number of flowers per cluster (2.63) was observed in T4. Days taken for fruit set was maximum in control T5 (132.66 days) whereas all other treatments T1 (118.16), T2 (118.33), T3 (117) T4 (113 days) took only maximum number of days and was on par with each other. Maximum days for harvesting 198.33 days was observed in T5 (control) whereas the minimum number of days was noted in by T4 (189.00 days) which was on par with other treatments. Days taken for fruit development (from fruit set to maturity) did not vary statistically. The size of fruits (6.27 cm) and average fruit weight (104.84 g) was found to be maximum in T3. Fruit color (at maturity and ripening) and number of arils/fruit did not vary significantly between treatments. Fruits of T2 and T5 did not have any translucent arils whereas T1 (0.27) had maximum number of translucent aril per fruit. The treatment T2 (2.03) had higher number of seeds when compared to control (1.35). Again the treatment T2 (35.17 g) recorded the maximum percentage of edible portion and were on par with T3. Longest shelf life 21.82 days was observed in T4 whereas the lowest (13.71 days) was observed in control. Paclobutrazol had effect on total number of fruits and it was maximum for T4 (203.70 fruits) and was on par with T2 (203.50 fruits). Highest yield was obtained from T4 (19.27 kg) and lowest in control (11.93). The lowest gamboge infection was observed in T2 (7.45 %) where as it was maximum in control. Maximum percentage of marketable fruits was obtained from T2 (92.5 %) and lowest from control T5 (58.51 %).

Coming to the quality parameters of fruit, TSS was found to be maximum in 14.61 in T1. Acidity was lowest in T2 (0.5 %) and highest in T3 (0.73). Through PBZ had no effect on reducing sugar, non-reducing sugar and total sugar content of fruit pulp were found to differ significantly and the highest value was reported in T2 (non reducing 10.92 % and total sugar 14.23 %). The maximum vitamin C content was observed in T4 (17.55 mg/100g) which was on par with T5 (17.32 mg/100g). The overall effect of PBZ in mangosteen at different levels indicated that PBZ had a suppressing effect on vegetative characters, effective in inducing early flowering and earliness in first harvest of fruits than in control trees. From the study it can be concluded that cultar application @ 40 ml per tree (PBZ @ 9.2 g ai /tree) (T4) is

effective to induce early flowering and higher yield; and 20 ml of cultar T2 (PBZ @ 4.6 g ai /tree) is superior considering the effective to induce flowering, yield, quality attributes and cost statistics of fruits in mangosteen.