STUDIES ON EFFICACY OF SHOOT BENDING AND PLANT GROWTH REGULATORS IN DIFFERENT MONTHS IN GUAVA CROP

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

HORTICULTURE (FRUIT SCIENCE)

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DECLARATION

I, hereby declare that the presented work in the thesis entitled **''Studies on Efficacy of Shoot Bending and Plant Growth Regulators in Different Months in Guava Crop''** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Deepika Saxena** working as **Associate Professor** in the School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigators. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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ABSTRACT

The present study, entitled "Studies on Efficacy of Shoot Bending and Plant Growth Regulators in Different Months in Guava Crop" was conducted at the Guava Orchard of Lovely Professional University, Phagwara, Punjab, over two consecutive years (2022–23 and 2023–24). The research aimed to standardize the optimal combination of shoot bending and plant growth regulators (PGRs) to enhance vegetative growth, reproductive performance, biochemical composition, and yield attributes in guava. The experiment employed a Factorial randomized block design (FRBD) with three replications, incorporating three PGRs i.e., Naphthalene Acetic Acid (NAA) at 100 and 200 ppm, Ethrel at 200 and 400 ppm, and Gibberellic Acid (GA_3) at 100 and 150 ppm—alongside a control. Additionally, shoot bending was performed in three different months (August, September, and October), resulting in a total of 21 treatment combinations.

Among plant growth regulators and branch bending maximum increase in mean values of vegetative parameters viz., Canopy spread (N-S) (0.59m),(0.54m) and, Stem Girth (24.61cm),(27.0cm), TCSA (48.91cm^2),(58.12cm^2), leaf length (8.6cm), (8.5cm) and new shoot per branch (29.30), (25.7) was recorded by NAA at 200ppm (C_2) and August branch bending (M_3) respectively. The combination of August shoot bending with NAA at 200 ppm (T_2: $M_1 \times C_2$) resulted in the highest canopy spread (0.63 m), stem girth (28.3 cm), TCSA (63.56 cm^2), and leaf length (9.7 cm).

For reproductive traits, NAA at 200 ppm (C_2) among the PGRs and October shoot bending (M_3) among shoot bending months, significantly enhanced fruit length (6.5 cm, 6.25 cm), fruit weight (136.2 g, 124 g), total number of fruits per plant (136.0, 117.5), and fruit retention (84.9%, 74.86%). The combination (T_{16}: $M_3 \times C_2$) (October shoot bending + NAA at 200 ppm) yielded the best performance in fruit length (6.81 cm), fruit weight (141.6 g), total number of fruits per plant (153.7), and fruit retention (86.8%).

Regarding biochemical parameters, GA_3 at 150 ppm (C_6) and October shoot bending (M_3) led to the highest total soluble solids (TSS: 11.7°B, 11.79°B), total sugar (9.97%, 9.02%), titratable acidity (0.21%, 0.24%), ascorbic acid (125 mg/100 g, 113.5 mg/100 g), and pectin content (1.41%, 1.18%). The combination (T_{20}: $M_3 \times C_6$) (October shoot bending + GA_3 at 150 ppm) further enhanced these traits, recording TSS (12.49°B), total sugar (10.42%), titratable acidity (0.17%), ascorbic acid (135.5 mg/100 g), and pectin content (1.61%).

For guava leaf composition, NAA at 200 ppm (C_2) and October shoot bending (M_3) positively influenced total chlorophyll (1.58 mg/100 g, 1.63 mg/100 g), total carbohydrates (10.42%, 10.37%), C:N ratio (3.6, 3.66), and ash content (5.8%, 6.0%). The combination (T_{16}: $M_3 \times C_2$) exhibited the highest total chlorophyll (1.75 mg/100 g), total carbohydrates (11.92%), C:N ratio (4.11), and ash content (6.6%). Additionally, essential leaf nutrient parameters, including nitrogen, phosphorus, potassium, zinc, and boron, were most enhanced by NAA at 200 ppm (C_2) and October shoot bending (M_3) and in combination by (T_{16}).

In terms of yield and yield efficiency, NAA at 200 ppm (C_2) recorded the highest mean yield (20.29 kg/tree) and yield efficiency (0.45 kg/cm^2) among the PGRs. October shoot bending (M_3) resulted in the highest yield (17.02 kg/tree) and yield efficiency (0.52 kg/cm^2). The combination (T_{16}: $M_3 \times C_2$) achieved the maximum yield (22.05 kg/tree) and yield efficiency (0.63 kg/cm^2).
From the present investigation, August shoot bending with NAA at 200 ppm (T_2: $M_1 \times C_2$) was most effective for vegetative parameters, while October shoot bending with GA_3 at 150 ppm (T_{20}: $M_3 \times C_6$) resulted in the best biochemical composition. Reproductive and yield related parameters were maximized in October shoot bending with NAA at 200 ppm (T_{16}: $M_3 \times C_2$) across both experimental years. Therefore, for profitable guava cultivation, October shoot bending combined with a foliar spray of NAA at 200 ppm is recommended to optimize growth, yield, and fruit crop quality.

Keywords: Guava fruit crop, Plant growth regulators, Shoot bending, Crop regulation.

Signature of Research Guide **Signature of the Student**

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Abbreviations	Descriptions
%	Percentage
@	at the rate
ºC	Degree Celsius
C.D.	Critical difference
Cm	Centimetre
Cm^2	Centimetre square
et al.	*et alii* (Co-workers)
FRBD	Factorial Randomized Block Design
Fig.	Figure
g or gm	Gram
Kg	Kilogram
i.e.,	That is
L.	Linneous
M	Meter
Mg	Milligram
mg/g	Milligram per gram
No.	Number
NS	Non-significant
Ppm	Parts per million
SE(d)	Standard error deviation
SE(m)	Standard error mean
TSS	Total soluble sugar
Zn	Zinc
B	Boron
RH	Relative Humidity
PGR	Plant growth regulators
TCSA	Truck cross-section area
Kg/cm^2	Kilogram per centimetre square

CHAPTER I

INTRODUCTION

Guava (*Psidium guajava* L.) is a tropical fruit originating from Central and South America however it is now widely grown in West Indies, Mexico, Florida, Louisiana, Arizona and in numerous regions of Africa, Indian subcontinent, and on oceanic islands (Toma and Luchian, 2019). Genus *Psidium* includes 96 accepted species. Most important is *Psidium guajava*, known as "the apple of the tropics". Apart from *Psidium guajava*, other important species include *Psidium cattleianum* (strawberry guava), *Psidium guineense* (Brazilian guava), and *Psidium friedrichsthalianum* (Costa Rican guava), which are also cultivated for their unique fruit characteristics.

Botanically, it belongs to the Myrtaceae family and is highly valued for its economic, nutritional, and medicinal benefits. It is a small evergreen tree or shrub, typically reaching a height of 3 to 10 meters. The tree features a shallow root system, making it well-suited to drought conditions. The bark is smooth and ranges from pale brown to grey, often peeling away in thin layers. The leaves are arranged oppositely along the branches, simple and oblong, measuring between 5 to 15 cm in length, with a prominent midrib and distinct veins, which give them a recognizable appearance. When crushed, the leaves release a characteristic aroma. Guava flowers are white, either solitary or clustered in small groups of two to three in the leaf axils on both current season growth. They have numerous stamens and emit a fragrant aroma (Singh *et al*.,2023). The flowers are primarily pollinated by insects, with honeybees playing a significant role in the process. The flowering period typically lasts 25 to 45 days, and successful pollination leads to the development of round or oval fruits (Singh and Mishra, 2022; Kumar *et al.,* 2023; Sharma *et al.,* 2023; Patel *et al*., 2023; Roy, 2020). Guava fruit ranges from 5–10 cm in diameter and 50–200 g in weight, and can be round, ovoid, or pear-shaped. It has a thin, light yellow to pink exocarp, a juicy, granular mesocarp with colors ranging from white to dark pink, and a central endocarp filled with 112–535 stony seeds. Its shelf life is short, about 3–5 days at room temperature, due to high respiration and metabolism. (Azzolini *et al*., 2005).

Guava is cultivated across more than 60 countries globally, with India leading as the foremost producer. Following India, Mexico and Thailand are the next largest producers of this fruit (NHB, 2023). In 2023, India stands as the premier guava producer worldwide, contributing 45-50% of global output. The country cultivated over 24 million metric tons of guava across approximately 300,000 hectares. The principal states in guava production are Uttar Pradesh, Maharashtra, Madhya Pradesh, Bihar, and West Bengal. (National Horticulture Board, 2023; Food and Agriculture Organization, 2023). Despite not being a major guava producer, regions such as Hoshiarpur and Patiala in Punjab have experienced a notable increase in guava cultivation due to their superior soil quality and favourable climatic conditions. In Punjab, guava is grown over an area of 7.8 hectares, yielding a production of 171.0 metric tons (NHB,2023).

Guava is highly adaptable to adverse climates and diverse soil types, making it vital for both commercial and subsistence farming. It tolerates saline soils and thrives in marginal areas, growing well in sandy to clay soils with a pH range of 4.5 to 9.5, while achieving optimal yields in sandy loam soils with a pH between 5 and 7. This evergreen shrub, capable of reaching up to 25 feet in height, flourishes in tropical to subtropical climates. It performs well in regions receiving 1,000 to 2,000 mm of annual rainfall and can withstand temperatures ranging from 15°C to 35°C, showcasing its resilience. (Kumar and Singh, 2022; Sharma and Patel, 2023).

Guava is widely regarded as a "superfruit" due to its exceptional nutritional benefits. Renowned for its extraordinarily high vitamin C content, this fruit stands out as a potent contributor to overall health, particularly in boosting the immune system and enhancing skin vitality (Takeda, 2023). Beyond its vitamin C richness, guava is also an excellent source of dietary fiber, which plays a crucial role in maintaining optimal digestive health by aiding in regular bowel movements and preventing constipation. Furthermore, guava is packed with essential nutrients, including vitamin A, which supports eye health and immune function, and folate, which is vital for cell growth and development. The fruit is also a rich source of key minerals such as potassium, which helps regulate blood pressure, and magnesium, which is important for muscle and nerve function. This remarkable combination of vitamins, minerals, and fiber makes guava a powerful ally in promoting overall well-being (Patel *et al.,* 2023; Rao *et al*., 2022). The fruit's nutritional profile is distinguished by its potent antioxidant properties, which are linked to a rich spectrum of bioactive compounds, such as flavonoids and polyphenols. These compounds not only combat oxidative stress but also play a pivotal role in preventing chronic diseases and promoting overall health. (Singh *et al*., 2023; Mishra and

Kumar, 2022). Current research has underscored guava's low glycemic index and abundant dietary fiber, both of which contribute to reduce the capacity to develop diabetes. These qualities make guava particularly beneficial for managing blood sugar levels and enhancing metabolic health (Cerio *et al.,* 2017). Furthermore, guava's capacity to enhance immune function, promote skin health, and support overall well-being further cements its status as an exceptionally nutritious fruit. (Verma *et al.,* 2023; Chandra and Sharma, 2022). Guava value-added goods are in high demand across the world. The production of jams and jellies extensively utilizes pectin from guava because of its outstanding gelling properties, which ensure the perfect texture and quality of these products (Smith, 2021). Moreover, the high levels of pectin in guava may play a crucial role in lowering cholesterol levels, thereby diminishing the probability of cardiovascular disease. (Singh *et al.*,2007). Throat and chest infections, coughs, and mouth ulcers are treated with guava leaf extracts, which are also used to treat leukorrhea (Irshad *et al*., 2020). In Ayurveda, guava is often referred to as a tridosha nashaka, or an immunity-boosting drink, and is prescribed for conditions of atyagni, or excessive digestion. The leaves, bark, fruits, and roots of the guava plant are employed to alleviate coughs, fevers, diarrhoea, digestive issues, halitosis, dental ailments, and various other health concerns. Additionally, the leaves are utilized for extracting dyes and tannins (Hiwale *et al.*,2015). The leaf extracts exhibit significant biological activities, including antioxidant, anticancer, antidiabetic, antidiarrheal, antibacterial, lipid-lowering, and hepatoprotective effects (Kumar *et al*.,2021).

Guava naturally flowers in three distinct periods: February-March (Ambe Bahar), June-July (Mrig Bahar), and October-November (Hasth Bahar), with harvests aligning with the rainy, winter, and spring seasons respectively (Liu *et al*., 2021). This cycle enables the production and availability of fruit throughout the year. Guava quality is profoundly affected by temperature and humidity, with fruit being notably superior during winter conditions as opposed to the rainy season. But in subtropical regions like Punjab, Haryana, Uttar Pradesh, northern West Bengal, and Bihar, the cooler winter temperatures present challenges for commercial production, lengthening the cultivation period to approximately 200 days from flowering to harvest. This prolonged duration and the insufficient warmth during winter make efficient guava farming more difficult in these areas. (Singh *et al.,* 2022). The cold temperatures of December and January impede the natural ripening process of guavas on the tree, resulting in fruit that remains unusually firm. This stunted maturation, driven by the cold conditions, adversely affects the texture and overall quality of the guavas, rendering them less appealing for consumption and diminishing their market value (Mishra *et al*., 2020). Therefore, effective crop regulation is pivotal, as it allows trees to recuperate and enhance their productivity during growth flushes, leading to improved overall yield and quality. This practice enables trees to use their resources more effectively, resulting in higher fruit yields. Furthermore, for higher plants, maximizing photosynthesis is essential for energy production. Ensuring optimal leaf positioning is crucial for capturing sufficient sunlight, which enhances the plant's ability to photosynthesize and flourish (Yofune *et al.,* 2023). Numerous techniques are applied in crop regulation to boost both production and fruit quality.

Crop regulation encompasses various methods aimed at optimizing fruit production and quality by controlling plant growth and development. Essential techniques include pruning, which enhances plant vitality and productivity by improving air flow and light penetration (Lakso *et al*., 2015); thinning, which boosts fruit size and uniformity by alleviating resource competition (Zhang *et al.,* 2019); and regulated irrigation, which mitigates stress and ensures uniform ripening (Cheng *et al*., 2021). Additionally, practices such as chemical thinning, shoot bending, and seasonal pruning (Lalhriatpuia *et al*., 2021) are critical for elevating both yield and quality, managing plant health, and fostering sustainable agricultural practices (Sharma *et al*., 2015; Yofune *et al.,* 2024).

Amongst the crop regulation practices shoot bending was found to be most promising. Shoot Bending can disrupt the downward flow of auxin in plants, which subsequently impacts the levels of cytokinin and strigolactone in dormant lateral buds, triggering their reactivation. (Mishra *et al*., 2021). Numerous studies have explored the effects of shoot bending on vegetative growth, specifically gravitropic responses, revealing that this manipulation leads to shorter shoots by primarily decreasing internode length. (Lauri *et al*., 2001). With respect to other preferable months of bending (Nandi *et al*., 2017) observed that bending in the month of October resulted in a leaf with the highest C: N ratio, the most blooming shootlets in a branch, and the highest yield. To maximize profit, it may be advantageous to standardize the timing of shoot bending to October or June.

Besides crop regulation methods plant hormones are also deployed exogenously on plants as growth promoters. Plant growth regulators are compounds that exert significant effects on plant growth and development, even when used in minimal concentrations. (Taiz *et al.,* 2015). The significant market value and essential role of PGRs in boosting global crop yields have brought them into increasing prominence. They significantly enhance agricultural productivity by alleviating environmental stress and promoting vigorous plant growth. The incorporation of PGRs into conventional farming practices permits for improved crop performance and consistency while upholding sustainability. Consequently, PGRs are essential for promoting sustainable agriculture and ensuring food security (Wu *et al*., 2024). Plant growth regulators (PGRs) include numerous compounds that affect different facets of plant growth and productivity. Plant growth regulators (PGRs) such as Naphthalene acetic acid (NAA), gibberellic acid (GA_3), and ethrel are extensively used in fruit crops to enhance fruit attributes, including yield, size, and quality. Naphthalene acetic acid (NAA), a synthetic auxin, significantly enhances fruit production by influencing various essential physiological processes. It augments fruit set and development by stimulating cell division and elongation within the ovary, leading to a greater number of larger fruits. Moreover, NAA promotes flowering by facilitating the shift from vegetative to reproductive growth stages and can delay fruit ripening, thereby prolong the harvest period and improve storage quality. Administered as a foliar spray or soil drench, NAA fosters higher yields, more uniform fruit quality, and enhanced commercial value. (Kumar *et al*., 2021 and Rudnicki *et al.,* 2020). It was studied by Gangwar *et al.* (2023) that a 150-ppm spray of Naphthalene acetic acid (NAA) significantly increased plant height.

Similarly, gibberellic acid (GA_3) is a vital plant growth regulator that significantly advances fruit crop development. It enhances flowering, promotes fruit set and size, and improves biochemical characteristics. By expediting the shift to flowering, GA_3 increases the number of blooms, which in turn boosts overall fruit yield. GA_3 also stimulates cell elongation and division, resulting in larger and more uniform fruits while simultaneously enhancing their nutritional quality by elevating levels of vitamins and antioxidants. Zhang *et al.,* (2022) provided compelling evidence that GA_3 application certainly improves fruit development and quality in crops such as apples and grapes, demonstrating its effectiveness in enhancing both the size and nutritional value of the produce. (Davies, 2010; Kumar *et al*., 2021; Morris *et al*., 2021). Consequently, applying

GA_3 at a concentration of 1 μM has been correlated with substantial stem elongation. (Yofune *et al.,*2023).

Ethrel, also referred as Ethephon, enhances fruit crop production through the optimization of physiological processes such as synchronized blooming, accelerated ripening, and elevated total soluble solids (TSS). These improvements are intricately linked to increased sugar content in the fruit. (Vidhya and Kumar, 2015). When applied, Ethrel generates ethylene, which increases blooming intensity by upregulating essential genes such as FT (FLOWERING LOCUST) and LFY (LEAFY), while concurrently down regulating floral repressors. This process transforms the apical meristem into a floral meristem. (Anantasook, Juntawong, and Phimchan, 2018). This mechanism ensures the development of flower buds, leading to more uniform harvests and increased yields. (Yadav *et al,* 2019). Ethrel also accelerates the ripening of climacteric fruits like apples and grapes, boosting sugar and soluble solid content. This improvement greatly enhances fruit quality, sweetness, and market appeal (Kalra and Tandon, 1983). The mechanism underpinning the efficiency of ethrel is ethylene mediated stimulation of enzymes responsible for starch hydrolysis and sugar transport, which are essential for the growth of high-quality fruits (Yadav *et al*., 2019). Strategic application of plant growth regulators (PGRs) with optimal timing and dosage is vital for maximizing their benefits. Consequently, PGRs have become essential tools in modern horticulture, greatly enhancing both the yield and quality of fruit crops.

In North India, guava flowering primarily occurs from April to May and again from August to October (Kumar *et al*., 2021; Ito *et al.,* 1999). However, in Punjab region shoot bending is commonly practiced during the summer months to enhance the quality of winter fruits, making them superior to those produced in the summer. There is limited research on the manipulation the flowering period, specifically from August to October, to optimize the vegetative, reproductive, and yield traits of guava. Therefore, the present study aims to evaluate the effects of various treatments such as NAA, GA_3, and ethrel at different concentrations of plant growth hormones combined with shoot bending techniques applied at different times of the year. The current experiment studies the efficacy of shoot bending and plant growth regulators in different months in Guava crop was planned with following objectives:

- To study the effect of shoot bending on yield attributes.

- To study shoot bending performed in three different months in guava.
- To study the effect of different plant growth regulators in combination with shoot bending in guava.

CHAPTER II

REVIEW OF LITERATURE

Pertinent literature associated with several facets of the present research, titled ‘‘**Studies on Efficacy of Shoot Bending and Plant Growth Regulators in Different Months in Guava Crop’’**, has been meticulously reviewed to emphasize plant growth regulators (3.1) and shoot bending (3.2) under the respective sub-categories.

3.1 Plant growth regulators

Recent advances in agriculture technology using plant growth regulators have emerged as a booster for various agroclimatic conditions. Plant growth hormones are sprayed on different crops to escalate their harvesting quantity and overall quality by manipulating different physiological processes in plants. Weaver (1972) has suggested notable uses of plant hormones. In 1978, Wittwer explored the crucial functions of growth regulators in enhancing crop production. Studies conducted in recent decades on vegetative, biochemical, and yield traits of fruits influenced by plant growth regulators are reviewed in this chapter as literature availability for guava fruit crop is minimal, thus other crops are also included to advocate the present investigation.

Plant hormones or regulators, including auxins, gibberellins, cytokinin, ethylene, and abscisic acid, are organic compounds that can alter or control different physiological functions in plants even in minimal amounts. Incorporating these growth regulators in modern agriculture has significantly contributed to advancing growth, yield, and quality in various fruit crops (Suman *et al.,*2017). Since hormones and their synthetic analogues were discovered, they have found extensive application in agriculture and horticulture to modify plant growth and developmental processes. Seed germination, vegetative growth, reproductive stage, maturity, senescence, and postharvest storage are some developmental processes explicitly intensified by plant hormones (Basra *et al*.,2000). Auxins are a class of hormones produced in the apical regions of shoots and roots. From these apices, they travel to areas where elongation occurs, promoting growth along the longitudinal axis (Went 1926). While auxins are present throughout the plant, they are predominantly concentrated in the growing tips of coleoptiles, buds, root tips, and leaves. (Bisht *et al*.,2018). Auxin plays a pivotal role in various developmental processes such as organogenesis, vascular tissue differentiation, root initiation, and tropism, with its primary functions at the cellular level being cell division and differentiation. (Guilfoyle and Hagen.,2007; Mockaitis and Estelle.,2008). It influences plant development by regulating senescence, leaf abscission, fruit formation, pathogen resistance, and responses to abiotic stress. Naphthalene acetic acid (NAA), a synthetic auxin, is particularly employed to reduce fruit drop in numerous horticultural crops. Synthetic auxins are widely utilized to promote fruit sets in numerous fruit plants. (Gumici *et al*.,2006; Khan *et al.,*2006). Similarly, Gibberellic acid (GA_3) is also a well-acknowledged PGR originating from the gibberellin family and was first discovered in the 20th century. Scientist Eiichi Kurosawa noticed elongation infested from a fungal pathogen *Gibberella fujikuroi* in rice crops. (Kurosawa, 1926). GA_3 has accomplished numerous roles in fruit production. It is used in enhancing fruit quality and yield by longing the senescence period, and hence extended shelf life is observed. (Janowska *et al*.,2003). Additionally, regulating fruit setting, and blossoming leads to persistent and increased yields, making it an inevitable tool for fruit production. (Dias, 2019; Prakash and Kumari, 2018). Ethrel, one of the essential PGR known as an ethephon that releases ethylene, is a pivotal hormone for plant physiology. In fruit crops, it is used for its ability to promote synchronized flowering for consistent fruit sets. Synchronization regulates erratic flowering. (Shah, 2023). Various Biochemical pathways responsible for cell well hydrolysis are co-regulated by Ethrel thereby imparting a soft texture to the pericarp. It also influences secondary metabolites viz., flavonoids and phenolics which administrate fruit color, taste, and nutrition (Zhang *et al.,*2015). The usage of PGRs has recently emerged as the most explicit way of increasing fruit productivity.

3.1.1. Effect of plant growth hormones on vegetative attributes of guava and other fruits

Peppers (*Capsicum annuum*) have shown notable responsiveness to NAA (Naphthalene Acetic Acid) treatments, particularly in terms of vegetative growth and physiological improvements. Ashraf and Foolad (2007) reported that NAA foliar sprays significantly elevated vegetative growth by enhancing root development, nutrient absorption, and shoot elongation. The improvement in root architecture led to more efficient uptake of essential minerals, contributing to better overall plant health and vigor. Furthermore, NAA treatments in peppers have been associated with increased chlorophyll content, which improves photosynthetic efficiency, and with enhanced flowering synchronization, which is critical for optimal fruit set and yield (Zhang *et al*., 2015). NAA also plays a role in reducing premature flower and fruit drop, thereby stabilizing yield and improving fruit quality in terms of size and uniformity (Kumar *et al*., 2021).

A study by Jain and Dashora (2010) compared the effects of various treatments, including NAA with concentration of 100 and 200 ppm, Ethrel with 250 and 500 ppm of concentration, Paclobutrazol with 250 and 500 ppm of concentrations, CCC (500 and 1000 ppm), and triacontanol (5 and 10 ppm) on guava cv. Sardar. Sixty days post-treatment, the greatest average shoot length (36.25%) was recorded with the 100ppm concentration of NAA treatment, closely followed by the 200 ppm NAA treatment (36.3%).

Similarly, Brar (2010) observed that PBZ and ethephon significantly influenced the vegetative growth of guava plants, noting an enhancement in both stock and scion girth with ethephon treatments. While, Brar and Bal (2010) further confirmed that ethephon-treated plants exhibited augmented stock and scion girth for guava planted at low spacing.

A study conducted by Syamal *et al.,* (2010) revealed that gibberellic acid GA_3 at concentrations of 100 and 150 ppm enhanced the plant height of papaya. Similarly, Saima *et al.,* (2014) carried out a study to analyze the impact of phytohormones strawberry cv chandler where GA_3 at 75 ppm maximized the plant height. While, Kacha *et al*., (2012) recorded an increase in the height of the bush at 177.33cm, the length of the shoot (99.17cm) with the foliar spray of NAA at 150 ppm in phalsa. While, Sharma and Tiwari., (2015) experimented on a seven-year-old guava fruit crop cv. Allahabad Safeda, reported maximum plant height (0.63m), canopy spread (0.34m), and canopy height (0.57m) with the application of NAA @100ppm in comparison with control of trial.

Rahman and Yadav (2022) conducted a study in a playhouse during 2020-21 at the School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, the influence of NAA and GA_3 on fruiting, flowering, and yield parameters of cultivar Indra was evaluated. The experiment tested three concentrations of GA_3 at 25, 50, and 75 ppm and NAA at 50, 100, and 150 ppm, with a DW in the control. An RBD with 3 replicas was employed to analyse the statistical parameters. The application of NAA at 100 ppm was associated with reduced days to fruit maturity (60.00 days), suggesting its effectiveness in improving crop maturity parameters.

Kumar *et al*. (2025) reported that foliar application of various chemicals had a significant influence on the vegetative growth of guava (*Psidium guajava* L.) cv. Hisar Safeda. Treatments involving micronutrients and plant growth regulators enhanced plant height, number of branches, and leaf area. These improvements in vegetative traits are indicative of better canopy architecture, which plays a crucial role in photosynthetic efficiency and overall plant health.

3.1.2. Effect of plant growth hormones on reproductive parameters of guava and other fruits

NAA has been specifically impactful in elevating fruit set and yield in apples (*Malus × domestica*) for reducing pre-harvest fruit drop, and hence improving yield altogether (Williams and Edgerton, 1974).

Singh *et al.* (1977) observed that GA_3 spray of 0 to 250 ppm at 15 days of intervals caused an increased fruit size in mango cv. Langra.

Monselise and Godschimidt, (1982) studied the effect of NAA on reducing premature fruit drop in oranges, where they noted that the targeted concentration of NAA will minimize fruit drop hence increase in fruit retention and yield is also observed.

Rajput and Singh (1982) analyzed that application GA_3 with 20 ppm and NAA with 40 ppm led to an increase in yield (76.6 kg/tree) and (86.4 kg/tree) respectively. Shoot length, fruit weight leaf area was also recorded positively. While Singh *et al.* (1982) noted that GA_3 @40ppm of concentrate has performed better for fruit length, width, and weight for ber cv. Banarasi Karaka.

Bal *et al*., (1984) examined the influence of growth regulators on the reproductive traits of ber cv. 'Sanaur-5' and observed minimized fruit drop percentage with the foliar spray of NAA at 25 ppm over control.

Agamy and Sholtour (1989) recorded that the NAA spray at 50 ppm concentration on 10-year guava tree at the flowering and fruit setting stage gave increased flowering and fruit set percentage as compared to control.

Baghel *et al.,* (1989) studied the foliar spray of 6% of urea and NAA acid was found to be promising in increasing the total number of flowers. However, Highest flowering and fruiting was addressed with the combination of NAA and urea at 150 ppm and 4 percent concentration respectively.

Banker and Prasad (1990) observed that fruit retention fruit and fruit set were influenced by GA_3 and NAA with individual concentration of 10 and 20 ppm or in combination in ber cv. Gola.

Bankar and Prasad (1993) reported that NAA at 10, 20 and 30 ppm enhanced fruit retention and fruit set in comparison control while increase in fruit weight and length was found with NAA at 30 ppm in ber.

Marini *et al., (*1993) observed a reduction in fruit drop in apple cv. Delicious which can be perhaps due to the pedicel thickness of fruit. Similarly, Singh *et al*., (1994) carried out an experiment with urea and NAA on mango cv. 'Langra' and observed an increased NAA concentration caused uplifted fruit retention and fruit size.

Hassan and Eissa (1996) demonstrated a study of chemical substances on seed and fruiting traits of guava tree, where NAA @50ppm gained an increase in fruit set and subsequent decrease in June pre harvest drop. Similar results were inspected by Rao and Nalawadi in grapes. While, Vijaylakshami and Srinivasn (1998) reported an increase in the number of panicles with spray of NAA at 20 ppm concentration.

Vijyalaxmi and Srinivasan, (1998) reported that the application of ethrel @200ppm has caused an evident increase in several flowers in off off-season for mango cv. 'Alphanso'. Likewise, outcomes were stated by Ramburn (2001), where 0.5gm PBZ plus 0.4g ethephon promoted blossoming intensity with erratic fruiting in litchi.

Tao *et al., (*1998) observed, increased fruit setting percentage with application of 15 ppm NAA in fuzi cv. of apple. Greenberg *et al., (*2000) noticed reduced fruit numbers with an increase in fruit size and total yield by application of 300 ppm NAA. Alike outcomes were supported by Nieto *et al*., (2000) where, 16ppm NAA noticed remarkable fruit growth. While, Pandey (1999) experimented on ber (*Ziziphus mauritiana* L.) cv. 'Banarasi Karaka' with NAA and GA_3 with 5, 10, 15, 20 mg/l at pea stage. Where he noted that GA_3 @15mg/l concentration gained highest fruit retention and yield.

A study was conducted by Pandey (1999) to analyse the efficacy of NAA and GA_3 on ber cv. 'Banarasi' and 'Karaka', where the application of NAA at 20 ppm gained the highest fruit retention and increased size, weight, volume, and overall yield. Similarly, Turn bull *et al*., (1999) published an article where they claimed ethylene releasing agents such as ethephon were hugely taken up by plants for induction of flowering in pineapple. Similarly, Onaha *et al.,* (2001) also recorded an increase in flower bud percentage with application of ethephon.

Brahmachari and Rani (2000) studied various GA_3 concentrations of 50 and 100 mg/l on Litchi cultivar Purbi at panicle initiation, immature fruiting, and fruit set stages where they found that GA_3 at 100 mg/l gained better fruit yield in comparison to other treatments.

Kale *et al*. (2000) experimented with a combination of NAA (20ppm) plus GA_3 (40ppm) plus zinc sulphate (0.4%) in ber fruit. They observed that the highest length of fruit (3.9 cm) and width of fruit (2.99 cm) were collected from combination while the lowest was with the untreated plant. Involvement of metabolism of hormones, rapid division of cells, and cell expansion could be the possible reason for getting better fruit size.

Singh and Mukherjee (2000) stated that NAA at 75 ppm in combination with urea gained a better fruit set, fruit weight values with a subsequent decrease in fruit drop percentage in chilli furthermore, days required to reach 50 percent flowering stage were also reduced.

Onaha *et al.,* (2001) relayed an enhanced flower bud induction and also emphasized on the impact of NAA on flower bud induction is positively correlated to healthy leaves. While Yeshayahu *et al*., (2001) undertook a research study, where they reported that NAA spray at 300 ppm promoted the fruit size in mandarin cv. 'Myovaza Satuma'.

Dokoozlian and Peacock, (2001) reported that the application NAA has significantly improved berry size and uniformity leading to fetching better market price. Aligned effect was advocated from the studies of Kumar *et al*., (2012) linking to enhanced shelf life by longing ripening duration.

Singh *et al.*, (2001) recorded decreased fruit drop and increased fruit set percentage with the application of PGR and micronutrients. With the combination spray of NAA @20ppm + GA_3 @40ppm + $ZnSO_4$ @0.4% maximized fruit drop (89.70%) and fruit retention (9.83%) were addressed. Metabolic processes at different levels are influenced by PGR; this was the reason claimed by the scientists.

Singh and Randhawa (2001) studied the PGRs and fungicides on quality, fruit drop and fruit yield in Umran cultivar of ber. Application of NAA, 2, 4-D and GA_3 each at 15, 30, and 60 ppm concentrations were made on the tree. NAA spray resulted as best in elevating quality and yield with remarkable decrease in fruit drop and increase in fruit set.

According to Dubey *et al*. (2002), the largest fruit dimensions in terms of length, width, and weight were consistently observed in the treatment utilizing 500 ppm of NAA throughout all cropping seasons for guava cv. Allahabad Safeda.

Kumar and Sathiamoorthy (2002) experimented to study the effect of plant hormones on black pepper cv. 'Panniyar-1' where they recorded the highest berry set percentage with application of 150ppm of NAA. Bhati and Yadav (2003) also studied the effects of foliar spray of NAA spray at 20 ppm in ber cv Gola, where they found an increase in length of fruit at 3.42cm, Breadth of fruit at 3.027cm, fruit weight at 17.52 g and yield of 56.44 kg/ tree.

Bhati *et al.,* (2003) studied foliar spray of NAA and urea on Gola cultivar of ber where NAA at 20 and 30 ppm displayed positive impact on fruit retention at 55.011 % and 52.134% respectively. Similarly, Rao *et al*., (2004) also discovered the spray of NAA (20ppm), Potassium sulphate (2.0%) and Zinc sulphate (0.4%) at the fruit setting stage has managed to regulate fruit drop thereby fruit set in ber cv. Banarasi Karaka.

Ram *et al.* (2005) carried out an experiment with NAA and GA_3 at a varied concentration where the results showed that GA_3 (25ppm) and NAA (15 ppm) had a positive effect on dimensions of ber fruit, including length and width of fruits along with wight of pulp, Total soluble solids and total sugar in ber fruit.

Singh *et al*., (2005) reported a positive influence of NAA in regard to the fruit set, under stress conditions which leads to an increase in the number of fruits per tree. Singh *et al*. (2006) recorded the largest size of fruit in regard to breadth, length, weight and yield at active growth phase with NAA spray of 60 ppm. Similarly, Yadav *et al.* (2001) examined that NAA 30 ppm and 1.5 % urea spray in ber has resulted in better fruit weight and size in comparison with control.

Saraswati *et al*., (2006) conducted a research trial on the influence of NA and $ZnSO_4$ on fruit drop, fruit setting, cracking, size of fruit, yield and quality of litchi cv Calcuttia. They observed increased fruit set/panicle (238.00), fruit retention (7.43%), no. of inflorescence/ tree (414.00), and length (3.99cm) and width (3.49cm) of litchi with the foliar spray of NAA @ 20 ppm and Zinc sulphate @0.6%.

Singh and Bal (2006) conducted an experiment including pruning and PGRs on physicochemical characteristics of guava fruit during the rainy season planted at different spacing, where they found that ethephon sprayed fruits had lesser number of seeds. Moreover, Nagargoje *et al*. (2007) recorded that the foliar spray of NAA at 100 ppm at 50% of the flowering stage and at the pea stage in August to September months witnessed notable fruit set in sapota.

Singh *et al.* (2007) undertook a trial to study PGRs and micro-nutrients physio-chemicals and yield characteristics of Aonla cultivar Narendra Aonla-10. They noted that spray of NAA @10 mg/l with Zinc sulphate @0.5% and GA_3 @25 mg/l has found to be better at fruit retention, fruit length and breadth, weight of fruit, weight of stone, weight of pulp, pulp: stone ratio and yield altogether. Parallel results were claimed by Vajendla *et al*. (2008) with NAA spray which caused a decrease fruit drop and increase flower retention and yield in mango

Iqbal *et al*., (2009) established a trial, with 28 trees of guava cv. red flesh to demonstrate the influence of NAA, the outcome showed a significant decrease in fruit drop with 45 ppm of NAA spray While, Patel *et al*. (2010) advocated that GA_3 at 50 mg/l positively influenced fruit set and fruit retention percentage along with flowering period in custard apple cv. Sindhan

Brar and Bal (2010) established a trail to analyse the influence of PGR on reproductive traits of guava cv Allahabad safeda where, ethephon was found to accelerates fruit maturity by up to a week in the rainy season and by up to two weeks in the winter season. Moreover, Painkr *et al*, (2012) observed an increase in fruit retention, yield, and quality attributes of mango cv. langra with the application of NAA at 400 ppm of concentration.

Kacha *et al*., (2012) investigated the influence of GA3, NAA and ethrel on quality and yield traits. Total ten treatments were included of NAA at 100,150 and 200 ppm, GA_3 at 50,100 and 150 ppm and ethrel at 500, 750 and 1000 ppm. And control spray. They reported an increase in flower/shoot at 151.21, number of fruits/shoot at 60.74, fruit weight at 49.80g and juice percentage (57.78%) with 200 ppm of NAA spray phalsa under south Saurashtra region.

Nkansah *et al*, (2012) made a study to analyze the influence of NAA and GA_3 on fruit retention, quality and yield of Mango cv. Keitt in Ghana for two consecutive years. Three concentrations at two varied trial regions were sprayed and they observed that GA_3 25 mg/l plus NAA 25 mg/l with increased fruit setting, retention percentage, total number of fruits, and weight of fruit.

Patel *et al.* (2013) discovered that the application of urea, GA_3, 2,4-D, $ZnSO_4$, NAA at pea and full bloom stage caused an immense increase in fruit retention at varied stages of fruit development in comparison with control. While, Garasiya *et al*. (2013) studied influence of PGRs on quality aspects of winter season guava cultivar L–49 (Sardar) and it was determined that the application of NAA at concentrations of 40 and 20 ppm was optimal for augmenting fruit weight, resulting in weights of 153.22 g and 136.13 g, respectively.

Lal *et al*. (2013) estimated the influence of plant hormones on the reproductive traits of guava, reporting that GA_3 at 50 ppm significantly enhanced fruit weight (182 g), fruit girth (10.23 cm), and fruit volume (178.3 cc). Similarly, Agnihotri *et al*. (2013) recorded the highest fruit length at harvest (97.30 cm) in guava with a foliar spray of 300 ppm NAA. In line with this, Garasiya *et al*. (2013) found that applying 40 and 20 ppm of NAA was the most effective method for increasing fruit diameter, measuring 5.63 cm and 5.36 cm, respectively.

Maji and Maiti (2014) studied the impact of Ethrel on the flowering and fruiting of guava, demonstrating that Ethrel spray significantly enhanced flowering and promoted synchronized blooming in guava trees. Similarly, Singh and Sharma (2015) reported a notable improvement in fruit weight and shape, with an enhanced fruit shape contributing to higher market prices.

Sharma and Tiwari (2015) obtained the incorporation of NAA with 100 ppm of its concentration marked to be best to uplift field attributes of guava cv Allahabad Safeda. Results displayed increased fruit length (6.54cm), diameter (5.4cm) and fruit volume (174.6 ml) at harvest while total number of fruits per plant (251.1) , mean weight of fruit at 223.27g and harvesting yield per tree (56.10kg).

In strawberries, NAA has been noted to lower fruit development therefore, fruit size and color were marked to increase. The exposure of NAA in the initial stages of fruit development has a significant impact on pigmentation and sugar percentage. (Lal and Das.,2017)

Patel *et al*. (2017) examined the influence of Ethrel on the flowering and fruit set of guava trees, observing that Ethrel treatment resulted in larger fruit size, a higher fruit-setting percentage, and increased yield. Similarly, Singh *et al*. (2019) recorded the highest fruit diameter (4.96 cm), fruit weight (47.46 g), and fruit volume (43.62 cc) with a combination of GA_3 and boron spray. Chaudhary *et al*. (2020) studied the effect of nutrients and PGRs on yield-attributing traits and overall yield in ber (*Ziziphus mauritiana* Lamk.) cv. Gola, concluding that a 50 ppm NAA concentration significantly enhanced fruit set, reduced fruit drop, and improved fruit retention, along with enhancing the physio-chemical traits of the plant.

According to Kumar *et al.* (2025), foliar application had a marked impact on reproductive characteristics of guava. The study observed a significant increase in flowering intensity, fruit set percentage, fruit size (length and diameter), and average fruit weight. Treatments involving a combination of micronutrients and plant growth regulators showed the best results, with substantial increases in total fruit yield per plant. These findings suggest that the foliar application not only enhances nutrient uptake but also plays a regulatory role in physiological processes related to flowering and fruit development. The improved reproductive traits are directly linked to better economic returns for guava growers.

3.1.3. Effect of plant growth hormones on yield parameters of guava and other fruits

In a research trial conducted by Kandu and Mitra (1997), plants were treated with aqueous solutions of NAA (50 and 100 ppm), 2,4-D (50 and 100 ppm), DNOC (5 and 10 ppm), and urea (10%). The study revealed that the highest annual yield per plant, 36.7 kg, was achieved with NAA at 50 ppm.

Chaudhary *et al*. (1997) studied crop regulation in guava cv. 'L-49' and found that the highest yield was achieved with the application of NAA at 250 ppm. Similarly, Yadav (1998) observed improved quality and yield traits in guava with a foliar spray of NAA at 10 ppm, combined with a few nutrients. His study recorded an increase in yield to 67.7 kg per tree, with 686 fruits per tree, a fruit volume of 19.6 mg/100g of pulp, and a minimal number of low-quality marketable fruits (19.6 per tree) when NAA was applied at 10 ppm.

Pandey (1999) studied that impact of NAA And GA_3 foliar spray on growth, fruit retention, harvesting output, and quality of ber of cultivar 'Banarasi' and 'Karaka' and found that by NAA spray at 5 to 20 ppm lead to maximized fruit weight, fruit volume and yield observation over control. Singh *et al.,* (2000) addressed the highest yield on guava cultivar Sardar with the foliar application of ethephon at 1800ppm.

Maibangre and Ahmed (2000) examined the effect of a 100 ppm NAA spray on pineapple and observed an increased yield compared to the control. Similarly, Ghosh (1998) recorded a similar effect on cashew nut yield with NAA treatment. On the other hand, Yadav *et al.* (2001) noted a significant decrease in yield values with the application of 50 to 100 ppm of Ethrel in guava trees, attributing the reduction to decreased moisture content caused by the Ethrel treatment. A study was conducted in guava crop cv. Arka Mridula by Ravi Shankar, (2003) and NAA sprayed at 400 ppm in combination with 50 per cent pruning gave the highest yield (11.62kg) per tree. While Mohammed *et al.,* (2006) investigated the spraying of urea (10, 15, and 20%), KI (0.5, 1 and 2%), MH (1000, 2000, and 3000 ppm), ethephon (600, 1200, and 1800 ppm), and NAA (200, 400, and 600 ppm). Maximum winter crop yield (359.3 q/ha) was achieved with a 600-ppm treatment of NAA. (Mohammed *et al.,* 2006).

Das *et al.* (2007) carried out research on seven-year-old guava cultivar Allahabad Safeda with varied growth regulators and chemicals. 10 and 20% urea, 100 and 200 ppm NAA, 40 and 60 ppm 2,4-D, 1 to 2% of Kl and control were used as experimental material. They found that NAA at 200 ppm gave the highest yield and profit for winter season for Sardar and Allahabad Safeda cv. Of guava. Similar trial was established by Iqbal *et al*. (2009) with 28 guava trees of the red flesh cultivar to demonstrate the influence of Naphthalene Acetic Acid (NAA). The outcome showed a significant increase in fruit yield with the application of a 45 ppm NAA spray. While, Shaban *et al*., (2009) studied the effect of pruning and plant growth regulators, where moderate pruning with ethephon @600ppm gave the maximum new shoots and fruits and also enhanced tree yield altogether.

Katiyar *et al*. (2009) experimented with a trial to analyse the effect of nutrients and PGR on physicochemical parameters and yield of Allahabad Safeda guava in Kanpur, Uttar Pradesh condition. With four chemical and three plant hormones, a total of 12 treatments were formulated viz., urea of 2%, KSO_4 of 1%, Borax of 0.2%, $ZnSO_4$ of 0.2% and GA_3 150 ppm, Ethrel 250 ppm, and NAA 100 ppm. The treatments were applied four times. The first spray was given at flowering, the second was given at 50 % flowering while the third and fourth was foliar sprayed at the fruit setting stage and at three weeks after fruit set. The results obtained displayed the highest yield of 95.39 Kg/tree with a combination of 2% urea and 100 NAA.

Iqbal *et al*. (2009) carried out a trial to examine the spray of NAA on fruit drop, yield, and physicochemical characteristic of Red Flesh guava under Pakistan condition. The recorded reduction in preharvest fruit drop with application of NAA. Highest reduction in fruit drop of 8.83 % was obtained with 45ppm spray of NAA. Highest yield was also recorded from NAA at 45 ppm followed by 60 ppm (44.6kg/plant).

Iqbal *et al*. (2009) examined the study of bahar treatment with different plant growth hormones under the Maharashtra region in hasta bahar where they recorded that, GA_3 @100ppm plus ethrel @600ppm plus CCC @1000ppm recorded highest number of fruits (213.87/tree) and harvesting yield of 38.26 kg/tree. Wahdan *et al.* (2011) examined the influence of chemicals on fruiting, growth, and yield of quality traits of Succary Abiad cultivar of mango in Egypt. They recorded that urea @2% plus NAA @40 and 60 ppm plus GA_3 @20 and 40 ppm application gave positive results in regards to yield at 73 and 80 kg/tree which was mcg higher than untreated plant (42.7 and 38.8kg/tree).

Nkansah *et al.* (2012) studied an experiment in regards with the influence of NAA and GA_3 on fruit retention, quality and output yield of mangoes cultivar Keitt in coastal savanna ecological region of Ghana, where they observed that spray of GA_3 and NAA has proven to be most efficient in increasing fruit retention, fruit setting, total number of fruits/cluster and per plant, fruit weigh and overall yield altogether. Similarly, Kacha *et al.,* (2012) witnessed maximum increase in yield at 171 kg per plant with the foliar spray of NAA at 200 ppm in phalsa under south -Saurashtra region.

Tiwari and Lal (2012) analyzed the influence on NAA, flower bud thinning, and pruning on regulation in the guava fruit cultivar Sardar. NAA 600pp and 800pp, flower bud thinning, one-pair leaf shoot pruning, and control were the six treatments established for the experiment. Maximum yield of 88.00 kg/tree was observed with one leaf pair pruning in winter season. Moreover, Lal *et al*. (2013) conducted a research trial to study the effect of PGR on the fruit growth and flowering of guava cultivar Allahabad Safeda under Assam region. Trial was set up on a 6-year-old guava tree with eleven treatments of varied concentrations of plant growth regulators. They reported that 50 ppm of GA_3 application has given a maximum yield of 37.1 kg/tree.

In a study by Garasiya *et al*., (2013) applying NAA at 40 and 20 ppm was found to be highly effective in significantly increasing the number of fruits per tree, with counts of 439.00 and 410.05, respectively. These treatments also substantially boosted yield, reaching 66.39 and 59.90 kg per tree, respectively. Similarly, Goswami *et al*. (2013) reported an increase in the number of fruits, fruit weight, and fruits per tree with the application of NAA at 500 ppm. In mango cv. Langra, Haidry *et al.* (2013) found that a spray of NAA at 20 ppm minimized fruit drop during all stages of development, maximizing fruit retention (22.20%) and yield (11.33 kg/tree). Sharma *et al*. (2013), in their study on 10-year-old Guava cv. (L-49) in the Jammu region, observed that a spray of NAA at 200 ppm in April and May led to an increase in yield to 49.96 kg per tree.

Goswami *et al*. (2013) recorded NAA 50 ppm foliar spray to be effective in elevating number of fruits per tree, fruit weight, number of stems at the time of pruning, number of hermaphrodite fl+

ower, and minimum drop in fruit per plant and overall yield number of fruit per plant of pomegranate cv. Sindhuri in Gujarat.

Malik *et al.* (2014) studied the effect of NAA on flower and fruit thinning in the summer crop of guava and found that flower drop increased to 69.45% with higher chemical concentrations, with NAA at 400 ppm showing the most pronounced effect, resulting in a yield of 32.75 kg per plant during winter. Similarly, Sharma *et al*. (2015) reported a positive correlation between yield traits, noting that the application of NAA at 100 ppm resulted in a yield of 56 kg per tree in guava cv. Allahabad Safeda.

3.1.4. Effect of plant growth hormones on quality parameters of guava and other fruits

Kundu and Mitra (1997) studied various crop regulation practices for guava where spray of NAA at 50 and 100 ppm concentrations was found to be most effective in decreasing the fruit acidity. Kundu and Mitra (1997) observed that applying NAA at 100 ppm in guava during winter resulted in the highest sugar/acid ratio of 35.46. While, Yadav *et al.* (2001) analyzed the influence of PGRs in 15-year-old guava tree cv L-19. PGR viz., NAA at 20, 40 and 60 mg/l, GA_3 at 50, 100 and 150 mg/l and ethrel at 50, 75 and 100 mg/l were used. Total sugar and TSS were found to have maximum value due to NAA followed by GA_3 and ethrel.

Rathore and Chandra (2002) recorded the highest vitamin C content (78.35 mg) in guava with the application of NAA at 20 ppm, GA3 at 40 ppm, and Zinc sulphate at 0.4%, while the lowest content was observed in the control group (65.16 mg). Dubey *et* *al*. (2002) found that increasing the concentration of NAA up to 250 ppm led to higher vitamin C levels in guava cv. Allahabad Safeda. In addition, Kaur et al. (2011) investigated the physico-chemical properties and biochemical composition of guava, finding that total sugars (3.60%) were comparatively higher in the Allahabad Safeda variety.

Bhati and Yadav (2003) noted that NAA spray at 20 ppm concentration at flowering stage in Gola cv. ber has evidently gained a good amount of TSS (19.44 ^{o}B), reducing sugar (4.2%) and ascorbic acid (168.7 mg/100g pulp) in comparison with untreated plants.

Ram *et al.* (2005) observed increased TSS and total sugar in ber fruit with the application of NAA, GA3, and ZnSO4. Similarly, Kher *et al*. (2005) found that a foliar spray of NAA at 60 ppm in guava cv. Sardar resulted in an increase in TSS (11.6%), while NAA at 80 ppm positively influenced total sugar. Ravi *et al*. (2005), in their examination of the influence of pre-harvest sprays of plant growth regulators, concluded that a 600 ppm NAA spray resulted in improved TSS/acid ratio, as well as increased total sugar and reduced sugar.

Mohammed *et al*. (2006) found that applying ethephon at 1800 ppm to guava cv. Sardar resulted in uplifted pectin content (0.80%) and reduced acidity. Furthermore, Jain and Dashora (2010) demonstrated an increase in total sugar at 7.53%, reducing sugar at 4.36%, non-reducing sugar at 3.01%, pectin content (0.80%) and lowest acidity (0.375%) through the application of 500 ppm ethrel.

Yadav and Rana (2006) studied the impact of NAA, $ZnSo_4$, Urea on fruit drop and ber quality, where they found an increase in Total soluble solids with combination NAA (20ppm) with $ZnSO_4$ (0.5%). Parallel results were documented by Ghosh *et al*. (2009) with the application of NAA at 25 ppm once after fruit setting stage and two spray at 21 days of interval resulted in significant increase in total sugar (13.7%), TSS (15.8 ^{o}B), pulp content (96%) and sugar to acid ratio (56.4) in ber cv. Banarasi Karka.

Chavan *et al*. (2009) studied the impact of PGRs on quality and yield traits of sapota cv. Kalipatti where they found that spray of NAA @150ppm prior flowering stage and at fruit set stage and fruit development stage gave highest TSS of 20.15 ^{o}Brix and titratable acidity of 0.211% which was greater than the value collected for control.

Iqbal *et al*. (2009) conducted a trial on red flesh variety of guava fruit, to evaluate the impact of Naphthalene Acetic Acid (NAA). The chemicals with 45 ppm NAA reported the maximum values for pulp per seed at 11.31, total soluble solids at 11%, and total sugars at 7.45%. Moreover, fruit drop was negatively correlated with all other traits except acidity, whereas the pulp/seed ratio positively correlated with total soluble solids, total sugars, and ascorbic acid content, and negatively correlated with acidity. Yadav *et al.* (2010) also found an increase in TSS, total sugar, and ascorbic acid with a decrease in acidity percentage with the spray of NAA @30ppm.

Bhowmick and Banik (2011) studied the effectiveness of NAA at 20, 40 and 60 ppm concentration in mango cv. Himsagar. They found that vitamin C (42.40 mg/100g) has evidently displayed an increase with NAA (40ppm) while NAA (60 ppm) has marked optimum reducing sugar percent (4.59%). Moreover, NAA (20ppm) has maximized TSS (19.42°B), and total sugars (15.76 %). as compared to untreated plants.

Jain and Dashora (2011) reported the highest TSS at 15.66%, and lowest acidity of 0.39% ascorbic acid of 205.18mg/100 gram of pulp, total sugars at 7.86%, reducing sugars at 4.58%, non-reducing sugars at 3.11% with the incorporation of 500 ppm ethrel in guava cv. sardar. Moreover, according to Pandey *et al.* (2012), a combination of NAA (20ppm) with GA_3 (40ppm) and $ZnSO_4$ is most promising in regards to In ber cultivar Banarasi Karaka, the TSS was recorded at 14.20 °B, total sugar at 10.71%, acidity at 0.17%, and ascorbic acid content at 78.35 mg per 100g of pulp.

Kacha *et al*., (2012) conducted an experiment with NAA and GA_3 and ethrel to study the quality and yield attributes of phalsa under south Saurashtra region. Treatments inclusive of NAA at 100,150 and 200 ppm, GA_3 at 50,100 and 150 ppm and ethrel at 500, 750 and 1000 ppm and control spray, where they recorded maximum TSS at 25.23%, and total sugar of 5.74%, reducing sugar at 2.01% with the foliar spray of ethrel at 750 ppm.

Mandal *et al.* (2012) investigated the effects of foliar applications of KNO_3 and NAA on the quality attributes of the winter crop of guava cv. Sardar. The plants were treated with NAA and potassium nitrate and harvested at peak maturity. The application of NAA (100 ppm) significantly mitigated spoilage, preserved superior fruit firmness, and maintained slightly desirable TSS and ascorbic acid content levels after 30 days of storage.

Guava trees were treated with 500 and 1000 ppm of PBZ and ethephon. The palatability rating and total soluble solids (TSS) and ascorbic acid levels of fruits during both the rainy and winter seasons were significantly elevated in plants treated with 1000 ppm ethephon compared to the untreated controls (Brar *et al.,* 2012). Similar increase in TSS/acid ratio (37.80), total sugars (7.49%), reducing sugar (4.73%), non-reducing sugar (2.76%) and a decrease in acidity (0.27%) of guava fruit were measured by Agnihotri *et al*. (2013) under the foliar spray of 300 ppm NAA.

Gill and Bal (2013) recorded a significant reduction in acidity at 0.12% and increased TSS at 19.68ºB, reducing sugar at 5.42%, non-reducing sugar at 4.57% and chlorophyll at 71 SPAD value with the foliar application of NAA@60ppm plus GA_3@30ppm plus urea @2% in ber fruit crop. Moreover, Garasiya *et al.* (2013) examined the influence of PGRs on the yield attributes of winter season guava, cultivar L-49. PGR viz., GA_3, NAA and CCC were used. They found that the NAA spray at 40 mg/l has performed most effectively for TSS, total sugar.

An incorporation of 40 ppm and 20 ppm NAA heavily boosted the value of the quality parameter, TSS (10.95 and 10.87%), ascorbic acid (180.30 and 173.97 mg/100g pulp) reducing sugar (3.79 and 3.65 %), non-reducing sugar (2.65 and 2.56 %), and total sugar (6.44 and 6.21 % respectively) and showed a decline in acidity (0.42%) as reported by Garasiya *et al.* (2013).

Sharma *et al.,* (2013) derived through the trial results that, NAA at 600 ppm gave the highest ascorbic acid content (261.293mg/ 100g) and additionally, Singh and Reddy (1997) examined guava crop regulation where results showed that the application of Ethephon at 1200 ppm maximized ascorbic acid content. Goswami *et al*. (2014) studied a trial on the effect of pre-harvest nutrient application on the physicochemical quality and storage behaviour of guava cv. L-49 in Kanpur for two consecutive years. The result displayed an increase in TSS (11.8ºB), ascorbic acid content (230.24 mg/100g of pulp), and a decrease in acidity (0.34%). Moreover, According to Anwal *et al*. (2015) recorded the highest data for total sugars (15.58%), non-reducing (1.75 %), reducing sugar (13.8 %), and TSS (16.78ºB) with foliar spray of NAA @40ppm at full bloom stage in pomegranate cv. Bhagwa.

Sharma and Tiwari (2015) studied the effect of growth regulators in guava where they obtained maximum ascorbic acid and pectin content with the application of NAA at 100 ppm on the contrary GA_3 sprayed trees gave the highest TSS (12.6 ºB), titratable acidity (0.35%) total sugars (10.42%), reducing sugar (5.82%) and non-reducing sugar

(4.60%). Similar experiment was conducted by Sharma *et al.,* (2015) on cv Allahabad Safeda which derived a positive influence on chemical traits such as acidity (0.25%), TSS (11.6^0B), Total sugar (9.61%), reducing sugar (5.70%) in guava crop.

Kishor *et al.* (2016) examined a study to analyze the influence of plant growth regulators in pomegranate cv. Bhagwa. Spray of GA_3 with 50 and 75 ppm and NAA with 50 and 75 ppm concentrations at 15 days intervals from the fruit set were performed. NAA 50 ppm gave ideal data for total sugars at 6%, (4.60%), non-reducing sugars (1.93%) and reducing sugars.

Singh *et al.* (2017) studied the influence of phytohormones on quality and yield of guava cultivar Allahabad Safeda where they found that NAA @200ppm and 150 ppm gave significant results in regards to TSS (11.47%), total sugar (7.43%), reducing sugar (4.48%), ascorbic acid (239.03g/100 g of pulp). Similar effects were noted by Kumar and Singh (2018) with significant increase in fruit flavor and sweetness with better sensory qualities inclusive of taste and aroma in guava. While, Sharma *et al.* (2019) emphasized that the ethrel application in guava has not only influenced fruit quality such as firmness and color but also extended the shelf life of fruits making it suitable for storage and transport.

Kumar *et al.* (2025) evaluated the influence of foliar treatments on the chemical composition of guava fruits. The results indicated an increase in total soluble solids (TSS), ascorbic acid (vitamin C), and sugar content, along with a reduction in fruit acidity. These chemical improvements contributed to better taste, nutritional value, and consumer acceptability. The treatment combinations that included both micronutrients and plant hormones were particularly effective in enhancing fruit quality. Thus, foliar nutrition was found to play a dual role, boosting both yield and the internal quality of guava fruits.

3.2. Shoot Bending

Bending of shoots is a pivotal horticultural operation used to frame the tree branches in the desired orientation. This constitutes bending of tender, younger and flexible branches at a certain angle and tying it to the ped, thus promoting horizontal growth and providing strong stature for a tree. Bent tree generally displays a reduction in terminal growth shoots due to an alteration in cell arrangement. (Ferree and Schupp, 2003). Lopez *et al.*, (2014) have claimed that the poroelastic behaviour of xylem is the important aspect related to Shoot bending while Wilson (2000) has stated that eradication of apical leads to wood synthesis with upward curvature, hence apical dominance can also be considered as a hindrance which contributes negatively to lateral growth. Due to shoot bending a change takes place in hydraulic pressure in the xylem, this rapidly translocates via a vascular system of plant in the upper and lower regions of the stem. The change in pressure is sensed and signaled to various plant parts including leaves, roots, and apical portion. In addition, when the shoot is bent the balance between fruit and vegetative growth is raptured which causes a reduction in the shoot's strength and size. This contributes to an increase in carbohydrates in the reproductive parts of plants. Therefore, more fruit is gained. (Giulivo 2011; Forshey *et al*. 1992).

3.2.1. Effect of shoot bending on quantitative traits of guava and other fruits

Wang (1987) conducted research to analyze the impact of different training methods on the harvesting output of guava, observing that fruit weight, number of fruits, and overall yield increased at the lower part of the tree with sheet bending. Similarly, Bargioni *et al*. (1995) experimented on five-year-old apple cultivar Golden Delicious, finding that shoot bending at 45° or 60° reduced shoot elongation by 40% and trunk circumference growth by 27%. Lauri *et al*. (1998) recorded a significant increase in the number of flowering buds on lateral shoots, as well as the number of flowers, leader shoots, and spurs, noting that bent branches had a higher fruit setting percentage compared to long lateral branches. In a study on Japanese pear, Ito *et al.* (1999) reported enhanced flower development with bent branches at a 45-degree angle in late June, with the highest concentration of zeatin found in the bent shoots. An aligned result derived by Lauri *et al.* (2001) carried out a research trial to examine the effect of Shoot Bending performed at different times to influence fruit production in apple trees. They reported that cultivar chantecler, led to a greater number of fruits with the June Shoot Bending whereas, for two years it gave similar results with the January Shoot Bending.

Ito *et al*. (2004) stated that Shoot Bending is correlated with noticeable changes in internal hormonal levels. They recorded that IAA concentration in the lateral buds increased in mid-July but in the bent branches, it certainly remained unchanged. Whereas, cytokinins in buds were certainly higher in bent trees than the untreated ones, hence, they claimed that with the reduction in auxin levels in shoots, there is an increase in cytokinin activity. Thus, this theory has drafted that alteration in internal hormones could contribute to an acceleration of flower growth. While, Han *et al*. (2008) claimed that bending practiced in the proximal region results in elevated vegetative growth. Moreover, bending also results in the removal of lateral shoots.

Bagchi *et al*. (2008) examined biochemical alteration in Guava leaf and bark through bending and pruning operations for off season flowering. They reported that bending practices have displayed significant increases in terms of proline, polyphenol, peroxidase, lipid, tryptophan, oxidase, catalase in leaves, bark and fruits. They suggested that the change in this enzyme could be the reason for increased flowering intensity.

Chutinanthakun *et al.* (2014) studied the tree jointing and Shoot Bending and its effect on internal concentrations of hormones and flowering of plum fruit. The results showed significant reduction in gibberellins concentrations with increase in abscisic acid volume in comparison with control. GA_3 was suggested as a suppressor and ABA as flower inducer for bent and bent joint categories which resulted in maximum flowering and fruit set while control received minimal. While, Jana *et al.* (2015) recorded an increase in flowering buds with the application of SADH and shoot bending through to ethylene synthesis in damaged cells.

Murri *et al*., (2015) carried out an experiment to analyse the shoot inclination at different angles viz., 0°,45°,90°,135° on size and fruit quality in peach cultivar Nactaross. They reported that 45° displayed the highest fruit size, weight while at 135° inclination fruits were rather smaller in size. While, Nasr *et al*., (2015) studied the effect of bending in pear where they found an increase in dry matter, spur %, floral precocity and overall yield. Xing *et al.* (2015) also derived similar results with Shoot Bending in terms of flower buds during the growing season.

Samant *et al*. (2016) conducted an experiment on shoot bending of guava at hot and humid climate of Eastern India. They reported that Shoot Bending causes an increase in shoot growth, flowering intensity, fruit quality and yield. While, Azizu *et al*. (2016) experimented to study bending and mandarin citrus cv. Borneo rima where they recorded that bending has vividly led to flowering five-year-old citrus trees. Additionally, it has also increased the number of new shoots, total length of new shoots per plant and total new leaves per plant.

P. Nandi *et al*. (2017) conducted an investigation to study the effect of shoot bending timing on guava cv. Khaja at the Horticulture Research Station, Mondouri of Bidhan Chandra Krishi Viswavidyalaya. Seven Shoot Bending months were selected viz., October, November, march, April, may, June and control. June bending was to be most efficient in early emergence of new shootlets (15 days), fruit set (197.67), flower initiation (40.33 days) while fruit weight (197.67g), fruit length (8.00cm) , fruit diameter (7.16cm) were also increase with the similar treatment. While bending in October recorded an increase in C:N ratio of leaf, flowering shootlets and overall yield (63.67).

Aly *et al*. (2017) examined the influence of shoot bending, shoot girdling, and gibberins on three-year-old pear plants and found that shoot bending and gibberins had a positive effect on fruit set per plant, total number of fruits per tree, total yield, fruit weight, fruit size, fruit length, fruit diameter, fruit firmness, leaf area, and the number of spurs. Similarly, Sarkar *et al*. (2017) studied the effects of bending, shoot pruning, and girdling as crop regulations in guava cultivar Kazi in Nagaland, where they recorded the highest yield with bent shoots. Cvetkovic *et al.* (2017) reported that bending of shoots encourages the formation of a proper crotch angle, while Jung and Choi (2010) noted that branch bending increases fruit yield and firmness. Budhiarto *et al*. (2018) found that bending trees to produce flowering and fruiting resulted in higher productivity compared to control trees, with flower retention percentage also increasing, and a significant reduction in flower drop (27%) in bent trees compared to untreated ones.

Mishra *et al*. (2020) studied and claimed that the control trial had taller growth as compared to bent branches. Shoot bent trees required minimum days for the emergence of new shoots (18 days) and flower initiation (50.5 days) concerning control which were 35.8 days and 50.5 days respectively. The days taken for fruit maturity also marked a reduction of 126.7 days with Shoot bending. Moreover, the highest number of fruits were also obtained from bent shoots.

Samant and Kishore (2021) studied a research trial to examine the response of guava cv. Arka Amulya to Shoot Bending during different seasons. They recorded a significant increase in average fruit weight, fruit harvest volume, total number of fruits, and harvesting yield compared to untreated plants.

Kumar *et al.* (2022) experimented to examine the influence of different crop regulation methods on vegetative traits of guava (*Psidium guajava* L.) cv. G-27. They recorded that, Mid-June bending took lesser days for sprouting of new shoots (13.17days), emergence of new leaf (15.17 days) while an increase in shoot length was at 30,60 and 90 days of bending done in mid-may which were 7.24,18.41 and 35.87 cm respectively.

While, Mishra and Singh (2022) reviewed crop regulation in fruit crop, reported that Shoot Bending performed in may month recorded good growth of shoots (56.91cm) in comparison with control.

Pratap *et al*., (2022) pointed out that with the shoot bending wood tension increases which leads to fall in phloem formation. While the C:N ratio was accumulated at peculiar regions due to the slow translocation of photosynthetic products which has contributed to more flower and fruit set.

3.2.2. Effect of shoot bending on qualitative traits of guava and other fruits

Abd El-Rahman *et al.* (2002) pointed out that bending performed in the month of winter at 45^{o} on three-year-old trees and 90^{o} on two-year-old witnessed a significant increase in TSS, Total sugar, and ascorbic acid while an increase in C/N ratio of spur wood was also observed with decrease in ABA level.

Colaric *et al*., (2006) studied the influence of Sheet Bending on organic acid, sugar, and phenolic content in cultivar Williams pear. They recorded that bending performed in summer gave the lowest amount of total sugars, citric acid and phenolic content whereas bending done in spring season gives good amounts of fructose, sorbitol, total sugars, caffeic acid and catechin. While, Kandil *et al*., (2006) analyzed the impact of bending and girdling on growth and fruiting of apple cultivar Anna. They reported an increase in TSS, total sugar, reducing sugars, leaf nutrients, carbohydrate content with reduced acidity percentage.

Han *et al.,* (2008) examined the effectiveness of Sheet Bending angle on physiological traits and fruit quality of fuji apple. They recorded the highest Vitamin C and pectin content with 110^{o} shoot bending. The negligible change was recorded in the total sugar percentage. With 110^{o} inclination reduction on acidity percentage was observed. While, Jung and Choi, (2010) conducted an experiment on apple trees trained to the Sole Axe system and reported an increase in fruit quality viz. skin colour, TSS, Vitamin-C, total sugar and subsequent decrease in titratable acidity.

Zhang *et al.* (2015) reported an increase in the concentration of ABA and ZR in the shoot apical meristem, with a reduction in IAA and GA3 concentrations at a bending angle of 70 to 110 degrees in apple trees. Similarly, Murri *et al.* (2015) examined the effects of various bending angles on the quality and growth of pears, recording an increase in total soluble solids, non-reducing sugar, reducing sugar, and ascorbic acid at a 45-

degree bending angle. Sarker *et al.* (2017) observed a positive increase in TSS, total sugars, TSS: Acid ratio, and vitamin C content, along with a decrease in acidity and core weight in guava cv. Kazi.

Khandekar *et al*. (2020) studied the impact of Shoot Bending angle on growth and flowering of wax apples. Sheet Bending was performed at different angles comprising 20º,45º, 65º and 85º with one control. They recorded an increase in fruit TSS at 45º followed by 65º angle for leaves while 85º bent shoots recorded the highest TSS for fruits. Highest chlorophyll content was recorded with 5º angle with mean value 44.16. Moreover, Highest K content was recorded with 85º degrees. On the other hand, Lu *et al*., (2022) carried out research on canopy position and microclimate on fruit development and quality of *Camellia Oleifera*. They reported significant changes in total solids, anthocyanin content, carbohydrate content. Ascorbic acid, and total sugars with the alternation in canopy orientation.

Zhang *et al*., (2023) carried out a research trial to study the effect of Shoot Bending on the canopy characteristics and growth of peach where they discovered an elevation in vitamin C percent. Total sugar, TSS, non-reducing sugar and carbohydrate content with decrease in acidity percent.

CHAPTER III

MATERIALS AND METHODS

The details of materials and methods followed in the research entitled ‘‘Studies on Efficacy of Shoot Bending and Plant Growth Regulators in Different Months in Guava Crop’’ are presented in this chapter

3.1 Experimental site

The present investigation was carried out for two consecutive years i.e., 2022-23 and 2023-24 at the Horticultural Orchard, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab.

3.2 Climate

The ancient city of Phagwara, steeped in historical importance, is situated in the Doaba region of Punjab. It occupies a strategic location between the Beas and Sutlej rivers, with geographical coordinates of 31.326° N latitude and 75.576° E longitude. The city's elevation stands at roughly 228 meters above sea level, contributing to its unique topographical profile (Singh *et al.,* 2021). Jalandhar's climatic patterns are typical of the region, featuring an annual rainfall average of 703mm. This precipitation is not evenly distributed throughout the year, with the bulk concentrated during the monsoon period spanning July to September (Kaur and Arneja, 2020).

3.3 Meteorological conditions of the experimental area

Meteorological data i.e., temperature and relative humidity (maximum and minimum), for the months between August 2022 to April 2024 is shown in Table 3.1.

Table 3.1 The meteorological data for an experimental area from 2022-23 and 2023-24.

Month	Year	Average Temperature (°C)		Average Relative Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
August	2022	34.51	27.00	92.37	70.38
September	2022	34	24	92	65
October	2022	31.12	16.24	90.07	49.72
November	2022	26.6	11.	92.8	51.7
December	2022	21.25	6.31	94.14	57.68
January	2023	15.9	10.43	75.93	62.76
February	2023	16	9	64	78
March	2023	26.41	17.83	54.25	43.58

Month	Year	Average Temperature (°C)		Average Relative Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
April	2023	38.6	27.66	42.03	31.33
August	2023	36.85	25.9	85.05	64.29
September	2023	35	24.2	80.55	63.36
October	2023	32.25	20.48	93.05	44.19
November	2023	25.86	14.16	89.05	45.33
December	2023	24.83	10.25	97.25	60.87
January	2024	15.8	10.41	75.89	62.71
February	2024	16.5	9.5	62.7	72.08
March	2024	26.46	17.88	52.01	42.18
April	2024	38.8	27.69	39.64	30.08

(Source: Department of Agro-meteorological, LPU, Punjab)

3.3.1 Temperature (°C)

An experiment was started in the months of August, September, and October for both years (2022-23). In 2022, the maximum mean temperatures recorded during the experimental period were 34.51°C in August, 34°C in September, and 31.12°C in October, with corresponding minimum temperatures of 27°C, 24°C, and 16.24°C. For 2023, the maximum mean temperatures were slightly different: 36.85°C in August, 35°C in September, and 32.25°C in October, while the minimum temperatures were 25.9°C, 24.2°C, and 20.48°C, respectively. This data is detailed in the accompanying fig. 3.1.

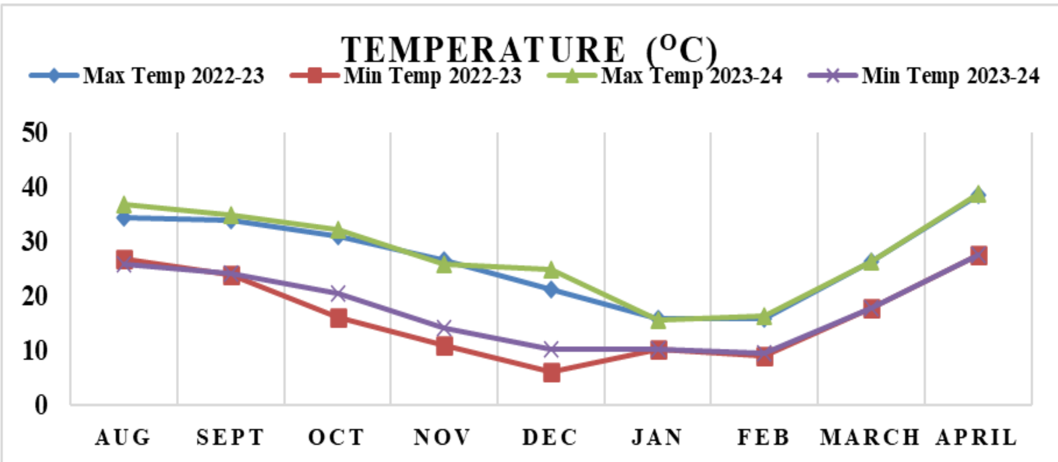


Fig. 3.1 Graphical representation of temperature for duration of 2022-23 to 2023-24.

3.3.2 Relative humidity (%)

The maximum mean relative humidity during the experiment was recorded in

August, September, and October of 2022, reaching 92.37%, 92%, and 90.077% respectively. The minimum relative humidity for those months was 70.36%, 65%, and 49.72%. In 2023, the maximum relative humidity in 2023 for the same months was slightly lower at 85.05%, 80.55%, and 93.05%, with minimum values of 64.29%, 63.36%, and 44.19% shown in fig. 3.2. These variations highlight the differences in atmospheric moisture levels between the two years.

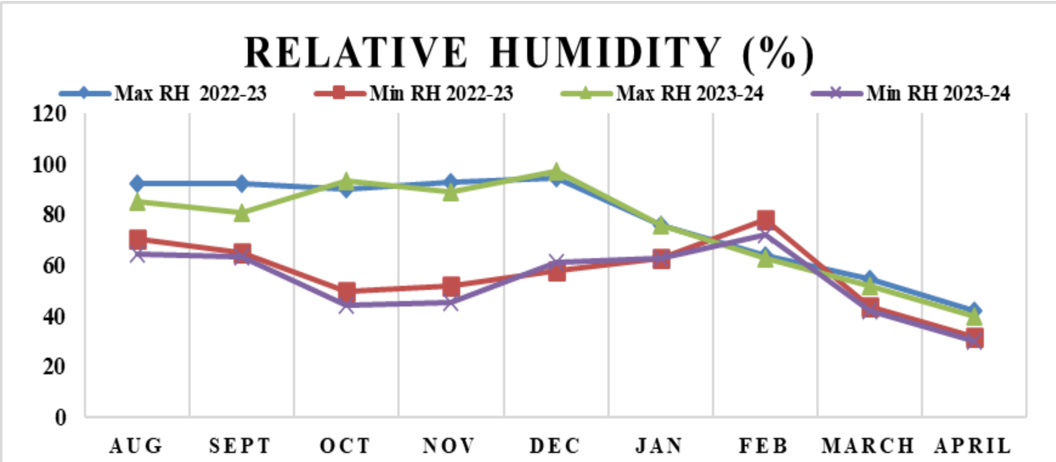


Fig. 3.2 Graphical representation of relative humidity for duration of 2022-23 to 2023-24.

3.3.3 Soil of the experimental field

3.4.1 Soil sample collection

At the beginning of the research a series of random soil samples were obtained from an experimental site. Prior, the surface layer was scraped off, after that V-shaped incision is made at the depth of 6 inches. One-inch-thick slice of soil was procured from one end of the incision. Total ten samples were collected with the sampling process in the zig-zag manner. 500 grams of homogenous composite soil sample was derived with the quartering method. These samples were used to examine the physical and chemical characteristics of soil. Table 3.2 represents physio-chemical properties of soil.

Table 3.2 Physio-chemical properties of experimental soil

Sr. No.	Characteristics of the soil	Content	Method of analysis	Reference
Mechanical				
i.	Coarse sand (%)	70%	Hydrometer	Bouyoucos (1962)

Sr. No.	Characteristics of the soil	Content	Method of analysis	Reference
			method	
ii.	Soil texture	Sandy loam	Sensory evaluation	
iii.	Silt (%)	14.3%	Hydrometer method	Bouyoucos (1962)
iv.	Clay (%)	15.7%	Hydrometer method	Bouyoucos (1962)
		Chemical		
i.	Organic carbon (%)	0.45%	Rapid titration method	Walkley and Black (1947)
ii.	Available nitrogen (kg ha^{-1})	145 kg ha^{-1}	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
iii.	Available phosphorus (kg ha^{-1})	13.8kg ha^{-1}	Olsen's method	Olsen *et al*. (1954)
iv.	Available potassium (kg ha^{-1})	168 kg ha^{-1}	Flame photometer method	Richards (1968)
v.	Electrical conductivity (dSm^{-1}) at 25ºC	0.31 dSm^{-1}	Using Solubridge	Richards (1968)
vi.	pH (1:2 soil water ratio)	7.6	Blackman's pH method	Piper (1950)

3.5 Details of experiment

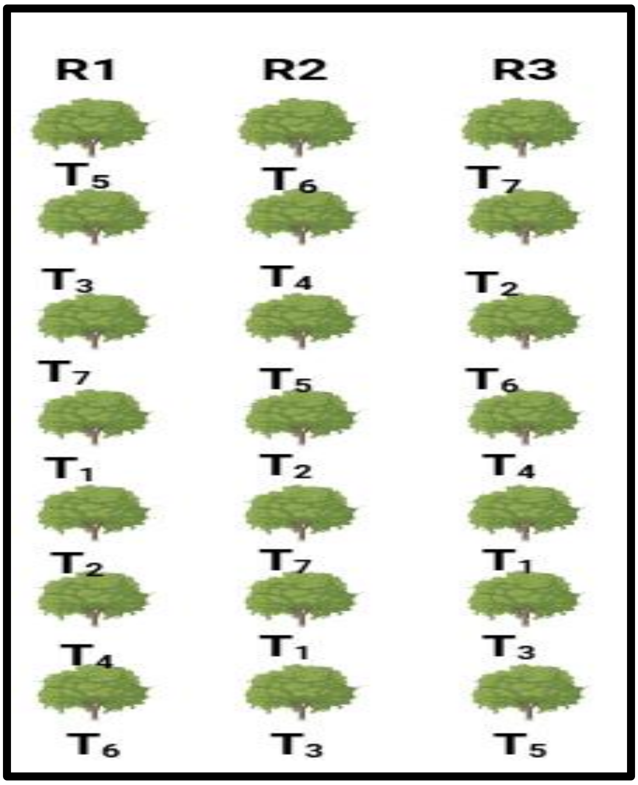
The experiment was carried out in Factorial Randomized Block Design with three replications. The details of the layout were as under:

1.	Name of crop	Guava (*Psidium guajava* L.)
2.	Name of cultivar	Allahabad safeda
3.	Plant age	Six-year-old
4.	Plant spacing	6m ×6m
5.	Number of replications	Three
6.	Number of treatments	Twenty-one
7.	Number of experimental plants	63
8.	Number of plant growth regulators	Three
9.	Number of experimental months	Three
10.	Statistical design	Factorial Randomized Block Design
11.	Factor	Shoot bending months
12.	Factor B	Plant growth regulators

3.6 Field practices followed

Fertilizer application involved the use of 13-20 kg of farmyard manure (FYM), 150 g of urea, 750-1000 g of superphosphate, and 300-500 g of muriate of potash (MOP) per tree, as recommended by Punjab Agricultural University (PAU) for Recommended fertilizer dose (RFD). These fertilizers were applied in split doses, with half administered 15 days prior to Shoot Bending and the remaining half at the marble stage of fruit development. Irrigation was provided at monthly intervals, and timely weeding was carried out two weeks after fertilizer application to ensure proper nutrient uptake and plant health.

3.7 Layout of experimental design



(T_1: $M_1 \times C_1$, T_2: $M_1 \times C_2$, T_3: $M_1 \times C_3$, T_3: $M_1 \times C_4$, T_5: $M_1 \times C_5$, T_6: $M_1 \times C_6$, T_7: $M_1 \times C_0$, T_8: $M_2 \times C_1$, T_9: $M_2 \times C_2$, T_{10}: $M_2 \times C_3$, T_{11}: $M_2 \times C_4$, T_{12}: $M_2 \times C_5$, T_{13}: $M_2 \times C_6$, T_{14}: $M_2 \times C_0$, T_{15}: $M_3 \times C_1$, T_{16}: $M_3 \times C_2$, T_{17}: $M_3 \times C_3$, T_{18}: $M_3 \times C_4$, T_{19}: $M_3 \times C_5$, T_{20}: $M_3 \times C_6$,T_{21}: $M_3 \times C_0$)

3.8 Combination details

The experiment comprised three months for shoot bending: M_1 (shoot bending in August), M_2 (shoot bending in September), and M_3 (shoot bending in October). Additionally, three plant growth regulators were applied at two different concentrations, including one control: C_1 (NAA @ 100 ppm), C_2 (NAA @ 200 ppm), C_3 (Ethrel @ 200 ppm), C_4 (Ethrel @ 400 ppm), C_5 (GA_3 @ 100 ppm), C_6 (GA_3 @ 150 ppm), and C_0 (Control). Experimental details are shown in Tables 3.3 and 3.4.

Table 3.3 Detail of plant growth regulators and shoot bending months.

Sheet bending months	**PGR (concentration in ppm)**						
	C_1	C_2	C_3	C_4	C_5	C_6	C_0
	NAA @100	NAA @200	Ethrel @200	Ethrel @400	GA_3 @100	GA_3 @150	Control
	Treatments (M×C)						
M_1 (August)	T_1	T_2	T_3	T_4	T_5	T_6	T_7
M_2 (September)	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
M_3 (October)	T_{15}	T_{16}	T_{17}	T_{18}	T_{19}	T_{20}	T_{21}

Treatments

I. Shoot bending months

a) August M_1

b) September M_2

c) October M_3

II. **Plant growth regulators**

a) NAA@100ppm C_1

b) NAA@200ppm C_2

c) Ethrel@200ppm C_3

d) Ethrel@400ppm C_4

e) GA_3@100ppm C_5

f) GA_3@150ppm C_6

g) Control C_0

Table 3.4 Detail of treatments in combination

Treatment	Combination ($M_n \times C_n$)	Plant growth regulator concentration (ppm)	Shoot bending month
T_1	$M_1 \times C_1$	C_1: NAA@100	August
T_2	$M_1 \times C_2$	C_2: NAA@200	August
T_3	$M_1 \times C_3$	C_3: Ethrel@200	August
T_4	$M_1 \times C_4$	C_4: Ethrel@400	August
T_5	$M_1 \times C_5$	C_5: GA_3@100	August
T_6	$M_1 \times C_6$	C_6: GA_3@150	August
T_7	$M_1 \times C_0$	C_0: Control	August
T_8	$M_2 \times C_1$	C_1: NAA@100	September
T_9	$M_2 \times C_2$	C_2: NAA@200	September
T_{10}	$M_2 \times C_3$	C_3: Ethrel@200	September
T_{11}	$M_2 \times C_4$	C_4: Ethrel@400	September
T_{12}	$M_2 \times C_5$	C_5: GA_3@100	September
T_{13}	$M_2 \times C_6$	C_6: GA_3@150	September
T_{14}	$M_1 \times C_0$	C_0: Control	September
T_{15}	$M_3 \times C_1$	C_1: NAA@100	October
T_{16}	$M_3 \times C_2$	C_2: NAA@200	October
T_{17}	$M_3 \times C_3$	C_3: Ethrel@200	October
T_{18}	$M_3 \times C_4$	C_4: Ethrel@400	October
T_{19}	$M_3 \times C_5$	C_5: GA_3@100	October
T_{20}	$M_3 \times C_6$	C_6: GA_3@150	October
T_{21}	$M_1 \times C_0$	C_0: Control	October

3.7.1 The procedure followed for shoot bending in guava

Shoot bending was carried out at thirty days in interval in hast bahar, starting from August 1st (M_1) and continuing until October (M_3), during the morning hours, specifically between 8:00 and 10:00 A.M. The bending was performed manually by thinning branches and shoots using a secateur. Representative secondary branches were selected from each experimental tree based on their flexibility (neither too tender nor too stiff). A feasible angle of 45^0 was created between the primary shoot and secondary branches using ropes tied to pegs in the soil. The ropes were untied after the emergence of new shootlets

3.7.2 Preparation and spraying of plant growth regulators

A foliar spray of PGRs was made once after the emergence of shootlets and subsequent untying of secondary branches.

Materials Required

- PGRs: NAA 100 and 200 ppm, ethrel 200 and 400 ppm and GA_3 100 and 150 ppm.
- Distilled water
- Weighing balance (accuracy up to 0.001 g)
- Volumetric flask (1000 mL)
- Magnetic stirrer
- Glass rod or spatula
- Dropper

a) **NAA @100ppm (C_1) and NAA @200ppm (C_2)**

Two NAA (Naphthalene Acetic Acid) solutions with concentrations of 100 ppm and 200 ppm were prepared for spraying on experimental plants. To make 6 litres of the 100 ppm solution, 600 mg of NAA was accurately weighed using an analytical balance; for the 200 ppm solution, 1200 mg of NAA was weighed for the same volume. Each measured amount of NAA was first dissolved in a small volume of ethanol to enhance solubility. Distilled water was gradually added to each container while stirring, and the final volumes were adjusted to 6 litres. The solutions were thoroughly mixed to ensure uniformity and were subsequently used to spray experimental plants.

b) Ethrel @200ppm (C_3) and ethrel @400ppm (C_4)

Two Ethrel solutions with concentrations of 200 ppm and 400 ppm were prepared for spraying on experimental plants. For the 200 ppm solution, 2.5 mL of Ethrel was measured, and for the 400 ppm solution, 5 mL was measured, diluted to a final volume of 6 litres. Each container was rinsed with distilled water to ensure full transfer of the Ethrel, and the remaining distilled water was added gradually while stirring. The final volumes were adjusted to 6 litres for both solutions. After thorough mixing to ensure uniformity, the solutions were used to spray experimental plants.

c) GA_3 @100ppm (C_5) and GA_3 @150ppm (C_6)

To prepare GA_3 (Gibberellic Acid) solutions at concentrations of 100 ppm and 150 ppm for spraying on experimental plants, 600 mg of GA_3 was weighed for the 100 ppm solution and 900 mg for the 150 ppm solution. GA_3, being slightly insoluble in water, was first dissolved in a small amount of ethanol to enhance solubility. Distilled water was gradually added while stirring, and the final volume was adjusted to 6 liters for both solutions. After thorough mixing, the solutions were applied to spray experimental plants.

3.8 Observations

The following observations were recorded during the experimental period in the year 2022-23 and 2023-24.

3.8.1 Vegetative Parameters

(i) Canopy spread(N-S) (m)
(ii) Canopy spread(E-W) (m)
(iii) Canopy height (m)
(iv) Stem girth (cm)
(v) Truck cross section area (cm^2)
(vi) Leaf length (cm)
(vii) Leaf width (cm)
(viii) No. of leaf pair per shoot
(ix) Days taken for emergence of new shootlets
(x) New shoots per branch
(xi) Shootlets length (cm)
(xii) Internode length (cm)

3.8.2 Reproductive Parameters

(i) Fruit length (cm)
(ii) Fruit diameter (cm)
(iii) Fruit weight (g)
(iv) Days required for fruit set
(v) Flower bud $plant^{-1}$
(vi) Initial fruit set $plant^{-1}$
(vii) Total number of fruits $plant^{-1}$
(viii) Fruit retention $plant^{-1}$ (%)

3.8.3 Biochemical parameters of fruits

(i) TSS (^{0}Brix)

(ii) Reducing sugar (%)

(iii) Non-reducing sugar (%)

(iv) Total sugar (%)

(v) Titratable acidity (%)

(vi) Ascorbic acid (mg /100g of pulp)

(vii) Sugar acid ratio

(viii) Pectin (%)

3.8.4 Biochemical parameters of leaf

(i) Total Chlorophyll (mg/100g of pulp)

(ii) C:N ratio

3.8.5 Leaf Nutrient parameters of leaf

(i) Nitrogen (%)

(ii) Phosphorous (%)

(iii) Potassium (%)

(iv) Zinc (ppm)

(v) Boron (ppm)

3.8.6 Proximate Analysis of leaf

(i) Total Carbohydrate (%)

(ii) Ash (%)

(iii) Moisture (%)

(iv) Protein (%)

3.8.7 Yield parameters

(i) Yield (kg/tree)

(ii) Yield Efficiency (kg/cm^2)

3.9 Methodology used for recording observations

3.9.1 Vegetative parameters

The observations were recorded after 60 days of treatment exposure to plant,

I. Canopy spread (N-S) (m)

Plant spread (North-South) direction was recorded by measuring tape and the average plant spread was worked out and recorded as plant spread (North-South) and was calculated using the formula, Increment in canopy spread (C_2-C_1)

II. Canopy spread (E-W)

A measuring tape was used to record a rise in plant spread (East-west) direction, and the average plant spread of the plant was calculated and recorded as plant spread (East-west) at the beginning (C_1) and at the time of harvesting (C_2) of treatment in meters.

III. Canopy height (m)

Canopy height is measured by measuring tape starting from the top leaf of the main stem to the bottom last leaf in meters at the start (CH_1) and at the harvesting period (CH_2) from the experimental tree.

IV. Stem girth (cm)

One circular line was drawn on the main trunk with white paint 20 cm above the ground and the observations were collected with a digital vernier calliper at initial and after 60 days in experimental pants in centimetres.

V. Trunk cross-sectional area (cm^2)

The trunk cross-sectional area was calculated as per the method given by Westwood (1993).

$$TCSA=\frac{(Girth)2}{4\pi}$$

VI. Leaf length (cm)

Length of leaf was measured with digital vernier calliper after 60 days of experiment from the ten representative leaves across the replicates and data was presented as average leaf length in centimetres.

VII. Leaf width (cm)

The width of leaf was recorded with a digital vernier calliper after 60 days of treatment from the ten leaves of each replication and the data was presented as average leaf width in centimetres.

VIII. Number of leaf pairs per shoot

New emerging pairs of leaves per bent shoots were recorded and average value was counted per tree after 60 days of treatment.

IX. Days taken for emergence of new shootlets.

Number of days taken for emergence of new shootlets from bent branches of the experimental plant were recorded.

X. New shoots per branch.

Number of new shootlets emerged per Shoot from the bent shoots of the experimental tree were recorded and the average value was counted per tree after 60 days of treatment.

XI. Length of shootlets (cm)

Length of newly emerged shootlets was measured by vernier calliper in centimetres after 60 days of the experiment across the replicates from ten representative shootlets and data was presented as average length of shootlets.

XII. Length of internode (cm)

A random sample of 10 healthy shootlets were selected from each combination and length of internode was recorded with a vernier calliper in centimetres after 60 days of the experiment. The mean data of the collected length of internode was expressed in centimetres

3.9.2. Reproductive Parameters

I. Fruit length (cm)

The length of the fruit was measured from the calyx end to the pointed end or apex of the fruit using a vernier calliper and expressed in centimetres from randomly selected healthy fruits. The data were presented as the mean fruit length for each combination.

II. Fruit diameter (cm)

Fruits were randomly selected from each treatment and replication, ensuring a representative sample. The equatorial diameter (the widest part of the fruit) was measured by placing the calliper jaws perpendicularly around the fruit's central axis, and the data were expressed as the average fruit diameter per combination in centimetres.

III. Fruit weight (g)

Fruits were plucked at the ripening stage from healthy fruits at the ripening stage and weighed by using an electronic balance and data was presented as average fruit weight in grams per combination.

IV. Days required for fruit set

The number of days from the start of the experiment to the onset of the fruit set were meticulously recorded from tagged branches and data expressed in average each experimental tree.

IV. Flower bud per plant

The number of buds per plant was carefully counted by direct observation from representative shoots, and the mean was subsequently calculated per combination.

VI. Initial number fruit set per plant

The fruit set observed during the initial stage was recorded meticulously across the replications from experimental branches and an average value was presented for each combination.

VII. Total number of fruits per plant at harvest

The total number of fruits set present per plant from representative shoots were recorded for two harvestings from each treatment and data was expressed in mean per combination.

VIII. Fruit retention per plant (%)

The total number of fruits at the time of harvest was divided to an initial number of fruit set divided to 100.

Fruit retention (%): $\frac{Number\ of\ fruits\ at\ harvest}{Initial\ number\ of\ fruit\ set} \times 100$

3.9.3 Biochemical analysis guava fruits

I. Total soluble solids (°Brix)

Total soluble solids in Guava were measured with the help of a digital refractometer. Couple of juice drops were placed on the prism column and readings were recorded. (A.O.A.C.,1990)

II. Estimation of total sugars (%)

The total and reducing sugar content in guava fruit was determined following the Lane and Eynon volumetric method, as described by AOAC (1990). For this analysis, 10 ml of fruit pulp was taken in a beaker, to which 2 ml of lead acetate was added to facilitate the precipitation of interfering substances. The resulting mixture was filtered using Whatman No. 1 filter paper. To remove excess lead acetate, potassium oxalate was introduced into the filtrate, followed by thorough mixing and a second filtration through the same filter paper. The final filtrate was diluted to 100 ml with distilled water, yielding the clarified solution required for sugar estimation. For the determination of total sugars, this clarified solution was subjected to acid hydrolysis by adding 5 ml of concentrated hydrochloric acid (60%). The hydrolysed sample was kept at room temperature for 24 hours, followed by heating in a water bath at 68°C for 10 minutes to ensure complete hydrolysis. The excess HCl in the solution was neutralized through sequential titration with 40% NaOH, 10% NaOH, and finally 0.1N NaOH, ensuring precise neutralization. The neutralized solution was subsequently titrated against a boiling mixture of 5 ml each of Fehling's A and Fehling's B solutions, employing methylene blue as an indicator. The titration was carried out until a brick-red precipitate was formed, signifying the endpoint. The total sugar content was then computed using the standard formula for sugar estimation.

$$\frac{Fehling\ Solution\ factor\ (0.05)}{Volume\ of\ filtrate\ made} \times \frac{Total\ sugar\ (\%) = Dilution\ made}{Volume\ of\ juice\ taken} \times \frac{Final\ Volume\ made}{Volume\ of\ aliquot\ taken} \times 100$$

III. Estimation of reducing sugars

The quantification of reducing sugars was conducted using a titration method similar to that employed for total sugar estimation. The analysis involved titrating the unhydrolyzed, delead, and clarified aliquot against a boiling Fehling's solution (prepared by mixing 5 ml each of Fehling's A and Fehling's B solutions). Methylene blue was used as an indicator to monitor the reaction progress. The titration was carried out until the formation of a brick-red precipitate, indicating the endpoint. Following the completion of the titration, the percentage of reducing sugars was determined using the standard formula.

$$\text{Reducing sugar (\%):}\ \frac{Fehling\ Solution\ factor\ (0.05)}{Volume\ of\ filtrate\ made} \times \frac{Dilution\ made}{Volume\ of\ fruit\ pulp\ taken} \times 100$$

IV. Estimation of non-reducing sugar (%)

There is no direct method for analysing non-reducing sugar, but we can get the non-reducing sugar content by subtracting the reducing sugar from the overall sugar content, which we utilized in the current experiment to estimate the non-reducing sugar content in Guava.

Non- reducing sugars (%) = Total sugars – Reducing sugars

V. Titratable acidity (%)

The acidity of guava juice was determined through a titration procedure using a 0.1 M sodium hydroxide (NaOH) solution. The guava juice sample was first prepared and transferred into a clean Erlenmeyer flask. A few drops of phenolphthalein, a pH indicator, were added to the juice to signal the end point of the titration. The 0.1 M NaOH solution was then gradually added from a burette to the flask while continuously swirling the mixture. The titration continued until a persistent color change was observed, indicating that all the free acids in the guava juice had been neutralized by the NaOH. The volume of NaOH used was recorded, and the acidity of the guava juice was calculated based on the amount of NaOH required for neutralization. This method provided a precise measure of the guava juice's acid content, which is crucial for evaluating its quality and flavor. (A.O.A.C.,1995).

VI. Ascorbic acid (mg/100g of pulp)

The procedure described by Ranganna (2003) was followed to assess ascorbic acid in Guava. First, the Guava pulp extract was homogenized and filtered. A 10 mL aliquot of the filtered extract was transferred to a 100 mL volumetric flask, and the volume was adjusted with 3% metaphosphoric acid. For the ascorbic acid determination, the aliquot was titrated with standardized 2,6-dichlorophenol indophenol dye until a pink endpoint appeared. The ascorbic acid content was then calculated using the given formula and expressed in milligrams per 100 grams of fresh weight.

$$\text{Ascorbic acid (mg/100g of fresh weight)} = \frac{Titre \times Dye\ factor \times Volume\ made\ up}{Aliquot\ taken \times Weight\ of\ Sample} \times 100$$

Where, dye factor was calculated by titrating standard of L-ascorbic acid solution (mg/100g) against 2,6-dichlorophenol indophenol dye.

$$\text{Dye factor} = \frac{0.5}{Titre\ Value}$$

VII. Sugar acid ratio

The ratio of total sugar to titratable acidity was calculated.

VIII. Pectin content (%)

Pectin was extracted using the gravimetric method underlined by Ranganna (2003). Fresh material (50 g) was blended and weighed into a 1000-ml beaker, then extracted with 400 ml of 0.05 N HCl for 2 hours at 80-90°C, replacing water lost by evaporation. After cooling, the contents were transferred to a 500-ml volumetric flask and made up to the mark with water, then filtered through No. 4 Whatman paper into a 500-ml conical flask. To solubilize the insoluble pectin, acid extraction was performed, and repeated extractions were done with cold water followed by boiling.

Aliquots of 100-200 ml were pipetted into two 1000-ml beakers, 250 ml of water was added, and the acid was neutralized using 1 N NaOH with phenolphthalein as the indicator. An excess of 10 ml of 1 N NaOH was added and allowed to stand overnight. Then, 50 ml of 1 N acetic acid was added, followed by 25 ml of 1 N calcium chloride, and the mixture was stirred. After standing for 1 hour, it was boiled for 1-2 minutes, then filtered through a pre-wetted filter paper. The precipitate was washed with cool water and tested for chlorides using silver nitrate. The filter paper containing the calcium pectate was transferred to the original weighing dish, dried overnight at 100°C, cooled in a desiccator, and weighed. The calculation is made using the following formula,

$$\%\text{ Calcium pectate} = \frac{Weight\ Ca\ Pectate \times 500 \times 100}{ml\ of\ filtrate\ taken \times weight\ of\ sample}$$

3.9.4 Biochemical analysis guava leaf

I. Total chlorophyll (mg/100 g of pulp)

The total chlorophyll content in guava leaves was measured using the acetone extraction method, following the procedures described by Pattering *et al*., (1940) and Comar *et al*., (1943). The guava leaves were first collected and dried to a constant weight before being ground into a fine powder. This powder was then mixed with acetone to extract the chlorophyll pigments. The chlorophyll extract was analyzed spectrophotometrically at wavelengths of 645 nm and 663 nm to determine the concentration of chlorophyll a and b, respectively. This method provided an accurate assessment of the chlorophyll content, which is essential for evaluating the photosynthetic potential and overall health of the guava leaves.

III. C: N ratio

The ratio of Carbohydrates to Nitrogen percentage of leaves was calculated.

3.9.5 Leaf nutrient analysis

The collection of leaf samples were made from the middle of the current season's growth, which was around the periphery of the tree.

I. Nitrogen (%)

The nitrogen content in guava (*Psidium guajava*) leaves was determined using the Kjeldahl method, which involved digestion, distillation, and titration. Finely ground, oven-dried leaf samples (0.5–1.0 g) were digested in a Kjeldahl flask using concentrated sulfuric acid (H_2SO_4) and a catalyst mixture (K_2SO_4 and $CuSO_4$ in a 10:1 ratio) to facilitate complete decomposition of organic matter. The digestion process was continued until the solution turned clear, indicating the breakdown of nitrogenous compounds into ammonium sulphate. After cooling, the digest was diluted and treated with 40% NaOH, releasing ammonia gas, which was subsequently distilled into 4% boric acid solution containing an indicator solution. The ammonia absorbed in boric acid was quantified through titration with 0.1 N HCl, with a color change from green to pink marking the endpoint. The nitrogen content was calculated using the formula

$$\text{Percentage of Nitrogen} = \frac{V \times N \times 1.4}{W}$$

where V represents the titrant volume, N the normality of HCl, and W the sample weight. This method provided an accurate estimation of total nitrogen in guava leaves, allowing for the evaluation of plant nutritional status. (Jones, 2001; Lachat Instruments, 1996).

II. Phosphorous (%)

Phosphorus content in guava leaves was determined using a colorimetric method following sulfuric acid digestion (Olsen and Sommers (1982). The leaves were oven-dried at 65–70°C until a constant weight was achieved and then ground to pass through a 0.5 mm sieve. Approximately 0.5 g of the ground leaf sample was weighed into a digestion tube, to which 5 mL of concentrated sulfuric acid (H_2SO_4) was added. The mixture was gently heated until the initial reaction subsided, then the temperature was increased to maintain boiling. After the solution darkened, indicating partial digestion, hydrogen peroxide (H_2O_2) was added cautiously to assist in complete digestion and decolorization. The solution was heated until it became clear, indicating complete oxidation of organic material, then allowed to cool and diluted to a known volume with distilled water. An aliquot of the digested sample was pipetted into a test tube, to which ammonium molybdate solution was added. Ascorbic acid was introduced to reduce the molybdate-phosphate complex, forming a blue-colored complex. After allowing 15–30 minutes for color development, the absorbance was measured at 880 nm using a spectrophotometer. The phosphorus concentration in the sample was determined by comparing the absorbance readings to a calibration curve prepared with standard phosphate solutions. To express phosphorus concentration in percent (%), following conversion formula was used,

$$P\ (\%) = \frac{Phosphorus\ concentration\ (mg/l)\ \times final\ Volume\ (ml)}{Sample\ weight} \times 100$$

III. Potassium (%)

Potassium content in guava leaves was determined using the flame photometry method (Jackson, 1973). The dried and ground guava leaf sample (0.5 g) was digested with nitric acid (HNO_3) and perchloric acid ($HClO_4$) to break down the organic matter and release potassium ions. After digestion, the solution was diluted to a known volume with distilled water. A series of standard potassium solutions was prepared, and their absorbance was measured using a flame photometer, with the specific wavelength of 766.5 nm used for potassium analysis. The potassium concentration in the sample was determined by comparing its absorbance to the calibration curve created from the standard solutions. The potassium content in the sample was calculated using the formula:

$$K\ (\%) = \frac{Potassium\ (mg/l) \times Final\ Volume\ (ml)}{Sample\ Weight\ (g)} \times 100$$

IV. Zinc (ppm)

The zinc content in guava leaves was determined using a spectrophotometric method following digestion. Approximately 0.5 g of dried, ground guava leaf sample was digested using 5 mL of concentrated nitric acid (HNO_3) and 2 mL of perchloric acid ($HClO_4$) until complete oxidation of organic material occurred. The digest was then cooled and diluted to a known volume (e.g., 50 mL) with distilled water. A 5 mL aliquot of the digested sample was reacted with 2,2'-bipyridyl or ammonium pyrrolidine dithiocarbamate (APDC) reagent, which forms a colored complex with zinc ions. After allowing the color to develop for 15–30 minutes, the absorbance of the solution was measured using a spectrophotometer at 520 nm, the specific wavelength for the zinc-bipyridyl complex (Marschner, 2012). A calibration curve was prepared using standard zinc solutions, and the zinc concentration in the sample was calculated by comparing its absorbance to the calibration curve. The zinc percentage in the leaf sample was then calculated using the formula:

$$Zn\ (ppm) = \frac{Zinc\ \ (mg/l) \times Final\ Volume\ (ml)}{Sample\ Weight\ (g)} \times 100$$

V. Boron (ppm)

To determine the boron content procedure outlined by (Jackson, 1973) where

0.5 g of dried guava leaves were grounded and placed in a porcelain or platinum dish, and 0.5 g of calcium hydroxide ($Ca(OH)_2$) was added to neutralize acids during ignition. The sample was ignited in a muffle furnace at 550°C for 4 hours until it turned into white-grey ash. After cooling, a small amount of distilled water (DW) was added, followed by 5 mL of 0.1 N hydrochloric acid (HCl) to dissolve the soluble components. The resulting solution was transferred to a 25 mL volumetric flask and made up to 25 mL with distilled water. A 1 mL aliquot of the solution was then analyzed using a spectrophotometer. The boron concentration in the sample was determined by comparing the absorbance of the sample to a calibration curve prepared with known boron standard solutions. The boron concentration was calculated using the formula.

$$\text{B (ppm)} = \frac{Absorbance\ of\ Sample}{Absorbance\ of\ Standard} \times Concentration\ of\ standard\ (ppm)$$

The boron content was expressed in ppm (parts per million)

3.9.6 Proximate analysis of guava leaf

I. Total carbohydrate (%)

The total carbohydrate content in the guava leaves was determined using the phenol-sulfuric acid method, as described by Dubois *et al.* (1956). The procedure involved first extracting carbohydrates from the guava leaf samples. A measured volume of the extract was mixed with concentrated phenol and sulfuric acid solutions in a test tube. The mixture was then heated to develop a color. After cooling, the intensity of the color was measured spectrophotometrically at 490 nm. The total carbohydrate concentration was calculated based on a standard curve prepared with known carbohydrate concentrations. This method provided an accurate quantification of the carbohydrate content in the guava leaves.

Absorbance corresponds to 0.1 ml of the test = x mg of glucose

$$\text{100 ml of the sample solution contains} = \frac{X}{0.1} \times 100\ mg\ of\ glucose$$

II. Ash (%)

Drying the sample at 100 ^{0}C over an electric heater. It was then ashed in a muffle furnace at 550 ^{0}C for 5 hrs. By AOAC (2005). It was calculated using the following formula:

$$Ash\ content\ (\%) = \frac{Weight\ of\ Ash}{Initial\ weight\ of\ dry\ matter} \times 100$$

III. Moisture (%)

Moisture content was determined by drying the fruit samples overnight in a hot-air oven at 105 ^{0}C. Moisture was determined and calculated using the AOAC method (2005).

$$Moisture\ content\ (\%) = \frac{Loss\ in\ weight}{Weight\ of\ sample} \times 100$$

IV. Protein (%)

Firstly, the nitrogen percentage was derived by the Kjeldahl digestion method. The nitrogen percentage is then multiplied by the conversion factor 6.25. Therefore, multiplying the nitrogen percentage by 5.32 converts it to an approximate percentage of protein in the guava leaves. (AOAC, 1995a)

$$Protein\ (\%) = Nitrogen\ (\%)\ \times 5.32$$

3.9.7 Yield attributes

I. Yield (kg/tree)

The total weight of guava fruits harvested from each combination was recorded and data was expressed in average yield in kilograms per tree.

II. Yield efficiency (Kg/cm^2)

The yield efficiency was calculated by adopting a method suggested by Westwood (1993). It is expressed in kg/cm^2 TCSA and calculated as under:

$$Yield\ efficiency = \frac{Yield\ (Kg/tree)}{Trunk\ cross\ sectional\ area\ (cm2)}$$

4.0 Statistical analysis

The experimental layout was a Factorial Randomized block design (FRBD) with three replications. The data obtained was analysed using OPSTAT Statistics software version 20. Two factorial analyses of variance (ANOVA) was used to evaluate significant differences in parameters studied in different treatments. Statistical significance, presented using letters in the tables below, was assumed at a level of 5% ($p < 0.05$).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter discusses the pooled results obtained from the study entitled "Studies on Efficacy of Shoot Bending and Plant Growth Regulators in Different Months in Guava Crop" conducted at the Fruit Research Orchard of Lovely Professional University, Punjab, for two consecutive years 2022-23 and 2023-24. It connects these findings to the existing literature. The data pertaining to the application of plant growth regulators and shoot bending are statistically significant, which are portrayed in the tabular format as well as in graphical form. ANOVA table for various traits is mentioned at the end of the appendices.

The results and discussions are displayed under the subsequent heads:

4.1 Effect of shoot bending and plant growth regulators on vegetative parameters of guava fruit crop

4.2 Effect of shoot bending and plant growth regulators on reproductive parameters of guava fruit crop

4.3 Effect of shoot bending and plant growth regulators on biochemical parameters of guava fruit

4.4 Effect of shoot bending and plant growth regulators on biochemical parameters of guava leaves

4.5 Effect of shoot bending and plant growth regulators on leaf nutrient parameter of guava leaves

4.6 Effect of shoot bending and plant growth regulators on proximate parameters of guava fruit crop

4.7 Effect of shoot bending and plant growth regulators on yield related parameters of guava fruit crop

4.1 Effect of shoot bending and plant growth regulators on vegetative parameters of guava fruit crop

4.1.1 Canopy spread (N-S) (m)

The pooled data obtained from the effect of shoot bending and PGRs on Canopy spread (N-S) have been interpreted in Table 4.1, portrayed in Fig. 4.1.1 and the analysis of variance is mentioned in Appendix I.

The data recorded from the plant growth regulator application was found to be significant in terms of canopy spread (N-S). Amongst the PGR, NAA at 200 ppm (C_2) gained the highest mean canopy spread (N-S) of 0.59m which was at par with NAA at 100 ppm (C_1) at 0.57m followed by GA_3 at 150 ppm (C_6) at 0.56m with lowest as noted from the control (C_0) at 0.36m. Shoot bending months have also significantly interacted with canopy spread (N-S) where August (M_1) gave the widest canopy spread (N-S) at 0.54m while October (M_3) gained the lowest value of 0.47m.

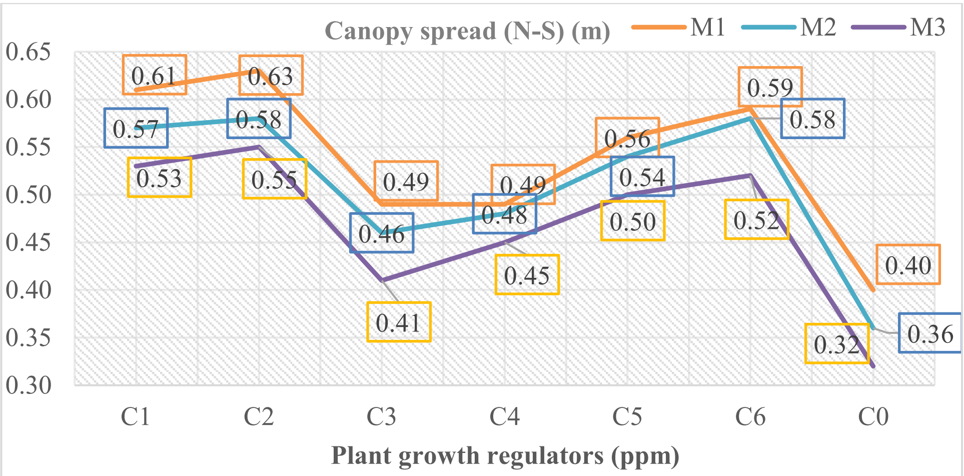


Fig. 4.1.1 Effect of shoot bending and plant growth regulators on canopy spread (N-S) (m) in guava fruit crop

Furthermore, the combination of shoot bending and PGR was found to be non-significant, T_2 ($M_1 \times C_2$) i.e., August bent shoots and NAA at 200 ppm recorded the highest observation of 0.63m followed by T_1 ($M_1 \times C_1$) at 0.55m, and the least data was collected from T_{21} ($M_3 \times C_0$) at 0.32m.

An application NAA significantly influenced the endogenous auxin levels within the plant which in turn likely facilitated enhanced cell expansion. This physiological response contributed to the promotion of canopy growth, underscoring the role of NAA in regulating vegetative development. These findings are consistent with the results reported by Kapadnis and Singh (2022) and Hamdy *et al*. (2017). Additionally, the higher temperatures observed in the month of August may have contributed to the increased canopy spread in the North-South direction, as warmer conditions are known to favour vegetative growth by accelerating biochemical processes that promote cell elongation (Körner, 2003). Notably, the treatment involving the combination of NAA at 200 ppm with shoot bending in August (T_2: $M_1 \times C_2$) recorded the highest canopy spread (N-S). Auxins are known to initiate cell elongation in regions where they accumulate, a process further enhanced by shoot bending, which redistributes auxins to areas of new growth, thereby contributing to the observed increase in canopy spread (N-S).

4.1.2 Canopy spread (E-W) (m)

The pooled data obtained from the effect of shoot bending and PGRs on Canopy spread (E-W) have been interpreted in Table 4.1, portrayed in Fig. 4.1.2 and the analysis of variance is mentioned in Appendix I.

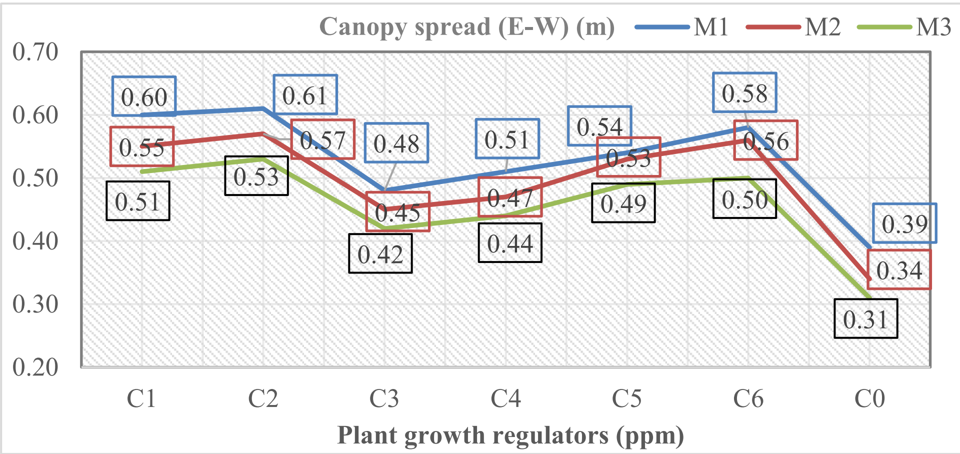


Fig. 4.1.2: Effect of shoot bending and plant growth regulators on canopy spread (E-W) (m) in guava fruit crop

Application of plant growth hormones was found to be significant with canopy spread in east-to-west orientation. From the experimental PGRs, NAA at 200 ppm (C_2) has given the widest mean data for Canopy spread in direction E-W at 0.57m and NAA at 100 ppm (C_1) at 0.55m with subtle variation which GA_3 followed at 150 ppm (C_6) at 0.5m. Control (C_0) guava tree has demonstrated least value at 0.35m. Shoot bending performed in different months were also analysed to be significant. August Shoot bending (M_1) has delivered a maximum mean value of 0.53m whereas the October Shoot bent tree (M_3) has achieved minimal data of 0.46m.

However, the interaction between shoot bending and PGRs were assessed as non-significant. Where, NAA at 200 ppm with August month shoot bending T_2 ($M_1 \times C_2$) has exhibited greater observations at 0.61m, while the lowest was recorded from control in October T_{21} ($M_3 \times C_0$) at 0.31m.

Involvement of auxin in rapid cell division in the cambium layer and generation of new tissues leads to expansion of branches and shoots. Parallel results were derived from the studies of Sharma and Tiwari (2015) and Singh *et al., (*2017) with the use of NAA. As mentioned in (Table 3.1) August has experienced higher temperature and relative humidity which plausibly contributes to an accelerated metabolic process encompassing photosynthesis and respiration heading to gregarious vegetative growth. Mamum *et al.* (2012) have also claimed similar findings concerning shoot bending.

4.1.3 Canopy height (m)

The pooled data obtained from the effect of shoot bending and PGRs on canopy height have been interpreted in Table 4.1, and depicted in Fig. 4.1.3 and the analysis of variance is mentioned in Appendix I.

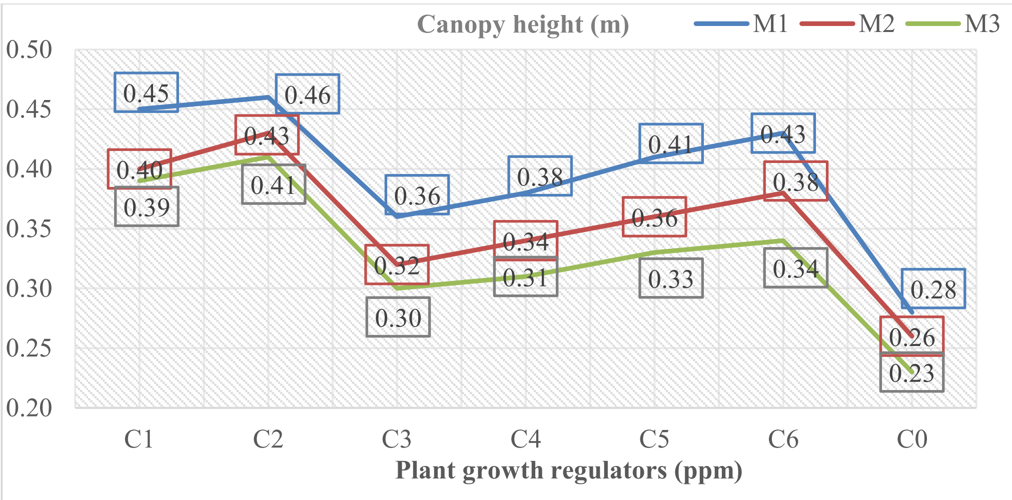


Fig.4.1.3: Effect of shoot bending and plant growth regulators canopy height (m) in guava fruit crop

The data gained from the experimental plant growth regulators was found to be significant. Maximum canopy height was obtained from NAA at 200 ppm (C_2) with a mean value of 0.43m which was at par with NAA at 100 ppm (C_1) at 0.41m followed by GA_3 at 150 ppm (C_6) at 0.38m while the minimum was recorded from Control (C_0) with 0.26m. Additionally, the shoot bending performed among different months established a significant interaction with the above trait. August (M_1) operated trees gave a significantly higher mean value of 0.40m for canopy height in comparison with October (M_3) at 0.33m which was the lowest.

A combination of plant growth regulators and shoot bending months have demonstrated non-significant interaction for canopy height. T_2 ($M_1 \times C_2$) which is August shoot bending plus NAA @200ppm captured maximum influence on canopy height at 0.46m in contrast to other combinations while October control T_{21} ($M_3 \times C_0$) at 0.23m was minimum.

Auxin can promote nutrient uptake and distribution and boost the growth of cells whereas GA_3 has a similar role in promoting cell elongation and cell division these could be a potential cause for achieving more pronounced results for canopy height with NAA spray. Hamdy *et al*. (2017) have recorded a similar effect on stem length with NAA and GA_3. The findings were aligned with Ghosh *et al*. (2013). August in Punjab is slightly on the warmer side as compared to September while October remains to be cooler. An increase in temperature vividly promotes enzymatic reactions which lead to an acceleration of cell growth and expansion leading to thicker stem girth. Sarkar *et al.* (2017) results are aligned with the present outcomes. In addition, a combination T_2 ($M_1 \times C_2$) has reported the highest value which was the union of NAA @200ppm and shoot bending in August month. Shoot bending promotes the activation of dormant buds on top of this external auxin spray which must have implied more rigorous cell division providing more scope for vegetative growth thereby maximum canopy height is captured.

4.1.4 Stem girth (cm)

The pooled data obtained from the effect of shoot bending and PGRs on stem girth have been illustrated in Table 4.1, portrayed in Fig. 4.1.4 and the analysis of variance is mentioned in Appendix I.

Application of plant growth hormones has shown significant interaction on stem girth of guava. NAA at 200 ppm (C_2) sprayed trees demonstrated maximum stem girth with a mean value of 24.6 cm which was at par with (C_1) NAA at 100 ppm at 24.3cm followed by 23.9 cm with (C_6) GA_3 150 ppm. Observations collected from Control (C_0) had a minimum stem girth of 20.4 cm. A positive significance was addressed from shoot bending months and stem girth. August (M_1) delivered maximum data with 27.0 cm contrary to October (M_3) became the underperforming month with 20 cm for stem girth.

Moreover, the interaction of shoot bending and PGR was found to be significant. August month shoot bending with NAA at 200 ppm concentration T_2 ($M_1 \times C_2$) depicted the highest stem girth of 28.3cm whereas, the lowest was gained from control in October T_{21} ($M_3 \times C_0$) at 18.1cm. An increase in vegetative growth with auxins, such as NAA, is often attributed to their ability to enhance nitrogen assimilation, a critical process for plant growth. This improved assimilation facilitates the biosynthesis of amino acids and proteins,

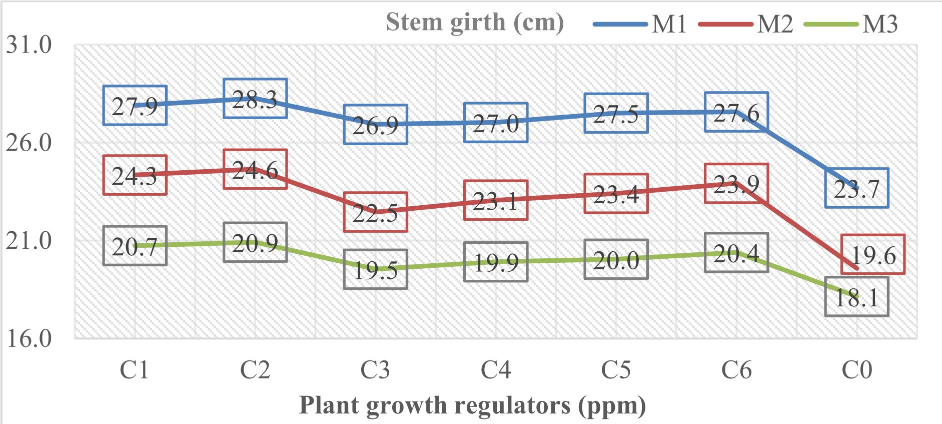


Fig. 4.1.4: Effect of shoot bending and plant growth regulators on stem girth (cm) in guava fruit crop

which are essential building blocks for cell division, expansion, and overall biomass accumulation in plants (Singh *et al*., 2017). Similar results were reported by Kumar (2021). As presented in meteorological (Table 3.1) August has shown a cumulative higher temperature range for both the experimental years (2022-23). An increase in atmospheric temperature increases the transpiration rate which leads to faster uptake of nutrients by plant and hence increased growth is witnessed (Hatfield *et al*., 2011) this could be a feasible cause for increased stem girth in (M_1). Whereas, amongst all the combinations, T_2 ($M_1 \times C_2$) has delivered the optimum value for stem girth in comparison with other combinations. Shoot bending and the NAA application in August could have certainly optimized hormonal distribution and improvised capture of sunlight leading to increased stem girth in guava.

4.1.5 Trunk cross-sectional area (cm^2)

The pooled data reflecting the influence of shoot bending and PGRs on trunk cross-sectional area is presented in Table 4.2, visualized in Fig.4.1.5, with the analysis of variance detailed in Appendix I.

The trunk cross-sectional area has shown significant value with the foliar spray of plant growth regulators. NAA at 200 ppm (C_2) delivered the maximum value for TCSA (48.92cm^2) which stands slightly higher in comparison with NAA at 100 ppm (C_1) at 47.81cm^2. After NAA, GA_3 at 150ppm (C_6) sprayed guava tree delivered better

Table 4.1: Effect of shoot bending and PGRs on canopy spread (N-S) (m), canopy spread (E-W) (m), canopy height (m), and stem girth (cm) in Guava fruit crop

Parameters	**Shoot Bending (Month)**	**Plant Growth Regulators (ppm)**							**Mean (C)**
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
Canopy spread (N-S) (m)	**M_1**	0.61	0.63	0.49	0.49	0.56	0.59	0.40	0.54
	M_2	0.57	0.58	0.46	0.48	0.54	0.58	0.36	0.51
	M_3	0.53	0.55	0.41	0.45	0.50	0.52	0.32	0.47
	Mean(M)	0.57	0.59	0.45	0.47	0.53	0.56	0.36	
CD at 5 %	Factor (M): 0.009				Factor (C): 0.014				Factor(M×C): NS**
Canopy spread (E-W) (m)	**M_1**	0.60	0.61	0.48	0.51	0.54	0.58	0.39	0.53
	M_2	0.55	0.57	0.45	0.47	0.53	0.56	0.34	0.50
	M_3	0.51	0.53	0.42	0.44	0.49	0.50	0.31	0.46
	Mean(M)	0.55	0.57	0.45	0.47	0.52	0.55	0.35	
CD at 5 %	Factor (M): 0.013				Factor (C): 0.008				Factor(M×C): NS**
Canopy height (m)	**M_1**	0.45	0.46	0.36	0.38	0.41	0.43	0.28	0.40
	M_2	0.40	0.43	0.32	0.34	0.36	0.38	0.26	0.36
	M_3	0.39	0.41	0.3	0.31	0.33	0.34	0.23	0.33
	Mean(M)	0.41	0.43	0.33	0.34	0.37	0.38	0.26	
CD at 5 %	Factor (M): 0.005				Factor (C): 0.005				Factor(M×C): NS**
Stem girth (cm)	**M_1**	27.9	28.3	26.9	27.0	27.5	27.6	23.7	27.0
	M_2	24.3	24.6	22.5	23.1	23.4	23.9	19.6	23.1
	M_3	20.7	20.9	19.5	19.9	20.0	20.4	18.1	20.0
	Mean(M)	24.3	24.6	22.9	23.3	23.6	23.9	20.4	
CD at 5 %	Factor (M): 0.285				Factor (C): 0.435				Factor(M×C): 0.754

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot Bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

observations for TCSA (46.39 cm^2). Whereas, the minimum mean value was recorded from Control (C_0) at 33.87 cm^2. Shoot bending carried out in different months on guava trees has demonstrated notable significance with TCSA trait where the August (M_1) bend Guava branches produced a pivotal effect on TCSA at 58.12 cm^2 in comparison with September (M_2) and October (M_3) with mean values of 42.57cm^2 and 31.77cm^2 respectively.

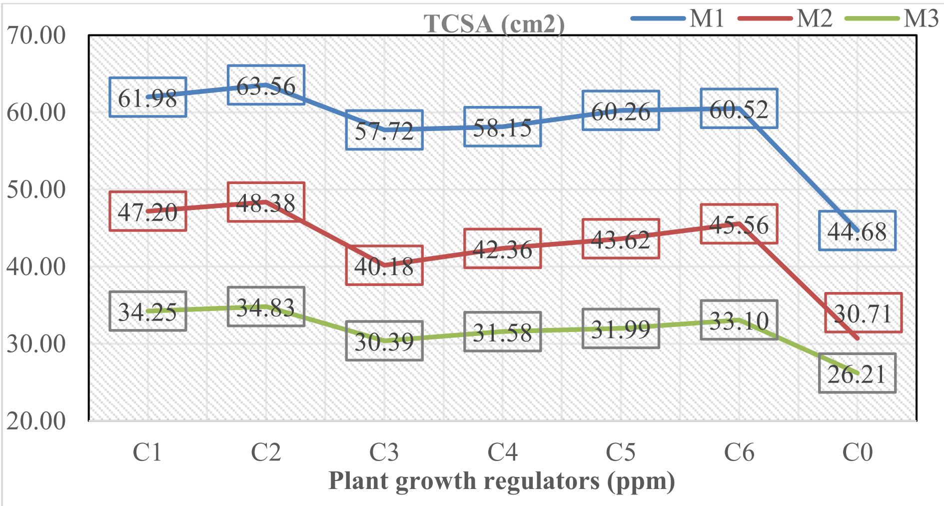


Fig. 4.1.5: Effect of shoot bending and plant growth regulators on TCSA (cm^2) in guava fruit crop

The incorporation of shoot bending plus PGR spray in the guava tree has revealed significant interaction with TCSA. Combinations, T_2 ($M_1 \times C_2$) NAA at 200ppm with August shoot bending has recorded a maximum TCSA of 63.56cm^2 while the minimum was achieved from October month control T_{21} ($M_3 \times C_0$) at 26.21cm^2.

NAA is a paramount auxin, which is witnessed to stimulate the secretion of protons in the cell wall, reducing the pH. This process in turn activates the enzymes breaking the bonds within the cell wall structure which leads to cell elongation and this could have likely contributed to success of NAA (Sharma and Tiwari, 2015) have derived parallel outcomes with the present findings. Furthermore, research has shown that the ideal increase in temperature is positively correlated to the photosynthetic rate and accumulation of biomass (Korner and Basler,2010). Besides this, shoot bending has been proven for the uniform distribution of carbohydrates in the apical portion (Taiz and Zeiger., 2010). Carbohydrates promote shoot elongation by supplying the energy and carbon skeletons needed for active cell division and elongation at the shoot apex.

This justification can satisfy the increase in TCSA August shoot bending. A combination of NAA with 200ppm plus August shoot bending has significantly contributed to the increase in TCSA. An exogenous application of NAA plus the movement of auxin on the lower side of bent branches could have vividly aided an increase in TCSA.

4.1.6 Leaf length (cm)

The pooled data obtained from the effect of shoot bending and PGRs on leaf length have been interpreted in Table 4.2, portrayed in Fig.4.1.6 and the analysis of variance is mentioned in Appendix I.

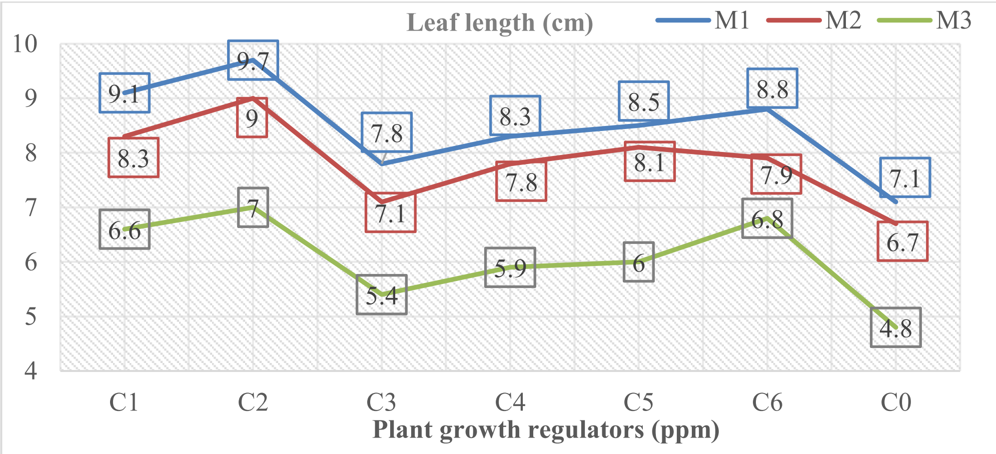


Fig. 4.1.6: Effect of shoot bending and plant growth regulators on leaf length (cm) in guava fruit crop

Foliar spray of plant growth regulators has significantly interacted with leaf length. Highest leaf length was recorded from NAA at 200 ppm (C_2) with a mean value of 8.6cm while the lowest was collected from Control (C_0) at 6.2cm. Shoot bending practiced in guava trees has displayed significant interaction with leaf length. Maximum data was obtained from the August bent tree (M_1) at 8.5cm while the minimum was from October (M_3) at 6.1cm. The interaction between leaf length and the combination was analysed to be Significant.

Moreover, T_2 ($M_1 \times C_2$) viz., a combination of NAA at 200ppm with August shoot bending has given an optimum leaf length of 9.7cm at par with (T_1) NAA at 100ppm with August shoot bending at 9.1cm and the smallest leaf length was collected from October control T_{21} ($M_3 \times C_0$) at 4.8cm.

Auxin plays a vital role in elevating the leaf primordia which leads to the production of more cells additionally it can induce plasticity in the cell wall (Davies, 2010). These collective actions of auxin could be a possible cause of the pronounced performance of NAA for leaf length. Babu *et al*. (1984) and Rahemi and Atahosseini (2003) have also discovered similar results. As mentioned in (Table 3.1) notable difference of relative humidity and temperature was recorded in which August month certainly had a higher percentage of humidity and temperature. An increase in RH % has marked to reduce the water losses from the leaves via the process of transpiration sending plants into stress conditions (Rawson *et al*. 1977) which can support the growth of leaf more in August than in other cooler months. A combination of August month bending plus NAA application has introduced the most pronounced effect on Guava leaf length. Bending involves the reactivation of dormant buds while the auxin prominently engages in cell division. This could be a possible cause for an increased leaf length in the Guava crop.

4.1.7 Leaf width (cm)

The pooled data recorded from the effect of shoot bending and PGRs on leaf width have been interpreted in Table 4.2, portrayed in Fig.4.1.7 and the analysis of variance is mentioned in Appendix I.

Guava tree incorporated with PGRs spray has shown significant leaf width value. Among the PGRs applied, NAA at 200 ppm (C_2) delivered the highest mean value of 5.9cm at par with NAA at 100 ppm (C_1) at 5.6cm followed by GA_3 at 150 ppm (C_6) at 5.1cm while the lowest was recorded from Control (C_0) at 3.7cm. Similarly, shoot bending performed in different months also displayed significance in terms of leaf length. August bent branches (M_1) recorded a maximum increase in leaf width of5.5cm whereas, the minimum was with October (M_3) at 4.0cm.

The combination of PGRs and shoot bending was found to be Significant. A combination of NAA at 200ppm spray plus August month shoot bending viz., T_2 ($M_1 \times C_2$) observed the highest leaf width of 6.8cm while control in October T_{21} ($M_3 \times C_0$) month gave the lowest leaf width of 3.1cm.

Profuse growth and merging of leaves with fewer divisions were observed by Snow and Snow (1937) when auxin was supplied, while a slower rate of multiplication and growth in plant parts occurred when auxin was present in trace amounts. This might be the underlying reason for increased leaf width with an application of NAA in guava trees. These results were found in alignment with Vastrad *et al.,* (2024). Moreover, shoot bending promotes better canopy management which aids the plant in capturing more sunrays thus, increasing the photosynthetic rate on top

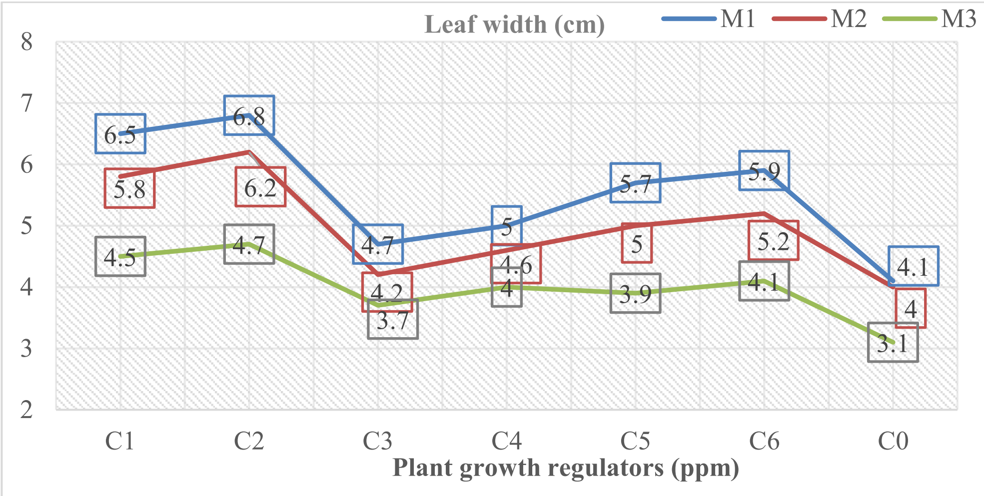


Fig. 4.1.7: Effect of shoot bending and plant growth regulators on leaf width (cm) in guava fruit crop

of this August month has experienced a higher degree of temperature which increases the transpiration rate allowing the photosynthetic products to move in different parts of a plant hence, producing more wide leaf length. However, Silveira and Thiebaut (2017) stated that uplifted temperature has a positive influence on plant traits, which justifies the present results. Furthermore, a notable increase in guava leaf width resulting from the combination of shoot bending in August and NAA (Naphthalene Acetic Acid) application can be explained by several physiological mechanisms. Shoot bending alters the hormonal equilibrium within the plant, particularly affecting the distribution of auxins, which stimulates the activation of dormant buds and encourages vegetative growth (Grey, 2004) while NAA plays a crucial role in promoting both cell division and cell elongation, processes essential for leaf expansion (Singh *et al.,* 2015). This could be a potential reason for increased leaf width.

4.1.8 Number of leaf pairs per shoot

The pooled data obtained from the effect of shoot bending and PGRs on number of leaf pairs per shoot have been depicted in Table 4.2, visualized in Fig.4.1.8 and the analysis of variance is mentioned in Appendix I.

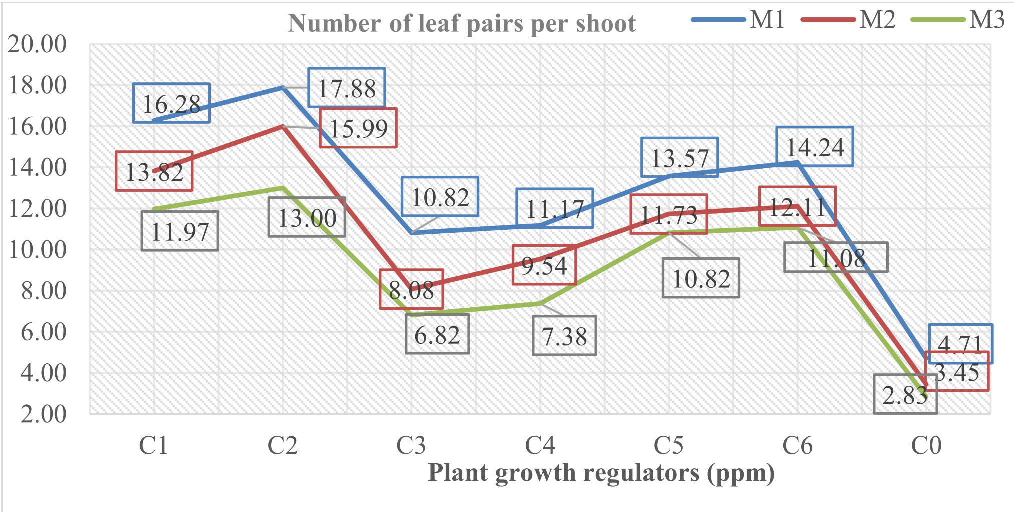


Fig. 4.1.8: Effect of shoot bending and plant growth regulators on number of leaf pairs per shoot in guava fruit crop

Plant growth regulators have displayed significant interaction with number of leaf pair per shoot. Highest number of leaf pairs per shoot was observed on NAA at 200 ppm (C_2) at 15.62 followed by NAA at 100 ppm (C_1) at 14.02 which is at par with 12.43 GA_3 at 150ppm (C_2). The lowest observation was recorded from control (C_0) at 3.66. On the other hand, branch-bending practice was analysed as significant with the number of leaf pair per shoot. The maximum number of leaf pair were collected from August bent branches (M_1) at 12.67 while the minimum was 9.13 from October bent branches (M_3).

Significance interaction was noted from the combinations of shoot bending. and PGRs. An increase in number of leaf pair of 17.88 was observed from T_2 ($M_1 \times C_2$) treated branches which was NAA at 200ppm spray plus August month shoot bending while least value of 2.83 was obtained from control of October month (T_{21}: $M_3 \times C_0$).

The likely explanation for this could be the ability of auxin to build a gradient through its translocation. The unidirectional movement of auxin from shoot apical to leaf primordia boosts the leaf growth and its proper positioning (Vaneeste and friml, 2009). This can be a potential cause for increased leaf width with NAA spray. Similar results were documented by (Tripathi and Badal,2022). Furthermore, August month has typical hot weather inclusive of temperature and humidity in comparison with other experimental bending months. (As showed in Table 3.1). The potential cause for this might be an elevated temperature which leads to more carbon production through respiration. Plus, trees developed in warmer regions undergo uniform growth in comparison with low-temperature regions (Way and Oren,2010). The results were consistent with the outcomes of Zhang *et al.*, (2023). These effects of shoot bending in August and NAA application in combination could have inclusively added a positive effect on a number of leaf pairs per shoot of the Guava fruit crop.

4.1.9 Days taken for emergence of new shootlets

The pooled data procured from the effect of shoot bending and PGRs on days taken for the emergence of new shootlets have been presented in Table 4.3, portrayed in Fig.4.1.9 and the analysis of variance is mentioned in Appendix I.

The effect of foliar application of PGRs marked a significant association with days taken for emergence of new shootlets in guava. Minimum mean number of days for emergence of new shootlets i.e., (24.74 days) were recorded from NAA at 200 ppm (C_2) which was on par with (C_1) NAA at 100 ppm (25.81 days). The greatest number of days for emergence of new shootlets were observed in the control trees (C_0) at 35.60 days. Similar significance was noted from shoot bending and days taken for emergence of new shootlets. Besides this, shoot bending operated in August month (M_1) took a lesser day for emergence of new shootlets at 26.51 days in comparison with October (M_3) at 31.73 days.

The incorporation of combination in guava tree showed a significant interaction with days taken for emergence of new shootlets. A combination of NAA with 200 ppm concentration with august month bending (T_2: $M_1 \times C_2$) displayed minimum days for the emergence of new shootlets (21.95 days) while maximum days to reach the emergence of shootlets were observed in October month control (T_{21}: $M_3 \times C_0$) at 37.81 days.

With the increase in auxin concentration, new shoot meristem is formed via affecting cytokinin distribution. High auxin certainly promotes cytokinin levels where cytokinin has ability to regenerate while auxin is responsible for rapid cell elongation (Ljung *et al*. 2005). This collective action could have caused earliness in new shootlets emergence. Results examined by Naor *et al*., (2003) have shown a humongous increase

Table 4.2 Effect of shoot bending and PGRs on TCSA (cm^2), leaf length(cm), leaf width (cm), number of leaf pair per shoot in guava fruit crop.

Parameters	Shoot Bending (Month)	Plant Growth Regulators (ppm)							Mean (C)
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
TCSA (cm^2)	**M_1**	61.98	63.56	57.72	58.15	60.26	60.52	44.68	58.12
	M_2	47.20	48.38	40.18	42.36	43.62	45.56	30.71	42.57
	M_3	34.25	34.83	30.39	31.58	31.99	33.10	26.21	31.77
	Mean(M)	47.81	48.92	42.76	44.03	45.29	46.39	33.87	
CD at 5 %	Factor (M): 0.009			Factor (C): 0.014					Factor(M×C): 0.025
Leaf Length(cm)	**M_1**	9.1	9.7	7.8	8.3	8.5	8.8	7.1	8.5
	M_2	8.3	9	7.1	7.8	8.1	7.9	6.7	7.8
	M_3	6.6	7	5.4	5.9	6	6.8	4.8	6.1
	Mean(M)	8.0	8.6	6.8	7.3	7.5	7.8	6.2	
CD at 5 %	Factor (M): 0.114			Factor (C): 0.174					Factor(M×C): 0.302
Leaf width (cm)	**M_1**	6.5	6.8	4.7	5.0	5.7	5.9	4.1	5.5
	M_2	5.8	6.2	4.2	4.6	5.0	5.2	4.0	5.0
	M_3	4.5	4.7	3.7	4.0	3.9	4.1	3.1	4.0
	Mean(M)	5.6	5.9	4.2	4.5	4.9	5.1	3.7	
CD at 5 %	Factor (M): 0.084			Factor (C): 0.128					Factor(M×C):0.222
Number of leaf pairs per shoot	**M_1**	16.28	17.88	10.82	11.17	13.57	14.24	4.71	12.67
	M_2	13.82	15.99	8.08	9.54	11.73	12.11	3.45	10.67
	M_3	11.97	13.00	6.82	7.38	10.82	11.08	2.83	9.13
	Mean(M)	14.02	15.62	8.57	9.36	12.04	12.48	3.66	
CD at 5 %	Factor (M): 0.176			Factor (C): 0.269					Factor(M×C): 0.466

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

in a lateral shoot with bending operation at optimal temperature. Moreover, the time and zone where the Shoot bending is performed play a crucial role in deciding the influence of bent shoots (Han *et al*. 2007). Punjab region has experienced increased temperature and relative humidity in August month (Shown in Table 3.1 and 3.2) as

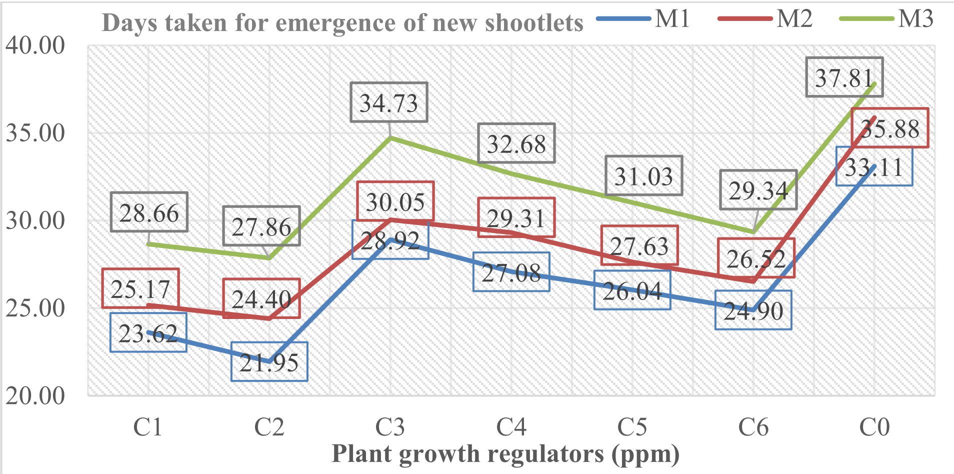


Fig. 4.1.9: Effect of shoot bending and plant growth regulators and on day taken for emergence of new shootlets in guava fruit crop

compared to September and October month which provides a scope for better transpiration and thus translocation of nutrient throughout the plant organs which can cause rapid shoot formation. Bending of shoots causes alternation in hormonal concentration which promotes wood tension leading to the production of more branching (Kijidani *et al*., 2023) on the other hand cell division, cell elongation, and organogenesis are caused by auxin. Hence, together this combination could have caused potential earliness in days taken for emergence of new shootlets.

4.1.10 New shoots per branch

The pooled observations collected from the effect of shoot bending and PGRs on new shoots per branch have been interpreted in Table 4.3, depicted in Fig.4.1.10 and the analysis of variance is mentioned in Appendix I.

Significant interaction was noted from PGRs and new shoots per branch. A greater mean number of new shoots per branch were reported in NAA at 200ppm (C_2) sprayed tree with a mean value of 29.30 which was nearly equal to (C_1) NAA at 100ppm observation (26.79) followed by (C_6) GA_3 at 150ppm at 24.70. whereas, lowest new shoots per branch (10.50) were emerged from control (C_0). Exposure of shoot bending among different months has gained significant value. A maximum increase in new shoots per branch was observed in August bent shoot (M_1) at 25.7 while the October month (M_3) gained a minimum of 20.3.

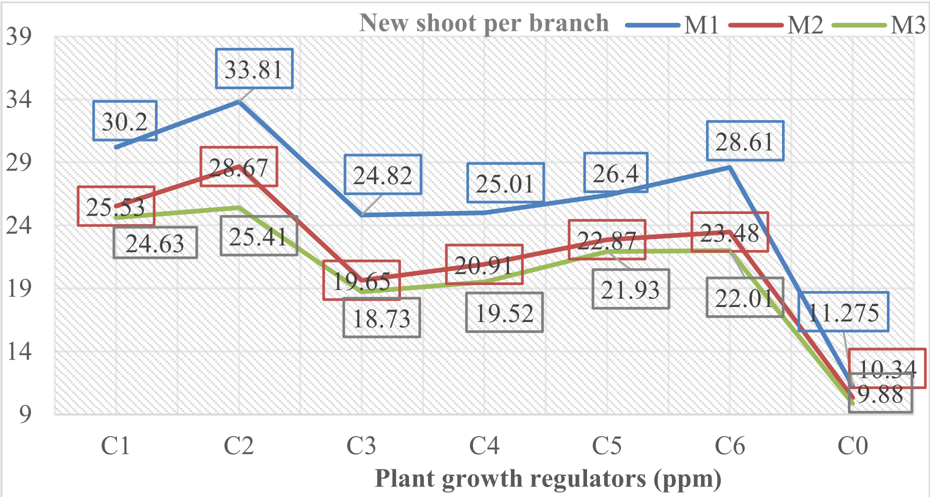


Fig.4.1.10: Effect of shoot bending and plant growth regulators on new shoots per branch guava fruit crop

Moreover, a combination of shoot bending and PGRs was found to be significant. (T_2: $M_1 \times C_2$) NAA at 200ppm with August shoot bending has a positive influence on new shoots per branch (33.81) while control trees in the month of October T_{21} ($M_3 \times C_0$) had fewer new shoots per Shoot i.e., 9.88.

Auxin is a major factor in promoting cell elongation and cell division which is vital in the growth and developmental process. They can enhance the permeability to water hence allowing cells to expand. Application of bioregulators significantly caused an increase in total dry weight and shoot system (Ibrahim *et al*.,2007) besides this, GA_3 has been observed to maximize plant stem growth (Ayala-Silva *et al*. 2005). This could be a potential cause of the increase in new shoots per branch with the application of NAA and GA_3. Moreover, the alternation of hormones viz., auxin and cytokinin caused by the bending of shoots promote more vegetative growth (Cline, 1997). Equivalent outcomes were noted from (Lauri *et al.* 1998) for shoot bending. In addition to this, shoot bending performed in optimal higher temperatures certainly leads to good stem growth. A study carried out by keller and Tarara (2010) claimed that shoots arising in higher temperatures evidently displayed vigorous growth. On the other hand, guava tree incorporated with T_2 combination gave desirable value. The application of NAA which is a synthetic auxin, supports the rapid organogenesis whereas, the shoot bending encourages the redistribution of endogenous hormones in turn more carbohydrate accumulation is seen. These reasons can justify the effectiveness of the (T_2: $M_1 \times C_2$) combination on new shoots per branch.

4.1.11 Shoot length (cm)

Pooled Observations collected from the effect of shoot bending and PGRs on shoot length have been interpreted in Table 4.3, visualized in Fig.4.1.11 and the analysis of variance is mentioned in Appendix I.

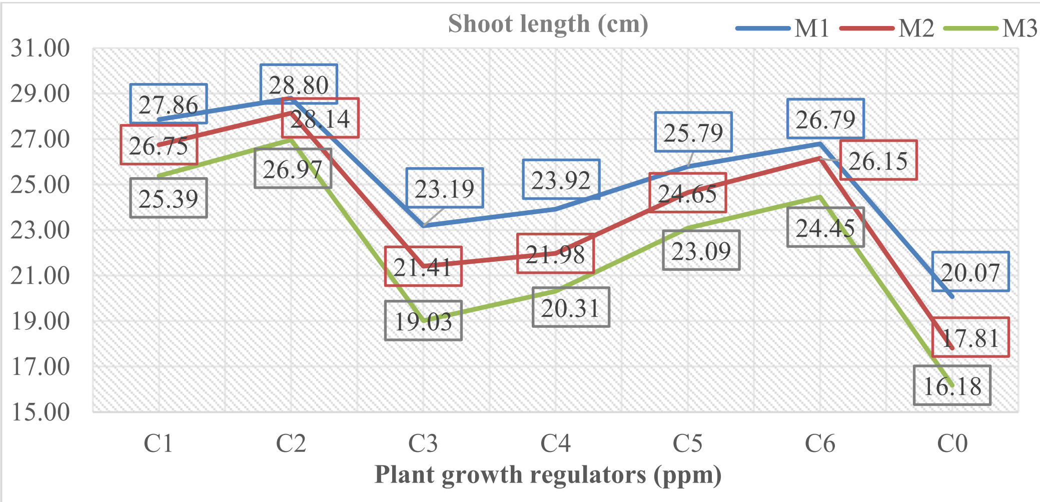


Fig.4.1.11: Effect of shoot bending and plant growth regulators on shoot length (cm) in guava fruit crop

The application of plant growth regulators has given significant values for shoot length. The maximum mean value of shoot length was observed with foliar spray of NAA at 200ppm (C_2) at 27.97cm at par with (C_2) NAA at 100ppm at 26.67cm followed by (C_6) GA_3 at 150ppm at 25.80cm while the minimum was obtained from control (C_0) at 18.02cm. Furthermore, shoot bending performed in different months noted significant interaction with shoot length, where the highest mean value was obtained from the August bent (M_1) guava tree at 25.20cm and the lowest was from October month (M_3) at 22.20cm.

In addition, combinations of shoot bending and PGRs were noted as significant. NAA at two concentrations 200 and 100ppm with August shoot bending has recorded a significant increase in shoot length i.e., T_2: ($M_1 \times C_2$) and T_1: ($M_1 \times C_1$) at 28.80cm and 27.86cm respectively while lowest shoot length of 16.18cm from control of October T_{21} ($M_3 \times C_0$).

Auxin has the ability to cut down pH within the cell wall which activates the enzymes referred to as expansions. Expansions encourage breakage of bonds between the cellulose fibre thus expanding the cell wall. This process was named as acid growth theory. (Rayle and Cleland, 1970). While the GA_3 accelerates the rate of cell division in shoot apices encouraging the protein synthesis and enzymes formations essential for cell wall loosening and expansion. Auxin and gibberellins also operate synergistically to promote the rapid formation of shoots. (Ross *et al.* 2001). This is a possible reason for the efficient shoot length of NAA and GA_3. Adjacent results were derived from Jain and Dashora (2010) and Sharma *et al*. (2015). Furthermore, shoot bending performed in the Guava trees strengthens the tree structure, and light penetration, enhances the hormonal distribution within the plant parts, promoting more vegetative growth. Corresponding outcomes were documented by Samant and Kishor (2021). Combination (T_2) which is the union of NAA and August shoot bending gave pronounced shoot length for the guava plant. Auxin like NAA increases cell division and cell elongation by promoting proton pumps. Meanwhile, shoot bending induces physiological stress which alerts the hormone distribution processes further encouraging cell elongation. This coordinated effect can be a pivotal reason for an increase in shoot length.

4.1.12 Internode length (cm)

Pooled data recorded from shoot bending and PGRs on Internode length have been demonstrated in Table 4.3 and visualized in Fig.4.1.12 and the analysis of variance is mentioned in Appendix I.

Significant values were noted from the application of PGRs. Highest mean internode length was recorded from the spray of NAA at 200ppm (C_2) at 3.16cm which was on par with (C_2) NAA at 100ppm at 3.11cm followed by (C_6) GA_3 at 150ppm at 3.07cm while the lowest was collected from control tree (C_0) at 2.32cm. Moreover, Significance was achieved from shoot bending performed in different months where the maximum average value for internode length was received from August bent shoots (M_1) of guava tree at 3.15cm while the minimum was from October month (M_3) at 2.60cm. Additionally, the combinations have noted significant interaction. NAA applied at concentrations of 200 ppm and 100 ppm, in conjunction with shoot bending during August, led to a marked increase in shoot length, specifically T_2: ($M_1 \times C_2$) and T_1: ($M_1 \times C_1$), reaching 3.25cm and 3.22cm, respectively. In contrast, the shortest shoot length of 1.96cm was observed in the control treatment of October, T_{21} ($M_3 \times C_0$).

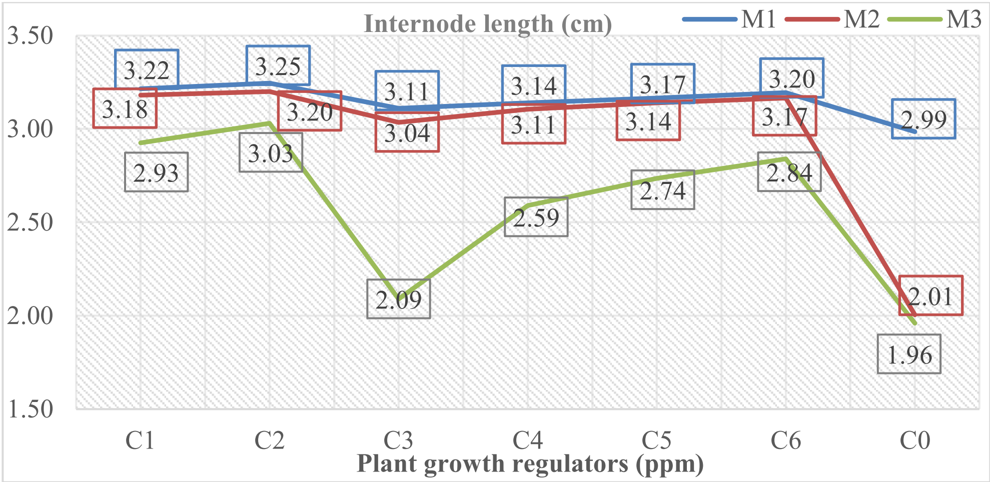


Fig.4.1.12: Effect of shoot bending and plant growth regulators on internode length (cm) in guava fruit crop

Auxin promotes vascular differentiation, enhancing the efficient transport of water and nutrients throughout the plant, which supports increased shoot growth. Additionally, auxin plays a key role in regulating both cell elongation and division, essential processes for plant development. By improving cell permeability to water, auxin aids in cell expansion. According to Taiz and Zeiger (2010), auxin also encourages the formation of lateral and adventitious roots, improving nutrient uptake and overall plant health. This may explain the rise in internode length with an application of NAA. Parallel findings were studied by Ghosh *et al*. (2013). On the other hand, August in Punjab experiences higher temperatures compared to September, with October being cooler (shown in Table 3.1). Increased temperatures enhance metabolic processes like photosynthesis and respiration, providing the plant with more energy and resources for tissue growth. This boost in cell division, expansion, and metabolism supports stronger vegetative development, particularly in stem elongation. These results align with the findings of Sarkar *et al*. (2017). Notably, the treatment combination of (T_2) which included NAA at 200 ppm along with August shoot bending, yielded the highest values. Shoot bending likely redistributes hormones, such as auxin, and enhances light penetration, further stimulating bud activation and promoting overall shoot growth. Additionally, the application of external auxin likely promoted more vigorous cell division, allowing for greater vegetative growth and ultimately increased internode length

4.3 Effect of shoot bending and PGRs on days taken for emergence of new shootlets, new shoot per branch, shoot and internode length (cm) of guava fruit crop

Parameters	Shoot Bending (Month)	Plant Growth Regulators (ppm)							Mean (C)
		C_1	C_2	C_3	C_4	C_5	C_6	C_0	
Days taken for emergence of new shootlets	**M_1**	23.62	21.95	28.92	27.08	26.04	24.90	33.11	26.51
	M_2	25.17	24.40	30.05	29.31	27.63	26.52	35.88	28.42
	M_3	28.66	27.86	34.73	32.68	31.03	29.34	37.81	31.73
	Mean(M)	25.81	24.74	31.23	29.69	28.23	26.92	35.60	
CD at 5 %	Factor (M): 0.336			Factor (C): 0.513				Factor(M×C): 0.888	
New shoot per branch	**M_1**	30.2	33.81	24.82	25.01	26.4	28.61	11.27	25.7
	M_2	25.53	28.67	19.65	20.91	22.87	23.48	10.34	21.6
	M_3	24.63	25.41	18.73	19.52	21.93	22.01	9.88	20.3
	Mean(M)	26.79	29.30	21.07	21.81	23.73	24.70	10.50	
CD at 5 %	Factor (M): 0.120			Factor (C): 0.183				Factor(M×C): 0.316	
Shoot length (cm)	**M_1**	27.86	28.80	23.19	23.92	25.79	26.79	20.07	25.20
	M_2	26.75	28.14	21.41	21.98	24.65	26.15	17.81	23.84
	M_3	25.39	26.97	19.03	20.31	23.09	24.45	16.18	22.20
	Mean(M)	26.67	27.97	21.21	22.07	24.51	25.80	18.02	
CD at 5 %	Factor (M): 0.254			Factor (C): 0.388				Factor(M×C):0.672	
Internode length (cm)	**M_1**	3.22	3.25	3.11	3.14	3.17	3.20	2.99	3.15
	M_2	3.18	3.20	3.04	3.11	3.14	3.17	2.01	2.98
	M_3	2.93	3.03	2.09	2.59	2.74	2.84	1.96	2.60
	Mean(M)	3.11	3.16	2.75	2.95	3.01	3.07	2.32	
CD at 5 %	Factor (M): 0.036			Factor (C): 0.055				Factor(M×C): 0.095	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6,T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0) **2**

Effect of shoot bending and PGRs on reproductive parameters of guava fruit crop.

4.2.1 Fruit length (cm)

The pooled data collected from the effect of shoot bending and PGRs on fruit length have been displayed in Table 4.4 and portrayed in Fig.4.2.1 and the analysis of variance is mentioned in Appendix I.

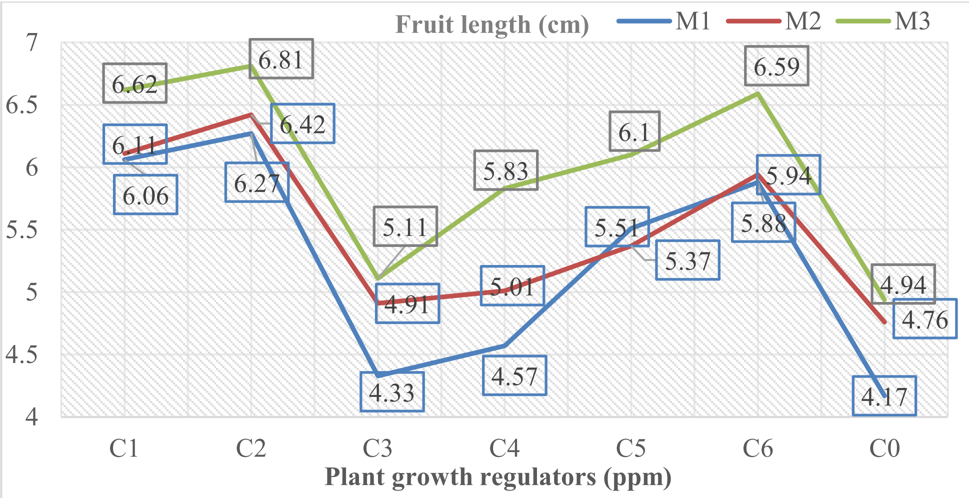


Fig.4.2.1: Effect of shoot bending and plant growth regulators on fruit length (cm) of guava fruit

Application of plant growth regulators has shown significance in terms of fruit length. The highest mean fruit length was observed with foliar spray of (C_2) NAA at 200 ppm at 6.50cm at par with 6.26cm from (C_1) NAA at 100 ppm while the lowest was recorded from control (C_0) at 4.62cm. A similar significance was observed with shoot bending performed in different months. Contradiction with vegetative parameters, maximum fruit length was observed in October month (M_3) at 6.0cm while the minimum was in August month (M_1) at 5.26cm.

Moreover, combinations of shoot bending and PGRs displayed Significant interaction. An increased fruit length of 6.81cm was recorded from NAA at 200ppm of concentration plus October Shoot bending ($T_{16:}$ $M_3 \times C_2$) in comparison with other combinations applied, while the lowest was recorded in August month (T_7: $M_1 \times C_0$) control at 4.17cm.

Auxin has an apprehensive role in fruit development. Anatomical research provided by Agusti *et al*. (2002) emphasized the uptake of photosynthates and cell enlargement hence navigating better fruit growth. In addition to this optimal increase in source sink relation was experienced with the application of exogenous auxin. (West wood,1993; Fuast,1989). Parallel results were derived from Stern *et al.,* (2007) studies.

According to the meteorological data (as shown in Table 3.1) a drop in temperature was observed from October to January month. Optimum cooler temperatures certainly restrict the respiration process allowing more carbohydrate production (Yamori *et al*., 2014). Kumakura and Shishido (1995) noticed an acceleration in fruit development in optimal cooler seasons. In addition to this, bent branches undergo better light penetration permitting more photosynthesis hence the assimilation of more carbohydrates. This could be a substantial cause for an increase in fruit length derived from October bent tree. Similar results were noticed from the findings of Budhiarto *et al*., (2018). Moreover, guava tree incorporated with a combination of auxin (NAA at 200ppm) plus the October bent Shoots ($T_{16:}$ M_{3}×C_{2}) has recorded highest fruit length. The potential cause for this could be an increased cell elongation by auxins and hormonal redistribution by shoot bending which collectively directs more nutrients to the fruits ultimately leading to enhanced fruit length.

4.2.2 Fruit diameter (cm)

The pooled data obtained from the effect of shoot bending and PGRs on fruit diameter have been interpreted in Table 4.4 and portrayed in Fig.4.2.2. The analysis of variance is mentioned in Appendix I.

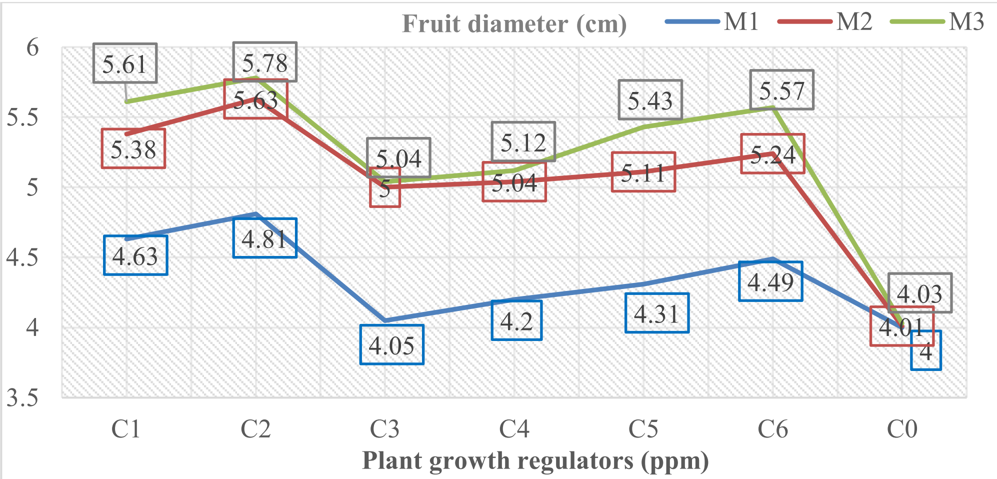


Fig.4.2.2: Effect of shoot bending and plant growth regulators on fruit diameter (cm) of guava fruit

Significant results were drawn with a foliar spray of PGRs. Maximum mean fruit diameter was recorded from spray of NAA at 200ppm (C_2) at 5.41cm which was on par with (C_1) NAA at 100ppm at 5.21cm followed by (C_6) GA_3 at 150ppm at 5.10cm. Minimum mean data was obtained from control (C_0) at 4.01cm. Shoot bending performed different months portrayed significant interaction, where highest fruit diameter of 5.21cm was obtained from October bent tree (M_3) whereas the lowest was from August (M_1) at 4.36cm.

Combinations incorporated on guava trees exhibited Significant interaction. Maximum increase in fruit diameter (5.78cm) was obtained from T_{16}: $M_3 \times C_2$) which is the union of October shoot bending and NAA spray at 200ppm concentration whereas the least value was recorded from August (T_7: $M_1 \times C_0$) month control at 4.00cm.

Polarization of cells in the procambium region which is a precursor of vascular tissues has a role in fibre formation in plants and is vividly affected by the presence of auxin. This in turn leads to fruit development (Aloni,2013; Suman *et al.,* 2017). This can be a plausible reason for an increase in fruit diameter with NAA spray. Corresponding results were observed by (Lal *et al.,* 2017). Shoot bending is performed in the tree by removing and thinning out the extra branches, flowers, and fruits. The branches are bent down in a horizontal orientation which encourages uniform distribution of nutrients. Lakso and Johnson (1990) claimed an increase in fruiting in apple trees when the branches are bent horizontally while the vertical branches produce smaller-sized fruits. This could be a potential cause for an increased fruit diameter from the October month bent tree. Aligned results were discovered by Mishra and Singh (2022). Moreover, the combination of (T_{16}) NAA at 200ppm with October month shoot bending has collected maximum values. When shoot bending is incorporated it discontinues the movement of hormones. Auxin is typically transferred in the downward region gaining an increase in length in turn. Meanwhile, the auxin application influences cell division and cell elongation. This could have acted synergistically contributing to increased fruit diameter.

4.2.3 Fruit weight (g)

The pooled data from the impact of shoot bending and plant growth regulators (PGRs) on fruit weight is detailed in Table 4.4, illustrated in Fig.4.2.3, and the variance analysis can be found in Appendix I. Foliar spray of PGRs has noted significant interaction with fruit weight. Highest fruit weight was derived with mean value of 136.2g with NAA at 200ppm (C_2) followed by 133.9g with NAA at 100ppm (C_2) while the lowest was observed in control (C_0) at 85.1g. In addition, shoot bending has noted significant observation, where higher fruit weight was recorded from October shoot bent (M_3) at 124.0g whereas, the lowest was recorded from August bent shoots (M_1) at 109.8g.

Moreover, combinations have displayed significant interaction with fruit weight trait of guava. Maximum fruit weight of 141.6g was observed in ($T_{16:}$ $M_3 \times C_2$) i.e., the union NAA application at 200ppm plus shoot bending in October month while minimum was obtained from August month control (T_7: $M_1 \times C_0$) at 77.1g.

Auxin is a major factor that helps differentiate and develop the xylem and phloem. This xylem and phloem referred to as the vascular system has a peculiar role in the translocation of water, nutrients, and sugar within plants. Besides it also encourages the uniform distribution

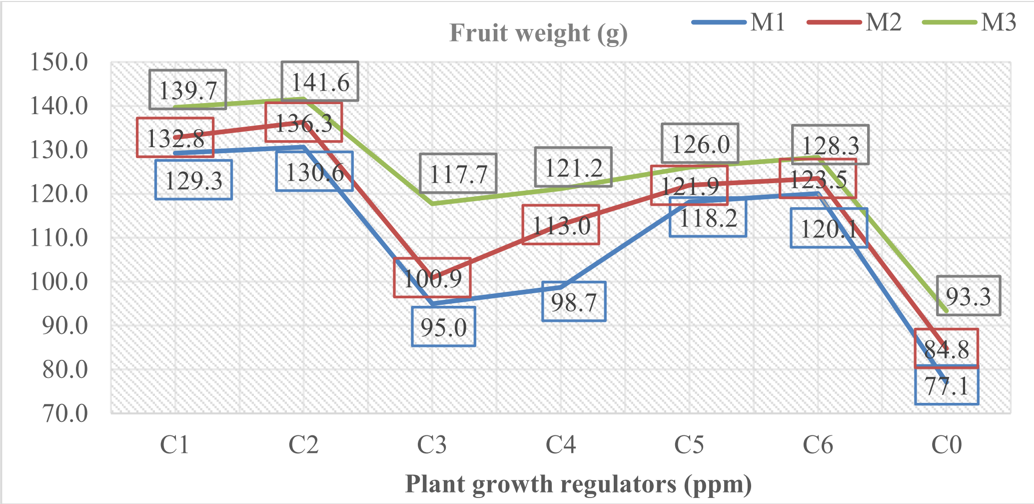


Fig.4.2.3: Effect of shoot bending and plant growth regulators and on fruit weight (g) of guava fruit

of carbohydrates and directs sugars and starches to the fruits at the developing stage (Aloni, 2013; Tiwari *et al*.,2005; Bangerth,1989). This may provide insight into the reasoning behind increased fruit weight by NAA spray. These findings conform with the research of (Bhati and Yadav,2003). Moreover, lower temperatures have been experienced from October to the first harvesting month i.e., December and January for both years as compared to other months (Shown in Table 3.1). Atmospheric temperature at a lower degree increases the soil moisture content which is positively correlated to water uptake by the pants and the optimal rate of water is pivotal for fruit development (Heinze *et al*., 2017). In addition to this, branch-bending leads to the redistribution of hormones causing an increase in plant growth. This may explain why the October bent shoot gave maximum fruit weight. These results corroborated outcomes derived by (Azizu *et al.,* 2016). Moreover, a Combination of October shoot bending and NAA at 200ppm spray (T_{16}) has reported highest fruit weight. This combination could have created a conducive environment for fruit growth by boosting hormonal regulations, and nutrient movement which extends the fruit development stage by decreasing the competition by shoot bending.

4.2.4 Days require for fruit set

Observed pooled values from the effect of shoot bending and PGRs on days require for fruit set have been displayed in Table 4.4 and portrayed in Fig 4.2.4 and the analysis of variance is mentioned in Appendix I.

Foliar spray of Plant growth regulators has given significant mean values. Guava tree sprayed with NAA at 200ppm (C_2) required minimum (62.9 days) for fruit set followed by NAA at 150ppm (C_1) at 64.2 days. While Control (C_0) required maximum days for fruit set at

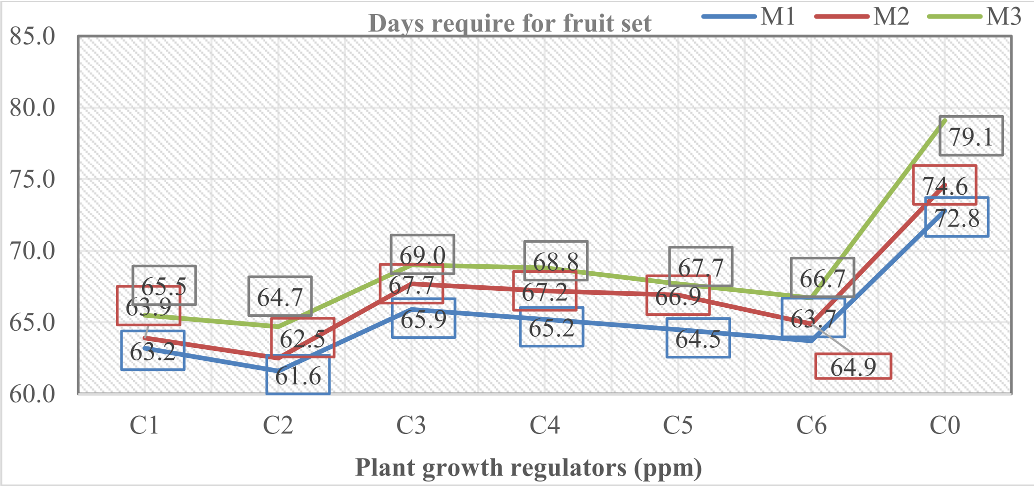


Fig.4.2.4: Effect of shoot bending and plant growth regulators and on days require for fruit set in guava fruit crop

75.5. Similar significance was noted in shoot bending for different months. Shoot bending performed in August month (M_1) required a short duration i.e., a lesser number of days to reach the fruit set at 64.6 days while October bent shoot (M_3) took a greater number of days for fruit set (67.8 days).

Combinations treated guava plant gave non-significant values. Minimum days required for the fruit set was observed with exposure of NAA at 200 ppm and August shoot bending (T_2: $M_1 \times C_2$) at 61.6 days in comparison with (T_{21}: $M_3 \times C_0$) October month control at 79.1 mean days which took a greater number of days to reach fruit set.

The presence of auxin is marked as essential to stimulate ovule differentiation and ovary development. At the onset of fertilization, auxin synthesis is reduced but after the commencement of fertilization auxin is released (Figueiredo *et al.,* 2015). This can be attributed to a faster fruit set by exogenous auxin i.e., NAA. Similar results were documented by Mahmood *et al.*, (2016). Shoot bending is a pivotal horticultural practice that regulates the canopy structure, increasing the CO_2 concentration in the inner canopy. An increase in C: N ratio is also associated with branch bending which leads to more fruiting. (Costes *et al.,* 2006). Parallel findings were claimed by Nandi *et al.,* (2017). A combination (T_{16}) of synthetic auxin (NAA at 200ppm) with October shoot bending required fewer days for fruit set. The bent shoot not only stops the uneven distribution of auxin but also causes uniformity in hormonal translocation. This uniform flow of auxin certainly promotes cell division and cell elongation at a faster pace. While the exogenous spray of auxin reinforces the effect by further stimulating the organogenesis. This combined effect could have reduced the days required to reach the fruit set.

Table 4.4 Effect of shoot bending and PGRs on fruit length (cm), fruit diameter (cm), fruit weight (g) and days require for fruit set in in guava fruit crop

Parameters	Shoot Bending (Month)	Plant Growth Regulators (ppm)							Mean C
		C_1	C_2	C_3	C_4	C_5	C_6	C_0	
Fruit Length (cm)	M_1	6.06	6.27	4.33	4.57	5.51	5.88	4.17	5.26
	M_2	6.11	6.42	4.91	5.01	5.37	5.94	4.76	5.50
	M_3	6.62	6.81	5.11	5.83	6.10	6.59	4.94	6.00
	Mean(M)	6.26	6.50	4.78	5.14	5.66	6.14	4.62	
CD at 5 %	Factor (M): 0.157			Factor (C): 0.103			Factor(M×C): 0.272		
Fruit Diameter (cm)	M_1	4.63	4.81	4.05	4.20	4.31	4.49	4.00	4.36
	M_2	5.38	5.63	5.00	5.04	5.11	5.24	4.01	5.06
	M_3	5.61	5.78	5.04	5.12	5.43	5.57	4.03	5.23
	Mean(M)	5.21	5.41	4.70	4.79	4.95	5.10	4.01	
CD at 5 %	Factor (M): 0.133			Factor (C): 0.087			Factor(M×C): 0.231		
Fruit Weight (g)	M_1	129.3	130.6	95.0	98.7	118.2	120.1	77.1	109.8
	M_2	132.8	136.3	100.9	113.0	121.9	123.5	84.8	116.2
	M_3	139.7	141.6	117.7	121.2	126.0	128.3	93.3	124.0
	Mean(M)	133.9	136.2	104.5	111.0	122.0	124.0	85.1	
CD at 5 %	Factor (M): 2.137			Factor (C): 1.399			Factor(M×C): 3.702		
Days require for fruit set	M_1	63.2	61.6	65.9	65.2	64.5	63.7	72.8	64.6
	M_2	63.9	62.5	67.7	67.2	66.9	64.9	74.6	66.1
	M_3	65.5	64.7	69.0	68.8	67.7	66.7	79.1	67.8
	Mean(M)	64.2	62.9	67.5	67.1	66.4	65.1	75.5	
CD at 5 %	Factor (M): 1.147			Factor (C): 0.751			Factor(M×C): NS**		

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

4.2.5 Flower bud plant^{-1}

The pooled data obtained from the effect of shoot bending and PGRs on flower bud per plant have been interpreted in Table 4.5, portrayed in Fig.4.2.5 and the analysis of variance is mentioned in Appendix I.

Significance was noted from foliar spray of plant growth regulators on flower bud per plant. The highest mean value of 170.2 for flower bud per plant was observed with foliar spray of NAA at 200ppm (C_2) at par with NAA at 100ppm (C_2) at 168.2. Whereas, the lowest flower bud per plant was recorded from Control (C_0) at 141.8. Moreover, shoot bending performed at different months gave significant value. An increase in flower bud per plant was recorded from October month (M_3) shoot bending at 178.5 while in contrast August month (M_1) gave the lowest at 142.4.

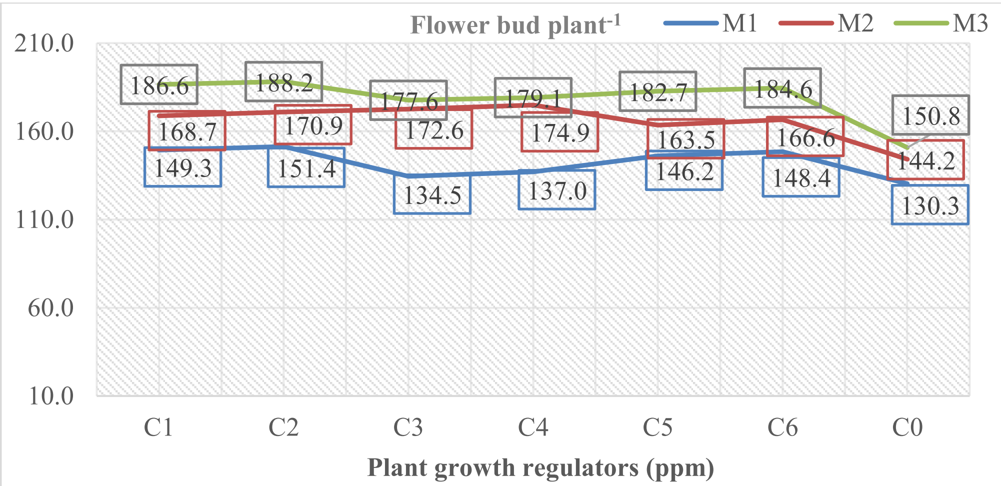


Fig.4.2.5: Effect of shoot bending and plant growth regulators on flower bud per plant

In addition, a combination of NAA at 200ppm with October month shoot bending (T_{16}: $M_3 \times C_2$) recorded a significant value of 188.2 while the minimum was observed with Control of August month (T_7: $M_1 \times C_0$) at 130.3.

The presence of auxin is noted during pollen germination of flowers. Higher levels of auxin were discovered in the growing tips of the pollen tube which has cause increase pollen tube development (Aloni *et al.,* 2006). Researchers have found more straight and slender pollen tube formation due to exogenous treatment of auxin (Wang *et al.*,1987; Wu *et al.,* 2008). This can be attributed to increase number of flower bud per plant with NAA application. Similar results were discovered by Singh *et al.,* (1994). Besides this, October month has recorded lowest mean temperature (as shown in Table

3.1) as compared to other experimental months. Hall *et al*., (1977) studies claimed that cooler temperature with warmer soil produces more flowering flushes in citrus. However, shoot bending induces an increase in cytokinin and auxin interaction which is essential for flower development. Similar effects were noted by Jung and Choi (2010). While the combination of NAA 200ppm plus October bending (T_2) derived maximum flower buds per plant. Shoot bending causes an increase in the rate of photosynthesis and carbohydrate assimilation. Whereas, auxin encourages cell division and cell elongation at a faster pace. This could be a potential reason for the increase in flower bud per guava plant.

4.2.6 Initial fruit set plant^{-1}

The pooled data obtained from the effect of shoot bending and PGRs on initial fruit set have been interpreted in Table 4.5, portrayed in Fig.4.2.6 and the analysis of variance is mentioned in Appendix I.

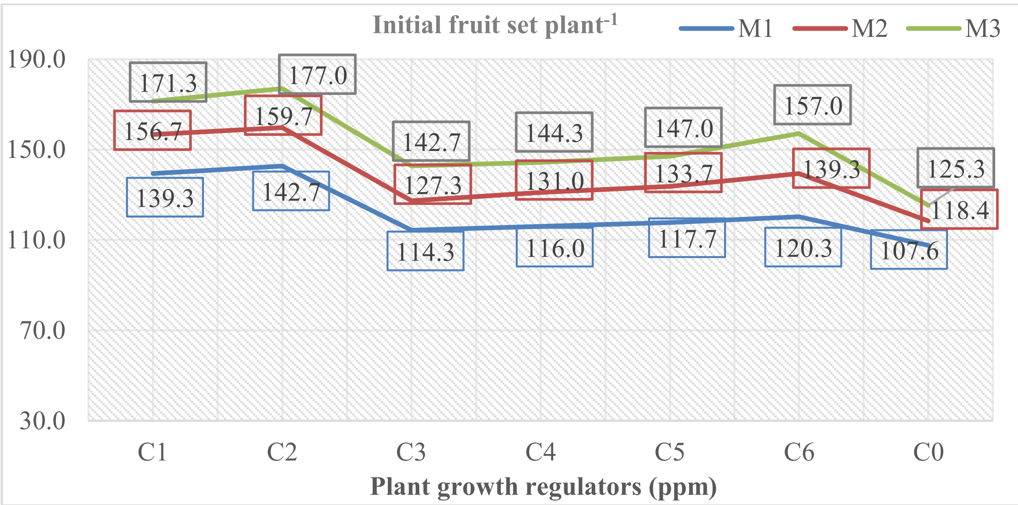


Fig.4.2.6: Effect of shoot bending and plant growth regulators on initial fruit Set per plant

Applied plant growth regulators have noticed significant mean values for initial fruit set in guava. Maximum initial fruit set was observed in tree with NAA at 200ppm (C_2) spray at 159.8 followed by NAA at 100ppm (C_1) at 155.8 while the minimum was reported at 117.1 with control (C_0). Similar significance was displayed by shoot bending practiced in different months. An increase in the initial fruit set was found in October bent tree (M_3) at 152.1 in comparison with other months. August bent shoots gave the least initial fruit set at 122.6.

A significant interaction was noted between PGRs and shoot bending. T_{16}: $M_3 \times C_2$ gave the highest initial fruit set of 177.0 which was a union of NAA at 200ppm concentration with October shoot bending while the lowest was recorded from control guava tree of the August month (T_7: $M_1 \times C_0$) at 107.6.

Auxin has a critical role in floral development; it is considered to a substantial in development of floral primordia and often it is found that discontinuation in auxin biosynthesis and its polar translocation cause failure flower and fruit formation. Moreover, it has a great influence on number and identity of floral organs (Cheng and Zhao.,2007). This aspect can be positively attributed to increase in initial fruit set by auxin spray. Kacha *et al.*, (2012) results were found in conformity with present outcomes. In addition, horizontal bending of branches induces hormonal changes in auxin. Typically, auxins are present in the shoot tips in vertical branches which causes apical dominance and lower branching. However, when the bending is incorporated, it disrupts the flow of auxin, reducing the apical dominance and permitting more lateral shoots, flowers, and fruits (Cline, 1991). Results were aligned with the findings of (Lauri *et al*.,2001). Furthermore, a combination of NAA accompanying October shoot bending (T_{16}) resulted in increased initial fruit set. October has reported a comparable drop in temperature as compared to August and September. (Shown in Table 3.1). Natural flow of auxin within the plants is slightly hampered for lower degrees of temperature which may reduce the flowering and fruiting of crop (Davies, 2010). Thus, this lack of auxin can be satisfied by spray of auxin exogenously leading to more fruit set. Plus. during the cooler temperature the process of pollination and fruit set is relatively slower which could be enhanced by shoot bending which strengthens the canopy structure, light penetration and air circulation. This collective approach could be a reason for getting enhanced initial fruit set.

4.2.7 Total number of fruits plant^{-1}

The pooled data obtained from the effect of shoot bending and PGRs on total number of fruits per plant have been interpreted in Table 4.5, portrayed in Fig.4.2.7 and the analysis of variance is mentioned in Appendix I.

Significant mean values were noticed for a foliar spray of PGRs on total number of fruits per plant. Amongst the PGRs, an increase in total number of fruits per plant were recorded with NAA at 200ppm (C_2) at 136.0 followed by NAA at 100ppm (C_1) at

131.0 while the least values were obtained from August month control (C_0) at 67.9. Furthermore, guava tree exposed with shoot bending in different months gave significant mean values. Maximum total number of fruits per plant was observed in October month bending (M_3) at 117.5 while the minimum was with August month bending (M_1) at 87.7.

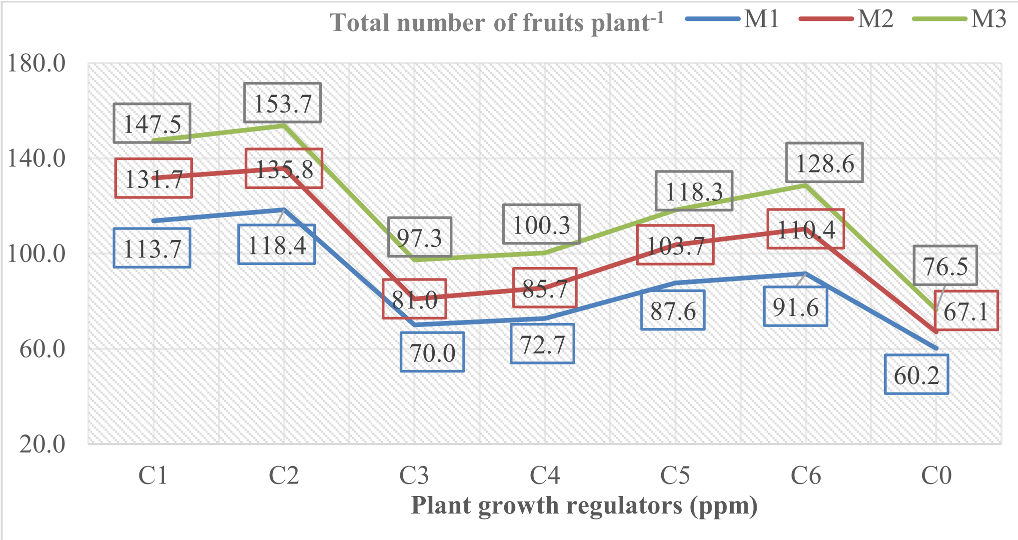


Fig.4.2.7: Effect of shoot bending and plant growth regulators on total number of fruits per plant

Combinations were found to be significant. An increase in a total number of fruits per plant was reported from NAA at 200ppm plus October shoot bending (T_{16}: $M_3 \times C_2$) at 153.7 in comparison with control trees of August (T_7: $M_1 \times C_0$) at 60.2 which was the lowest.

Recent studies have emphasized the pivotal role of auxin in fruit growth and development. Silencing of *ARF4* which found in pericarp of fruit has resulted in increased accumulation of chlorophyll and starch and sugar which can be evident enough to suggest the movement of auxin signalling in fruit growth (Pattison *et al.*, 2014). This might be a contributing factor to an increased total number of fruits per plant seen with NAA spray. Similar outcomes were obtained from the research of (Neito-Angel *et al.*,2000). Moreover, shoot bending performed in October month (M_3) gave maximum total number of fruits. Punjab reason has a typical cooler climate in October till January (Shown in Table 3.1). This drop in temperature leads to more vigorous flowering but the ideal cooler temperature is plant specific. High temperature affects the assimilation of photosynthetic products negatively leading to reduced translocation to floral buds (Hussey, 1963). Parallel effect was examined by (Menzel *et al*.,1987) for lower temperature. In addition to this bending of shoots could have captured more sunlight causing an increase in photosynthetic rates. These results were confirmed by (Mishra *et al*., 2010). The combined effect of NAA with shoot bending has given positive results. Since auxin has a peculiar role in cell elongation, cell differentiation, and organogenesis whereas, shoot bending introduces better hormonal distribution required for enhanced fruit development. Employment of both strategies together may have enhanced the total number of fruits at harvest.

4.2.8 Fruit retention plant^{-1} (%)

The pooled data pertaining from the effect of shoot bending and PGRs on Fruit retention per plant (%) have been illustrated in Table 4.5 and depicted in Fig.4.2.8 The analysis of variance is mentioned in Appendix I.

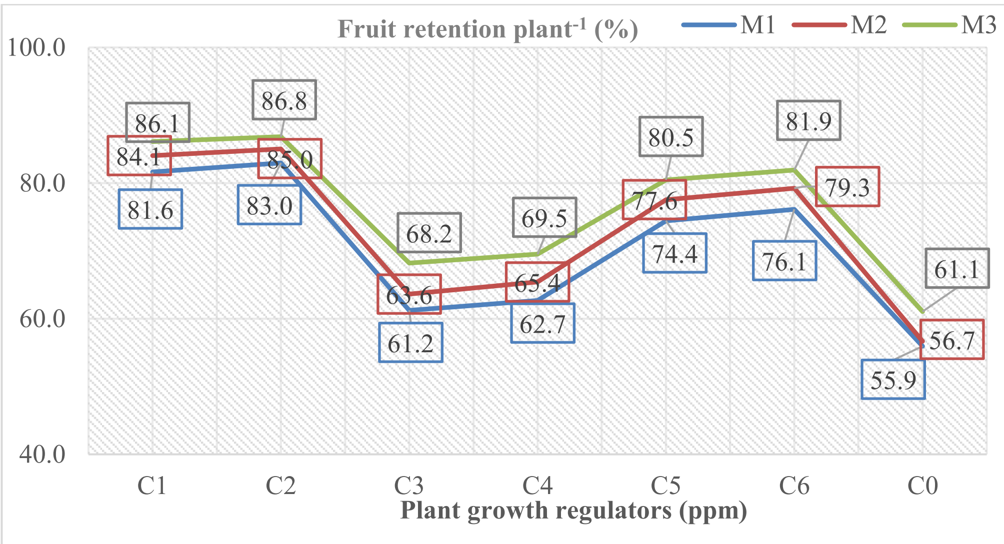


Fig.4.2.8: Effect of shoot bending and plant growth regulators on fruit retention per plant (%)

Foliar spray of plant growth regulators gave significant mean values with fruit retention percentage. Amongst experimental plant hormones, NAA at 200ppm (C_2) gave highest fruit retention at 84.9% which was on par with NAA at 100ppm spray (C_1) at 83.9% followed by GA_3 at 150ppm (79.1%). Lowest fruit retention was received from the control (C_0) at 57.9%. Significant values were observed by shoot bending performed in different months. Maximum fruit retention was analysed from October month bending (M_3) at 76.3% whereas the minimum was from August month (M_1) at 70.7%.

Table 4.5 Effect of shoot bending and PGRs on flower bud per plant, initial fruit set, total number of fruits per plant, fruit retention per plant in guava fruit crop

Parameters	Shoot Bending (Month)	Plant Growth Regulators (ppm)							Mean (C)
		C_1	C_2	C_3	C_4	C_5	C_6	C_0	
Flower bud plant^{-1}	**M_1**	149.3	151.4	134.5	137.0	146.2	148.4	130.3	142.4
	M_2	168.7	170.9	163.5	166.6	172.6	174.9	144.2	165.9
	M_3	186.6	188.2	177.6	179.1	182.7	184.6	150.8	178.5
	Mean(M)	168.2	170.2	161.6	163.7	164.1	166.5	141.8	
CD at 5 %	Factor (M): 1.95			Factor (C): 2.98				Factor(M×C): 4.33	
Initial fruit set plant^{-1}	**M_1**	139.3	142.7	114.3	116.0	117.7	120.3	107.6	122.6
	M_2	156.7	159.7	127.3	131.0	133.7	139.3	118.4	138.0
	M_3	171.3	177.0	142.7	144.3	147.0	157.0	125.3	152.1
	Mean(M)	155.8	159.8	128.1	130.4	132.8	138.9	117.1	
CD at 5 %	Factor (M): 1.57			Factor (C): 2.41				Factor(M×C): 4.17	
Total number of fruits plant^{-1}	**M_1**	113.7	118.4	70.0	72.7	87.6	91.6	60.2	87.7
	M_2	131.7	135.8	81.0	85.7	103.7	110.4	67.1	102.2
	M_3	147.5	153.7	97.3	100.3	118.3	128.6	76.5	117.5
	Mean(M)	131.0	136.0	82.8	86.2	103.2	110.2	67.9	
CD at 5 %	Factor (M): 0.969			Factor (C): 1.48				Factor(M×C): 2.563	
Fruit retention plant^{-1} (%)	**M_1**	81.6	83.0	61.2	62.7	74.4	76.1	55.9	70.7
	M_2	84.1	85.0	63.6	65.4	77.6	79.3	56.7	73.1
	M_3	86.1	86.8	68.2	69.5	80.5	81.9	61.1	76.3
	Mean(M)	83.9	84.9	64.4	65.9	77.5	79.1	57.9	
CD at 5 %	Factor (M): 1.314			Factor (C): 0.86				Factor(M×C): 2.27	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2:NAA@200ppm,C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

Combinations have displayed significant values for fruit retention per plant. An increase in fruit retention was recorded from combination T_{16} ($M_3 \times C_2$) at 86.8% which was union of NAA at 200ppm plus October month bending. While control of August month i.e., (T_7: $M_1 \times C_0$) gave the lowest value at 55.9%.

Auxin has marked to restrict the abscission layer formation by regulation the ethylene production. Increase in auxin concentration is negatively correlated to ethylene production. The balance between auxin and ethylene hormones plays a vital role in fruit retention. (Sanyan and Bangerth,1998). This physiology can explain the increase in fruit retention witnessed from NAA. These results are corroborated with the findings of Singh and Mukherjee (2000). Shoot bending led to horizontal bending of branches which alters the distribution pattern of auxins. Since the auxins are located in the shoot apical causing an apical dominance. However, bending disrupts the polar movement of auxin and directs its flow towards lateral buds and developing fruits which can be indirectly involved in more fruit retention. (Robbie *et al*., 1993). Similar findings were observed by (Jung and Choi.,2010). In addition to this. Combination of NAA and shoot bending have given positive response for fruit retention. Auxin influences cell division, cell differentiation, and overall fruit formation. Besides this, it inhibits the formation of the abscission layer. Meanwhile bending of branches reduces the competition among the fruits. This in combination could be a potential cause for an increase in fruit retention percentage.

4.3 Effect of shoot bending and PGRs on biochemical parameters of guava fruit.

4.3.1 TSS (°Brix)

The pooled data gathered on the impact of shoot bending and PGRs on the TSS (°B) are discussed in Table 4.6 and illustrated in Figure 4.3.1, with the variance analysis detailed in Appendix I.

Significant TSS mean values were obtained from the foliar spray of PGRs. Maximum TSS was found in GA_3 at 150ppm (C_6) sprayed tree at 11.7°B followed by GA_3 at 100 ppm (C_5) at 11.35°B while the lowest was observed in control (C_0) at 9.57°B. Furthermore, hoot bending has noted significant observation where highest TSS was obtained from fruits of October bent shoot (M_3) at 11.79°B while the lowest was collected from August month (M_1) at 9.47°B.

Combinations of shoot bending and PGRs were found to be significant. An increase in TSS was recorded with (T_{20}: $M_3 \times C_6$) i.e., a spray of GA_3 with October month shoot bending at 12.49°B in comparison with control of August month (T_7: $M_1 \times C_0$) at 7.93°B which was the lowest.

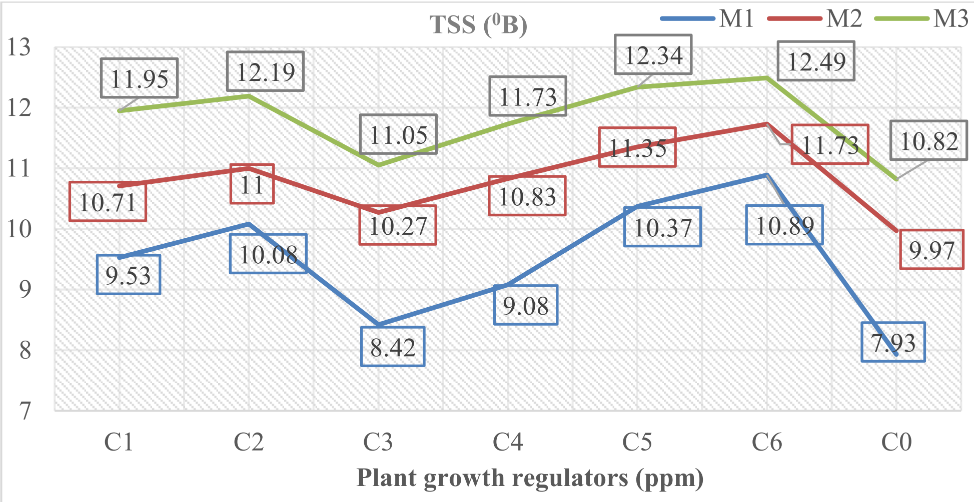


Fig.4.3.1: Effect of shoot bending and plant growth regulators on TSS (^{0}B) of guava fruit

Gibberellins stimulate enzyme activity like sucrose synthase, and invertase and with the help of this enzyme the complex carbohydrates are broken down into smaller units mainly glucose and fructose. The assimilation of these smaller sugars is directed to fruits (Marschner,1995). This can contribute to an increased TSS in fruits with GA_3 (C_6). The results conform with the outcomes of Talat *et al., (*2020) and Lal and Das, (2017). On the other hand, a drop in temperature was recorded in October month till the harvesting months of January and February for both consecutive years 2022-23 (Shown in Table 3.1). Cooler temperature is reported to reduce the metabolic rate of fruits which includes the rate of respiration. Consumption of sugars is increased with a decrease in respiration rate permitting more carbohydrate assimilation (Jones *et al*., 2024). Moreover, shoot bending promotes better light penetration which increases the photosynthetic rate. This could be a plausible reason for the increase in TSS through shoot bending. Parallel findings are obtained from (Samant *et al.,* 2016). The combination of GA_3 at 150ppm plus October shoot bending (T_{20}) gave optimum TSS value. Application of GA_3 increases metabolic rates which in turn increases sugar accumulation while shoot bending improves the canopy structure and hormonal translocation. This combined approach could have attributed to increased TSS of Guava fruit.

4.3.2 Reducing sugar (%)

The pooled data pertaining to the effect of shoot bending and PGRs on reducing sugar (%) have been interpreted in Table 4.6 and depicted in Fig.4.3.2 and the analysis of variance is mentioned in Appendix I.

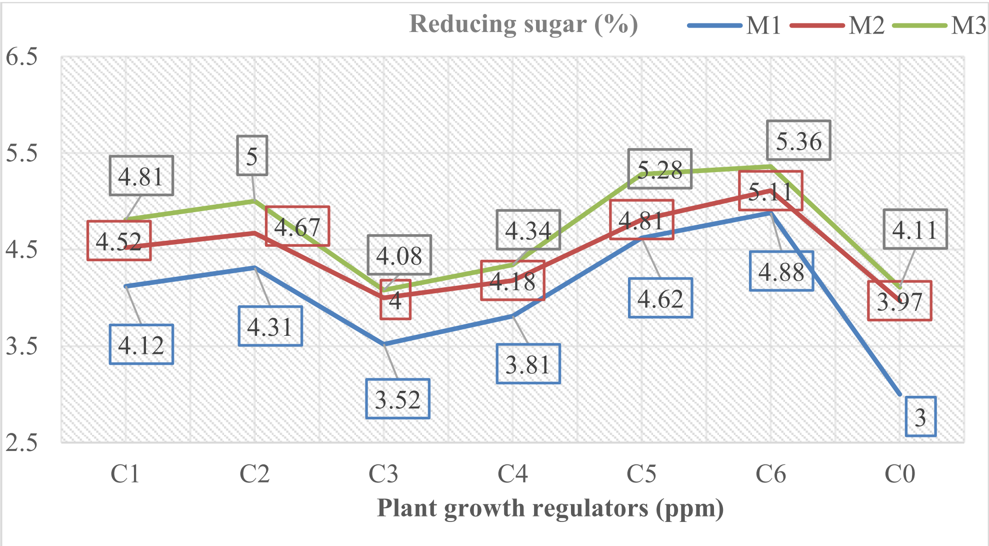


Fig.4.3.2: Effect of shoot bending and plant growth regulators on reducing sugar (%) of guava fruit

Plant growth regulators applied with different concentrations displayed significant mean reducing sugar percentage. The highest reducing sugar was recorded from a spray of GA_3 at 150ppm (C_6) at 5.12% at par with GA_3 at 100ppm (C_5) at 4.90% whereas the lowest was reported from control (C_0) at 3.69%. Significant value was noted with different months of shoot bending. Maximum reducing sugar was obtained from October shoot bending (M_3) at 4.71% while the minimum was from (M_1) August month bending at 4.04%.

The combinations have recorded Significant values for reducing sugar %. However, highest percent of reducing sugar of 5.36% was detected from (T_{20}: $M_3 \times C_6$), a union of October month bending plus GA_3 at 150ppm application while the lowest was recorded from the control of August month (T_7: $M_1 \times C_0$) at 3.0%.

Gibberellins play a pivotal role in increasing the flow of photosynthates by improving the source-sink relationship of leaves as a source to fruit as a sink. An optimal transfer of sugars into fruits ensures a higher level of sugar accumulation in fruits

(Rademacher, 2000). This might justify the increased level of reducing sugar witnessed with GA_3 spray. Similar findings were recorded by (Hamdy *et al*., 2017). In addition, bending of the shoot influences auxin redistribution, light penetration, and source-sink relationship. The disrupted auxin movement encourages better xylem and phloem development in a bent shoot which leads to improved nutrient uptake, while improved light penetration causes an increased rate of photosynthetic activity lastly, the optimization of the source sink ratio leads to accumulation of carbohydrates at faster at pace (Ito *et al*., 2004). Similar results were encountered by (Sarker *et al*., 2017). Moreover, temperature can be a factor that could have played a participatory role in enhancing reducing-sugar percent. As meteorological data collected from October month till the harvesting duration gave lower degree of temperature as compared to September and August (Shown in Table 3.1). While, higher temperatures result in the disruption of Photosystem II (Hu *et al.,* 2024). And this can significantly reduce rate of photosynthesis and thereby sugar accumulation. These mechanisms could have collectively boosted the increase in reducing sugar when applied in combination.

4.3.3 Non-reducing sugar (%)

The pooled data reported from the effect of shoot bending and PGRs on non-reducing sugar (%) have been interpreted in Table 4.6 and displayed in Fig.4.3.3 and the analysis of variance is mentioned in Appendix I.

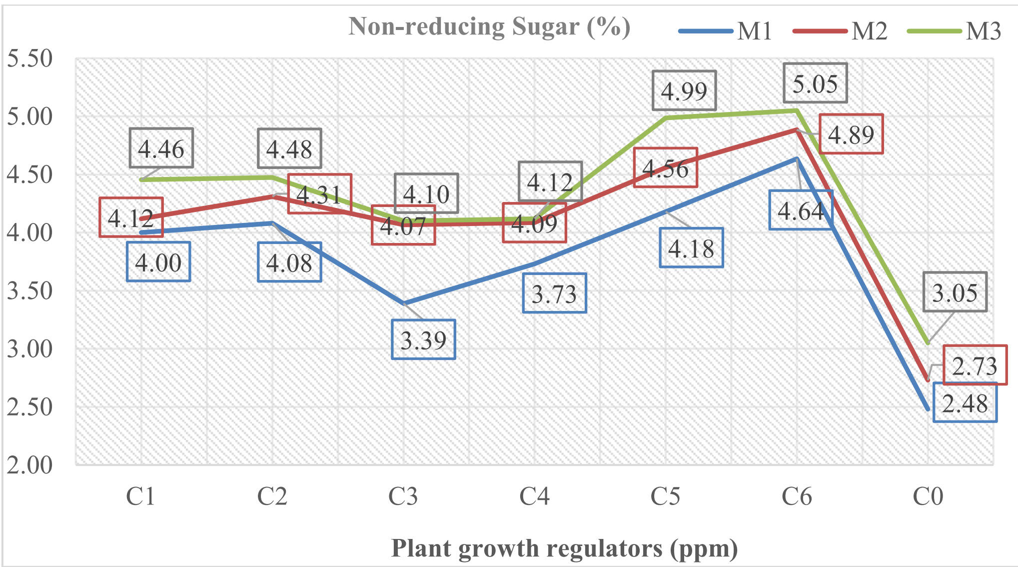


Fig.4.3.3: Effect of shoot bending and plant growth regulators on non-reducing sugar (%) of guava fruit

Significant mean values were derived from PGRs application on non-reducing sugar percentage. Among the plant growth hormones GA_3 at 150ppm (C_6) gave maximum reducing sugar content at 4.86% at par with GA_3 at 100ppm (C_5) at 4.58% followed by NAA at 200ppm (C_2) at 4.29%. The lowest value was noted from control (C_0) at 2.75%. In addition, guava tree exposed to shoot bending at different months displayed significant value. The highest observation was reported from the fruits of October bent branches (M_3) at 4.32% while the lowest was from August month (M_3) at 3.79%.

The combinations were found to be significant where the increased non-reducing sugar was derived from the spray of GA_3 at 150ppm with October month shoot bending i.e., (T_{20}: $M_3 \times C_6$) at 5.05% while the least was obtained from August month control (T_7: $M_1 \times C_0$) at 2.48%.

Phytohormones such as gibberellic acid are studied to influence the size and strength of the sink by affecting the cell expansion hence gaining more assimilates into the plant parts. Additionally, GA_3 is also noted to stimulate source-sink relationship by inducing uniform transport and increasing phloem movement with sucrose to the sink. (Roopendra *et al*., 2018). Parallel outcomes were witnessed by (Kumar *et al.*, 2014). This could be a possible reason for the increased non-reducing percent by GA_3 application. Moreover, shoot bending leads to better orientation of branches which improves the light penetration and thus photosynthesis. An increase in photosynthetic rate leads to higher production of carbohydrates. Moreover, it also regulates the transfer of energy to shoots, instead, it directs it to fruit growth (Khandekar *et al*., 2020). This can satisfy the reasoning behind increased non-reducing percent through shoot bending. Present results are in alignment with (Murri *et al.* 2015). Combination (T_{20}) gibberellic acids with October shoot bending have given a more pronounced value. GA_3 stimulates a better source and sink relationship leading to more carbohydrate accumulation while the shoot bending redistributes the photo-assimilates from shoot to fruit further, boosting sugar accumulation. These cumulative reasons explain the enhanced non-reducing sugar percentage.

4.3.4 Total sugar (%)

The pooled data reflecting the impact of shoot bending and PGRs on total sugar (%) are presented in Table 4.6, illustrated in Fig.4.3.4, and the analysis of variance is provided in Appendix I

Significant mean data was collected for total sugar percent with the foliar spray PGRs at different concentrations. The maximum increase in total sugar (9.97%) was reported in GA_3 at 150ppm (C_6) sprayed tree which was on par with GA_3 at 100ppm (C_5) at 9.48% followed by NAA at 200ppm (C_2) at 8.95%. Whereas, the minimum value was obtained from the control (C_0) at 6.13%. Shoot bending incorporated at different months gave significant results where the highest total sugar was derived from October month bending (M_3) at 9.02% and the lowest was from August bent (M_1) fruits at 7.78%.

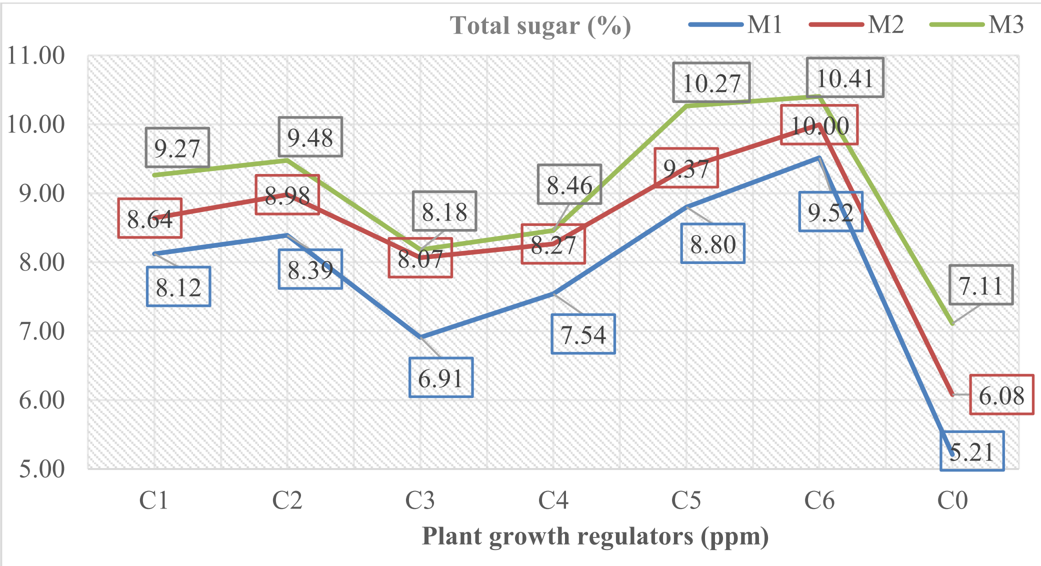


Fig.4.3.4: Effect of shoot bending and plant growth regulators on total sugar (%) of guava fruit

Combinations were given significant values for total sugar in guava fruits. However, an increased total sugar percentage were recorded from (T_{20}: $M_3 \times C_6$) at 10.41% which as the combination of GA_3 with 150ppm concentration and October shoot bending on the other hand, decreased total sugars (5.21%) were observed in control of August month i.e., (T_7: $M_1 \times C_0$).

Gibberellins are vividly used as a plant growth promoter. As it influences growth and development by enhancing cell elongation and cell division. On the other hand, it has an intriguing participation in carbohydrate allocation. With efficient sugar translocation from leaves to fruits the sugar assimilation is increased apparently. Further, the enzymes viz., sucrose synthase and invertase which are responsible for converting carbohydrates into monohydrates like fructose are positively correlated to GA_3 formation. This could be the potential cause for increased total sugar in guava fruits through GA_3 (C_6) application. Similar results were observed by Sharma and Tiwari., (2015) and Wojtania *et al.,* (2016). Moreover, Punjab region typically experiences reduced temperature from experimental months to harvesting (shown in Table 3.1.). Sugar metabolism dynamically reacts to the different temperature regimes. Ideal a drop in temperature can influence a reduction in respiration and transpiration rate which causes an apparent decrease in water losses and energy consumption. While shoot bending on other sides optimizes the uniform translocation of photo-assimilates. This can be a valid illustration of increased total sugars. The outcomes are in corroboration with the findings of (Kandil *et al*., 2006). These actions collectively could have elevated the total sugar percent in combination (T_{20}) applied Guava tree fruits.

4.3.5 Titratable acidity (%)

The pooled data from the impact of shoot bending and PGRs on titratable acidity (%) is detailed in Table 4.7, depicted in Fig.4.3.5, with the analysis of variance provided in Appendix I.

Significant mean values were observed with the foliar application of plant growth regulators on titratable acidity. Reduction in acidity (0.21%) was observed with the spray of GA_3 at 150ppm (C_6) at par with GA_3 at 100ppm (C_5) at 0.23% subsequently followed by NAA at 200ppm (C_2) at 0.26% while the highest titrable acidity was observed in control (C_0) at 0.34%. Significant titrable acidity content was noted from shoot bending. Among the shoot bending months, October (M_3) had a positive influence on acidity at 0.24% while August month (M_1) responded with negligible effect at 0.32%.

Combinations displayed significant interaction with acidity percent. Amongst the combination minimum value of 0.17% was noted from (T_{20}: $M_3 \times C_6$) which was union of GA_3 at 150ppm plus October shoot bending. Whereas, the maximum was obtained from control of August month (T_7: $M_1 \times C_0$) at 0.37%.

Gibberellins are certainly involved in the quality enhancement of fruits which is the key point is a reduction in acidity. GA_3 plays a vital role in organic acid metabolism. Studies have found that perhaps, it has a certain participation in downregulating enzyme activity like phosphoenolpyruvate carboxylase (PEPC) which

Table 4.6 Effect of shoot bending and PGRs on TSS (^{0}Brix), reducing sugar (%), non-reducing sugar (%), total sugar (%) in guava fruit.

Parameters	**Shoot Bending (Month)**	**Plant Growth Regulators (ppm)**							**Mean (C)**
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
1. TSS (^{0}Brix)	**M_1**	9.53	10.08	8.42	9.08	10.37	10.89	7.93	9.47
	M_2	10.71	11	10.27	10.83	11.35	11.73	9.97	10.83
	M_3	11.95	12.19	11.05	11.73	12.34	12.49	10.82	11.79
	Mean(M)	10.73	11.09	9.91	10.54	11.35	11.7	9.57	
CD at 5 %	Factor (M): 0.196			Factor (C): 0.299				Factor(M×C): 0.518	
Reducing sugar (%)	**M_1**	4.12	4.31	3.52	3.81	4.62	4.88	3.00	4.04
	M_2	4.52	4.67	4.00	4.18	4.81	5.11	3.97	4.47
	M_3	4.81	5.00	4.08	4.34	5.28	5.36	4.11	4.71
	Mean(M)	4.48	4.66	3.87	4.11	4.90	5.12	3.69	
CD at 5 %	Factor (M): 0.068			Factor (C): 0.103				Factor(M×C): 0.179	
Non-reducing sugar (%)	**M_1**	4.00	4.08	3.39	3.73	4.18	4.64	2.48	3.79
	M_2	4.12	4.31	4.07	4.09	4.56	4.89	2.73	4.11
	M_3	4.46	4.48	4.10	4.12	4.99	5.05	3.05	4.32
	Mean(M)	4.19	4.29	3.85	3.98	4.58	4.86	2.75	
CD at 5 %	Factor (M): 0.062			Factor (C): 0.095				Factor(M×C): 0.164	
Total sugar (%)	**M_1**	8.12	8.39	6.91	7.54	8.80	9.52	5.21	7.78
	M_2	8.64	8.98	8.07	8.27	9.37	10.00	6.08	8.49
	M_3	9.27	9.48	8.18	8.46	10.27	10.41	7.11	9.02
	Mean(M)	8.68	8.95	7.72	8.09	9.48	9.97	6.13	
CD at 5 %	Factor (M): 0.155			Factor (C): 0.237				Factor(M×C): 0.41	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T_4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

influences organic acid synthesis. This could be a potential reason behind the reduced acidity percentage. A similar pattern was reported by the studies of Thakur *et al*., (1990)

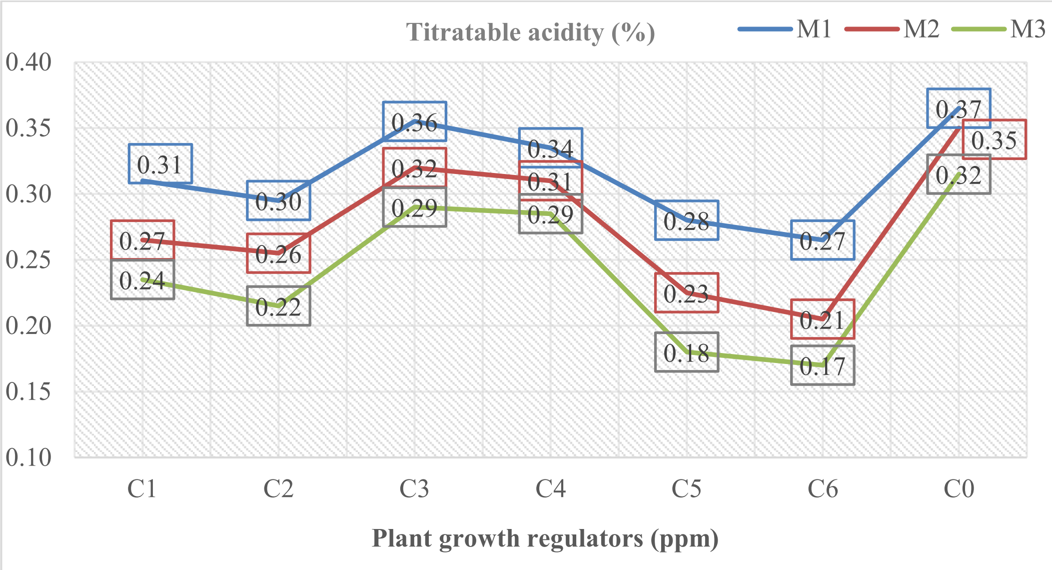


Fig.4.3.5: Effect of shoot bending and plant growth regulators on titratable acidity (%) of guava fruit

in litchi fruit. In addition, meteorological data obtained for October to February witnessed a slightly cooler temperature as compared to other months (shown in Table 3.1). Cooler temperature reduces the enzyme activity which is involved in the Kreb Cycle, and is required for metabolism of organic acids. Hence less acid is metabolized (Saltveit, 2002). In addition, shoot bending influences the optimization of the source and sink ratio which is responsible for better fruit quality. These can be a potential cause for a reduction in acidity. These results conform with (Tamang *et al.,* 2021). Furthermore, combination T_{20} has caused a reduction in acidity percentage. GA_3 is often involved in sugar metabolism which dilutes the organic acid concentration within the fruit while the shoot bending influences the source-sink ratio leading to increased photo-assimilation. Together, these activities might have caused a decreased titratable acidity percent.

4.3.6 Sugar acid ratio

The pooled observed values from the effect of shoot bending and PGRs on sugar acid ratio have been displayed in Table 4.7 and visualized in Fig.4.3.6 and the analysis of variance is mentioned in Appendix I.

Application of PGRs noticed significant mean value. Highest sugar acid ratio was recorded with the application GA_3 at 150ppm (C_6) at 48.62 followed by GA_3 at 100ppm (C_5) at 43.37. In contrast, lowest was obtained from control (C_0) at 18.07. Shoot bending has derived a significant value for sugar-acid ratio. Amongst different months October shoot bending (M_3) gave an optimum value of 40.31. While the August shoot bend tree gave the lowest at 25.46. A significant interaction was displayed between the combination and sugar acid ratio of guava fruit.

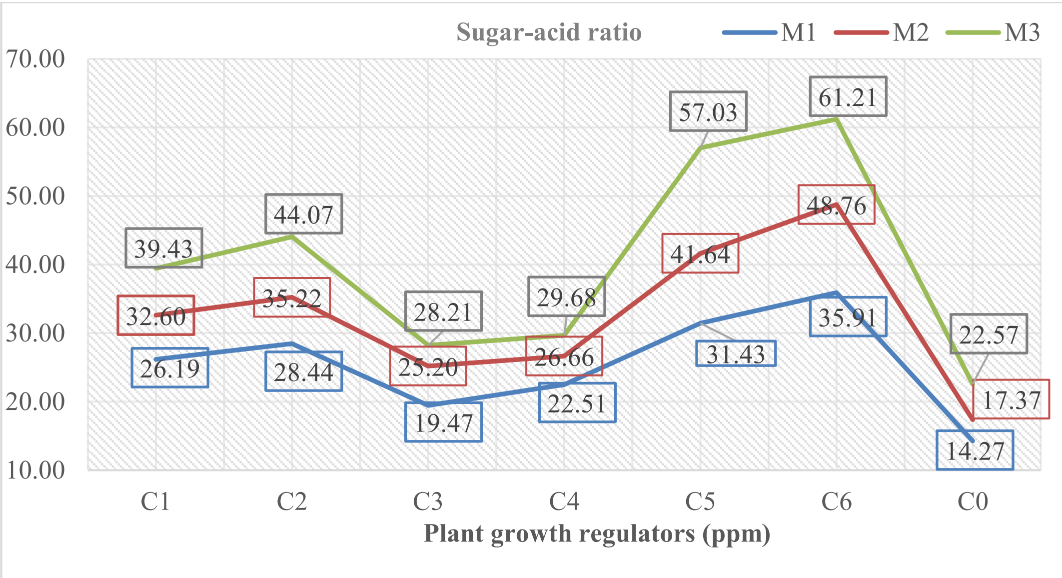


Fig.4.3.6: Effect of shoot bending and plant growth regulators on sugar-acid ratio of guava fruit

Amongst the combinations, maximum data was recorded from (T_{20}: $M_3 \times C_6$) i.e., foliar spray of GA_3 at 150ppm with shoot bending in October at 61.21 while control of august month (T_7: $M_1 \times C_0$) had no effect of sugar acid ratio (14.27).

GA_3 plays a critical role in carbohydrate assimilation. As it directly influences the sink-source relationship which is responsible for transfer of photosynthetic products to fruits. The degradation of complex carbohydrates into simpler ones is carried out by enzymes alike sucrose synthase and invertase. This leads to more sugar accumulation and an increased in sugar content causes a drastic decrease in organic acid. (Wojtania *et al.,* 2016). This could have been attributed to the increased sugar-acid ratio by GA_3 application (C_6). Parallel results were discussed in the studies of (Lal and Das, 2017). Moreover, shoot bending leads to optimized canopy structure, improved light penetration, alternation in hormonal movement, and reduced fruit competition. These factors have contributed to the unidirectional flow of sugars into fruits leading to increased sugar and decreased acidity percent. Nandi *et al.*, (2017) have suggested similar results corresponding to present outcomes. Moreover, when applied together, combinations (T_{20}: $M_3 \times C_6$) could have led to a cumulative effect resulting in enhanced outcomes for the sugar-acid ratio.

4.3.7 Ascorbic acid (mg/100g of pulp)

The pooled data pertaining the influence of shoot bending and PGRs on ascorbic acid have been interpreted in Table 4.7, portrayed in Fig.4.3.7 and the analysis of variance is mentioned in Appendix I.

A significant mean value for ascorbic acid was noted with PGRs. Amongst the plant growth regulators, maximum content was recorded from GA_3 at 150ppm (C_6) at 125mg/100g followed by GA_3 at 100ppm (C_5) at 121.2mg/100g whereas, the minimum was reported from control (C_0) at 76.4mg/100g. Shoot bending incorporated in the guava tree gave significant ascorbic acid content. October shoot bent trees (M_3) displayed an increased ascorbic acid (113.5mg/100g) in comparison with August bent (M_1) which was lowest at 92.4mg/100g.

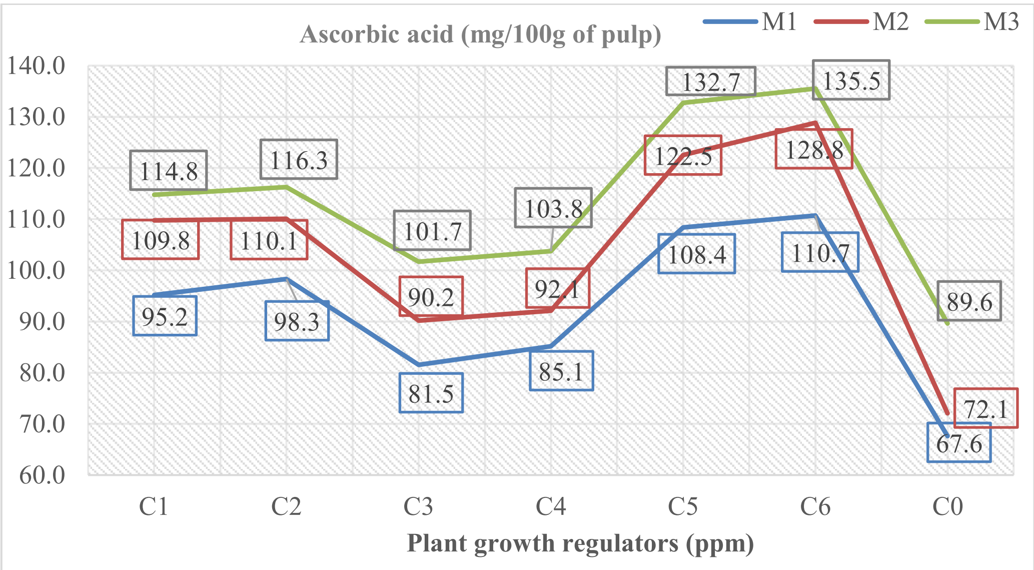


Fig.4.3.7: Effect of shoot bending and plant growth regulators on ascorbic acid (mg/100g) of guava fruit

Moreover, combinations have given significant values, where the highest ascorbic acid was obtained with the application of GA_3 at 150pm with October shoot bending i.e., (T_{20}: $M_3 \times C_6$) at 135.5mg/100g while the lowest was observed in August month control (T_7: $M_1 \times C_0$) at 67.6mg/100g of guava pulp.

The plausible reason for the increased ascorbic acid of guava fruit with GA_3 could be due to the indefinite synthesis of glucose-6-phosphate during the growth and development of fruit which is claimed to be a precursor of Vitamin-C. (Kumar and Singh, 1993). These results are aligned with the outcomes of (Kumar *et al.*,1998; Thakur *et al.*,1990). In addition, as shown in (Table 3.1), lower temperature and relative humidity are recorded in October to February month for both consecutive years (2022-24). The better ascorbic acid content with bending treatments practiced in October month could be attributed to a prolonged cooler climate in harvesting periods, better capture of sunlight, and uniform allocation of photosynthates. Kliewer and Lider (1970) suggested that despite the retardation of respiratory substrate, lower temperature also increases translocation of photosynthate from source to sink. The results are in conformity with the findings of (Tamang *et al.,*2021). Besides this, the combination (T_{20}) of GA_3 at 150ppm with October month bending gave ideal ascorbic acid content. The integration of these approaches might have worked synergistically contributing to an overall increase in ascorbic acid.

4.3.8 Pectin content (%)

The pooled data recorded from the influence of shoot bending and PGRs on pectin content (%) have been interpreted in Table 4.7 and depicted in Fig.4.3.8. The analysis of variance is mentioned in Appendix I.

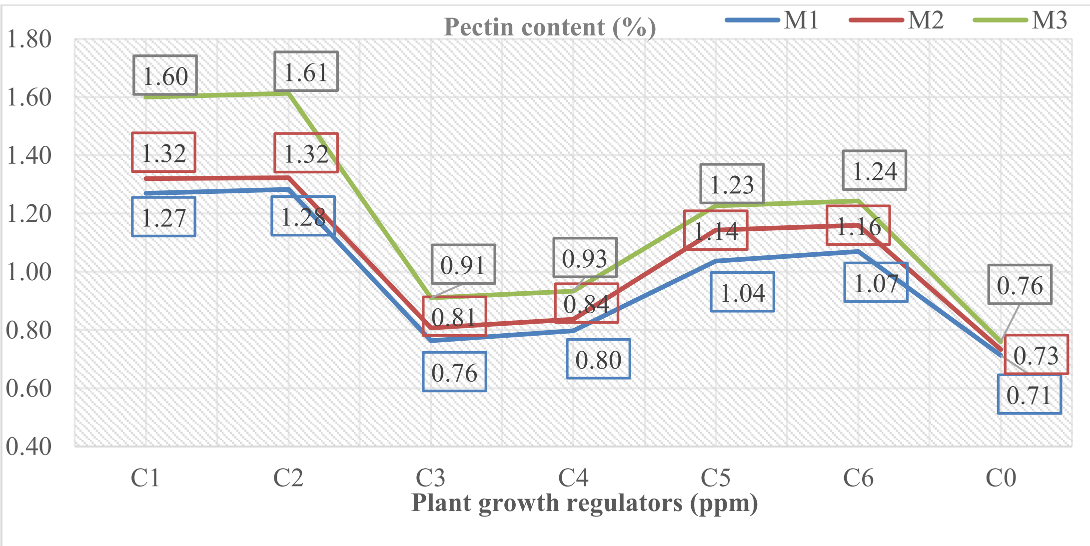


Fig.4.3.8: Effect of shoot bending and plant growth regulators on pectin content (%) of guava fruit

Foliar application of plant growth regulators noticed a significant mean pectin percentage. Among the PGRs, increased pectin content was derived from NAA at 200ppm (C_2) at 1.41% at par with a spray of NAA at 100ppm (C_1) at 1.40% followed by GA_3 at 150ppm (C_6) at 1.16%. In contradiction to this, control (C_0) has displayed a decreased value at 0.74%. A significant interaction was noted from shoot bending practiced at different months. Where highest pectin content (1.18%) was observed in October bent shoots (M_3) while the lowest was derived from August month bending (M_1) at 0.99%.

Combinations have interacted significantly. An increase in pectin content was recorded with (T_{16}: $M_3 \times C_2$,) at 1.61% which was a union of NAA at 200ppm spray with shoot bending in October month while the lowest was observed with August month control (T_7: $M_1 \times C_0$) at 0.71%

Application of NAA at a relatively higher concentration gave ideal results for pectin content (C_2). Plant growth regulators alike auxins, can solubilize the pectin substances present within the middle lamella (Kumar *et al.,*2010). Sharma and Tiwari have suggested similar results for guava fruits. Moreover, shoot bending influences fruit development by inducing the resource distribution of carbohydrates and nutrients (Davies, 2010). Increased assimilation of carbohydrates can be inclusive of pectin present in the cell wall as it is one of the paramount structural polysaccharides. This could be a potential cause for increased pectin content. On the other hand, auxin plays a vital role in influencing cell elongation by increasing the plasticity of cells allowing more water uptake this can lead to rapid cell formation and thereby increased pectin content. While the shoot bending affects the polar translocation of auxin, further boosting pectin in the cell wall. This synergistic effect of auxin and shoot bending (T_{16}) might have worked together giving increased pectin content in return for Guava fruits.

4.4 Effect of shoot bending and PGRs on biochemical parameters of guava leaf.

4.4.1 Nitrogen (%)

The pooled data obtained from the effect of shoot bending and PGRs on nitrogen (%) have been interpreted in Table 4.8, depicted in Fig.4.4.1 and the analysis of variance is mentioned in Appendix I.

Significant mean values were derived from the foliar spray of plant growth regulators. The highest nitrogen percent was recorded from NAA at 200ppm (C_2)

Table 4.7 Effect of shoot bending and PGRs on titratable acidity (%), sugar acid ratio, ascorbic acid (mg/100g), pectin content (%) in guava fruit

Parameters	**Shoot bending (Month)**	**Plant Growth Regulators (ppm)**							**Mean (C)**
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
1. Titratable Acidity (%)	**M_1**	0.31	0.30	0.36	0.34	0.28	0.27	0.37	0.32
	M_2	0.27	0.26	0.32	0.31	0.23	0.21	0.35	0.28
	M_3	0.24	0.22	0.29	0.29	0.18	0.17	0.32	0.24
	Mean(M)	0.27	0.26	0.32	0.31	0.23	0.21	0.34	
CD at 5 %	Factor (M): 0.004			Factor (C): 0.002				Factor(M×C): 0.007	
2. Sugar Acid Ratio	**M_1**	26.19	28.44	19.47	22.51	31.43	35.91	14.27	25.46
	M_2	32.60	35.22	25.20	26.66	41.64	48.76	17.37	32.49
	M_3	39.43	44.07	28.21	29.68	57.03	61.21	22.57	40.31
	Mean(M)	32.74	35.91	24.29	26.28	43.37	48.62	18.07	
CD at 5 %	Factor (M): 0.629			Factor (C): 0.412				Factor(M×C): 1.09	
Ascorbic acid (mg/100g)	**M_1**	95.2	98.3	81.5	85.1	108.4	110.7	67.6	92.4
	M_2	109.8	110.1	90.2	92.1	122.5	128.8	72.1	103.7
	M_3	114.8	116.3	101.7	103.8	132.7	135.5	89.6	113.5
	Mean(M)	106.6	108.2	91.1	93.7	121.2	125.0	76.4	
CD at 5 %	Factor (M): 1.535			Factor (C): 1.005				Factor(M×C): 2.659	
3. Pectin content (%)	**M_1**	1.27	1.28	0.76	0.80	1.04	1.07	0.71	0.99
	M_2	1.32	1.32	0.81	0.84	1.14	1.16	0.73	1.05
	M_3	1.60	1.61	0.91	0.93	1.23	1.24	0.76	1.18
	Mean(M)	1.40	1.41	0.83	0.86	1.14	1.16	0.74	
CD at 5 %	Factor (M): 0.019			Factor (C): 0.012				Factor(M×C): 0.033	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

applied guava tree at 2.84% which was on par with NAA at 100ppm (C_1) at 2.82% followed by GA_3 at 150ppm (C_6) at 2.80% whereas, the control (C_0) gave lowest value at 2.66%. Shoot bending practiced at different months in guava trees noticed significant value for leaf nitrogen. Maximum observations were recorded from (M_3) October month bending at 2.84% in contrast August month (M_1) gave minimum nitrogen at 2.71%.

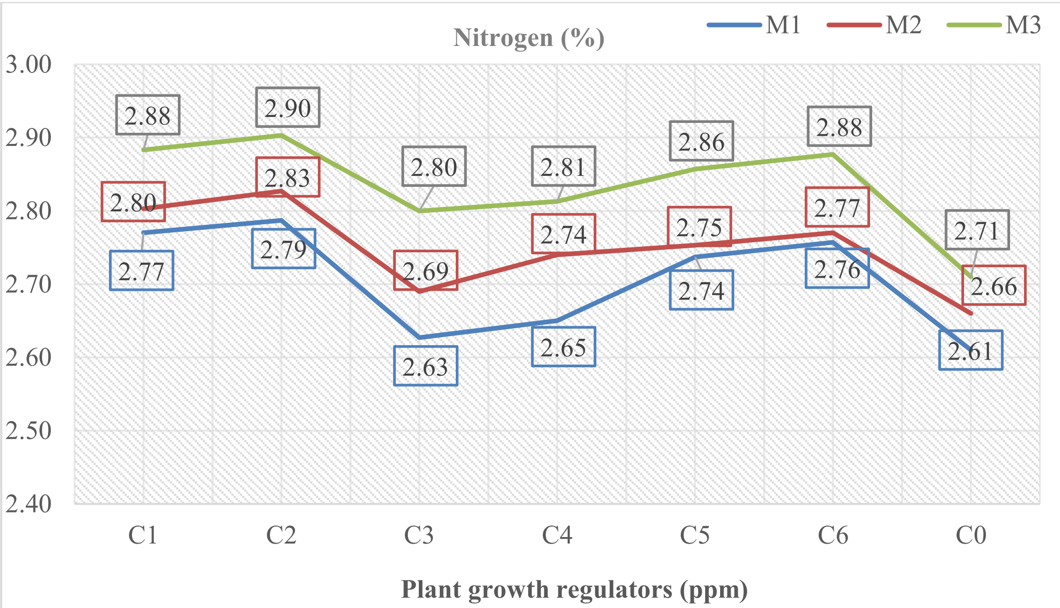


Fig.4.4.1: Effect of shoot bending and plant growth regulators on nitrogen (%) in guava leaves

Furthermore, combinations have displayed non-significant interaction on leaf nitrogen. Amongst the combination, an increase in leaf nitrogen percentage (2.90%) was obtained from spray of NAA at 200ppm with October Shoot bending (T_{16}: $M_3 \times C_2$) which was at par with (T_{15}: $M_3 \times C_1$) and (T_{20}: $M_3 \times C_6$) at 2.88% while control tree of August month (T_7: $M_1 \times C_0$) had negligible effect gaining the least value (2.61%).

Nitrogen is the most crucial nutrient essential for normal plant growth. Nitrogen is available in the form of (NH_4^+) ammonium and nitrate (NO_3^+). Metabolic and signalling pathways portray that NH_4^+ and NO_3^+, tryptophan individually or collectively regulates auxin biosynthesis (Fu *et al.*,2022). This indicates the indirect relationship between nitrogen and auxin. Moreover, research has also found that auxin has a role in influencing N uptake and assimilation by modulating the expression of N enzymes and transporters which are responsible for nitrogen metabolism (Li, 2024). This can justify the increase in leaf nitrogen content by NAA. Rahman *et al.,* (2007) have suggested parallel results. Moreover, shoot bending influences the canopy orientation which improves light availability to the lower leaves leading to increased photosynthetic processes. In addition, it can alter the source-sink relationship, improving better uptake of nitrogen from roots to leaves (Taiz *et al.*,2010). Similar results were claimed by (Nandi *et al.,* 2017). Moreover, according to weather data recorded October month experienced a slight drop in temperature (shown in Table 3.1). Lower temperatures have been witnessed to affect the solubility and availability of nutrients in soil making it more accessible for nutrient uptake by roots (Park *et al.*, 1973). This could be a potential reason for an increased in the leaf nitrogen percentage of the Guava crop.

4.4.2 Total chlorophyll (mg/100g of pulp)

The pooled data obtained from the effect of shoot bending and PGRs on total chlorophyll have been interpreted in Table 4.8, portrayed in Fig.4.4.2 and the analysis of variance is mentioned in Appendix I.

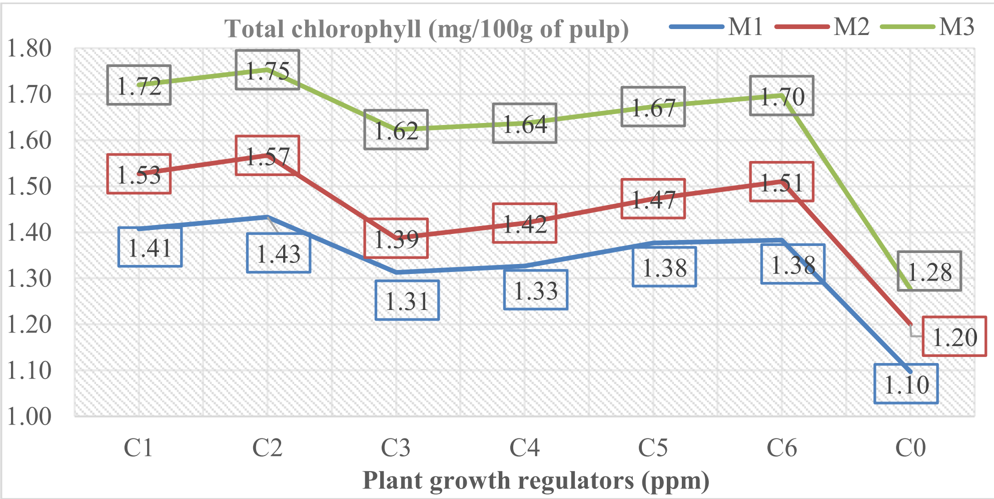


Fig.4.4.2: Effect of shoot bending and plant growth regulators on total chlorophyll (mg/100g of pulp) of guava leaf

Foliar spray of PGRs at different concentrations is noticed to be significant, Among the applied plant growth regulators, NAA at 200ppm (C_2) recorded highest total mean chlorophyll at 1.58mg/100g while NAA at 100ppm (C_1) also gave the optimum values with slight variation (1.55mg/100g). GA_3 at 150ppm (C_6) sprayed canopy recorded second highest chlorophyll at 1.53mg/100g while lowest was obtained from the control (C_0) at 1.19mg/100g. Besides, significant values were noticed from shoot bending operations. Maximum total chlorophyll was determined from leaves of October bent shoots (M_3) at 1.63mg/100g while the minimum was with August bent shoot (M_1) at 1.33mg/100g. Moreover, the combinations were found to be significant with total chlorophyll content.

However, from all the combinations highest values were obtained from (T_{16}: $M_3 \times C_2$) i.e., spray of NAA at 200ppm and October shoot bending at 1.75mg/100g whereas, the lowest was found in control of August month (T_7: $M_1 \times C_0$) at 1.10mg/100g.

Auxin plays a paramount role in regulating a series of genes or proteins present in chloroplast which have great impact on the growth of organelles. Auxin is found to be linked with 29 chloroplast proteins viz., chlorophyll a-b binding protein (CABs), pentatricopeptides repeats, and photosystem I protein (Xing and Xue, 2012). Metabolic pathways of glycolysis and phosphoserine include the enzymes which regulate chlorophyll biosynthesis. While this both pathways have a substantial role in tryptophan synthesis which in turn is a major precursor of auxin (Salazar-Iribe and De-la-Pena, 2020). This can highlight the indirect or direct role of auxin in chloroplast formation Hence increase in c11hloroplasts could have led to a subsequent increase in chlorophyll content by NAA application (C_2). On the other hand, shoot bending influences the light distribution which increases photosynthesis, auxin translocation which reduces apical dominance giving more reproductive shoots, and vascular relationships which are responsible for nutrient uptake (Robbie *et al*., 1993). However, with better nutrient uptake caused by comparatively lower temperatures in October, more nitrogen can be available to plants, thus increasing the chlorophyll content. This can suggest the reasoning behind increased total chlorophyll content through October shoot bending (M_3). Present results are in alignment with (Ding *et al*., 2021). Moreover, auxin increases the amount of leaf chlorophyll by promoting cell and chloroplast development while the shoot bending influences the sunlight distribution and photosynthetic intensity by altering the canopy structure. Together this combination (T_{16}) could have attributed to increased chlorophyll content for guava leaves.

4.4.3 Total carbohydrate (%)

The pooled observations recorded from the effect of shoot bending and PGRs on total carbohydrates percent have been interpreted in Table 4.8, depicted in Fig.4.4.3 and the analysis of variance is mentioned in Appendix I.

A significant effect was noticed from PGR application on total carbohydrate percent of guava leaf. Among the plant growth regulators, NAA at 200ppm (C_2) gave the maximum mean total carbohydrate value at 10.42% which was on par with NAA at 100ppm (C_1) at 9.99% followed by GA_3 at 150ppm (C_6) at 9.68%. Whereas, minimum data was recorded from (C_0) control at 7.61%. Moreover, shoot bending carried in different months displayed significant mean values. The highest total carbohydrate percentage was analyzed from October shoot bending (M_3) at 10.37% whereas, August Shoot (M_1) bending gave the lowest data (8.71%). In addition, combinations were found Significant.

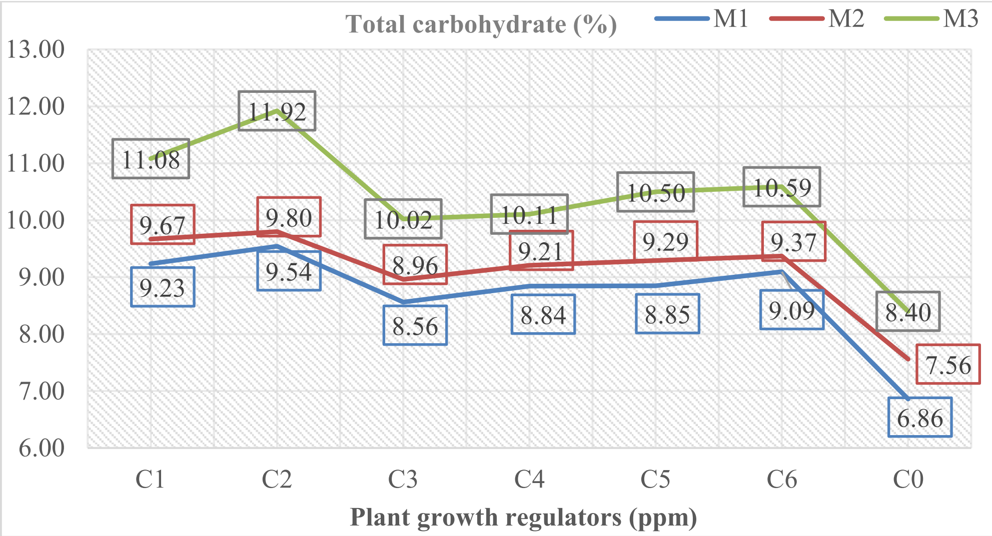


Fig.4.4.3: Effect of shoot bending and plant growth regulators on total carbohydrate (%) of guava leaf

A combination of NAA at 200ppm plus October month bending (T_{16}: $M_3 \times C_2$) displayed a positive influence on carbohydrate content at 11.92% while (T_7: $M_1 \times C_0$) August month control had negligible effect with 6.86%.

Auxin plays a vital role in stimulating glucose uptake and its utilization. The enzymes responsible for carbohydrate synthesis such as hexokinase and β-Glucan synthetase were increased by auxin treatment. As suggested by (Abdul-Baki and Ray, 1971). Moreover, optimization of the sink-source ratio increases the translocation of phloem to the targeted organs is induced by auxin (Morris and Arthur, 1984). This can be attributed to increased carbohydrate percentage in NAA sprayed trees. Parallel outcomes were discussed in studies of (Agusti *et al.,* 2002). The Punjab region typically records a slight decrease in temperature in October month (shown in Table 3.1) as compared to August and September. Higher temperature can enhance the respiration rate increasing carbohydrate consumption while the comparatively lower temperature can slow down the respiration process due to decreased activity of enzymes (Seydel *et al*.,2022). While the shoot bending induces better light capture for shaded leaves, which increases photosynthetic activity. Additionally, it can impair the resource allocation with the plant including carbohydrates (Cline, 1997). This can be a potential reason for increased total carbohydrates through October shoot bending. Present outcomes are in alignment with (Nandi *et al.,*2017). Combination (T_{16}) has gained pronounced value for total carbohydrate percent of leaf. The combined exposure of synchronized action by auxin and shoot bending can be attributed to increased carbohydrates.

4.4.4 C: N ratio

The pooled data on the effect of shoot bending and PGRs on the C: N ratio is presented in Table 4.8, illustrated in Fig.31 and the variance analysis is provided in Appendix I.

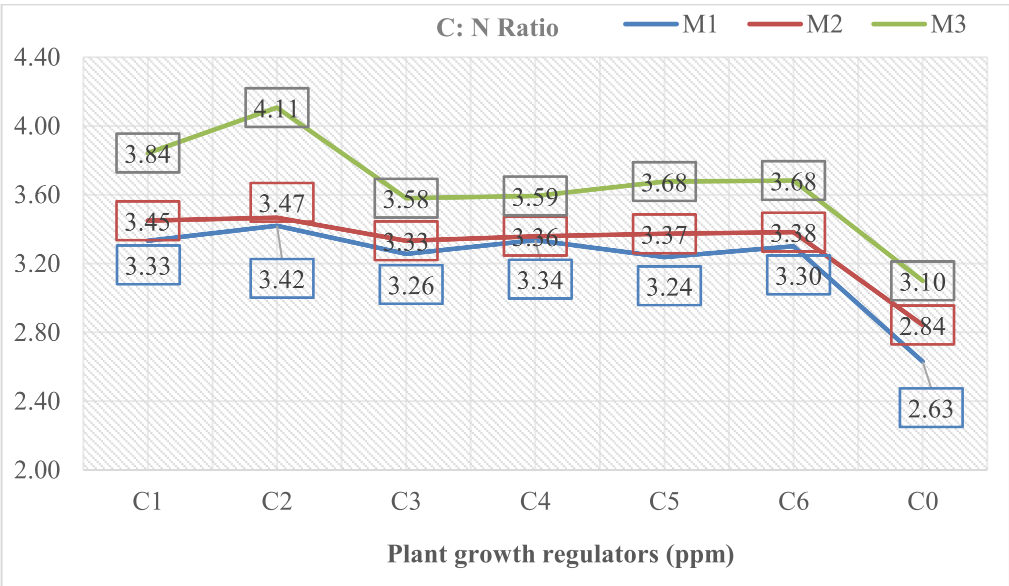


Fig.4.4.4: Effect of shoot bending and plant growth regulators on C: N ratio of guava leaf

Plant growth regulators were found to be significant with a mean value of C: N ratio. Highest C: N ratio was reported from NAA at 200ppm (C_2) at 3.66 on par with NAA at 100ppm (C_1) at 3.54 followed by GA_3 at 150ppm (C_6) at 3.46 whereas, the lowest was obtained from control (C_0) at 2.86. Significant values were noted from shoot bending. Among the shoot bending months, October (M_3) has given a maximum C: N ratio of 3.66 while the minimum was collected from August month (M_1) at 3.22. In addition, combinations have displayed significant interaction with C: N ratio.

However, from the combinations incorporated in the guava tree, an application of NAA at 200ppm with October shoot bending T_{16} ($M_3 \times C_2$) had a positive influence on the C: N value (4.11) while August month (T_7: $M_1 \times C_0$) gave minimum value at 2.63.

Auxin plays a substantial role in the synthesis and allocation of carbohydrates by stimulating the enzymes responsible for its biosynthesis. Auxin often works synergistically with gibberellins and cytokinin to regulate carbohydrate metabolism (Morris and Arthur, 1984). Moreover, the repression of sugars often represents nitrogen deficiency in plants. This reduces the photosynthesis and respiration processes which results in more carbohydrate accumulation in comparison with nitrogen (Paul and Driscoll, 1997). Parallel results were discovered from the findings of Samim *et al.,* (2021). Moreover, shoot bending influences the distribution pattern of Carbon. It affects the flow of photosynthates from mature leaves to the developing leaves and then to shoot tips in the growing shoots while it restricts the flow of photosynthates from shoots to leaves for non-growing shoots (Mika, 1969). This redefined carbon assimilation leads to more carbohydrate production. This, in turn, causes an increase in carbohydrate assimilation in the leaf and other reproductive organs with a decrease in nitrogen content and vegetative organs. Our results are in agreement with the findings of (Nandi *et al*., 2017). Moreover, a combination of these two viz., spray of NAA and shoot bending in October month has collected an increased C: N ratio for Guava leaf indicating more reproductive growth. This can be attributed to the combined action.

4.5 Effect of shoot bending and PGRs on leaf nutrients of guava tree.

4.5.1 Phosphorous (%)

The pooled data recorded from the influence of shoot bending and PGRs on phosphorous (%) have been interpreted in Table 4.9, portrayed in Fig.4.5.1 and the analysis of variance is mentioned in Appendix I.

A significant mean value was noticed by PGRs on the phosphorous percentage of guava leaves. From the plant growth regulators applied, maximum phosphorous percent was observed from NAA at 200ppm (C_2) at 0.25% followed by NAA at 100ppm (C_1) and GA_3 at 150ppm (C_6) with mean values of 0.23 and 0.21% respectively. Contradiction to this control (C_0) at 0.10% gave a minimum value. In addition, shoot

Table 4.8 Effect of shoot bending and PGRs and on nitrogen (%), total chlorophyll (mg/100), total carbohydrate (%), C: N ratio in Guava leaves

Parameters	**Shoot Bending (Month)**	**Plant Growth Regulators(ppm)**							**Mean (C)**
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
Nitrogen (%)	**M_1**	2.77	2.79	2.63	2.65	2.74	2.76	2.61	2.71
	M_2	2.80	2.83	2.69	2.74	2.75	2.77	2.66	2.75
	M_3	2.88	2.90	2.80	2.81	2.86	2.88	2.71	2.84
	Mean(M)	2.82	2.84	2.71	2.73	2.78	2.80	2.66	
CD at 5 %	Factor (M): 0.045			Factor (C): 0.068				Factor(M×C): NS**	
Total Chlorophyll (mg/100g)	**M_1**	1.41	1.43	1.31	1.33	1.38	1.38	1.10	1.33
	M_2	1.53	1.57	1.39	1.42	1.47	1.51	1.20	1.44
	M_3	1.72	1.75	1.62	1.64	1.67	1.70	1.28	1.63
	Mean(M)	1.55	1.58	1.44	1.46	1.51	1.53	1.19	
CD at 5 %	Factor (M): 0.03			Factor (C): 0.02				Factor(M×C): 0.052	
Total Carbohydrate (%)	**M_1**	9.23	9.54	8.56	8.84	8.85	9.09	6.86	8.71
	M_2	9.67	9.80	8.96	9.21	9.29	9.37	7.56	9.12
	M_3	11.08	11.92	10.02	10.11	10.50	10.59	8.40	10.37
	Mean(M)	9.99	10.42	9.18	9.39	9.55	9.68	7.61	
CD at 5 %	Factor (M): 0.173			Factor (C): 0.265				Factor(M×C): 0.459	
C:N ratio	**M_1**	3.33	3.42	3.26	3.34	3.24	3.30	2.63	3.22
	M_2	3.45	3.47	3.33	3.36	3.37	3.38	2.84	3.32
	M_3	3.84	4.11	3.58	3.59	3.68	3.68	3.10	3.66
	Mean(M)	3.54	3.66	3.39	3.43	3.43	3.46	2.86	
CD at 5 %	Factor (M): 0.061			Factor (C): 0.094				Factor(M×C): 0.162	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T_4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

bending displayed significance with the phosphorous percentage of the leaf. The highest data was observed from October bent shoots (M_3) at 0.23% while the lowest was found in August month bending (M_1) at 0.15%.

Moreover, combinations noticed significant interaction with leaf phosphorous content. Amongst the combination, T_{16} ($M_3 \times C_2$) i.e., application of NAA at 200ppm with October shoot bending resulted in increased phosphorous percent at 0.29% while control trees in August month (T_7: $M_1 \times C_0$) had negligible effect at 0.08%.

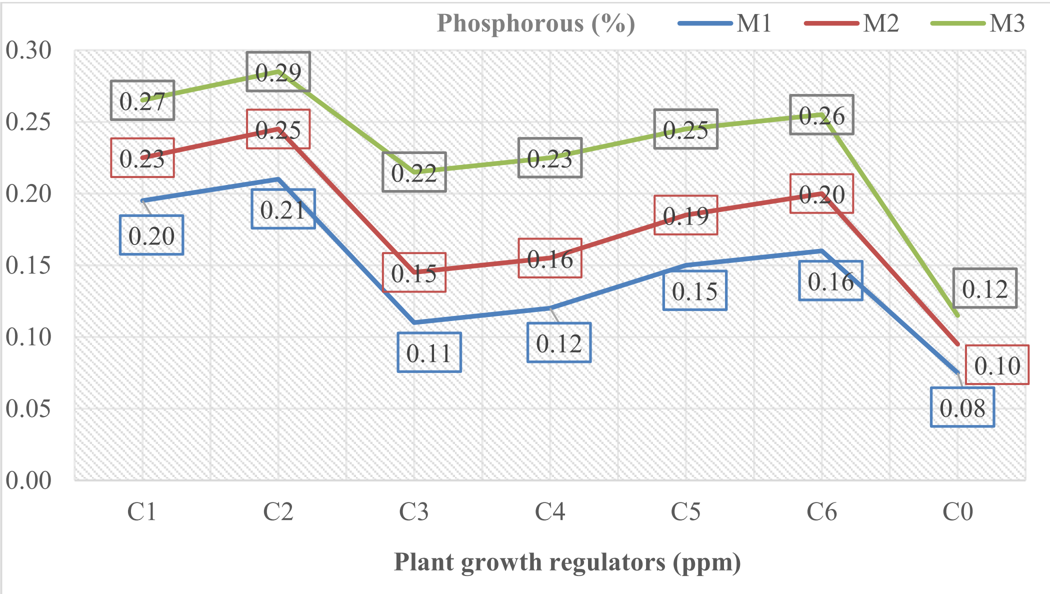


Fig.4.5.1: Effect of shoot bending and plant growth regulators on phosphorous (%) of guava leaf

Auxins is suggested to promote elongation and root branching. Encouraging lateral root development and increasing root hairs and root surface area, increases the contact between soil and root surface. Exogenous application of auxins is found to increase lateral growth in roots (Jan *et al*.,2024). This extended root system permits the plants to absorb more phosphorous which is generally in immobile form. This uploaded phosphorous by roots can be subsequently transferred to leaves. This can be a plausible cause for increased phosphorous percent with NAA spray. Our outcomes are in agreement with Vance *et al.*, (2003). Moreover, the bending of shoots alters the canopy direction which introduces a redistribution of plant hormones, peculiarly auxins. When shoots are bent horizontally, auxin moves to the lower side of the shoot and stem, encouraging a strong root system which in turn explores a large volume of soil giving more nutrient uptake (Samant and Kishor, 2021). In addition to this, it also induces mechanical stress and stress helps in better resource acquisition including nutrients in the soil (Valladares *et al*., 2007). While extreme temperatures, phosphorus in soil tends to become chemically fixed binding with iron, aluminum (in acidic soils), or calcium (in alkaline soils) making it unavailable to plants. In contrast, moderate October temperatures help keep phosphorus in a more soluble and plant-available form (Muindi, 2019). This can reasons are be attributed to pronounced phosphorous content through bending (M_3). Furthermore, the combination of NAA with October shoot bending (T_{16}) witnessed a positive influence. As auxin induces better root formation while shoot bending could have acted synergistically promoting a better source-sink ratio leading to more phosphorous absorption and translocation to the guava leaves.

4.5.2 Potassium (%)

Pooled observations recorded from the influence of shoot bending and PGRs on phosphorous (%) have been interpreted in Table 4.9, portrayed in Fig.4.5.2 and the analysis of variance is mentioned in Appendix I.

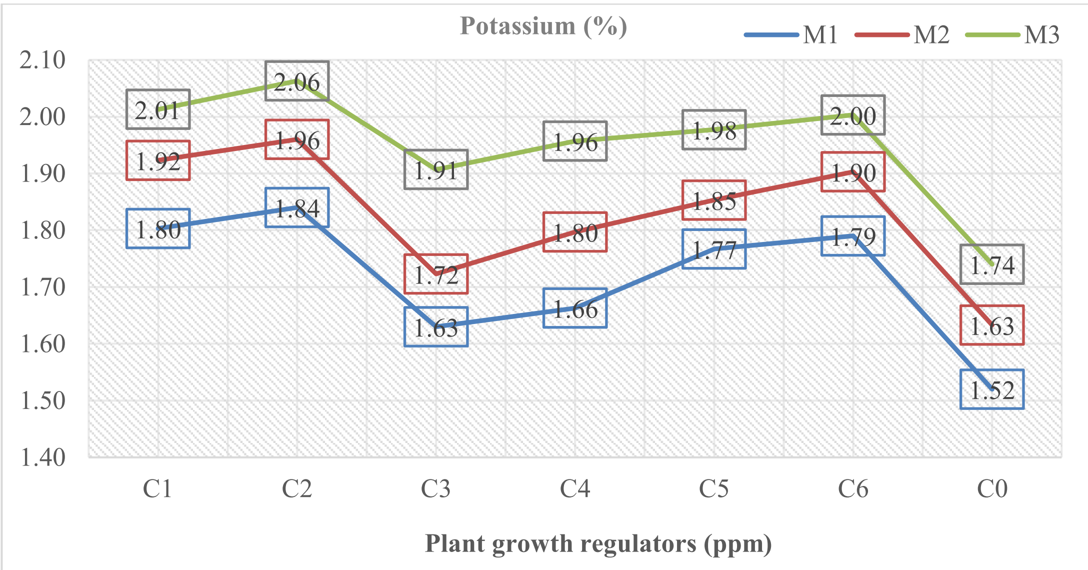


Fig.4.5.2 Effect of shoot bending and plant growth regulators on potassium (%) of guava leaf

Foliar application of plant growth regulators was found to be significant. From the PGRs applied, a spray of NAA at 200ppm (C_2) was reported as best performing with a mean value of 1.95% which was on par with NAA at 100ppm (C_1) at 1.91 followed by GA_3 at 150ppm (C_6) at 1.90%. While the control (C_0) gave the lowest performance at 1.63%. Besides this, shoot bending has attributed to significant results.

Amongst the different months, October month shoot bending received highest potassium content at 1.95% while August (M_1) recorded lowest at 1.72%.

Combination has noted to be non-significant. Amongst the combinations, guava tree incorporated with NAA at 200pmm plus October shoot bending (T_{16}: $M_3 \times C_2$) recorded a maximum increase in potassium percentage at 2.06% while the minimum was obtained from (T_7: $M_1 \times C_0$) control trees of August month at 1.52%.

Auxin plays a pivotal role in strengthening root growth and development allowing more nutrient uptake from roots to the leaves. Auxin is thought to modulate the activity of ions transporter and channels viz., HAK/KUP/KT in root cells, which are substantially involved in potassium uptake. Hence enhancing more efficient potassium absorption from soil to leaves (Giehl and Wiren, 2014). In addition to this, auxin also influences the phloem movement, which can contribute to better nutrient uptake (Taiz and Zeirger, 2010). A typical drop in temperature is recorded for October month (Shown in Table 3.1). Not the freezing but a slight decrease in temperature can decrease the soil water viscosity which can improve the rate of diffusion of nutrients like potassium making it feasible for root absorption (Kramer and Broyer, 1995). Meanwhile, the bending of shoots induces better vascular differentiation, which impairs the xylem and phloem flow leading to rigorous nutrient uptake (Mika, 1969). This can be collectively attributed to increased potassium content by shoot bending in October (M_3).

4.5.3 Zinc (ppm)

The pooled observations pertaining effect of shoot bending and PGRs on zinc content have been interpreted in Table 4.9 and displayed in Fig.4.5.3. The analysis of variance is mentioned in Appendix I.

Application of plant growth regulators was found significant with zinc content. Amongst the PGRs applied, NAA at 200ppm (C_2) gave the highest mean value for zinc content at 84.13ppm closely followed by NAA at 100ppm (C_1) at 81.70ppm while the lowest zinc content was derived from control (C_0) at 45.48ppm. Furthermore, Significant interaction was pointed out by shoot bending and leaf zinc content. October shoot bending (M_3) recorded maximum zinc contention at 82.86ppm while the minimum was obtained from the August bent tree (M_1) at 64.06ppm.

In addition, combinations also displayed significant values. Combination (T_{16}:

$M_3 \times C_2$) which was a union of NAA at 200ppm spray plus shoot bending in October month gave positive results at 93.77ppm while least value for zinc was derived from the control tree of August month (T_7: $M_1 \times C_0$) at 40.22ppm.

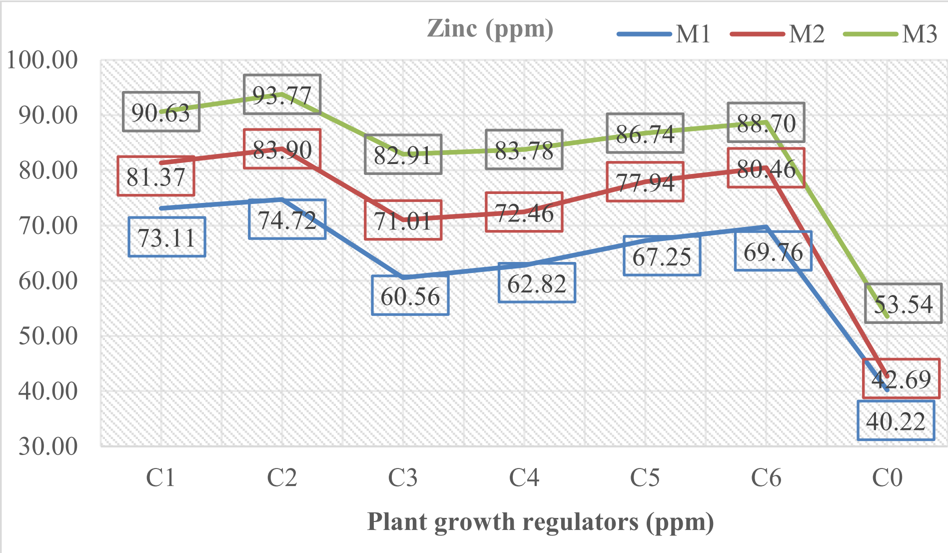


Fig.4.5.3: Effect of shoot bending and plant growth regulators on zinc (ppm) content of guava leaf

Auxin plays an important role in stimulating the lateral development of roots and their hairs. Thus, this provides a scope for better nutrient uptake. Additionally, auxins can affect the zinc expression by influencing the transporter ion activity which is pivotal for Zinc uptake. However, vascular activity is also severely impaired by auxin which contributes to better nutrient and food translocation (Giehl and Wiren, 2014). Increased translocation and absorption of nutrients could have led to better Zinc content in the leaf by NAA spray. Whereas amongst the shoot bending October month had given optimum Zn value. Mechanical stress induced by the shoot bending facilitates increased resource allocation, which includes nutrients. (Valladares *et al.*,2007). The horizontal bending of shoots causes auxin to translocate on the bottom of the shoots and roots system, which induces vigorous root branching causing a further increase in nutrient uptake (Robbie *et al.*, 1993). This could be a potential reason underlying the increase in Zn content with bending incorporation. In extreme cold or hot soils, zinc can become fixed by binding with soil components like iron or aluminium oxides, especially in high pH soils (Alloway, 2009). However, in October, the soil temperature is generally favourable (20–30°C), reducing this fixation and keeping zinc in available ionic forms (e.g., Zn^{2+}). Hence, Combination (T_{16}) has given an ideal Zn value for guava leaves. Auxin has suggested amplifying the zinc uptake by influencing Zn transporter activity leading to more efficient transport of Zinc to leaves while the bending influences the source sink allocation. Collectively, this mechanism could have led to an elevated Zinc content within guava leaves.

4.5.4 Boron (ppm)

The pooled data obtained from the effect of shoot bending and PGRs on boron content have been interpreted in Table 4.9, portrayed in Fig.4.5.4 and the analysis of variance is mentioned in Appendix I.

A significant increase was recorded from foliar spray of plant growth regulators. Highest increase in mean leaf boron content was recorded from NAA at 200ppm (C_2) at 133.8ppm followed by NAA at 100ppm (C_1) at 131.7ppm. In contrast control (C_0) at gave the least data at 85.8ppm. In addition, shoot bending performed in different months were noted to be significant, where the maximum boron was derived from October bent shoots (M_3) at 132.5ppm while the minimum was with August shoot bending (M_1) at 110ppm.

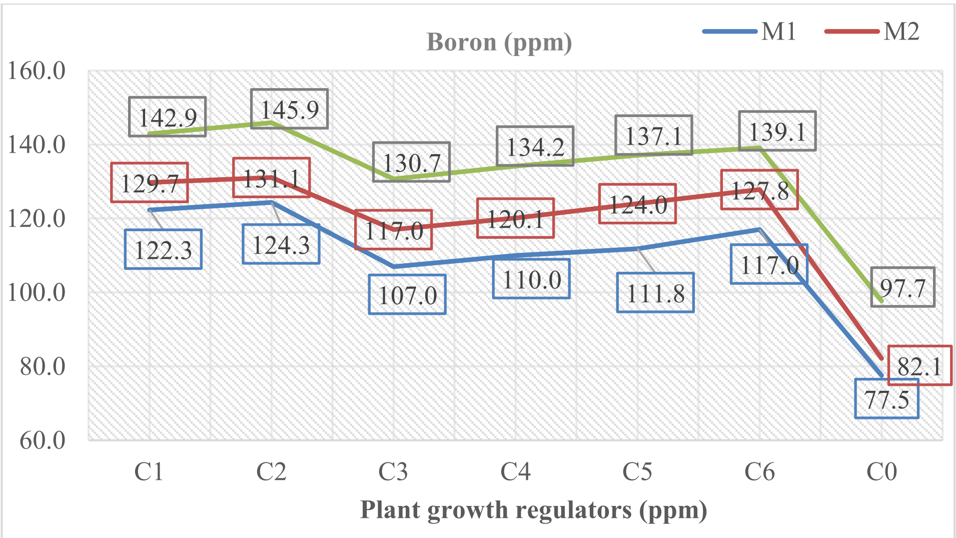


Fig.4.5.4: Effect of shoot bending and plant growth regulators on boron (ppm) content of guava leaf

Furthermore, for combinations non-significance was noted. Maximum performance was collected from a combination of NAA spray at 200ppm and hoot bending in the month of October (T_{16}: $M_3 \times C_2$) at 145.9ppm while August month control (T_7: $M_1 \times C_0$) gave reduced Boron concentration for guava leaves at 77.5ppm.

Boron and auxin were suggested to work synergistically. In the studies undertaken by (Li *et al*.,2016) a decrease in auxin content led to a drop in boron concentration establishing a relationship between boron and auxin. This can be an explanation for increased boron content by auxin spray NAA. Even though the boron and auxin interaction has been noted in many plants, the relationship remains unclear (Martin-Rejano *et al*.,2011). Moreover, auxin affects phloem transport, potentially aiding in improved nutrient uptake (Taiz and Zeiger, 2010). Besides this, shoot bending fosters uniform xylem and phloem differentiation resulting in increased nutrient absorption (Mika, 1969). However meteorological data recorded for October month gave a slightly reduced temperature in comparison with August and September (Shown in Table 3.1). A modest decline in temperature can lower down the viscosity of soil water resulting in an increased diffusion rate of nutrients making them more available to plants (Kramer and Broyer, 1995). Meanwhile, better vascular differentiation is induced by shoot bending, disrupting the xylem and phloem flow, thereby enhancing nutrient uptake (Mika, 1969). This process may explain the increased zinc content resulting from shoot bending in October (M_3).

4.6 Effect of shoot bending and PGRs on proximate parameters of guava leaf.

4.6.1 Ash (%)

The pooled observations of the impact of shoot bending and PGRs on ash (%) is summarized in Table 4.10, depicted in Figure 4.6.1, with the variance analysis detailed in Appendix I.

Application of PGRs at different concentrations has recorded significant values for Ash content. Maximum mean value for ash content was obtained from NAA at 200ppm (C_2) at 5.8% which was on par with NAA spray at 100ppm (C_1) at 5.6% followed by GA_3 with 150ppm (C_6) at 5.4%. The minimum observation was observed from control (C_0) at 4.3%. Furthermore, significance was noticed from bent shoot for ash percentage. The highest Ash content was obtained from October bent shoots (M_3) at 6.0% while the lowest was with August (M_1) at 4.3%.

Moreover, combinations have gained significant interaction with ash percentage in guava leaves. Among the combinations T_{16} (which was union of NAA spray at 200ppm with October month bending i.e., $M_3 \times C_2$) recorded an increase in ash content at 6.6% while least observations were collected from August month control (T_7: $M_1 \times$

Table 4.9 Effect of shoot bending and PGRs on phosphorous (%), potassium (%), zinc (ppm), boron (ppm) in guava leaves

Parameters	Shoot bending (Month)	Plant Growth Regulators (ppm)							Mean (C)
		C_1	C_2	C_3	C_4	C_5	C_6	C_0	
Phosphorous (%)	M_1	0.20	0.21	0.11	0.12	0.15	0.16	0.08	0.15
	M_2	0.23	0.25	0.15	0.16	0.19	0.20	0.10	0.18
	M_3	0.27	0.29	0.22	0.23	0.25	0.26	0.12	0.23
	Mean(M)	0.23	0.25	0.16	0.17	0.19	0.21	0.10	
CD at 5 %	Factor (M): 0.003		Factor (C): 0.002			Factor(M×C): 0.005			
Potassium (%)	M_1	1.80	1.84	1.63	1.66	1.77	1.79	1.52	1.72
	M_2	1.92	1.96	1.72	1.80	1.85	1.90	1.63	1.83
	M_3	2.01	2.06	1.91	1.96	1.98	2.00	1.74	1.95
	Mean(M)	1.91	1.95	1.75	1.81	1.87	1.90	1.63	
CD at 5 %	Factor (M): 0.069			Factor (C): 0.045			Factor(M×C): NS**		
Zinc (ppm)	M_1	73.11	74.72	60.56	62.82	67.25	69.76	40.22	64.06
	M_2	81.37	83.90	71.01	72.46	77.94	80.46	42.69	72.83
	M_3	90.63	93.77	82.91	83.78	86.74	88.70	53.54	82.87
	Mean(M)	81.70	84.13	71.49	73.02	77.31	79.64	45.48	
CD at 5 %	Factor (M): 0.87			Factor (C): 0.569			Factor(M×C): 1.506		
Boron (ppm)	M_1	122.3	124.3	107.0	110.0	111.8	117.0	77.5	110.0
	M_2	129.7	131.1	117.0	120.1	124.0	127.8	82.1	118.8
	M_3	142.9	145.9	130.7	134.2	137.1	139.1	97.7	132.5
	Mean(M)	131.7	133.8	118.2	121.4	124.3	128.0	85.8	
CD at 5 %	Factor (M): 2.517		Factor (C): 1.648			Factor(M×C): NS**			

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0 : Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

C_0) at the 3.7%.

Auxin influences various physiological processes such as uptake, translocation, and assimilation of essential nutrients by impairing better root system which increases the root surface area. This permits more efficient nutrient uptake of minerals viz. calcium, potassium, and magnesium from the soil depth. These elements are transferred through the vascular system to the leaves. Auxin is a major factor in upregulating the expression for peculiar transporter proteins (H+-ATPase) which acidifies the cell wall facilitating the uptake of cations like Ca and Mg (Marschner 2012; Davies, 2013). In the leaf, these minerals form the overall ash content which is calibrated by burning other organic material. This could be a potential reason for the increased ash percentage observed with NAA. Similar results were discussed in the research of (Nejad *et al*.,2014). Furthermore, shoot bending influences nutrient uptake by strengthening the root system, improving vascular tissue efficiency, introducing mechanical stress responses, and optimizing better light penetration and photosynthesis (Robbie *et al*., 1993). Ash content varies with climate conditions, especially temperature and soil nutrient dynamics. Crops grown in cooler, stable post-monsoon conditions like October tend to accumulate more minerals due to efficient transpiration driven uptake and slower vegetative respiration (Singh, 2012).

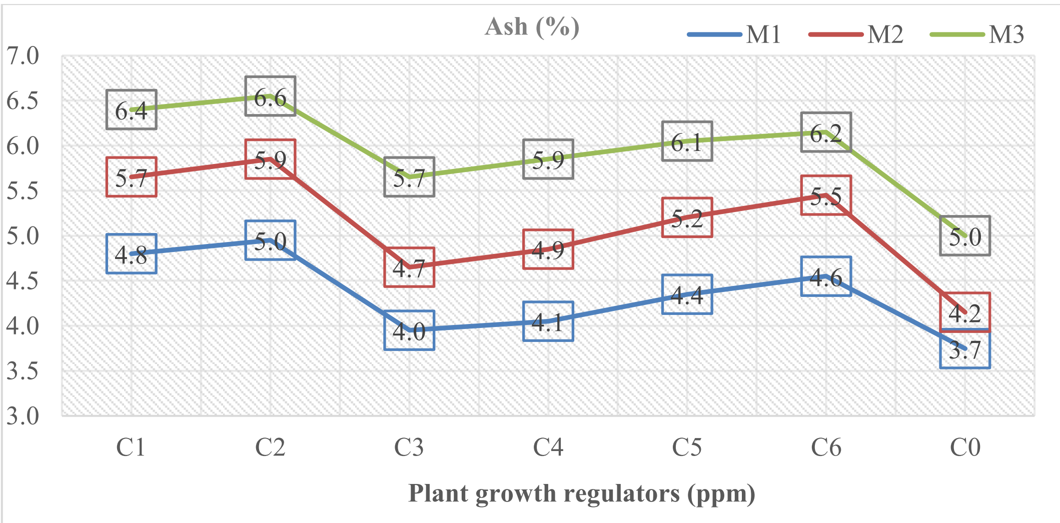


Fig.4.6.1: Effect of shoot bending and plant growth regulators on ash (%) of guava leaf

This combined effect can positively affect nutrient acquisition and thus ash content by shoot bending in October. In addition, combination (T_{16}) has given optimum ash percent. Auxin influences root development which leads to better nutrient uptake while bending participates in auxin redistribution, stimulating the lateral root whereas the mechanical stress attributed to bent shoots boosts the vascular transport. This synergy increases mineral concentrations resulting in elevated ash percentage.

4.6.2 Moisture (%)

The pooled data on the effect of shoot bending and PGRs on moisture (%) are presented in Table 4.10, illustrated in Figure 4.6.2, with the analysis of variance provided in Appendix I.

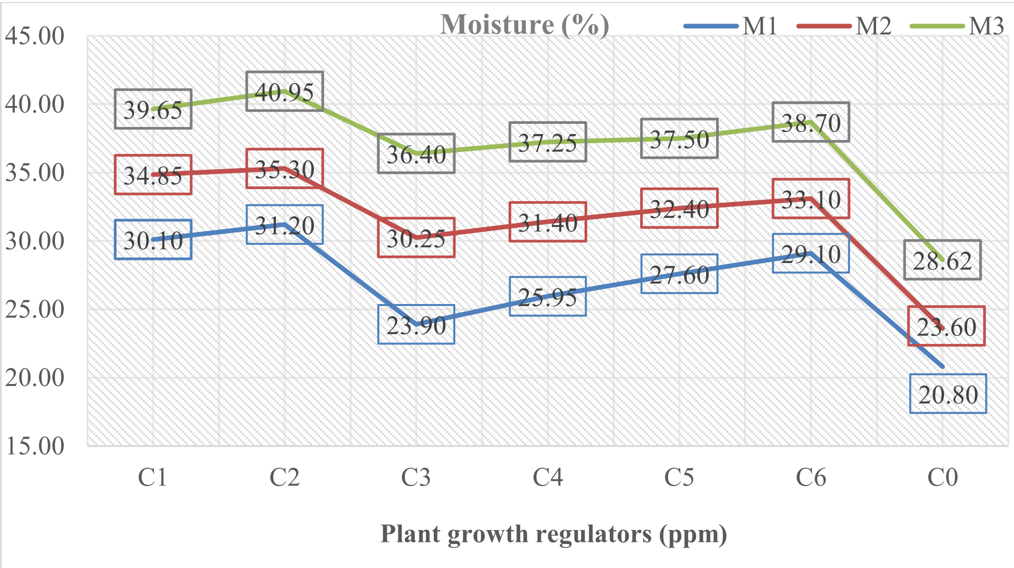


Fig.4.6.2: Effect of shoot bending and plant growth regulators on moisture (%) of guava leaf

Significant values were noted at par with PGRs. The highest mean value was obtained from NAA at 200ppm (C_2) at 35.82% on par with NAA spray at 100ppm (C_1) at 34.87% closely followed by GA_3 at 150ppm (C_6) at 33.63%. Whereas, lowest moisture content was recorded from control (C_0) at 24.34%. Moreover, shoot bending practiced in different month gave significant interaction with leaf moisture percentage. An increased data was observed in October bent shoots (M_3) at 37.01% while August month bending (M_1) received least data (26.95%).

Besides this, combinations also have shown significant interaction. Guava tree exposed to combination of NAA spray at 200ppm with October month bending (T_{16}: $M_3 \times C_2$) gave maximum moisture percent (40.95%) in contrast control tree of August month (T_7: $M_1 \times C_0$) gave minimum at 20.80%.

Auxin promotes the growth of a larger, more efficient root system that can draw more water from the soil. Additionally, it activates the aquaporins which are membrane proteins that facilitate water transport within the cell (Taiz and Zeiger, 2010). This increased water translocation and retention in the cell can contribute to higher moisture content in guava leaves sprayed with NAA. Shoot bending influences the redistribution of hormones especially auxins which stimulate better root branching and thus increase the nutrient uploading and translocation. Moreover, bent shoots can improve vascular differentiation, which in turn increases water transport across the plants. (Mika, 1969). Punjab region undergoes a slight drop in temperature in October as compared to August and September (shown in Table.3.1). Cooler temperature promotes the conservation of moisture within the plant organs by restricting respiration rates. This could be a possible reason for increased moisture percent with shoot bending (M_3) for October month. The combination (T_{16}) has given an efficient moisture percentage for guava leaves. The combination of auxin (NAA) with shoot bending has interplayed significantly leading to better water uptake and less transpiration conserving moisture as a result.

4.6.3 Protein (%)

The pooled data recorded from the effect of shoot bending and PGRs on protein (%) is detailed in Table 4.10, depicted in Figure 4.6.3, with the variance analysis provided in Appendix I.

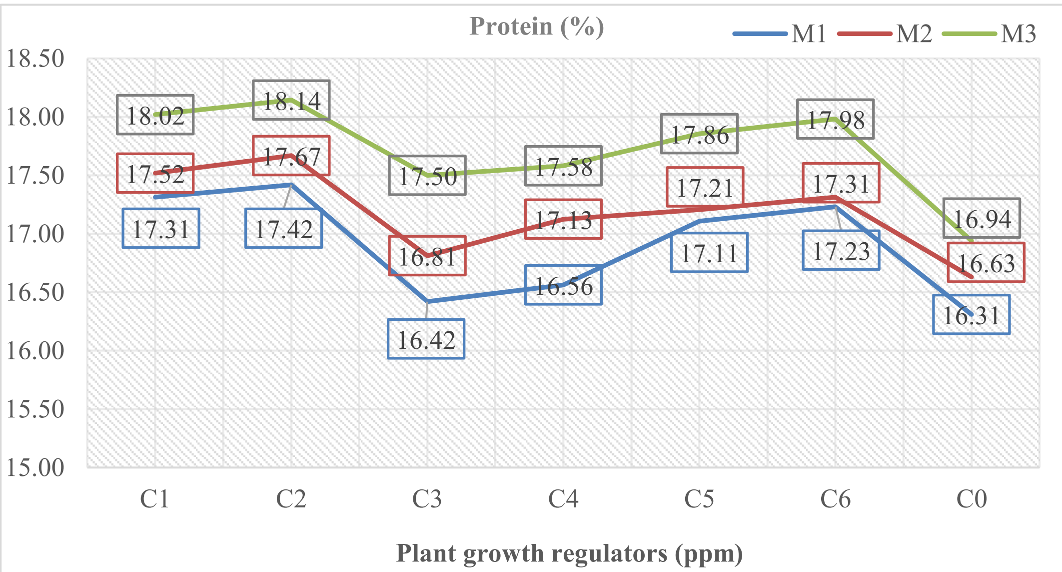


Fig.4.6.3: Effect of shoot bending and plant growth regulators on protein (%) of guava leaf

Foliar spray of plant growth regulators at varied concentrations has reported significant mean values. The highest mean protein content for guava leaves was calculated from NAA at 200ppm (C_2) at 17.74% which was on par with NAA spray at 100ppm (C_1) at 17.62% closely followed by GA_3 at 150ppm (C_6) at 17.51%. The minimum observation was observed from the control (C_0) at 16.63%. Furthermore, significance was noticed from bent shoots for protein content. Among the different months, the maximum protein content was derived from October bent shoots (M_3) at 17.72% while the minimum was obtained from August shoot bending (M_1) at 16.91%. Moreover, combinations have gained non-significant interaction with protein percentage for a leaf of guava.

The combinations (T_{16}: $M_3 \times C_2$) which was the union of NAA spray at 200ppm with October month bending recorded an increase in protein content at 18.14% while the least observations were reported from the control tree of August month (T_7: $M_1 \times C_0$) at 16.31%.

Metabolic pathways required for ammonium, and nitrate are the same as those of tryptophan which is required by auxin synthesis (Fu *et al.*,2022). Moreover, auxin has a role in inducing increased nitrogen uptake by influencing N transporters (Li, 2024). However, our results have recorded increased nitrogen content with the NAA application (C_2). This can indicate the increase in protein percentage as nitrogen is a vital unit of amino acids which are the building blocks of proteins (Mengel *et al*.,2001). With more nitrogen plants can synthesize more amino acids leading to increased protein content. The findings are in correspondence with Nejad *et al*., (2014). Shoot bending affects the redistribution of auxin, capture of sunlight, and enhanced source-sink ratio. This redistribution of auxin enhances the uniform growth of the xylem and phloem resulting in increased nutrient uptake and translocation (Ito *et al*., 2004). Moreover, with increase in mineral uptake especially nitrogen boosts protein synthesis by activating enzymes such as ribosomes and proteases (Lui *et al*., 2023). This can be attributed to increased protein content by shoot bending in October (M_3).

4.7. Effect of shoot bending and PGRs on yield attributes of guava fruit crop.

4.7.1 Yield (kg/tree)

The pooled data regarding the influence of shoot bending and PGRs on yield

Table 4.10 Effect of shoot bending and PGRs on ash (%), moisture (%), and protein (%) in guava leaves

Parameters	Shoot bending (Month)	Plant Growth Regulators (ppm)							Mean (C)
		C_1	C_2	C_3	C_4	C_5	C_6	C_0	
Ash (%)	M_1	4.8	5.0	4.0	4.1	4.4	4.6	3.7	4.3
	M_2	5.7	5.9	4.7	4.9	5.2	5.5	4.2	5.1
	M_3	6.4	6.6	5.7	5.9	6.1	6.2	5.0	6.0
	Mean(M)	5.6	5.8	4.8	4.9	5.2	5.4	4.3	
CD at 5 %	Factor (M): 0.1			Factor (C): 0.065				Factor(M×C): 0.173	
Moisture (%)	M_1	30.10	31.20	23.90	25.95	27.60	29.10	20.80	26.95
	M_2	34.85	35.30	30.25	31.40	32.40	33.10	23.60	31.56
	M_3	39.65	40.95	36.40	37.25	37.50	38.70	28.62	37.01
	Mean(M)	34.87	35.82	30.18	31.53	32.50	33.63	24.34	
CD at 5 %	Factor (M): 0.509			Factor (C): 0.333				Factor(M×C): 0.881	
Protein (%)	M_1	17.31	17.42	16.42	16.56	17.11	17.23	16.31	16.91
	M_2	17.52	17.67	16.81	17.13	17.21	17.31	16.63	17.18
	M_3	18.02	18.14	17.50	17.58	17.86	17.98	16.94	17.72
	Mean(M)	17.62	17.74	16.91	17.09	17.39	17.51	16.63	
CD at 5 %	Factor (M): 0.287			Factor (C): 0.439				Factor(M×C): NS**	

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

(kg per tree) have been analysed in Table 4.11, illustrated in Figure 4.7.1, and the variance analysis is provided in Appendix I.

Foliar spray of plant growth regulators at various concentrations has shown notable significance on the yield of guava. Among the PGRs applied, the highest mean yield of 20.29 kg/tree was reported with spray NAA at 200 ppm concentration (C_2) on par with NAA at 100 ppm (C_1) at 18.05kg/tree subsequently followed by GA_3 at 150ppm (C_6) at 15.71kg/tree. While the lowest yield was obtained from control (C_0) at

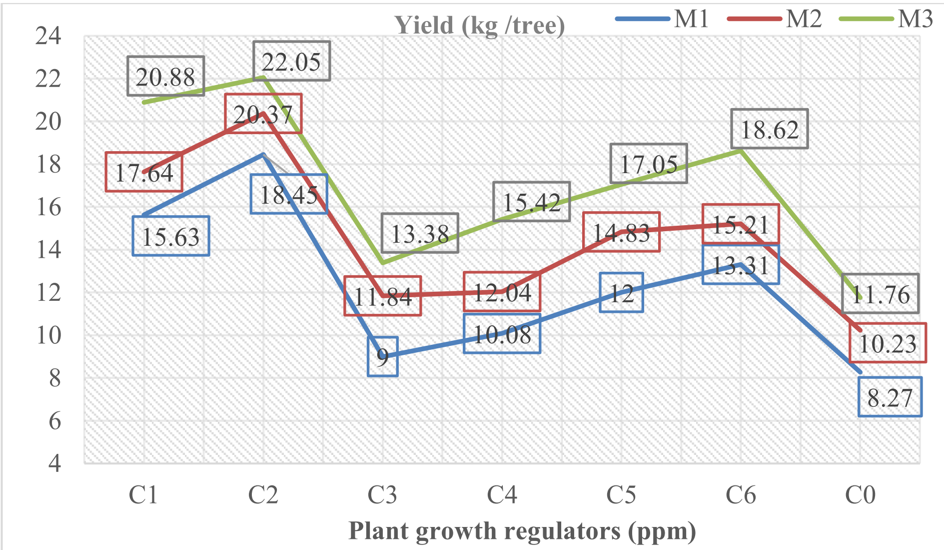


Fig.4.7.1: Effect of shoot bending and plant growth regulators on yield (kg /tree) of guava fruit crop

10.09 kg/tree. Significance was noted for shoot bending values. From the experimental months, branch-bending practiced in October month (M_3) recorded a maximum increase in yield (17.02 kg/tree) while the minimum was observed in August month (M_1) at 12.39 kg/tree.

A significant interaction was shown by a combination on guava yield. Application of NAA at 200ppm with October shoot bending (T_{16}: $M_3 \times C_2$) contributed to a more pronounced yield (22.05 kg/tree) while August month control (T_7: $M_1 \times C_0$) was least performing with a yield of 8.27 kg/tree.

Auxin has a critical role in better fruit development by enhancing cell elongation and division which leads to the growth of organs such as leaves, stems, and fruits at a faster pace, (Taiz and Zeiger, 2010), induces improved flowering and fruit set by promoting differentiation of flower organs (Davies, 2010), and impairing root development which in turn results in better water nutrient uptake (Marschner, 2012). Increased yield with PGRs directly corresponds to increased fruit retention, fruit size, and weight (Lal and Das, 2017) and our results have shown increased value for reproductive parameters. This illustrates the apparent increase in yield by NAA application. This result conforms with (Shawky *et al.,* 1978; Shikhamany and Reddy, 1989). In addition, meteorological data collected, October to harvesting months February experienced a slight decrease in temperature and relative humidity (Shown in Tables 3.1 and 3.2). A decrease in temperature can enhance flowering vigor, though the optimal cooler temperature varies by plant species. Conversely, high temperatures negatively impact the assimilation of photosynthetic products, resulting in reduced translocation to fruits (Hussey, 1963). Similar results are suggested by (Menzel *et al.*,1987). However, increased yield under bending treatment is correlated to increased flower and fruits. Bending branches horizontally promotes an even distribution of nutrients. According to Lakso and Johnson (1990), apple trees exhibit increased fruiting with horizontal shoot bending, whereas vertical branches tend to produce smaller fruits. This could have collectively led to increased yield in guava tree with October bending. Moreover, applying auxin (NAA at 200 ppm) together with shoot bending in October (T_{16}) enhances nutrient distribution and root development, leading to improved plant growth and fruit yield. This combined approach increases overall productivity by optimizing nutrient absorption and fruit set, creating optimal conditions for higher yields.

4.7.2 Yield efficiency (kg/cm^2)

The pooled data obtained from the effect of shoot bending and PGRs on yield efficiency **(**kg/cm^2**)** have been interpreted in Table 4.11, portrayed in Fig.4.7.2 and the analysis of variance is mentioned in Appendix I.

An Application of PGRs has noted significant mean yield efficiency. An increased yield efficiency was obtained from NAA at 200 ppm (C_2) application at (0.45kg/cm^2) which was at par with NAA at 100 ppm (C_1) at (0.41kg/cm^2) closely followed by (0.37kg/cm^2) with GA_3 spray at 150ppm (C_6). Whereas minimum data was calculated from control (C_0) at 0.29 kg/cm^2 Shoot bending performed in different months recorded significant values. The highest yield efficiency was observed from October bent shoots (M_3) at (0.52kg/cm^2) while the lowest was observed from August bent shoots (M_1) at (0.20kg/cm^2).

Moreover, combinations incorporated in the guava tree noted significant interaction. Amongst the combinations (T_{16}: $M_3 \times C_2$) (which was the union of NAA at 200ppm plus October shoot bending) displayed a positive influence on yield efficiency at 0.63kg/cm^2 while (T_7: $M_1 \times C_0$) August month control has a negligible effect on it with a value of 0.15 kg/cm^2.

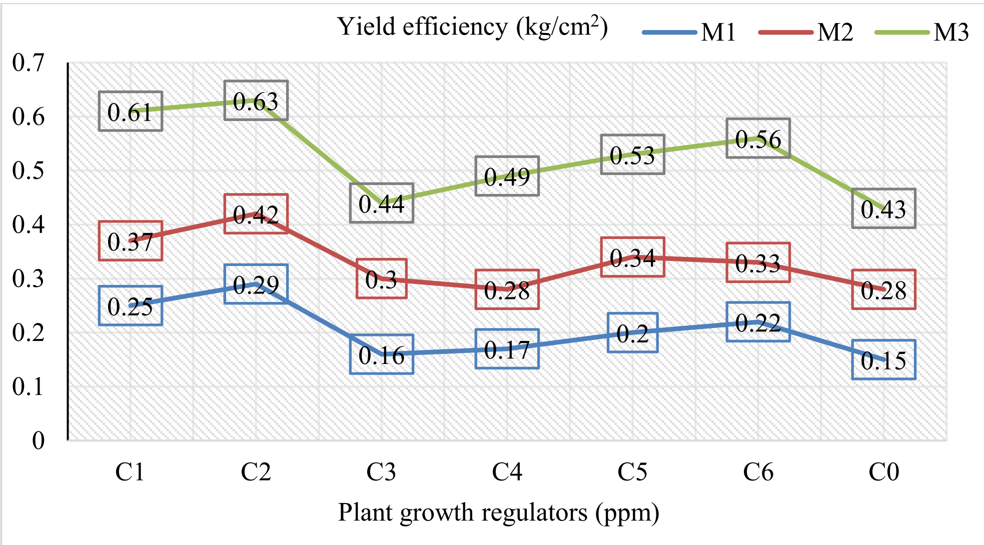


Fig.4.7.2: Effect of shoot bending and plant growth regulators on yield efficiency (kg/cm^2) of guava fruit crop

Auxin promotes root development, leading to improved nutrient absorption and distribution by enhancing vascular differentiation throughout the plant. Additionally, it stimulates cell elongation, which results in larger fruit size and ultimately yield. (Davies, 2010). Our results have suggested an increase in reproductive traits with NAA application. When a plant allocates more resources to reproductive structures, such as flowers or fruits, it typically has fewer resources available for vegetative growth, including leaves and stems (Gomulkiewicz and Holt,1995). This can be well illustration for increased yield efficiency by auxin application. Moreover, our results have recorded increased fruiting and yield with shoot bending performed in October (M_3) with a decrease in TCSA. The improvement in fruiting resulting from shoot bending can be linked to its effects on increasing the C/N ratio, enhancing source capacity, and strengthening sink function. Plus, bending helps to maintain lower levels of gibberellins while boosting levels of flowering-related hormones such as cytokinin, abscisic acid, and ethylene (Sanyal and Bangerth, 1998). Additionally, shoot bending diverts the flow

Table 4.11 Effect of shoot bending and PGRs on yield (kg/tree) and yield efficiency (kg/cm^2) of guava fruit crop.

Parameters	**Shoot bending (Month)**	**Plant Growth Regulators (ppm)**							**Mean (C)**
		C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_0**	
Yield (kg /tree)	**M_1**	15.63	18.45	9.00	10.08	12.00	13.31	8.27	12.39
	M_2	17.64	20.37	11.84	12.04	14.83	15.21	10.23	14.59
	M_3	20.88	22.05	13.38	15.42	17.05	18.62	11.76	17.02
	Mean(M)	18.05	20.29	11.41	12.51	14.63	15.71	10.09	
CD at 5 %	Factor (M): 0.211 Factor (C): 0.323 Factor(M×C): 0.559								
Yield Efficiency (kg/cm^2)	**M_1**	0.25	0.29	0.16	0.17	0.20	0.22	0.15	0.20
	M_2	0.37	0.42	0.30	0.28	0.34	0.33	0.28	0.33
	M_3	0.61	0.63	0.44	0.49	0.53	0.56	0.43	0.52
	Mean(M)	0.41	0.45	0.30	0.32	0.36	0.37	0.29	
CD at 5 %	Factor (M): 0.011 Factor (C): 0.007 Factor(M×C): 0.019								

(M_1: Shoot bending in August Month, M_2: Shoot bending in September month, M_3: Shoot bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_0: Control; T_1: M_1C_1, T_2: M_1C_2, T_3: M_1C_3, T4: M_1C_4, T_5: M_1C_5, T_6: M_1C_6, T_7: M_1C_0, T_8: M_2C_1, T_9: M_2C_2, T_{10}: M_2C_3, T_{11}: M_2C_4, T_{12}: M_2C_5, T_{13}: M_2C_6, T_{14}: M_2C_0, T_{15}: M_3C_1, T_{16}: M_3C_2, T_{17}: M_3C_3, T_{18}: M_3C_4, T_{19}: M_3C_5, T_{20}: M_3C_6, T_{21}: M_3C_0)

of photosynthetic products to reproductive organs. Thus, an increase in yield could have led to a decrease in TCSA. This result is in partial conformity with (Samant and Kishor, 2021) as it indicates of about increased yield through shoot bending. Further, the above combination i.e., (T_{16}) has displayed increased yield efficiency. The combination of auxin (NAA at 200ppm) with October shoot bending may have acted synergistically resulting further increase in yield with decreased trunk cross-section area.

a) Guava tree before shoot bending **b) Guava tree after shoot bending**

Plate 1. Pictorial view of the experimental tree before and after shoot bending

(a) Initiation of shoot emergence following

(b) New shoot appeared on bent shoots

Plate 2. Pictorial view shoot emergence

Pictorial view in August month

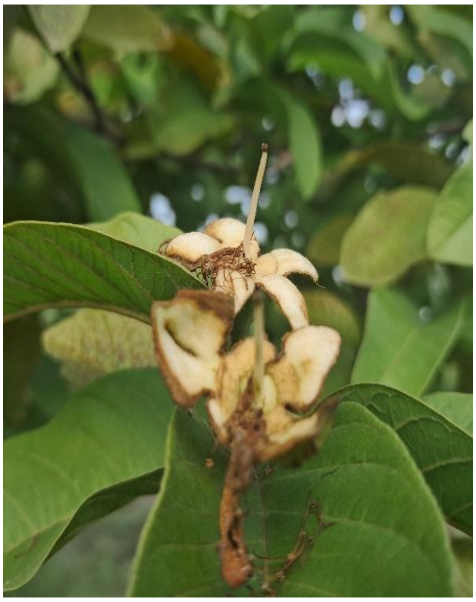
Pictorial view in September month

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

Pictorial view in October month

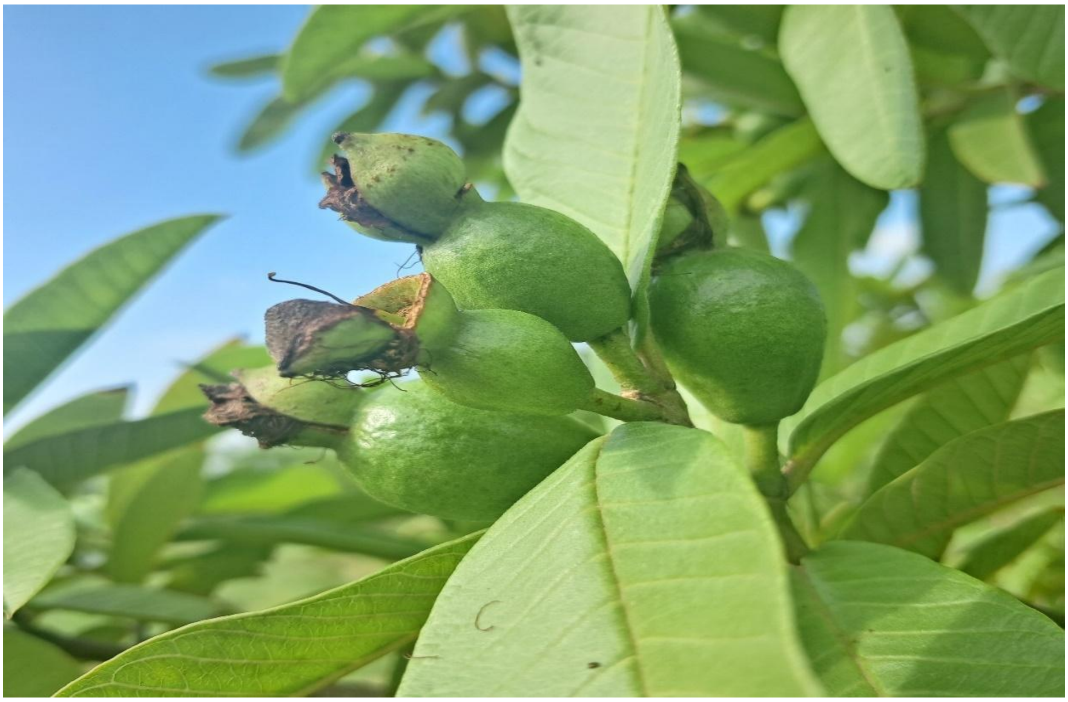
Plate 3. Development of bud (a and b) and petal opening stage (c) after application of plant growth regulators and shoot bending in combination

(a) Blossom stage **(b) Anther shedding stage**



(c) Fruit setting stage **(d) Completion of fruit set**

Plate 4. Pictorial view from blossom till completion of fruit set after application of plant growth regulators and shoot bending in combination



(a) Fruitlets development stage

(b) Fruit maturation stage

Plate 5. Pictorial view of fruitlets development and at fruit maturation stage

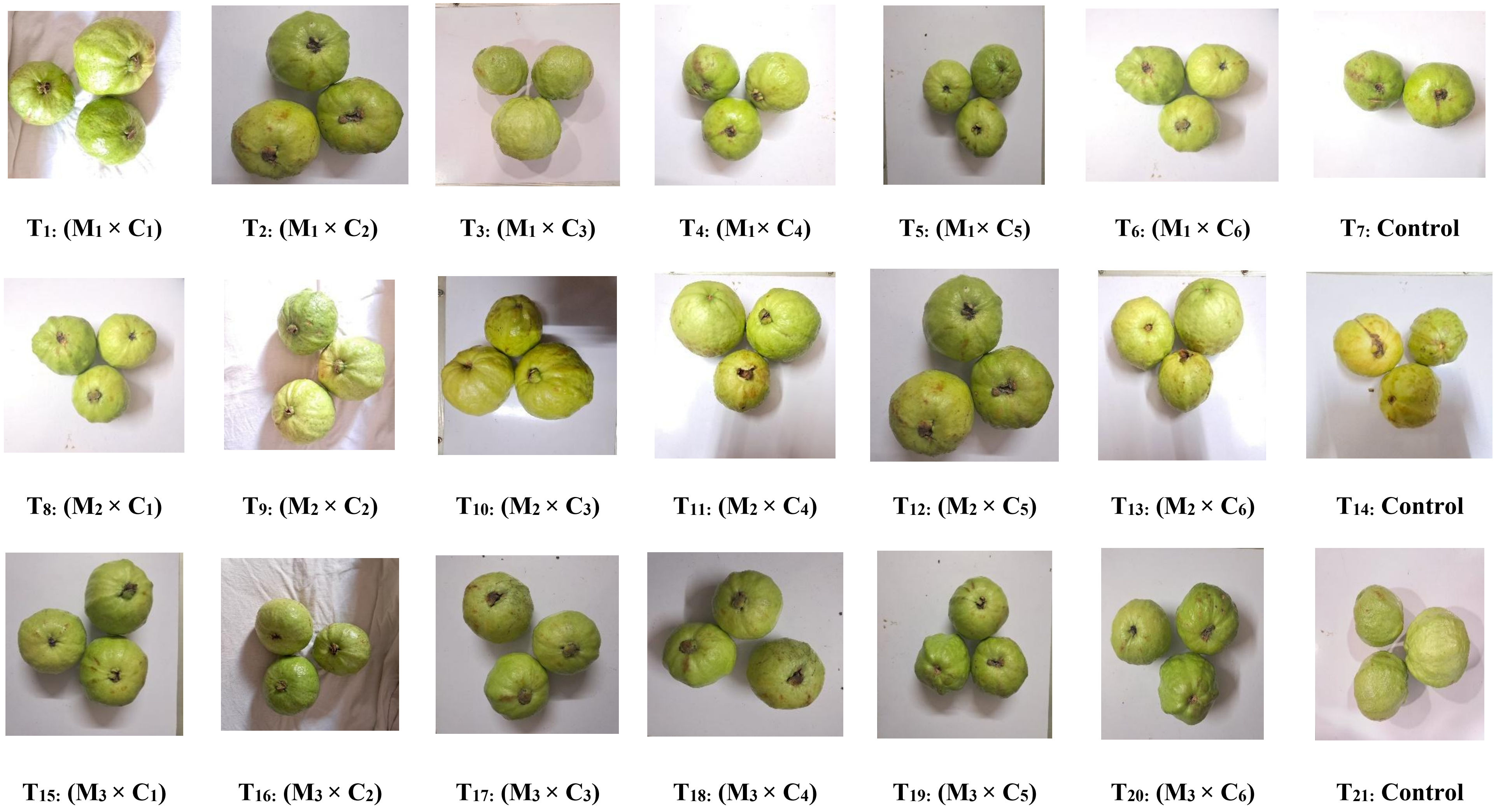


Plate 6. Pictorial view of harvested guava fruits from experimental tree

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The findings of this study demonstrate the beneficial effects of shoot bending and the application of plant growth regulators on various aspects, including vegetative growth, reproductive performance, biochemical properties, and yield characteristics of guava. A summary of the experiment, titled "Studies on efficacy of shoot bending and plant growth regulators in Different Months in Guava Crop," conducted during 2022-23 and 2023-24 at the Guava Orchard of Lovely Professional University, Punjab, is provided below.

The findings of the ANOVA revealed the mean values for shoot bending and plant growth regulators which were found to be significant for the maximum parameters. The interaction of plant growth regulators and shoot bending significantly influenced key parameters, including canopy spread (N-S), canopy height, stem girth, TCSA, leaf length and width, leaf pairs per shoot, shootlet emergence, new shoots per branch, shoot and internode length, as well as fruit characteristics like length, diameter, weight, and total number. It also impacted flower buds per plant, initial fruit set, fruit retention, fruit TSS, sugar composition (reducing, non-reducing, total sugar), titratable acidity, sugar-acid ratio, ascorbic acid, pectin, leaf chlorophyll, carbohydrate, C:N ratio, phosphorus, zinc, ash, moisture and overall yield, and yield efficiency.

5.1 Vegetative Parameters

5.1.1 Canopy spread (N-S) (m)

Among the plant growth regulators applied highest Canopy spread was observed in (C_2) NAA at 200 ppm sprayed guava tree with mean value of 0.59m.

From the experimental bending months (M_1) August bent shoots gave widest canopy spread for (N-S) with a mean value of 0.54m.

From the combinations (T_2: $M_1 \times C_2$) (NAA at 200ppm × August shoot bending) recorded highest results at 0.63m.

5.1.2 Canopy spread (E-W) (m)

Among the plant growth regulators used, the maximum canopy spread was recorded in guava trees treated with 200 ppm of NAA (C_2), with an average of 0.57 meters.

In terms of bending months, August-bent shoots (M_1) resulted in the widest canopy spread from north to south, with an average of 0.53 meters.

The combination of NAA at 200 ppm and shoot bending in August (T_2: $M_1 \times C_2$) produced the highest canopy spread, measuring 0.61 meters.

5.1.3 Canopy height (m)

The guava trees treated with 200 ppm of NAA (C_2) showed the greatest canopy height, averaging 0.43 meters among all PGR application.

Among the bending months, August-bent shoots (M_1) achieved the widest canopy height in the north-south direction, with an average of 0.40 meters.

The combination of 200 ppm NAA and August shoot bending (T_2: $M_1 \times C_2$) yielded the largest canopy height, measuring 0.46 meters.

5.1.4 Stem girth (cm)

Guava trees treated with 200 ppm NAA (C_2) exhibited the widest, averaging 24.61cm from all plant growth regulators sprayed.

August-bent shoots (M_1) resulted in the broadest stem girth with an average of 27.0cm.

The combination of 200 ppm NAA and shoot bending in August (T_2: $M_1 \times C_2$) produced the greatest canopy spread, reaching 28.3cm.

5.1.5 Trunk cross-sectional area (cm^2)

Guava trees treated with 200 ppm of NAA (C_2) demonstrated the most substantial TCSA, with an average of 48.92cm^2, outperforming all other plant growth regulator treatments.

August-bent shoots (M_1) resulted in the thickest stem girth, averaging 58.12cm^2.

The combination of 200 ppm NAA and shoot bending in August (T_2: $M_1 \times C_2$) achieved the highest canopy spread, measuring 63.56cm^2.

5.1.6 Leaf length (cm)

Guava trees treated with 200 ppm of NAA (C_2) exhibited the Leaf length, with an average of 8.6cm, surpassing all other plant growth regulator applications.

Amongst all the branch-bending months, August-bent shoots (M_1) produced the greatest stem girth, averaging 8.5cm.

The combination of 200 ppm NAA and shoot bending in August (T_2: $M_1 \times C_2$) resulted in the widest canopy spread, reaching 9.7cm.

5.1.7 Leaf width (cm)

From the PGRs applied, Guava trees treated with 200 ppm of NAA (C_2) recorded highest the Leaf width at 5.9cm.

August shoot bending (M_1) gave excellent results with a mean value of 5.5cm in comparison with other months.

Combinations of NAA at 200ppm concentration and shoot bending in August (T_2: $M_1 \times C_2$) demonstrated a maximum leaf width of 6.8cm.

5.1.8 Number of leaf pairs per shoot

Among the applied plant growth regulators, guava trees treated with 200 ppm of NAA (C_2) recorded the greatest number of leaf pairs per shoot with mean value of 15.62.

August shoot bending (M_1) produced superior results, with an average number of leaf pairs per shoot of 12.67 compared to other months.

The combination of 200 ppm NAA and shoot bending in August (T_2: $M_1 \times C_2$) achieved the highest number of leaf pairs per shoot reaching 17.88.

5.1.9. Days taken for emergence of new shootlets

From the experimental plants, NAA at 200ppm (C_2) concentration recorded shortest days for emergence of new shootlets at 24.74 days.

On the other hand, reduced days taken for the emergence of new shootlets were witnessed by August shoot bending (M_1) at 26.51 days.

Among the combinations, NAA at 200ppm plus shoot bending in August (T_2: $M_3 \times C_2$) shows a significant decrease in days taken for emergence of new shootlets at 21.95 days.

5.1.10. New shoots per branch

Among the experimental plants, NAA at 200 ppm (C_2) resulted in the maximum new shoots per Shoot with an average of 29.30.

Similarly, August shoot bending (M_1) gave the highest new shoots per branch with a mean value of 25.7.

The combination of NAA at 200 ppm and August shoot bending (T_2: $M_3 \times C_2$) recorded pronounced data for with average of 33.81 new shoots per branch.

5.1.11. Shoot length (cm)

The longest shoot length was recorded from 200ppm of NAA (C_2) with a mean value of 27.97cm as compared to other PGRs applied

Moreover, from months of shoot bending August (M_1) gave the optimal mean value for shoot length of 25.20cm.

From the combinations, NAA at 200 ppm and August shoot bending (T_2: $M_3 \times C_2$) recorded the highest shoot length at 28.80cm.

5.1.12. Internode length (cm)

The maximum Internode length observed was 3.16 cm with a 200 ppm NAA treatment (C_2), outperforming other plant growth regulators.

Additionally, shoot bending in August yielded the best mean Internode length of 3.15cm.

The combination of 200 ppm NAA and August shoot bending (T_2: $M_3 \times C_2$) resulted in the longest Internode length of 3.25cm.

5.2 Reproductive Parameters

5.2.1 Fruit length (cm)

The greatest Fruit length was recorded at 6.5 cm with a 200 ppm NAA treatment (C_2), surpassing all other plant growth regulators.

Furthermore, shoot bending conducted in October (M_3) produced the highest average fruit length of 6.25 cm.

The optimal internode length of 6.81 cm was achieved with the combination of 200 ppm NAA and October shoot bending ($T_{16:}$ $M_3 \times C_2$).

5.2.2 Fruit diameter (cm)

From the plant growth regulators spray on Guava tree, greatest fruit diameter was reported from 200 ppm NAA treatment (C_2) at 5.41cm.

Moreover, among the shoot bending conducted in different months October (M_3) gave highest mean value at 5.23cm for fruit diameter.

The Highest fruit diameter was recorded from a combination of 200 ppm NAA and October shoot bending ($T_{16:}$ $M_3 \times C_2$) at 5.78cm in comparison with other.

5.2.3 Fruit weight (g)

The highest fruit weight on guava trees was 136.2g with a 200 ppm NAA treatment (C_2) as compared to other PGRs sprayed tree.

Among different shoot bending timings, October (M_3) resulted in the best average fruit weight of 124g.

The heaviest fruit weight of 141.6g was obtained from the combination of 200 ppm NAA and shoot bending in October ($T_{16:}$ $M_3 \times C_2$), outperforming all other combinations.

5.2.4 Days require for fruit set

From the experimental plant, the Guava tree sprayed with a 200 ppm NAA treatment (C_2) gave the least number of days for fruit set at a mean value of 62.9 days as compared to other PGRs sprayed tree.

Among shoot bending incorporated in different months August (M_1) recorded lesser days for fruit set at 64.6 days.

Reduction in days required for fruit set was observed from combination of 200 ppm NAA and shoot bending in August ($T_{2:}$ $M_1 \times C_2$) at 61.6 which was smallest amongst all combinations

5.2.5 Flower bud plant^{-1}

The guava tree treated with 200 ppm NAA (C_2) demonstrated the maximum flower bud per plant at 170.2 compared to other plant growth regulators.

Among the different shoot bending timings, October (M_3) achieved a highest flower bud per plant with a value of 178.5.

The combination of 200 ppm NAA and shoot bending in October ($T_{16:}$ $M_3 \times C_2$) resulted in the pronounced flower bud per plant at 188.2 in comparison with other combinations incorporated.

5.2.6 Initial fruit set plant^{-1}

Highest initial fruit set per plant was noticed in NAA at 200ppm (C_2) spray tree at 159.8 as compared with other PGRs.

Guava tree practiced with October month (M_3) shoot bending gave maximum initial fruit set per plant with value of 152.1.

Moreover, from the incorporated combination ($T_{16:}$ $M_3 \times C_2$) which was October shoot bending and NAA with 200ppm displayed increased fruit set per plant at the initial stage at 177.0.

5.2.7 Total number of fruits plant^{-1}

The highest initial total number of fruits per plant was observed in guava trees treated with the application of 200 ppm NAA (C_2), reaching 136.0, which was superior to other plant growth regulators.

Among the various shoot bending treatments, those performed in October (M_3) yielded the highest total number of fruits per plant, with a mean value of 117.5

Additionally, the combination of October shoot bending and 200 ppm NAA ($T_{16:}$ $M_3 \times C_2$) resulted in an even greater total number of fruit set per plant, at 153.7

5.2.8 Fruit retention plant^{-1} (%)

Guava trees treated with 200 ppm NAA (C_2) exhibited the highest Fruit retention per plant with a mean value of 84.9%.

Among the different shoot bending treatments, those conducted in October (M_3) produced the greatest fruit retention percentage at 76.3%.

Maximum fruit retention was recorded from the combination of October shoot bending with 200 ppm NAA ($T_{16:}$ $M_3 \times C_2$) at 86.8%

5.3 Biochemical parameters of fruit

5.3.1 TSS (°Brix)

Application of GA_3 at 150ppm (C_6) on the Guava tree resulted in the highest TSS at 11.9°B as compared to other PGRs.

Among the various shoot bending treatments, October (M_3) achieved the maximum TSS at 11.79°B.

The combination of October shoot bending and GA_3 at 150ppm concentration (T_{20}: $M_3 \times C_6$) resulted in the increased TSS at 12.49°B.

5.3.2 Reducing sugar (%)

Among the plant growth regulators, application GA_3 at 150ppm (C_6) resulted in increased mean reducing sugar % at 5.12%.

Moreover, from the shoot bending months October (M_3) achieved the maximum mean reducing sugar at 4.71%.

In addition, from the incorporated combinations, October shoot bending plus GA_3 at 150ppm concentration (T_{20}: $M_3 \times C_6$) recorded highest value of 5.36% for reducing sugar.

5.3.3 Non-reducing sugar (%)

The application of GA_3 at 150 ppm (C_6) among plant growth regulators led to the highest mean non-reducing sugar percentage, recorded at 4.86%.

` Additionally, shoot bending performed in October (M_3) produced the greatest mean non-reducing sugar content at 4.32%.

Furthermore, the combination of October shoot bending with 150 ppm GA_3 (T_{20}: $M_3 \times C_6$) resulted in the highest non-reducing sugar level, reaching 5.05%.

5.3.4 Total sugar (%)

Among the plant growth regulators, GA_3 at 150 ppm (C_6) was found to produce the maximum mean non-reducing sugar percentage at 9.97%.

The shoot bending conducted in October (M_3) also resulted in the highest mean non-reducing sugar content at 9.02% in comparison with other shoot bending months.

Moreover, the combination of October shoot bending and 150 ppm concentration of GA_3 (T_{20}: $M_3 \times C_6$) yielded the highest total sugar percent at 10.41% .

5.3.5 Titrable acidity (%)

The application of GA_3 at 150 ppm of concentration (C_6) was reported in the lowest mean titrable acidity content at 0.21% among the plant growth regulators.

October shoot bending (M_3) produced the minimum acidity content level at 0.24%, outperforming other bending months.

Additionally, the combination of October shoot bending and 150 ppm GA_3 (T_{20}: $M_3 \times C_6$) achieved the total sugar percentage, reaching 0.17%.

5.3.6 Sugar acid ratio

GA_3 at 150 ppm (C_6) recorded the highest mean sugar acid ratio 48.62 among the plant growth regulators applied.

Shoot bending in October (M_3) gave a maximum sugar-acid ratio of 40.3 surpassing the other bending months.

Moreover, the combination of October shoot bending with 150 ppm GA_3 (T_{20}: $M_3 \times C_6$) reported the highest sugar acid ratio at 61.21.

5.3.7 Ascorbic acid (mg/100g of pulp)

The highest mean ascorbic acid content of 125mg/100g was observed with the application of GA_3 at 150 ppm (C_6) among the plant growth regulators.

October shoot bending (M_3) resulted in the maximum ascorbic content at 113.5mg/100g, outperforming other bending months.

Furthermore, the combination of October shoot bending and 150 ppm GA_3 (T_{20}: $M_3 \times C_6$) recorded the highest value of 135.5mg/100g for ascorbic acid content.

5.3.8 Pectin content (%)

Among the plant growth regulators, application of NAA at 200 ppm (C_2) led to increased pectin content, measured at 1.41%.

shoot bending conducted in October (M_3) resulted in the greatest pectin content at 1.18% in comparison other bending months.

Additionally, the combination of October shoot bending plus 150 ppm GA_3 (T_{20}: $M_3 \times C_6$) produced the highest ascorbic acid content of 1.61%.

5.4. Biochemical parameters of leaf

5.4.1 Nitrogen (%)

Among the PGRs applied, the highest Nitrogen percent was witnessed from the observations of NAA at 200ppm (C_2), with a mean value of 2.84%.

Moreover, the highest Nitrogen content was derived from October bent shoot (M_3) of guava leaves at 2.84%.

The combination of NAA at 200ppm with October shoot bending (T_{16}: $M_3 \times C_2$) displayed the highest (2.90%) nitrogen leaf content compared to other combinations.

5.4.2 Total chlorophyll (mg/100g of pulp)

Applying NAA at 200 ppm (C_2) resulted in the highest total chlorophyll content among the plant growth regulators, with a mean value of 1.58mg/100g of pulp.

Additionally, the guava leaves from October shoot bending (M_3) showed the maximum chlorophyll content at 1.63mg/100g.

The combination of NAA at 200 ppm and October shoot bending (T_{16}: $M_3 \times C_2$) yielded an increased chlorophyll content in the leaves, recorded at 1.75mg/100g surpassing all other treatment combinations.

5.4.3 Total carbohydrate (%)

The highest total chlorophyll content, at 10.42%, was observed with the application of NAA at 200 ppm (C_2) among the plant growth regulators.

Moreover, guava leaves from October shoot bending (M_3) exhibited the highest chlorophyll level, reaching 10.37%.

The combination of NAA at 200 ppm concentration plus October shoot bending (T_{16}: $M_3 \times C_2$) led to even greater chlorophyll content in the leaves, recorded at 11.92%, exceeding all other treatments.

5.4.4 C: N ratio

Application of NAA at 200ppm (C_2) reported to have a greater mean C:N ratio of 3.2.

Moreover, shoot bending performed in the month October gave highest mean C:N ratio of 3.66 comparison with the other two months.

The combination of NAA at 200ppm spray with shoot bending in October month (T_{16}: $M_3 \times C_2$) recorded maximum increase in C:N ratio at 4.11.

5.5. Leaf Nutrient content of leaves

5.5.1 Phosphorous (%)

Among the applied PGRs spray of NAA at 200 ppm (C_2) resulted in a higher mean phosphorous % in Guava leaf at 0.25%.

Additionally, shoot bending carried out in October (M_3) showed the greatest mean leaf phosphorous content, reaching 0.23 compared to the other months.

The combination of NAA at 200 ppm with October shoot bending (T_{16}: $M_3 \times C_2$) led to the maximum increase in the P content, recorded at 2.09%.

5.5.2 Potassium (%)

The highest potassium percentage was recorded from NAA at 200 ppm (C_2) application at 1.95%

Shoot bending performed in October (M_3) displayed an increased potassium percentage at 1.95% in comparison with other months.

Among the formulated combinations, maximum K content was observed from a combination of NAA at 200 ppm plus October shoot bending (T_{16}: $M_3 \times C_2$) at 2.06%.

5.5.3 Zinc (ppm)

The application of NAA at 200 ppm (C_2) received the highest zinc content, measured at 84.13 ppm.

Shoot bending conducted in October (M_3) also exhibited an elevated Zinc content of 82.87ppm, surpassing other months.

Among the treatment combinations, the maximum zinc level, 93.77 ppm, was recorded from the combination of NAA at 200 ppm with October shoot bending (T_{16}: $M_3 \times C_2$).

5.5.4 Boron (ppm)

NAA application at 200 ppm (C_2) resulted in the maximum boron concentration, recorded at 133.8 ppm.

Similarly, shoot bending performed in October (M_3) demonstrated a higher boron content, reaching 132.5 ppm, outperforming the other months.

Among all treatment combinations, the optimal boron level, 145.9 ppm, was observed from the combination of 200 ppm NAA with October shoot bending (T_{16}: $M_3 \times C_2$).

5.6 Proximate parameters of leaves

5.6.1 Ash (%)

Maximum mean ash percentage (5.8%) was found in tree spray with NAA at 200ppm (C_2) in comparison with other PGRs.

The highest mean ash content was obtained from October bent shoots (M_3) of guava tree at 6.0%.

Among the combinations incorporated increased ash content in guava leaf was recorded from the combination of 200 ppm NAA with October shoot bending (T_{16}: $M_3 \times C_2$) at 6.6%.

5.6.2 Moisture (%)

The highest mean moisture percentage of 35.82% was observed in trees treated with NAA at 200 ppm (C_2), outperforming other plant growth regulators.

October shoot bending (M_3) produced the maximum mean moisture content in guava leaves, recorded at 37.01%.

The combination of 200 ppm NAA with October shoot bending (T_{16}: $M_3 \times C_2$) resulted in the greatest increase in ash content, reaching 40.95%.

5.6.3 Protein (%)

The application of NAA at 200 ppm (C_2) resulted in the highest mean protein percentage of 17.74% for Guava leaves, surpassing other plant growth regulators.

Shoot bending performed in October (M_3) yielded the highest mean moisture content in guava leaves, recorded at 17.72%.

Additionally, the combination of 200 ppm NAA plus October shoot bending (T_{16}: $M_3 \times C_2$) led to a significant increase in protein content, 18.14%.

5.6 Yield and yield parameters of guava fruit crop.

5.6.1 Yield (kg/tree)

The highest mean Yield per tree, 20.29 kg/tree was noted in trees treated with 200 ppm NAA (C_2), exceeding the values observed with other plant growth regulators.

Guava trees subjected to shoot bending in October (M_3) showed the maximum Yield at 17.02 kg/tree.

Among the various treatment combinations, applying 200 ppm NAA along with October shoot bending (T_{16}: $M_3 \times C_2$) resulted in the greatest yield from guava tree, at 22.05 Kg/Tree.

5.6.2 Yield efficiency (kg/cm^2)

The maximum mean yield efficiency, 0.45kg/cm^2, was recorded in guava trees applied with 200 ppm NAA (C_2), surpassing yields from other plant growth regulators.

Trees that underwent shoot bending in October (M_3) demonstrated the highest yield efficiency of 0.52kg/cm^2

From the different combinations, the spray of 200 ppm NAA combined with October shoot bending (T_{16}: $M_3 \times C_2$) produced the highest yield efficiency reaching 0.63kg/cm^2.

CONCLUSION

Conclusions acquired from the present investigation revealed that the combination of shoot bending with the application of plant growth regulators in guava cultivation can significantly boost vegetative growth, reproductive traits, biochemical properties, and yield performance. Although fruit yield is the ultimate goal in commercial fruit production, robust vegetative growth and biochemical content are essential for efficient sink performance in fruit crops. In this regard, vegetative and reproductive traits viz., (TCSA, stem girth, shoot length and Total number of fruits per plant, fruit retention percent) were significantly affected by plant growth regulators and shoot bending. Among the PGRs, NAA at 200 ppm (C_2) resulted in the highest improvement across all vegetative and reproductive parameters compared to others. August (M_1) proved to be the most favorable month for shoot bending, yielding superior vegetative growth contrary to this, October (M_3) bent shoots delivered ideal values for reproductive traits. The combination treatment (T_2: $M_1 \times C_2$), involving NAA at 200 ppm and August shoot bending, emerged as the most effective strategy for promoting optimal vegetative growth while for reproductive traits (T_{16}: $M_3 \times C_2$) (NAA at 200ppm plus October month bending) recorded highest results. An increased vegetative growth has shown a comparable negative effect on the reproductive traits of Guava. Moreover, for the biochemical content (TSS, Total sugar, Acidity, and pectin percentage) of Guava fruits contradiction was recorded from the observed values. From PGRs, GA_3 at 150ppm (C_6) sprayed Guava tree recorded an elevated percentage for all quality parameters. Moreover, from shoot bending October (M_3) month gained maximum results. From the combination, (T_{20}: $M_3 \times C_6$) interaction of October shoot bending and GA_3 spray gave optimal values. Increased pectin levels align with the ideal requirements for guava jam and jelly, as it serves as a natural thickening agent, enhancing texture and consistency. Regarding the major biochemical proximate parameters of guava leaves, the combination of NAA application at 200 ppm with October shoot bending (T_{16}: $M_3 \times C_2$) yielded the highest levels of Total chlorophyll, carbohydrates, Ash, moisture, and the C: N ratio which are major contributing factors for increased reproductive intensity in a plant. Among the plant growth regulators and shoot bending NAA at 200 ppm (C_2) and the October shoot bending (M_3) respectively showed the most significant results. The application of PGRs and shoot bending has improved nutrient absorption in Guava plants, as indicated by the leaf nutrient analysis. Maximum uptake of nitrogen, phosphorous, potassium, boron, and zinc were observed from NAA 200ppm (C_2) and October shoot bending (M_3) alone and its combination of (T_{16}: $M_3 \times C_2$) October shoot bending and NAA at 200ppm. The yield attributing parameters viz., yield (kg per plant) and yield efficiency were recorded maximum from NAA at 200ppm (C_2) application. However, for shoot bending October (M_3) revealed the highest performance. Among the combination, (T_{16}: $M_3 \times C_2$) interaction of October shoot bending and 200ppm of NAA recorded the highest yield and yield efficiency. It can be concluded that for achieving better vegetative growth August shoot bending plus spray of NAA at 200ppm should be considered as technology. But for better reproductive growth, nutrient uptake and yield parameters application of NAA at 200ppm with October month shoot bending can be recommended based on the results of the present investigation.

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APPENDICES
Appendix-I

1. Canopy spread (N-S) (m)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">
Replication	2	0.002		
Factor A	6	1.483	0.247	1,086.58
Factor B	2	0.04	0.02	87.664
Interaction A X B	12	0.006	0.001	2.224
Error	40	0.009	0	
Total	62	1.54		

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	0.61	0.63	0.49	0.49	0.56	0.59	0.40	0.54
M2	0.57	0.58	0.46	0.48	0.54	0.58	0.36	0.51
M3	0.53	0.55	0.41	0.45	0.50	0.52	0.32	0.47
Mean M	0.57	0.59	0.45	0.47	0.53	0.56	0.36	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.014	0.007	0.005
Factor(B)	0.009	0.005	0.003
Factor (A X B)	NA	0.012	0.009

2. Canopy Spread (E-W) (m)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			
Factor A	6	1.766	0.294	1,647.61	0
Factor B	2	0.027	0.014	75.744	0
Interaction A X B	12	0.004	0	1.877	0.06794
Error	40	0.007	0		
Total	62	1.805			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	0.60	0.61	0.48	0.51	0.54	0.58	0.39	0.53
M2	0.55	0.57	0.45	0.47	0.53	0.56	0.34	0.50
M3	0.51	0.53	0.42	0.44	0.49	0.50	0.31	0.46
Mean M	0.55	0.57	0.45	0.47	0.52	0.55	0.35	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.013	0.006	0.004
Factor(B)	0.008	0.004	0.003
Factor (A X B)	N/A	0.011	0.008

3. Canopy Height (m)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			
Factor A	6	0.365	0.061	957.58	0
Factor B	2	0.034	0.017	265.932	0
Interaction A X B	12	0.006	0	7.293	0
Error	40	0.003	0		
Total	62	0.407			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	0.45	0.46	0.36	0.38	0.41	0.43	0.28	0.40
M2	0.40	0.43	0.32	0.34	0.36	0.38	0.26	0.36
M3	0.39	0.41	0.30	0.31	0.33	0.34	0.23	0.33
Mean M	0.41	0.43	0.33	0.34	0.37	0.38	0.26	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.008	0.004	0.003
Factor(B)	0.005	0.002	0.002
Factor (A X B)	NA	0.007	0.005

4. Stem girth (cm)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<= "" th="">	Significance <="" th="">
Replication	2	0.02			
Factor A	6	102.866	17.144	82.718	0
Factor B	2	520.526	260.263	1,255.72	0
Interaction A X B	12	7.052	0.588	2.835	0.00663
Error	40	8.291	0.207		
Total	62	638.755			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	27.9	28.3	26.9	27.0	27.5	27.6	23.7	27.0
M2	24.3	24.6	22.5	23.1	23.4	23.9	19.6	23.1
M3	20.7	20.9	19.5	19.9	20.0	20.4	18.1	20.0
Mean M	24.3	24.6	22.9	23.3	23.6	23.9	20.4	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.435	0.215	0.152
Factor(B)	0.285	0.14	0.099
Factor (A X B)	0.754	0.372	0.263

5. Trunk cross-sectional Area (cm^2)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.467			
Factor A	6	1,351.37	225.228	339.418	0
Factor B	2	7,374.29	3,687.15	5,556.53	0
Interaction A X B	12	140.603	11.717	17.657	0
Error	40	26.543	0.664		
Total	62	8,893.27			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	61.98	63.56	57.72	58.15	60.26	60.52	44.68	58.124
M2	47.20	48.38	40.18	42.36	43.62	45.56	30.71	42.571
M3	34.25	34.83	30.39	31.58	31.99	33.10	26.21	31.765
Mean M	47.807	48.923	42.764	44.029	45.291	46.393	33.868	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.779	0.384	0.272
Factor(B)	0.51	0.251	0.178
Factor (A X B)	1.349	0.665	0.47

6. Leaf length (cm)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.032			
Factor A	6	33.708	5.618	169.289	0
Factor B	2	65.051	32.526	980.102	0
Interaction A X B	12	1.169	0.097	2.935	0.00522
Error	40	1.327	0.033		
Total	62	101.287			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	9.1	9.7	7.8	8.3	8.5	8.8	7.1	8.471
M2	8.3	9	7.1	7.8	8.1	7.9	6.7	7.843
M3	6.6	7	5.4	5.9	6	6.8	4.8	6.071
Mean M	8	8.567	6.767	7.333	7.533	7.833	6.2	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.174	0.086	0.061
Factor(B)	0.114	0.056	0.04
Factor (A X B)	0.302	0.149	0.105

7. Leaf Width (cm)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Signficance<="" th="">
Replication	2	0.043			
Factor A	6	31.334	5.222	289.838	6
Factor B	2	25.311	12.656	702.381	2
Intraction A X B	12	2.609	0.217	12.066	12
Error	40	0.721	0.018		40
Total	62	60.018			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	6.5	6.8	4.7	5	5.7	5.9	4.1	5.529
M2	5.8	6.2	4.2	4.6	5	5.2	4	5
M3	4.5	4.7	3.7	4	3.9	4.1	3.1	4
Mean M	5.6	5.9	4.2	4.533	4.867	5.067	3.733	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.128	0.063	0.045
Factor(B)	0.084	0.041	0.029
Factor (A X B)	0.222	0.11	0.077

8. Number of leaf pair per shoot

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" " th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.211			
Factor A	6	863.477	143.913	1,821.61	0
Factor B	2	132.11	66.055	836.107	0
Interaction A X B	12	11.867	0.989	12.517	0
Error	40	3.16	0.079		
Total	62	1,010.83			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	16.28	17.88	10.82	11.17	13.57	14.24	4.71	12.67
M2	13.82	15.99	8.08	9.54	11.73	12.11	3.45	10.67
M3	11.97	13.00	6.82	7.38	10.82	11.08	2.83	9.13
Mean M	14.02	15.62	8.57	9.36	12.04	12.48	3.66	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.269	0.133	0.094
Factor(B)	0.176	0.087	0.061
Factor (A X B)	0.466	0.229	0.162

9. Days taken for emergence of new shootlets

Analysis of variance table

Source of variation<="" th="">	**DF**	**Sum of squares<="" " th="">**	**Mean squares<="" th="">**	**F-calculated<="" th="">**	**Significance<="" th="">**
Replication	2	0.423			
Factor A	6	738.979	123.163	428.141	0
Factor B	2	292.328	146.164	508.097	0
Interaction A X B	12	8.081	0.673	2.341	0.02199
Error	40	11.507	0.288		
Total	62	1,051.32			

Two-way-mean table

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C0**	**Mean C**
M1	23.62	21.95	28.92	27.08	26.04	24.90	33.11	26.51
M2	25.17	24.40	30.05	29.31	27.63	26.52	35.88	28.42
M3	28.66	27.86	34.73	32.68	31.03	29.34	37.81	31.73
Mean M	25.81	24.74	31.23	29.69	28.23	26.92	35.60	

Table of SEM, SED, and C.D

Factors	**C.D.**	**SE(d)**	**SE(m)**
Factor(A)	0.513	0.253	0.179
Factor(B)	0.336	0.166	0.117
Factor (A X B)	0.888	0.438	0.31

10. New shoots per Shoot

Analysis of variance table

Source of variation<="" th="">	**DF**	**Sum of squares<="" " th="">**	**Mean squares<="" th="">**	**F-calculated<="" th="">**	**Significance<="" th="">**
Replication	2	0.082			
Factor A	6	163.685	27.281	747.676	0
Factor B	2	258.873	129.437	3,547.43	0
Interaction A X B	12	3.89	0.324	8.885	0
Error	40	1.459	0.036		
Total	62	427.989			

Two-way-mean table

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C0**	**Mean C**
M1	30.2	33.81	24.82	25.01	26.4	28.61	11.275	13.8
M2	25.53	28.67	19.65	20.91	22.87	23.48	10.34	11.5
M3	24.63	25.41	18.73	19.52	21.93	22.01	9.88	8.9
Mean M	13.2	13.8	9.9	10.7	11.4	12.0	8.9	

Table of SEM, SED, and C.D

Factors	**C.D.**	**SE(d)**	**SE(m)**
Factor(A)	0.183	0.09	0.064
Factor(B)	0.12	0.059	0.042
Factor (A X B)	0.316	0.156	0.11

11. Shoot length (cm)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.697			
Factor A	6	658.606	109.768	665.986	0
Factor B	2	94.807	47.404	287.609	0
Interaction A X B	12	7.988	0.666	4.039	0.00041
Error	40	6.593	0.165		
Total	62	768.691			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	27.86	28.80	23.19	23.92	25.79	26.79	20.07	25.20
M2	26.75	28.14	21.41	21.98	24.65	26.15	17.81	23.84
M3	25.39	26.97	19.03	20.31	23.09	24.45	16.18	22.20
Mean M	26.67	27.97	21.21	22.07	24.51	25.80	18.02	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.388	0.191	0.135
Factor(B)	0.254	0.125	0.089
Factor (A X B)	0.672	0.331	0.234

12. Internode length (cm)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.006			
Factor A	6	4.644	0.774	236.181	0
Factor B	2	3.381	1.691	515.868	0
Interaction A X B	12	1.95	0.162	49.575	0
Error	40	0.131	0.003		
Total	62	10.112			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	3.22	3.25	3.11	3.14	3.17	3.20	2.99	3.15
M2	3.18	3.20	3.04	3.11	3.14	3.17	2.01	2.98
M3	2.93	3.03	2.09	2.59	2.74	2.84	1.96	2.60
Mean M	3.11	3.16	2.75	2.95	3.01	3.07	2.32	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.055	0.027	0.019
Factor(B)	0.036	0.018	0.012
Factor (A X B)	0.095	0.047	0.033

13. Fruit length (cm)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.09			
Factor A	6	30.382	5.064	187.373	0
Factor B	2	6.035	3.017	111.658	0
Interaction A X B	12	1.25	0.104	3.855	0.00062
Error	40	1.081	0.027		
Total	62	38.838			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	6.06	6.27	4.33	4.57	5.51	5.88	4.17	5.256
M2	6.11	6.42	4.91	5.01	5.37	5.94	4.76	5.503
M3	6.62	6.81	5.11	5.83	6.1	6.59	4.94	6
Mean M	6.263	6.5	4.783	5.137	5.66	6.137	4.623	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.157	0.077	0.055
Factor(B)	0.103	0.051	0.036
Factor (A X B)	0.272	0.134	0.095

14. Fruit Diameter (cm)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.01			
Factor A	6	14.569	2.428	125.036	0
Factor B	2	9.418	4.709	242.499	0
Interaction A X B	12	1.137	0.095	4.879	0.00007
Error	40	0.777	0.019		
Total	62	25.911			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	4.63	4.81	4.05	4.2	4.31	4.49	3.71	4.314
M2	5.38	5.63	5	5.04	5.11	5.24	3.8	5.029
M3	5.61	5.78	5.04	5.12	5.43	5.57	3.92	5.21
Mean M	5.207	5.407	4.697	4.787	4.95	5.1	3.81	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.133	0.066	0.046
Factor(B)	0.087	0.043	0.03
Factor(A X B)	0.231	0.114	0.08

15. Fruit Weight (g)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	1.372			
Factor A	6	17,444.36	2,907.39	581.98	0
Factor B	2	2,101.52	1,050.76	210.333	0
Interaction A X B	12	448.061	37.338	7.474	0
Error	40	199.828	4.996		
Total	62	20,195.14			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	129.3	130.6	95.0	98.7	118.2	120.1	77.1	109.8
M2	132.8	136.3	100.9	113.0	121.9	123.5	84.8	116.2
M3	139.7	141.6	117.7	121.2	126.0	128.3	93.3	124.0
Mean M	133.9	136.2	104.5	111.0	122.0	124.0	85.1	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	2.137	1.054	0.745
Factor(B)	1.399	0.69	0.488
Factor (A X B)	3.702	1.825	1.29

16. Days require for fruit set
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	13.589			
Factor A	6	265.209	44.201	30.717	0
Factor B	2	107.116	53.558	37.22	0
Interaction A X B	12	7.223	0.602	0.418	0.94725
Error	40	57.559	1.439		
Total	62	450.695			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	63.2	61.6	65.9	65.2	64.5	63.7	72.8	64.6
M2	63.9	62.5	67.7	67.2	66.9	64.9	74.6	66.1
M3	65.5	64.7	69.0	68.8	67.7	66.7	79.1	67.8
Mean M	64.2	62.9	67.5	67.1	66.4	65.1	75.5	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	1.147	0.565	0.4
Factor(B)	0.751	0.37	0.262
Factor (A X B)	N/A	0.979	0.693

17. Flower bud plant^{-1}

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" " th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	5.138			
Factor A	6	94,029.32	15,671.55	1,606.25	0
Factor B	2	14,080.73	7,040.37	721.598	0
Interaction A X B	12	1,241.22	103.435	10.602	0
Error	40	390.266	9.757		
Total	62	1.90826			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	149.3	151.4	134.5	137.0	146.2	148.4	130.3	142.4
M2	168.7	170.9	172.6	174.9	163.5	166.6	144.2	165.9
M3	186.6	188.2	177.6	179.1	182.7	184.6	150.8	178.5
Mean M	168.2	170.2	161.6	163.7	164.1	166.5	141.8	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	2.987	1.472	1.041
Factor(B)	1.955	0.964	0.682
Factor (A X B)	4.33	2.55	1.803

18. Initial fruit set plant^{-1}

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Signficance<="" th="">
Replication	2	1.937			
Factor A	6	70,651.43	11,775.24	1,853.91	0
Factor B	2	9,158.51	4,579.25	720.962	0
Interaction A X B	12	343.048	28.587	4.501	0.00015
Error	40	254.063	6.352		
Total	62	80,408.98			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	139.3	142.7	114.3	116.0	117.7	120.3	107.6	122.6
M2	156.7	159.7	127.3	131.0	133.7	139.3	118.4	138.0
M3	171.3	177.0	142.7	144.3	147.0	157.0	125.3	152.1
Mean M	155.8	159.8	128.1	130.4	132.8	138.9	117.1	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	2.41	1.188	0.84
Factor(B)	1.578	0.778	0.55
Factor (A X B)	4.174	2.058	1.455

19. Total number of fruits plant^{-1}

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	2	6.222		
Factor A	6	6	97,284.98	16,214.16	6,771.58
Factor B	2	2	10,697.27	5,348.64	2,233.77
Interaction A X B	12	12	951.397	79.283	33.111
Error	40	40	95.778	2.394	
Total	62	62	96.258		

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	113.7	118.4	70.0	72.7	87.6	91.6	60.2	87.7
M2	131.7	135.8	81.0	85.7	103.7	110.4	67.1	102.2
M3	147.5	153.7	97.3	100.3	118.3	128.6	76.5	117.5
Mean M	131.0	136.0	82.8	86.2	103.2	110.2	67.9	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	1.48	0.729	0.516
Factor(B)	0.969	0.478	0.338
Factor (A X B)	2.563	1.263	0.893

20. Fruit retention plant^{-1}

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	3.452			
Factor A	6	10,073.07	1,678.85	889.541	0
Factor B	2	1,275.47	637.735	337.906	0
Interaction A X B	12	728.583	60.715	32.17	0
Error	40	75.493	1.887		
Total	62	12,156.07			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	81.6	83.0	61.2	62.7	74.4	76.1	55.9	70.7
M2	84.1	85.0	63.6	65.4	77.6	79.3	56.7	73.1
M3	86.1	86.8	68.2	69.5	80.5	81.9	61.1	76.3
Mean M	83.9	84.9	64.4	65.9	77.5	79.1	57.9	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	1.314	0.648	0.458
Factor(B)	0.86	0.424	0.3
Factor (A X B)	2.275	1.122	0.793

21. TSS (ºBrix)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<= "" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.104			
Factor A	6	37.415	6.236	63.693	0
Factor B	2	64.799	32.4	330.934	0
Interaction A X B	12	2.386	0.199	2.031	0.04677
Error	40	3.916	0.098		
Total	62	108.62			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	9.53	10.08	8.42	9.08	10.37	10.89	7.93	9.47
M2	10.71	11.00	10.27	10.83	11.35	11.73	9.97	10.84
M3	11.95	12.19	11.05	11.73	12.34	12.49	10.82	11.80
Mean M	10.73	11.09	9.91	10.54	11.35	11.70	9.57	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.299	0.148	0.104
Factor(B)	0.196	0.097	0.068
Factor (A X B)	0.518	0.255	0.181

22. Reducing sugar (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.013			
Factor A	6	15.362	2.56	218.753	0
Factor B	2	4.882	2.441	208.553	0
Interaction A X B	12	0.77	0.064	5.484	0.00002
Error	40	0.468	0.012		
Total	62	21.495			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	4.12	4.31	3.52	3.81	4.62	4.88	3	4.037
M2	4.52	4.67	4	4.18	4.81	5.11	3.97	4.466
M3	4.81	5	4.08	4.34	5.28	5.355	4.11	4.711
Mean M	4.483	4.66	3.867	4.11	4.903	5.115	3.693	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.103	0.051	0.036
Factor(B)	0.068	0.033	0.024
Factor (A X B)	0.179	0.088	0.062

23 Non-reducing sugar (%)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Signficance<="" th="">
Replication	2	0.006			
Factor A	6	24.534	4.089	414.585	0
Factor B	2	3.041	1.52	154.162	0
Interaction A X B	12	0.494	0.041	4.173	0.00031
Error	40	0.395	0.01		
Total	62	28.47			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	4	4.08	3.39	3.73	4.18	4.635	2.48	3.785
M2	4.12	4.31	4.065	4.085	4.56	4.885	2.73	4.108
M3	4.455	4.475	4.1	4.12	4.985	5.05	3.05	4.319
Mean M	4.192	4.288	3.852	3.978	4.575	4.857	2.753	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.095	0.047	0.033
Factor(B)	0.062	0.031	0.022
Factor (A X B)	0.164	0.081	0.057

24 Total sugar (%)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.071			
Factor A	6	87.322	14.554	237.616	0
Factor B	2	16.221	8.111	132.42	0
Interaction A X B	12	1.782	0.149	2.425	0.01791
Error	40	2.45	0.061		
Total	62	107.846			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	8.12	8.39	6.91	7.54	8.80	9.52	5.21	7.784
M2	8.64	8.98	8.07	8.27	9.37	10.00	6.08	8.485
M3	9.27	9.48	8.18	8.46	10.27	10.41	7.11	9.023
Mean M	8.675	8.948	7.718	8.088	9.478	9.972	6.133	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.237	0.117	0.082
Factor(B)	0.155	0.076	0.054
Factor (A X B)	0.41	0.202	0.143

25 Titrable Acidity (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			
Factor A	6	0.13	0.022	1,370.73	0
Factor B	2	0.057	0.028	1,801.38	0
Interaction A X B	12	0.004	0	22.031	0
Error	40	0.001	0		
Total	62	0.192			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	0.31	0.30	0.36	0.34	0.28	0.27	0.37	0.32
M2	0.27	0.26	0.32	0.31	0.23	0.21	0.35	0.28
M3	0.24	0.22	0.29	0.29	0.18	0.17	0.32	0.24
Mean M	0.27	0.26	0.32	0.31	0.23	0.21	0.34	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.004	0.002	0.001
Factor(B)	0.002	0.001	0.001
Factor (A X B)	0.007	0.003	0.002

26 Sugar Acid Ratio

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<= "" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.896			
Factor A	6	6,330.80	1,055.13	2,437.25	0
Factor B	2	2,318.87	1,159.43	2,678.17	0
Interaction A X B	12	570.731	47.561	109.861	0
Error	40	17.317	0.433		
Total	62	9,238.61			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	26.19	28.44	19.47	22.51	31.43	35.91	14.27	25.46
M2	32.60	35.22	25.20	26.66	41.64	48.76	17.37	32.49
M3	39.43	44.07	28.21	29.68	57.03	61.21	22.57	40.31
Mean M	32.74	35.91	24.29	26.28	43.37	48.62	18.07	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.629	0.31	0.219
Factor(B)	0.412	0.203	0.144
Factor (A X B)	1.09	0.537	0.38

27 Ascorbic acid (mg/100g of pulp)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	34.698			
Factor A	6	16,104.77	2,684.13	1,041.18	6
Factor B	2	4,674.35	2,337.18	906.596	2
Interaction A X B	12	294.471	24.539	9.519	12
Error	40	103.119	2.578		40
Total	62	21,211.41			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	95.2	98.3	81.5	85.1	108.4	110.7	67.6	92.4
M2	109.8	110.1	90.2	92.1	122.5	128.8	72.1	103.7
M3	114.8	116.3	101.7	103.8	132.7	135.5	89.6	113.5
Mean M	106.6	108.2	91.1	93.7	121.2	125.0	76.4	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	1.535	0.757	0.535
Factor(B)	1.005	0.496	0.35
Factor (A X B)	2.659	1.311	0.927

28 Pectin content (%)
Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			
Factor A	6	4.041	0.674	1,722.30	0
Factor B	2	0.416	0.208	531.819	0
Interaction A X B	12	0.135	0.011	28.754	0
Error	40	0.016	0		
Total	62	4.608			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	1.27	1.28	0.76	0.80	1.04	1.07	0.71	0.99
M2	1.32	1.32	0.81	0.84	1.14	1.16	0.73	1.05
M3	1.60	1.61	0.91	0.93	1.23	1.24	0.76	1.18
Mean M	1.40	1.41	0.83	0.86	1.14	1.16	0.74	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.019	0.009	0.007
Factor(B)	0.012	0.006	0.004
Factor (A X B)	0.033	0.016	0.011

29 Nitrogen (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.034			
Factor A	6	0.229	0.038	7.53	0.00002
Factor B	2	0.182	0.091	17.937	0
Interaction A X B	12	0.012	0.001	0.192	0.99812
Error	40	0.203	0.005		
Total	62	0.66			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	2.77	2.79	2.63	2.65	2.74	2.76	2.61	2.71
M2	2.80	2.83	2.69	2.74	2.75	2.77	2.66	2.75
M3	2.88	2.90	2.80	2.81	2.86	2.88	2.71	2.84
Mean M	2.82	2.84	2.71	2.73	2.78	2.80	2.66	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.068	0.034	0.024
Factor(B)	0.045	0.022	0.016
Factor (A X B)	N/A	0.058	0.041

30 Total Chlorophyll (mg/100g of pulp)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.001			
Factor A	6	0.93	0.155	159.151	0
Factor B	2	0.916	0.458	470.484	0
Interaction A X B	12	0.033	0.003	2.849	0.00642
Error	40	0.039	0.001		
Total	62	1.92			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	1.41	1.43	1.31	1.33	1.38	1.38	1.10	1.33
M2	1.53	1.57	1.39	1.42	1.47	1.51	1.20	1.44
M3	1.72	1.75	1.62	1.64	1.67	1.70	1.28	1.63
Mean M	1.55	1.58	1.44	1.46	1.51	1.53	1.19	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.03	0.015	0.01
Factor(B)	0.02	0.01	0.007
Factor (A X B)	0.052	0.025	0.018

31 Total Carbohydrate (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Signficance<="" th="">
Replication	2	0.249			
Factor A	6	42.835	7.139	93.017	0
Factor B	2	31.469	15.735	205.008	0
Interaction A X B	12	2.031	0.169	2.205	0.03063
Error	40	3.07	0.077		
Total	62	79.655			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	9.233	9.543	8.56	8.84	8.85	9.093	6.86	8.711
M2	9.667	9.8	8.963	9.21	9.29	9.37	7.56	9.123
M3	11.08	11.92	10.023	10.107	10.497	10.587	8.4	10.373
Mean M	9.993	10.421	9.182	9.386	9.546	9.683	7.607	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.265	0.131	0.092
Factor(B)	0.173	0.085	0.06
Factor (A X B)	0.459	0.226	0.16

32 C:N ratio

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.002			
Factor A	6	3.75	0.625	64.789	0
Factor B	2	2.387	1.193	123.728	0
Interaction A X B	12	0.242	0.02	2.092	0.04035
Error	40	0.386	0.01		
Total	62	6.767			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	3.333	3.42	3.423	3.336	3.237	3.3	2.63	3.24
M2	3.449	3.467	3.467	3.359	3.373	3.383	2.843	3.334
M3	3.843	4.107	3.84	3.593	3.677	3.683	3.1	3.692
Mean M	3.542	3.664	3.577	3.429	3.429	3.456	2.858	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.094	0.046	0.033
Factor(B)	0.061	0.03	0.021
Factor (A X B)	0.163	0.08	0.057

33 Phosphorous (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			2
Factor A	6	0.139	0.023	2,589.51	6
Factor B	2	0.075	0.037	4,187.14	2
Interaction A X B	12	0.006	0	52.656	12
Error	40	0	0		40
Total	62	0.219			62

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	0.20	0.21	0.11	0.12	0.15	0.16	0.08	0.15
M2	0.23	0.25	0.15	0.16	0.19	0.20	0.10	0.18
M3	0.27	0.29	0.22	0.23	0.25	0.26	0.12	0.23
Mean M	0.23	0.25	0.16	0.17	0.19	0.21	0.10	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.003	0.001	0.001
Factor(B)	0.002	0.001	0.001
Factor (A X B)	0.005	0.002	0.002

34 Potassium (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.012			
Factor A	6	0.67	0.112	21.277	0
Factor B	2	0.582	0.291	55.402	0
Interaction A X B	12	0.016	0.001	0.254	0.99307
Error	40	0.21	0.005		
Total	62	1.49			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	1.80	1.84	1.63	1.66	1.77	1.79	1.52	1.72
M2	1.92	1.96	1.72	1.80	1.85	1.90	1.63	1.83
M3	2.01	2.06	1.91	1.96	1.98	2.00	1.74	1.95
Mean M	1.91	1.95	1.75	1.81	1.87	1.90	1.63	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.069	0.034	0.024
Factor(B)	0.045	0.022	0.016
Factor (A X B)	N/A	0.059	0.042

35 Zinc (ppm)

Analysis of variance table

Source of variation<="" th="">	**DF**	**Sum of squares<="" th="">**	**Mean squares<="" th="">**	**F-calculated<="" th="">**	**Significance<="" th="">**
Replication	2	1.329			
Factor A	6	9,191.10	1,531.85	1,852.03	0
Factor B	2	3,718.73	1,859.36	2,247.99	0
Interaction A X B	12	111.747	9.312	11.259	0
Error	40	33.085	0.827		
Total	62	13,055.99			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	73.11	74.72	60.56	62.82	67.25	69.76	40.22	64.06
M2	81.37	83.90	71.01	72.46	77.94	80.46	42.69	72.83
M3	90.63	93.77	82.91	83.78	86.74	88.70	53.54	82.87
Mean M	81.70	84.13	71.49	73.02	77.31	79.64	45.48	

Table of SEM, SED, and C.D

Factors	**C.D.**	**SE(d)**	**SE(m)**
Factor(A)	0.87	0.429	0.303
Factor(B)	0.569	0.281	0.198
Factor (A X B)	1.506	0.743	0.525

36 Boron (ppm)

Analysis of variance table

Source of variation<="" th="">	**DF**	**Sum of squares<="" th="">**	**Mean squares<="" th="">**	**F-calculated<="" th="">**	**Significance<="" th="">**
Replication	2	6.6			
Factor A	6	14,236.74	2,372.79	342.42	0
Factor B	2	5,409.15	2,704.58	390.301	0
Interaction A X B	12	75.933	6.328	0.913	0.54272
Error	40	277.178	6.929		
Total	62	20,005.60			

Two-way-mean table

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C0**	**Mean C**
M1	122.3	124.3	107.0	110.0	111.8	117.0	77.5	110.0
M2	129.7	131.1	117.0	120.1	124.0	127.8	82.1	118.8
M3	142.9	145.9	130.7	134.2	137.1	139.1	97.7	132.5
Mean M	131.7	133.8	118.2	121.4	124.3	128.0	85.8	

Table of SEM, SED, and C.D

Factors	**C.D.**	**SE(d)**	**SE(m)**
Factor(A)	2.517	1.241	0.877
Factor(B)	1.648	0.812	0.574
Factor (A X B)	N/A	2.149	1.52

37 Ash (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.011			
Factor A	6	14.523	2.42	223.148	0
Factor B	2	27.167	13.584	1,252.29	0
Interaction A X B	12	0.468	0.039	3.592	0.00112
Error	40	0.434	0.011		
Total	62	42.603			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	4.8	5.0	4.0	4.1	4.4	4.6	3.7	4.3
M2	5.7	5.9	4.7	4.9	5.2	5.5	4.2	5.1
M3	6.4	6.6	5.7	5.9	6.1	6.2	5.0	6.0
Mean M	5.6	5.8	4.8	4.9	5.2	5.4	4.3	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.1	0.049	0.035
Factor(B)	0.065	0.032	0.023
Factor (A X B)	0.173	0.085	0.06

38 Moisture (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<=" " th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.227			
Factor A	6	789.716	131.619	465.116	0
Factor B	2	1,064.84	532.42	1,881.47	0
Interaction A X B	12	22.273	1.856	6.559	0
Error	40	11.319	0.283		
Total	62	1,888.38			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	30.10	31.20	23.90	25.95	27.60	29.10	20.80	26.95
M2	34.85	35.30	30.25	31.40	32.40	33.10	23.60	31.56
M3	39.65	40.95	36.40	37.25	37.50	38.70	28.62	37.01
Mean M	34.87	35.82	30.18	31.53	32.50	33.63	24.34	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.509	0.251	0.177
Factor(B)	0.333	0.164	0.116
Factor (A X B)	0.881	0.434	0.307

40 Protein (%)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.04			
Factor A	6	8.944	1.491	7.076	0.00003
Factor B	2	7.1	3.55	16.851	0
Interaction A X B	12	0.462	0.038	0.183	0.99852
Error	40	8.426	0.211		
Total	62	24.971			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	**Mean C**
M1	17.31	17.42	16.42	16.56	17.11	17.23	16.31	16.91
M2	17.52	17.67	16.81	17.13	17.21	17.31	16.63	17.18
M3	18.02	18.14	17.50	17.58	17.86	17.98	16.94	17.72
Mean M	17.62	17.74	16.91	17.09	17.39	17.51	16.63	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.439	0.216	0.153
Factor(B)	0.287	0.142	0.1
Factor (A X B)	N/A	0.375	0.265

40 Yield (Kg Tree^{-1})

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0.049			
Factor A	6	949.889	158.315	1,390.79	0
Factor B	2	240.543	120.271	1,056.58	0
Interaction A X B	12	8.046	0.671	5.891	0.00001
Error	40	4.553	0.114		
Total	62	1,203.08			

Two-way-mean table

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C0**	**Mean C**
M1	15.63	18.45	9	10.08	12	13.31	8.27	12.39
M2	17.64	20.37	11.84	12.04	14.83	15.21	10.23	14.59
M3	20.88	22.05	13.38	15.42	17.05	18.62	11.76	17.02
Mean M	18.05	20.29	11.41	12.51	14.63	15.71	10.09	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.323	0.159	0.112
Factor(B)	0.211	0.104	0.074
Factor (A X B)	0.559	0.275	0.195

41 Yield Efficiency (Kg/cm^2)

Analysis of variance table

Source of variation<="" th="">	DF	Sum of squares<="" th="">	Mean squares<="" th="">	F-calculated<="" th="">	Significance<="" th="">
Replication	2	0			
Factor A	6	0.245	0.041	296.139	0
Factor B	2	1.094	0.547	3,971.39	0
Interaction A X B	12	0.015	0.001	9.222	0
Error	40	0.006	0		
Total	62	1.359			

Two-way-mean table

	C1	C2	C3	C4	C5	C6	C0	Mean C
M1	0.25	0.29	0.16	0.17	0.2	0.22	0.15	0.2
M2	0.37	0.42	0.3	0.28	0.34	0.33	0.28	0.33
M3	0.61	0.63	0.44	0.49	0.53	0.56	0.43	0.52
Mean M	0.41	0.45	0.3	0.32	0.36	0.37	0.29	

Table of SEM, SED, and C.D

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.011	0.006	0.004
Factor(B)	0.007	0.004	0.003
Factor (A X B)	0.019	0.01	0.007

Appendix II
Standard Meteorological Data for the year 2022

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
01-01-2022	18	6	75	64	0	0
02-01-2022	19	6	72	60	0	0
03-01-2022	18	12	74	65	2	0
04-01-2022	16	12	78	66	4	1
05-01-2022	15	8	72	58	2	21.5
06-01-2022	14	7	78	65	0	19.5
07-01-2022	14	8	70	64	0	21
08-01-2022	12	6	74	63	2	18.5
09-01-2022	11	9	74	66	2	15
10-01-2022	14	11	72	57	0	9
11-01-2022	15	11	80	68	8	0
12-01-2022	18	11	82	62	4	0
13-01-2022	17	11	78	61	2	0
14-01-2022	15	13	72	62	4	0
15-01-2022	19	12	78	64	2	0
16-01-2022	18	11	72	60	2	0
17-01-2022	18	13	76	62	4	0
18-01-2022	19	10	78	60	4	0
19-01-2022	17	10	76	60	2	0
20-01-2022	16	14	74	61	0	2
21-01-2022	15	10	70	60	0	0
22-01-2022	15	13	74	55	4	0
23-01-2022	14	12	72	58	0	0
24-01-2022	14	13	78	62	2	0
25-01-2022	15	12	74	60	4	0
26-01-2022	16	13	74	64	0	0
27-01-2022	12	10	80	68	4	0
28-01-2022	18	9	86	68	2	0
29-01-2022	18	10	78	66	0	0
30-01-2022	17	8	80	68	4	0
31-01-2022	18	8	82	70	4	0
01-02-2022	14	8	86	64	4	0
02-02-2022	15	8	84	68	Calm condition	0
03-02-2022	16	8	68	60	2	0.5
04-02-2022	17	9	70	62	4	0
05-02-2022	16	10	72	60	2	0
06-02-2022	12	11	75	60	Calm condition	0
07-02-2022	13	8	86	62	Calm condition	0
08-02-2022	10	7	80	64	4	0
09-02-2022	14	7	80	66	Calm condition	0
10-02-2022	12	10	72	64	4	0
11-02-2022	11	8	76	62	2	0
12-02-2022	17	8	78	60	4	0
13-02-2022	16	10	80	66	2	0
14-02-2022	17	8	82	62	4	0
15-02-2022	18	9	70	60	Calm condition	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
16-02-2022	17	8	72	62	4	0
17-02-2022	18	8	74	58	2	0
18-02-2022	17	8	74	58	Calm Condition	0
19-02-2022	16	9	72	54	Calm Condition	0
20-02-2022	18	9	71	56	4	0
21-02-2022	21	10	70	52	Calm Condition	0
22-02-2022	20	11	67	50	2	0
23-02-2022	22	11	68	51	4	0
24-02-2022	20	11	67	50	Calm Condition	0
25-02-2022	20	12	66	52	2	0
26-02-2022	15	8	60	48	6	16
27-02-2022	18	10	62	48	2	0
28-02-2022	16	9	64	48	4	0
01-03-2022	18	10	60	48	2	0
02-03-2022	16	9	62	50	0	0
03-03-2022	17	10	60	49	4	0
04-03-2022	20	9	58	48	4	0
05-03-2022	21	10	56	46	0	0
06-03-2022	22	10	52	44	0	0
07-03-2022	20	11	54	45	4	0
08-03-2022	22	13	56	44	0	0
09-03-2022	24	18	54	42	0	0
10-03-2022	20	18	55	44	0	0
11-03-2022	20	20	56	42	4	0
12-03-2022	18	18	54	42	2	0
13-03-2022	22	20	54	44	0	0
14-03-2022	26	20	58	48	4	0
15-03-2022	28	20	50	40	4	0
16-03-2022	32	19	58	42	0	0
17-03-2022	30	22	56	40	2	0
18-03-2022	32	20	56	42	4	0
19-03-2022	32	20	54	40	0	0
20-03-2022	30	19	55	42	8	0
21-03-2022	32	23	52	40	0	0
22-03-2022	33	23	54	42	0	0
23-03-2022	34	22	52	44	0	0
24-03-2022	32	23	50	44	4	0
25-03-2022	30	21	50	42	4	0
26-03-2022	31	20	52	40	12	0
27-03-2022	32	21	50	38	0	0
28-03-2022	30	20	48	45	4	0
29-03-2022	31	19	52	48	2	0
30-03-2022	32	20	54	42	6	0
31-03-2022	32	25	50	44	4	0
01-04-2022	32	22	52	40	0	0
02-04-2022	33	23	53	42	6	0
03-04-2022	34	22	52	43	4	0
04-04-2022	30	24	48	44	12	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
05-04-2022	34	24	47	40	2	0
06-04-2022	32	24	45	38	0	0
07-04-2022	34	26	44	36	0	0
08-04-2022	35	26	42	34	0	0
09-04-2022	40	27	45	32	4	0
10-04-2022	40	27	42	30	16	0
11-04-2022	42	26	44	32	0	0
12-04-2022	44	28	48	37	4	0
13-04-2022	42	29	45	36	0	0
14-04-2022	40	26	44	34	2	0.5
15-04-2022	41	27	44	32	2	0
16-04-2022	40	27	45	34	4	0
17-04-2022	42	28	46	35	0	0
18-04-2022	40	28	44	30	12	0
19-04-2022	40	29	42	32	34	0
20-04-2022	37	30	38	25	12	0
21-04-2022	38	30	38	26	10	0
22-04-2022	39	29	39	27	14	0
23-04-2022	40	28	38	26	4	0
24-04-2022	42	30	36	25	22	0
25-04-2022	41	32	38	24	6	0
26-04-2022	42	31	39	22	12	0
27-04-2022	40	31	32	20	2	0
28-04-2022	42	32	31	21	10	0
29-04-2022	41	32	30	22	10	0
30-04-2022	41	32	30	21	10	0
01-05-2022	41	30	36	22	0	0
02-05-2022	42	31	35	20	8	0
03-05-2022	40	30	34	20	12	0
04-05-2022	34	31	34	23	20	0
05-05-2022	41	27	38	23	6	0
06-05-2022	40	29	40	20	8	0
07-05-2022	42	30	38	19	18	0
08-05-2022	43	30	36	22	10	0
09-05-2022	36	30	35	18	22	0
10-05-2022	40	30	36	22	22	0
11-05-2022	42	32	38	28	24	0
12-05-2022	40	33	39	37	16	0
13-05-2022	38	32	37	37	26	0
14-05-2022	37	30	35	28	10	0
15-05-2022	42	32	34	27	12	0
16-05-2022	42	31	36	32	18	0
17-05-2022	40	32	32	28	18	0
18-05-2022	41	32	32	25	6	0
19-05-2022	37	31	33	32	24	0
20-05-2022	42	33	30	29	10	0
21-05-2022	40	32	30	25	24	0
22-05-2022	42	30	32	31	12	0
23-05-2022	42	27	30	37	16	11.2
24-05-2022	36	26	32	36	4	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
25-05-2022	40	24	34	38	4	0
26-05-2022	39	28	37	38	8	0
27-05-2022	42	30	39	39	0	0
28-05-2022	40	32	43	36	0	0
29-05-2022	40	32	44	34	46	0
30-05-2022	36	33	40	42	0	0
31-05-2022	38	30	41	40	10	0
01-06-2022	32	31	40	37	4	0
02-06-2022	38	30	42	36	0	0
03-06-2022	40	31	34	38	22	0
04-06-2022	41	32	32	42	8	0
05-06-2022	43	30	32	40	0	0
06-06-2022	40	32	29	42	4	0
07-06-2022	40	31	30	43	5	0
08-06-2022	48	34	27	42	6	0
09-06-2022	38	32	28	40	12	0
10-06-2022	39	34	26	38	14	0
11-06-2022	40	33	62	48	26	0
12-06-2022	38	28	60	45	17	0
13-06-2022	39	34	27	36	6	0
14-06-2022	40	35	28	34	0	0
15-06-2022	36	30	52	58	21	0
16-06-2022	40	30	50	55	12	0
17-06-2022	38	34	40	37	11	0
18-06-2022	44	35	44	49	9	0
19-06-2022	40	31	42	36	13	0
20-06-2022	34	29	44	48	0	65.4
21-06-2022	38	29	44	49	24	5.2
22-06-2022	42	28	42	51	12	0
23-06-2022	40	27	44	50	26	0
24-06-2022	40	28	42	52	16	0
25-06-2022	41	30	44	49	0	0
26-06-2022	40	32	52	55	5	0
27-06-2022	38	34	48	49	1	0
28-06-2022	43	34	50	56	32	0
29-06-2022	44	32	52	58	12	0
30-06-2022	40	30	50	56	14	0
01-07-2022	38	32	58	64	40	0
02-07-2022	42	30	61	55	14	0
03-07-2022	44	32	57	58	18	35.2
04-07-2022	44	29	56	62	4	4.2
05-07-2022	42	32	60	67	10	0
06-07-2022	43	31	63	58	8	0
07-07-2022	45	32	62	67	0	0
08-07-2022	44	32	64	69	4	0
09-07-2022	40	33	62	64	0	0
10-07-2022	39	30	60	60	10	0
11-07-2022	36	33	64	62	18	0
12-07-2022	37	33	65	60	4	0
13-07-2022	37	30	60	60	20	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
14-07-2022	38	32	58	61	26	0
15-07-2022	32	32	54	61	4	6.2
16-07-2022	37	30	56	58	2	0
17-07-2022	36	31	54	56	0	4.7
18-07-2022	35	32	57	62	4	2.6
19-07-2022	36	32	56	67	10	8.4
20-07-2022	34	31	80	69	23	47.4
21-07-2022	29	25	86	70	8	142.6
22-07-2022	35	26	72	64	18	0
23-07-2022	36	28	78	68	9	0
24-07-2022	37	27	76	65	12	0
25-07-2022	34	27	64	62	14	0
26-07-2022	37	28	70	64	9	0
27-07-2022	37	27	77	69	9	1.4
28-07-2022	37	25	73	69	5	1
29-07-2022	30	26	74	61	13	0.5
30-07-2022	29	25	72	64	8	0.9
31-07-2022	34	24	76	65	4	0.7
01-08-2022	35	24	75	62	11	0
02-08-2022	36	26	78	68	1	0
03-08-2022	36	27	79	67	13	0
04-08-2022	35	26	78	68	11	0
05-08-2022	34	25	77	65	9	0
06-08-2022	34	26	78	62	4	0.1
07-08-2022	35	26	74	67	4	0
08-08-2022	36	25	73	62	9	0
09-08-2022	39	28	72	62	5	0
10-08-2022	39	29	78	62	5	0
11-08-2022	26	24	76	63	16	8.3
12-08-2022	37	25	70	61	5	0
13-08-2022	35	26	72	60	10	0
14-08-2022	35	27	71	68	9	4.6
15-08-2022	29	25	73	64	18	3.2
16-08-2022	34	25	72	64	3	0
17-08-2022	34	26	78	69	15	0
18-08-2022	33	26	78	68	8	0
19-08-2022	35	28	75	60	5	1.2
20-08-2022	34	27	77	61	3	0.5
21-08-2022	35	25	72	67	5	0.5
22-08-2022	33	26	78	64	5	1.4
23-08-2022	33	26	78	63	10	3.3
24-08-2022	35	26	71	60	10	0.8
25-08-2022	33	25	74	68	6	0.7
26-08-2022	34	26	77	64	8	0.1
27-08-2022	34	25	78	68	5	0
28-08-2022	34	25	78	69	7	0
29-08-2022	34	27	76	65	6	1.6
30-08-2022	35	25	72	61	9	1.7
31-08-2022	37	26	77	61	9	0.1
01-09-2022	36	27	77	62	9	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
02-09-2022	36	26	76	64	7	1
03-09-2022	36	26	74	62	6	0.1
04-09-2022	36	26	71	68	4	0
05-09-2022	38	25	70	61	11	0
06-09-2022	37	25	68	61	12	0
07-09-2022	38	25	72	64	10	0
08-09-2022	38	26	70	61	11	0
09-09-2022	39	26	67	60	12	0
10-09-2022	38	25	73	61	1	0
11-09-2022	38	26	78	73	10	0
12-09-2022	35	25	77	64	9	0.2
13-09-2022	36	23	72	64	12	0.5
14-09-2022	36	24	69	62	11	0
15-09-2022	33	25	70	67	8	0.4
16-09-2022	32	24	71	68	11	1.4
17-09-2022	33	21	68	61	19	2.6
18-09-2022	38	24	78	64	13	0
19-09-2022	38	24	74	61	17	0
20-09-2022	37	25	70	63	10	0
21-09-2022	39	25	70	62	14	0
22-09-2022	35	25	72	64	10	0.5
23-09-2022	34	23	71	62	14	0.1
24-09-2022	30	23	77	64	10	2.1
25-09-2022	23	21	76	63	9	2.4
26-09-2022	35	20	67	60	12	0
27-09-2022	35	22	70	61	10	0
28-09-2022	35	23	72	67	12	0
29-09-2022	36	23	74	60	9	0
30-09-2022	37	23	70	67	12	0
01-10-2022	37	23	55	46	6	0
02-10-2022	36	23	59	43	12	0
03-10-2022	37	23	54	45	12	0
04-10-2022	37	22	52	41	10	0
05-10-2022	37	21	54	42	7	0
06-10-2022	34	22	50	42	9	0
07-10-2022	32	21	55	46	8	0
08-10-2022	32	21	59	43	9	0
09-10-2022	32	21	54	44	8	0
10-10-2022	30	19	67	53	3	0
11-10-2022	31	20	62	55	2	0
12-10-2022	36	24	50	42	6	0
13-10-2022	32	23	59	43	2	0
14-10-2022	32	20	54	44	2	0
15-10-2022	36	24	56	47	4	0
16-10-2022	34	20	52	41	2	0
17-10-2022	32	23	54	46	4	0
18-10-2022	32	20	54	44	0	0
19-10-2022	32	21	56	45	2	0
20-10-2022	31	20	56	46	2	0
21-10-2022	31	19	54	41	3	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
22-10-2022	30	19	50	41	2	0
23-10-2022	30	20	56	44	2	0
24-10-2022	30	19	57	42	2	0
25-10-2022	29	18	57	46	3	0
26-10-2022	30	18	51	43	8	0
27-10-2022	29	18	53	43	3	0
28-10-2022	30	19	52	47	3	0
29-10-2022	29	16	54	41	2	0
30-10-2022	29	19	51	42	0	0
31-10-2022	30	19	51	42	2	0
01-11-2022	30	19	51	45	4	0
02-11-2022	28	18	52	47	2	0
03-11-2022	28	19	58	48	6	0
04-11-2022	29	17	54	42	2	0
05-11-2022	27	18	55	44	2	0
06-11-2022	29	18	56	42	2	0
07-11-2022	29	16	51	48	2	0
08-11-2022	28	14	56	46	0	0
09-11-2022	28	14	53	44	2	0
10-11-2022	27	14	52	44	3	0
11-11-2022	27	16	54	41	3	0
12-11-2022	27	13	52	44	2	0
13-11-2022	27	13	56	47	2	0
14-11-2022	27	14	54	46	2	0
15-11-2022	26	14	58	47	4	0
16-11-2022	27	13	57	48	2	0
17-11-2022	26	14	58	48	2	0
18-11-2022	27	14	57	47	2	0
19-11-2022	26	14	58	48	3	0
20-11-2022	25	13	59	49	3	0
21-11-2022	24	14	58	41	2	0
22-11-2022	24	12	59	48	4	0
23-11-2022	23	12	56	44	2	0
24-11-2022	24	15	54	46	0	0
25-11-2022	24	14	55	47	2	0
26-11-2022	21	12	56	48	0	0
27-11-2022	21	10	55	44	0	0
28-11-2022	22	10	52	41	0	0
29-11-2022	22	10	56	44	0	0
30-11-2022	23	11	54	42	0	0
01-12-2022	25	11	89	77	0	0
02-12-2022	24	13	89	79	2	0
03-12-2022	26	14	80	68	5	0
04-12-2022	28	12	79	65	8	0
05-12-2022	27	13	80	61	2	0
06-12-2022	27	8	100	54	0	0
07-12-2022	27	9	89	60	4	0
08-12-2022	26	9	89	61	4	0
09-12-2022	28	11	89	53	0	0
10-12-2022	28	14	90	63	10	0

Date	MaxT	MinT	RH	RH	Wind speed (km/hr)	RF,mm
11-12-2022	29	13	89	57	12	0
12-12-2022	27	11	80	55	4	0
13-12-2022	27	12	90	77	10	0
14-12-2022	26	10	89	79	8	0
15-12-2022	25	10	97	65	10	0
16-12-2022	25	10	89	75	5	0
17-12-2022	27	10	90	85	5	0
18-12-2022	26	10	89	70	2	0
19-12-2022	25	11	88	75	4	0
20-12-2022	23	10	90	80	6	0
21-12-2022	25	10	89	79	5	0
22-12-2022	24	9	90	79	5	0
23-12-2022	22	9	97	75	5	0
24-12-2022	23	7	98	70	5	0
25-12-2022	19	7	98	74	6	0
26-12-2022	21	9	93	78	5	0
27-12-2022	22	9	96	78	10	0
28-12-2022	23	8	93	86	10	0
29-12-2022	21	9	98	88	6	2
30-12-2022	22	12	89	79	6	0
31-12-2022	22	8	89	77	10	0

Appendix-III

Standard Meteorological Data for the year 2023

DATE	Max Temp (°C)	Min Temp (°C)	RH (%)	RH (%)	Windspeed (km/hr)	Rain (mm)
01-12-2023	22.7	10.1	91.2	59.7	6.48	0.2
02-12-2023	24.5	8.85	93.5	55.08	2.88	0
03-12-2023	24.28	8.67	93.6	61.8	1.8	0
04-12-2023	23.5	10.3	94.7	55.3	3.24	0
05-12-2023	23.04	9.52	95.15	54.7	5.76	0
06-12-2023	24.18	7.55	95.3	45.9	6.12	0
07-12-2023	23.8	8.97	94.27	42.8	6.84	0
08-12-2023	23.48	5.78	94.15	47.58	2.88	0
09-12-2023	22.57	5	95.17	59.13	5.76	0
10-12-2023	21.88	5.38	94.08	46.88	7.92	0
11-12-2023	23.11	5.33	93.58	52.6	2.52	0
12-12-2023	22.19	5.04	94.16	57.34	1.8	0
13-12-2023	22.26	3.47	94.15	37.47	3.6	0
14-12-2023	22.16	4.1	93.48	50.03	6.48	0
15-12-2023	21.47	5.2	94.3	55.48	1.08	0
16-12-2023	21.1	2.68	93.88	51.66	2.88	0
17-12-2023	20.81	5.97	93.87	55.72	5.4	0
18-12-2023	20.63	4.03	94.57	55.87	7.2	0
19-12-2023	20.96	2.73	95.62	50	6.84	0
20-12-2023	22.81	2.46	94.45	52.83	1.08	0
21-12-2023	20.71	2.72	93.92	52.85	3.6	0
22-12-2023	19.45	3.54	95.03	68.31	2.52	0
23-12-2023	23.23	8.89	92.34	54.06	2.88	0
24-12-2023	22.9	5.66	93.66	67.12	3.6	0
25-12-2023	19.75	5.96	95.21	65.54	5.4	0
26-12-2023	18.71	6.31	96.01	79.36	1.44	0.4
27-12-2023	20.2	6.56	95.87	72.15	1.56	0
28-12-2023	21	7.6	94.3	68.9	2.5	0
29-12-2023	17.4	9.8	95	66	2.3	0
30-12-2023	12.6	8.5	90	70	2.1	0
31-12-2023	11.4	9.2	94	76	2.5	0