DETERMINATION OF OPTIMUM MATURITY STAGE IN MANGO (*Mangifera indica* L.) FOR FRUIT QUALITY

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(2019-12-048)

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THESIS

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DECLARATION

I, **Janmitha Shetty** (2019-12-048) hereby declare that the thesis entitled **"Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality"** is a bonafide record of research done by me during the course of research and that it has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Velllanikkara
Date: 19 /11/2021

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CERTIFICATE

Certified that this thesis entitled **"Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality"** is a record of research work done independently by **Ms. Janmitha Shetty** (2019-12-048) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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JANMITHA SHETTY

DEDICATED TO MY PARENTS

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INTRODUCTION

1. INTRODUCTION

Mango (*Mangifera indica* L.), known as the king of fruits is rich in carbohydrates, proteins, vitamin A, vitamin C and minerals such as calcium, iron, and phosphorus. It is the most popular fruit in markets worldwide, because of its superb flavour, appealing scent, colour, taste, and nutritional characteristics (Arauz, 2000). Acceptability of mango fruit is based on both external and internal factors affecting quality (Kader, 2002). The important factors are cultivar, harvest ripeness, pre- and post-harvest handling procedures, mechanical damage, chilling injury *etc.* (Kader 2008; Brecht et al., 2010). It also contains anti-oxidant, anti-inflammatory, anti-diuretic, and wound-healing properties (Chaudhary *et al*., 2017). Because of its nutritional advantages, outstanding flavour, and various utilities, mango is India's national fruit, and it has a unique position among the country's fruit harvests.

Mangoes are said to have originated in southern Asia, notably eastern India, Burma, and the Andaman Islands (Subramanyam *et al.,* 1975; Tjiptono *et al*., 1984). Over 150 different types of mango are grown all over the world. With an annual production of around 16,337,400 tonnes, India is the world's largest mango producer, accounting for 42.2 percent of global output (Madhavan *et al*., 2019).

In India, mangoes are grown in Uttar Pradesh, Andhra Pradesh, Karnataka, Bihar, Gujarat, Tamil Nadu, Odisha, West Bengal, Jharkhand, and Maharashtra. With a share of 23.47 percent and the best output, Uttar Pradesh leads the way in mango production. Early maturing mango cultivars include Alphonso, Kesar, Rajapuri, and Dashehari, while late maturing cultivars include Neelum, Malgoa, Karanjio, Amrapali, Totapuri, Langra, Sardar, and Vashi Badami. However, new late maturing hybrids like Ratna, Sindhu, Neelphonso, Neeleshan, Neeleshwari, Sonpari, and others are becoming increasingly popular.

In Kerala, flowering in mango begins in November - December, while harvesting is in March -April. As a result, these are the first mango fruits to appear in Indian markets at the start of each season (Radha and Nair, 2000). It aided Kerala mango growers in obtaining the highest possible price due to increasing demand for mango earlier in the season. Mango is grown on 79,496 hectares in Kerala, with an annual production of 4,20,048 MT and a yield of 5.20 tonnes per hectare (GOK,

2017). Alphonso, Bangalora, Banganpalli, Sindhura, Neelam and some local varieties like Chandrakaran, Muvandan are the commercial cultivars grown in Kerala. Many varieties are being introduced to Kerala of which Mallika and Ratna are late introductions. But detailed and definitive information on the performance of these varieties in terms of maturity standards under Kerala conditions is lacking. Hence, an attempt was made to assess the performance of vital mango varieties in Kerala.

The normal practice is to harvest fruits early in the season during the premature stage itself in order to capture early market, but immature fruits have air pockets that affect the taste and flavour and will not ripen properly, whereas over-mature fruits lose storage life. Fruits should be harvested when firm and at a mature-green colour stage for the export market as well. Thus, fruits harvested at the proper maturity stage ripen normally after harvest and have a long shelf life. A simple and feasible criterion for determining fruit maturity is a computational method that uses heat unit accumulation during fruit growth and development.

The mango varieties in College mango orchard planted in high density with 3m*3m spacing were used for the study. Flowers were tagged at the time of fruit set and observations on maturity standards were recorded on successive growth stages and the effect of maturity on ripening was also observed. Hence the study helped in determining the appropriate maturity stage for improving quality and consumer acceptance with following objectives.

1. Define ideal harvesting stage of mango fruits
2. To find out the effect of maturity stage on ripening, shelf life and post-harvest quality.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The quality of mango fruit is determined by the stage at which the harvesting is done. Fruits that are picked too early are of low quality as the physico - chemical parameters for taste and appearance, required for consumption are not attained. Mangoes harvested at full maturity had a shorter shelf life, but those harvested early had a higher weight loss but improved storability (Shahjahan *et al.,* 1994). Size, shape, colour, total soluble solids, acidity, pH, physiological loss in weight, juice, pulp, and moisture content are all key quality factors for table use and adding value to mango fruit (Jha *et al*., 2008). Under diverse agro-climatic circumstances, the fruit's physico-chemical composition varies as well (Kumar, 1997; Dhillon *et al*., 2004; Shivanandam *et al*., 2008). Hence, a detailed review on the changes during growth of mango fruits.

2.1. PHYSICAL CHARACTERS

Mango maturity is usually determined by observing the changes occurring on the fruit surface during development as well as by counting days after full bloom or days after fruit set. According to Litz (2009), early flowering and fruit setting, appealing fruit colour and size, and resistance to major diseases and other biotic-abiotic stressors are all desirable characteristics in a mango cultivar. A better way to judge mango fruit maturity is to look at a mix of physical indices including shape and size, as well as flesh colour and detachment of the first fruit from the tree (Slaughter, 2009). Subjective maturity characteristics include skin roughness, fruit hardness, shape, size, shoulder growth, and peel colour.

2.1.1 Fruit dimensions

Since the fruit has 3 different dimensions, all three dimensions are measured to properly comprehend the size of the fruit. Mohsenin (1980) has reported that, the fruit size measured in three principal axis can be expressed in geometrical mean diameter. Bibi *et al*. (2006), has reported that Alphonso mango had longest fruit when compared to Fajri and Sindhuri. According to Wongmetha *et al*. (2015), after 110 days of anthesis the length and breadth of mango cv. Jinhwang's nearly reached its maximum and at the end of maturity it was 58 % of its width. El-Agamy *et al*. (2018) studied the growth of mango in two seasons and found that in the first and second

seasons, the length and diameter of the fruit ranged between 14.0–8.7 cm, 10.0–6 cm and 11.0–6.4 cm respectively. The average length and width of mango cv. Keitt were higher (13.50 and 10.5 cm) than that of the cv. Sensation (8.60 and 6.45 cm) respectively.

2.1.2 Weight

According to Naik (1985) the fully matured Alphonso and Ratna mango fruits weighed 280 and 403 g, respectively. In mango fruit, during maturation from semi-ripe to ripe, the weight of the fruit decreased steadily, eventually dropping by 10.70 percent on the 11th day after harvest when the fruits had turned to golden yellow colour and had a pleasant aroma (Badhe *et al*. 2007). Fajri had the highest green and matured fruit weights (453.0 g and 403.0 g) respectively, which were similar to those reported by Jilani *et al*., (2010), who found the highest fruit weight in Fajri and the lowest in Anwar Ratual. According to Bakshi *et al*. (2013), among the 15 mango genotypes, Mallika had the largest fruit weight (182.16 g), followed by Baramasi (176.40 g), and Selection-4 had the smallest (64.83 g). Total fruit weight and fruit pulp weight varied from 727.0 to 327.37 g and 594.2 to 211.48 g, respectively, in the 2016 season, and from 720.0 to 333.35 g and 593.0 to 229.01 g, respectively, in the 2017 season, according to El-Agamy *et al*. (2018). However, Keitt cultivar had the highest average weight (723.50 and 593.60 g), whereas Sensation cultivar had the lowest average weight (330.36 and 220.25 g) for both total fruit weight and fruit pulp weight.

2.1.3. Specific gravity

Specific gravity increases as the mango fruit matures (Kasantikul *et al*., 1984). One of the important assessments of fruit quality is specific gravity and is usually related to internal breakdown, decay, water distribution and insect infestation. Raghavendra Prasad *et al*. (2004) reported that at 110 days after fruit set, Alphonso mango had a specific gravity of 1.04. According to Badhe *et al*. (2007), in the case of Alphonso mango, a specific gravity of 1.00 to 1.04 is considered to be of the most optimal age.

2.1.4. Shoulder development

IPGRI (2006) has developed the discriptors of Mango and according to them the slope of ventral shoulder of mango can be slopping abruptly, ending in a long curve or raising and then rounded.

2.1.5. Firmness

Jarimopas and Kitthawee (2007) investigated the firmness of mango fruit (cv. Nam Dokmai and Chok Anan) and observed that it remained essentially unaltered from immature to completely mature stages, despite stiffness quickly decreasing as the fruit developed. In cv. Jinhwang's 50 DAA, fruit strength rose from 5.35 kilogram force (kgf) to 9.25 kgf at 110 DAA, and declined by 140 DAA to 8.05 kgf (Wongmetha *et al*., 2015).

2.1.6. Colour

The mango harvest mostly depends on the color of fruit. Unripe mangoes are green and transform from dark green to olive green when maturing and eventually become yellow or orange when chlorophyll is decreased and carotenoid pigments build up (Tharanathan *et al*., 2006). Abourayya *et al*. (2011) have also reported the importance of the various fruit colours of mango cultivars in various cultivars. Peel colour is still not a better sign of maturity because it appears when the fruit begins to soften and, in many instances, the colour change is also not consistent.

2.1.7. Stone characters

Abirami *et al*. (2004) found significant variation (0.05 percent) in stone length and width of different mango cultivars. Badhe *et al*. (2007) divided mango into four groups, with Grade I (45.02 g) having the largest stone weight, followed by Grade II (35.16), Grade III (31.0 g), and Grade IV (24.90 g) having the smallest stone weight, and the mean stone weight being 34.02 g. The findings revealed that the larger the fruit weight, the larger the size of the stones. According to Anila and Radha (2005), stone weight varied from 22.55 to 47.76 and was highest in Ratna, but the percentage contribution of stone to fruit weight was lowest in this variety (12 %). According to Hada and Singh (2017), Sepiya has the smallest stone length (5.72 cm) and breadth

(1.92 cm), while Mallika has the largest stone length (12.49 cm) and breadth (4.25 cm) respectively.

2.2 BIOCHEMICAL CHARACTERS

Starch buildup during growth and ripening is a fundamental chemical alteration of mango fruit (Quintana *et al*., 1984). Mango is considered as one of the most nutrient-dense tropical fruits. The sweet fruit is available in a variety of sizes, colours, aromas, fragrances, and compositions (FAO, 2002). Jahurul *et al*. (2015) revealed that mango is a great source of phytonutrient chemicals, such as Provitamin A, Carotenoids, vitamins (B6, C and A), phenolics as gallic acid, syringic acid, gentisyl-protocatechuic acid, mangiferine, ellagic acid, and quercetin).

2.2.1 Total soluble solids (TSS)

Raghavendra Prasad *et al*. (2004) reported that at 110 days after fruit set the total soluble solids of the chemical indicators for fruit maturity in Alphonso mango was 8.72° Brix**.** In mango Cv. Kent, the value of the total soluble solids varied, based on the date of harvest, between 8.3° Brix and 10° Brix at fruit harvest and between 14.2° Brix and 20° Brix at ambient temperature after fruit ripening has occurred (Emmanuel *et al*., 2009). According to Bakshi *et al*. (2013), Dashehari had the highest T.S.S (20.25°B), mirroring Mallika (20.15°B) and Langra (19.85°B), whereas Desi-2 had the lowest TSS (16.25°B).

2.2.2 Titratable acidity

According to Hoda *et al*. (2003), the acidity of mango fruit varies depending on the time of harvest and the prevailing agro-climatic conditions. Lebrun *et al*. (2008) measured titratable acidity of mango cv. Cogshall in green and ripe fruit at various stages of development from 61-115 days after flowering and found that there was no significant difference in titratable acidity owing to harvest dates for either green or mature fruit. Naz *et al*. (2014) observed that highest titratable acidity in Sindhuri (0.49 %) followed by Anwar Ratual Late (0.41%). The fruits of Samar Bahisht Chausa and Fajri differed considerably between themselves and had the lowest titratable acidity content of 0.12 % and 0.14 %. TA in mango arose from 3.79% at 50 DAA to 4.63 % at 80 DAA and then dramatically dropped towards

maturity (Wongmetha *et al*., 2015). Lokesh Bora *et al*. (2017) found that Langra have the greatest titrable acidity (0.29 %), followed by Swarna Jahangir (0.25%), while Ratna and Sabri were found to have least acidity content (0.14%).

2.2.3 Ascorbic acid

The fruit's ascorbic acid concentration, which ranges from 32 to 200 mg per 100 g of edible pulp, makes it a great source of vitamin C, among many other nutrients (Akinyele and Keshinro, 1980). The ascorbic acid level was found to be between 21.66 mg/100 g to 125.40 mg/100 g (Mitra *et al*., 2001). Sindu had the highest level of ascorbic acid (52.14 mg/100 g), whereas, Rad had the lowest (5.32 mg/100 g), according to Uddin *et al*. (2006). Ascorbic acid is the principle biologically active form of vitamin C and vitamin C is extremely unstable in contrast to other organic acids (Robles-Sánchez *et al.*, 2009). Azad *et al*., (2009) observed that the content of ascorbic acid of the fruit from the mango was greatly influenced by the harvesting stages and storage period. It was the highest just after the harvest and gradually decreased over time while at the last edible stage. Langra had the highest amount of ascorbic acid at the initial stage, which decreased sharply at full maturity.

2.2.4 Total sugar

Hubbard *et al.* (1990) suggested that buildup of sucrose occurred later in fruit growth and the final sugar levels were highly obtained during ripening. The highest percentage of sugar was found in Rad (20.34 %), while the lowest level of sugar was found in Mixed Special (12.7 %) (Uddin *et al*., 2006). The total sugar content of mango fruits was greatly affected by harvest and storage phases. It rose swiftly from harvest to ripe stage, and then declined little at the last edible stage. It was the smallest in the first harvest, steadily increased with the passage of time, and peaked in the last harvest (Azad *et al*. 2009). In all kinds, total sugars quickly increased at full ripeness and subsequently decreased somewhat at the last edible stage, according to the findings.

2.2.5 Reducing sugar

The findings are consistent with those of Chaudhari *et al*. (1997), who found that 19 South Indian mango varieties had reduced sugar levels ranging from 2.6 to 7.1

%. According to Uddin *et al*. (2006), the highest reducing sugar level (7.37 %) was found in Rad, while the lowest reducing sugar content (2.82 %) was found in Mixed Special, followed by Sindhu (2.88 %).

2.2.6 Non-reducing sugar (NRS)

The amount of non-reducing sugars in mango fruits was affected by harvest and storage phases. It grew during the ripening stage but decreased significantly towards the last edible stage. According to Shyamalamma *et al*. (1995), the progressive increase of non-reducing sugars as maturation progressed was consistent with the findings of Azad *et al*. (2009), NRS improved significantly from harvest to full ripeness, then reduced somewhat at the last edible stage in all cultivars.

2.2.7 Total Phenols

Padilha (2005) discovered 23.53 mg GAE/100g of total phenolic components in unripe fruits and 22.14 mg GAE/100g in ripe fruits in methanolic (80 %) extracts of mango "Tommy Atkins." Using a variety of solvents, Ajila *et al*. (2007) found that acetone extracted the most phenolic compounds from mango peel, up to 80 %, as did Pereira *et al*. (2007) in a mulberry study and Soares (2008) in an apple study. Gallic acid and gallotannins are the primary phenolic chemicals found in mango fruit, according to reports (Kim *et al.,* 2007; Masibo and He, 2008). After working with "Tommy Atkins" and examining Ecuadorian mangoes, Ribeiro *et al*. (2007) and Vasco *et al*. (2008) determined that these fruits contained approximately 60 mg GAE/100g of phenolic compounds. Gallic acid and gallotannins are virtually unchanged after 4 days of storage, according to Kim *et al*. (2009). This shows that these chemicals maintain phenolic content during the early stages of maturity. Among numerous mango types, the ‘Ataulfo' mango was shown to have the highest phenolic content and antioxidant capacity (Manthey and Perkins-Veazie, 2009).

2.2.8 Total carotenoids

Hoda *et al*. (2003) found variations in total carotenoid levels ranging from 2.33 mg/100 g to 44.95 mg/100 g. The carotenoid content in fruits improves the nutritional values as well as the appearance and especially in international trade where the use of artificial colour is forbidden. Amrapali had the highest carotenoids (8.38

mg/100 g) content, followed by Mallika (7.42 mg/100 g), while Mahmood Bahar (1.53 mg/100 g) had the lowest (Lokesh Bora *et al*. 2017).

2.2.9 β –carotene

The amount of β - carotene increased progressively, with peak at the last harvest and lowest after harvest. The highest ß-carotene was at the final edible stage (Azad *et al*., 2009). According to Manthey *et al*. (2009), Tommy Atkins had the lowest average ß-carotene content (4.9 1.5 $mgkg^{-1}$ FW), while mango var. Ataulfo had (26.1 4.4 $mgkg^{-1}$ FW). The average ß-carotene content of 'Haden, Kent, and Keitt' were closer to 'Tommy Atkins' than 'Ataulfo' with 6.8 ± 3.3, 12.9 ± 5.1, and 10.4 ± 2.4, respectively. In the 'Mallika' variety (0.89 mg/100 g), bioaccessible amounts of β-carotene were higher than 'Badami' (0.79 mg/100 g).

2.2.10 Crude fibre

The investigation carried out by Ubwa *et al*. (2014), revealed that there is no significant differences in the crude fibre content of Hindi, Julie, and Local mango fruits. The maximum crude fibre concentration 1.110 g/100g was found in cv. Julie, while the lowest crude fibre content of 0.840 g/100g was found in cv. Hindi. In another study conducted by Kothalawala and Jayasinghe (2017) it was noted that, Karthakolomban (3.16 g/100 g) has the most crude fibre, followed by Gira Amba (2.06 g/100 g) and Bettiamba (1.98 g/100 g). Willard had the least amount of crude fibre (1.17 mg/100 g).

2.2.11 Total chlorophyll

The loss of Chlorophyll during fruit ripening is generally accompanied with the revelation of carotenoids and the fruit attaining a rich yellow-red colour. The contents of Chl. a and Chl. b at the 'Green-Unripe' stage were 11.37 mg and 5.1 mg /100g, respectively, and upon ripening, roughly 67 % loss was observed at both temperatures (Janave *et al*., 2005).

2.3 HEAT UNITS

The application of heat units in relation to crop maturity has long been recognised in annuals, according to Appleman and Eaton (1921), and is based on the

direct relationship between temperature and reaction rate (Van Hoffs Rule) over the temperature range of 0-50°C. According to Sengupta *et al*. (1996), the average number of days from blossoming to maturity is used as a maturity criterion in mango.

Different parameters are used to determine the maturity stage of mango fruits. As an efficient and practical criterion for determining fruit maturity, a computational method based on heat unit (HU) accumulation during fruit growth and development is applied (Halepotara *et al*., 2019). HU requirement obtained are measured by measuring the amount of heat that has accumulated over the course of 24 hours. The average of the daily maximum and minimum temperatures is compared to a base temperature, T_{base} (typically 10 °C), to determine HU. The base temperature for mango is 17.9 °C (Halepotara *et al*., 2019).

Changes in temperature between seasons affected mango fruit growth differently at different locales and in different seasons (Mathieu *et al*., 2005). Halepotara *et al*. (2019) concluded that mango cv. Kesar, collected at 105 days after fruit set and with a 1020 HU accumulation, was the best. Fruits harvested at 105 days had higher physical traits and quality parameters, such as TSS, minimal acidity, sugars, and carotenoid content, and were more marketable with less spoiling, making them more acceptable in the market.

To complete the different phenophases of mango, according to Singh *et al*. (1998), each genotype requires an accumulation of heat units of a specified amount. After 120 and 105 days of mango fruit development, Alphonso obtained the most heat units for fruit development (1072.75 degree days).

2.4. PHYSIOLOGICAL CHARACTERS

Fruits undergo numerous physiological and biochemical changes during storage after harvest. Another essential component governing diverse physiological and biochemical changes throughout mango storage and ripening is physiological maturity (Azad *et al.* 2009). Physico-chemical features of mango cv. Alphonso fruits vary with their maturity stage, according to Zagade and Pujari's (2014).

2.4.1 Physiological loss in weight (PLW)

The PLW in mango during ripening is caused by factors such as respiration, transpiration, and biological features (Naryana *et al*., 1996). Yashoda *et al*. (2006), found 10% PLW due to cultivar differences or ripening circumstances. Naz *et al*. (2014) observed that cv. Fajri had the highest PLW (10.97 %), followed by cvs. Anwar Ratual Late (7.00 %) and Samar Bahisht Chaunsa (6.60 %) had the highest PWL, while cvs with the lowest PWL is Sindhri and Aman Dusahri, with 2.60 and 2.53 % respectively.

2.4.2 Respiration rate/Ethylene evolution

The increase in ethylene production in fully developed mango fruit was also seen (Quintana *et al*., 1984). Tadesse *et al*. (2002) revealed that the vigorous growth of the fruit causes high respiration rates and ethylene production in immature fruit. The ethylene peak at 50 DAA occurred 3 days after measuring (3.52 l C_2H_4kg/h), but the ethylene production rate of fruit at 80, 140, and 110 DAA remained nearly constant until the conclusion of sampling (Wongmetha *et al*., 2015).

2.5 SENSORY EVALUATION

The sensory profile of any fruit provides a solid foundation as quality indicator for increasing mango export in a highly competitive worldwide market. Color, flavour, and taste are important sensory qualities that influence consumer acceptance of mangoes. In judgement of sensory characteristics and acceptability, according to Mtebe *et al*. (2006), the fruit maturation period is key. Consumers' decisions to acquire a certain type of fruit or its fruit products are influenced by the sensory profile of mangoes, particularly colour (Gössinger *et al*. 2008). According to Naz *et al*. (2014), the results for sensory metrics such as aftertaste and tongue feel revealed that Anwar Ratual and Samar Bahisht Chaunsa are statistically similar and achieved the greatest scores, followed by Aman Dusahri, while Mango cv. Sindhuri receiving the lowest score.

Emmanuel *et al*. (2009) opined that the organoleptic quality of mango pickles made with var. Kent. was better 100 days after flowering when compared with 76, 82, 88 and 94 days after flowering. Fruit of mango variety Carabao collected at 115-120 days after flower induction had the greatest eating quality in terms of fragrance, sweetness, sourness, taste, and overall acceptability, according to sensory examination at table-ripe stage (Yaptenco *et al*., 2013)

2.6 PRE – TREATMENTS FOR GOOD POST HARVEST QUALITY

Mango (*Mangifera indica* L.) is a worldwide popular fruit for its outstanding taste, appealing aroma, flavour and nutrients**.** The purpose of pre-treatments after harvest is to optimize quality and to reduce precocious ripening and damage to fruit.

2.6.1 Hot water treatment

Many fruits and vegetables withstand a water exposure of 50-60 °C for up to 10 min, however shorter exposure may be adequate to treat many plant pathogenic post-harvest conditions (Barkai-Golan and Phillips, 1991). Hot water dips are helpful in controlling fungal pathogens, because fungal spores and latent infections reside either on the surface or in the first couple of cells under the fruit or vegetable peel (Lurie, 1998). According to Prusky *et al*. (1999), hot water treatment could help with postharvest deterioration reduction and also removal of sap and debris, as well as an improvement in fine colour and shine, improves the overall beauty of mango fruits. The easiest heat treatment, which consists of immersion of the commodity into a hot tank at a given time dependent on commodity and intended damage (Esguerra and Bautista, 2007).

Mansour *et al.* (2006) observed that when mango was treated with hot air for 4 hours at 50ºC, also with hot water for 5 min at 40 ºC, after harvest reduction in darkening of peels seen. Alternaria rot on mango fruits might be controlled at 50-55 ºC for 20 s, by spraying and blowing hot water (Pursky *et al*., 2009). Ndlela *et al*. (2017) reported that the hot-water treatment of mango variety Apple (46.1ºC for 68 min) is an efficient therapy for post-harvest mango fruit fly disinfestation (*Bactrocera dorsalis*). Chatha *et al*. (2020) noted that hot water treatment and gamma irradiation therapy can be applied in industry for improving the storage life of black and white Chausa mango.

2.6.2 Ethrel

Mangoes are being artificially ripened with calcium carbide, generally known as masala. But it also contains arsenic and phosphorus hydroxide pollutants that are particularly harmful to human health and the environment (Hossain *et al*., 2015). Consumers need alternatives to artificial ripening that are safe. Ethrel (2-Chloroethylphosphonic acid) is well known for inducing early and consistent ripening in a number of fruits including Amrapali mangoes, which are collected immature.

Ethrel/Ethylene gas was allowed to be used for artificial ripening of fruits under the Food Safety and Standards (Prohibition and Restriction on Sales) Regulations (2011). It is an ethylene-releasing compound that improves fruit colour development and accelerates the ripening process.

The benefits of ethylene-induced ripening for Ataulfo mangoes were recently reported (Montalvo *et al*., 2007). A study by Montalvo *et al*. (2007) found that exogenous ethylene can accelerate ripening reactions and provide a homogenous exterior hue. It is possible to speed up the ripening process in mangoes by applying ethylene to the fruit (Kader and Mitcham, 2008).

Many fruits are ripened by dipping them in a solution of 500 to 2000 ppm ethrel (Mohamed and Abu-Goukh, 2003). An effective growth regulator in several tropical fruits, such as guava (Mohamed Nour *et al*., 2010). Ethrel has been shown to improve the quality of fruits. Ethrel treatment accelerated mango ripening, although the reaction varied depending on the concentration of Ethrel used. After 5 to 8 days, the fruits were treated with ethrel @ 1000 ppm, resulting in a 100 % ripening rate.

Using ethylene or ethrel to stimulate fruit ripening and raise TSS has been observed for oranges (El Rayes, 2000) and mangoes (Kim *et al*., 2001). A study by Kulkarni *et al*. (2004) found that mango fruits treated with ethrel had higher TSS and sugar levels. Dhillon and Mahajan (2011) reported that fruits treated with ethrel, results in an increase in total soluble solids in pear. Singh *et al*. (2012) observed a high proportion of sugar with ethrel treatment in mango and papaya.

Ethrel was also observed to accelerate chlorophyll breakdown in various fruits including mango (Mohamed and Goukh, 2003; Siddiqui and Dhua, 2009; Gupta *et al*.,

2015), banana (Kulkarni *et al*., 2011) and papaya (Singh *et al.,* 2012). Fruits treated with Ethrel spray (600 ppm) began to turn yellow within four days, whereas untreated control fruits stayed green (Gurjar *et al*., 2017).

2.6.3 Ozonization

Another powerful oxidizing agent is ozone, which can be in the form of a gas or dissolved in water. O_3 molecules are the primary cause of ozone activity (Barbosa-Martínez *et al*., 2002). A postharvest therapy with O_3 has been used on fruit in order to delay physiological and biochemical changes. 15 days of ozone treatment on whole and sliced tomatoes resulted in good appearance, overall quality and microbiological reduction (Aguayo *et al*., 2006). Ozone at 2 L L^{-1} for 20 minutes and 10 L L^{-1} for 10 min dramatically reduced ethylene production immediately after treatment. According to Ali *et al*. (2014), the thick peel of ozone-treated papaya contributed to the fruit's lower weight loss when compared to tomatoes and cranberries.

Ozone has been used for water purification since 1904, and as a disinfectant in fruits and preserved foods since the 1930s (Berger and Hansen, 1965; Ewell, 1938). Electrical discharges in nature produce ozone, an allotropic form of oxygen. Ozone has been used as a phytosanitary and germicidal agent on apples (Gooch, 1996), peaches (Ridley and Sims, 1996), strawberries (Bergerand Hansen, 1965; Ridley and Sims, 1996).

On table grapes cultivar ‘Thompson seedless,' ozonized air at 0 °C for 14 days caused light to medium toxicity to the berry stems without affecting any qualitative features of the fruits (Luchsinger *et al*., 1999). Monaco *et al*. (2016) discovered that ozone-treated mangoes (var. Palmer) kept their antioxidant activity even after 14 days in cold storage. Controlled or modified atmospheres containing ozone could be effective strategies for maintaining the quality of fruits and vegetables in cold storage and transit, as well as controlling decay organisms. Ozone has an advantage over chlorine since it leaves no hazardous compound.

2.6.4 Sanitization

Chlorine is a powerful disinfectant that is commonly used in the fresh horticulture produce business to eliminate microbiological contamination in process water, as well as to prevent postharvest infections and food-borne illnesses (Zhuang *et al*., 1995). To maintain sufficient accessible chlorine activity in process water, the total chlorine concentration may need to reach 300 ppm, and the contact duration may need to be increased to 10-15 min (Suslow, 1997). To minimize the initial microbial load on fruits destined for fresh-cut processing, a variety of disinfection chemicals or sanitizing procedures have been used (USFDA, 2001). Washing and brushing the fruit in tap water at 11.7 °C did not lower microbial populations in the stem scar substantially (P0.05), whereas chlorinated water reduced populations by about 1 log cfu/cm^2. Brushing with chlorinated tap water reduced populations by about 2 log cfu/cm^2, than chlorinated tap water alone. Dashehari mangoes immersed with aqueous calcium chloride and calcium nitrate (2 and 4 % each) solutions for five minutes reduced post-harvest losses and delayed ripening. It also led to a higher level of stiffness and a reduced rate of physiological weight loss (Periyathambi *et al*., 2013).

To prevent fungal disinfection of mango fruit and increase shelf life, APEDA (2007) recommended postharvest treatment with hot water (52 ºC for 3-4 min) and sodium hypochlorite (200 ppm). Mango fruits of the variety Kesar treated with 8 % $CaCl_2$ and 100 ppm GA_3 exhibited superiority in terms of quality parameters such as total soluble solids (TSS) and total sugars, although titrable acidity, ascorbic acid, and PLW all decreased linearly during ripening (Sakhale *et al*., 2009).

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The study on the "Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality" was conducted in the department of Post-Harvest Technology, College of Agriculture, Vellanikkara, Thrissur, Kerala during 2019-2021. Vellanikkara is 22.25 m above sea level, latitude 10º 32`N and longitude 70º 10`E.

Two experiments were carried out as part of the study.

3.1 Studies on growth and maturation of selected mango cultivars

3.2 Studies on the effect of maturity on ripening of cv. Ratna

The mango varieties Ratna and Mallika, grown in college orchard planted in spacing of 3 m x 3 m were used for the study. Ratna is a hybrid variant from Alpanso and Neelum and is of Indian origin grown in state of Maharastra and some parts of Karnataka. Mallika is the result of the hybridization of Neelum and Dasheri. These two varieties were introduced to Kerala's agro-climatic conditions and are having good acceptability.

3.1 STUDIES ON GROWTH AND MATURATION OF SELECTED MANGO CULTIVARS

The flowers were tagged at the time of fruit set from November 2020. Different coloured tags were used for tagging and fruits were collected during the growth stage from 90 days onwards at an interval of 10 days.

3.1.1 Treatments

T1: 90 Days after fruit set

T2: 100 Days after fruit set

T3: 110 Days after fruit set

3.1.2 Lay out

The experiment was laid out with 3 treatments and 5 replications of each in a Completely Randomized Design (CRD)

Plate 1. Mango orchard, College of Agriculture

Plate 2. Stage of fruit set

Plate 3. Tagging during fruit set

10 DAFS (01/12/20) **30 DAFS (19/12/20)**

Plate 4a. Stages of maturity

55 DAFS (15/01/21)

70 DAFS (28/01/21)

90 DAFS (20/02/21)

Plate 4b. Stages of maturity

90 DAFS (20/02/21)

100 DAFS (02/03/21)

110 DAFS (12/03/21)

Plate 5. Growth stages of cv. Ratna

90 DAFS (02/01/21 - 02/04/21)

110 DAFS (02/01/21 - 22/04/21)

120 DAFS (05/02/21-05/06/21)

140 DAFS (10/01/21-29/05/21)

Plate 6. Growth stages of cv. Mallika

3.1.3 Observations

The physical and biochemical parameters were recorded at 10 days interval as detailed below.

3.1.3.1 Physical parameters

3.1.3.1.1 Fruit dimensions

The length was measured from the base to the tip of the fruit and diameter at the widest point in centimeters (cm) using a computerized Vernier caliper.

3.1.3.1.2 Fruit weight

The weight of fresh fruit was obtained using a precision weighing balance and expressed in grams (g).

3.1.3.1.3 Fruit peel and pulp colour

The colour change of mango fruits seen as peel colour noted with the help of International Plant Genetic Resources (IPGR) descriptor. The peel and pulp color of mature or ripe fruit of mango are as follows;

Peel color

1. Green
2. Greenish yellow
3. Yellow
4. Green with red blush
5. Green with purple patches

Pulp color

1. Light yellow
2. Golden yellow
3. Yellow orange
4. Orange

5. Greenish yellow

6. Yellow

7. Light orange

8. Dark orange

3.1.3.1.4 Fruit firmness

Fruit firmness measured using Vaiseshika digital force gauge, model 6003E or hand held fruit pressure tester. Readings were taken in three positions of fruit area and average was recorded in kilogram per cm^2 (Kg/cm^2).

3.1.3.1.5 Specific gravity

The specific gravity was determined by using the formula weight by volume, where volume was measured by water displacement method in cubic centimeters (cc).

3.1.3.1.6 Shoulder development

The shoulder development was noted as described by IPGRI (2006) and according to them the slope of ventral shoulder of mango can be slopping abruptly, ending in a long curve or raising and rounded.

3.1.3.1.7 Stone characters

3.1.3.1.7.1 Dimensions

The length was measured from the base to the tip of the fruit and diameter at the widest point in centimeters (cm) using a computerized Vernier caliper.

3.1.3.1.7.2 Stone weight

The weight of fresh fruit was obtained using a precision weighing balance and expressed in grams (g).

3.1.3.1.7.3 Stone color

As described in IPGRI descriptor. Color was observed immediately after the extraction.

3.1.3.1.7.4 Stone texture

As per the IPGRI descriptor the stone texture is noted as soft and coarse.

3.1.3.2 Biochemical parameters

3.1.3.2.1 Total Soluble Solids (TSS)

TSS was measured by using a digital refractometer with a brix range of 0-32 degrees for fruits and vegetables.

3.1.3.2.2 Titratable acidity (%)

Titratable acidity was determined by titration method were five grams of fruit sample was digested with distilled water and the amount was made upto 100 ml. Using phenolphthalein as an indicator, an aliquot of the solution was treated with standard alkali (Ranganna, 1997).

3.1.3.2.3 Ascorbic acid (mg/100g)

The ascorbic content was estimated by the method of Sadasivam and Manickam (1996), using three percent meta-phosphoric acid to extract 5 grams of fruit pulp and titrated with 2, 6 - dichlorophenol indophenol dye to evaluate the ascorbic acid level (Sadasivam and Manickam, 1996).

3.1.3.2.4 Sugars (%)

The reducing sugar, non-reducing and total sugar were estimated and expressed in percentage. Fehling's solution was used in a titrimetric method to assess total sugar and reducing sugar (Ranganna, 19997). By removing reducing sugar from total sugar, we got non-reducing sugar.

3.1.3.2.5 Total carotenoids (mg/100g)

Total carotenoids were estimated by using five grams of fruit sample and ground using a pestle and mortar with acetone. The extract was decanted into a conical flask, and the extraction was stored continuously until the residue was colorless. The extract was transferred to a separating funnel containing petroleum ether. The solution was shaken and set aside for a while. The separated liquid was

then transferred to petroleum ether, and the colour intensity was measured with a spectrophotometer at 452nm (AOAC, 1984).

3.1.3.2.6 Total phenol (mg/100g)

Folin-Ciocalteu reagent (FCR) was used to calculate total soluble phenols, employing catechol as a standard reference (Sadasivam and Manickam, 1991). The colour intensity was measured with spectrophotometer at 650nm against a reagent blank.

3.1.3.2.7 β- carotene (mg/100g)

1 gram of fruit sample was ground with 10ml hexane : acetone (60:40) and centrifuged at 3000 rpm for 5 min then colour intensity was measured with a spectrophotometer at 663 nm, 645 nm, 505 nm, 453 nm (Ranganna, 1995).

3.1.3.2.8 Crude fiber (%)

Crude fiber was estimated using standard analytical method of Association of Official Analytical Chemists, (AOAC, 2000). Two gram sample was ground with pestle and mortor. After extract boil with 200ml dilute H_2SO_4, then was filtered through muslin and washed with boiling water and again boiled with 200ml dilute sodium hydroxide solution for 30 min and filtered through muslin cloth again and washed with 25 ml of boiling 1.25 % H_2SO_4, three 50 ml portions of water and 25 ml alcohol and digested, removed the residue and transfered to ashing dish.

3.1.3.2.9 Total chlorophyll (mg/100g)

Total chlorophyll was determined using 80% acetone, (Porra, 2002) where 1 gram fruit sample was cut into small pieces, digested in 10 ml acetone, and crushed thoroughly with a mortar and pestle. The crushed material was then placed into a centrifuge tube and agitated for 10 minutes at 5000 rpm. At 646.6 nm and 663.6 nm, the absorbance was measured.

3.1.3.3 Heat units

Heat unit (HU) requirement is measured by measuring the amount of heat that has collected over the course of 24 hours. The daily maximum and minimum temperature recorded by the Dept. of Agricultural Meteorology were used for the study. The average of the daily maximum and minimum temperatures was compared to a base temperature, T base (typically 10 °C), to determine HU. The base temperature for mango is 17.9 °C (Halepotara *et al*., 2019).

$$HU = (T_{max} + T_{min}/2) - T_{base}$$

3.1.3.2 Sensory evaluation

Organoleptic evaluation was done on nine-point hedonic scale by a panel of 10 semi-trained people. The cut fruit pieces were evaluated for the quality and using spss statistical tool the ranks were analyzed.

Mango fruits were evaluated for quality attributes like colour, appearance, texture, taste etc. In the evaluation, a score card had been used.

3.2 STUDIES ON THE EFFECT OF MATURITY ON RIPENING OF CV. RATNA

Fruits at the optimum mature stage and ten days prior to maturity collected from the orchard were taken to the post graduate lab attached to the Dept. of Post-Harvest Technology. Preliminary cleaning was done by using ordinary tap water and the treatments were given. Treated fruits packed in ventilated CFB boxes were kept under ambient condition.

3.2.1 Treatments

T_1: Control

Fruits washed and packed in CFB boxes.

T_2: Ethrel spray (200ppm)

200ppm ethrel spray was prepared by dissolving 0.2ml Bayer ethrel in one litre water.

T_3: Hot water dip (50 ± 2^0C for 1 minute) + Ethrel spray (200ppm)

Boiling water at 50ºC and then dipping mango for one minute later spraying 200 ppm ethrel.

T_4: Sanitization (dipping in 100 ppm chlorine water for 5 minutes) +

Ethrel spray (200 ppm)

100 ppm chlorine water is prepared by dissolving 1ml sodium hypochlorite in 400 ml water and then dipping mango fruit for 5 minutes and later spraying with 200 ppm ethrel.

T_5: Ozonization (2ppm Ozone) + Ethrel spray (200ppm)

Switch on Anion Ozonizer and keep the knob in 1 litre water for 12 sec after that takeout knob and place the fruit in the same water for 15 min later spray with 200pm ethrel.

3.2.2 Lay out

The experiment was designed with five treatments and three replications of each in a Completely Randomized Design (CRD).

3.2.3 Observations

Observation on physiological and biochemical parameters were taken in details as follows:

3.2.3.1 Physiological parameter

Physiological parameters like, Physiological loss in weight (PLW), Respiration rate/Ethylene evolution were recorded.

3.2.3.1.1 Physiological loss in weight (PLW)

PLW was determined by the formula of Srivastava and Tandon (1968). Here initial weight was taken after harvest and the final weight was taken at the time of analysis.

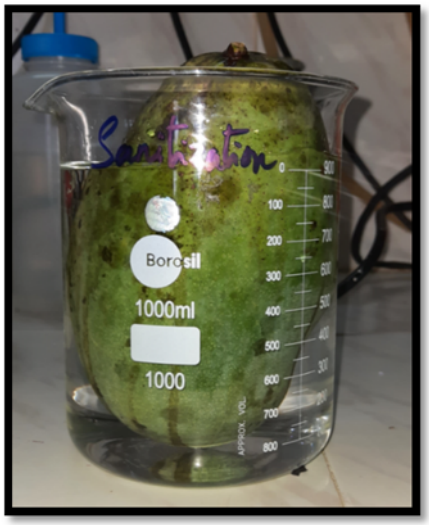
$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Final weight} \times 100}{\text{Initial weight}}$$

Harvested Mango fruits

Ethrel spray

Plate 7a. Pre-treatments in cv. Ratna

Hot water dip + ethrel spray



Sanitization + ethrel spray

Ozonization + Ethrel spray

Plate 7b. Pre-treatments on cv. Ratna

Plate 8. Storage in corrugated fiber board boxes

3.2.3.1.2 Respiration/Ethylene evolution (ppm)

Fruits were kept in zip log bag before one hour of estimation and then using Bioconservacion ethylene analyzer, evolution of ethylene was measured in ppm.

3.2.3.2 Biochemical parameters

3.2.3.2.1 Total Soluble Solids (TSS)

TSS was estimated as mentioned in 3.1.3.2.1.

3.2.3.2.2 Acidity (%)

Acidity was estimated as mentioned in 3.1.3.2.2.

3.2.3.2.3 Ascorbic acid (mg/100g)

Ascorbic acid was calculated as mentioned in 3.1.3.2.3.

3.2.3.2.4 Sugars

Sugars were estimated as mentioned in 3.1.3.2.4.

3.2.3.3 Sensory evaluation

Sensory evaluation was estimated as mentioned in 3.1.3.4.

RESULTS

4. RESULTS

The results of the study entitled "Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality" conducted in the Department of Post-Harvest Technology, College of Agriculture, Vellanikkara, during the year of 2019-20 and 2020-21 are presented here under the following titles.

4.1 Studies on growth and maturation of selected mango cultivars

4.2 Studies on the effect of maturity on ripening of cv. Ratna

4.1 STUDIES ON GROWTH AND MATURATION OF SELECTED MANGO CULTIVARS

The flowers were tagged at the time of fruit set and fruits were collected during the growth stage from 90 days onwards at an interval of 10 days. The results on both physical and biochemical parameters were recorded.

4.1.1 Physical parameters

Physical parameters considered in this experiment are fruit length, fruit diameter, fruit weight, fruit peel and pulp colour, fruit firmness, specific gravity, shoulder development and stone characters. Table 1a. and 1b. shows the data pertaining to these parameters.

4.1.1.1 Fruit dimensions (cm)

In mango cv. Ratna, no significant difference was observed in fruit length and diameter during the three growth stages of 90, 100, and 110 days after fruit set (DAFS). In cv. Ratna, the longer fruit (10.73 cm) was observed 90 DAFS followed by 100 DAFS (10.61 cm) and 110 DAFS (10.44 cm) and diameter was highest in 110 DAFS (26.1 cm) followed by 100 DAFS (25.26 cm) and 90 DAFS (25.24 cm) as shown in the Table 1a.

Significant difference was observed in fruit length and diameter during the four growth stages of 90, 110, 120 and 140 DAFS in cv. Mallika and significantly longer fruits were observed in 90 DAFS (18.45 cm) followed by 120 DAFS (17.38 cm), 140

DAFS (14.80 cm) and 110 DAFS (14.28 cm) and diameter was highest in 120 DAFS (33.93 cm) followed by 90 DAFS (32.68 cm), 110 DAFS (30.12 cm) and 140 DAFS (28.03 cm) as shown in the Table 1b.

4.1.1.2 Fruit weight (g)

During the three stages of growth, non-significant difference were recorded for fruit weight in cv. Ratna. Maximum fruit weight was recorded in 100 DAFS (383.94 g) followed by 90 DAFS (364.00 g) and 110 DAFS (358.80 g) as shown in the Table 1a.

Significant difference were observed among the four growth stages for fruit weight in cv. Mallika. Maximum fruit weight was 90 DAFS (859.40 g) followed by 110 DAFS (833.68 g), 120 DAFS (706.55 g) and 140 DAFS (623.95 g) as shown in the Table 1b.

Table 1a. Physical parameters of mango cv. Ratna

Treatments	Specific gravity	Length (cm)	Diameter (cm)	Weight (g)	Peel colour	Pulp colour	Shoulder development	Fruit firmness (kg/cm^2)
T_1	1.18	10.73	25.24	364.00	G	LY	Raising and then rounded	6.07
T_2	1.16	10.61	25.26	383.94	GY	LY	Raising and then rounded	2.87
T_3	1.03	10.44	26.10	358.80	GY	O	Raising and then rounded	1.40
SE(d)	0.10	0.27	0.54	27.50	-	-	-	0.30
CD	NS	NS	NS	NS	-	-	-	0.66

T_1- 90 Days after fruit set, **T_2**- 100 Days after fruit set, **T_3** -110 Days after fruit set
LY- Light Yellow, **O**- orange, **GY**- Greenish yellow, **G**- Green

4.1.1.3 Fruit peel and pulp colour

Fruit peel and pulp colour are most important qualitative parameters and play major role in consumer preference. In both the cultivars Ratna and Mallika, peel colour was green on 90 DAFS and on maturity colour slowly changed to greenish yellow. Pulp colour was light yellow in 90 and 100 DAFS and on 110 DAFS it was orange in cv. Ratna. In cv. Mallika, pulp colour was light yellow in 90 and 110

DAFS, yellow colour in 120 DAFS and golden yellow in 140 DAFS as show in the Table 1a and 1b.

4.1.1.4 Fruit firmness

Firmness is one of the most important quality aspect of mango for consumers because it reflects the fruit's ripening stages (Jha *et al*., 2010). Significant difference were noticed in 3 stages of growth for fruit firmness which reduced upon ripening. In cv. Ratna at 110 DAFS the firmness was lowest (1.40 kg/cm^2) and highest in 90 DAFS (6.07 kg/cm^2) followed by 100 DAFS (2.87 kg/cm^2) as shown in the Table 1a.

In cv. Mallika, significant difference was observed in four growth stages for fruit firmness. There was drastic reduction during ripening and it was lowest during 140 DAFS (0.73 kg/cm^2) followed by 120 DAS (1.80 kg/cm^2), 110 DAFS (7.11 kg/cm^2) and 90 DAFS (9.04 kg/cm^2) as shown in the Table 1b

4.1.1.5 Specific gravity

In cv. Ratna specific gravity was found to be 1.03 to 1.18 and highest specific gravity was observed in 90 DAFS (1.18) followed by 100 DAFS (1.16) and lowest is in 110 DAFS (1.03) as shown in the Table 1a.

In cv. Mallika, highest specific gravity was recorded in 90 DAFS (1.18) followed by 110 (1.09) and 120 DAFS (1.08) and lowest was observed in 140 DAFS (1.05) as shown in the Table 1b.

4.1.1.6 Shoulder development

Shoulder development was observed based on IPGRI (2006). The mode of shoulder development was same in all the three and four stages of growth both in Ratna and Mallika respectively. In Ratna, it is raising and then rounded where as in Mallika it is slopping abruptly as shown in the Table 1a and 1b.

Table 1b. Physical parameters of mango cv. Mallika

Treatments	Specific gravity	Length (cm)	Diameter(cm)	Weight(g)	Peel colour	Pulp colour	Shoulder development	Fruit firmness (kg/cm^2)
T_1	1.18	18.45	32.68	859.4	G	LY	Sloping abruptly	9.04
T_2	1.09	14.28	30.12	833.68	GY	LY	Sloping abruptly	7.11
T_3	1.08	17.38	33.93	706.55	GY	Y	Sloping abruptly	1.80
T_4	1.05	14.80	28.03	623.95	GY	GY	Sloping abruptly	0.73
SE(d)	0.03	0.63	0.87	40.11	-	-	-	0.41
CD	0.08	1.39	1.92	88.37	-	-	-	0.90

T_1 - 90 Days after fruit set, **T_2** - 110 Days after fruit set, **T_3** -120 Days after fruit set, **T_4** - 140 Days after fruit set.

G- Green, **GY**- Greenish Yellow, **LY**-Light Yellow, **Y**- Yellow, **GY**-Golden Yellow

4.1.1.7 Stone characters

Stone characters includes, stone dimension, stone weight, stone colour and texture. The data concerned with these parameters is in Table 1c and 1d.

4.1.1.7.1 Dimensions (cm)

In cv. Ratna significant variations were observed in stone length and diameter for three stages of growth. Highest stone length was recorded in 90 DAFS (8.16 cm) followed by 100 (7.96 cm) and 110 DAFS (7.49 cm) and diameter was highest in 110 DAFS (10.68 cm) followed by 100 (10.26 cm) and 90 DAFS (9.84 cm) as shown in the Table lc.

In cv. Mallika, significant variation was observed in four stages of growth for stone length and diameter. Both the parameters were highest in 90 DAFS (14.84 cm, 25.16 cm) followed by 110 (14.18 cm, 16.84 cm), 120 (12.81 cm, 14.91 cm) and 140 DAFS (11.83 cm, 12.63 cm) respectively as shown in the Table 1d.

Table 1c. Stone character of mango cv. Ratna

Treatments	Length (cm)	Diameter (cm)	Weight (g)	Colour	Texture
T_1	8.16	9.84	34.87	Y	Coarse
T_2	7.96	10.26	41.23	Y	Coarse
T_3	7.49	10.68	44.51	DO	Coarse
SE(d)	0.219	0.184	0.880	-	-
CD	0.48	0.41	1.94	-	-

T_1- 90 Days after fruit set, **T_2**- 100 Days after fruit set, **T_3** -110 Days after fruit set

Y- Yellow, **DO**- Dark Orange

4.1.1.7.2 Stone weight (g)

In cv. Ratna significant difference was observed in three stages of growth for stone weight. Maximum stone weight was noticed in fruits harvested 110 DAFS (44.51 g) followed by 100 (41.23 g) and 90 DAFS (34.87 g) as shown in the Table 1c.

In cv. Mallika significant differences were noticed in four stages of growth and maximum fruit weight was observed in 140 DAFS (66.73 g) followed by 120 (65.25 g), where it was lowest at 90 DAFS (51.45 g) as shown in the Table 1d.

4.1.1.7.3 Colour

The Stone colour was described based on IPGRI descriptor. In cv. Ratna stone colour was yellow during 90 and 100 DAFS and dark orange during 110 DAFS and in Mallika, the colour was light yellow in all stages of maturity i.e. 90, 110, 120 and 140 DAFS as shown in the Table 1c and 1d.

4.1.1.7.4 Texture

Stone texture was described based on IPGRI descriptor and texture of stone was coarse is all stages of maturity like 90, 100 and 110 DAFS in cv. Ratna and in cv. Mallika, the texture was soft in all stages of maturity.

Table 1d. Stone character of mango cv. Mallika

Treatments	Length (cm)	Diameter (cm)	Weight (g)	Colour	Texture
T_1	14.84	25.16	51.45	LY	Soft
T_2	14.18	16.84	64.19	LY	Soft
T_3	12.81	14.91	65.25	LY	Soft
T_4	11.83	12.63	66.73	LY	Soft
SE(d)	0.848	1.082	2.139	-	-
CD	1.87	2.38	4.71	-	-

T_1 - 90 Days after fruit set, **T_2** - 110 Days after fruit set, **T_3** -120 Days after fruit set, **T_4** - 140 Days after fruit set

LY- Light Yellow

4.1.2 Biochemical parameters

Biochemical parameters such as acidity, ascorbic acid, TSS, sugars, total carotenoids, total phenols, beta-carotene, crude fiber and total chlorophyll were estimated to find out the relationship between maturity and quality.

4.1.2.1 Total soluble solids (TSS) (ºbrix)

In mango cultivar Ratna, the significant difference was noticed in total soluble solids (TSS) among three stages of fruit growth. TSS was less during initial stage of growth and it increased during maturation. The highest TSS (21.12 ºbrix) was recorded in 110 DAFS followed by 100 (16.98 ºbrix) and 90 DAFS (9.24 ºbrix) as shown in Table 2a.

In mango cv. Mallika significant difference was found in TSS among four stages of growth. The highest TSS was in 140 DAFS (20.18 ºbrix) followed by 120 (18.63 ºbrix) and 110 DAFS (10.88 ºbrix). The lowest TSS was found in 90 DAFS (4.08 ºbrix) as shown in Table 2b.

4.1.2.2 Tritratable acidity (%)

During three stages of growth of 90, 100 and 110 DAFS, significant differences were observed for acidity in mango cv. Ratna and it was highest during initial stages of maturity and decreased towards ripening. Lowest acidity (0.30 %) was

seen in 110 DAFS, followed by 100 (0.56 %) DAFS and 90 DAFS (1.19 %) as shown in the Table 2a.

Significant difference was observed in four stages of growth in mango cv. Mallika and lowest acidity (0.73 %) was noticed during 140 DAFS, followed by 120 (0.86 %), 110 (1.28 %) and 90 DAFS (1.56 %) as shown in the Table 2b.

4.1.2.3 Ascorbic acid (mg/100g)

Mango cultivars varied in ascorbic acid content in different growth stages. In the Initial days, the ascorbic acid content was more and as fruit matured it decreased. In mango cv. Ratna, highest ascorbic acid (69.05 mg/100g) was seen in 90 DAFS followed by 100 (68.88 mg/100g) and 110 DAFS (33.48 mg/100g) as shown in the Table 2a.

In mango cv. Mallika, highest ascorbic acid (80.38 mg/100g) was noted in 90 DAFS, followed by 110 (77.95 mg/100g), 120 (69.56 mg/100g) and 140 DAFS (61.21 mg/100g) as shown in the Table 2b.

4.1.2.4 Sugars (%)

Sugar levels differed significantly between three stages of fruit growth in the mango cultivar Ratna. It was less during the early stages of growth and gradually increased as the fruit matured. Highest total sugar, reducing sugar and non-reducing sugar (19.04 %, 2.73 % and 16.31 %) was detected in 110 DAFS, followed by 100 (13.15 %, 2.51 % and10.64 %) and 90 DAFS (5.34%, 1.69% and 3.66%) as shown in the Table 2a.

Sugar levels in the mango cultivar Mallika differed significantly at four stages of fruit development. It was low in the beginning stages of development and gradually increased as the fruit reached maturity. Maximum sugars i.e. total, reducing and non-reducing sugars were noted in 140 DAFS (17 %, 4.7 % and 12.30 %) followed by 120 (11.98 %, 2.63 % and 9.35 %), 110 (7.13 %, 1.73 % and 5.35 %) and 90 DAFS (3.4 %, 1.53 % and 1.87 %) respectively as shown in the Table 2b.

Table 2a. Biochemical parameters of mango cv. Ratna

Treatments	TSS (oBrix)	TA (%)	AA (mg/100g)	TS (%)	RS (%)	NRS (%)	TP (mg/100g)	Tc (mg/100g)	β-carotene (mg/100g)	CF (%)	TC (mg/100g)
T_1	9.24	1.19	68.88	5.34	1.69	3.66	74.00	65.88	0.05	3.23	0.01
T_2	16.98	0.56	69.05	13.15	2.51	10.64	55.20	27.93	0.11	2.83	0.01
T_3	21.12	0.30	33.48	19.04	2.73	16.31	32.06	14.65	0.88	2.59	0.01
SE(d)	0.64	0.09	2.17	0.91	0.16	0.86	4.08	12.90	0.06	0.183	0.01
CD	1.41	0.19	4.78	2.01	0.35	1.90	8.99	28.42	0.133	NS	NS

T_1 - 90 Days after fruit set, **T_2** - 100 Days after fruit set, **T_3** -110 Days after fruit set

TA-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**- Non-Reducing Sugar, **TP**-Total Phenol, **Tc**-Total carotenoid, **CF**-Crude Fiber, **TC**-Total Chlorophyll

Table 2b. Biochemical parameters of mango cv. Mallika

Treatments	TSS (ºBrix)	TA (%)	AA (mg/100g)	TS (%)	RS (%)	NRS (%)	TP (mg/100g)	Tc (mg/100g)	β-carotene (mg/100g)	CF (%)	TC (mg/100g)
T_1	4.08	1.56	80.38	3.4	1.53	1.87	57.5	56.26	0.02	3.85	0.03
T_2	10.88	1.28	77.95	7.13	1.73	5.35	26.25	43.76	0.02	3.55	0.02
T_3	18.63	0.86	69.56	11.98	2.63	9.35	50.63	29.28	0.03	3.44	0.02
T_4	20.18	0.73	61.21	17.00	4.7	12.30	47.5	7.563	0.03	3.44	0.01
SE(d)	0.92	0.29	3.06	0.77	0.36	0.85	7.50	3.56	0.001	0.51	0.003
CD	2.02	0.63	6.74	1.695	0.79	1.87	16.51	7.84	0.004	NS	0.01

T_1- 90 Days after fruit set, **T_2**- 110 Days after fruit set, **T_3** -120 Days after fruit set, **T_4** - 140 Days after fruit set
TA-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**- Non-Reducing Sugar, **TP**-Total Phenol, **Tc**-Total carotenoid, **CF**-Crude Fiber, **TC**-Total Chlorophyll

4.1.2.5 Total phenol (mg/100g)

Total phenol content differed significantly during 3 stages of growth viz., 90, 100 and 110 DAFS in cv. Ratna. Highest phenol content (74 mg/100g) was observed in 90 DAFS followed by 100 (55.20 mg/100g) and 110 DAFS (32.06 mg/100g) as shown in the Table 2a.

In cv. Mallika, highest phenol content (57.50 mg/100g) was noticed in 90 DAFS followed by 120 (50.63 mg/100g), 140 (47.50 mg/100g) and 110 DAFS (26.25 mg/100g) as shown in the Table 2b.

4.1.2.6 Total carotenoid (mg/100g)

Total carotenoid content varied significantly among three growth stages. In cv. Ratna highest carotenoid (65.88 mg/100g) was recorded in fruits harvested 90 DAFS followed by 100 (27.93 mg/100g) and 110 DAFS (14.65 mg/100g) as in the Table 2a.

Significant difference was observed in total carotenoid during four stages of growth in cv. Mallika and highest (56.26 mg/100g) was noted in fruits harvested 90 DAFS, followed by 110 (43.76 mg/100g), 120 (29.28mg/100g) and 140 DAFS (7.56 mg/100g) as in the Table 2b.

4.1.2.7 β-carotene (mg/100g)

Stages of harvest had significant effect on β-carotene content of mango fruits. The amount of β-carotene increased with the progress of maturity. In mango cv. Ratna, highest β-carotene (0.88 mg/100g) was spotted in fruits harvested 110 DAFS, followed by 100 (0.11 mg/100g) and 90 DAFS (0.05 mg/100g) as in the Table 2a.

During four stages of growth in mango cv. Mallika, highest β-carotene (0.03mg/100g) was recorded in 140 DAFS, followed by 120 (0.03 mg/100g), 110 (0.02 mg/100g) and 90 DAFS (0.02 mg/100g) as shown in the Table 2b.

4.1.2.8 Crude fiber

During three stages of growth, no significant difference was found in crude fiber content of mango cv. Ratna and it was higher in the early days and decreased as

the fruit matured. Highest crude fiber (3.23 %) was recorded 90 DAFS, followed by 100 (2.83 %) and 110 DAFS (2.59 %) as shown in the Table 2a.

In mango cv. Mallika, no significant difference was observed in crude fiber content in four growth stages. Highest crude fiber (3.85 %) was observed in 90 DAFS, followed by 110 (3.55 %), 120 (3.44 %) and 140 DAFS (3.42 %) as shown in the Table 2b.

4.1.2.9 Total chlorophyll

In mango cv. Ratna, chlorophyll content was steady (0.01 mg/100g) and there was no significant difference among three stages of growth i.e. 90, 100 and 110 DAFS as shown in the Table 2a.

During four growth stages in mango cv. Mallika, significant difference was observed in chlorophyll content which was highest in 90 DAFS (0.03 mg/100g), followed by 110 (0.02 mg/100g), 120 (0.02 mg/100g) and 140 DAFS (0.01 mg/100g) as shown in the Table 2b.

4.1.3 Heat units (HU)

In mango cv. Ratna the heat unit requirement for three growth stages of 90, 100 and 110 DAFS was 989.05, 1023.35 and 1107.75 respectively as shown in the Table 3a.

During four growth stages of mango cv. Mallika, the heat unit requirement was 957.65, 1185.70, 1314.70 and 1507.00 for 90, 110, 120 and 140 DAFS respectively as shown in the Table 3b

Table 3a. Heat unit requirement of mango cv. Ratna

Cultivar (Ratna)	
Treatments (days)	**Heat units**
90	989.05
100	1023.35
110	1107.75

Table 3b. Heat unit requirement of mango cv. Mallika

Cultivar (Mallika)	
Treatments (days)	**Heat units**
90	957.65
110	1185.70
120	1314.70
140	1507.00

4.1.4 Sensory evaluation

In mango cv. Ratna, total score was highest in 110 DAFS (60.2), followed by 100 DAFS (57.2). Lowest total score was recorded in 90 DAFS (49.6) as shown in the Table 4a. Mango cv. Ratna at 110 DAFS recorded the highest score in all the attributes (appearance, colour, taste, odour, overall acceptability etc.) and it is followed by 100 DAFS as shown in the Table 4a.

In mango cv. Mallika, total score was highest (65.00) in 140 DAFS, followed by 120 DAFS (59.50). Lowest total score was recorded in 90 DAFS (49.6) as shown in the Table 4b. Mango cv. Mallika, with growth stage of 140 DAFS were recorded the highest score in all the attributes (appearance, colour, taste, odour, overall acceptability etc.) and it was followed by 120 DAFS as shown in the Table 4b.

It is evident from the study that among the various maturity periods, when mango cv. Ratna was harvested at 110 DAFS with accumulation of 1107.75 HU and cv. Mallika at 140 DAFS with accumulation of 1507.00 HU was found to be the best stage of harvest for fruit quality and marketable life. Both varieties had maximum marketable fruit with better quality parameters when harvested at their respective maturity period. These stages of harvest had maximum total soluble solids and sugars and minimum acidity, ascorbic acid, total carotenoid, total phenol etc. as compared to rest of the maturity stages.

Table 4a. Sensory evaluation of mango cv. Ratna

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T_1	6.00 (1.10)	6.00 (1.20)	6.20 (1.40)	6.40 (1.40)	5.60 (1.30)	6.20 (1.10)	6.60 (1.40)	6.00 (1.00)	6.20	49.6
T_2	7.00 (2.20)	6.80 (2.40)	7.20 (1.90)	7.00 (2.10)	7.20 (2.10)	7.40 (2.20)	7.20 (2.10)	7.00 (2.00)	7.20	57.2
T_3	7.80 (2.70)	6.80 (2.40)	8.20 (2.70)	7.40 (2.50)	7.40 (2.60)	8.00 (2.70)	7.60 (2.50)	8.00 (3.00)	7.50	60.2
K	0.71	0.80	0.54	0.39	0.45	0.74	0.48	1.00		

T_1- 90 Days after fruit initiation, **T_2**- 100 Days after fruit initiation, **T_3** -110 Days after fruit initiation. The values in parenthesis represents mean rank value.

Table 4b. Sensory evaluation of mango cv. Mallika

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T_1	7.00 (1.88)	6.75 (1.88)	6.00 (1.12)	6.00 (1.25)	6.00 (1.25)	5.75 (1.00)	6.25 (1.12)	6.00 (1.12)	6.22	49.75
T_2	7.00 (1.88)	6.25 (1.25)	7.00 (2.25)	6.75 (2.38)	6.50 (1.88)	7.00 (2.12)	7.00 (2.12)	6.75 (2.00)	6.78	54.25
T_3	7.25 (2.25)	7.50 (3.25)	7.25 (2.88)	7.25 (2.88)	7.25 (3.00)	7.75 (3.00)	7.75 (3.25)	7.50 (3.00)	7.44	59.50
T_4	8.25 (4.00)	7.75 (3.62)	8.00 (3.75)	7.75 (3.50)	8.50 (3.88)	8.50 (3.88)	8.00 (3.50)	8.25 (3.88)	8.13	65.00
K	0.92	0.89	0.81	0.62	0.91	0.95	0.87	0.93		

T_1- 90 Days after fruit initiation, **T_2**- 110 Days after fruit initiation, **T_3** -120 Days after fruit initiation, **T_4** - 140 Days after fruit initiation
The values in parenthesis represents mean rank value.

4.2 STUDIES ON THE EFFECT OF MATURITY ON RIPENING OF CV. RATNA

Harvested fruits were washed, cleaned and subjected to the pre-treatments and packed in CFB boxes and stored under ambient condition. Results on both physiological and biochemical parameters were recorded in 3 days intervals.

4.2.1 Physiological parameters

4.2.1.1 Physiological loss in weight (PLW)

Physiological loss in weight (PLW) is one of the indicators of the quality of fruits during storage. With respect to time and storage conditions, every fresh commodity loses weight after harvest. In this experiment, PLW was recorded in 3 and 6 days interval for matured and ten days prior to fruit maturity under ambient condition. Significant difference was observed among the treatments in mango cv. Ratna as given in the Table 5a, 5b, 6a and 6b.

Fruits that were ozonized and sprayed with ethrel (T_5) showed lowest PLW (2.16 %) and the highest PLW (3.10 %) was when fruits were dipped in hot water and sprayed with ethrel (T_3) after 3 days of storage of matured fruits as shown in the Table 6a. After 6 days of storage of matured fruit, PLW was lowest (5.36 %) when fruits were sprayed with ethrel (T_2) and highest PLW (6.79 %) was recorded when fruits were sanitized and sprayed with ethrel (T_4) as shown in the Table 6b.

Fruits without any treatment i.e. control (T_1) showed lowest PLW (2.03 %) and highest PLW (3.30 %) was seen when fruits were sanitized and sprayed with ethrel after 3 days interval of pre-matured fruits as shown in the Table 5a. Even after 6 days of storage of pre- matured fruits, PLW was lowest (6.36 %) in control and highest (7.41 %) when fruits were sanitized and sprayed with ethrel as shown in the Table 5b.

4.2.1.2 Ethylene evolution (ppm)

Ethylene evolution varied significantly between five treatments in both matured and pre-matured with 3 days intervals. After 3 days of storage of matured fruits, highest ethylene evolution (2.57 ppm) was recorded, when fruits were ozonized

and sprayed with ethrel and lowest ethylene evolution (0.40 ppm) was seen when fruits were dipped in hot water and sprayed with ethrel as shown in the Table 6a. Ethylene evolution was highest (2.70 ppm) when fruits were ozonized and sprayed with ethrel and lowest (0.63 ppm) when fruits were dipped in hot water and sprayed with ethrel even after 6 days of storage as shown in the Table 6b.

Ethylene evolution was highest (1.10 ppm) when fruits were sprayed with ethrel and lowest (0.33 ppm) in fruits without any treatment in 3 days storage of pre-matured fruits as shown in the table 5a. Fruits when sprayed with ethrel have highest ethylene evolution (22.87 ppm) and lowest (0.77 ppm) when fruits were dipped in hot water and sprayed with ethrel as shown in the Table 5b.

4.2.2 Biochemical parameters

4.2.2.1 Total Soluble Solids (TSS) (ºbrix)

The treatment showed significant difference in total soluble solids (TSS) at 3 and 6 days after storage in both mature and pre-matured fruits. In mature fruits, highest TSS (13.33 ºbrix) was reported when fruits were ozonized and sprayed with ethrel and lowest (8.53 ºbrix) when fruits were sprayed with ethrel after 3 days of storage as shown in the Table 6a. After 6 days of storage, highest TSS (22.80 ºbrix) was reported when fruits were dipped in hot water and sprayed with ethrel and lowest TSS (17.43 ºbrix) was seen in fruits without any treatment as shown in the Table 6b.

In pre- mature fruits TSS was highest (12.50 ºbrix) when fruits were ozonized and sprayed with ethrel and lowest (8.23 ºbrix) in fruits without any treatment after 3 days of storage as shown in the Table 5a. After 6 days of storage, highest TSS (17.20 ºbrix) was reported when fruits were dipped in hot water and sprayed with ethrel and lowest TSS (14.57 ºbrix) when fruits were ozonized and sprayed with ethrel as shown in the Table 5b.

Table 5a. Effect of pre- treatments on physiological and biochemical parameters in mango cv. Ratna after 3 days of storage (90 DAFS)

Treatments	PLW (%)	TSS (^{0}Brix)	TA (%)	TS (%)	RS (%)	NRS (%)	AA (mg/100g)	Ethylene evolution (%)
T_1	2.03	8.23	2.33	3.15	1.67	1.48	77.15	0.33
T_2	2.53	11.37	2.39	3.37	1.69	1.68	75.19	1.10
T_3	2.68	8.37	1.19	3.33	1.67	1.65	76.26	0.73
T_4	3.30	12.37	1.02	8.54	1.80	6.74	58.82	0.70
T_5	3.15	12.50	0.62	10.35	2.47	7.88	51.11	0.73
SE(d)	0.09	0.16	0.04	0.05	0.03	0.07	0.34	0.10
CD	0.21	0.35	0.10	0.12	0.08	0.15	0.77	0.23

T_1- Control, **T_2**- Ethrel spray, **T_3**- Hot water dip + ethrel spray, **T_4**- Sanitization + ethrel spray
T_5- Ozonization + ethrel spray
PLW- Physiological Loss in Weight, **TA**-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**-Non- Reducing Sugar, **TSS**- Total Soluble Solids.

Table 5b. Effect of pre- treatments on physiological and biochemical parameters in mango cv. Ratna after 6 days of storage (90 DAFS)

Treatments	PLW (%)	TSS (^{0}Brix)	TA (%)	TS (%)	RS (%)	NRS (%)	AA (mg/100g)	Ethylene evolution (%)
T_1	6.36	16.40	0.88	14.52	1.49	13.03	72.83	0.83
T_2	6.57	16.83	0.27	10.43	1.59	8.83	71.13	22.87
T_3	6.50	17.20	0.89	13.85	2.10	11.75	49.73	0.77
T_4	7.41	16.50	0.42	14.63	3.12	11.81	53.51	1.50
T_5	6.66	14.57	0.44	14.42	1.80	12.62	81.17	10.27
SE(d)	0.03	0.19	0.03	0.05	0.04	0.06	12.51	0.18
CD	0.06	0.43	0.06	0.12	0.10	0.13	NS	0.41

T_1- Control, **T_2**- Ethrel spray, **T_3**- Hot water dip + ethrel spray, **T_4**- Sanitization + ethrel spray
T_5- Ozonization + ethrel spray
PLW- Physiological Loss in Weight, **TA**-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**- Non-Reducing Sugar, **TSS**- Total Soluble Solids.

4.2.2.2 Tritratable acidity (%)

The treatment had a significant effect on acidity at 3 and 6 days after storage in both mature and pre-mature fruit. In mature fruit, lowest acidity (1.53 %) was noted when fruit were dipped in hot water and sprayed with ethrel after 3 days of storage as shown in the table 6a. Lowest acidity was reported in fruits without any treatment (0.13 %) followed by fruits treated with ozone and sprayed with ethrel (0.24 %) after 6 days of storage as shown in the Table 6b.

Acidity was lowest (0.62 %) when fruits were ozonized and sprayed with ethrel in pre-mature fruit after 3 days of storage as shown in the Table 6a. After 6 days of storage, lowest acidity (0.27 %) was reported when fruits were sprayed with ethrel in pre-mature fruits as shown in the Table 6b.

4.2.2.3 Sugars (%)

In matured fruits, total sugar, reducing and non- reducing sugar were maximum (10.55 %, 2.17 % and 8.38 %) when fruits were ozonized and sprayed with ethrel and minimum (3.57 %, 2.16 % and 1.39) when fruits were dipped in hot water and sprayed with ethrel after 3 days of storage as shown in the Table 6a. After 6 days of storage, maximum (15.47 %, 2.43 % and 13.05 %) total sugar, reducing and non-reducing sugar were found when fruit were ozonized and sprayed with ethrel and minimum (11.77 %, 2.69 % and 9.08 %) when fruits were sanitized and sprayed with ethrel as shown in the Table 6b.

In pre-matured fruits, maximum total, reducing and non- reducing sugars (10.35 %, 2.47 % and 7.88 %)were recorded when fruits were ozonized and sprayed with ethrel and minimum (3.33 %, 1.67 % and 1.65 %) when fruits were dipped in hot water and sprayed with ethrel after 3 days of storage as shown in the Table 6a. After 6 days of storage, maximum total and reducing sugars (14.63 % and 3.12 %) were found when fruits were sanitized and sprayed with ethrel and non- reducing sugar (12.62 %) was maximum with ozonized and sprayed with ethrel and minimum (13.85 %, 2.10 % and 11.75 %) when fruits sprayed with ethrel as shown in the Table 6b.

Table 6a. Effect of pre- treatments on physiological and biochemical parameter of matured fruit after 3 days of storage (100 DAFS)

Treatments	PLW (%)	TSS (^{o}brix)	TA (%)	TS (%)	RS (%)	NRS (%)	AA (mg/100g)	Ethylene evolution (%)
T_1	2.18	11.50	1.92	9.11	2.18	6.93	75.89	2.13
T_2	2.74	8.53	2.02	8.59	2.04	6.55	66.07	2.30
T_3	3.10	10.47	1.53	3.57	2.16	1.39	74.35	0.40
T_4	2.64	10.40	2.04	2.14	1.03	1.11	77.14	0.57
T_5	2.16	13.33	1.42	10.55	2.17	8.38	72.07	2.57
SE(d)	0.04	0.16	0.04	0.07	0.03	0.07	0.39	0.10
CD	0.09	0.36	0.10	0.16	0.07	0.16	0.87	0.22

T_1- Control, **T_2**- Ethrel spray, **T_3**- Hot water dip + ethrel spray, **T_4**- Sanitization + ethrel spray, **T_5**- Ozonization + ethrel spray
PLW- Physiological Loss in Weight, **TA**-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**- Non-Reducing Sugar, **TSS**- Total Soluble Solids.

Table 6b. Effect of pre- treatments on physiological and biochemical parameter of matured fruit after 6 days of storage (100 DAFS)

Treatments	PLW (%)	TSS (^{0}brix)	TA (%)	TS (%)	RS (%)	NRS (%)	AA (mg/100g)	Ethylene evolution (%)
T_1	5.57	17.43	0.13	13.88	3.14	10.74	82.02	0.67
T_2	5.36	19.07	0.26	14.70	4.95	9.75	50.85	2.53
T_3	5.64	22.80	0.35	15.41	2.51	12.90	67.73	0.63
T_4	6.79	19.40	0.35	11.77	2.69	9.08	76.07	0.73
T_5	5.75	17.50	0.24	15.47	2.43	13.05	57.56	2.70
SE(d)	0.08	0.26	0.02	0.20	0.10	0.12	0.24	0.12
CD	0.18	0.59	0.05	0.44	0.23	0.28	0.54	0.27

T_1- Control, **T_2**- Ethrel spray, **T_3**- Hot water dip + ethrel spray, **T_4**- Sanitization + ethrel spray, **T_5**- Ozonization + ethrel spray
PLW- Physiological Loss in Weight, **TA**-Titratable Acidity, **AA**-Ascorbic Acidity, **TS**-Total Sugar, **RS**-Reducing Sugar, **NRS**- Non-Reducing Sugar, **TSS**- Total Soluble Solids.

4.2.2.4 Ascorbic acid (mg/100g)

In matured fruits ascorbic acid content varied significantly among treatments and was highest (77.14 mg/100g) when fruits were sanitized and sprayed with ethrel and lowest (66.07 mg/100g) with fruits sprayed with ethrel in 3 days after storage as shown in the Table 6a. After 6 days of storage, maximum (82.02 mg/100g) ascorbic acid was recorded when fruits were under control i.e. without any treatment and minimum (50.85 mg/100g) was noted when fruits were sprayed with ethrel as shown in the Table 6b.

In pre- matured fruits, maximum (77.15 mg/100g) ascorbic acid was recorded when fruits were under control i.e. without any treatment and minimum (51.11 mg/100g) was noted when fruits were ozonized and sprayed with ethrel in 3 days of storage as shown in the Table 5a. After 6 days of storage, maximum (81.17 mg/100g) ascorbic acid was noted when fruits were ozonized and sprayed with ethrel and minimum (49.73 mg/100g) ascorbic acid was found when fruits were dipped in hot water and sprayed with ethrel as shown in the Table 5b.

4.2.3 Sensory evaluation

In mature fruits, after 3 days of storage, the total score was highest when fruits were sanitized and sprayed with ethrel (56.40) followed by ozonized and sprayed with ethrel (T_5) (53.80). The lowest (49.40) total score was recorded in control fruits (T_1). Sanitized fruits (T_4) scored the highest score in half of the total attributes evaluated (colour, flavour, odour, taste and overall acceptability). Ozonized fruits (T_5) were recorded highest score in appearance, texture and overall acceptability. After taste and colour was highest in ethrel sprayed (T_2) fruit as shown in the Table 7a.

After 6 days of storage in mature fruits, the total score was highest when fruits were ozonized and sprayed with ethrel (68.20) followed by sanitized and sprayed with ethrel (67.80). The lowest (60.80) total score was recorded in control fruits (T_1). Ozonized fruits (T_5) scored the highest score in half of the attributes evaluated (appearance, colour, flavour, texture, odour and overall acceptability). Sanitized fruits

recorded highest score in after taste. Colour and taste scored highest in ethrel sprayed and hot water dipped (T_3) fruits respectively as shown in the Table 7b.

In pre- mature fruits, after 3 days of storage, the total score was highest (52.80) when fruits were ozonized and sprayed with ethrel followed by sanitized and sprayed with ethrel (50.20). The lowest (42.60) total score was recorded in control fruits (T_1). Ozonized fruits (T_5) scored the highest score in half of the attributes evaluated (appearance, texture, colour, odour, taste and overall acceptability). Sanitized fruits recorded highest score in after taste and flavour as shown in the Table 8a.

After 6 days of storage in pre- mature fruits, the total score was highest when fruits were sanitized and sprayed with ethrel (64.40) followed by ethrel sprayed fruit (62.80). The lowest (60.40) total score was recorded in control fruits (T_1). Sanitized fruits (T_4) scored the highest score in half of the total attributes evaluated (appearance, colour, odour, taste, after taste and overall acceptability). Ozonized fruits were recorded highest score in texture. The control scored highest in flavour as shown in the Table 8b.

Table 7a. Effect of pre-treatments on sensory qualities of fruits in 90 DAFS after 3 days of storage

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T_1	5.40 (1.60)	5.40 (1.30)	5.40 (1.80)	4.60 (1.50)	5.20 (1.70)	5.80 (1.50)	5.40 (1.70)	5.40 (1.70)	5.33	42.60
T_2	6.40 (3.40)	6.60 (3.70)	6.00 (2.80)	5.40 (3.10)	6.00 (3.40)	6.60 (3.10)	6.00 (3.00)	6.20 (2.90)	6.15	49.20
T_3	5.80 (2.30)	6.40 (3.20)	6.20 (3.10)	5.20 (2.60)	6.00 (3.20)	6.40 (2.60)	5.80 (2.60)	6.20 (2.90)	6.00	48.00
T_4	6.40 (3.50)	6.20 (2.80)	6.60 (4.00)	5.60 (3.50)	5.60 (2.40)	7.00 (3.90)	6.60 (4.00)	6.20 (2.90)	6.28	50.20
T_5	6.80 (4.20)	6.80 (4.00)	6.20 (3.30)	6.00 (4.30)	6.60 (4.30)	7.00 (3.90)	6.40 (3.70)	7.00 (4.60)	6.60	52.80
K	0.56	0.54	0.32	0.58	0.56	0.50	0.40	0.74		

The values in parenthesis represents mean rank value.

Table 7b. Effect of pre-treatments on sensory qualities of fruits in 90 DAFS after 6 days of storage

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T1	7.20 (2.10)	7.40 (1.90)	8.00 (3.50)	7.40 (2.10)	7.40 (2.70)	7.60 (2.40)	7.60 (2.60)	7.80 (2.60)	7.55	60.40
T2	8.00 (3.30)	7.80 (2.80)	7.80 (3.00)	8.00 (3.60)	7.80 (3.70)	7.80 (2.80)	7.60 (2.50)	8.00 (3.10)	7.85	62.80
T3	7.40 (2.90)	7.80 (2.80)	7.60 (2.50)	7.80 (3.10)	7.20 (2.20)	7.80 (2.80)	7.60 (2.50)	7.80 (2.60)	7.63	61.00
T4	8.40 (4.00)	8.20 (3.70)	7.80 (3.00)	7.60 (2.60)	7.60 (3.20)	8.40 (4.20)	8.20 (3.90)	8.20 (3.60)	8.05	64.40
T5	7.20 (2.70)	8.20 (3.80)	7.80 (3.00)	8.00 (3.60)	7.60 (3.20)	7.80 (2.80)	8.00 (3.50)	8.00 (3.10)	7.83	62.60
K	0.31	0.40	0.08	0.38	0.22	0.32	0.26	0.18		

The values in parenthesis represents mean rank value.

Table 8a. Effect of pre-treatments on sensory qualities of fruits in 100 DAFS after 3 days of storage

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T1	6.20 (2.30)	6.00 (2.30)	6.20 (2.40)	6.40 (3.10)	5.80 (1.90)	6.00 (2.00)	6.20 (2.70)	6.60 (2.70)	6.18	49.40
T2	6.40 (2.80)	6.80 (3.50)	6.20 (2.20)	5.80 (2.10)	6.80 (3.00)	6.40 (2.30)	6.60 (3.30)	6.40 (2.20)	6.43	51.40
T3	6.40 (2.70)	6.60 (3.00)	6.60 (3.20)	6.40 (3.20)	6.80 (3.00)	6.80 (3.10)	6.40 (2.80)	6.60 (2.50)	6.58	52.60
T4	6.80 (3.50)	6.80 (3.50)	7.60 (4.20)	6.40 (3.10)	7.20 (3.90)	8.00 (4.70)	6.40 (3.10)	7.20 (3.80)	7.05	56.40
T5	7.00 (3.70)	6.40 (2.70)	6.60 (3.00)	6.60 (3.50)	6.80 (3.20)	6.80 (2.90)	6.40 (3.10)	7.20 (3.80)	6.73	53.80
K	0.20	0.16	0.29	0.15	0.23	0.59	0.03	0.30		

The values in parenthesis represents mean rank value.

Table 8b. Effect of pre-treatments on sensory qualities of fruits in mature 6 days of storage

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Mean	Total score
T1	7.00 (1.70)	7.40 (1.90)	7.40 (1.70)	7.80 (2.40)	7.60 (1.80)	7.80 (1.90)	7.80 (2.40)	8.00 (1.80)	7.60	60.80
T2	7.60 (2.30)	8.40 (3.70)	8.00 (2.90)	7.80 (2.60)	7.80 (2.50)	8.20 (2.70)	7.80 (2.30)	8.20 (2.30)	7.98	63.80
T3	8.20 (3.40)	7.80 (2.40)	7.80 (2.40)	7.80 (2.70)	8.00 (2.50)	8.80 (3.90)	8.40 (3.50)	8.60 (3.30)	8.18	65.40
T4	8.40 (3.70)	8.40 (3.70)	8.20 (3.20)	8.20 (3.40)	8.60 (3.90)	8.60 (3.50)	8.40 (3.60)	8.60 (3.30)	8.48	67.80
T5	8.40 (3.90)	8.40 (3.30)	9.00 (4.80)	8.40 (3.90)	8.80 (4.30)	8.40 (3.00)	8.20 (3.20)	9.00 (4.30)	8.53	68.20
K	0.43	0.37	0.71	0.21	0.53	0.38	0.31	0.51		

The values in parenthesis represents mean rank value.

Mangoes harvested 10 and 20 days prior to ripe mature stage can be stored for 6 days under ambient conditions after giving pre-treatment consisting of Ozonization and ethrel spray

DISCUSSION

5. DISCUSSION

5.1 STUDIES ON GROWTH AND MATURATION OF SELECTED MANGO CULTIVARS

5.1.1 Physical parameters

5.1.1.1 Fruit dimensions

In mango varieties, fruit dimension varied during successive growth and development phases. In mango cv. Ratna fruit length varied from 10.73 cm at 90DAFS and 10.44 cm at 110 DAFS and diameter varied from 26.1 cm at 110 DAFS to 25.24 cm. In mango cv. Mallika significant differences were observed in fruit dimensions and length varied from 18.45 cm at 90 DAFS and 14.28 cm at 140 DAFS whereas diameter varied from 33.93 cm at 90 DAFS to 28.03 cm at 140 DAFS. Mannan *et al*. (2003) reported that in mango fruit length ranged from 6.33cm to 15.53cm in different cultivars. According to Bora *et al*. (2017), in mango cv. Mallika highest length recorded was 12.55cm similar to present study. The length was highest at 90 DAFS and reduced during the next stage which means that after a particular growth period there will be no increase in fruit length whereas the diameter was found to increase till harvest. The differences in fruit length and perimeter may be due to their genetic nature.

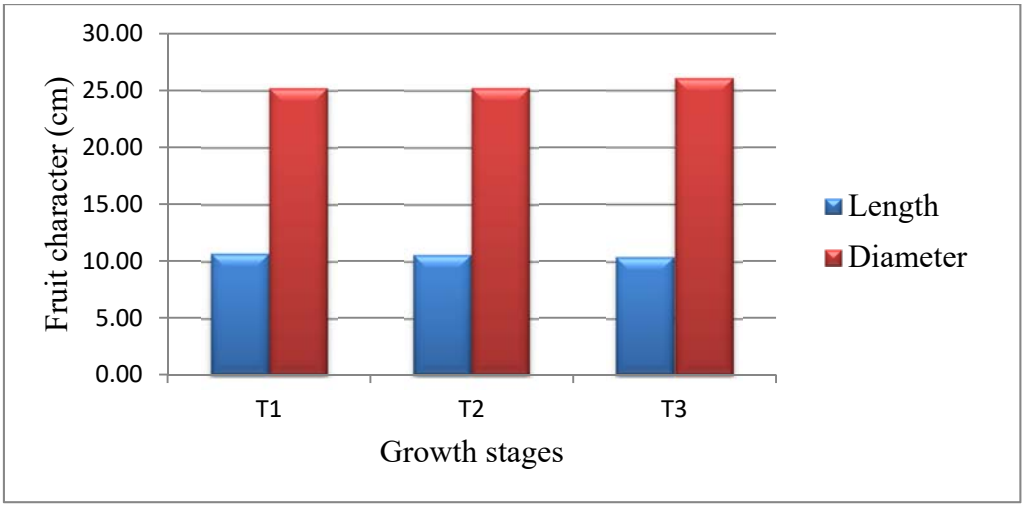


Fig 1a. Effect of stages of development on length and diameter of mango cv. Ratna

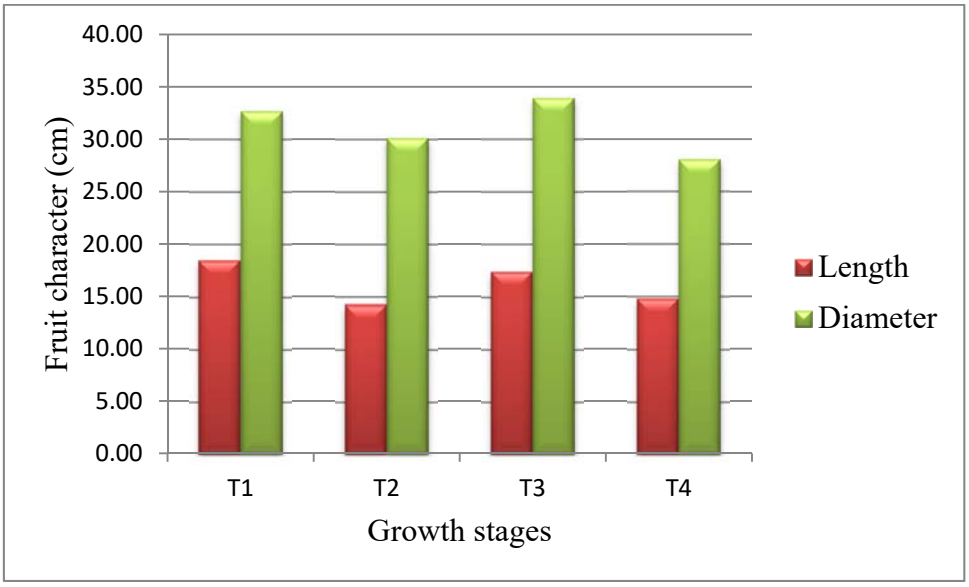


Fig 1b. Effect of stages of development on length and diameter of mango cv. Mallika

5.1.1.2 Fruit weight

In mango cv. Ratna fruit weight ranged from 358.8 g at 110 DAFS and 383.94 g at 100 DAFS and it conforms to the report of Anila and Radha (2005) where the weight was 398.01 g in cv. Ratna. The fruit weight of cv. Mallika ranged from 623.95 at 140 DAFS and 859.4 g at 120 DAFS , similar to the finding of Bora *et al*., (2017) where the weight of Mallika was 340.17 g. The difference in fruit weight could be due to varietal or genetic characteristics, environmental factors and management practice.

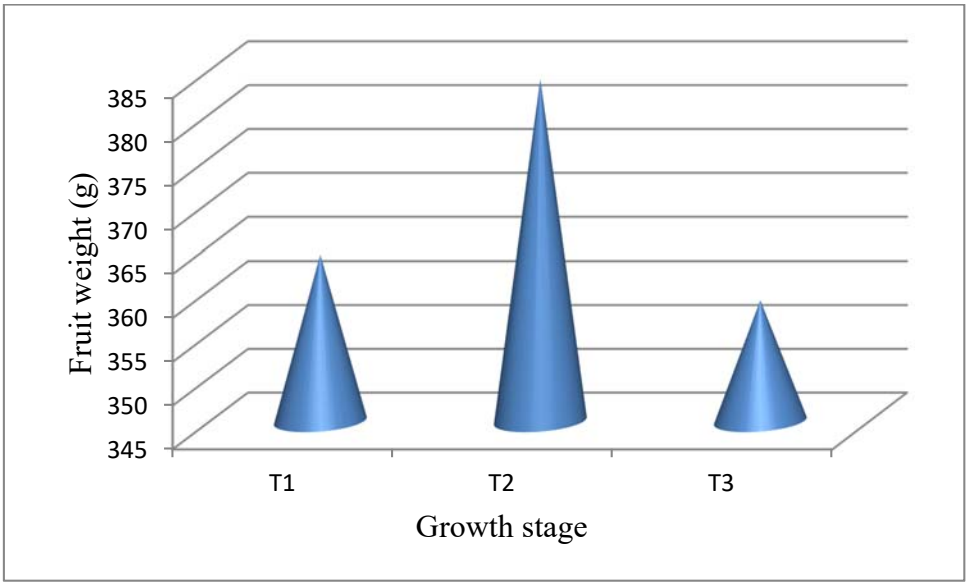


Fig 2a. Effect of stages of development on weight of mango cv. Ratna

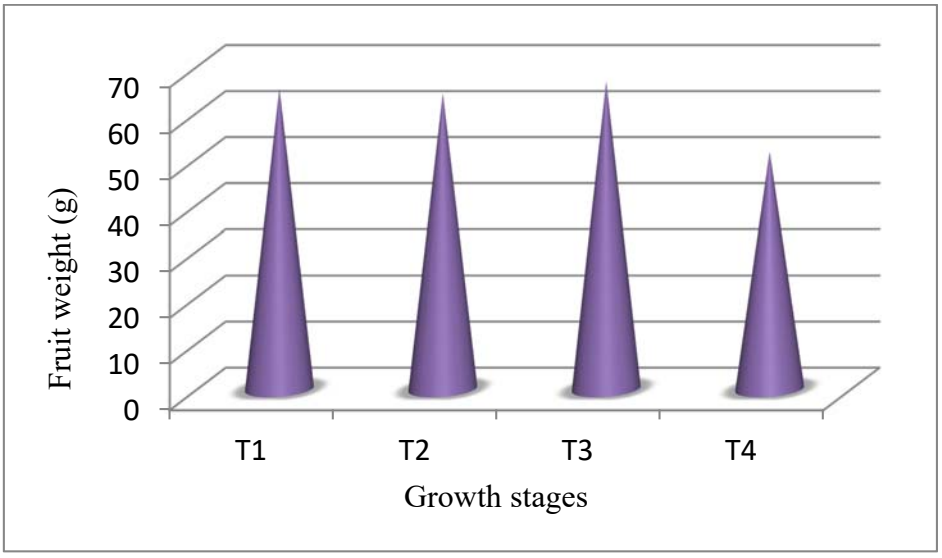


Fig 2b. Effect of stages of development on weight in mango cv. Mallika

5.1.1.3 Specific gravity

Specific gravity is the key indicator for quality assessment of fruits and is always related to the internal quality in fruits such as internal breakdown, water distribution, decay and insect infestation. In cv. Ratna, specific gravity of fully matured fruit was 1.03, similar to the observations made by Anila and Radha (2005). In cv. Mallika, specific gravity varied significantly during maturity and it ranges from 1.18-1.05 and in fully matured stage specific gravity was 1.05 and it was similar with study conducted by Hada and Singh (2018).

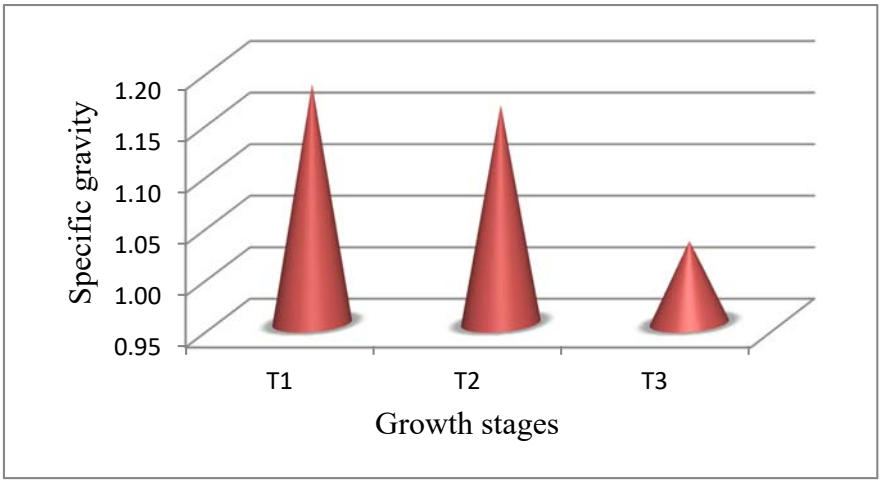


Fig 3a. Effect of stages of development on specific gravity in mango cv. Ratna

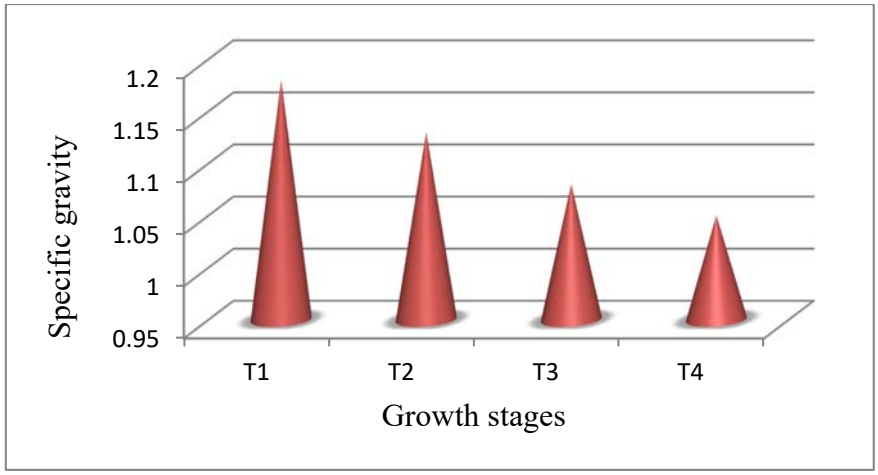


Fig 3b. Effect of stages of development on specific gravity mango in cv. Mallika

5.1.1.4 Fruit peel and pulp colour

Consumers' perception of fruit quality is influenced by visual attributes such as the colour of the peel and the colour of the fruit pulp (Cissé *et al*., 2015). In mango varieties, peel and pulp colour changes as fruit matures towards ripening. In cv. Ratna peel colour changed from green to greenish yellow and pulp colour changed from light yellow to orange. This result was in agreement with the results of Anila and Radha (2005). In mango cv. Mallika the peel colour changed from green to greenish yellow and pulp colour from light yellow to golden yellow. The degradation of chlorophyll and the synthesis of carotenoids are primarily responsible for the colour changes in mango (Tadmor *et al*., 2010). Consumers purchase fruits based on their visibility, a product with better visual quality will be regarded as superior to others. The development of yellow colour in mango is probably due to chlorophyll breakdown and carotenoid synthesis.

5.1.1.5 Fruit firmness/texture

Fruit firmness generally decreases as fruits mature and significantly reduces as they ripen. Regardless of ripening temperatures, the softening of fruit pulp occurred as the ripening period progressed (Gill *et al*., 2017). Sethy and Kumar (2018) has reported that depolymerization or shortening of chain length of pectin substances occurs during fruit ripening, accompanied by an increase in pectin esterase and polygalactronase activities resulting in soft texture of fruits.

In this study, it was seen that there is significant difference in firmness of fruits in both the cultivars of mango as the days to maturity advanced. In cv. Ratna at 110 DAFS the firmness was lowest (1.40 kg/cm^2) and highest at 90 DAFS (6.07 kg/cm^2). In cv. Mallika, it was lowest during 140 DAFS (0.73 kg/cm^2) followed by 120 DAS (1.80 kg/cm^2), 110 DAFS (7.11 kg/cm^2) and 90 DAFS (9.04 kg/cm^2). Mango firmness and sensory characteristics have been reported to vary with cultivar (Jarimopas and Kitthawee, 2007). The firmness of the pulp during ripening can be considered as a positive attribute with regard to the consumer acceptance.

Enzymatic degradation of cell walls caused by an increase in the activity of polygalacturonase and cellulase during ripening (Zoghbi, 1994) results in a softening or decline of firmness (Johnston *et al*., 2002). According to Shattir *et al.* (2010), the decrease in flesh firmness is due to changes in cell wall, which are linked to the action of hydrolytic enzymes on the cell wall.

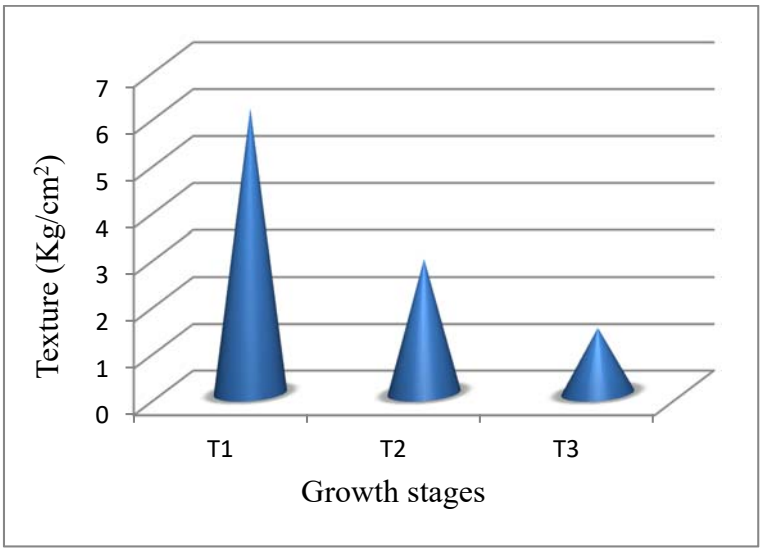


Fig 4a. Effect of stages of development on texture in mango cv. Ratna

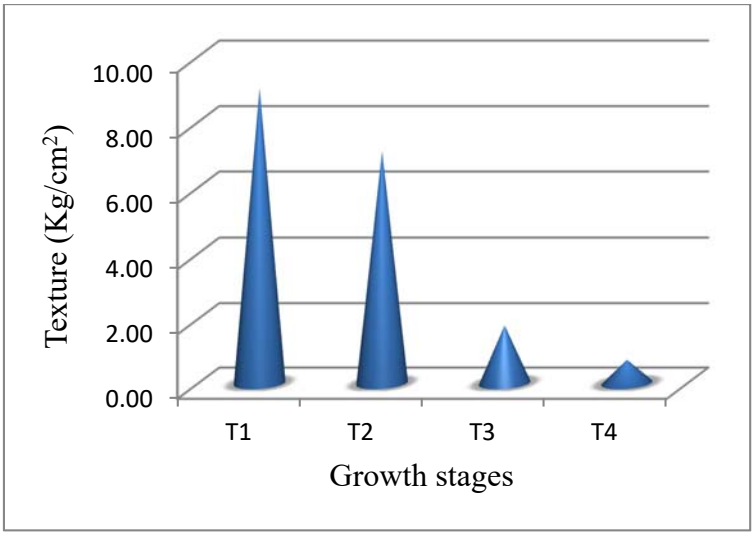


Fig 4b. Effect of stages of development on texture in mango cv. Mallika

5.1.1.6 Shoulder development

The mode of shoulder development is specific to each variety as given in IPGRI descriptor and it was similar in all the three and four stages of growth in both cvs. Ratna and Mallika respectively. In Ratna it is raising and then rounded similar result was observed by Anila and Radha in 2005 and in cv. Mallika it is slopping abruptly.

5.1.1.7 Stone characters

The size of the mango stone determines pulp quantity leading to the consumer acceptability. Significant variation was observed among the growth stages in both the cultivars. In mango cv. Ratna stone length ranged from 8.16 cm at 90 DAFS and 7.49 cm at 110 DAFS and diameter from 10.68 to 9.84 cm. Indian *et al*. (2018) reported that the length of stone in cv. Ratna was 6.32cm which was similar with the present study.

In mango cv. Mallika, the stone length and diameter ranged from 11.83 cm to 14.84 cm and 12.63 cm to 25.16 cm respectively. According to Hada and Singh (2017), maximum stone length (12.49 cm) and breadth (4.25 cm) was observed in Mallika, this result conforms to the present result. The differences in stone characteristics could be due to changes in environmental interaction and genetic composition.

Sarkar *et al*. (2001) found that seed weight varied within cultivars due to differences in fruit weight and size. Highly significant variation was recorded in different stages of maturity in both the cultivars. In cv. Ratna, stone weight varied from 34.87 g at 90 DAFS and 44.51 g at 110 DAFS as shown in Fig. 6a. and this result was similar with the result obtained by Indian *et al*. (2018) where he reported stone weight of cv. Ratna 27.73 g.

In cv. Mallika, stone weight ranged from 51.45g at 90 DAFS and 66.73g at 140 DAFS as shown in the Fig. 6b. and the current findings on stone weight are also conforms with the previous findings of Hada and Singh (2017), who observed that stone weight (31.40 g) in cv. Mallika. Soil, environmental conditions, and genetic influence may all play a role in stone weight variation.

Colour and texture of stone was described based on IPGRI descriptors. Both the parameters differed in both the cultivars and in cv. Ratna, colour and texture was yellow to dark orange and coarse respectively and cv. Mallika colour was light yellow and texture was soft.

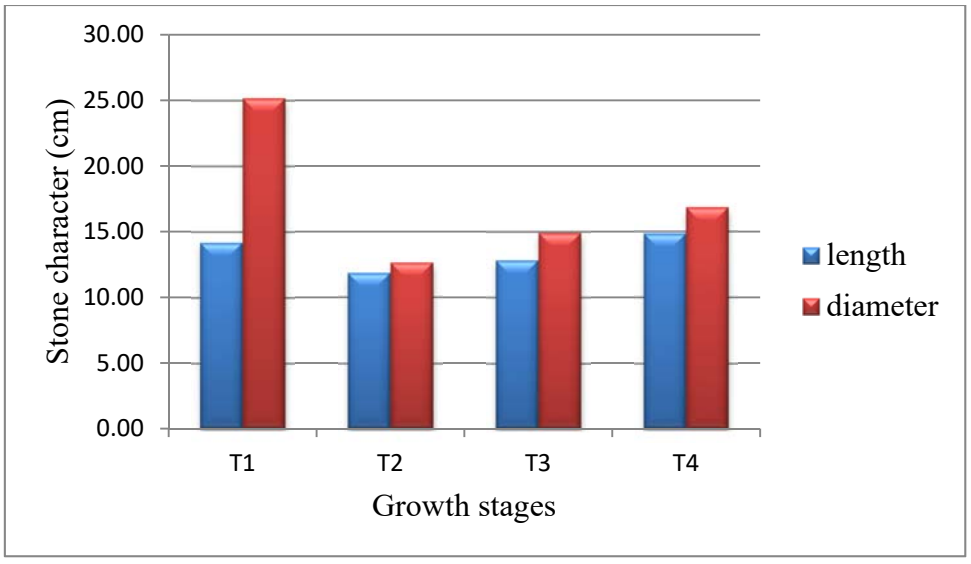


Fig 5a. Effect of stages of development on stone length and diameter in mango cv. Mallika

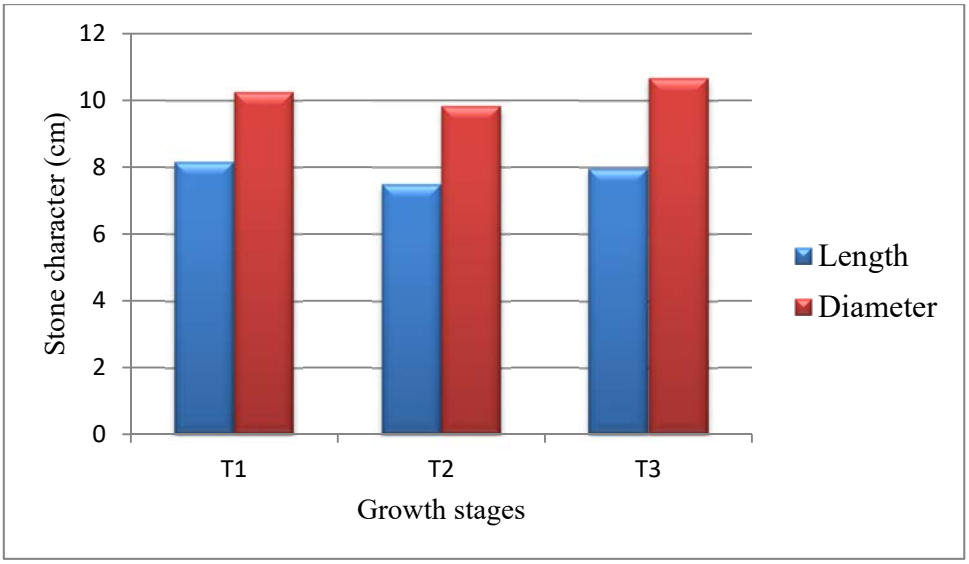


Fig 5b. Effect of stages of development on stone length and diameter in mango cv. Ratna

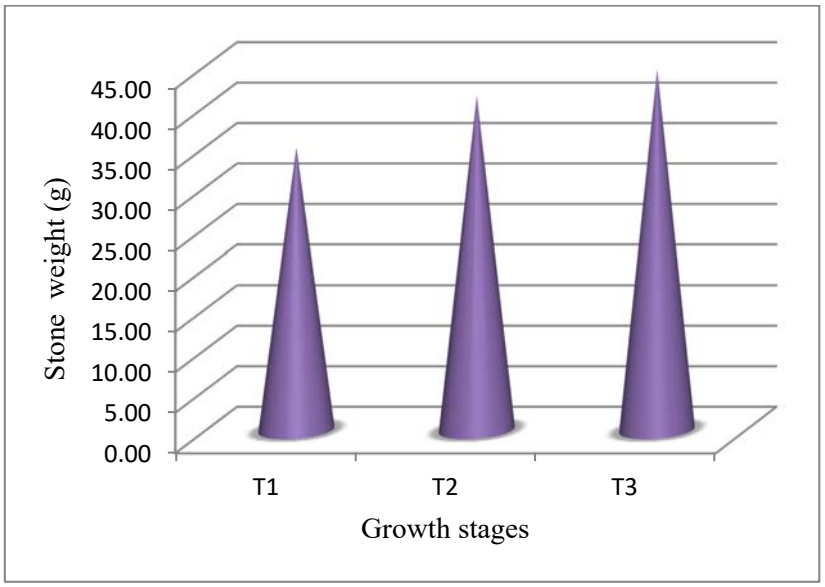


Fig 6a. Effect of stages of development on stone weight in mango cv. Ratna

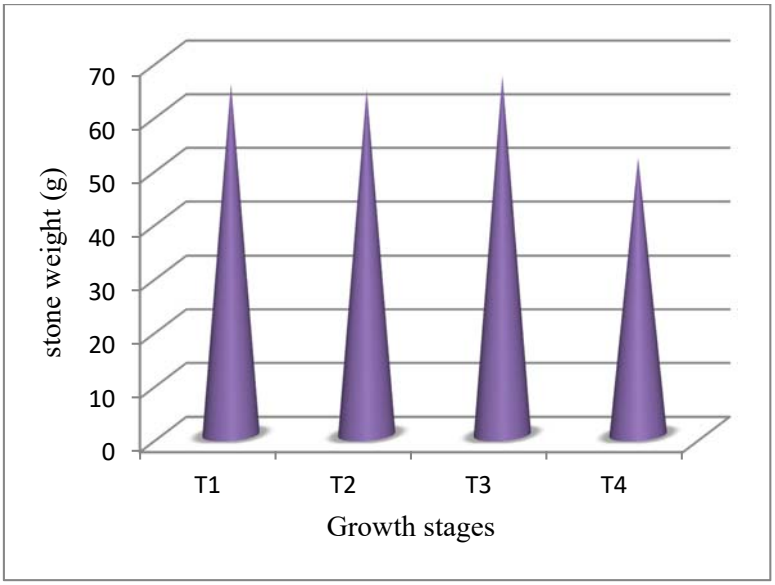


Fig 6b. Effect of stages of development on stone weight in mango cv. Mallika

5.1.2 Biochemical parameters

Fruits at their mature stage were tested for biochemical parameters such as acidity, ascorbic acid, sugars, total soluble solids (TSS), total chlorophyll, crude fibre and total carotenoids. The biochemical parameters differed significantly from one growth stage to the next.

5.1.2.1 Total soluble solids (TSS)

As fruit ripens TSS increases. In this study both Ratna and Mallika varieties showed significant difference between the treatments for total soluble solids (TSS).

In mango cv. Ratna, TSS was lowest in 90 DAFS (9.24 ºbrix) and highest at 110 DAFS (21.12 ºbrix). This result coincides with the results obtained by Anila and Radha (2005) where they found the TSS of cv. Ratna was highest (24 ºbrix). In cv. Mallika, the TSS was highest on 140 DAFS (20.18 ºbrix) and this result is in conforms with the reports of Hada and Anil kumar (2018). Mango fruit with a higher TSS is a positive factor. According to Anila and Radha (2003), the TSS of ripe mango local varieties in Kerala varied widely from 10 to 24 ºBrix, which conforms with the present research.

TSS of fruit is a genetic trait that can be influenced by the date of harvesting in mango (Kumar, 1998). Total soluble solids are determined by the hydrolysis of polysaccharides and their conversion to sugars. The conversion of carbohydrates to organic acids could be one of the reasons for a variety's inherent TSS.

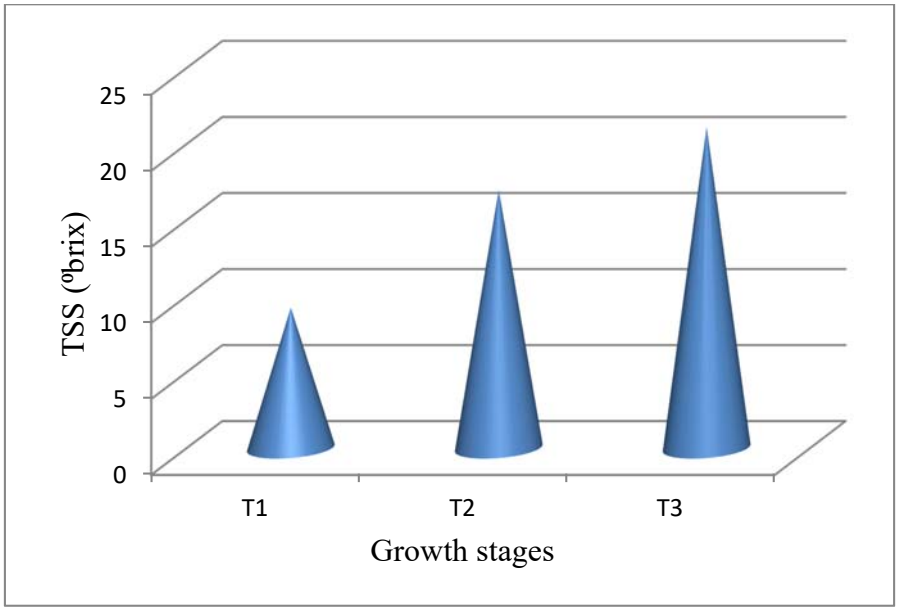


Fig 7a. Effect of stages of development on TSS in mango cv. Ratna

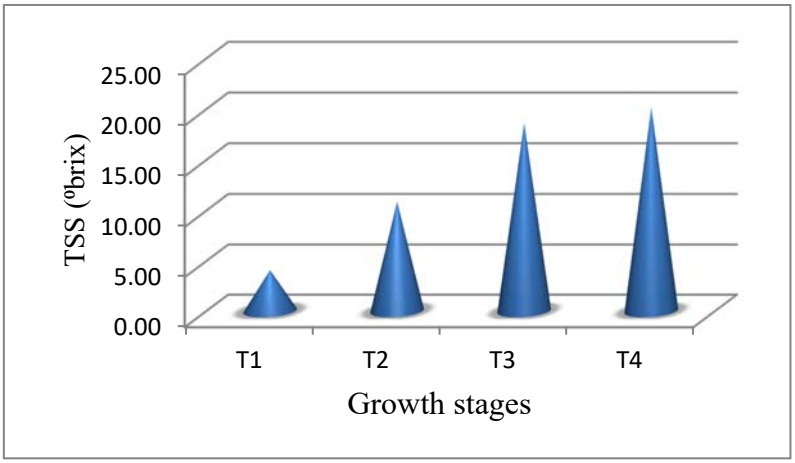


Fig 7b. Effect of stages of development on TSS in mango cv. Mallika

5.1.2.2 Tritratable Acidity (%)

Acidity was found to be decreasing as maturity advance. In mango cv. Ratna, acidity ranged from 0.30 % to 1.19 % and lowest acidity was reported in ripe mature

fruit (0.30 %). Similar findings have also been reported by Anila and Radha (2005). In cv. Mallika, acidity ranged from 0.73 % to 1.56 % and lowest acidity was reported in ripe mature fruit (0.73%). According to the findings of Bora *et al*. (2017) the acidity in mango cv. Mallika is 0.24 %, this result was partial similar to the present result.

The conversion of citric acid into sugars, which were used by fruit in its metabolic process was attributed well with decrease in acidity (Lee *et al*., 2010). The level of titratable acidity in mango fruits decreases over time as the skin changes colour and the sugar content rises.

Acidity of the fruit is affected by the ripening stage of the variety and environmental condition. The differences in acidity among the varieties can be considered as the varietal characters. The variations in fruit acidity were also reported by Kumar (1998), Mitra *et al.,* (2001) and Mannan *et al,* (2003) in different cultivars of mango.

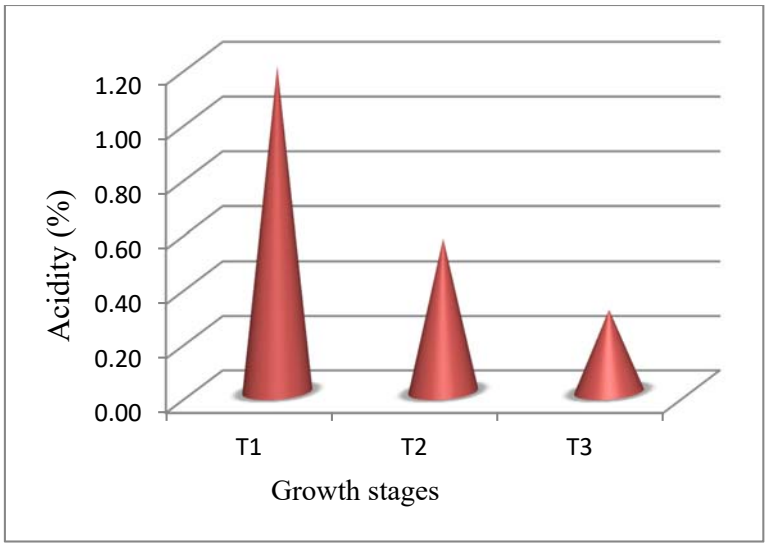


Fig 8a. Effect of stages of development on acidity in cv. Ratna

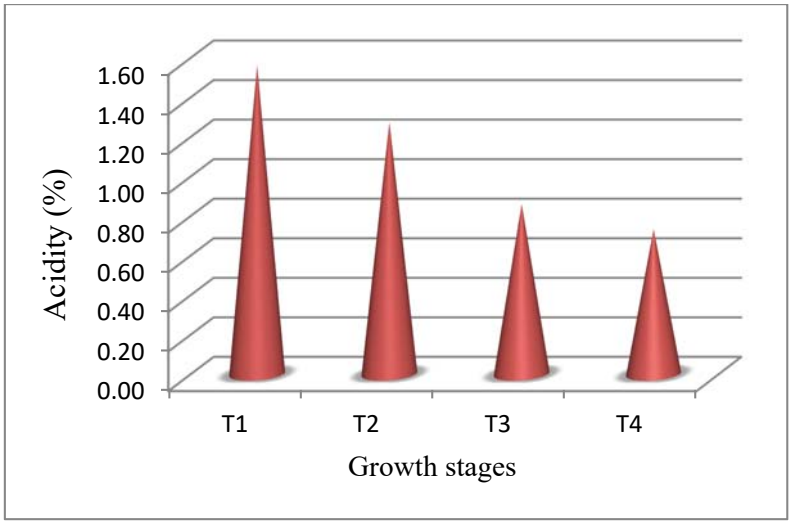


Fig 8b. Effect of stages of development on acidity in cv. Mallika

5.1.2.3 Sugars (%)

Sugar levels differed significantly between three stages of fruit growth in the mango cultivar Ratna. It was less during the early stages of growth and gradually increased as the fruit matures. Highest total sugar, reducing sugar and non-reducing sugar (19.04 %, 2.73 % and 16.31 %) was detected in 110 DAFS, followed by 100 (13.15 %, 2.51 % and10.64 %) and 90 DAFS (5.34 %, 1.69 % and 3.66 %) as shown in the Fig 9a. The present result is confirming the finding of Anila and Radha (2005) who recoded 20.66% and 2.97 %, total and reducing sugar respectively.

Sugar levels in the mango cultivar Mallika differed significantly at four stages of fruit development. It was low in the beginning stages of development and gradually increased as the fruit reaches maturity. Maximum sugars i.e. total, reducing and non-reducing sugar was noted in 140 DAFS (17.00 %, 4.70 % and 12.30 %) followed by 120 (11.98 %, 2.63 % and 9.35 %), 110 (7.13 %, 1.73 % and 5.35 %) and 90 DAFS (3.40 %, 1.53 % and 1.87 %) respectively as shown in the Fig 9b. The present result was partially similar to the findings of Bora *et al*. (2017) who recorded 20.82 %, 4.98 % and 15.04 % of total, reducing and non-reducing sugar respectively.

The sugar content of mango increases with increase in days of maturity. When the fruits are over-ripe, the value of total sugar rises initially and then falls as a result of its faster utilisation in respiration (Hoda, 2001). The content of reducing sugars in

mangoes varied with the seasons and ripening characteristics of the fruits, and this phenomenon could be due to varietal characteristics.

Total sugar variability could be due to genetic differences as well as agro-climatic conditions. The sweetness of the fruit may be due to the conversion of starch, acids, and other insoluble substances into soluble form during ripening. According to Verma *et al*. (1988), the ripening of mango fruit is associated with an increase in sugars.

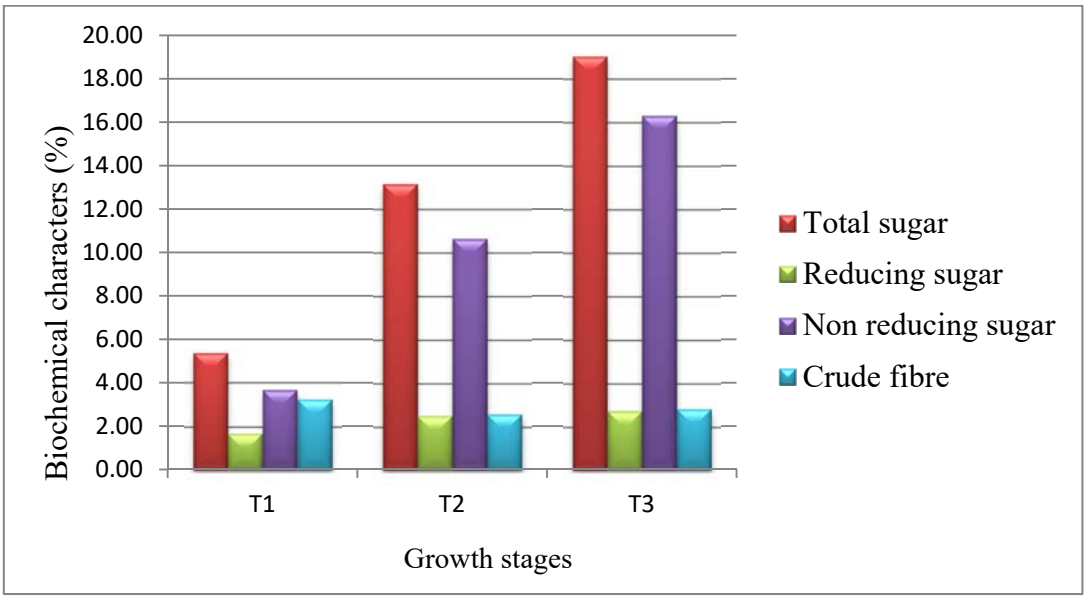


Fig 9a. Effect of stages of development on sugars and crude fibre in mango cv. Ratna

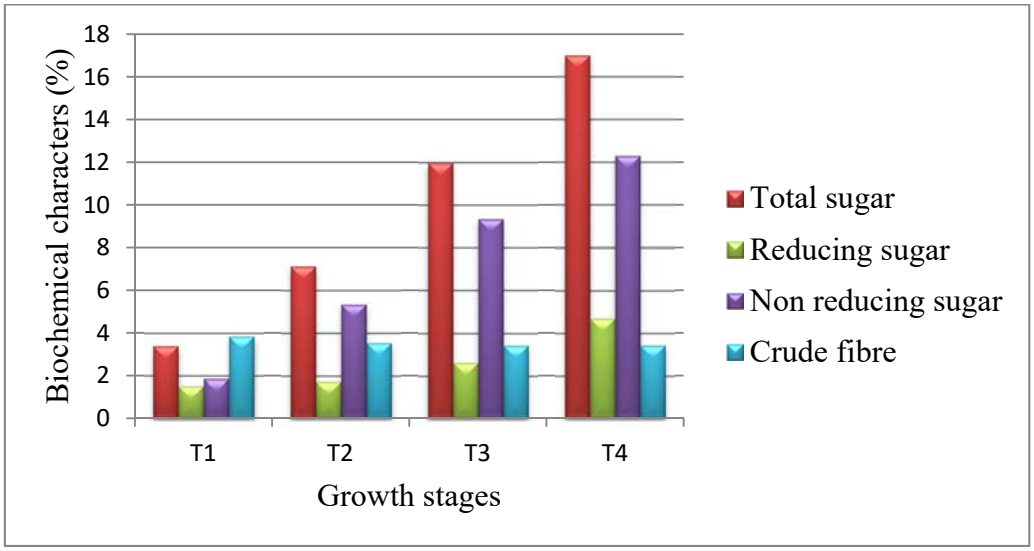


Fig 9b. Effect of stages of development on sugars and crude fibre in mango cv. Mallika

5.1.2.4 Crude fibre (%)

During three stages of growth, no significant difference was remarked in crude fiber content of mango cv. Ratna and it was higher in the early days and decreased as the fruit matured. Highest crude fiber (3.23 %) was recorded during 90 DAFS, followed by 100 (2.83 %) and 110 DAFS (2.59 %) as shown in the Fig 9a.

In mango cv. Mallika, no significant difference was observed in crude fiber content in four growth stages. Highest crude fiber (3.85 %) was observed in 90 DAFS, followed by 110 (3.55%), 120 (3.44 %) and 140 DAFS (3.42 %) as shown in the Fig 9b.

According to Mutua *et al*. (2016), crude fibre content varied between 2.64 and 3.71 %.

5.1.2.5 Ascorbic acid (mg/100g)

Mango cultivars varied in ascorbic acid content during different growth stages wherein the initial period of growth, ascorbic acid content was more and as fruit matured it decreased significantly. In mango cv. Ratna highest ascorbic acid (69.05 mg/100g) was seen in 90 DAFS followed by 100 (68.88 mg/100g) and 110 DAFS (33.48 mg/100g) as shown in the Fig 10a. Anila and Radha (2005) reported that ascorbic acid content of mango cv. Ratna is 31.30 mg/100g which conforms to the present study.

In mango cv. Mallika, highest ascorbic acid (80.38 mg/100g) was noted in 90 DAFS, followed by 110 (77.95 mg/100g), 120 (69.56 mg/100g) and 140 DAFS (61.21 mg/100g) as shown in the Fig 10b. The nature and extent of genetic variability present in the experimental material could explain the variation in ascorbic acid levels.

The higher level of ascorbic acid could be due to the continuous synthesis of glucose 6- phosphate, which is a precursor to ascorbic acid, during the growth and development of fruits. The catalytic effect of growth substances on the biosynthesis of ascorbic acid from sugars is most quick to attribute for the increase in ascorbic acid

content (Hada and Singh, 2018). However, climate conditions, factors prevailing during the ripening etc. influence ascorbic acid content.

5.1.2.6 Total carotenoid (mg/100g)

Carotenoids give fruits a more natural appearance, and their higher content in fruits has distinct advantages, especially in international trade where the use of artificial colour is discouraged. Cancer, cardiovascular disease, age-related macular degeneration, and photosensitivity associated with UV exposure have all been linked to carotenoid consumption (Cooperstone and Schwartz, 2016).

Total carotenoid varied significantly among three growth stages. In cv. Ratna highest carotenoid (65.88 mg/100g) was recorded in 90 DAFS followed by 100 (27.93 mg/100g) and 110 DAFS (14.65 mg/100g) as in the Fig 10a.

Significant differences were observed in total carotenoid during four stages of growth in cv. Mallika and highest (56.26 mg/100g) was noted in 90 DAFS, followed by 110 (43.76 mg/100g), 120 (29.28 mg/100g) and 140 DAFS (7.56 mg/100g) as in the table 2b. Similar findings was recorded by Bora *et al*. (2017) where they found total carotenoid content of cv. Mallika is 7.42 mg/100g.

Hoda *et al*. (2003) found variations in total carotenoids content ranging from 2.33 mg/100 g to 44.95 mg/100g. Biosynthesis, degradation, and stable storage all contribute to carotenoid accumulation in chromoplasts (Nisar *et al*., 2015). The colours of the fruits are enhanced during maturity due to the presence of pigments. The syntheses of pigments are at a faster rate during fruit ripening and slowly decline during senescence (Pino *et al*., 2005)

5.1.2.7 Total phenol (mg/100g)

In mango pulp, phenolic acids are the most abundant compounds. Ferulic acid is a phenolic compound found in fruits and vegetables that is produced by the metabolism of phenylalanine and tyrosine (Balasubashini *et al*., 2003). Consumption of ripened mango is better, as it contains a high content of phenolic acids, which play a significant role in quenching and neutralizing the free radicals to improve consumers' health.

Total phenol content differed significantly during three stages of growth viz. 90, 100 and 110 DAFS in cv. Ratna. Highest phenol content (74 mg/100g) was observed in 90 DAFS followed by 100 (55.20 mg/100g) and 110 DAFS (32.06 mg/100g) as shown in the Fig 10a.

In cv. Mallika, highest phenol content (57.5 mg/100g) was noticed in 90 DAFS followed by 120 (50.63 mg/100g), 140 (47.5 mg/100g) and 110 DAFS (26.25 mg/100g) as shown in the Fig 10b.

Wide range was observed in phenolic content in mango from 68 mg GAE/100g to 266 mg GAE/100g (Wu *et al*., 2004). Differences in variety, climate, maturation, extraction method, and agricultural system can all contribute to this variation.

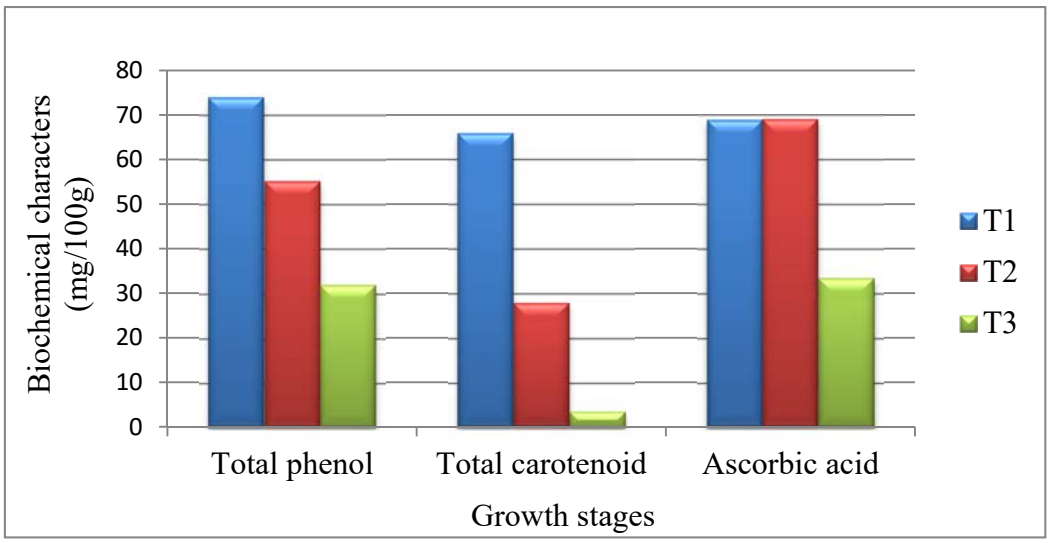


Fig 10a. Effect of stages of development on total phenol, total carotenoid and ascorbic acid in mango cv. Ratna

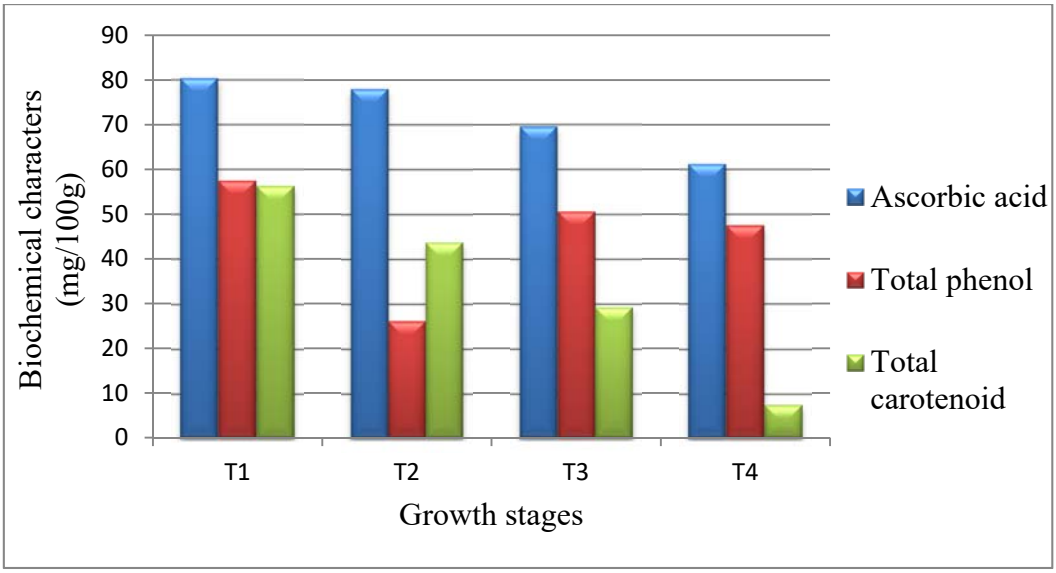


Fig 10b. Effect of stages of development on total phenol, total carotenoid and ascorbic acid in mango cv. Mallika

5.1.2.8 β- carotene (mg/100g)

In mango cv. Ratna, highest β-carotene (0.88 mg/100g) was spotted in 110 DAFS, followed by 100 (0.11 mg/100g) and 90 DAFS (0.05 mg/100g) as in the Fig 11a. and during four stages of growth in mango cv. Mallika, highest β-carotene (0.03 mg/100g) was remarked in 140 DAFS, followed by 120 (0.03 mg/100g), 110 (0.02 mg/100g) and 90 DAFS (0.02 mg/100g) as shown in the Fig 11b.

In several cultivars, β-carotene is the most abundant carotenoid. Mango fruits develop pigments during ripening as a result of carotenoid biosynthesis, changes in carbohydrates or starch conversion to sugars, organic acids, phenolics, and volatile compounds, resulting in ripening and softening to acceptable quality (Gill and Jawandha, 2008).

Stages of harvest had significant effect on β-carotene content of mango fruits. The amount of β-carotene was increased with the progress of maturity. It was the lowest after harvest and the highest at the last edible stage. With the delay in harvest, the amount of β-carotene increased gradually, peaking at the last harvest. The findings of the study conformed to those of Absar *et al*. (1993) and Mondal *et al*. (1995).

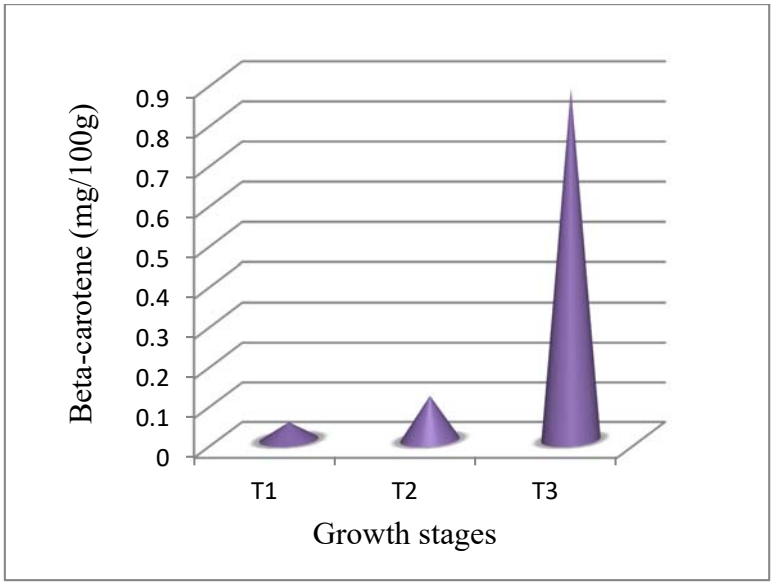


Fig11a. Effect of stages of development on β-carotene in mango cv. Ratna

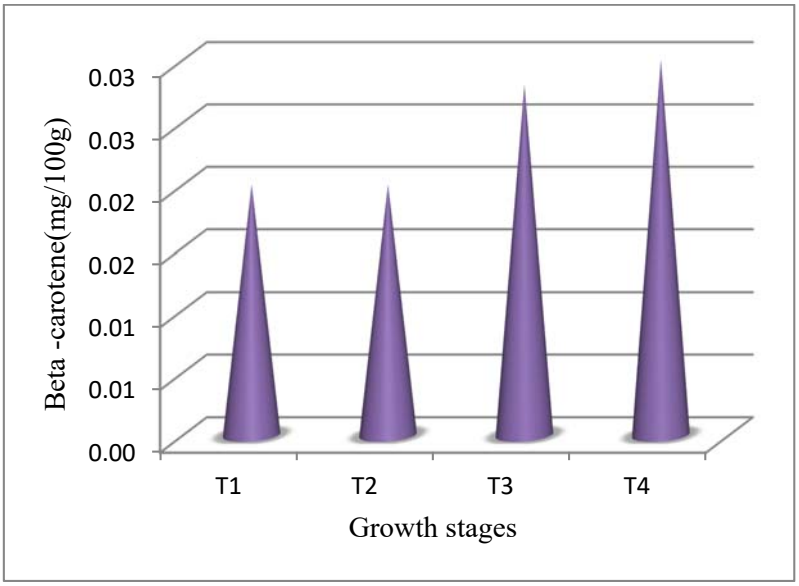


Fig11b. Effect of stages of development on β-carotene in mango cv. Mallika

5.1.2.9 Total chlorophyll

In mango cv. Ratna, chlorophyll content was steady (0.01 mg/100g) and there was no significant difference among three stages of growth i.e. 90, 100 and 110 DAFS as shown in the Fig. 12a.

During four growth stages in mango cv. Mallika, significant difference was observed in chlorophyll content and it was highest in 90 DAFS (0.03 mg/100g), followed by 110 (0.02 mg/100g), 120 (0.02 mg/100g) and 140 DAFS (0.01 mg/100g) as shown in the Fig.12b.

The yellowing of the mangoes was most likely caused by chlorophyll breakdown and carotenoid synthesis in conjunction with the underlying pulp carotenoid. The chlorophyll pigment imparts green colour during the initial growth stages and they disappear on maturation, with the generation of carotenoid and esterification by fatty acid and chromoplast pigment (Marin *et al*., 2004)

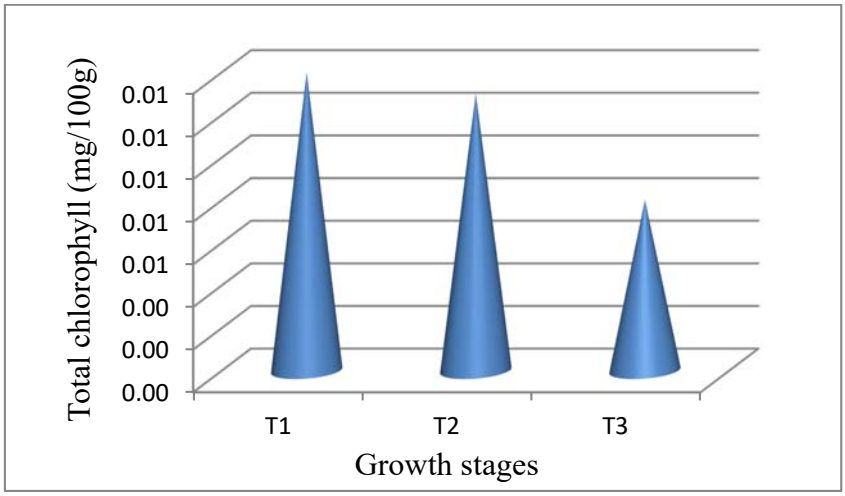


Fig12a. Effect of stages of development on total chlorophyll in mango cv. Ratna

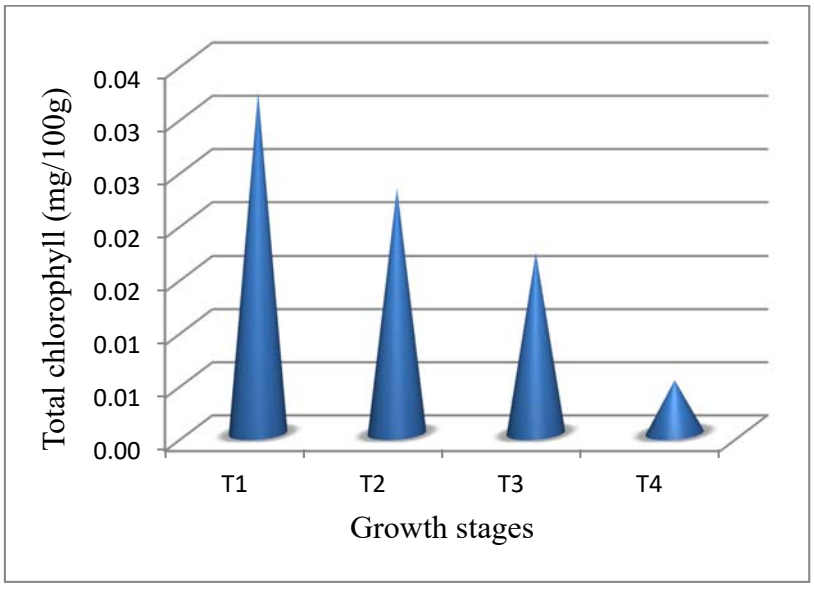


Fig12b. Effect of stages of development on total chlorophyll in mango cv. Mallika

5.1.3 Heat units

Fruit growth is dependent on physiological and biochemical processes that are influenced by the temperature prevailing during fruit development, according to Tukey (1960). In present study heat unit requirement increased during maturity stage.

The accumulation of HU varies at different maturity periods due to climatic conditions, particularly temperature, and is directly related to physiological processes in the fruit.

In Kerala HU requirement in cv. Ratna for 90, 100 and 110 DAFS was 989.05, 1023.35 and 1107.75 respectively. Similarly, Burondkar *et al*., (2000) found that cv. Ratna recorded duration and total heat units of 127 and 112 days and 849 and 866 degree days respectively and in cv. Mallika, during four growth stages, the heat unit requirement was 957.65, 1185.70, 1314.70 and 1507.00 for 90, 110, 120 and 140 DAFS respectively, because of the temperature prevailing in this region. Rai *et al.* (2003) reported the total degree days required for cv. Mallika as 2238 .63 HU which was similar with present study. By recording HU, days to maturity can be fixed in these varieties in Kerala.

5.1.4 Sensory evaluation

In mango cv. Ratna, total score was highest in 110 DAFS (60.2), followed by 100 DAFS (57.2) and lowest total score was recorded in 90 DAFS (49.6) as shown in the Fig 13a. and at 110 DAFS recorded the highest score in all the attributes (appearance, colour, taste, odour, overall acceptability etc.) and it was followed by 100 DAFS as shown in the Fig 13a. In mango cv. Mallika, total score was highest (65.00) in 140 DAFS, followed by 120 DAFS (59.50) and lowest total score was recorded in 90 DAFS (49.6) as shown in the Fig 13b. and the growth stage of 140 DAFS recorded highest score in all the attributes (appearance, colour, taste, odour, overall acceptability etc.) followed by 120 DAFS as shown in the Fig 13b.

To conclude in mango cv. Ratna, harvest at 110 DAFS showed highest total score and at this stage most of the quality attributes were found to be best in terms of fruit quality and marketable acceptability and wherein cv. Mallika, highest total score and major quality attributes were found to be best when harvested at 140 DAFS.

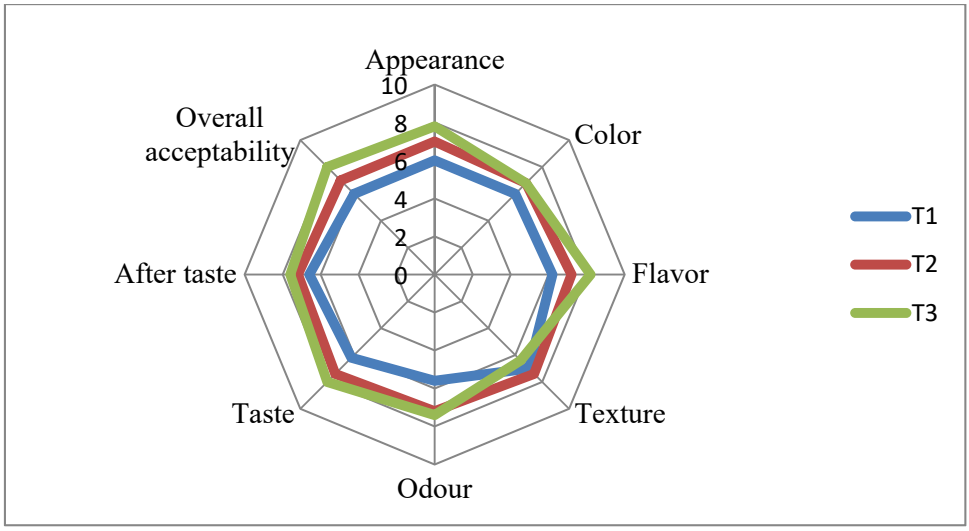


Fig 13a. Effect of stages of development on sensory attributes of mango cv. Ratna

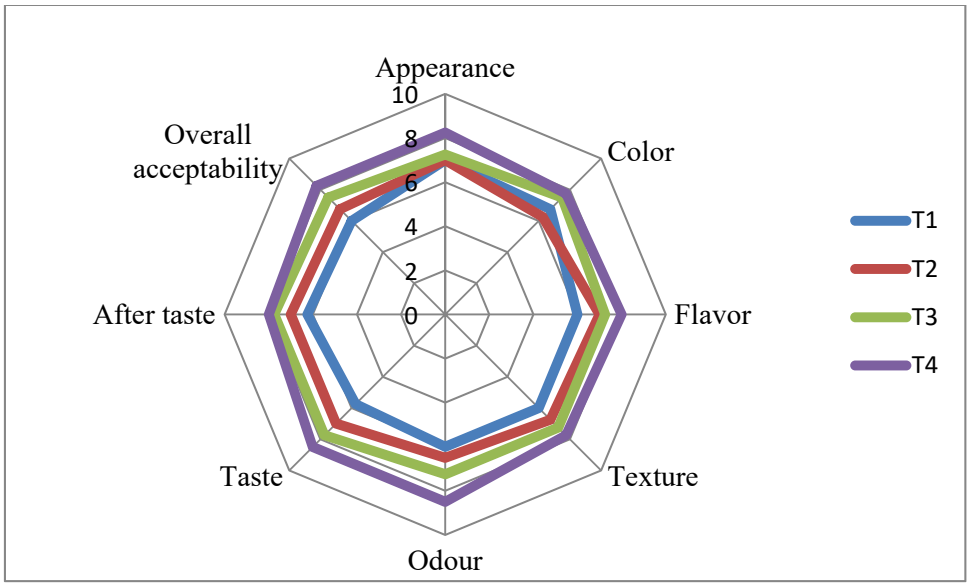


Fig 13b. Effect of stages of development on sensory attributes of mango cv. Mallika

5.2 STUDIES ON THE EFFECT OF MATURITY ON RIPENING OF CV. RATNA

In Kerala, commercial cultivation of mango is limited to a few pockets in Palakkad district. The introduction of varieties from Konkan and other mango growing tracts of India has shown an improvement in marketing and trade of some popular varieties viz. Alphonzo, Ratna, Bennet Alphonzo, Neelum, Mallika. etc. Mango fruits gain acceptance and popularity among consumers when it is served with the correct ripeness. The quality attributes like appearance, taste, flavour and nutritional profile are the key contributing factors to improve the organoleptic quality

of mango. Harvesting done at correct maturity stage escalate the quality of fruits even during storage. But every fresh commodity loses weight over time and in relation to the environment in which it is kept for storage. The fruits harvested at proper maturity, can be stored for a longer period. Since the maturity standards vary with the geographical location and environmental factors, an attempt was made to study the effect of maturity on ripening of mango cv. Ratna grown in the orchard at College of Agriculture, Vellanikkara.

5.2.1 Physiological parameters

The physiological characters of the fruits vary according to the metabolic activities taking place inside the fruit. The treatments given before the storage of matured and pre matured fruit show differential behavior during storage as shown below.

5.2.1.1 Physiological loss in weight (PLW)

Fresh mango fruits lose weight during storage due to physiological activities such as respiration, transpiration, and other biochemical changes (Naryana *et al*., 1996 and Thinh *et al*., 2013). In present study, PLW showed significant variation, when different pre-treatments were given for matured and pre-matured fruit. The mango fruits harvested prior to maturity at 90 DAFS showed significantly greater weight loss throughout the ripening period compared to matured fruits harvested at 100 DAFS. PLW was increasing with increase in storage period resulting in decreased shelf life due to weight loss. In both 90 and 100 DAFS the fruits PLW were lowest during initial 3 days of storage and it increased as storage period increased to 6 days as shown in the Fig 14. and thus lead to reduction in shelf life.

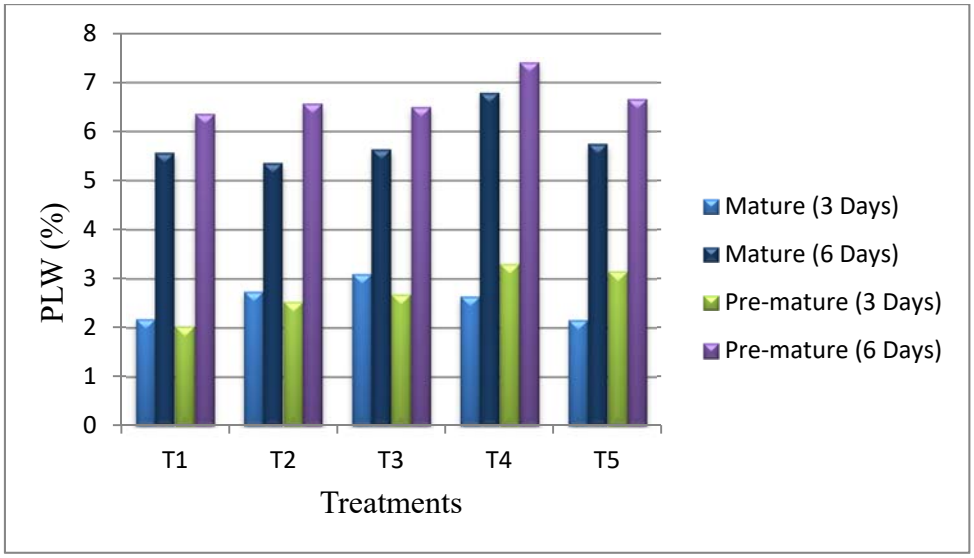


Fig 14. Effect of pre-treatments on PLW of mango cv. Ratna

5.2.1.2 Ethylene evolution (%)

The active growth of the fruit causes a high rate of respiration and ethylene production in young fruit (Tadesse *et al*., 2002). Ethylene evolution varied significantly between five treatments in both matured and pre-matured with 3 days intervals. After 3 days of storage of matured fruits, highest ethylene evolution (2.57 %) was recorded, when fruits were ozonized and sprayed with ethrel and lowest ethylene evolution (0.40 %) was seen when fruits were dipped in hot water and sprayed with ethrel as shown in the Fig 15. Ethylene evolution was highest (2.70 %) when fruits were ozonized and sprayed with ethrel and lowest (0.63 %) when fruits were dipped in hot water and sprayed with ethrel even after 6 days of storage as shown in the Fig 15.

Ethylene evolution was highest (1.10 %) when fruits were sprayed with ethrel and lowest (0.33 %) in fruit without any treatment in 3 days storage of pre-matured fruit as shown in the table 6a. Fruits when sprayed with ethrel have highest ethylene evolution (22.87 %) and lowest (0.77 %) when fruits were dipped in hot water and sprayed with ethrel as shown in the Fig 15. Higher Ethylene evolution at 3 days after storage indicates that it is tending towards maturity and it lowers after 6 days of storage resulting in complete ripened stage.

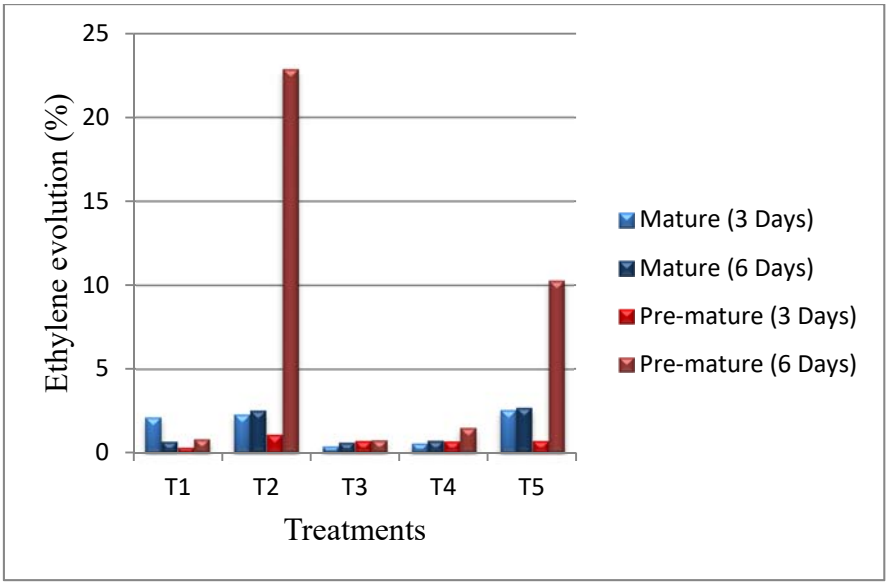


Fig 15. Effect of pre-treatments on ethylene evolution of mango cv. Ratna

5.2.2 Biochemical parameters

5.2.2.1 Total Soluble Solids (TSS) (^{0}Brix)

The treatment showed significant difference on total soluble solids (TSS) at 3 and 6 days after storage in both mature and pre-matured fruit. In mature fruits, highest TSS (13.33 ^{0}*brix*) was reported when fruits were ozonized and sprayed with ethrel and lowest (8.53 ^{0}*brix*) when fruits were sprayed with ethrel after 3 days of storage as shown in the Fig 16. After 6 days of storage, highest TSS (22.80 ^{0}*brix*) was reported when fruits were dipped in hot water and sprayed with ethrel and lowest TSS (17.43 ^{0}*brix*) was seen in fruits without any treatment as shown in the Fig 16.

In pre-mature fruits TSS was highest (12.50 ^{0}*brix*) when fruits were ozonized and sprayed with ethrel and lowest (8.23 ^{0}*brix*) in fruits without any treatment after 3 days of storage as shown in the Fig 16. After 6 days of storage, highest TSS (17.20 ^{0}*brix*) was reported when fruits were dipped in hot water and sprayed with ethrel and lowest TSS (14.57 ^{0}*brix*) when fruits were ozonized and sprayed with ethrel as shown in the Fig 16. The increased TSS content in fruits might be due to the conversion of carbohydrates into sugars, organic acids and other soluble materials by metabolic process during repining (Das and Balamohan, 2013). According to Laisk *et al*. (1989), ozone decomposes at the cell wall and plasma membrane rather than intercellular regions. Increased membrane permeability and electrolyte leakage are two most

common responses to ozone treatment (Beckerson and Hofstra 1980; Liew and Prange 1994).

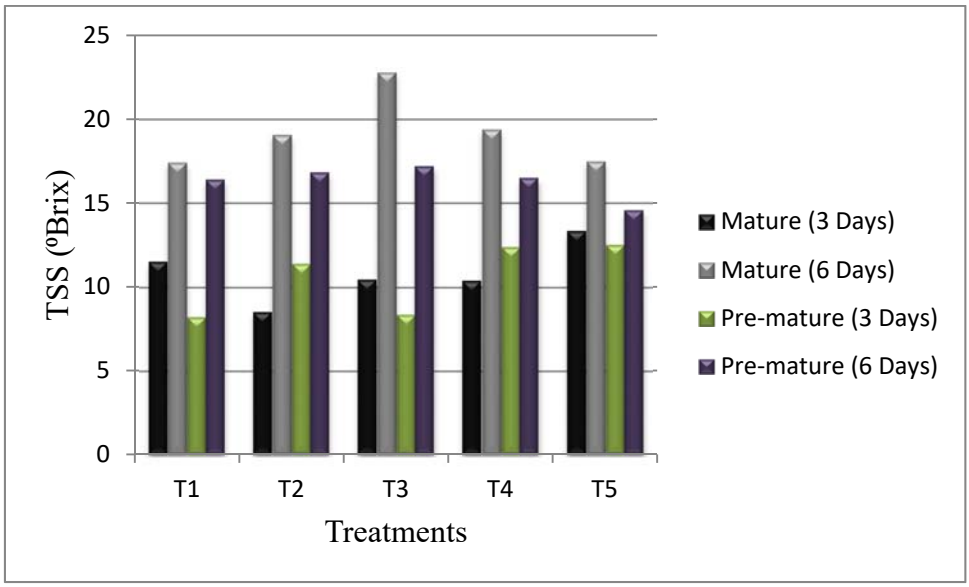


Fig 16. Effect of pre-treatments on TSS of mango cv. Ratna

5.2.2.2 Acidity (%)

In mature fruits, lowest acidity (1.53 %) was noted when fruit were dipped in hot water and sprayed with ethrel after 3 days of storage. Lowest acidity was reported in the fruits without any treatment (0.13 %) followed by fruits treated with ozone and sprayed with ethrel (0.24 %) after 6 days of storage as shown in the Fig 17.

Acidity was lowest (0.62 %) when fruits were ozonized and sprayed with ethrel in pre- mature fruit after 3 days of storage. After 6 days of storage, lowest acidity (0.27 %) was reported when fruits were sprayed with ethrel in pre- mature fruits as shown in the Fig 17.

The decrease in acidity during ripening could be due to metabolic changes in the fruits or the use of organic acid in the respiratory process (Das *et al*., 2011).

Increased membrane permeability and electrolyte leakage are two most common responses to ozone treatment (Beckerson and Hofstra 1980; Liew and Prange 1994).

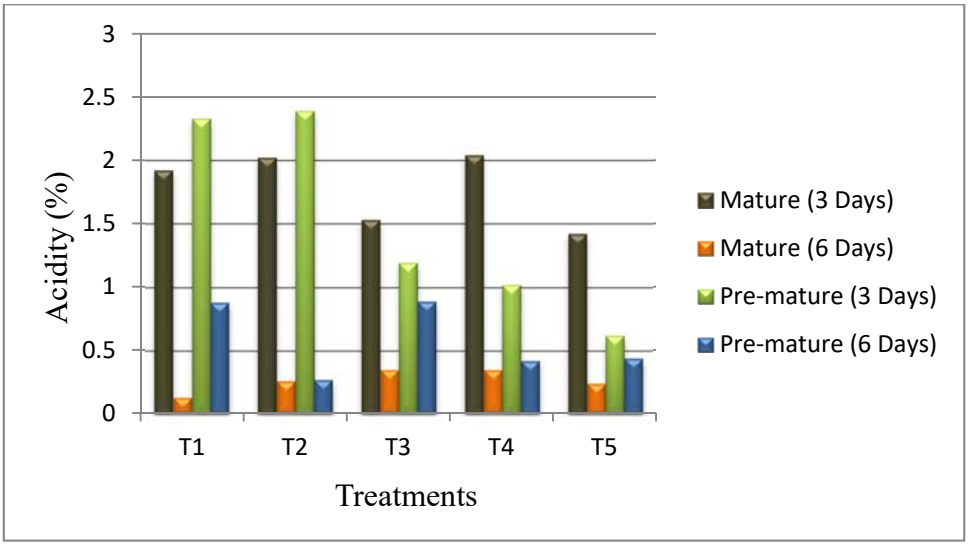


Fig 17. Effect of pre-treatments on Acidity of mango cv. Ratna

5.2.2.3 Sugars (%)

The maximum total sugar and non- reducing sugar was observed when fruits were ozonized and sprayed with ethrel (15.47 % and 12.62 %). The lowest was reported when fruits were sanitized and sprayed with ethrel (11.77 % and 9.08 %). The highest reducing sugar of (2.69 %) was reported when fruits were sanitized and sprayed with ethrel and lowest (2.10 %) when fruits were sprayed with ethrel alone.

The sugar content of mangoes increases as they ripen. During ripening, the enzyme conversion of free organic acid to simple sugar, as well as the breakdown of complex carbohydrates into simple form, causes an increase in total sugar content (Jassi *et al*., 2019).

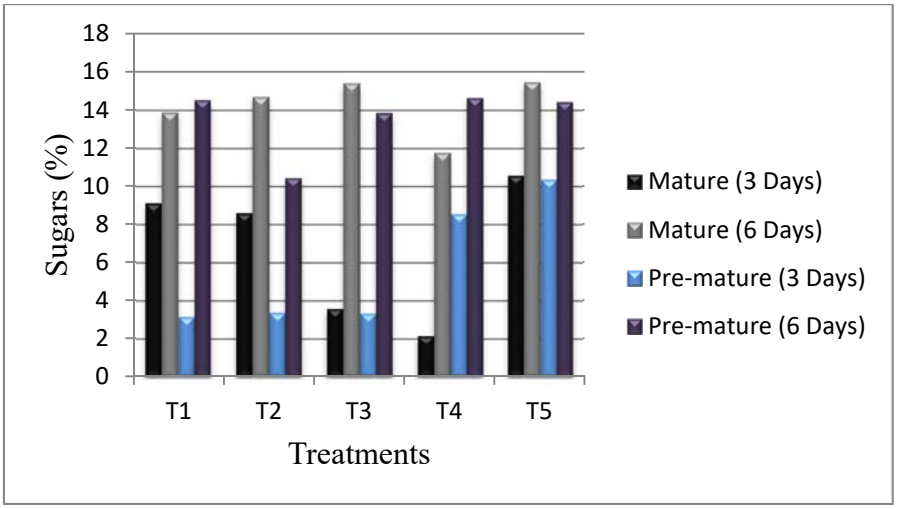


Fig 18. Effect of pre-treatments on sugars of mango cv. Ratna

5.2.2.4 Ascorbic acid (mg/100g)

As the mango ripens, the amount of ascorbic acid in the fruit decreases. In mature fruit (100DAFS) maximum (82.02 mg/100g) ascorbic acid was recorded when fruits were under control i.e., without any treatment and minimum (50.85 mg/100g) was noted when fruits were sprayed with ethrel as shown in the Fig 19. In ten days prior maturity fruits (90 DAFS), maximum (81.17 mg/100g) ascorbic acid was noted when fruits were ozonized and sprayed with ethrel and minimum (49.73 mg/100g) ascorbic acid was found when fruits were dipped in hot water and sprayed with ethrel as shown in the Fig 19.

It was previously reported that exogenous application of ethylene increased the acid content of mango fruit (Medlicott, 1987).

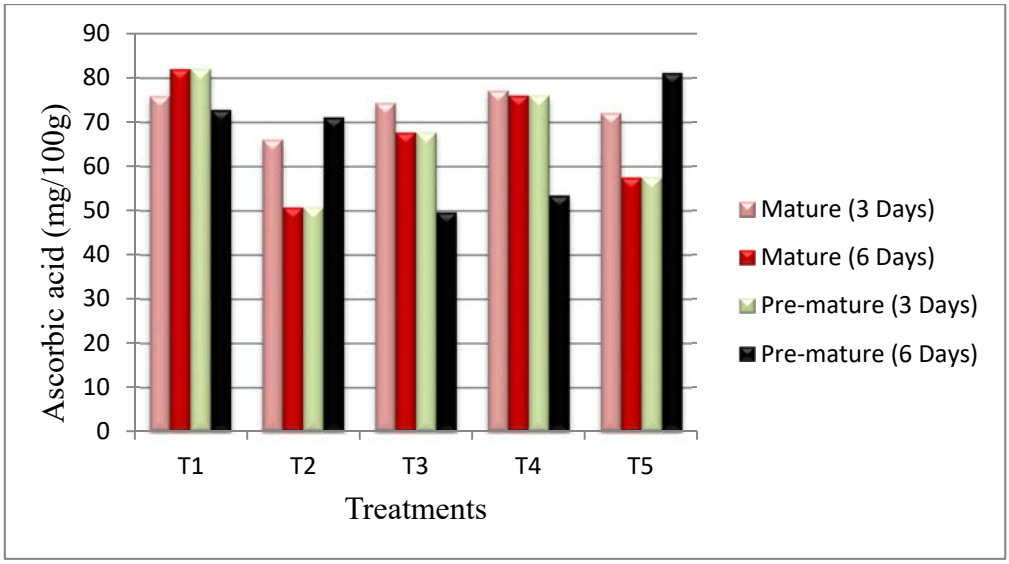


Fig 19. Effect of pre-treatments on Ascorbic acid of mango cv. Ratna

5.2.3 Sensory evaluation

In mature fruits, after 3 days of storage, the total score was highest when fruits were sanitized and sprayed with ethrel (56.40) followed by ozonized and sprayed with ethrel (T_5) (53.80). The lowest (49.40) total score was recorded in control fruits (T_1). Sanitized fruits (T_4) scored the highest score in half of the total attributes evaluated (colour, flavour, odour, taste and overall acceptability). Ozonized fruits (T_5) recorded highest score in appearance, texture and overall acceptability. After taste and colour was highest in ethrel sprayed (T_2) fruit as shown in the Fig 20a.

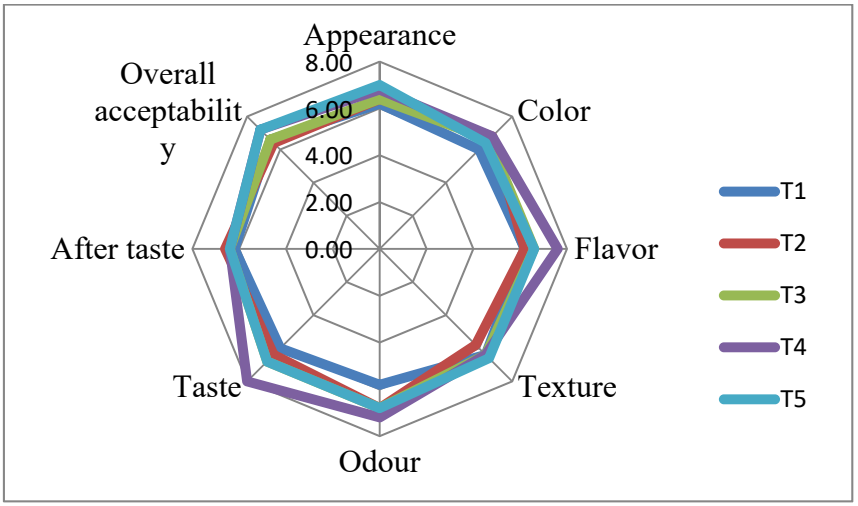


Fig 20a. Effect of pre-treatments on sensory attributes of mature fruit (3 DAS)

After 6 days of storage in mature fruits, the total score was highest when fruits were ozonized and sprayed with ethrel (68.20) followed by sanitized and sprayed with ethrel (67.80). The lowest (60.80) total score was recorded in control fruits (T1). Ozonized fruits (T5) scored the highest score in half of the attributes evaluated (appearance, colour, flavour, texture, odour and overall acceptability). Sanitized fruits were recorded highest score in after taste. Colour and taste scored highest in ethrel sprayed and hot water dipped (T3) fruits respectively as shown in the Fig 20b.

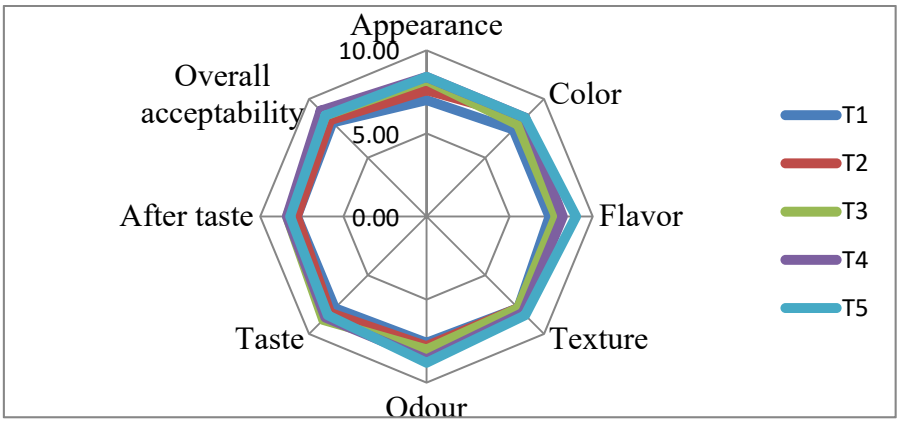


Fig 20b. Effect of pre-treatments on sensory attributes of mature fruit (6 DAS)

In 90 DAFS after 3 days of storage, the total score was highest (52.80) when fruits were ozonized and sprayed with ethrel followed by sanitized and sprayed with ethrel (50.20). The lowest (42.60) total score was recorded in control fruits (T_1). Ozonized fruits (T_5) scored the highest score in half of the attributes evaluated (appearance, texture, colour, odour, taste and overall acceptability). Sanitized fruits were recorded highest score in after taste and flavour as shown in the Fig 20c.

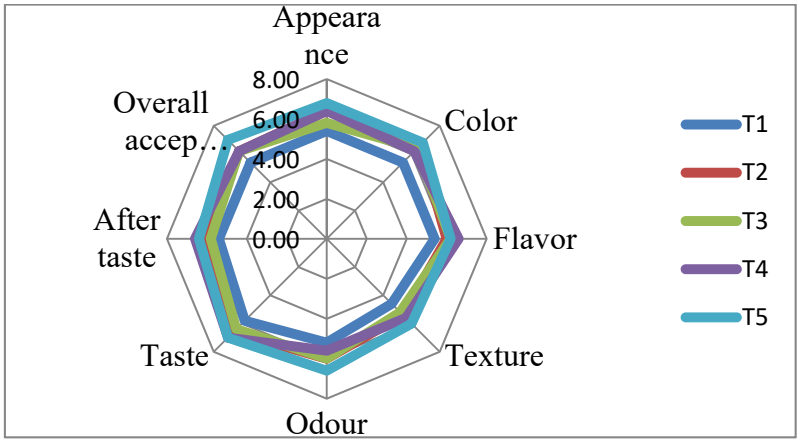


Fig 20c. Effect of pre-treatments on sensory attributes of pre- mature fruit (3 DAS)

After 6 days of storage in pre- mature fruits, the total score was highest when fruits were sanitized and sprayed with ethrel (64.40) followed by ethrel sprayed fruit (62.80). The lowest (60.40) total score was recorded in control fruits (T_1). Sanitized fruits (T_4) scored the highest score in half of the total attributes evaluated (appearance, colour, odour, taste, after taste and overall acceptability). Ozonized fruits were recorded highest score in texture. Control scored highest in flavour as shown in the Fig 20d.

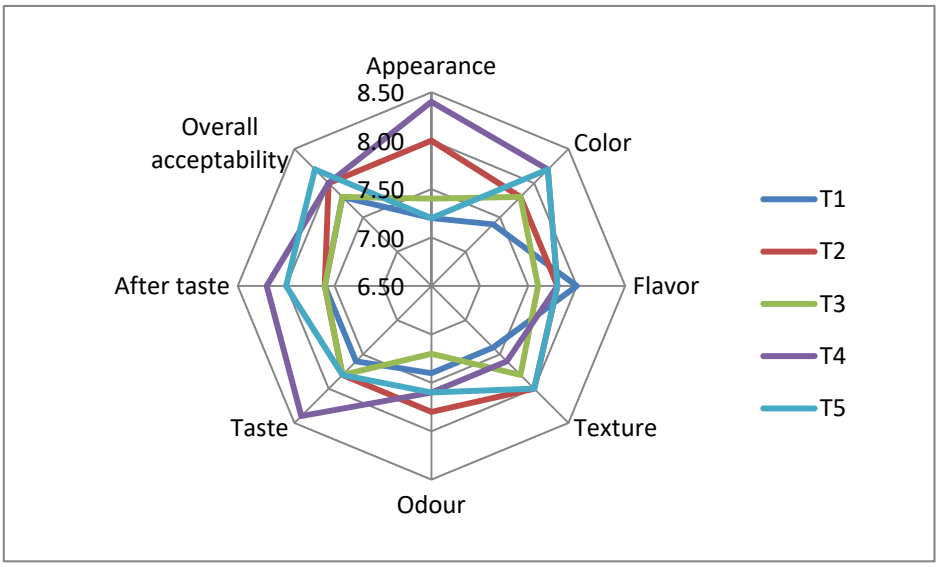


Fig 20d. Effect of pre-treatments on sensory attributes of pre- mature fruit (6 DAS)

SUMMARY

6. SUMMARY

The present study on the "Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality" was carried out at the Department of Post-Harvest Technology, College of Agriculture, Vellanikkara, Thrissur, Kerala, during 2019-20 and 2020-21 with the objective to find out the ideal harvesting stage of two important mango varieties viz. Ratna and Mallika for good organoleptic qualities and shelf life.

The varieties of mango grown in the college orchard were utilized for the study. Flowers were tagged at the time of fruit set and observations on external appearance, peel, pulp colour, stone characters and biochemical changes were taken at 90, 100,110 120 and 140 days after fruit set (DAFS) as per the IPGRI descriptor. Heat unit requirements for maturity were also studied, for determining optimum days for maturity. The findings are summarized below:

- In mango cv. Ratna, fruits harvested 110 DAFS with accumulation of 1107.75 HU recorded good quality attributes. Fruits harvested at this stage had attractive length (10.44 cm), diameter (26.1 cm), weight (358.8 g), firmness (1.40 kg/cm^2), specific gravity (1.03), stone length (7.49 cm), stone weight (10.68 g), TSS (21.12 ºbrix), acidity (0.30 %), ascorbic acid (33.48 mg/100g), total sugar (19.04 %), total phenol (32.06 mg/100g), total carotenoid (14.65 mg/100g), β-carotene (0.88 mg/100g), crude fibre (2.59 %) and total chlorophyll (0.01 mg/100g) with a score of 8.00 in overall acceptability in sensory evaluation.
- In mango cv. Mallika, fruits harvested 140 DAFS with accumulation of 1507.00 HU recorded good quality attributes. Fruits harvested 140 DAFS had good length (14.80 cm), diameter (28.03 cm), weight (623.95 g), firmness (0.73 kg/cm^2), specific gravity (1.05), stone length (11.83 cm), stone diameter (12.63 cm), stone weight (66.73 g), TSS (20.18 ºbrix), acidity (0.73%), ascorbic acid (61.21 mg/100g), total sugar (17.00 %), total phenol (47.5 mg/100g), total carotenoid (7.56 mg/100g), β-carotene (0.03 mg/100g), crude fibre (3.44 %) and total chlorophyll (0.01 mg/100g) with a score of 8.25 in overall acceptability in sensory evaluation.

Study on effect of maturity on ripening was done in the variety cv. Ratna at the mature stage. The fruits were harvested at the optimum maturity stage (100 DAFS) and ten days prior to maturity stage (90 DAFS) and kept for ripening after giving five different pre-treatments and the findings are as follows.

- Physiological loss in weight (PLW) was increased with increase in storage period and resulted in decrease in shelf life because of more loss in weight but the TSS and sugar increased however storability was less. High ethylene evolution on 3 days after storage indicated that it was tending towards maturity and it lowered after 6 days of storage resulting in complete ripened stage.
- Fruits of mango cv. Ratna harvested 10 and 20 days prior to ripe mature stage can be stored for 6 days under ambient conditions after giving Ozonization (200 ppm, ozone) and spraying with ethrel (200 ppm).

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APPENDIX

APPENDIX I

Score card for sensory evaluation of mango

9 point hedonic scale

Product code	Appearance	Colour	Texture	Flavour	Odour	Taste	After taste	Overall acceptability

Note: You are provided with samples of mango fruits and requested to rank them according to the scale given below as per your liking.

Scale:

Like extremely	**9**
Like very much	**8**
Like moderately	**7**
Like slightly	**6**
Neither like nor dislike	**5**
Dislike slightly	**4**
Dislike moderately	**3**
Dislike very much	**2**
Dislike extremely	**1**

Date: **Name:**

Signature:

DETERMINATION OF OPTIMUM MATURITY STAGE IN MANGO (*Mangifera indica* L.) FOR FRUIT QUALITY

By

JANMITHA SHETTY
(2019-12-048)

ABSTRACT OF THE THESIS

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Abstract

Mango (*Mangifera indica* L.), the national fruit of India is nutritionally rich in carbohydrates, proteins, vitamins and minerals such as calcium, iron, and phosphorus and hence known as the "King of fruits". Mangoes are popular in markets worldwide because of unique flavour, appealing aroma, colour and taste (Arauz, 2000). In Indian subcontinent flowering of mango starts from November in Kerala and extends to February – March in Northern India. Mangoes from Kerala fetch higher price in the main markets at other parts of the country due to earliness. But commercial cultivation of mango in Kerala is limited to a few pockets in Palakkad district and the national varieties such as Alphonso, Banganapalli, Amrapali, Ratna and Mallika are occasional. The adaptation of different varieties to the climatic conditions prevailing fruiting and yielding behaviour of the varieties, production and post-harvest management practices followed by the growers, prevailing marketing system, are some of the problems of mango cultivation in Kerala.

Mango fruits gain acceptance and popularity among consumers when it is served with the correct ripeness. Mangoes harvested at full maturity had a shorter shelf life, but those harvested early had a higher weight loss but improved storability (Shahjahan *et al.,* 1994). Maturity standards in relation to the quality of important commercial varieties have not been studied when grown under humid tropical conditions of Kerala. Hence a study on the "Determination of optimum maturity stage in mango (*Mangifera indica* L.) for fruit quality" was carried out at the Department of Post-Harvest Technology, College of Agriculture, Vellanikkara, Thrissur, Kerala during 2019- 21 with the objective to find out the ideal harvesting stage of two important mango varieties viz. Ratna and Mallika for good organoleptic qualities and shelf life.

The varieties of mango grown in the college orchard were utilized for the study. Flowers were tagged at the time of fruit set and observations on external appearance, peel, pulp colour, stone characters and biochemical changes were taken at 90, 100,110 120 and 140 days after fruit set (DAFS) as per the IPGRI descriptor. Heat unit requirements for maturity were also studied, for determining optimum days for maturity. In case of mango cv. Ratna, 90, 100 and 110 DAFS are the three stages of

growth and in cv. Mallika, 90, 110,120 and 140 DAFS are four stages of growth. Physical and biochemical characters were studied at different stages of growth. In mango cv. Ratna fruits harvested 110 DAFS with accumulation of 1107.75 HU recorded good quality attributes. Fruits harvested at this stage had attractive length (10.44 cm), diameter (26.1 cm), weight (358.8 g), firmness (1.40 kg/cm^2), specific gravity (1.03), stone length (7.49 cm), stone weight (10.68 g), TSS (21.12 ºbrix), acidity (0.30 %), ascorbic acid (33.48 mg/100g), total sugar (19.04 %), total phenol (32.06 mg/100g), total carotenoid (14.65 mg/100g), β-carotene (0.88 mg/100g), crude fibre (2.59 %) and total chlorophyll (0.01 mg/100g) with a score of 8.00 in overall acceptability in sensory evaluation.

In mango cv. Mallika fruits harvested 140 DAFS with accumulation of 1507.00 HU was found to be good in quality attributes. Fruits harvested 140 DAFS had good length (14.80 cm), diameter (28.03 cm), weight (623.95 g), firmness (0.73 kg/cm^2), specific gravity (1.05), stone length (11.83 cm), stone diameter (12.63 cm), stone weight (66.73 g), TSS (20.18 ºbrix), acidity (0.73%), ascorbic acid (61.21 mg/100g), total sugar (17.00 %), total phenol (47.5 mg/100g), total carotenoid (7.56 mg/100g), β-carotene (0.03 mg/100g), crude fibre (3.44 %) and total chlorophyll (0.01 mg/100g) with a score of 8.25 in overall acceptability in sensory evaluation.

Study on effect of maturity on ripening was done in the variety cv. Ratna at their mature stage. Fruits harvested at the optimum maturity stage (100 DAFS) and ten days prior to maturity stage (90 DAFS) were kept for ripening after giving five different pre-treatments, viz., control (T_1), ethrel spray (T_2), hot water dip with ethrel spray (T_3), sanitization with ethrel spray (T_4) and ozonisation with ethrel spray (T_5). Treated fruits packed in ventilated CFB boxes were kept under ambient condition and observations were recorded at 3 days interval. PLW increased with increase in storage period resulted in decrease in shelf life because of more loss in weight but the TSS and sugar increased however storability was less. High ethylene evolution on 3 days after storage indicates that it is tending towards maturity and it lowers after 6 days of storage resulting in complete ripened stage. Thus it can be concluded that the fruits of mango cv. Ratna harvested 10 and 20 days prior to ripe mature stage can be stored for 6 days under ambient conditions after giving pre-treatment consisting of Ozonization @ 200 ppm and ethrel spray @ 200 ppm.