IMPROVING QUALITY AND SHELF LIFE OF MANGOSTEEN (*Garcinia mangostana* L.)

By

Ance Mathew

(2009-12-108)

DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR- 680 656

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THESIS

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DEPARTMENT OF POMOLOGY AND FLORICULTURE

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DECLARATION

I hereby declare that the thesis entitled **"Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.)"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara — Ance Mathew

15-11-2013 — (2009-12-108)

CERTIFICATE

Certified that this thesis entitled **"Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.)"** is a record of research work done independently by Ms. Ance Mathew under my guidance and supervision and that it has not previously formed the basis for award of any degree, fellowship or associateship to her.

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We the undersigned, members of the Advisory Committee of **Ms. Ance Mathew**, a candidate for the degree of **Master of Science in Horticulture**, agree that the thesis entitled **"Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.)"** may be submitted by Ms. Ance Mathew in partial fulfillment of the requirement of the degree.

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"Trust in the LORD with all your heart; and lean not to your own understanding. In all your ways acknowledge him, and he will direct your paths" - Proverbs 3:5-6

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Dedicated to

My loving

Ammachy & Family

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Abbreviations

^{0}Bx – Degree brix

µm – micro meter

BA– Benzyl Adenine

CS – Colour stage

CI – Chilling injury

DAS – Days after storage

GA_3 – Gibberllic acid

GD – Gamboge disorder

H_3BO_3 – Boric acid

KH_2PO_4– Mono potassium phosphate

kPa – Kilo Pascal

LDPE – Low density poly ethylene

NF – Normal fruits

PLW – Physiological loss in weight

PME – Pectin methyl esterase

PVC – Poly vinyl chloride

RARS – Regional Agricultural Research station

RH – Relative humidity

RT – Room temperature

SA – Salicylic acid

TFD – Translucent flesh disorder

TSS – Total soluble solids

Introduction

1. INTRODUCTION

The mangosteen (*Garcinia mangostana* L.) has been hailed as the 'Queen of tropical fruits' due to its instant visual and taste appeal (Cruz, 2001). It belongs to Clusiaceae family and is one of the best flavoured fruits in the world. Mangosteen fruits have a ready market in the western countries where it is considered as a tropical delicacy. Mangosteen extracts and processed products have now entered in the worldwide health - food and nutritional supplement market. Thailand is the world's largest producer of mangosteen. Malaysia, Vietnam, and Indonesia are also major producers (Osman and Milan, 2006).

The edible aril is white, soft and juicy with a sweet, slightly acidic taste and pleasant aroma. The fruit rind contains mangostins that are popularly used in herbal cosmetics for anti-acne properties (Pothitriat and Gritsanapan, 2008). Mangosteen has been included among an emerging category of novel functional foods sometimes called "super fruits" presumed to have a combination of appealing characteristics, such as taste, fragrance and visual qualities, rich in nutrients, antioxidant strength and potential impact for lowering risk against human diseases (Henrylito and Tacio, 2011). The latest scientific researches show that mangosteen contains a class of naturally occurring poly-phenolic compounds known as xanthones. Xanthones have a property which helps heal cells damaged by free radicals, slows aging, and ward off degenerative diseases. In addition, the mangosteen has long been used as anti-inflammatory, antibacterial medicine and also for the treatment of infections and wounds.

Currently, there is an ever-growing demand for mangosteen fruits in the metros, but the production has not yet grown to support even one-third of the current demand. Although the fruit has long been regarded as having great economic potential, mangosteen has not received much attention from farmers. In Kerala, it is grown mainly on the embankments of the rivers Pampa, Manimala and Achankovil in the districts of Pathanamthitta, Alapuzha and Kollam. Since, it

has not been very popular among the people in Kerala, the traders used to procure the fruits from the growers in these regions and send it to Chennai, the main market. The trading hub in Kerala is Konni, in Pathanamthitta district. (Nair, 2007).

Quality grading of mangosteen fruits which is very important for consumer acceptance is based on both external factors such as colour, shape, size, skin blemishes and internal factors such as translucent flesh, gummy latex and hardening of pericarp. Physiological disorders that hinder growing export market include irregular shape, damage caused by insects with symptoms of decay, fruit cracking, yellow gumming, pericarp hardening and mostly the translucent flesh disorder, observed in the recent years. (Pamplona and Garcia, 2001).

The major problems in mangosteen production are low fruit quality due to Translucent Flesh Disorder (TFD) and Gamboge Disorder (GD). It is considered that both transparent flesh and gamboge disorders remains almost "unsolvable" physiological disorders until today especially as it is influenced by agro-climatology and other environmental factors. Consequently, these disorders have downgraded the fruit quality which affects its marketability and price both in the local and international markets as well. Probable reasons for occurrence of these disorders and feasible remedial measures need to be investigated.

Mangosteen fruits have a storage and marketable life of not more than one week under tropical ambient conditions (Kosiyachinda, 1986). At room temperature, mangosteen fruits become hard and difficult to open after 20 days. Longer periods of storage cause the outer skin to toughen and the rind to become rubbery; later, the rind hardens and becomes difficult to open and the flesh turns dry. Low temperature storage is commonly used to maintain quality and storage life of many fruits but it induces chilling injury in mangosteen. Pericarp hardening occurs when mangosteen is stored at chill temperatures for a prolonged period (Bunsiri *et al.*, 2003).

Owing to lack of information on appropriate post harvest treatments, packaging, temperature etc. the fruits not only lose their quality but also encounter a substantial post harvest loss. Even though mangosteen has much export potential, its relatively short storage life affects the quality at the place of destination. Fruit is normally transported by air to distant markets and sometimes sea shipment is employed for nearby countries. However, air freight is very expensive with a high cost of distribution, whereas unsatisfactory fruit quality is often the corollary of longer duration of sea freight. Extending the storage life of mangosteen would facilitate export by sea to foreign markets and achieving optimum fruit quality, in addition to expanding domestic markets.

The demand of mangosteen in world market has increased markedly. Even though some research efforts have helped to increase the productivity of mangosteen to some extent, the purpose of obtaining maximum profit will be served, if the increased production is supplemented with the similar efforts to minimise the physiological disorders (TFD & GD) and also to enhance the shelf life.

Therefore the present study has been focused

1. To investigate whether the incidence of translucent flesh and gamboge disorders could be managed and quality of the fruit could be improved by various foliar nutrient applications during pre-harvest stages.

2. To improve shelf life of mangosteen fruits by keeping them at different temperature regimes after giving post harvest treatments using various nutrients/growth regulators.

Review of Literature

2. REVIEW OF LITERATURE

Mangosteen (*Garcinia mangostana* L.) has been considered as the most delicious fruit of the tropics and hence called “the queen of the fruits” (Fairchild, 1915) or the “finest fruit of the world” (Dalhgren, 1947). Mangosteen is an important seasonal fruit throughout Southeast Asia. It is mainly consumed fresh, and is regarded as one of the best flavoured fruits in the world. Fruits can be stored successfully for short periods of time. It can also be canned, frozen or processed into juice, jam, preserve, syrup and candy. Its demand often exceeds supply (Osman and Milan, 2006).

2.1. DESCRIPTION OF SPECIES

The genus *Garcinia* was named by Linnaeus for Laurent Garcin (1683-1757), a Swiss botanist with the Dutch Indies Company, who had published the first description of mangosteen (Corner, 1988). The genus *Garcinia* L. belongs to the family Clusiaceae (syn. Guttiferae) which contains about 35 genera and up to 800 species (Osman and Milan, 2006). The family Clusiaceae is pantropical and comprises mostly large evergreen trees, or erect shrubs, with smooth, thin bark and white or yellow latex.

Lamoureux (1980), Corner (1988) and Verheij (1992) provided the following description on *Garcinia mangostana* L. Mangosteen is a small or medium height evergreen tree, 6-25m, with a straight trunk, symmetrically branched to form a conical crown. Leaves are opposite, entire and cuspidate at the apex, oblong-elliptical, shortly petiolate (1-2 cm) and the apical pair of leaves on a branchlet are clasping to conceal the terminal bud. Leaves 15-25 cm long and 4.5-13 cm wide, shining and coriaceous, dark green, rarely yellow green, glabrous above, dull pale green beneath. Central and lateral veins of leaves paler in colour than the lamina and obvious to the eye.

Trees bearing male flowers are unknown, although described by Roxburgh in 1832, Richards (1990) states that this must have been the flower of a related species. Mangosteen shows obligate agamospermy. Female flowers are solitary, paired, or rarely 3 at apices of branchlets; pedicels 1.75-2 cm long and thick. Sepals 4 in 2 pairs, outer ones yellow-green 2 cm long, inner ones smaller with red margins. Petals 4, broadly obovate, 2-5 cm long and thick fleshy, yellow green with red margins or more or less entirely red. Staminodes many and shorter than the ovary, 1-2 seriate and 0.5 cm long. Ovary is broadly ellipsoid to globose, sessile and 4-8 celled. Stigma is sessile, 4-8 radiate and large in diameter. Fruit is a depressed globose shaped berry with thick pericarp, dark purple in colour with fleshy sweet aril. Fruits retain persistent sepals and stigma lobes. All parts of the plant contain yellow latex (Osman and Milan, 2006).

2.2. ORIGIN AND DISTRIBUTION

The mangosteen, as a cultigen, is indigenous to the Malay Archipelago (Wester, 1921; Bailey, 1946; Ochse *et al.,* 1961; Gil *et al.,* 1972). Its cultivation extends throughout Southeast Asia, Myanmar and Indo-China, where it has diffused as a home garden and wayside species; although in recent times small orchards have been established in these regions, especially in Peninsular Malaysia, Borneo, Java and the Philippines.

Despite the many species with edible fruits, mangosteen is thought to be closely related to only 2 other species: *G. hombroniana* and *G. malaccensis*, themselves indigenous to Malaysia, although the distribution of *G. hombroniana* extends to the Nicobar Islands. *G. hombroniana* is mostly wild but also planted because its wood is valued and plant parts are used in medicine. *G. malaccensis* is always wild, never planted or cultivated and is a scarcer species with a scattered distribution. Mainly juveniles of *G. malaccensis* have been found in the permanent plot in Pasoh Reserve, Negeri Sembilan in Peninsular Malaysia (Saw *et al.,* 1991).

Both wild species were well described by Richards (1990) who stated that *G. malaccensis* resembles *G. hombroniana* to a degree and *G. hombroniana* resembles mangosteen. The three species, *G. malaccensis*, *G. hombroniana* and *G. mangostana* form a natural morphological grouping with no other close relatives. These close relatives of *G. mangostana* are facultative agamospermous species and both are diploids. *G. mangostana* is a polyploid and probably tetraploid being an allotetraploid and having arisen as a hybrid between a cultivated *G. hombroniana* as the female parent and a wild *G. malaccensis* as the male parent. Chromosome number have been found to be 2n=56-76, 88-90-96, 120-130 (Verheij, 1992).

2.3. SPREAD OF CULTIVATION

The major mangosteen producing countries are in Southeast Asia, namely Thailand, Malaysia, Philippines and Indonesia. Thailand is the world's largest producer. About 85 per cent of the total production among these four countries is in Thailand (Diczbalis, 2009).

Apart from the cultivation in Southeast Asia and Myanmar, mangosteen was introduced into Sri Lanka around the year 1800 and thrives there in moist regions up to 600 m above mean sea level. (Macmillan, 1935). It was first cultivated in India during the eighteenth century and between 1880 and 1890, at the Kallar and Burliar stations in erstwhile Madras State (Krishnamoorthy *et al.*, 1964). It is now mostly seen on the lower slopes of Nilgiri Hills between 360 and 1060 m and near Courtallam.

The bulk of production in India is concentrated in homesteads of Kerala in the districts of Kottayam and Pathanamthitta along catchment areas of the rivers Pampa, Achancoil, Manimala and Meenachil and the low lying areas. Another small production centre is in Pariyaram village of Chalakkudi in Thrissur district. Another point of cultivation is the home gardens in hilly areas of Wyanad. The major harvesting season in the plains is from end of May to mid June while in

high altitudes it is during Aug-Sep. Thus in Kerala, fruits are available in two distinct periods (George *et al.,* 1996).

Mangosteen was introduced to the West Indies before 1955 and the seed was distributed through the Royal Botanic Gardens at Kew, UK (Popenoe, 1928). Outside Southeast Asia, cultivation was more in the West Indies. Mangosteen was introduced in Brazil in 1935 and currently is cultivated mainly in the states of Para and Bahia (Sacramento *et al.,* 2007). Karp (2010) reports that commercial cultivation and marketing in the United States started recently. Native to Indonesia and Malaysia, mangosteen trees require a fully tropical climate and cannot be grown commercially in the contiguous United States. For more than a century, attempts have been made to cultivate mangosteen for the United States market; in 1990s small plantings were established in Hawaii and Puerto Rico, some of which are beginning to bear fruits. Interest in the health benefit of mangosteen has boosted public awareness and consumption of mangoteen products in recent years.

2.4. ECOLOGY

Specific climatic requirement limit the distribution of mangosteen to the equatorial band between 10^0N and 10^0S latitudes (Verheij, 1992). Mangosteen is associated with areas of low elevation i.e. less than 500 m above mean sea level (Galang, 1955; Gil *et al.,* 1972). It can be grown in higher elevation but has a slower growth rate (Nakasone and Paull, 1998). Cultivation in higher altitudes is characteristic of India.

Species of *Garcinia* are found mostly in the warm and humid tropics of South and Southeast Asia as second storey trees. All wild species are adapted to shade and mangosteen is regarded as a shade tolerant tree (Ochse *et al.,* 1961; Gil *et al.,* 1972; Verheij, 1992). Mangosteen appears to require an uninterrupted water supply with a short dry season of 15-30 days, the latter initiating flowering. Ideally rainfall should be well distributed throughout the

year. Mangosteen trees can grow successfully in other areas when a constant supply of water is provided through irrigation during the dry season. Mangosteen thrives in the temperature range of 20^0-35^0C when RH is over 80 per cent. Temperature below 5^0C and above 38^0- 40^0C is lethal and since growth is slowed at temperatures 15^0- 20^0C, this range is not recommended for cultivation (Vietmeyer, 1975).

The photosynthetic rate is steady over a 27^0-35^0C range, under 20-50 per cent shade (Wiebel *et al.*, 1995). There are no reports of photoperiod response. Shade is essential during the first 2-4 years of growth both in the nursery and during early field establishment (Nakasone and Paull, 1998).The suitable sunlight intensity to be 40-70 per cent. Foliage and fruits are susceptible to sunburn in direct sunlight (Verheij, 1992).

The best soils for mangosteen cultivation are porous, deep, wet but well drained, slightly acidic, clay loams rich in organic matter (Galang, 1955; Almeyda and Martin, 1976). Mangosteen can grow successfully on a wide range of soils. In spite of a relatively weak root system, the trees can tolerate heavy soils which impede water movement, provided that the transpiration is limited by high humidity and shade. Under dry conditions, irrigation is needed and thick mulches are very beneficial (Verheij, 1992).

2.5. FLOWERING, FRUIT SET AND MATURATION

Mangosteen trees are slow to come into bearing. They usually produce their first fruits 10-15 or more years after planting (Ochse *et al.*, 1961). Bearing age under good care can be 7-9 years after planting (Almeyda and Martin, 1976). In Sri Lanka, plants have been reported to produce 2 crops a year: a light crop in January from flowers produced in August and a heavy crop in July and August from flowers produced in January (Popenoe, 1928). The fruiting season in the Philippines is from June to December (Galang, 1955). The fruit is usually available in Malaysia during June to August and December to February. In

lowland areas of Sri Lanka, the harvest is from May to July or in highland areas September to October. Krishnamoorthy *et al.* (1964) described two main seasons of flowering in mangosteen, April to May and October to November. Mangosteen is a seasonal fruit and it takes about 5-6 months from flowering to fruit ripening (Gil *et al.*, 1972). In Puerto Rico the harvest period is July and August for unshaded trees and November to December if shaded (Almeyda and Martin, 1976). However, depending on zone, weather conditions and farm management practices, fruiting season can begin four to six weeks earlier.

There are reports of existence of male and hermaphrodite flowers in mangosteen (CSIR, 1948). Krishnamoorthy *et al.* (1964) had reported female trees with staminodes. Mangosteen was reported to be unisexual and dioecious, but only female trees with infertile staminodes had been found in Malaya and Java (Purseglove, 1969). Richards (1990) observed mangosteen to be invariable and almost all being females.

Flowers of mangosteen were borne terminally on branchlets, mostly single to three, 5-6 cm in diameter, sepals 4 in 2 pairs, inner pair reddish, petals 4, yellowish, edge red, falling early, ovary 4-8 celled, stigma sessile with as many lobes as cells of ovary (Purseglove, 1969). Parhenocarpy and apomixes in mangosteen had been suggested by Lim (1984). Singh (1985) also reported parthenocarpic fruit development in mangosteen. Veeraragavathatham and Balashanmugham, (1989) described male flowers in mangosteen borne in 3 to 9 flowered terminal fascicles. There are reports of trees producing flowers in clusters up to 12 (Rai, 2004).

Mangosteen fruits have pinkish-red skin when mature, turning to a dark purple skin and white flesh. The skin should be thick and soft, but firm, when ripe. Fruit have a soft, sweet, slightly-acid flesh with a pleasant flavor. Fruits are at the edible, ripe stage when the skin has darkened to reddish purple, no latex remains in the skin, and the flesh segments separate easily from the skin (Tongdee

and Suwanagal, 1989) and soluble solid content ranges from 17 to 20 per cent and titrable acidity from 0.7 to 0.8 per cent (Kader, 2002).

Anabesa (1992) conducted a study to establish the optimal harvest period for mangosteen based on days after flower opening as determined by the physico-chemical and sensory characteristics of mangosteen fruit. Results showed that mangosteen fruits harvested as early as 113 to 116 days after flower opening had qualities comparable to those harvested at full ripeness (119 days from flower opening). Fruits which were harvested on the 113th day from flower opening had total soluble solids of 20.05 degree Brix; an edible portion of 23.95 per cent and a peel colour of greenish purple. On the other hand, those which were harvested on the 116th day from flower opening had total soluble solids of 20.73 degree Brix; an edible portion of 24.85 percent and a peel colour of grey purple with green streaks. The sensory evaluation showed that fruits harvested at 113 and 116 days from flower opening had flesh flavour and texture comparable to the fully ripe ones. Kanchanapom and Kanchanapom (1998) reported that the earliest mangosteen fruits can be harvested after fruit set is 11-12 weeks (77-84 days).

2.6. FRUIT QUALITY

The fruits are mostly eaten fresh as a dessert fruit. The quality of mangosteen fruit is affected by differences in climatic conditions (Popenoe, 1928). The fruit has high moisture content. The soft aril, the edible portion makes up about 25-30 per cent of the fruit. The fruit is a globular, indehiscent berry and either spherical or slightly flattened (Yaccob and Tindall, 1995). The fruits on a dry weight basis are made of aril 20%, rind 37%, seed 26% and calyx with peduncle 17% (Nakasone and Paull, 1998). Each mangosteen fruit weighs approximately 55-75g and contains 2-3 well developed seeds (Osman and Milan, 2006). Another report indicates that mangosteen presents an average of 32.5% of pulp, 18.17^{0} Brix and 1% of acidity (Sacramento *et. al.*, 2007).

The sugars present are sucrose, glucose and fructose (CSIR, 1948). It is generally low in minerals (Tongdee and Suwanagul, 1989) and vitamins, but calcium, phosphorous and ascorbic acid levels are comparatively high (Poomipamorn and Kumkong, 1997). The per cent of total soluble solids range from approximately 13-20 per cent depending on the maturity stage of the fruit. When immature, the range is 13-15.2 per cent, but when ripe, it is about 18.3-19.0 per cent. Aril contains a high percentage of carbohydrates, mostly in the form of sugars (Nakasone and Paull, 1998).

Pratt and Rosario (1913) reported that the seed contains about 30 per cent oil. The mangosteen aril possesses a delicate flavor. MacLeod and Pieris (1982) analysed the volatile compounds that contribute to the aroma and detected about 52 compounds. The seeds possess a nutty flavour (Coronel, 1983). Compounds isolated from the fruit peel of mangosteen contain abundant xanthones, especially alpha-mangostin (Yodhnu *et al.,* 2009). It has a long history of use as a medicinal plant, mostly in Southeast Asia (Obolskiy *et al.,* 2009). It has been used as traditional medicine such as anti-inflammatory and antibacterial and is popularly applied to cosmetic and pharmaceuticals products.

2.7. PLANT NUTRIENTS ON FRUIT GROWTH AND QUALITY

In mangosteen, leaf nutrients transferred to accumulate in fruits leading to increase in fruit size and peel thickness (Patarapiyapun, 1995). Poowarodom *et al.* (2002), also reported that N, P, K and Mg concentration in the mangosteen leaf decreased with increasing leaf age. Fruits required K during fruit development, therefore, K in leaves decrease with the progress of fruit development.

From results of nutrient analysis in mangosteen leaves, Poowarodom *et al.* (2002), reported that N, P, K, Ca and Mg concentrations were 1.33, 0.09, 1.27, 1.01 and 1.05 g/100g (dried weight), respectively, and Fe, Mn, Cu and Zn concentrations were 32.05, 90.60, 22.30 and 22.20 mg kg^{-1} ,

respectively. A study conducted in Malaysia revealed that P, K, Mg, Fe and Na concentrations in mangosteen fruits were 0.013, 0.045, 0.007, 0.013, 0.001 and 0.007g/100g, respectively (MAO, 2002).

The imbalance or deficiency of essential nutrients in soil and plants may cause poor fruit quality. To classify this issue, the pattern of plant nutrient accumulation and nutrient requirement in soils and mangosteen trees during fruit development period were investigated (Pechkeo *et al*., 2007). Mangosteen fruit qualities were not significantly different between the outer and inner canopy fruits. Likewise, most of the plant nutrients accumulation in mangosteen leaf peel and flesh nutrient were not significantly different between two fruit positions. It was remarkable that nutrient accumulation in the fruit decreased from blooming to harvest period. Mangosteen (leaf, peel and flesh) required higher amounts of N, P, K, Ca and Mg for growth in early stage of fruit development period (from bloom to 6^{th} week after bloom) and S and B in the late stage of fruit development period (from 6^{th} week after bloom) compared with other growth periods.

Leaf analysis was used as a guide to diagnose nutritional status and as a fertilizer tool for mangosteen plant (Liferdi *et al.,* 2008). Leaf age is the main factor to estimate plant nutritional status. It was found that leaves of four and five month ages were the best to be used as leaf samples to diagnose P status since they have the highest correlation (above 0.7) between P concentration in the leaf and fruit yield. P concentration decreased as the age of the leaves increased.

2.8. PHYSIOLOGICAL DISORDERS

Translucent flesh disorder (TFD) and gamboge disorder (GD) are physiological disorders of mangosteen (*Garcinia mangostana* L.) fruits caused by excess water or heavy rainfall prior to harvest (Sdoodee and Limpun-Udom, 2002). The incidence of TFD and GD are both major problems of mangosteen production in the humid tropics (Yaacob and Tindall, 1995), because these disorders cause hard flesh with poor flavour.

2.8.1. Gamboge Disorder (GD)

In gamboged mangosteen fruit, the pericarp and the fruit pulp are discolored by yellowish resin which turns reddish brown and hardened later. Affected fruit exude yellow latex which is responsible for the discoloration and change in taste. In fact, the yellow resin is naturally produced by several organs which consist of branched canal-liked secretory ducts. They are found in the exocarp, mesocarp and endocarp, aril of the fruit, flower, stem and leaf. The biggest secretory ducts are located in the endocarp which continues from the fruit stalk to the fruit. The bitter yellow resin permeates into the aril as a result of broken latex secretory ducts caused by excessive rain, winds, care less fruit handling which induce physical damage to the fruit pericarp and also due to some types of pest infestation, particularly by caspids (Sdoodee and Limpun- Udom, 2002).

The gamboge disorder occurs where latex seeps into the flesh (aril) turning it yellow and giving it a bitter taste. The gamboge also moves onto the outer surface of the fruit. This is a pre harvest disorder of unknown cause that makes it difficult to separate the aril from the surrounding tissue, even in ripe fruit; it causes hardening of the pericarp (Paull and Ketsa, 2002). GD was found to be due to large difference in water potential between the soil and the plant, and particularly when there is rapid movement of water and solutes into the fruit after sudden rewatering (Sdoodee and Limpun-Udom, 2002).

Sdoodee and Limpun-Udom (2002) suggested that a mild soil water deficit of approximately -70kPa should be maintained during pre-harvest. However, some balance will be needed as any abrupt changes in such soil water potential values, as a result of rainfall, are likely to lead to a high occurrence of GD. According to Poerwanto *et al.* (2009), latex secretory ducts are usually broken at 5-15 weeks after anthesis during the rapid fruit growth period. The seed and aril growth rates are reported to be faster than the pericarp causing a building up of internal pressure to the endocarp. The resultant pressure causes the secretory ducts to break especially when the epithelial cells of the ducts are weak.

2.8.2. Translucent Flesh Disorder (TFD)

Flesh translucency (TFD) of mangosteen fruit shows as a water soaking of the flesh. The incidence of TFD was caused by excess water during the pre-harvest stage of fruit development, where water-uptake was driven by the difference in osmotic potential between that of rain water and that of the affected fruits. When water content in fruit is high, this leads to a breakdown of apoplast or symplast compartmentation which is exhibited as the occurrence of TFD (Luckanatinvong, 1996). Symptoms are internal and include flesh changes from white to translucent and textural changes from soft to firm and crisp. This disorder may result from mechanical injuries, nutrient imbalance, and/or excessive water uptake into the flesh (Kader, 2002).

In the mangosteen fruit, excess water supply by either rain or by irrigation during pre-harvest has been shown to cause TFD incidence (Laywisakul, 1994; Sdoodee and Limpun-Udom, 2002). Under severe conditions of excess water, fruit cracking is also concurrently found in fruits with translucent flesh disorder. Pankasemsuk *et al.* (1996), observed that fruits exhibiting translucent flesh disorder had significantly higher rind (65%) and flesh (82%) water contents than fruits with normal flesh (63% and 80% in the rind and flesh, respectively). Specific gravity of translucent flesh fruit was >1 and that of normal flesh fruit was <1. Fruit specific gravity and natural transverse rind cracking were used to separate translucent-fleshed fruits from normal fruits. Translucent-fleshed fruits had a lower soluble solids concentration and titratable acid percentage than normal fruits. Translucent flesh was induced in normal fruits following water infiltraion at 39 kPa for 5 minutes.

2.9. YIELD

Singh (1985) reported an average yield of 200 to 400 fruits per tree in India as compared to 500 to 1500 fruits in other countries. Kay-ming (1990) observed that in Hainan, China average yield from 18-20 year old bearing tree

was 23-25 kg indicating that the yield of mangosteen tree is rather low and not stable. Under optimum conditions in Malaysia, mangosteen trees begin to fruit 8-10 years after planting. The yield varies from tree to tree and from season to season. The first crop may yield 100-300 fruits per tree and about 500 in a fully grown tree. The yield steadily increases up to 1000-2000 fruits per tree in the 10-20th years of cropping. In Thailand, an average yield of 400 fruits per tree is reported (Osman and Milan, 2006).

In the Nilgiri hills in Southern India, trees in two small orchards produced an average of 360 fruits per year over a period of 18 years, the best trees yielding consistently up to 500 fruits per year (Verheij, 1992). Older trees (45 years) can yield 3000 fruits per tree and then decline in yield (Kanchanapom and Kanchanapom, 1998). In Indonesia, the yield increases from average of 10-20 fruits per tree after the 5th year to more than 1000 fruits per tree after 15th year. In Australia, yields are variable and about 400-900 fruits can be harvested from each mature tree (Chay-Prove, 2004).

It was found that in mangosteen, the total yield per tree was higher in trees grown in the river belts. The trees grown in the rocky terrain were stunted and yield per tree was significantly poor (250-500 fruits per tree). On the other hand, an adult healthy tree grown in the river belts yielded up to 1500 fruits (George *et al*., 1996). Yields of 200-800 fruits per full grown plant have been reported in places with good soils and up to 2000 fruits per tree have been noted. Average crops to aim for are 400-700 fruits per tree (Osman and Milan, 2006).

2.10. EFFECT OF PRE-HARVEST FOLIAR NUTRITION

Plants usually absorb water and nutrients by their roots, therefore fertilizers are traditionally applied into soil. While soil application can supply enough nutrients to improve plant production, it also causes world-wide anxiety about environmental contamination for nutrients leaching into ground water (Dinnes *et al.,* 2002). The efficient use of fertilizers to increase crop yield is an

important goal in agricultural systems. However matching nutrient application to crop requirements is not easy. It has been and will continue to be an ambitious pursuit for researchers and growers to maximize nutrient uptake by crops on the other hand, minimizing fertilizer application and leaching loss (Dong *et al.,* 2005)

The power of plant leaves to absorb nutrients has resulted in the fact that the foliar application of nutrients becomes a recurrent method for supplying nutrients to plants (Swietlik and Faust, 1984). Foliar fertilization has the advantage of low application rates, uniform distribution of fertilizer materials and quick responses to applied nutrients. Moreover, hidden hungers can easily be managed (Umer *et al.,* 1999).

2.10.1. Reduction of Gamboge & Translucent Flesh Disorders

Physiological disorders associated with inadequate calcium (Ca) nutrition have been reported in numerous tree fruits including mangosteen (Pludbuntong *et al.,* 2007; Poovarodom and Boonplang, 2008). Mangosteen fruit with low Ca is susceptible to translucent flesh and gamboge disorders. High potassium (K) to Ca ratio was linked to translucent flesh disorder which is a consequence of impaired membrane function. Meanwhile, gamboge disorder was associated with imbalanced calcium-boron ratio.

Kheoruenromn (1990) stated that calcium deficiency together with the excess water in the plant might be the reason for fruit cracking. Potassium, calcium and boron concentrations in the peel of normal fruits were observed to be higher than those of TFD fruits. Moreover, Ca concentration in the flesh of normal fruits was higher compared to that of TFD fruits, whereas boron, potassium and magnesium concentration in the flesh of normal fruits were found to be lower than those of TFD fruits (Limpun-Udom, 2001; Pechkeo *et al.,* 2007). Calcium deficiency results in imbalance of K, Ca and B in the mangosteen fruit, which might be the cause of TFD.

Calcium deficiency increases membrane permeability and contributes to the release of solutes from cytoplasm. Low Ca concentration in fruits are not primarily caused by low Ca supply or low Ca uptake by the plant but by limited ability of the plant to distribute Ca in phloem (Bangerth, 1979). It has been suggested that Ca uptake by the fruit occurred only during the first part of its growth period (Faust, 1989) while Zavalloni *et al.* (2001), reported that Ca uptake was continuous and linear until harvest.

Limpun-Udom (2001) found that Ca and B concentrations in the peel and Ca concentration in the flesh of normal mangosteen fruit (NF) were high compared with TFD and GD fruits, whereas B concentration in the flesh of NF fruits were lower than those of TFD and GD fruits. An important role of boron is to support Ca function in plant. Pechkeo *et al.* (2007) reported that the applications of $CaCl_2$ and H_3BO_3 could increase Ca and B concentrations in peel and flesh of mangosteen fruits. Spraying with 10% $CaCl_2$ could also increase the percentages of normal fruits (NF), whereas the percentages of defective fruits (TFD and GD) decreased. Spraying 10% $CaCl_2$+0.5 mg kg^{-1}B enhanced the efficiency of Ca to increase the ratio of NF: TFD and GD.

Sdoodee and Limpun- Udom (2002) reported that gamboge and translucent flesh disorder can be rectified by application of adequate calcium nutrient to mangosteen trees. Calcium as one of the important components of the middle lamella in the form of calcium pectate that binds together the contiguous cell walls is a major factor in withstanding such pressure. Hence, application of dolomite fertilizer at rate of 18-24 tons/ha has been reported to improve calcium content in the exocarp and leaves; and at the same time, it effectively reduces gamboge (GD). Also, it is reported that applications of $CaCl_2$ spray effectively reduced yellow spots either on the pericarp or the aril of mangosteen.

Poovarodom and Boonplang (2008) found that the ratio of K/Ca in the flesh is a good indicator of TFD. The study revealed that high K/Ca ratio led to more TFD in mangosteen. In general, flesh Ca decreased with fruit size while

flesh K increased. As a result, larger fruits tend to have more TFD than smaller ones. When soil Ca was applied, the number of GD was significantly lower than the control. The soil Ca treatment became even more effective when combined with B spray or Ca + B spray, particularly the latter. However, treatment of soil Ca together with Ca spray did not reduce GD considerably. It was found that the nutrient concentrations in all parts of GD fruits were not measurably different from normal or TFD fruit.

2.10.2. Keeping quality

In comparison to other similar fruits Mehaisen *et al*. (2005), reported that Baladi Guava trees (*Psidium guajava* L.) (local cv.) of 9 years old planted in clay soil were sprayed in 2002 and 2003 seasons with two concentrations (0.25 %, 0.5 %) of either Boron as boric acid or zinc as zinc sulphate. Results in both seasons showed that pre-harvest treatments were effective in improving fruit quality and storability, especially zinc and boron at 0.50 %.

Calcium nitrate at 1.0 per cent applied as foliar sprays at two different stages in aonla fruits showed the minimum physiological loss in weight (PLW) which was closely followed by $Ca(NO_3)_2$ at 0.75 per cent as compared to untreated fruits, where maximum PLW was recorded after 15 days of storage. The PLW increased gradually and progressively under all the treatments with the prolonged storage periods. The reduced PLW in fruits during storage is mainly due to reduced rate of transpiration and respiration. Minimum pathological loss was recorded under 1.0 per cent Ca $(NO_3)_2$ treatment at 5, 10 and 15 days after storage, while, maximum loss was found under control. Calcium treatment reduces the internal breakdown and disease incidence. It is known that calcium is an integral part of the cell as calcium pectate and it maintains fruit firmness (Yadav and Shukla, 2009)

2.10.3. Quality & Yield attributes

A foliar spray at the fruit development stage is more effective than applying fertilizer to the soil. Balanced nutrient at proper time is one of the means to reach a commercial fruit production, improved yield and fruit quality. Foliar program at key stages can have a marked positive effect on fruit yield and quality (Barker and Pilbeam, 2006).

Poovarodom (2009) reported that a strong relationship between fruit diameter and fruit weight was observed. The concentration of Ca, K, Mg and B in the fruits declined sharply during the first 5 weeks of fruit set before leveling off. However, the total amount of each nutrients accumulated in the fruits (including Ca) increased throughout the season reaching the maximum value at the end of fruit growth, right before harvest. Phloem appears to facilitate movement of K, Mg and B into fruits. The continuous increase of accumulated Ca until harvest suggests that, in order to raise Ca content effectively, soil or spray application of Ca should not be limited to the early period after the fruit sets but extended to harvest.

Foliar application of B increased yield and fruit quality of grape (Donna, 1986). Boron (H_3BO_3) is considered to be a nutrient that increases the phloem carbohydrate movement (Marschner, 1995) which may increase fruit soluble solid content. Wojcik (1999) reported that boron decreased acidity in fruit of prune. Soil drench or foliar application of boron has increased yield and fruit quality, in raspberry (Wojcik, 2005).

Dixi and Gamdagin (1978) claimed that a foliar spray application of $ZnSO_4$ in March and April increased size, TSS and juice of oranges. Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory factor of a large number of enzymes (Bowler *et al.,* 1994). Zinc induces pollen tube growth through its role on tryptophan as an auxin precursor biosynthesis (Chaplin and Westwood, 1980). Growth of the receptacle is controlled primarily by auxin, which is synthesized in achenes

(Archbold and Dennid, 1984), therefore $ZnSO_4$ is applied to increase fruit number, size and quality. Zinc and boron have important role on pollination, fruit set and total yield (Motesharezade *et al.*, 2001). Zinc has also shown to have an important role in photosynthesis and related enzymes, resulting in increasing sugar and decreasing acidity (Abedy, 2001). $ZnSO_4$ permits normal development of new leaves (Barker and Pilbeam, 2006).

Ashok and Reddy (2008) reported that highest fruit yield was recorded in mango trees (Mango cv. Baneshan) treated with H_3PO_4 0.5 per cent or K_2HPO_4 1.0 per cent spray. Average fruit weight and titrable acidity was highest in trees treated with K_2HPO_4 1.0 per cent spray. The effect of potassium on increasing fruit weight and dimensions was reported for many fruits. Saleh *et al.* (2007) reported that potassium dihydrogen phosphate as a foliar spray had a positive effect on leaf mineral content, yield and fruit quality of Thompson seedless grapevines specially when sprayed at 1% concentration every 10 days or 1.5% every 20 days from the beginning of April till end of July. Sarrwy *et al.* (2010) observed that foliar spraying of potassium nitrate and mono potassium phosphate at different concentrations in picual olive trees caused a remarked promotion in leaf nutrient status, yield and fruit quality compared to control trees.

2.11. SHELF LIFE OF MANGOSTEEN

Mangoteen (*Garcinia mangostana* L.) fruit has short shelf life at ambient temperatures. Low temperature storage is commonly used to maintain quality and extend shelf life, but it can also cause chilling injury (CI), of which pericarp hardening is a common symptom for mangosteen fruit. The pericarp hardening can occur when the mangosteen fruit is stored at chill temperatures for a prolonged period (Uthairatanakij and Kesta, 1996). Jarimopas *et al.* (2009) investigated postharvest damage in fresh mangosteens at wholesale level in Thailand from April to Oct. 2004. A total of 37.1% of the production yield was rendered inedible by damage during this period. Damages included fruit cracking, hardened rinds, rough surfaces, translucent flesh, gummosis and decay.

2.12. POST HARVEST LIFE UNDER DIFFERENT TEMPERATURE CONDITIONS

Temperature and RH of the storage room are prime factors affecting the shelf-life of mangosteen. Suitable storage conditions for mangosteen reported by many researchers are in the range of 4-13°C at 85-90% RH depending on the stage of ripening, harvesting method and transportation (Martin, 1980; Augustin and Azudin,1986). At low temperatures (9-12°C), mangosteen may have a storage life of up to four weeks (Martin, 1980). At present, the best method for fruit storage is by keeping the fruit under refrigeration. Mangosteen fruits have a storage and marketable life of not more than one week under tropical ambient conditions (Kosiyachinda, 1986).

Fruit colour is an important marketing attribute of mangosteen and influences both consumer acceptance and sales. The attractive purplish-red of mangosteen is mainly due to anthocyanin (Du and Francis, 1977). Anthocyanin contents in mangosteen fruit pericarp stored at 15^0, 25^0, 30^0 (RT) and 35^0C were increased accordingly from stage 1 to stage 6 and had the highest level of anthocyanin at stage 6. The fruits stored at 35^0C had the highest anthocyanin content followed by at 30^0, 15^0, 25^0, respectively with non-statistical difference. It was found that temperature had no effect on anthocyanin content in any stage of fruit development (Ratanamarno *et al.*, 2005).

The eating quality of mangosteen fruits stored at 12^0C was better than that of fruits stored at 3^0 and 6^0C. Eating quality at 12^0C did not diminish until 10 days of storage, but only less than half acceptable after 25 days of storage (Choehom *et al.,* 2003). Pericarp firmness of mangosteen fruit at the red brown and red purple maturity stages stored at 6^0 and 12^0 C did not change until day 12 and then firmness increased rapidly, several fold, thereafter. The increase was greater at 6^0C than at 12^0C and the more mature red purple fruit had greater firmness than red brown fruit (Dangcham *et al.,* 2008).

Fruit held at room temperature after harvest can be stored for three weeks (Martin, 1980). Storage at 13°C is suitable for maintaining a high standard of quality, and the ideal transit temperature range is 13-25°C. Experiments have shown that fruits can be stored for 7 weeks at 4.5°C and 85-90% RH, but hardening of the pericarp under such conditions causes a reduction in fruit quality (Chacko *et al.,* 1995). Fruits that have been harvested at a stage suitable for export can be kept the longest under storage. The optimum temperature of the cold room for storage is 2°C. At this temperature, fruits can be kept for 42 days. However, the optimum storage period at this temperature is from 1-21 days after harvest. Fruits kept in a cold room should be sealed in airtight plastic bags. During this time, fruits maintain initial quality and are suitable for consumption. Storage for longer periods will cause the rind to harden and change colour (Osman and Milan, 2006).

2.12.1. Chilling Injury (CI)

Mangosteen has a thick skin covering the white aril, which is edible. It has been reported that optium storage conditions for the mangosteen were between 4^0C and 6^0C at 85% to 90% relative humidity (RH) for a maximum storage time of 49 days. However, storage at low temperatures induces hardening and browning of the skin, rendering it unmarketable (Salunkhe and Desai, 1984). Damage to skin does not affect senescence of the aril, but 25% of the skin damaged fruit, became inedible (Augustin and Azudin, 1986). CI symptoms induced at low temperature also often becomes more expressed upon transfer to subsequent non-chilling or high temperatures.

Immature fruits are generally more sensitive to CI than mature fruit (Wang, 1990). In contrast, with mangosteen fruit, it was found that the more mature fruit were more sensitive to CI than less mature fruit. This was similar to blackheart injury in mature pineapple fruit (Zhou *et al.,* 2003). Kondo *et al.* (2003) reported that the hardening and browning, which are associated with chilling injury (CI), were observed only in the skin of fruit stored at 7°C.

However, the hardening of skin was not accompanied by moisture loss. Storage at <10°C leads to rapid hardening and darkening of the pericarp when mangosteen fruits are returned to ambient temperature (Uthairatanakij and Ketsa, 1996; Choehom, 1997).

2.13. EFFECT OF DIFFERENT POST-HARVEST TREATMENTS ON SHELF LIFE ENHANCEMENT

2.13.1. LDPE Packing

Studies to determine the extension of storage time of mangosteen fruits when packed in polyethylene (LDPE) film bags with different thicknesses at temperatures of 8°C and 13°C were carried out by (Pakkasarn *et al.,* 2003). These authors found that, compared to non-packed fruits, the use of polyethylene film bag, regardless of thickness and temperature of storage, increased the shelf life of fruits. Fruits kept at 13 °C and packed in LDPE film bag of 40 and 80 μm had the longest retention period (24 days), but the thickness of 40 μm maintained higher quality than that of 80 μm. These same authors later compared the use of 40 μm LDPE with 42 μm PVC (polyvinyl chloride) to prolong the preservation of the fruit at 13 ºC, individually and in packs of four (4). LDPE was more effective than PVC, and the package with four fruits was better than the individually packed fruits in terms of respiration inhibition, ethylene production, weight loss, shell brightness, chlorophyll cup, and firmness of the fruit. Therefore, fruits packed with LDPE had a storage period of 24 days. Fruits individually wrapped in LDPE or PVC lasted for 20 and 16 days, respectively. Soluble solids and acidity were not adversely affected.

2.13.2. Cling film wrapping

Anabesa *et al*. (2001) reported that the cling film provided an effective barrier to moisture loss. After 5 days under ambient conditions, weight loss of fruits was 4.04-5.64% compared to 10.77-13.14% of the control fruits. Alleviation of water stress by the use of cling wrap retarded the physiological deterioration of fruits, extending their shelf life by 3 to 6 days over that of the

control. Regardless of the maturity stage of the fruits, the film wrap significantly delayed hardening of the pericarp by 3 to 5 days.

2.13.3. Ethylene absorbent ($KMnO_4$)

Mangosteen is a climacteric fruit. Ethylene production in mangosteen is about 29µL/kg/hr (Noichinda, 1992). Strawberries packed in PVC film containing ethylene absorbent (KMnO4) stored at low temperatures, showed a decrease in respiratory rate and an increase in storage life from 20 to 30 days, maintaining the relationship sugars/acids acceptable for consumption. (Hao and Hao, 1993). Jiang *et al.* (1997), found that PVC packing (0.07mm thickness) containing ethylene absorbers, K_2MnO_4–amargosite and $KMnO_4$, respectively, was more efficient in prolonging conservation of post-harvest bananas, by offering a longer pre-climacteric period. Chamara *et al.*(2000), reported that there is a longer fruit ripening delay when potassium permanganate combination with polyethylene film is utilised. Several studies have shown that $KMnO_4$ applications delay fruit softening and increase post harvest life (Illeperuma and Jayasuriya, 2002; Castro *et al.*, 2005; Correa *et al.*, 2005).

2.13.4. Calcium chloride treatment

Post harvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus extending storage life of fresh fruits (Chaplin and Scott, 1980). Calcium treatment help to retain fruit firmness, increases Vitamin C content (Poovaiah, 1986). According to John (1987), addition of calcium improves rigidity of cell walls and obstructs enzymes such as polygalcturonase from reaching their active sites, thereby retarding tissue softening and delaying ripening. Cheour *et al.*(1990), stated that the application of calcium increased fruit calcium content and influenced several post harvest senescence changes involving free sugars, organic acids, anthocyanin content and texture of fruits.

2.13.5. Presoaking with water

Noichinda (1992) found that the peak of ethylene production in mangosteen fruits occurred 2.5-3 days after climacteric peak. Water applied through cut surface of fruit stem caused the increases of respiration and ethylene production and the fruits attained Colour stage (CS) - 4 faster by 2 days. Ethylene production resulted in rapid occurrence of climacteric peak.

2.13.6. Gibberellic Acid (GA_3) treatment

Gibberellins (GA_3) are a group of growth substances, which are known to retard ripening and senescence of fruits. The effect of GA_3 seems to be mainly on colour development, although other aspects of ripening processes are also affected (Khader, 1992). Noichinda (1992) found that mangosteen with fruit stem and calyxes dipped in 1000ppm GA_3 solution had lower concentrations of inernal CO_2 and ethylene as compared to control.

According to Wills *et al.* (1998), during ripening of fleshy fruits, changes occur in tissue permeability and cellular compartmentation. The GA_3 treatment which causes the decrease in the tissue permeability and thereby reducing the rate of water loss, leads to delayed fruit ripening. Sudha *et al.* (2007) postulated that the reduction of weight loss in the fruits treated with GA_3 might be due to its anti-senescent action.

2.13.7. Salicylic Acid (SA) treatment

Lam *et al.*(1987), stated that the Salicylic acid as antitranspirant chemical, which can retard the moisture loss associated with pericarp browning of fruits. Besides, senescent changes resulting to losses in physicochemical changes and nutritional qualities can also be inhibited; consequently fruit storage life could be markedly prolonged. SA has been shown to inhibit the conversion of ACC (Aminocyclopropanecarboxylate) into ethylene (Leslie and Romani, 1988) by suppressing ACC oxidase activity (Fan *et al.,* 1996). SA is also involved in local and systemic resistance to pathogens (Yalpani *et al.,* 1994; Kang *et al.,* 2003).

Salicylic acid is a plant hormone inhibiting ethylene biosynthesis and delaying the senescence (Ozeker, 2005).

Salicylic acid (SA), a common plant-produced phenolic compound, is an endogenous growth regulator, which participates in the regulation of physiological processes in plants. Exogenous application of salicylic acid may influence stomata closure, ion uptake and transport (Khadiga, 1993), inhibition of ethylene biosynthesis, transpiration and stress tolerance. Accordingly Khan *et al.* (2003), reported that exogenous salicylic acid pretreatment could change the antioxidant system and maintain the nutritional value of fruits and vegetables, which have a higher ability to withstand oxidation injuries. Also found that application of SA was effective in reducing the rate of respiration and ethylene production and yielding higher amount of ascorbic acid.

2.13.8. Benzyl adenine treatment

Choehom *et al.* (2003), reported that BA delayed calyx and stem shriveling during storage, thereby allowing at least 25 days of storage. It is concluded that storage of mangosteen at 3 and 6°C induced unacceptable pericarp discoloration and pericarp hardening, whereas storage at 12°C did not. Dipping in BA can be used to extend the storage period at 12°C.

2.13.9. Sodium erythorbate treatment

Fresh cut mangosteens dipped in the solution consisting of Sodium erythorbate and calcium chloride, prior to storage under Modified Atmospheric Packaging (5% O_2 and 9% CO_2), resulted in the best overall retention of lightness, firmness and sensory quality (Manurakchinakorn *et al.*, 2010)

2.13.10. N – acetyl cystene treatment

In sliced bananas higher cysteine concentrations delayed browning and softening and maintained higher visual quality for 7 days at 5^0C (Kader *et al.*, 2006).

2.14. PHENOLS AND POST HARVEST LIFE OF MANGOSTEEN

Mangosteen fruit is a rich source of phenolic compounds such as xanthones, condensed tannins and anthocyanins (Mahabusarakam *et al.,* 1987; Jung *et al.,* 2006; Fu *et al.,* 2007). Phenolic compounds constitute about one-third of the dietary phenols and they are present in plants in the free and bound forms (Robbins, 2003). The content of phenolics in fruits is affected by the degree of maturity at harvest, genetic differences, pre harvest environmental conditions, post harvest storage conditions and processing (Shahidi and Naczk, 2004).

Zadernowski *et al.* (2008) reported that the mangosteen rind contains over threefold more total phenols than the peel, while the edible aril is a very poor source of phenolics. Total phenols ranged from 6.4 ± 0.5 g/kg d.m.^{A} in the aril to over 218.1 ± 18.0 g/kg d.m.^{A} in the rind (^{A}:- g (+)-catechin equivalents per Kg of dry matter of sample).

The phenolic acids are mainly located in the pericarp of mangosteen fruit. The peel, rind and aril of the mangosteen contain eight, six and five phenolic acids respectively. Free phenolic acids comprised from 5.5% (rind) to 18.7% (peel) of the total phenolic acids present in mangosteen fruits. Hydroxybenzoic acid derivatives were the major phenolic acids found in the peel and rind, while hydroxycinnamic acid derivatives dominated in the aril.

The fraction of free phenolic acids may not make a significant contribution to the aril flavour (Bunsiri *et al.,* 2003) tentatively identified to two free phenolic acids, namely sinapic and p-coumaric acids, in the pericarp of mangosteen fruit. These phenolics are involved with lignin synthesis in mangosteen pericarp leading to its hardening. Rapid decrease in the content of these phenolic acids was noticed in fruits subjected to mechanical impact. The rate of the disappearance of these phenolic acids was, however, enhanced by fruit maturity and the presence of oxygen. Bound phenolic acids were the predominant phenolic acids in mangosteen fruits. Phenolic acids liberated from soluble esters

comprised from 41.4% (peel) to 76.5% (aril) of the total phenolic acids present in the fruits. Phenolic acids are mainly located in the pericarp of mangosteen and that hydroxybenzoic acid derivatives are the major phenolic acids found in mangosteen fruits. (Zadernowski *et al.,* 2008).

Pericarp hardening is clearly associated with an increase in firmness and lignin contents. A negative correlation exists between total free phenolics and lignin contents and pericarp firmness (Uthairatanakj and Kesta, 1996). The decrease in total phenolics and increase in lignin contents occurred before the pericarp hardening in fruit stored at low temperature, suggested that phenolics incorporated into lignin (Bunsiri *et al.,* 2003), resulting increased lignin contents and then pericarp hardening. Total free phenolics contents in reddish purple fruit stored at 6ºC for 12 days were lower than those stored at 6ºC for 0 and 6 days. After transfer to room temperature, phenolics contents decreased slightly, but there was no significant difference with increasing storage time (Dangcham and Ketsa, 2007).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.)" was carried out in the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur during 2009-2011.

3.1. EXPERIMENT SITE, SOIL AND CLIMATE

The experiment was laid out in the orchard of the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara. The area is located at an elevation of 22.5 m above mean sea level and between 10^0 32' N latitude and 76^0 3' E longitudes.

The soil of the experimental site was sandy loam in texture and acidic in reaction. The area lies in a typical warm humid tropical climate with more than 80% of the rainfall getting distributed through South-West and North-East monsoon showers. The climatalogical data during the period of investigation are given in Appendix I.

3.2. MANGOSTEEN TREES

Eight year old bearing mangosteen trees in the Orchard, College of Horticulture, Vellanikkara were utilised for the experiments to improve fruit quality and to minimise flesh disorders.

3.3. MANGOSTEEN FRUITS

Good quality mangosteen fruits for storage studies were collected from RARS Ambalavayal, Wayanad and the orchard of College of Horticulture, Vellanikkara.

3.4. GENERAL MANAGEMENT IN THE EXPERIMENT FIELD

In the experiment plot mangosteen trees were maintained with proper shading, irrigation, manuring and other intercultural operations. Stray incidences

of leaf eating caterpillars were noticed in the new flushes which were controlled by spraying recommended doses of contact insecticide.

3.5. EXPERIMENTAL DETAILS

3.5.1. Experiment 1 – Improving fruit quality and minimising flesh disorders

Experiments were conducted to find out the effect of foliar application of nutrients on the fruit quality improvement and also on the reduction of flesh disorders including Gamboge (GD) and Translucent Flesh Disorders (TFD). Each treatment was given as three foliar sprays during 4^{th}, 8^{th} and 12^{th} week after bloom.

Design – CRD

No. of treatments – 11

No. of replications – 3

3.5.1.1. Treatments

T 1 – Control

T 2 – Calcium chloride 1%

T 3 – Calcium chloride 2%

T 4 – Boron 0.1% (0.5% Borax)

T 5 – Boron 0.2% (1.0% Borax)

T 6 – Calcium chloride 2% + Boron 0.1%

T 7 – Calcium chloride 2% + Boron 0.2%

T 8 – Zinc sulfate 300ppm

T 9 – Urea 0.5%

T 10 – Potassium nitrate 2%

T 11 – Mono potassium phosphate 0.5%

3.5.2. Experiment 2 – Enhancing shelf life

Experiments were done in order to understand optimum storage conditions required for the fruits. Fruits free of bruises were harvested at commercial maturity and subjected to following treatments. Treated fruits were packed in LDPE bags having 0.05 mm thickness and stored at five temperature regimes 5 ± 1^0C, 10 ± 1^0C, 15 ± 1^0C, 20 ± 1^0C and room temperature.

Design – CRD

No. of treatments – 20

No. of replications – 3

No. of fruits/treatment – 20

3.5.2.1. Treatments

T 1 – With ethylene absorbent ($KMnO_4$)

T 2 – Presoaking in cold water

T 3 – Presoaking in hot water (50^0C for 1 minute)

T 4 – Wrapping individual fruits with cling film

T 5 to T 7 – Dipping calyx and stem end in BA 100, 200, 300ppm

T 8 to T 10 – Dipping calyx and stem end in GA_3 200, 400, 600ppm

T 11 to T 13 – Dipping calyx and stem end in Salicylic acid 1%, 2% and 3%

T 14 – Dipping fruit in Sodium erythorbate 2%

T 15 – Dipping fruit in N – acetyl cystene 0.05%

T 16 – Dipping fruit in Calcium chloride 0.2%

T 17 – Dipping fruit in Sodium erythorbate 2% + Calcium chloride 0.2%

T 18 – Dipping fruit in N – acetyl cystene 0.05%+ Calcium chloride 0.2%

T 19 – Farmer's practice (Keeping in rattan basket and covered with dried banana leaves)

T 20 – Control

3.6. OBSERVATIONS

The main observations recorded are detailed below.

3.6.1. Experiment 1 – Improving fruit quality and minimising flesh disorders

3.6.1.1. Time of flowering

Date of first flowering of individual trees was recorded.

3.6.1.2. Fruit retention

Number of fruits dropped at various stages of fruit development was noted and remaining fruits retained were counted.

3.6.1.3. Days to maturity

Flowers were tagged on the day of anthesis and the days taken from fruit set to reach harvest maturity was noted.

3.6.1.4. Percentage occurrence of Gamboge and Translucent Flesh Disorder

Number of fruits affected with gamboge and translucent flesh disorder out of total number of fruits per treatment was noted and expressed as percentage.

3.6.1.5. Position of fruits affected with translucent flesh and gamboges disorders

Direction and position of fruits affected with translucent flesh and gamboges disorders were noted.

3.6.1.6. Fruit diameter at fortnightly interval

Circumference of the fruits was measured using a thread and its length measured using a meter scale at every 2 week interval from fruit set to

maturity. Fruit diameter (2r) was calculated from the circumference (2πr) and the average expressed in centimeters.

3.6.1.7. Fruit physical characters at harvest

3.6.1.7.1. Fruit length, breadth and circumference

Length, breadth and circumference of the fruits were measured using a thread and its length measured using a meter scale and the average expressed in centimeters.

3.6.1.7.2. Fruit number and weight

Individual fruits in each treatment were labeled immediately after harvest. Then number of fruits was counted and fruit weight was recorded using an electronic balance and the average expressed in grams.

3.6.1.7.3. Fruit colour

The ripe fruits were classified into purplish red, purple, dark purple or black as per the colour indices developed by MAO (2002).

3.6.1.7.4. Fruit firmness

Firmness of fruit was measured using the instrument Penetrometer and the average expressed in kg/cm^2.

3.6.1.7.5. Specific gravity of fruits

Specific gravity of fruits was determined by simple technique suggested by Mohsenin (1970). The fruit was first weighed in air using a digital balance and then it was weighed by submerging into water at room temperature. The specific gravity of mangosteen was calculated as

$$\ell = \frac{(W_{air}) \times (\ell_{water})}{(W_{displaced\ water})}$$

where, ℓ is the Specific gravity of the mangosteen fruit; W_{air} the Weight of the fruit in the air; ℓ_{water} the Specific gravity of water; $W_{displaced\ water}$ is the weight of water displaced.

3.6.1.7.6. Rind – Pulp ratio of fruits

The fruit rind was carefully separated from white segmented pulp and the weight was recorded separately to calculate rind/pulp ratio.

$$\text{Rind – Pulp ratio} = \frac{\text{Weight of rind}}{\text{Weight of pulp}}$$

3.6.1.7.7. Number of segments

The number of white juicy segments was counted immediately after the fruit was opened and the average expressed as number.

3.6.1.7.8. Number of viable seeds

The number of viable seeds per fruit was counted and the average expressed as number.

3.6.1.7.9. Colour of pulp

Pulp colour of fruits were noted.

3.6.1.7.10. Sorting of fruits according to size

Fruits from individual trees were sorted according to fruit size and they were grouped into four with fruits having weights of <50g, 50-75g, 75-100g and >100g.

3.6.1.8. Fruit chemical characters at harvest

3.6.1.8.1. Moisture content

Weight of fruit samples immediately after harvest was taken and samples were dried in an oven maintained at 60^0C till the weight of the samples remained constant. Moisture content of fruits were determined by reducing final weight from initial weight and expressed as percentage.

3.6.1.8.2. Total soluble solids (TSS)

Total soluble solids was determined in freshly extracted juice of ripe fruits using Erma hand refractometer with a range of $0\text{-}30^0$ brix and expressed in degree brix (AOAC, 1980).

3.6.1.8.3. Acidity

Titrable acidity of the fruit pulp was estimated by titration with standard sodium hydroxide solution and expressed as percent anhydrous citric acid following Ranganna (1977).

3.6.1.8.4. Ascorbic acid

Ascorbic acid content of fruit at harvest stage was estimated by titration with 2, 6 – dichlorophenol indophenol dye and was expressed as mg per 100g of fresh fruit (Sadasivam and Manickam, 1997).

3.6.1.8.5. Total sugars

Total sugars were estimated by the Lane and Eynon method as outlined by Ranganna (1977) and expressed in percentage.

3.6.1.8.6. Organoleptic evaluation of fruits

A score chart was prepared based on nine Point Hedonic scale, where zero denotes poor and nine represent excellent quality. Quality attributes included in the score chart were taste, flavour, colour and texture. Organoleptic evaluation of ripe fruits was done by a panel of 15 semi trained persons.

3.6.1.9. Chemical Analysis

3.6.1.9.1. Soil analysis

Soil samples before treatment and after harvest were collected from the experimental area to compare nutrient status.

i) Available nitrogen

Available nitrogen was determined by using Alkaline permanganate method (Subbaiah and Asija, 1956).

ii) Available phosphrous

Available phosphrous in the soil samples were extracted using Bray No. 1 reagent (Bray and Kurtz, 1945) and estimated colorimetrically by

reduced molybdate Ascorbic acid blue colour method (Watanabe and Olsen, 1965) using a spectrophotometer (Model: Genesys 20).

ii) Available potassium

Available potassium in the soil samples were extracted using neutral normal ammonium acetate and its content in the extract was estimated by flame photometry (Jackson, 1958).

iii) Available calcium and magnesium

Available calcium and magnesium in the soil samples were extracted using neutral normal ammonium acetate and its content in the extract was analysed using Perkin Elmer Atomic Absorption Spectrophotometer (Model: Analyst 400).

iv) Available zinc

Available zinc in soil samples were extracted using 0.1M HCl (Sims and Johnson, 1991). 2g soil with 20 ml of 0.1M HCl was shaken for 5 minutes. It was filtered through Whatmann No.42 filter paper and the filtrate was collected and analysed for Ca, Mg, and Zn using Perkin Elmer Atomic Absorption Spectrophotometer (Model: Analyst 400).

v) Available boron

Available boron in soil samples were extracted using hot water method and estimated colorimetrically by Azomethine - H method (Berger and Troug, 1939; Gupta, 1972) using a spectrophotometer (Model: Genesys 20).

3.6.1.9.2. Standard leaf, Fruit rind and pulp analysis

The leaf samples of 2 month old leaves were taken from four directions (west, east, north, and south), 3-4 leaves each of central branches of each tree, were gathered (Liferdi *et. al*., 2008). Fruit rind and pulp samples were collected separately immediately after harvest.

Samples were dried in an oven maintained at 70 ± 5^0C till the weight of the samples remained constant. The dried samples were ground, mixed, and then chemically analysed for major nutrients, *viz.*, nitrogen, phosphorous, potassium, calcium, magnesium and micronutrients *viz.*, boron and zinc.

i) Estimation of nitrogen in plant samples

N in the plant samples were determined by using block digestor cum distillation unit (Model: Kel Plus). Digestion was done by using concentrated H_2SO_4 at 450^0C. Digested samples were distilled by using 40% NaOH and distillate was collected to 2% boric acid. This was titrated against 0.02N H_2SO_4. By using this titre value N content in the plant samples were calculated (Jackson, 1958).

ii) Estimation of other nutrients in plant samples

Total P, K, Ca, Mg, Zn, B in the plant sample was estimated after digestion of the sample with 2:1 nitric- perchloric acid mixture.

a) Estimation of total phosphrous in plant samples

P in the digest was determined by the Vanado molybdate yellow colour method (Piper, 1966) measuring the colour intensity in a spectrophotometer (Model: Analyst 400).

b) Estimation of potassium in plant samples

K content in the digest was estimated by flame photometry (Jackson, 1958).

c) Estimation of boron in plant samples

B in the digest was determined colourimetrically by Azomethine-H method (Bingham, 1982) using a spectrophotometer (Model: Genesys 20).

d) Estimation of Ca, Mg and Zn in plant samples

The digested samples were analysed for Ca, Mg and Zn (Piper, 1966) using Perkin Elmer Atomic Absorption Spectrophotometer (Model: Analyst 400).

3.6.1.10. Fruit yield

Number and weight of fruits obtained from each tree during each harvest was recorded to arrive at the total yield from individual trees.

3.6.1.11. Keeping quality

The 'keeping quality' was calculated as number of days from harvest maturity till the fruits remained marketable and retaining edible qualities at normal atmospheric conditions. Fruits were declared as unmarketable when it showed symptoms of decay or mould growth or shriveling to the tune of 25 per cent or more.

3.6.1.12. Incidence of pest and diseases

Constant caution and monitoring of the experimental area was exercised to check the incidence of pest and diseases.

3.6.1.13. Weather parameters

The meteorological data were collected from the Agro met observatory of the College of Horticulture, Vellanikkara. The weekly data on the maximum and minimum temperature (^{0}C), sunshine (hours per day), rainfall (mm), relative humidity (%) were recorded for the period of investigation. The details of the meteorological observations for this period are presented in Appendix – I.

3.6.2. Experiment 2: Enhancing shelf life

Observations were taken at 3 days interval.

3.6.2.1. Firmness

Firmness of fruits was measured using the instrument Penetrometer and the average expressed in kg/cm^2.

3.6.2.2. Weight loss

Change in weight was recorded using an electronic balance and weight loss was expressed as percentage.

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

3.6.2.3. Phenol content in fruits

Phenol content of fruit at harvest stage was estimated using Folins cio-calteau reagent and expressed as mg phenol/100g of sample (Sadasivam and Manickam, 1997).

3.6.2.4. Change in TSS

TSS was determined using Erma hand refractometer and the change in TSS was expressed in degree brix (AOAC, 1980).

3.6.2.5. Change in titratable acidity

Titrable acidity of the fruit pulp was estimated by titration with standard sodium hydroxide solution and the change in titratable acidity was expressed as percent anhydrous citric acid following Ranganna (1977).

3.6.2.6. Change in rind colour

Change in rind colour was noted and categorised according to the following scale

0-None

1-Slight (<25% skin area)

2-Moderate (25-50% skin area)

3-Severe (>50% skin area)

3.6.2.7. Change in pulp colour

Change in pulp colour was noted and categorised according to the following scale

0-None

1-Slight (<25% skin area)

2-Moderate (25-50% skin area)

3-Severe (>50% skin area)

3.6.2.8. Storage life

Storage life was determined by counting the number of days from harvest maturity till the fruits remained marketable and retaining edible qualities at normal atmospheric conditions.

3.7. STATISTICAL ANALYSIS

The data recorded on the various experiments were subjected to statistical analysis following the methods of Panse and Sukhatme (1985).

Results

4. RESULTS

The results of the experiment entitled “Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.) are presented in this chapter.

4.1. EXPERIMENT 1 – IMPROVING FRUIT QUALITY AND MINIMISING FLESH DISORDERS

Mangosteen trees utilised for experiment -1 flowered and set fruits during 2nd and 3rd week of February 2011 (Plate 1 and 2).

4.1.1. Fruit characters

4.1.1.1. Fruit retention

Flower and fruit drop was maximum during first month of anthesis and thereafter fruit drop was less. Treatments showed significant difference with respect to this character (Table 1). The highest percentage of fruit retention (88.49%) was observed in trees treated with 2% $CaCl_2$ (T3) which significantly differed from all other treatments (Plate 3), followed by trees treated with 1% $CaCl_2$ (T2) with 81.42% fruit retention.

Trees treated with combinations of calcium chloride and boron as foliar spray also showed positive results. Trees treated with 2% $CaCl_2$ + 0.1% B (T6), 2% $CaCl_2$ + 0.2% B (T7) and 0.5% KH_2PO_4 (T11) retained about 75% of fruits and these three treatments were on par. The lowest fruit retention percentage of 36.14% was found in control trees (Plate 4).

4.1.1.2. Days from flowering to harvest

Days taken from fruit set to harvest as influenced by various treatments are presented in table 1. Different treatments had significant influence on the days to reach harvest maturity. The shortest number of days for harvest (84.33 days) was recorded in trees treated with 0.5% KH_2PO_4 (T11) closely followed by 2% KNO_3 (T10) with 85.33 days and both the treatments were on par. Control trees took the longest period for harvest (101.00 days) followed by

Plate 1 – Flowering in Mangosteen

Plate 2 – Fruit set in Mangosteen

Table 1. Effect of treatments on fruit retention and days to harvesting maturity

Treatments	*Fruit retention (%)*	*Fruit drop (%)*	*Days from flowering to harvest (no.)*
T1	36.14^{h}	63.86^{a}	101.00^{a}
T2	81.42^{b}	18.58^{g}	91.00^{c}
T3	**88.49^{a}**	**11.51^{h}**	96.33^{b}
T4	62.51^{e}	37.49^{d}	88.33^{c}
T5	66.57^{d}	33.43^{e}	97.00^{b}
T6	75.01^{c}	24.99^{f}	90.66^{c}
T7	74.59^{c}	25.41^{f}	99.00^{ab}
T8	58.73^{f}	41.27^{c}	100.67^{a}
T9	43.61^{g}	56.39^{b}	98.33^{ab}
T10	56.98^{f}	43.02^{c}	**85.33^{d}**
T11	74.10^{c}	25.90^{f}	**84.33^{d}**

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

Plate 3 – High fruit retention with $CaCl_2$ 2% treatment

Plate 4 – Flower and fruit drop in control trees

trees treated with 300ppm $ZnSO_4$ (T8) with 100.67 days and they were statistically on par with trees sprayed with combination of 2% $CaCl_2$ + 0.2% B (T7) and 0.5% urea (T9).

4.1.1.3. Percentage occurrence of gamboge and translucent flesh disorder

Treatments showed significant variation in the percentage occurrence of gamboge and translucent flesh disorder (Table 2 and Plate 5). Minimum incidence of gamboge disorder was observed in fruits harvested from trees treated with 2% $CaCl_2$ (T3) and 1% $CaCl_2$ (T3). T3 recorded 9.97% and T2 recorded 9.83% of GD which were statistically on par. T6 and T7, calcium chloride and boron combinations also reduced gamboge incidence to 10-11 percent. T6 was on par with T2 and T3, and T7 was in turn par with T6. Fruits harvested from control trees showed highest percentage of gamboge disorder (39.20%).

Highest percentage of occurrence (22.17%) of translucent flesh disorder was observed in fruits from control trees. Fruits harvested from trees treated with 2% $CaCl_2$ (T3) exhibited lowest percentage of TFD (11.27%) which was statistically on par with 1% $CaCl_2$ (T2) and combination spray of 2% $CaCl_2$ + 0.2% B (T7) with 12% and 12.33% TFD respectively. Other treatments which reduced TFD were T8 (300ppm $ZnSO_4$), T4 (0.1% boron) and T5 (0.2% boron). All these treatments recorded only 12-13% TFD.

4.1.1.4. Position of fruits affected with gamboge and translucent flesh disorder

Position of gamboge and translucent flesh disorder affected fruits were observed and presented in table 3. In all the treatments fruits affected with GD and TFD were seen more in outer canopy. Significant difference exists between treatments in the outer and inner canopy. Least percentage (34.33) of GD and TFD in the inner canopy was observed in fruits from trees treated with combination of 2% $CaCl_2$ + 0.2% B (T7). In the case of outer canopy lowest percentage (59.97) of affected fruits was noticed with T10 which was on par with

Table 2. Effect of treatments on the occurrence of GD and TFD

Treatments	*GD (%)*	*TFD (%)*
T1	39.20^{a}	22.17^{a}
T2	**09.83^{f}**	**12.00^{ef}**
T3	**09.97^{f}**	**11.27^{f}**
T4	32.14^{c}	13.05^{de}
T5	36.90^{b}	12.87^{de}
T6	**10.21^{ef}**	13.92^{d}
T7	**11.23^{e}**	**12.33^{ef}**
T8	32.09^{c}	12.78^{de}
T9	37.03^{b}	16.93^{c}
T10	22.73^{d}	17.44^{c}
T11	23.20^{d}	18.90^{b}

Treatment means having similar alphabets in superscript, do not differ significantly

Table 3. Effect of position of fruit on the tree on GD and TFD

Treatments	*Inner Canopy (%)*	*Outer Canopy (%)*
T1	35.50^{bcd}	64.50^{abc}
T2	34.33^{d}	65.67^{a}
T3	34.93^{cd}	65.07^{ab}
T4	36.17^{bc}	63.83^{bc}
T5	36.67^{b}	63.33^{c}
T6	38.50^{a}	61.50^{d}
T7	34.33^{d}	**65.67^{a}**
T8	34.77^{cd}	65.23^{ab}
T9	36.63^{b}	63.37^{c}
T10	**40.03^{a}**	59.97^{d}
T11	38.50^{a}	61.50^{d}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***
T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***
T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

Gamboge disorder

Translucent flesh disorder

Plate 5 – Physiological disorders in mangosteen fruit

T6 and T11 (61.50). In general 34 to 40% GD and TFD affected fruits were in the inner canopy and 60 to 65% in the outer canopy.

4.1.2. Fruit diameter at fortnightly interval

Effect of various foliar nutrition treatments on fruit diameter at fortnightly interval is given in table 4. Fruit diameter was significantly different at all stages of development except 8th week. Pattern of fruit growth was not uniform in all treatments (Plate 6).

The fruit diameter after fourth and sixth week of fruit development was highest (2.63cm and 4.40cm respectively) in 2% KNO_3 spray (T10) and lowest diameter (1.77cm and 3.37cm respectively) was observed in T4 (0.2% B). After ten weeks of fruit development, fruits with highest diameter (5.90cm) was found in T9 (0.5% urea) and smallest fruits was observed in T6 (2% $CaCl_2$ + 0.1% B) and control with same diameter of 5.33cm. At the time of harvest, after twelve weeks biggest fruit was found in T9 (0.5% urea) with a diameter of 6.17cm followed by T10 (2% KNO3) and T11 (0.5% KH_2PO_4) with a diameter of 6.03cm which were statistically on par and in turn par with T8 – 300ppm $ZnSO_4$ (6.00cm). Minimum fruit diameter of 5.53cm was recorded in control and was on par with all treatments except the above superior ones.

4.1.3. Grading of fruits according to size

Fruits from individual trees were sorted and graded according to their size and were grouped into four *viz*. fruits with weight <50g, 50-75g, 75-100g and >100g (Table 5 and Fig.1). In all the four groups fruits varied in size significantly (Plate 7). T2 (2% $CaCl_2$) recorded 22 small fruits with <50g weight which was the highest in the first group and was significantly different from all other treatments. In the same group T7 (2% $CaCl_2$ + 0.2% B) produced 2.50 fruits which was the lowest.

Table 4. Diameter of fruit at fortnightly interval (cm)

Treatments	***4th week***	***6th week***	***8th week***	***10th week***	***12th week***
T1	2.20^{bc}	3.53^{de}	5.23^{a}	5.33^{e}	5.53^{c}
T2	2.03^{bcde}	3.70^{d}	5.20^{a}	5.50^{bcde}	5.67^{c}
T3	2.27^{bc}	3.77^{cd}	5.23^{a}	5.43^{de}	5.67^{c}
T4	1.77^{e}	3.37^{e}	5.10^{a}	5.43^{de}	5.67^{c}
T5	1.97^{cde}	3.67^{d}	5.23^{a}	5.40^{de}	5.63^{c}
T6	1.83^{de}	3.67^{d}	5.23^{a}	5.33^{e}	5.67^{c}
T7	2.23^{bc}	4.03^{bc}	5.27^{a}	5.47^{cde}	5.63^{c}
T8	2.10^{bcd}	3.77^{cd}	5.33^{a}	5.63^{bc}	6.00^{b}
T9	2.30^{b}	4.06^{b}	5.37^{a}	**5.90^{a}**	**6.17^{a}**
T10	**2.63^{a}**	**4.40^{a}**	5.27^{a}	5.53^{bcd}	**6.03^{ab}**
T11	2.27^{bc}	3.77^{cd}	5.27^{a}	5.67^{b}	**6.03^{ab}**

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

Plate 6 - Mangosteen fruit development at different growth stages

In the second group with fruits having weight in the range of 50-75g, 114 fruits (60% of total fruits/tree) were produced by T6 (2% $CaCl_2$ + 0.1% B) which was the highest number of fruits recorded which was on par with T7 (2% $CaCl_2$ + 0.2% B) with 113.54 fruits (60% of total fruits/tree). The lowest number of 16 fruits was recorded in T8 (300ppm $ZnSO_4$) followed by 23.67 fruits in control and were significantly different from each other.

In the third group with fruit weight ranging from 75g to 100g maximum number of fruits were grouped in T3 (2% $CaCl_2$) with 106.30 fruits (50% of total fruits/tree) followed by T2 (1% $CaCl_2$) with 106 fruits (52.70% of total fruits/tree) without any statistical difference. Trees treated with 2% KNO3 (T10) recorded 16.67 fruits which was the least in the group and was on par with T8 – 300ppm $ZnSO_4$ (19.33 fruits).

In the group of largest fruits with >100g weight, T9 (0.5% urea) produced 101.70 fruits (60% of total fruits/tree) which was significantly superior from all others (Plate 8). T9 was followed by T11 (0.5% KH_2PO_4), T10 (2% KNO_3) and T8 (300ppm $ZnSO_4$) with 86, 60 and 57 fruits respectively. T5 (0.2% boron) produced only 5.64 big fruits which was the lowest number recorded and was on par with control (6.70 fruits).

4.1.4. Physical characters of fruit at harvest

Data related to fruit physical characters are furnished in table 6.

4.1.4.1. Fruit Length

Fruits harvested from trees treated with different foliar sprays showed significant difference in their length. The longest fruits with 4.41 cm length were observed in T9 (0.5% urea). This was followed by T10 (2% KNO_3) and T11 (0.5% KH_2PO_4) with fruit lengths of 4.22cm and 4.21cm respectively. T4 (0.1% B) produced shortest fruit with 3.91cm length followed by control as well as trees treated with 0.2% B (T5) with 3.92cm length and were on par.

Table 5. Effect of treatments on fruit size

Treatments	***Number of fruits***				***Total no. of fruits/tree***
	<50g	***50-75g***	***75-100g***	***>100g***	
T1	6.00^{d}	23.67^{f}	30.67^{d}	6.70^{gh}	67.00^{f}
T2	**22.00^{a}**	64.67^{b}	**106.00^{a}** (52.70%)	8.33^{fg}	**201.00^{a}**
T3	10.00^{c}	69.70^{b}	**106.30^{a}** (50%)	15.67^{e}	**201.67^{a}**
T4	5.70^{d}	28.33^{e}	49.30^{c}	11.67^{f}	95.00^{e}
T5	3.33^{de}	34.70^{d}	56.33^{b}	5.64^{h}	100.00^{de}
T6	15.67^{b}	**114.00^{a}** (60%)	54.70^{bc}	13.67^{ef}	**198.00^{a}**
T7	2.50^{e}	**113.54^{a}** (60%)	33.00^{d}	42.17^{d}	**198.33^{a}**
T8	12.00^{c}	16.00^{g}	19.33^{e}	57.67^{c} (50%)	105.00^{cd}
T9	5.30^{d}	28.03^{e}	49.30^{c}	**101.70^{a}** (60%)	184.33^{b}
T10	4.33^{de}	32.00^{de}	16.67^{e}	60.00^{c} (50%)	113.00^{c}
T11	12.50^{c}	43.50^{c}	56.33^{b}	86.00^{b} (40%)	**198.00^{a}**

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

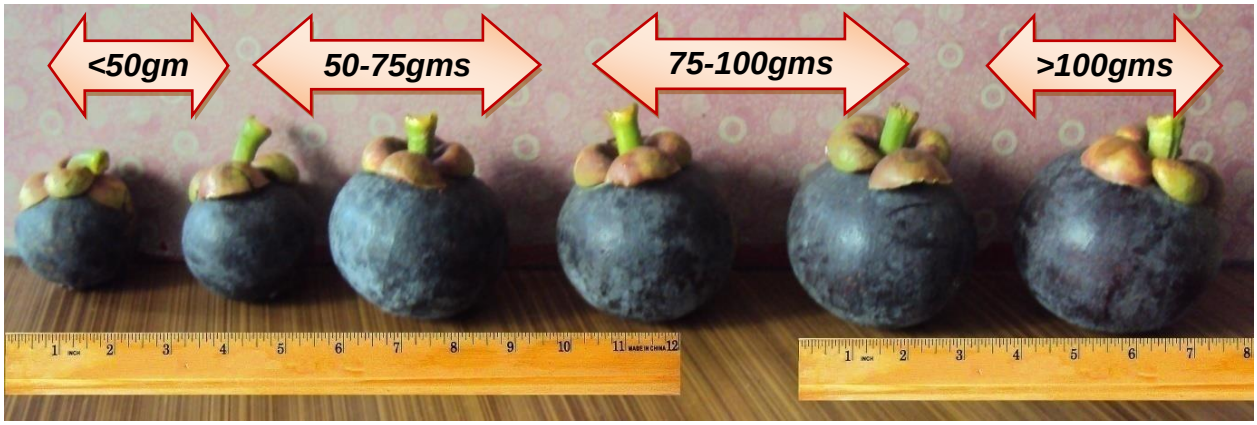

Plate 7 – Sorting of fruits according to size

Plate 8 – Heavy yield of mangosteen with 0.5% urea foliar nutrition

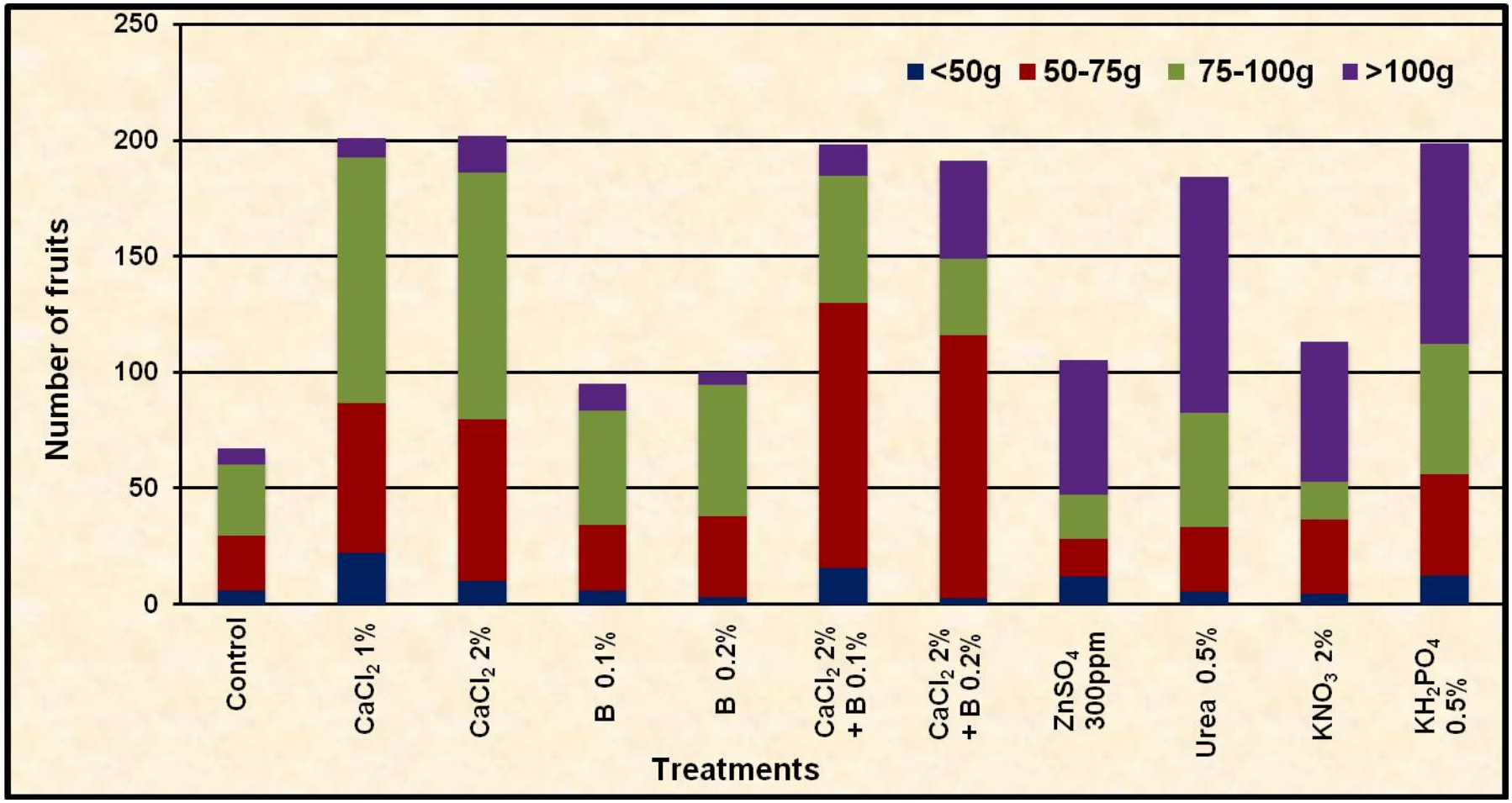

Fig 1 – Effect of treatments on fruit size and no. of fruits

Table 6. Effect of treatments on fruit measurements, number of fruits and yield/tree

Treatments	*Length (cm)*	*Breadth (cm)*	*Circumference (cm)*	*Weight (g)*	*No. of fruits/tree*	*Yield (kg/tree)*
T1	3.92^{f}	4.53^{f}	17.36^{c}	79.43^{e}	67.00^{f}	5.27^{k}
T2	3.98^{d}	5.13^{cd}	17.80^{c}	84.46^{d}	**201.00^{a}**	16.98^{d}
T3	3.98^{d}	5.17^{cd}	17.80^{c}	84.97^{d}	**201.67^{a}**	17.01^{c}
T4	3.91^{f}	4.57^{f}	17.80^{c}	85.20^{d}	95.00^{e}	8.11^{j}
T5	3.92^{f}	4.89^{e}	17.68^{c}	83.53^{d}	100.00^{de}	8.16^{i}
T6	4.14^{c}	4.93^{e}	17.80^{c}	72.83^{f}	**198.00^{a}**	14.47^{e}
T7	3.95^{e}	5.03^{d}	17.68^{c}	73.80^{f}	**198.33^{a}**	14.40^{f}
T8	4.15^{c}	5.23^{bcd}	18.84^{b}	106.73^{c}	105.00^{cd}	11.50^{h}
T9	**4.41^{a}**	**5.57^{a}**	**19.37^{a}**	**113.17^{a}**	184.33^{b}	**21.74^{a}**
T10	4.22^{b}	5.37^{abc}	18.93^{ab}	110.47^{ab}	113.00^{c}	13.81^{g}
T11	4.21^{b}	5.50^{ab}	18.93^{ab}	107.03^{bc}	**198.00^{a}**	20.30^{b}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

4.1.4.2. Fruit breadth

All the treatments differed significantly with respect to fruit breadth. Highest value of fruit breadth (5.57cm) was observed in T9 (0.5% urea) followed by 5.50cm in T11 (0.5% KH_2PO_4) and 5.37cm in T10 (2% KNO_3) which were statistically on par. The lowest fruit breadth (4.53cm) was given by control followed by T4 (0.1% B) with 4.57cm and were on par.

4.1.4.3. Fruit Circumference

There was significant difference in fruit circumference among treatments. Highest fruit circumference (19.37cm) was observed in T9 (0.5% urea) followed by T10 (2% KNO_3) and T11 (0.5% KH_2PO_4) with 18.93cm. T10 and T11 were statistically on par with T9 and in turn par with T8 – 300ppm $ZnSO_4$ (18.84cm). Fruits with least circumference (17.36 cm) were produced by control and it was on par with all other treatments except the superior ones.

4.1.4.4. Fruit Weight

The data on the mean weight of fruit showed significant difference among treatments. The heaviest fruits with 113.17g was produced by trees treated with 0.5% urea (T9) which statistically on par with T10 – 2% KNO_3 (110.47g) and was superior to all other treatments followed by T11 (107.03g) and T8 (106.73g). The lowest fruit weight was observed in treatment T6 (2% $CaCl_2$ + 0.1% B) with 72.83g followed by T7 (2% $CaCl_2$+ 0.2% B) with 73.80g and were statistically on par.

4.1.4.5. Total number of fruits per tree

Analysis of data on the number of fruits per tree showed significant difference among the treatments. The treatment T3 (2% $CaCl_2$) produced highest number of fruits per tree (201.67) followed by T2 (1% $CaCl_2$) with 201 fruits, T7 (2% $CaCl_2$ + 0.2% B) with 198.33 fruits and T6 (2% $CaCl_2$ + 0.1% B) as well as T11 (0.5% KH_2PO_4) with 198 fruits. All the five treatments were on par. Control trees produced only 67 fruits which was the lowest among the treatments.

4.1.4.6. Fruit Yield

The data on fruit yield per tree showed significant difference among treatments. The highest fruit yield (21.74kg/tree) was recorded in T9 (0.5% urea) followed by T11 (0.5% KH_2PO_4) with 20.30kg/tree which were significantly different from each other and from rest of treatments. Higher values for yield were also recorded in other treatments like T3 – 2% $CaCl_2$ (17.01kg/tree) and T2 – 1% $CaCl_2$ (16.98kg/tree). The lowest yield was obtained in control trees with 5.27kg/tree.

4.1.4.7. Colour of ripe fruits

No significant variation was observed between the treatments with respect to colour of mature and ripe fruits during the period of study. A uniform pattern of colour development was noted in the fruits from maturity to full ripeness. A fully mature fruit was identified by a light yellow pink colour with pink or red lines or patches appearing on the outer surface of rind. Then the fruit completely changed to pink, red, dark red, red purple and finally to purple, dark purple or black. After this stage during senescence fruit rind hardening occurred, with difficulty in opening of fruits, rendering it unfit for consumption.

4.1.4.8. Colour of fruit pulp

No significant variation was observed in the pulp colour of normal fruit during the period of study. Healthy fruit pulp was white to slightly yellowish white in colour. Yellow to brown fruit pulp in gamboge affected fruits and cream translucent hard flesh in TFD affected fruits were also observed.

4.1.4.9. Fruit firmness

Statistical analysis of the data on fruit firmness revealed the occurrence of significant difference among treatments (Table 7). T3 – 2% $CaCl_2$ recorded maximum fruit firmness (9.10kg/cm^2) followed by T2 –1% $CaCl_2$ with 8.97kg/cm^2, both being statistically on par. Control trees produced fruits with a firmness of 6.40kg/cm^2 which was the lowest value recorded among the

treatments.T5 (0.2% B) also produced fruits with lower value of firmness (6.47kg/cm^2) which do not differ significantly from control. All other treatments were superior to the control.

4.1.4.10. Specific gravity of fruits

Specific gravity of mangosteen fruits varied significantly among treatments as presented on t able7. The least specific gravity (0.970) was recorded in T2 (2% $CaCl_2$), followed by T3 (2% $CaCl_2$) as well as T7 (2% $CaCl_2$+ 0.2% B) with 0.977 specific gravity which were statistically on par. The highest value of 1.017 was observed in T9 (0.5% urea) which is on par with control having a value of 1.013.

4.1.4.11. Rind-Pulp ratio

The treatments differ significantly in the case of rind-pulp ratio of fruits (Table 7). The lowest value of 1.77 was reported in T10 (2% KNO_3) which was on par with T9 (0.5% urea) with a value of 1.80, followed by T11 (0.5% KH_2PO_4) with a ratio of 1.87. The highest value of 2.46 was recorded by T3 (2% $CaCl_2$) which was significantly different from all other treatments.

4.1.4.12. No. of segments

The treatments differ significantly in the case of number of segments in fruit (Table 7). Fruits with highest number of segments per fruit (7 no.) where observed in T9 (0.5% urea) and T11 (0.5% KH_2PO_4) followed by T10 (2% KNO_3) and T8 (300ppm $ZnSO_4$) with 6.70 and 6.30 segments/ fruit respectively.T10 and T8 are found to be statistically on par with T9 and T11. Fruits with least number (5 no.) of segments were produced on T5 (0.2% B) and the control.

Table 7. Effect of treatments on firmness, specific gravity, rind-pulp ratio, number of segments and seeds per fruit

Treatments	*Firmness (kg/cm^2)*	*Specific gravity*	*Rind-Pulp ratio*	*No. of segments/fruit*	*No. of viable seeds/fruit*
T1	6.40^{g}	1.013^{ab}	2.03^{de}	5.00^{f}	0.67^{b}
T2	**8.97^{ab}**	**0.970^{g}**	2.27^{b}	5.67^{cde}	1.00^{ab}
T3	**9.10^{a}**	**0.977^{fg}**	2.46^{a}	5.33^{de}	1.00^{ab}
T4	7.73^{d}	0.987^{de}	2.00^{e}	5.70^{cde}	0.70^{b}
T5	6.47^{g}	0.990^{d}	2.27^{b}	5.00^{f}	1.33^{ab}
T6	8.83^{bc}	0.980^{ef}	2.13^{c}	5.67^{cde}	1.00^{ab}
T7	8.73^{c}	**0.977^{fg}**	2.10^{cd}	6.00^{bcd}	1.30^{ab}
T8	8.73^{c}	1.007^{bc}	1.90^{f}	6.30^{abc}	1.00^{ab}
T9	6.77^{f}	1.017^{a}	**1.80^{g}**	**7.00^{a}**	**1.70^{a}**
T10	7.17^{e}	0.987^{de}	**1.77^{g}**	6.70^{ab}	1.30^{ab}
T11	7.10^{e}	1.003^{c}	**1.87^{fg}**	**7.00^{a}**	**1.70^{a}**

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control
T2-$CaCl_2$ 1%
T3-$CaCl_2$ 2%
T4-Boron 0.1%
T5- Boron 0.2%
T6- $CaCl_2$ 2% + Boron 0.1%
T7-$CaCl_2$ 2% + Boron 0.2%
T8-$ZnSO_4$ 300ppm
T9-Urea 0.5%
T10-KNO_3 2%
T11-KH_2PO_4 0.5%

4.1.4.13. No. of viable seeds

Analysis of data on the number of viable seeds per fruit showed significant difference among the treatments (Table 7). The highest number of viable seeds (1.70 no.) were observed in T9 (0.5% urea) and T11 (0.5% KH_2PO_4) which was on par with all other treatments except T4 (0.2% B) and T1, the control trees in which mean number of viable seeds per fruit was less than one.

4.1.5. Fruit quality at harvest

Fruit quality in terms of moisture content, TSS, acidity, ascorbic acid total sugars and keeping quality is given in table 8

4.1.5.1. Moisture content

Significant variation was observed in the moisture content of fruits among different treatments of foliar nutrition. Highest moisture content 70.87 per cent was observed in T9 (0.5% urea) and it was significantly different from all other treatments followed by 67.43 per cent in T11 (0.5% KH_2PO_4), 66.65 per cent in T7 (2% $CaCl_2$ + 0.2% B) and 66.41 per cent in T10 (2% KNO_3). Minimum moisture content of 61.00 per cent was recorded in fruits treated with 1% $CaCl_2$ as foliar spray (T2).

4.1.5.2. Total Soluble Solids (TSS)

Significant difference in TSS was noticed among the treatments. T11 (0.5% KH_2PO_4) recorded the highest TSS of 18.23^0 Bx, followed by T10 (2% KNO_3) with 18.20^0 Bx and T8 (300ppm $ZnSO_4$) with 18.17^0 Bx and all these three treatments were on par. Fruits with least TSS was seen in T6 (2% $CaCl_2$ + 0.1% B) with 17.00^0 Bx followed by control with 17.03^0 Bx which were on par.

4.1.5.3. Total sugars

Analysis of data on total sugar of fruits showed significant difference among the treatments. Fruits from trees treated with 0.5% mono potassium phosphate (T11) registered highest value of total sugars (17.65%)

closely followed by fruits from 2% potassium nitrate treatment (17.44%) and both were statistically on par. Lowest value of total sugars (14.56%) was noted in fruits from treatments with combination spray of 2% calcium chloride and 0.2% boron (T7) and control trees (14.60%) which were on par.

4.1.5.4. Acidity

The data on the acidity of fruits revealed significant difference among the 11 treatments studied. Lowest value of acidity (0.28%) was noticed in treatments with 0.5% urea (T9) and 2% KNO_3 (T10), both statistically on par. Highest percentage of acidity (0.44%) was observed in fruits treated with 0.5% KH_2PO_4 (T11) followed by 300ppm $ZnSO_4$ (T8) with 0.41% acidity, both statistically on par.

4.1.5.5. Ascorbic acid

The treatments varied significantly in the case of ascorbic acid content of fruits. The highest ascorbic acid content of 10.75mg/100g was found in T8 (300ppm $ZnSO_4$) followed by T11 (0.5% KH_2PO_4) and T4 (0.2% Boron) with 10.47mg and 10.34mg ascorbic acid per 100g of fruit respectively. T8, T11 and T4 were on par with each other. T6 (2% $CaCl_2$ + 0.1% B) produced fruits with lowest ascorbic acid content of 5.03mg/100g followed by T7 (2% $CaCl_2$ + 0.2% B) with 5.17mg/100g and were on par.

4.1.5.6. Organoleptic evaluation of fruits

A detailed assessment of the organoleptic quality in terms of overall acceptability of fruits from different treatments indicated that those fruits harvested from T10 (2% KNO_3) was most acceptable with a score of 32.40 followed by T9 (0.5% urea) with a score of 31.73 which were significantly different from each other and with rest of treatments. The lowest mean score for overall acceptability was found in control fruits (T1) with 24.33 followed by T2 (1% $CaCl_2$) and T3 (2% $CaCl_2$) with score of 25.23 and 25.03 respectively and were on par. The score chart of organoleptic evaluation is given in appendix –II.

Table 8. Effect of treatments on fruit quality

Treatments	*Moisture content (%)*	*TSS (^{0}Bx)*	*Total sugars (%)*	*Acidity (%)*	*Ascorbic acid (mg/100g)*	*Keeping quality (days)*	*Overall acceptability*
T1	65.77^{cd}	17.03^{e}	14.60^{f}	0.38^{bc}	5.85^{d}	6.00^{f}	24.33^{g}
T2	61.0^{g}	17.67^{bc}	15.32^{cd}	0.35^{cde}	6.67^{c}	19.67^{b}	25.23^{f}
T3	62.65^{f}	17.60^{cd}	15.00^{de}	0.33^{de}	8.30^{b}	**21.33^{a}**	25.03^{f}
T4	63.84^{ef}	17.83^{abc}	16.50^{b}	0.37^{bcd}	**10.34^{a}**	15.00^{c}	26.90^{e}
T5	62.50^{f}	18.03^{ab}	16.31^{b}	0.38^{bc}	8.43^{b}	16.00^{c}	29.10^{c}
T6	64.84^{de}	17.00^{e}	14.85^{de}	0.32^{ef}	5.03^{e}	15.70^{c}	28.17^{d}
T7	66.65^{bc}	17.23^{de}	14.56^{f}	0.33^{de}	5.17^{e}	19.30^{b}	28.63^{c}
T8	65.97^{bcd}	**18.17^{a}**	16.49^{b}	0.41^{ab}	**10.75^{a}**	10.30^{e}	28.34^{d}
T9	**70.87^{a}**	18.00^{abc}	15.62^{c}	**0.28^{f}**	5.99^{d}	14.00^{d}	31.73^{b}
T10	66.41^{bc}	**18.20^{a}**	**17.44^{a}**	**0.28^{f}**	6.26^{d}	10.70^{e}	**32.40^{a}**
T11	67.43^{b}	**18.23^{a}**	**17.65^{a}**	0.44^{a}	**10.47^{a}**	13.67^{d}	28.77^{c}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

4.1.4.7. Keeping quality

Keeping quality of fruits varied significantly in various treatments. The highest mean value for shelf life (21.33 days) was noticed in T3 (2% $CaCl_2$) and was significantly superior to all other treatments. It was followed by T2 (1% $CaCl_2$) with 19.67days and T7 (2% $CaCl_2$ + 0.2% B) with 19.30 days and both were on par. The lowest shelf life was observed in fruits from control trees with a storage life of 6 days.

4.1.6. Nutrient content of soil

The data on nutrient status of soil before foliar nutrient application (initial soil sample) and after harvest of fruits (final soil sample) are presented on table 9.

4.1.6.1. Available Nitrogen

Available nitrogen content in the soil was 350.00kg/ha initially before foliar spray of nutrients. But in the final soil sample, after harvest it was found that available nitrogen in the soil was reduced to 260.40kg/ha.

4.1.6.2. Available Phosphorus

Before foliar spray of nutrients available phosphorous content in the soil was found as 22.64kg/ha. In the final soil sample after harvest of fruits phosphorous content was reduced to 20.31kg/ha.

4.1.6.3. Available Potassium

Available potassium content in the soil initially was 160.50kg/ha before foliar nutrition. After harvest of fruits it was 165.54kg/ha in the final soil sample.

4.1.6.4. Available Calcium

Initial soil sample before foliar spray of nutrients contained 219.00 mg kg^{-1} of available calcium. But after harvest of fruits in the final soil sample available calcium content was reduced to 190.30 mg kg^{-1}.

Table 9. Nutrient content of soil before treatments and after harvest of fruits

Nutrient content	***Initial soil sample***	***Final soil sample***
Available N (kg/ha)	350.00	260.40
Available P (kg/ha)	22.64	20.31
Available K (kg/ha)	160.50	165.54
Available Ca (mg kg^{-1})	219.00	190.30
Available Mg (mg kg^{-1})	143.04	133.85
Available Zn (mg kg^{-1})	1.05	0.79
Available B (mg kg^{-1})	0.47	0.42

4.1.6.5. Available Magnesium

Available magnesium content in the soil before foliar treatments was noted as 143.04 mg kg^{-1}. In the soil sample analysed after harvest of fruits available magnesium content was found as 133.85 mg kg^{-1}.

4.1.6.6. Available Zinc

Available zinc content in the soil before foliar applications was 1.05 mg kg^{-1}. But after harvest of fruits in the final soil sample available zinc content was recorded as 0.79 mg kg^{-1}.

4.1.6.7. Available Boron

In the initial soil sample available boron content found was 0.47 mg kg^{-1} before foliar application of nutrients. After harvest of fruits available boron content in the soil was 0.42 mg kg^{-1}.

4.1.7. Nutrient content of plant sample

Nutrient contents *viz.* nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron of standard leaf, fruit rind and pulp were estimated.

4.1.7.1. Standard Leaf Analysis

Data pertaining to nutrient content of standard leaves before foliar nutrient application and after harvest of fruits presented in table 10. Treatments differed significantly with respect to N, P, K, Ca, Mg, Zn and B contents of standard leaf.

4.1.7.1.1. Nitrogen

The nitrogen content in standard leaves of mangosteen trees taken for study ranged from 1.20% to 1.55% before foliar treatments. The highest nitrogen content was recorded in T9 (0.5% urea) with an increase in nitrogen content from 1.25% to 1.83% after harvest of fruits which was superior to rest of treatments. Standard leaves from control trees had the lowest percentage of nitrogen (1.18%) and value was lower than the initial N content of 1.37%.

4.1.7.1.2. Phosphorus

Phosphorus content in standard leaves before foliar application ranged from 0.110% to 0.252%. Standard leaves from trees treated with 0.5% mono potassium phosphate had the highest phosphorus content with an increase in phosphorus content from the initial value of 0.175% to 0.350% after harvest which was significantly different from other treatments. Minimum phosphorus content of 0.171% was noted in T9 (0.5% urea) which was on par with T7 (combination spray of 2% $CaCl_2$ and 0.2% boron) with 0.191% phosphorus content.

4.1.7.1.3. Potassium

Initial potassium content in standard leaf ranged from 1.16% to 1.46% in mangosteen trees taken for experiment. Trees treated with 2% KNO_3 (T10) had the highest percentage of potassium (1.66%) in standard leaves and was significantly superior to other ten treatments. The initial value of potassium in T10 was only 1.24%. The lowest percentage of potassium was found in standard leaves from T8 (300ppm $ZnSO_4$) with 1.14% which was on par with control (1.26%) where the initial and final values of potassium did not differ much.

4.1.7.1.4. Calcium

The calcium content in standard leaves of mangosteen ranged from 1.26% to 2.11% before foliar applications. The highest calcium in standard leaves was observed in T3 (2% $CaCl_2$) with 2.45% where the initial value was only 1.63% and was significantly different from rest of treatments. Standard leaves from trees treated with 300ppm $ZnSO_4$ (T8) and control trees had the lowest calcium content with 1.43% and 1.45% respectively and were not significantly different. Compared to the initial values the final values of calcium was predominantly high in all the treatments involving calcium namely T2, T3, T6 and T7. Final values of calcium were low in T8, T10 and T11 compared to the initial values.

4.1.7.1.5. Magnesium

Standard leaf of mangosteen trees taken for study initially had magnesium content ranging from 0.122% to 0.166% and the final values ranged from 0.125% to 0.178%. Maximum percentage of magnesium in standard leaves was recorded in T11 (0.5% KH_2PO_4) with 0.178% where the initial value was 0.130% and was significantly superior to all other treatments. The minimum magnesium content of 0.125% was noted in T8 (300ppm $ZnSO_4$).

4.1.7.1.6. Zinc

The zinc content in standard leaves of mangosteen trees initially ranged from 28.70 mg kg^{-1} to 42.70 mg kg^{-1}. The highest zinc content of 44.00 mg kg^{-1} from an initial value of 38.00 mg kg^{-1} was noted in standard leaves from T8 (300ppm $ZnSO_4$) which was significantly different from rest of treatments. The lowest zinc content of 26.67mg kg^{-1} was found in T10 (2% KNO_3) which was on par with control (29.33 mg kg^{-1}). In most of the treatments initial and final values did not vary much with respect to zinc content eg. T2, T3, T4, T5, T9, T10 and T11.

Table 10. Effect of treatments on nutrient content of leaf

Treatments	*Nitrogen (%)*		*Phosphorus (%)*		*Potassium (%)*		*Calcium (%)*		*Magnesium (%)*		*Zinc (mg kg^{-1})*		*Boron (mg kg^{-1})*	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
T1	1.37	1.18^{i}	0.252	0.274^{b}	1.28	1.26^{de}	1.43	1.45^{h}	0.151	0.142^{g}	28.70	29.33^{fg}	28.24	29.02^{ef}
T2	1.26	1.43^{e}	0.243	0.241^{c}	1.34	1.32^{cd}	1.88	**2.11^{c}**	0.166	0.172^{b}	38.67	37.33^{c}	25.10	25.88^{fg}
T3	1.20	1.32^{g}	0.218	0.212^{def}	1.43	1.41^{bcd}	**1.63**	**2.45^{a}**	0.161	0.164^{c}	31.33	30.67^{ef}	30.59	31.37^{de}
T4	1.26	1.27^{h}	0.190	0.232^{cd}	1.31	1.36^{bcd}	1.75	1.84^{ef}	0.150	0.154^{e}	42.70	40.70^{b}	35.69	37.65^{bc}
T5	1.34	1.26^{h}	0.183	0.207^{ef}	1.33	1.35^{bcd}	1.73	1.94^{de}	0.145	0.152^{e}	32.00	33.30^{de}	31.37	40.78^{b}
T6	1.25	1.48^{d}	0.182	0.216^{de}	1.45	1.44^{bc}	1.26	**1.97^{d}**	0.156	0.159^{d}	40.00	36.00^{cd}	34.51	36.08^{c}
T7	1.24	1.51^{c}	0.223	0.191^{fg}	1.46	1.43^{bcd}	1.66	**2.27^{b}**	0.138	0.148^{f}	32.70	35.33^{cd}	**32.71**	**45.49^{a}**
T8	1.55	1.37^{f}	0.318	0.276^{b}	1.16	1.14^{e}	2.07	1.43^{h}	0.139	0.125^{i}	**38.00**	**44.00^{a}**	32.31	31.38^{de}
T9	**1.25**	**1.83^{a}**	0.161	0.171^{g}	1.43	1.34^{bcd}	1.55	1.64^{g}	0.122	0.138^{h}	30.00	30.70^{ef}	35.29	34.19^{cd}
T10	1.34	1.36^{f}	0.110	0.112^{h}	**1.24**	**1.66^{a}**	1.91	1.86^{def}	0.138	0.136^{h}	26.67	26.67^{g}	27.45	28.24^{ef}
T11	1.50	1.55^{b}	**0.175**	**0.350^{a}**	1.28	1.50^{b}	2.11	1.80^{f}	**0.130**	**0.178^{a}**	34.00	32.00^{ef}	20.39	23.53^{g}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

4.1.7.1.7. Boron

Initial boron content in the standard leaves ranged from 20.39 mg kg^{-1} to 35.69 mg kg^{-1}. Trees treated with combination spray of 2% $CaCl_2$ + 0.2% B (T7) had the highest boron content of 45.49 mg kg^{-1} as compared to initial value of 32.71 mg kg^{-1} which was significantly superior to other treatments. Minimum boron content was noted in T11 (0.5% KH_2PO_4) with 23.53 mg kg^{-1} which was on par with T2 (1% $CaCl_2$) with boron content of 25.88 mg kg^{-1}. In all the treatments where boron was a component namely T4, T5, T6 and T7 the final values of boron in the standard leaf was conspicuously high compared to initial values.

4.1.7.2. Fruit rind and pulp analysis

The data on nutrient contents of fruit rind and pulp from all treatments at the time of harvest are presented in table 11. All the treatments varied significantly with respect to N, P, K, Ca, Mg, Zn and B contents of fruit rind and pulp.

4.1.7.2.1. Nitrogen

Rind of fruits from trees treated with 2% KNO_3 (T10) had the highest nitrogen content of 0.91% which was on par with T9 – 0.5% urea (0.90%). Lowest percentage of nitrogen content was found in T5 (0.2% boron) followed by the control (T1) with 0.30% and 0.35% of nitrogen respectively. T5 and T1 were on par with each other.

The highest value for nitrogen in the fruit pulp was recorded in T9 (0.5% urea) with 0.79% followed by T10 (2% KNO_3) with 0.75% nitrogen. T10 was on par with T5 (0.2% boron) with 0.74% of nitrogen content. Lowest percentage of nitrogen was found in fruits treated with combination spray of 2% $CaCl_2$ and 0.1% boron (T6) with 0.43% nitrogen which was significantly lower than all other treatments. When nitrogen content in rind and pulp were taken together T9 and T10 were the superior treatments.

4.1.7.2.2. Phosphorus

The maximum phosphorus content in fruit rind of 0.300% was noted in T11 (0.5% KH_2PO_4) followed by T4 – 0.1% boron with 0.235% which were significantly different from each other and with other treatments. Minimum phosphorus contents of 0.096% and 0.087% were recorded in T10 (2% KNO_3) and T8 (300ppm $ZnSO_4$) respectively and they were on par.

Treatments with 0.5% mono potassium phosphate (T11) and 0.5% urea (T9) had significantly highest phosphorous content in the pulp with 0.252% and 0.244% respectively, which were on par with each other and with T10 – 2% potassium nitrate (0.239%). Minimum phosphorus content of fruit pulp was observed in combination spray of 2% calcium chloride and 0.2% boron (T7), 2% calcium chloride alone (T3) and combination spray of 2% calcium chloride with 0.1% boron (T6) with phosphorus content of 0.076%, 0.085% and 0.100% respectively which were on par with each other. When phosphorus content of rind and pulp were taken into account T11 was the best treatment followed by T9 and T4.

4.1.7.2.3. Potassium

In all the treatments potassium content of the rind was higher than that of the pulp. The highest percentage of potassium in the fruit rind was observed in T10 (2% KNO_3) with 1.76% followed by T11 (0.5% KH_2PO_4) with 1.70% which were significantly different. T11 was on par with T2 – 1% $CaCl_2$ (1.66%). Lowest potassium content of 1.45% was noted in T9 (0.5% urea) and T4 (0.1% Boron) and were on par with control (1.48%).

Highest quantity of potassium in fruit pulp was noticed in treatments with 2% KNO_3 (T10) and 0.5% KH_2PO_4 (T11) with 1.04% and 1.03% of potassium respectively which were on par with each other and with T3 – 2% $CaCl_2$ (1.02%) and T7 – 2% $CaCl_2$ + 0.2% B (0.93%). Minimum potassium content of fruit pulp was noticed in fruits from trees treated with 0.5% urea (T9) which was on par with T4 – 0.1% boron (0.82%), control (0.81%) and T5 – 0.2%

boron (0.76%). When rind and pulp were considered together superior treatments were T10 and T11 followed by T3.

4.1.7.2.4. Calcium

In general calcium content was more in the rind than the pulp. Trees treated with 2% $CaCl_2$ (T3) and those trees with combination spray of 2% $CaCl_2$ + 0.2% B (T7) had the highest percentage (0.391% and 0.387% respectively) of calcium in fruit rind which were on par and were followed by 0.339% and 0.319% of calcium in T2 (1% $CaCl_2$) and T6 (2% $CaCl_2$ + 0.1% B) respectively which were also on par. The lowest percentage of calcium was noticed in T11 (0.5% KH_2PO_4) with 0.211% which was on par with six other treatments except the above mentioned superior ones.

The highest percentage of calcium in fruit pulp was recorded in T7 (2% $CaCl_2$ + 0.2% B) with 0.172% calcium followed by T6 – 2% $CaCl_2$ + 0.1% B and T3 – 2% $CaCl_2$ with 0.130% and 0.123%. But there was no significant difference between T6 and T3. Lowest percentage of calcium in fruit pulp was noted in T5 – 0.2% boron (0.043%) which was on par with T4 – 0.1% boron (0.063%). When pulp and rind were considered together T7 was the most superior followed by T3, T6 and T2.

4.1.7.2.5. Magnesium

Much difference was not noticed between the rind and pulp with respect to magnesium. The highest value for magnesium in fruit rind was recorded in T11 (0.5% KH_2PO_4) with 0.146% followed by 0.114% in T2 (1% $CaCl_2$) which were significantly different from each other and from other treatments. Minimum magnesium content was found in T10 (2% KNO_3) which was on par with T5 (0.2% Boron) with magnesium content of 0.044% and 0.047% respectively.

Trees treated with 0.5% KH_2PO_4 (T11) had the highest percentage of magnesium in fruit pulp with 0.109% followed by 0.096% in T2 (1% $CaCl_2$) which differed significantly with each other and with rest of treatments. The lowest percentage of magnesium was recorded in T9 (0.5% urea) with 0.055%

which was on par with 0.057% of magnesium in T10 (2% KNO_3). When magnesium content of rind and pulp were taken together T11 was the best treatment closely followed by T2.

4.1.7.2.6. Zinc

Much variation in zinc content was noticed between rind and the pulp. Significantly higher zinc content in fruit rind was observed in treatment with 300ppm $ZnSO_4$ (28.00 mg kg^{-1}) followed by T10 – 2% KNO_3 (26.00 mg kg^{-1}) which were significantly different. T10 was on par with T9 – 0.5% urea (25.30 mg kg^{-1}). Minimum zinc content was noted in fruit rind from T11 (0.5% KH_2PO_4) with 17.33 mg kg^{-1} which was statistically on par with T6 (2% $CaCl_2$ + 0.1% B) and T7 (2% $CaCl_2$ + 0.2% B) with zinc contents of 18.70 mg kg^{-1} and 18.00 mg kg^{-1} respectively.

Whenever zinc content was high in the rind it was high in the pulp as well. The highest zinc content in fruit pulp was in the treatment with 300ppm $ZnSO_4$ (T8) with 30.67 mg kg^{-1} zinc followed by 25.30 mg kg^{-1} in T10 (2% KNO_3) which were significantly different. T10 was on par with T5 – 0.2% boron (23.30 mg kg^{-1}), T4 – 0.1% boron (22.70 mg kg^{-1}) and T9 – 0.5% urea (22.00 mg kg^{-1}). T5, T4 and T9 were not significantly different from each other. Minimum zinc content was recorded in fruit pulp from T11- 0.5% KH_2PO_4 and control with 14.67 mg kg^{-1} and 16.00 mg kg^{-1} respectively which were on par with T6 – 2% $CaCl_2$ + 0.1% boron (17.30 mg kg^{-1}) and T2 – 1% $CaCl_2$ (17.33 mg kg^{-1}). T2 and T6 were not significantly different.

4.1.7.2.7. Boron

The highest boron content of 12.94 mg kg^{-1} in the rind was recorded in 0.2% boron (T5) followed by T6 (2% $CaCl_2$ + 0.1% B) and T7 (2% $CaCl_2$ + 0.2% B) with 10.12 mg kg^{-1} and 9.57 mg kg^{-1} respectively which were significantly different. But there was no significant difference between T6 and T7. Lowest boron content was found in T11 – 0.5% KH_2PO_4 (4.78 mg kg^{-1}) and control (4.94 mg kg^{-1}) which were not significantly different.

Table 11. Effect of treatments on nutrient content in rind and pulp`

Treatments	*Nitrogen (%)*		*Phosphorus (%)*		*Potassium (%)*		*Calcium (%)*		*Magnesium (%)*		*Zinc (mg kg^{-1})*		*Boron (mg kg^{-1})*	
	Rind	***Pulp***	***Rind***	***Pulp***	***Rind***	***Pulp***	***Rind***	***Pulp***	***Rind***	***Pulp***	***Rind***	***Pulp***	***Rind***	***Pulp***
T1	0.35^{g}	0.50^{g}	0.134^{e}	0.218^{bc}	1.48^{ef}	0.81^{def}	0.217^{c}	0.069^{cd}	0.057^{e}	0.087^{c}	19.33^{f}	16.00^{e}	4.94^{g}	2.43^{e}
T2	0.55^{de}	0.62^{e}	0.159^{d}	0.141^{e}	1.66^{bc}	0.92^{bcd}	0.339^{b}	0.094^{c}	0.114^{b}	0.096^{b}	22.67^{de}	17.33^{de}	7.69^{d}	4.78^{c}
T3	0.76^{c}	0.60^{e}	0.157^{de}	0.085^{f}	1.63^{cd}	1.02^{ab}	**0.391^{a}**	0.123^{b}	0.095^{c}	0.082^{cd}	22.00^{e}	20.00^{cd}	6.67^{e}	4.08^{d}
T4	0.44^{f}	0.72^{c}	0.235^{b}	0.193^{cd}	1.45^{f}	0.82^{def}	0.247^{c}	0.063^{de}	0.065^{d}	0.079^{d}	24.67^{bc}	22.70^{bc}	8.71^{c}	6.27^{b}
T5	0.30^{g}	0.74^{bc}	0.150^{de}	0.173^{d}	1.51^{e}	0.76^{ef}	0.221^{c}	0.043^{e}	0.047^{fg}	0.071^{e}	24.00^{cd}	23.30^{bc}	**12.94^{a}**	**7.61^{a}**
T6	0.85^{b}	0.43^{h}	0.204^{c}	0.100^{f}	1.60^{d}	0.88^{cd}	0.319^{b}	0.130^{b}	0.064^{d}	0.065^{f}	18.70^{fg}	17.30^{de}	10.12^{b}	5.80^{b}
T7	0.61^{d}	0.55^{f}	0.189^{c}	0.076^{f}	1.53^{e}	0.93^{abc}	**0.387^{a}**	**0.172^{a}**	0.056^{e}	0.062^{fg}	18.00^{fg}	20.00^{cd}	9.57^{b}	6.35^{b}
T8	0.72^{c}	0.65^{d}	0.087^{f}	0.177^{d}	1.52^{e}	0.84^{cde}	0.233^{c}	0.080^{cd}	0.059^{e}	0.081^{d}	**28.00^{a}**	**30.67^{a}**	5.73^{f}	4.94^{c}
T9	0.90^{ab}	**0.79^{a}**	0.190^{c}	**0.244^{a}**	1.45^{f}	0.72^{f}	0.232^{c}	0.086^{cd}	0.051^{f}	0.055^{h}	25.30^{bc}	22.00^{bc}	7.61^{d}	3.76^{d}
T10	**0.91^{a}**	0.75^{b}	0.096^{f}	0.239^{ab}	**1.76^{a}**	**1.04^{a}**	0.214^{c}	0.085^{cd}	0.044^{g}	0.057^{gh}	26.00^{b}	25.30^{b}	5.57^{f}	5.10^{c}
T11	0.52^{e}	0.35^{i}	**0.300^{a}**	**0.252^{a}**	1.70^{b}	**1.03^{a}**	0.211^{c}	0.087^{cd}	**0.146^{a}**	**0.109^{a}**	17.33^{g}	14.67^{e}	4.78^{g}	3.61^{d}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

The highest boron content of fruit pulp with 7.61 mg kg^{-1} was seen in T5 - 0.2% boron, which also recorded highest value of boron in rind. It was followed by T7 (2% $CaCl_2$ + 0.2% B), T4 (0.1% B) and T6 (2% $CaCl_2$ + 0.1% B) with 6.35 mg kg^{-1}, 6.27 mg kg^{-1} and 5.80 mg kg^{-1} respectively. Treatments T7, T4 and T6 were on par. The lowest boron content was found in control with 2.43 mg kg^{-1} which was significantly different from other treatments.

4.1.8. Pest and Diseases

In the experimental field stray incidence of leaf eating caterpillar was noticed which was controlled by spraying recommended doses of plant protection chemicals (Ekalyx 0.05%). No other serious pests or diseases were observed in the mangosteen trees under study.

4.1.9. Weather data

The weather data during the period of investigation are given in Appendix I.

4.2. EXPERIMENT 2 – ENHANCING SHELF LIFE

4.2.1. Shelf life at 5±1^{0}C temperature regime

4.2.1.1. Storage life of fruits at 5±1^{0}C

Mangosteen fruits stored at 5±1^{0}C were severely affected by chilling injury and storage life was limited to nine days only. Statistical analysis of storage data at 5±1^{0}C showed that all the treatments varied significantly (Table 12). The longest storage period with lowest percentage of fruit loss (50.00%) on 12th day of storage was observed in fruits treated with salicylic acid 3% (T13), salicylic acid 2% (T12) and GA_3 600ppm (T10) and all these were statistically on par. Highest fruit loss of 53.30% was noted after nine days of storage in fruits under control and those fruits presoaked in cold water (T2).

4.2.1.2. Physiological loss in weight at 5±1^{0}C

Mangosteen fruits stored at 5±1^{0}C under various treatments had significant difference with regard to physiological loss in weight during all stages of storage from 9th day onwards (Table 13). During initial days of storage on 3rd and 6th day weight loss was found nil in all treatments. On 9th and 12th day only slight increase in fruit weight loss was observed. Fruits wrapped with cling film (T4) and those fruits treated with salicylic acid 3% (T13) and salicylic acid 2% (T12) were the best treatments with no weight loss even after nine days of storage. T13 had lowest percentage of weight loss with 0.23% on 12DAS followed by 0.33% and 0.34% in T12 and T4 respectively which were on par and were significantly different from T13. Fruits kept in rattan baskets (T19) had maximum weight loss of 0.79% on 9DAS followed by fruits under control (0.73%) and T2 – fruits presoaked in cold water (0.74%) which were significantly different from T19 and with other treatments. T2 and control (T20) were not significantly different. T14 (0.05% N – acetyl cystene) and T3 (presoaked in hot water) had maximum weight loss on last day of storage period (12DAS).

Table 12. Effect of treatments on shelf life (percentage loss of fruits) at 5±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	0	23.33^{abc}	50.00^{ab}	-
T2	0	30.00^{a}	53.33a	-
T3	0	23.33^{abc}	50.00^{ab}	-
T4	0	26.70^{ab}	50.00^{ab}	-
T5	0	16.67^{cde}	33.33^{def}	56.67^{bcd}
T6	0	13.30^{de}	36.67^{cde}	63.33^{ab}
T7	0	16.67^{cde}	33.33^{def}	56.67^{bcd}
T8	0	23.30^{abc}	40.00^{bcd}	66.67^{a}
T9	0	13.33^{de}	36.67^{cde}	60.00^{abc}
T10	0	16.70^{cde}	**23.30^{f}**	**50.00^{d}**
T11	0	13.30^{de}	33.33^{def}	60.00^{abc}
T12	0	10.00^{e}	**26.67^{ef}**	**50.00^{d}**
T13	0	10.00^{e}	**23.30^{f}**	**50.00^{d}**
T14	0	20.00^{bcd}	36.67^{cde}	53.33^{cd}
T15	0	23.33^{abc}	43.33^{abcd}	66.67^{a}
T16	0	20.00^{bcd}	46.67^{abc}	63.33^{ab}
T17	0	16.67^{cde}	40.00^{bcd}	60.00^{abc}
T18	0	20.00^{bcd}	36.67^{cde}	66.67^{a}
T19	0	26.70^{ab}	50.00^{ab}	-
T20	0	30.00^{a}	53.33a	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 13. Effect of treatments on weight loss (%) at 5±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	0	0	0.37^{gh}	-
T2	0	0	0.74^{b}	-
T3	0	0	0.71^{b}c	-
T4	0	0	**0.00^{j}**	-
T5	0	0	0.65^{d}	0.74^{bc}
T6	0	0	0.70^{bc}	0.75^{b}
T7	0	0	0.68^{cd}	0.74^{bc}
T8	0	0	0.38^{g}	0.61^{f}
T9	0	0	**0.33^{h}**	**0.44^{hi}**
T10	0	0	**0.28^{i}**	**0.41^{i}**
T11	0	0	0.33^{h}	0.47^{h}
T12	0	0	**0.00^{j}**	**0.33^{j}**
T13	0	0	**0.00^{j}**	**0.23^{k}**
T14	0	0	0.70^{bc}	0.80^{a}
T15	0	0	0.64^{d}	0.70^{cd}
T16	0	0	0.38^{g}	0.55^{g}
T17	0	0	0.47^{f}	0.69^{de}
T18	0	0	0.55e	0.65^{e}
T19	0	0	0.79a	-
T20	0	0	0.73b	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

4.2.1.3. Change in total soluble solids (TSS) as ^{0}Bx at 5±1^{0}C

Statistical analysis of data revealed that mangosteen fruits stored at 5±1^{0}C varied significantly with regard to TSS during all the intervals of storage period (Table 14). Fruits treated with salicylic acid 3% (T13) with 17.16^{0}Bx had lowest concentration of TSS on three days after storage which was on par with those fruits treated with GA_3 600ppm (T10) salicylic acid 2% (T12) and $CaCl_2$ 0.2% (T16) with 17.26^{0}Bx, 17.20^{0}Bx and 17.23^{0}Bx respectively.

After six and nine days of shelf life also lowest concentrations of TSS was found in T13 with 17.36^{0}Bx and 17.63^{0}Bx respectively. T13 was on par with T12 (17.43^{0}Bx and 17.66^{0}Bx respectively) and T16 (17.47^{0}Bx and 17.66^{0}Bx respectively) on 6DAS and 9DAS. After twelve days of storage at the end of shelf life, T13 had least TSS with 17.83^{0}Bx followed by T12 (18.00^{0}Bx) and T16 (18.03^{0}Bx). But T12 and T16 did not differ significantly from each other on 12DAS. Within nine days of storage, maximum TSS content was noted in control (19.03^{0}Bx) which was on par with fruits presoaked in cold water (T2) with TSS value of 19.00^{0}Bx.

4.2.1.4. Change in percentage of acidity at 5±1^{0}C

Mangosteen fruits stored at 5±1^{0}C under various treatments had significant difference with regard to titratable acidity during all stages of storage (Table 15). During initial days of storage on 3rd and 6th day of shelf life acidity ranges from 0.383% to 0.277%. Fruits treated with GA_3 600ppm (T10), salicylic acid 3% (T13) and salicylic acid 2% (T12) recorded the highest values at all intervals of storage with 0.350% acidity even after nine days of storage. T10, T13 and T12 were on par with each other at all intervals of storage. T13 and T12 retained maximum percentage of acidity even at the end of its storage on 12th day with 0.313% and 0.307% respectively which were statistically on par. Fruits kept as control and those in rattan baskets (T19) had faster reduction in acidity with 0.253% and 0.257% within 9DAS respectively which were on par with each other and with T2 – fruits presoaked in cold water (0.260%).

Table 14. Effect of treatments on change in TSS (^{0}Bx) at 5±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	17.83^{cd}	18.13^{d}	18.50^{f}	-
T2	18.10^{b}	18.56^{b}	19.00^{ab}	-
T3	18.06^{b}	18.43^{b}	18.80^{cd}	-
T4	17.93^{c}	18.30^{c}	18.76^{d}	-
T5	17.73^{d}	18.06^{d}	18.50^{f}	19.00^{a}
T6	17.53^{e}	17.83^{ef}	18.03^{h}	18.46^{c}
T7	17.46^{ef}	17.83^{ef}	18.00^{h}	18.40^{c}
T8	17.50^{ef}	17.76^{fg}	18.00^{h}	18.37^{cd}
T9	17.46^{ef}	17.80^{fg}	17.93^{hi}	18.26^{e}
T10	17.26^{gh}	17.53^{hij}	17.76^{jk}	18.16^{f}
T11	17.43^{ef}	17.66^{gh}	17.93^{hi}	18.30^{de}
T12	**17.20^{gh}**	**17.43^{jk}**	**17.66^{kl}**	**18.00^{g}**
T13	**17.16^{h}**	**17.36^{k}**	**17.63^{l}**	**17.83^{h}**
T14	17.56^{e}	17.93^{e}	18.36^{g}	18.83^{b}
T15	17.90^{c}	18.16^{d}	18.50^{f}	19.07^{a}
T16	**17.23^{gh}**	**17.47^{ijk}**	**17.66^{kl}**	**18.03^{g}**
T17	17.26^{gh}	17.53^{hij}	17.83^{ij}	18.16^{f}
T18	17.33^{fg}	17.60^{hi}	17.93^{hi}	18.46^{c}
T19	18.06^{b}	18.46^{b}	18.90^{bc}	-
T20	18.50^{a}	18.86^{a}	19.03^{a}	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 15. Effect of treatments on change in acidity (%) at 5±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	0.320^{ij}	0.293^{fg}	0.266^{gh}	-
T2	0.300^{k}	0.277^{h}	0.260^{hi}	-
T3	0.323^{ij}	0.300^{efg}	0.270^{fg}	-
T4	0.317^{j}	0.293^{fg}	0.243^{j}	-
T5	0.337^{gh}	0.313^{e}	0.273^{efg}	0.257^{f}
T6	0.347^{fg}	0.300^{efg}	0.280^{ef}	0.246^{fg}
T7	0.343^{fg}	0.313^{e}	0.283^{e}	0.253^{f}
T8	0.353^{ef}	0.330^{d}	0.300^{cd}	0.276^{cd}
T9	0.360^{de}	0.350^{bc}	0.303^{cd}	0.283^{c}
T10	**0.383^{a}**	**0.357^{ab}**	**0.350^{a}**	**0.300^{b}**
T11	0.363^{cde}	0.350^{bc}	0.327^{b}	0.286^{c}
T12	**0.380^{ab}**	**0.363^{ab}**	**0.350^{a}**	**0.307^{ab}**
T13	**0.383^{a}**	**0.366^{a}**	**0.350^{a}**	**0.313^{a}**
T14	0.340^{gh}	0.313^{e}	0.280^{ef}	0.247^{fg}
T15	0.330^{hi}	0.307^{ef}	0.296^{d}	0.237^{g}
T16	0.373^{abc}	0.350^{bc}	0.323^{b}	0.270^{de}
T17	0.370^{bcd}	0.340^{cd}	0.300^{cd}	0.250^{f}
T18	0.363^{cde}	0.330^{d}	0.310^{c}	0.260^{ef}
T19	0.316^{j}	0.290^{gh}	0.257^{i}	-
T20	0.300^{k}	0.277^{h}	0.253^{i}	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

4.2.1.5. Change in phenol content (mg/100g) at 5±1^{0}C

At 5±1^{0}C, all treatments showed significant difference with regard to total phenol contents in fruits at all intervals of shelf life (Table 16). On 3rd day of storage fruits treated with salicylic acid 3% (T13) had maximum phenol content of 0.852 mg/100g which was on par with T12 – salicylic acid 2% (0.843 mg/100g), T10 – GA_3 600ppm (0.839 mg/100g) and T9 –GA_3 400ppm (0.834 mg/100g). T12, T13 and T10 retained highest phenol content on nine days after storage also with 0.767 mg/100g, 0.759 mg/100g and 0.757 mg/100g respectively and were not significantly different. Total phenol content was found minimum on 3DAS in fruits presoaked in cold water (T2) and control fruits (T20) with 0.714 mg/100g and 0.719 mg/100g respectively and were on par. After nine days fruits presoaked in hot water and control fruits recorded lowest phenol contents with 0.521 mg/100g and 0.535 mg/100g respectively which did not differ significantly.

4.2.1.6. Rind hardening (kg/cm^2) at 5±1^{0}C

Mangosteen fruits kept at 5±1^{0}C with various treatments showed significant differences with respect to rind hardening (Table 17). Pericarp hardening was very severe at 5±1^{0}C due to chilling injury. Pericarp hardening was very severe in fruits under control (T1), fruits packed in rattan baskets covered with dried banana leaves (T19) and those fruits treated with $CaCl_2$ 0.2% (T16), with fruit firmness of 15.67kg/cm^2, 15.40kg/cm^2 and 15.30kg/cm^2 respectively within nine days after storage. These treatments were on par with each other and were on par with T18 –N acetyl cystene 0.05% + $CaCl_2$ 0.2% (14.43kg/cm^2).

Slow rate of pericarp hardening was found in fruits treated with SA 3% (T13) and SA 2% (T12) with fruit firmness of 6.13kg/cm^2 and 6.27kg/cm^2 respectively on three days after storage. There was no significant difference between T13 and T12 which were on par with T1– with ethylene absorbent ($KMnO_4$) and T10 – GA_3 600ppm with fruit firmness of 6.40kg/cm^2. On six days after storage also T13 had minimum hardening with 7.53kg/cm^2 followed by T12 with 7.77kg/cm^2. After completing nine days of shelf life T13 and T12 had

Table 16. Effect of treatments on change in phenol content (mg/100g) at 5±1^{0}C

Treatments	*3DAS*	*9DAS*
T1	0.827^{b}	0.731^{b}
T2	0.714^{h}	0.556^{i}
T3	0.750^{fg}	0.521^{j}
T4	0.791^{de}	0.608^{gh}
T5	0.772^{ef}	0.698^{cd}
T6	0.787^{de}	0.688^{d}
T7	0.799^{cd}	0.702^{cd}
T8	0.801^{cd}	0.703^{cd}
T9	**0.834^{ab}**	0.711^{c}
T10	**0.839^{ab}**	**0.757^{a}**
T11	0.822^{bc}	0.714^{c}
T12	**0.843^{ab}**	**0.767^{a}**
T13	**0.852^{a}**	**0.759^{a}**
T14	0.755^{fg}	0.556^{i}
T15	0.758^{fg}	0.618^{fg}
T16	0.774^{ef}	0.622^{fg}
T17	0.763^{f}	0.670^{e}
T18	0.755^{fg}	0.632^{f}
T19	0.735^{gh}	0.597^{h}
T20	0.719^{h}	0.535^{j}

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 17. Effect of treatments on rind hardening (kg/cm^2) at 5±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	6.40^{hij}	8.73^{m}	11.47^{e}	-
T2	7.17^{bc}	10.17^{e}	13.40^{bc}	-
T3	6.95^{cde}	10.07^{f}	13.07^{c}	-
T4	7.10^{bc}	9.83^{h}	11.65^{de}	-
T5	7.13^{bc}	9.97^{g}	12.10^{cde}	14.57^{e}
T6	6.87^{cde}	9.57^{i}	12.97^{cd}	14.03^{g}
T7	7.03^{bcd}	9.97^{g}	12.83^{cd}	14.17^{f}
T8	6.70^{efg}	9.33^{j}	12.17^{cde}	13.73^{i}
T9	6.57^{fgh}	8.90^{l}	11.27^{ef}	13.27^{j}
T10	**6.40^{hij}**	**7.93^{n}**	**10.17^{fg}**	**12.33^{k}**
T11	6.47^{ghi}	8.93^{l}	11.27^{ef}	13.23^{j}
T12	**6.27^{ij}**	**7.77^{o}**	**9.87^{g}**	**11.17^{l}**
T13	**6.13^{ij}**	**7.53^{p}**	**9.93^{g}**	**12.27^{k}**
T14	7.03^{bcd}	9.13^{k}	12.30^{cde}	13.87^{h}
T15	6.77^{def}	9.10^{k}	11.73^{de}	15.03^{c}
T16	7.50^{a}	12.13^{b}	15.30^{a}	16.00^{a}
T17	6.97^{bcde}	10.97^{d}	13.40^{bc}	14.77^{d}
T18	7.50^{a}	12.17^{b}	14.43^{ab}	15.83^{b}
T19	7.17^{bc}	11.93^{c}	15.40^{a}	-
T20	7.27^{ab}	12.46^{a}	15.67^{a}	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

minimum firmness values of 9.93kg/cm^2 and 9.87kg/cm^2 respectively which did not differ significantly and were on par with T10 (10.17kg/cm^2). At the end of storage period, on 12th day of shelf life lowest fruit firmness was recorded in T12 (11.17kg/cm^2) followed by T13 (12.27kg/cm^2) and T10 (12.33kg/cm^2) which were significantly different. T10 and T13 were statistically on par.

4.2.1.7. Change in rind colour at 5±1^{0}C

The data depicting the mean score of rind colour of fruits under various treatments at 5±1^{0}C are presented in table 18. Mangosteen fruits stored at 5±1^{0}C had colour change in the rind from 3rd day of storage onwards, mainly due to chilling injury. Chilling injury was very visible in fruit rind as light to dark brown patches with dried and shriveled calyx and stem end. Least discolouration trend of fruit rind was noticed on fruits treated with salicylic acid 2% (T12), salicylic acid 3% (T13) and N-acetyl cystene 0.05% (T15), with none to slight change in rind colour on 3rd day (0.33, 0.00 and 0.33 respectively) and 6th day (1.00, 0.67 and 0.67 respectively) of storage. Slight to moderate rind colour change was noticed on 9DAS (2.00, 1.67 and 1.67 respectively), and moderate to severe change in rind colour on 12DAS (2.67 for all superior treatments). Fruits treated with cold water (T2), those fruits packed in rattan basket with banana leaves (T19) and control showed maximum discolouration of rind with more than 50% rind colour faded (3.00) within 9DAS.

4.2.1.8. Change in pulp colour at 5±1^{0}C

The data indicating the mean score of pulp colour of fruits under various treatments at 5±1^{0}C are presented in table 19. Mangosteen fruit pulp was also affected by chilling injury at lower temperature of 5±1^{0}C. White aril turned into pink or orange red colour with off flavour as a result of chilling injury. At 5±1^{0}C most of the treatments expressed none to slight colour change on the third day of storage itself. But there was no discolouration of pulp in fruits treated with

Table 18. Effect of treatments on change in rind colour at 5±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	0.67	1.00	2.00	-
T2	1.33	1.67	3.00	-
T3	0.33	1.33	2.67	-
T4	1.00	1.67	2.67	-
T5	0.67	1.67	2.67	3.00
T6	1.00	1.00	2.33	3.00
T7	1.00	1.67	2.33	3.00
T8	1.00	1.67	2.67	3.00
T9	1.00	2.00	2.33	3.00
T10	0.67	1.67	2.00	3.00
T11	0.67	1.00	2.33	3.00
T12	**0.33**	**1.00**	**2.00**	**2.67**
T13	**0.00**	**0.67**	**1.67**	**2.67**
T14	0.67	1.33	2.00	3.00
T15	**0.33**	**0.67**	**1.67**	**2.67**
T16	1.33	1.67	2.67	3.00
T17	0.67	1.00	2.33	3.00
T18	0.67	1.33	2.33	3.00
T19	1.33	2.33	3.00	-
T20	2.00	2.33	3.00	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 19. Effect of treatments on change in pulp colour at 5±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*
T1	0.33	1.00	1.67	-
T2	1.00	1.33	3.00	-
T3	1.00	1.00	2.33	-
T4	0.67	1.33	2.00	-
T5	0.67	1.00	2.00	2.67
T6	0.33	1.00	2.00	2.67
T7	0.67	1.33	2.33	2.67
T8	0.67	1.00	2.00	2.67
T9	0.67	1.33	2.00	3.00
T10	0.67	1.00	1.67	2.67
T11	0.33	1.00	2.33	3.00
T12	**0.00**	**0.67**	**1.33**	**2.33**
T13	**0.00**	**0.33**	**1.67**	**2.00**
T14	0.67	1.33	2.00	3.00
T15	**0.00**	**0.67**	**1.67**	**2.33**
T16	**0.67**	**1.00**	**2.00**	**2.67**
T17	0.67	1.33	2.33	3.00
T18	0.67	1.33	2.67	3.00
T19	1.00	2.00	3.00	-
T20	1.67	2.33	3.00	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

salicylic acid 2% (T12), salicylic acid 3% (T13) and N-acetyl cystene 0.05% (T15) on 3rd day of shelf life. In T12, T13 and T15 none to slight discolouration of aril on 6DAS (0.67, 0.33 and 0.67 respectively), slight to moderate change in colour on 9DAS (1.33, 1.67 and 1.67 respectively) and moderate to severe deterioration of fruit pulp on 12DAS (2.33, 2.00 and 2.33 respectively) were recorded. Maximum discolouration of fruit pulp within nine days after storage was observed in fruits presoaked in cold water (T2), those fruits packed in rattan basket with banana leaves (T19) and control with more than 50% pulp damage (3.00).

4.2.2. Shelf life at 10±1^{0}C temperature regime

4.2.2.1. Storage life of fruits at 10±1^{0}C

Fruits stored at 10±1^{0}C also showed symptoms of chilling injury and storage life was limited to 12-15 days. Shelf life at10±1^{0}C varied significantly among treatments (Table 20). Percentage of fruit loss was lowest (46.67%) in fruits treated with salicylic acid 3% (T13) on 15 days after storage. It was followed by 50.00% and 56.70% in fruits treated with salicylic acid 2% (T12) and $CaCl_2$ 0.2% (T16) respectively at 15th day of storage and were on par. The shortest storage period of nine days was found in control with 56.67% fruit loss.

4.2.2.2. Physiological loss in weight at 10±1^{0}C

Mangosteen fruits stored at 10±1^{0}C under different treatments showed significant difference with respect to physiological loss in weight of fruits during all stages of storage from 9th day of shelf life onwards (Table 21). There was no physiological weight loss noticed till 9th day at 10±1^{0}C in all treatments. Minimum weight loss of 0.19% was found in T13 (salicylic acid 3%) which was on par with T4 - cling film wrapped fruits (0.20%), T12 – salicylic acid 2% (0.20%) and T16 – $CaCl_2$ 0.2% (0.22%). These superior treatments retained minimum rate of change of weight loss till last day of storage on 15th day

Table 20. Effect of treatments on shelf life (percentage loss of fruits) at 10±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	0	20.00^{bcd}	46.70^{ab}	70.00^{b}	-	-
T2	0	23.30^{abc}	46.67^{ab}	73.30^{ab}	-	-
T3	0	20.00^{bcd}	43.30^{b}c	53.33^{c}	-	-
T4	0	16.70^{cde}	40.00^{bcd}	53.30^{c}	-	-
T5	0	16.67^{cde}	40.00^{bcd}	46.70^{c}	80.00^{a}	-
T6	0	10.00^{efg}	26.70^{ef}	46.67^{c}	73.30^{b}	-
T7	0	13.30^{def}	23.33^{efg}	43.33^{cd}	76.67^{b}	-
T8	0	10.00^{efg}	30.00^{de}	46.67^{c}	56.70^{c}	-
T9	0	10.00^{efg}	16.67^{fgh}	33.33^{e}	53.33^{c}	-
T10	0	3.30^{gh}	13.30^{gh}	30.00^{ef}	53.33^{c}	-
T11	0	10.00^{efg}	26.67^{ef}	50.00^{c}	73.33^{b}	-
T12	0	0.00^{h}	16.70^{fgh}	36.67^{de}	**50.00^{c}**	-
T13	0	0.00^{h}	10.00^{h}	23.30^{f}	**46.67^{d}**	66.70^{d}
T14	0	16.67^{cde}	30.00^{de}	53.33^{c}	-	-
T15	0	13.33^{def}	23.30^{efg}	53.30^{c}	-	-
T16	0	6.67^{fgh}	16.70^{fgh}	36.67^{de}	**56.70^{c}**	-
T17	0	13.33^{def}	33.30^{cde}	53.33^{c}	-	-
T18	0	13.30^{def}	23.33^{efg}	43.30^{cd}	73.30^{b}	-
T19	0	26.70^{ab}	43.30^{bc}	80.00^{a}	-	-
T20	0	30.00^{a}	56.67^{a}	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 21. Effect of treatments on weight loss (%) at 10±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	0	0	0.38^{f}	0.53^{ef}	-	-
T2	0	0	0.61^{b}	0.73^{ab}	-	-
T3	0	0	0.59^{b}	0.72^{b}	-	-
T4	0	0	**0.20^{jkl}**	0.36^{j}	-	-
T5	0	0	0.43^{de}	0.58^{cd}	0.70^{a}	-
T6	0	0	0.42^{ef}	0.51^{f}	0.62^{bc}	-
T7	0	0	0.47^{c}	0.56^{de}	0.64^{b}	-
T8	0	0	0.39^{ef}	0.46^{g}	0.59^{c}	-
T9	0	0	0.27^{gh}	0.39^{hij}	0.54^{d}	-
T10	0	0	0.24^{hij}	0.36^{j}	0.43^{f}	-
T11	0	0	0.23^{hijk}	0.37^{ij}	0.49^{e}	-
T12	**0**	**0**	**0.20^{jkl}**	**0.29^{k}**	**0.33^{g}**	-
T13	**0**	**0**	**0.19^{l}**	**0.25^{l}**	**0.32^{g}**	**0.43**
T14	0	0	0.41^{ef}	0.47^{g}	-	-
T15	0	0	0.46^{cd}	0.60^{c}	-	-
T16	0	0	**0.22^{ijkl}**	0.40^{hi}	0.55^{d}	-
T17	0	0	0.25^{hi}	0.37^{ij}	-	-
T18	0	0	0.29^{g}	0.41^{h}	0.60^{c}	-
T19	0	0	0.59^{b}	0.75^{a}	-	-
T20	0	0	0.71^{a}	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

with 0.32% and 0.33% weight loss in T13 and T12 respectively which did not differ significantly. Control fruits had maximum weight loss of 0.71% on 9th day which was significantly different from rest of treatments. T19 (fruits kept in rattan baskets) had maximum weight loss of 0.75% which was on par with T2 – fruits presoaked in cold water (0.73%).

4.2.2.3. Change in total soluble solids (TSS) as ^{0}Bx at 10±1^{0}C

Mangosteen fruits stored at 10±1^{0}C under various treatments showed significant difference with regard to TSS values during all stages of storage (Table 22). The slowest rate of change in TSS was found in fruits treated with salicylic acid 3% (T13) and salicylic acid 2% (T12) with TSS value 17.03^{0}Bx and 17.16^{0}Bx after three days of storage. T12 was on par with T11 (SA 1%), T16 ($CaCl_2$ 0.2%) and T18 (N – acetyl cystene 0.05% + Calcium chloride 0.2%) with TSS values of 17.23^{0}Bx, 17.23^{0}Bx and 17.26^{0}Bx respectively. On 6th day of shelf life lowest TSS value of 17.23^{0}Bx was found in T13, followed by T12 (17.40^{0}Bx). T12 was on par with T10 – GA_3 600ppm (17.50^{0}Bx), T11 – SA 1% (17.46^{0}Bx), T17 – Sodium erythorbate 2% + $CaCl_2$ 0.2% (17.50^{0}Bx) and T18 – N - acetyl cystene 0.05% + $CaCl_2$ 0.2% (17.46^{0}Bx).

After nine days of storage T13 was having 17.37^{0}Bx followed by T12 with17.66^{0}Bx and they differed significantly. On 12th day of storage, lowest value of TSS was again found in T13 with 17.57^{0}Bx followed by T11 (17.97^{0}Bx), T12 (17.93^{0}Bx) and T16 (17.97^{0}Bx) which differed significantly. There was no significant difference between T11, T12 and T16 which were statistically on par with T10 and T18 (18.03^{0}Bx for both T10 and T8) and they did not differ significantly. Towards the end of shelf life on 15DAS, lowest TSS value of 18.06^{0}Bx was found in T13 followed by T12 with 18.50^{0}Bx and they differed significantly. Faster rate of TSS change was found in T19 (fruits kept in rattan baskets covered with banana leaves) and T2 (fruits presoaked in cold water). Highest TSS value of 19.33^{0}Bx was observed in T19 which was on par with T2 with 19.27^{0}Bx after twelve days of storage itself.

Table 22. Effect of treatments on change in TSS (^{0}Bx) at 10±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	17.70^{cde}	17.97^{de}	18.46^{cd}	18.90^{e}	-	-
T2	17.96^{a}	18.33^{b}	18.77^{ab}	19.27^{ab}	-	-
T3	17.80^{bc}	18.27^{b}	18.73^{b}	19.13^{cd}	-	-
T4	17.76^{bc}	18.13^{c}	18.66^{b}	19.07^{cd}	-	-
T5	17.73^{bcd}	18.03^{cd}	18.57^{c}	19.03^{d}	19.50^{a}	-
T6	17.60^{ef}	17.87^{ef}	18.37^{d}	18.67^{f}	19.27^{c}	-
T7	17.63^{def}	17.93^{de}	18.47^{cd}	18.87^{e}	19.40^{b}	-
T8	17.60^{ef}	17.90^{ef}	18.37^{d}	18.83^{e}	19.50^{a}	-
T9	17.47^{g}	17.53^{g}	17.83^{fg}	18.27^{h}	18.93^{d}	-
T10	17.30^{h}	17.50^{gh}	17.77^{fgh}	18.03^{ij}	18.73^{e}	-
T11	17.23^{hi}	17.46^{gh}	17.73^{gh}	17.97^{j}	18.63^{f}	-
T12	**17.16^{i}**	**17.40^{h}**	**17.66^{h}**	**17.93^{j}**	**18.50^{h}**	-
T13	**17.03^{j}**	**17.23^{i}**	**17.37^{i}**	**17.57^{k}**	**18.06^{i}**	19.40
T14	17.53^{fg}	17.80^{f}	18.16^{e}	18.47^{g}	-	-
T15	17.47^{g}	17.56^{g}	17.87^{f}	18.33^{h}	-	-
T16	17.23^{hi}	17.53^{g}	17.73^{gh}	17.97^{j}	18.57^{fg}	-
T17	17.30^{h}	17.50^{gh}	17.77^{fgh}	18.10^{i}	-	-
T18	17.26^{hi}	17.46^{gh}	17.77^{fgh}	18.03^{ij}	18.50^{h}	-
T19	17.96^{a}	18.47^{a}	18.87^{a}	19.33^{a}	-	-
T20	17.83^{b}	18.27^{b}	18.77^{ab}	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

4.2.2.4. Change in percentage of acidity at 10±1^{0}C

Statistical analysis of data on percentage of acidity in mangosteen fruits under different treatments stored at 10±1^{0}C showed significant difference at all the intervals of storage period (Table 23). On 3rd and 6th day of storage acidity ranged from 0.373% to 0.283% which further reduced up to 0.223% on 15th day, the end of storage life at this temperature regime. Maximum acidity retention was noticed in fruits treated with salicylic acid 3% (T13), salicylic acid 2% (T12) and calcium chloride 0.2% (T16). T13 had maximum acidity of 0.333% followed by 0.323% and 0.316% in T12 and T16 on twelve days after storage which were significantly different. But T12 and T16 were on par on 12DAS. At end of storage on 15th day also T13 had highest acidity with 0.306% followed by T12 and T16 with 0.297% and 0.280% which were significantly different from each other. Fast rate of reduction in acidity occurred in T2 - fruits presoaked in cold water (0.253% and 0.247% respectively) and T19 - fruits in rattan baskets (0.266% and 0.250% respectively) within nine and twelve days of storage. T2 and T19 were significantly different from each other and T19 on par with T15 (N- acetyl cystene 0.05%) with 0.273% on 9DAS. After twelve days T2 was on par with T8 –GA_3 200ppm (0.256%), T15 (0.253%) and T19 (0.250%)

4.2.2.5. Change in phenol content (mg/100g) at 10±1^{0}C

Mangosteen fruits stored at 10±1^{0}C under various treatments also showed significant difference with regard to phenol content on all intervals of storage period (Table 24). Fruits treated with salicylic acid 2% (T12) had maximum phenol content with 0.882 mg/100g on 3rd day of storage followed by T13 (salicylic acid 3%) with 0.865 mg/100g which were significantly different from each other. T13 was on par with T10 – GA_3 600ppm (0.859 mg/100g) and T11 –salicylic acid 1% (0.856 mg/100g). On 9th day T12 and T13 retained highest phenol content with 0.833 mg/100g and 0.830 mg/100g respectively which were on par and were significantly superior to rest of treatments. After fifteen days also

Table 23. Effect of treatments on change in acidity (%) at 10±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	0.347^{def}	0.327^{efg}	0.303^{de}	0.293^{d}	-	-
T2	0.297^{i}	0.283^{l}	**0.253^{j}**	**0.247^{h}**	-	-
T3	0.346^{def}	0.317^{ghi}	0.300^{e}	0.280^{e}	-	-
T4	0.343^{ef}	0.320^{fgh}	0.306^{de}	0.290^{d}	-	-
T5	0.347^{def}	0.313^{hi}	0.303^{de}	0.273^{ef}	0.223^{h}	-
T6	0.343^{ef}	0.320^{fgh}	0.300^{e}	0.290^{d}	0.243^{g}	-
T7	0.343^{ef}	0.313^{hi}	0.297^{ef}	0.270^{f}	0.257^{ef}	-
T8	0.330^{g}	0.307^{ij}	0.287^{fg}	0.256^{gh}	0.250^{fg}	-
T9	0.353^{bcde}	0.330^{def}	0.313^{cd}	0.293^{d}	0.260^{e}	-
T10	0.360^{bc}	0.340^{bcd}	0.326^{ab}	0.307^{c}	0.273^{cd}	-
T11	0.357^{bcd}	0.333^{cde}	0.320^{bc}	0.300^{cd}	0.270^{d}	-
T12	**0.363^{ab}**	**0.353^{a}**	**0.337^{a}**	**0.323^{b}**	**0.297^{b}**	**-**
T13	**0.373^{a}**	**0.350^{ab}**	**0.336^{a}**	**0.333^{a}**	**0.306^{a}**	**0.297**
T14	0.340^{f}	0.297^{jk}	0.280^{gh}	0.260^{g}	-	-
T15	0.317^{h}	0.293^{kl}	0.273^{hi}	0.253^{gh}	-	-
T16	**0.373^{a}**	**0.343^{abc}**	**0.333^{a}**	**0.316^{b}**	**0.280^{c}**	-
T17	0.356^{bcd}	0.336^{cde}	0.313^{cd}	0.297^{d}	-	-
T18	0.350^{cdef}	0.337^{cde}	0.307^{de}	0.293^{d}	0.270^{d}	-
T19	0.296^{i}	0.287^{kl}	**0.266^{i}**	**0.250^{gh}**	-	-
T20	0.316^{h}	0.283^{l}	0.270^{hi}	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 24. Effect of treatments on change in phenol content (mg/100g) at 10±1^{0}C

Treatments	*3DAS*	*9DAS*	*15DAS*
T1	0.722^{j}	0.593^{h}	-
T2	0.709^{jk}	0.475^{j}	-
T3	0.712^{jk}	0.597^{gh}	-
T4	0.725^{j}	0.623^{fg}	-
T5	0.822^{f}	0.689^{d}	0.578^{f}
T6	0.829^{ef}	0.686^{d}	0.597^{ef}
T7	0.820^{fg}	0.736^{c}	0.618^{de}
T8	0.843^{cde}	0.703^{d}	0.620^{de}
T9	0.841^{de}	0.763^{b}	0.691^{c}
T10	**0.859^{bc}**	**0.760^{bc}**	**0.696^{c}**
T11	0.856^{bcd}	0.765^{b}	0.639^{d}
T12	**0.882^{a}**	**0.833^{a}**	**0.762^{b}**
T13	**0.865^{b}**	**0.830^{a}**	**0.794^{a}**
T14	0.747^{i}	0.622^{fg}	-
T15	0.761^{i}	0.629^{ef}	-
T16	0.805^{gh}	0.684^{d}	0.595^{ef}
T17	0.798^{h}	0.631^{ef}	-
T18	0.753^{i}	0.654^{e}	0.548^{g}
T19	0.697^{k}	0.521^{i}	-
T20	0.711^{jk}	0.535^{i}	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

T13 and T12 had maximum phenol contents of 0.794 mg/100g and 0.762 mg/100g respectively which were significantly different. Minimum phenol content was noticed in T19 (fruits kept in rattan baskets) with 0.697 mg/100g on 3rd day which was on par with fruits presoaked in cold water (T2), control fruits (T20) and fruits presoaked in hot water (T3) with 0.709 mg/100g, 0.711 mg/100g and 0.712mg/100g respectively. After nine days T2 had lowest phenol content with 0.475 mg/100g.

4.2.2.6. Rind hardening (kg/cm^2) at 10±1^{0}C

Mangosteen fruits stored at 10±1^{0}C under all 20 treatments showed significant variation with regard to hardening of rind at all intervals of storage (Table 25). Pericarp hardening as a result of chilling injury was found at 10±1^{0}C also. Within twelve days of storage maximum pericarp hardening of 15.20 kg/cm^2 was noted in fruits kept in rattan baskets covered with dried banana leaves (T19) which was significantly different from all other treatments. T19 was followed by control (15.00kg/cm^2), T2 – presoaked in cold water (14.97kg/cm^2) and T16 – $CaCl_2$ 0.2% (14.83kg/cm^2) and these were on par with each other

In this temperature fruits treated with SA 3% (T13) and SA 2% (T12) had the lowest fruit firmness with 7.00kg/cm^{2}and 7.03kg/cm^2 respectively on three days after storage which were not significantly different from each other and were on par with T10 –GA_3 600ppm (7.13kg/cm^2). On 6th day of shelf life T12 with 7.96kg/cm^2 had the minimum rind hardening which was significantly superior to all other treatments and was on par with T10 (8.10kg/cm^2) and T13 (8.12kg/cm^2). T10 and T13 were not significantly different on 6DAS. After nine days of storage T13 showed lowest firmness value of 9.80kg/cm^2 followed by T12 with 10.27kg/cm^2 which differed significantly. T12 was on par with T10 (10.40kg/cm^2). On 12DAS also T13 had minimum fruit firmness of 10.67kg/cm^2 which was significantly different from all other treatments followed by T12 (11.97kg/cm^2) and T10 (12.10kg/cm^2).T12 and T10 were on par. Towards the

Table 25. Effect of treatments on rind hardening (kg/cm^2) at 10±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	7.80^{e}	8.33^{fg}	12.50^{e}	14.07^{de}	-	-
T2	8.27^{b}	9.03^{e}	13.53^{c}	14.97^{b}	-	-
T3	7.90^{de}	9.73^{b}	13.37^{cd}	14.13^{de}	-	-
T4	7.47^{f}	8.47^{h}	12.53^{e}	13.97^{ef}	-	-
T5	7.40^{fg}	8.97^{ef}	12.57^{e}	13.70^{gh}	14.83^{b}	-
T6	7.37^{fgh}	8.47^{h}	13.17^{d}	13.23^{j}	15.00^{b}	-
T7	7.27^{ghi}	8.70^{g}	12.23^{f}	13.57^{hi}	14.40^{d}	-
T8	7.47^{f}	8.23^{i}	11.43^{h}	13.40^{ij}	14.50^{cd}	-
T9	7.23^{hi}	8.15^{i}	10.60^{i}	12.33^{l}	13.43^{e}	-
T10	7.13^{ij}	8.10^{ij}	10.40^{ij}	12.10^{m}	13.17^{f}	-
T11	7.27^{ghi}	8.23^{i}	11.83^{g}	12.60^{k}	13.50^{e}	-
T12	7.03^{j}	7.96^{j}	10.27^{j}	11.97^{m}	12.97^{g}	-
T13	7.00^{j}	8.12^{ij}	9.80^{k}	10.67^{n}	12.50^{h}	13.73
T14	7.33^{fgh}	8.27^{i}	12.03^{fg}	13.83^{fg}	-	-
T15	7.37^{fgh}	8.53^{h}	12.07^{f}	13.77^{fgh}	-	-
T16	8.13^{c}	9.27^{d}	13.77^{b}	14.83^{b}	15.27^{a}	-
T17	8.03^{cd}	9.47^{c}	13.50^{c}	14.23^{cd}	-	-
T18	8.00^{cd}	9.13^{de}	13.33^{cd}	14.37^{c}	14.60^{c}	-
T19	7.97^{d}	9.53^{c}	14.10^{a}	15.20^{a}	-	-
T20	10.30^{a}	12.40^{a}	14.20^{a}	15.00^{b}	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

end of storage life on 15th day T13 showed minimum firmness of 12.50kg/cm^2 followed by T12 with 12.97kg/cm^2.

4.2.2.7. Change in rind colour at 10±1^{0}C

The data pertaining to the mean score of rind colour of fruits under various treatments at 10±1^{0}C are furnished in table 26. Fruits stored at10±1^{0}C also expressed symptoms of chilling injury with rind colour change from 3rd day of storage onwards. Moderate to severe damage to skin colour was observed on 12th day of storage in most of treatments at 10±1^{0}C. Fruits with calyx and stem end dipped in salicylic acid 3% (T13) and those fruits dipped in N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) retained rind colour for longest period of 15days with none to slight changes on 3rd (0.33 and 0.00 respectively) and 6th (0.67 and 0.33 respectively) day of storage for both treatments. Slight to moderate change was noticed for T13 on 9DAS (1.33) and12DAS (2.00) whereas only slight rind colour change was recorded (1.00) for T18 at 9th day of storage. Moderate to severe rind colour deterioration was exhibited by T13 on 15DAS (2.67) and 18DAS (3.00) and for T18 on 12 DAS (2.00) and 15DAS (2.67). Minimum colour retention trend of fruit rind (>50% skin discoloured) was observed in fruits presoaked in cold water (T2) and control (T20) within 9DAS (3.00).

4.2.2.8. Change in pulp colour at 10±1^{0}C

The data pertaining to the mean score of rind colour of fruits under various treatments at 10±1^{0}C are furnished in table 27.Chilling injury symptoms were expressed in fruits stored at 10±1^{0}C also. Change in pulp colour was noticed on 3rd day of storage in most of treatments. Fruits treated with salicylic acid 3% (T13), N-acetyl cystene 0.05% (T15) and N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) retained white colour of aril on 3DAS. In these treatments on 6th day of storage none to slight pulp colour change (0.33, 0.67 and 0.33 respectively); on 9DAS slight to moderate change in colour (1.00, 1.00, 0.67 respectively) and on12 DAS (1.67, 2.00 and 2.00 respectively) were noticed. At end of shelf life moderate to severe pulp colour change with 2.33 and 2.67 in T13 and T18 respectively was found on 15DAS. After 18 days T13 still retained 50% pulp

Table 26. Effect of treatments on change in rind colour at 10±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	0.33	1.00	1.67	2.67	-	-
T2	1.33	2.33	3.00	3.00	-	-
T3	0.67	1.00	2.00	3.00	-	-
T4	0.00	0.67	1.67	2.67	-	-
T5	0.33	1.00	1.67	2.33	3.00	-
T6	0.67	1.67	1.67	2.67	3.00	-
T7	0.67	1.33	2.00	3.00	3.00	-
T8	0.33	1.67	2.00	3.00	3.00	-
T9	1.33	2.00	2.33	3.00	3.00	-
T10	0.67	1.67	2.00	3.00	3.00	-
T11	0.67	1.33	2.00	2.67	3.00	-
T12	0.67	1.33	1.67	2.33	3.00	-
T13	**0.33**	**0.67**	**1.33**	**2.00**	**2.67**	**3.00**
T14	0.33	1.00	2.00	2.67	-	-
T15	0.00	1.00	1.67	2.67	-	-
T16	1.33	2.00	2.33	3.00	3.00	-
T17	0.33	0.67	1.67	2.67	-	-
T18	**0.00**	**0.33**	**1.00**	**2.00**	**2.67**	-
T19	1.33	2.00	2.33	3.00	-	-
T20	1.67	2.33	3.00	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 27. Effect of treatments on change in pulp colour at 10±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*
T1	0.33	0.67	1.67	2.33	-	-
T2	1.00	2.00	2.33	3.00	-	-
T3	0.33	1.00	1.67	2.67	-	-
T4	0.33	0.67	1.33	2.67	-	-
T5	0.33	0.67	1.33	2.33	3.00	-
T6	0.67	1.00	1.67	2.00	2.67	-
T7	0.33	1.00	1.33	2.00	2.67	-
T8	0.33	1.33	2.00	2.33	3.00	-
T9	0.67	1.33	2.00	2.67	3.00	-
T10	0.33	0.67	1.67	2.33	3.00	-
T11	0.33	1.00	1.67	2.00	2.67	-
T12	0.33	1.00	1.33	2.00	3.00	-
T13	**0.00**	**0.33**	**1.00**	**1.67**	**2.33**	**2.67**
T14	0.33	1.00	1.67	2.33	-	-
T15	**0.00**	**0.67**	**1.00**	**2.00**	-	-
T16	0.67	1.00	1.33	2.67	3.00	-
T17	0.33	0.67	1.67	2.67	-	-
T18	**0.00**	**0.33**	**0.67**	**2.00**	**2.67**	-
T19	1.00	2.00	2.33	3.00	-	-
T20	1.33	2.33	3.00	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

colour (2.67). Maximum discolouration of pulp colour occurred in fruits under control (3.00) within 9DAS with more than 50% fading of pulp colour. Fruits kept in rattan baskets covered with banana leaves (T19) and those presoaked in cold water (T2) also showed moderate to severe pulp colour change (2.33) on 9DAS and severe damage (3.00) on 12DAS.

4.2.3. Shelf life at 15±1^{0}C temperature regime

4.2.3.1. Storage life of fruits at 15±1^{0}C

Mangosteen fruits kept at 15±1^{0}C gave the best results with 27-30 days of shelf life. All the treatments showed significant difference at15±1^{0}C (Table 28). The longest storage period of 30 days with 50% fruit loss was found in fruits treated with GA_3 600ppm (T10) followed by those fruits treated with salicylic acid 2% (T12) and salicylic acid 3% (T13) with 43.30% fruit loss at 27th day of storage which were statistically on par. Shortest shelf life with 50% fruit loss on 15DAS was recorded in control.

4.2.3.2. Physiological loss in weight at 15±1^{0}C

Statistical analysis of data on physiological loss in weight of mangosteen fruits under different treatments stored at 15±1^{0}C showed significant difference at all the intervals of storage period from 6th day onwards (Table 29). At this temperature range weight loss of fruits started from six days after storage and continued up to last day of storage with a slow rate of change within a range of 0.17% to 7.77%. Fruits treated with salicylic acid 3% (T13) and fruits wrapped in cling film (T4) had minimum weight loss of 0.17% and 0.18% respectively on 6th day which was on par with T11 – salicylic acid 1% (0.21%), T12 – salicylic acid 2% (0.20%) and T16 – $CaCl_2$ 0.2% (0.21%). These superior treatments retained minimum weight loss till last day of storage. On 15th day T4 (0.85%), T13 (0.97%), T12 (0.99%), T11 (1.00%) and T16 (1.07%) had minimum weight loss which were not significantly different from each other. Towards end of storage on 27th day T13 had lowest value of 3.98% followed by T12 with 4.27% which were significantly different from each other and with rest of treatments.

Table 28. Effect of treatments on shelf life (percentage loss of fruits) at 15±1^{0}C

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	0	0.00^{c}	6.67^{cde}	23.33^{abc}	26.67^{bc}	36.70^{c}	40.00^{ab}	46.67^{bcd}	56.70^{a}	-
T2	0	6.70^{abc}	16.67^{abc}	26.67^{ab}	33.33^{b}	50.00^{a}	-	-	-	-
T3	0	3.33^{bc}	6.70^{cde}	23.33^{abc}	26.70^{bc}	46.67^{b}	50.00^{a}	-	-	-
T4	0	0.00^{c}	6.67^{cde}	13.30^{de}	16.67^{def}	26.70^{cde}	30.00def	50.00^{bc}	-	-
T5	0	6.67^{abc}	13.33^{bcd}	20.00^{bcd}	23.33^{cd}	23.30^{def}	36.70^{cd}	53.30^{ab}	-	-
T6	0	0.00^{c}	10.00^{cde}	16.67^{cde}	20.00^{cde}	23.33^{def}	30.00^{def}	36.67^{de}	50.00^{ab}	-
T7	0	0.00^{c}	3.33^{de}	3.33^{f}	10.00^{f}	16.67^{ef}	23.33^{fgh}	36.67^{de}	53.30^{ab}	-
T8	0	6.67^{abc}	13.33^{bcd}	16.70^{cde}	26.67^{bc}	33.30^{cd}	40.00^{ab}	46.67^{bcd}	50.00^{ab}	-
T9	0	3.30^{bc}	6.67^{cde}	10.00^{ef}	20.00^{cde}	23.33^{def}	26.67^{efg}	33.33^{ef}	46.70^{ab}	60.00^{a}
T10	0	0.00^{c}	3.33^{de}	16.67^{cde}	16.67^{def}	20.00^{ef}	23.33^{fgh}	33.33^{ef}	**43.30^{c}**	**50.00^{ab}**
T11	0	6.70^{abc}	16.67^{abc}	23.33^{abc}	26.67^{bc}	26.70^{cde}	33.30^{cde}	43.30^{cd}	53.33^{ab}	-
T12	0	0.00^{c}	13.33^{bcd}	10.00^{ef}	13.33^{ef}	20.00^{ef}	20.00^{gh}	26.67^{f}	**43.30^{c}**	56.67^{ab}
T13	0	0.00^{c}	3.33^{de}	3.33^{f}	10.00^{f}	13.30^{f}	16.67^{h}	26.67^{f}	**43.30^{c}**	53.30^{ab}
T14	0	6.70^{abc}	13.30^{bcd}	16.67^{cde}	20.00^{cde}	23.33^{def}	30.00^{def}	43.33^{cd}	56.67^{a}	-
T15	0	6.67^{abc}	13.33^{bcd}	20.00^{bcd}	23.30^{cd}	26.67^{cde}	36.67^{cd}	40.00^{de}	50.00^{ab}	-
T16	0	0.00^{c}	3.30^{de}	16.67^{cde}	16.70^{def}	20.00^{ef}	23.33^{fgh}	33.33ef	46.70^{ab}	56.70^{ab}
T17	0	0.00^{c}	3.33^{de}	10.00^{ef}	23.33^{cd}	33.33^{cd}	36.70^{cd}	46.67^{bcd}	56.67^{a}	-
T18	0	0.00^{c}	6.70^{cde}	10.00^{ef}	26.67^{bc}	23.30^{def}	30.00^{def}	36.67^{de}	50.00^{ab}	-
T19	0	13.30^{a}	23.30^{a}	26.70^{ab}	46.70^{a}	50.00^{a}	-	-	-	-
T20	0	10.00^{ab}	20.00^{ab}	30.00^{a}	50.00^{a}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 29. Effect of treatments on weight loss (%) at 15±1^{0}C

Treat - ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	0	0.28^{hi}	**0.32^{ghi}**	0.97^{ef}	1.78^{ef}	2.59^{f}	2.63^{j}	4.45^{f}	5.36^{f}	-
T2	0	0.81^{a}	1.16^{a}	3.43^{a}	3.62^{ab}	5.78^{a}	-	-	-	-
T3	0	0.48^{c}	0.56^{bc}	1.57^{c}	3.48^{b}	5.17^{b}	7.29^{a}	-	-	-
T4	**0**	**0.18^{l}**	**0.21^{i}**	**0.55^{k}**	**0.85^{g}**	**1.18^{i}**	**2.51^{jk}**	**3.20^{j}**	-	-
T5	0	0.40^{ef}	0.51^{bcd}	1.50^{c}	2.88^{c}	4.16^{c}	6.38^{b}	7.77^{a}	-	-
T6	0	0.38^{f}	0.45^{cde}	1.05^{e}	2.10^{ef}	3.95^{cd}	5.58^{c}	6.21^{b}	7.09^{a}	-
T7	0	0.40^{ef}	0.52^{bcd}	1.10^{e}	2.49^{d}	3.16^{e}	4.37^{e}	5.07^{e}	5.83^{e}	-
T8	0	0.35^{g}	0.43^{def}	1.01^{e}	1.96^{ef}	2.74^{f}	4.65^{d}	5.58^{c}	5.94^{de}	-
T9	0	0.29^{h}	0.38^{efg}	0.73^{hi}	1.51^{f}	2.14^{gh}	4.12^{f}	5.55^{c}	6.03^{d}	6.47^{a}
T10	0	0.25^{ij}	**0.31^{ghi}**	0.77^{gh}	1.82^{ef}	3.13^{e}	4.20^{ef}	5.15^{de}	6.01^{d}	6.26^{b}
T11	0	**0.21^{kl}**	**0.27^{hi}**	0.63^{ij}	**1.00^{g}**	**1.97^{h}**	2.90^{i}	3.70^{gh}	5.09^{gh}	-
T12	**0**	**0.20^{kl}**	**0.25^{i}**	**0.60^{j}**	**0.99^{g}**	**1.93^{h}**	2.69^{ij}	3.52^{hi}	**4.27^{j}**	5.32^{c}
T13	**0**	**0.17^{l}**	**0.22^{i}**	**0.59^{j}**	**0.97^{g}**	**1.84^{h}**	**2.35^{k}**	**3.41^{ij}**	**3.98^{k}**	**4.39^{e}**
T14	0	0.39^{f}	0.45^{cde}	1.26^{d}	2.59^{cd}	3.73^{d}	4.42^{e}	5.38^{cd}	6.40^{c}	-
T15	0	0.43^{de}	0.46^{cde}	1.33^{d}	2.66^{cd}	4.05^{cd}	5.57^{c}	6.15^{b}	6.65^{b}	-
T16	0	**0.21^{kl}**	**0.26^{hi}**	0.55^{k}	**1.07^{g}**	**2.01^{h}**	3.24^{h}	3.90^{g}	4.47^{i}	**5.01^{d}**
T17	0	0.25^{ij}	**0.30^{hi}**	0.77^{gh}	1.78^{ef}	2.44^{fg}	3.42^{h}	4.38^{f}	4.98^{h}	-
T18	0	0.22^{jk}	**0.34^{fghi}**	0.87^{fg}	1.94^{ef}	2.59^{f}	3.73^{g}	4.54^{f}	5.17^{g}	-
T19	0	0.44^{d}	0.59^{b}	1.31^{d}	2.12^{e}	3.83^{d}	-	-	-	-
T20	0	0.77^{b}	1.10^{b}	2.49^{b}	3.82^{a}	-	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Faster rate of change in weight loss was found in control with maximum weight loss of 3.82% within fifteen days after storage which was on par with T2 – fruits presoaked in cold water with 3.62%. Fruits presoaked in hot water (T3) also showed an increased weight loss with maximum weight loss of 7.29% on 21st day of storage which was significantly different from remaining treatments. Maximum weight loss of 7.77% was found in T5 - BA 100ppm on 24th day of storage towards end of post harvest life which was significantly different from other treatments.

4.2.3.3. Change in total soluble solids (TSS) as ^{0}Bx at 15±1^{0}C

Change in TSS was very slow at 15±1^{0}C compared to other storage temperatures. Fruits kept at 15±1^{0}C retained their TSS quality for longer period compared to other temperature regimes. The data presented in table 30 clearly indicate the statistical difference of TSS among treatments at various intervals of storage at 15±1^{0}C. The lowest TSS values were observed in T10 – GA_3 600ppm (17.00^{0}Bx) followed T9 – GA_3 400ppm (17.06^{0}Bx) and T13 – SA 3% (17.06^{0}Bx) on 3rd day of storage and they continued at a slow rate of increase, in the rest of shelf life. T10 was statistically superior to all other treatments but T9 and T13 were on par on 3DAS. After six days of storage lowest TSS content was noted in T13 (17.17^{0}Bx) which was on par with T10 (17.20^{0}Bx) followed by T9 (17.27^{0}Bx). T9 was on par with T10.

On 9thand 12th days of storage T10 showed lowest TSS values with 17.27^{0}Bx and 17.43^{0}Bx respectively followed by T9 and T13 (17.43^{0}Bx and 17.57^{0}Bx respectively). T10 was statistically superior to all other treatments. There was no significant difference between T9 and T13. Both T9 and T13 were on par with T8 (GA_3 200ppm) with 17.53^{0}Bx and 17.67^{0}Bx respectively, T12 (SA 2%) with 17.50^{0}Bx and 17.63^{0}Bx respectively and T16 ($CaCl_2$ 0.2%) with 17.53^{0}Bx and 17.63^{0}Bx respectively on 9DAS and 12DAS.

Table 30. Effect of treatments on change in TSS (^{0}Bx) at 15±1^{0}C

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	17.20^{fg}	17.40^{gh}	17.53^{gh}	17.67^{hi}	17.83^{hi}	18.13^{jk}	18.37^{h}	18.77ef	19.27^{bc}	-
T2	17.80^{b}	18.00^{b}	18.33^{b}	18.67^{bc}	18.93^{c}	19.43^{b}	-	-	-	-
T3	17.73^{bc}	17.97^{bc}	18.33^{b}	18.56^{cd}	18.77^{d}	19.17^{d}	19.43^{ab}	-	-	-
T4	17.26^{f}	17.57^{f}	17.87^{e}	18.27^{e}	18.60^{e}	18.83^{g}	18.97^{e}	19.37^{bc}	-	-
T5	17.70^{bc}	17.97^{bc}	18.33^{b}	18.56^{cd}	18.77^{d}	19.33^{c}	19.47^{a}	19.67^{a}	-	-
T6	17.60^{cd}	17.90^{cd}	18.27^{b}	18.50^{d}	18.77^{d}	19.13^{de}	19.37^{b}	19.63^{ab}	19.83^{a}	-
T7	17.43^{e}	17.77^{e}	17.97^{d}	18.33^{e}	18.63^{e}	19.00^{f}	19.13^{d}	19.47^{ab}	19.77^{a}	-
T8	17.20^{fg}	17.37^{ghi}	17.53^{gh}	17.67^{hi}	17.83^{hi}	18.13^{jk}	18.37^{h}	19.13^{cd}	19.07^{d}	-
T9	**17.06^{hi}**	**17.27^{jk}**	**17.43^{h}**	**17.57^{i}**	**17.67^{j}**	**17.97^{l}**	**18.17^{j}**	**18.47^{gh}**	**19.00^{d}**	**19.57^{ab}**
T10	**17.00^{ij}**	**17.20^{kl}**	**17.27^{i}**	**17.43^{j}**	**17.60^{j}**	**17.93^{l}**	**18.27^{i}**	**18.53^{fgh}**	**18.83^{e}**	**19.47^{b}**
T11	17.23^{fg}	17.43^{g}	17.57^{g}	17.73h	17.93^{h}	18.17^{j}	18.47^{g}	18.77^{ef}	19.37^{b}	-
T12	17.13^{gh}	17.30^{ij}	17.50^{gh}	17.63^{hi}	17.80^{i}	18.00^{l}	18.30^{hi}	18.63^{g}	19.27^{bc}	19.67^{a}
T13	**17.06^{hi}**	**17.17^{l}**	**17.43^{h}**	**17.57^{i}**	**17.77^{i}**	**17.83^{m}**	**18.13^{j}**	**18.33^{h}**	**18.53^{f}**	**19.33^{c}**
T14	17.63^{cd}	17.83^{de}	18.07^{c}	18.47^{d}	18.70^{de}	19.07^{def}	19.27^{c}	19.67^{a}	19.87^{a}	-
T15	17.53^{de}	17.80^{e}	18.07^{c}	18.37^{e}	18.67^{de}	19.03^{ef}	19.20^{cd}	19.47^{ab}	19.77^{a}	-
T16	17.16^{fgh}	17.33^{hij}	17.53^{gh}	17.63^{hi}	17.83^{hi}	18.03^{kl}	18.37^{h}	18.67^{efg}	19.37^{b}	
T17	17.23^{fg}	17.43^{g}	17.73^{f}	17.97^{g}	18.23^{g}	18.43^{i}	18.67^{f}	18.93^{de}	19.27^{bc}	-
T18	17.26^{f}	17.53^{f}	17.83^{e}	18.13^{f}	18.47^{f}	18.67^{h}	19.00^{e}	19.47^{ab}	19.83^{a}	-
T19	17.93^{a}	18.03^{b}	18.47^{a}	18.97^{a}	19.06^{b}	19.60^{a}	-	-	-	-
T20	17.80^{b}	18.20^{a}	18.47^{a}	18.73^{b}	19.27^{a}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1% 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

On fifteen days after storage, lowest TSS content was noted in T9 and T10 with 17.67^0Bx and 17.60^0Bx respectively followed by T12 (17.80^0Bx) and T13 (17.77^0Bx). There was no significant difference between T12 and T13 which were on par with T8 and T16 with TSS value of 17.83^0Bx. After eighteen days of shelf life T13 showed least value with 17.83^0Bx which was statistically superior to all other treatments followed by T9 (17.97^0Bx), T10 (17.93^0Bx) and T12 (18.00^0Bx) and these three treatments did not differ significantly with each other.

On 21st day of storage lowest TSS was noticed in T13 with 18.13^0Bx followed by T9 (18.17^0Bx) which were statistically on par. After 24 days of shelf life T13 with 18.33^0Bx had the lowest TSS content followed by T12 with 18.63^0Bx both were significantly different from each other and superior to other treatments. T9 (18.47^0Bx) and T10 (18.53^0Bx) were in terms with T12. At last part of storage on 27DAS and 30DAS, lowest TSS values were recorded in T13 with 18.53^0Bx and 19.33^0Bx respectively followed by T10 with 18.83^0Bx and 19.47^0Bx respectively. Both T10 and T13 differed significantly with each other and with other treatments on 27DAS and 30DAS. The fast rate of increase in TSS along with fast ripening was found in control, fruits kept in rattan baskets covered with dried banana leaves (T19) and those presoaked with cold water (T2). Maximum TSS value of 19.27^0Bx was observed in control within fifteen days of storage. On 18th day, at last day of its shelf life fruits kept in rattan baskets (T19) shown highest TSS value (19.60^0Bx) followed by fruits presoaked in cold water (T2) with 19.43^0Bx, which were significantly different.

4.2.3.4. Change in percentage of acidity at 15±1^{0}C

At 15±1^{0}C, all treatments showed significant difference with regard to percentage of acidity in fruits at all intervals of shelf life (Table 31). Compared to other storage temperatures a slow rate of reduction in acidity was noticed within a range of 0.370% to 0.240% up to 12th day of shelf life which later reduced to 0.220% on 27DAS towards last part of storage at this temperature.

Table 31. Effect of treatments on change in acidity (%) at 15±1^{0}C

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	0.350^{bc}	0.340^{cd}	0.326^{d}	0.303^{e}	0.287^{de}	0.280^{d}	0.273^{c}	0.263^{d}	0.253^{cd}	-
T2	0.307^{gh}	0.300^{i}	0.280^{j}	0.270^{j}	0.257^{g}	0.240^{g}	-	-	-	-
T3	0.310^{gh}	0.307^{hi}	0.290^{hi}	0.277^{hij}	0.260^{fg}	0.243^{fg}	0.233^{gh}	-	-	-
T4	0.320^{fg}	0.306^{hi}	0.293^{ghi}	0.276^{hij}	0.260^{fg}	0.250^{fg}	0.237^{gh}	0.220^{jk}	-	-
T5	0.313^{gh}	0.300^{i}	0.297^{fgh}	0.280^{hi}	0.267^{fg}	0.247^{fg}	0.233^{gh}	0.227^{ij}	-	-
T6	0.337^{cde}	0.307^{hi}	0.303^{ef}	0.283^{gh}	0.270^{f}	0.267^{e}	0.253^{ef}	0.247^{fg}	0.220^{e}	-
T7	0.326^{ef}	0.323^{fg}	0.310^{e}	0.303^{e}	0.290^{de}	0.273^{de}	0.263^{cde}	0.250^{ef}	0.253^{cd}	-
T8	0.340^{cde}	0.327^{ef}	0.300^{fg}	0.297^{ef}	0.293^{d}	0.280^{d}	0.270^{cd}	0.260^{de}	0.257^{bc}	-
T9	0.343^{bcd}	0.346^{bcd}	0.340^{bc}	0.323^{bcd}	0.313^{bc}	0.303^{bc}	0.300^{ab}	0.280^{bc}	0.267^{b}	0.250^{c}
T10	**0.370^{a}**	**0.357^{ab}**	**0.347^{ab}**	**0.323^{bcd}**	**0.317^{abc}**	**0.313^{ab}**	**0.300^{ab}**	**0.297^{a}**	**0.280^{a}**	**0.263^{b}**
T11	0.357^{ab}	0.347^{bcd}	0.337^{c}	0.320^{cd}	0.307^{c}	0.300^{c}	0.293^{b}	0.283^{b}	0.260^{bc}	-
T12	**0.363^{a}**	**0.353^{ab}**	**0.350^{a}**	**0.327^{bc}**	**0.320^{ab}**	**0.317^{a}**	**0.310^{a}**	**0.307^{a}**	**0.283^{a}**	**0.277^{a}**
T13	**0.367^{a}**	**0.360^{a}**	**0.346^{ab}**	**0.340^{a}**	**0.327^{a}**	**0.310^{abc}**	**0.303^{ab}**	**0.303^{a}**	**0.287^{a}**	**0.280^{a}**
T14	0.330^{def}	0.317^{fgh}	0.303^{ef}	0.290^{fg}	0.287^{de}	0.273^{de}	0.260^{de}	0.240^{fgh}	0.227^{e}	-
T15	0.327^{ef}	0.313^{gh}	0.300^{fg}	0.297^{ef}	0.280^{e}	0.253^{f}	0.243^{fg}	0.237^{ghi}	0.226^{e}	-
T16	**0.367^{a}**	**0.350^{abc}**	**0.340^{bc}**	**0.330^{b}**	**0.320^{ab}**	**0.313^{ab}**	**0.310^{a}**	**0.297^{a}**	**0.287^{a}**	**0.270^{ab}**
T17	0.347^{bc}	0.326^{ef}	0.323^{d}	0.320^{cd}	0.313^{bc}	0.300^{c}	0.293^{b}	0.270^{cd}	0.267^{b}	-
T18	0.343^{bcd}	0.337^{de}	0.320^{d}	0.317^{d}	0.306^{c}	0.283^{d}	0.273^{c}	0.260^{de}	0.243^{d}	-
T19	0.306^{gh}	0.300^{i}	0.287^{ij}	0.273^{ij}	0.256^{g}	0.240^{g}	-	-	-	-
T20	0.303^{h}	0.280^{j}	0.267^{k}	0.240^{k}	0.233^{h}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

T10 (GA_3 600ppm), T13 (salicylic acid 3%), T12 (salicylic acid 2%) and T16 ($CaCl_2$ 0.2%) showed higher retention of acidity with 0.297%, 0.307%, 0.303% and 0.297% respectively even after 24 days of shelf life which were on par. Maximum percentage of acidity was observed in T13 (0.280%) and T12 (0.277%) at end of storage period on 30th day and they were on par with T16 (0.270%). Minimum acidity retention rate was noticed in control fruits with 0.233% within 15th day of storage which was significantly different from other treatments.

4.2.3.5. Change in phenol content (mg/100g) at 15±1^{0}C

Statistical analysis of data on phenol contents in mangosteen fruits under different treatments stored at 15±1^{0}C showed significant difference at all the intervals of storage period (Table 32). Degradation of phenol at this temperature was found gradual in all treatments compared to other low temperatures. T13 – salicylic acid 3% and T12 – salicylic acid 2% recorded maximum phenol contents of 0.890 mg/100g and 0.882 mg/100g respectively. On 15th day maximum phenol content of 0.791 mg/100g was observed in T12 which was on par with T13 (0.788 mg/100g), T10 – GA_3 600ppm (0.784 mg/100g), T9 – GA_3 400ppm (0.781 mg/100g) and T11 – salicylic acid 1% (0.777 mg/100g). Maximum phenol contents was found even after 21st and 27th day in T10 (0.752 mg/100g and 0.709 mg/100g respectively), T12 (0.747 mg/100g and 0.715 mg/100g respectively) and T13 (0.742 mg/100g and 0.719 mg/100g respectively) which were not significantly different from each other. Fruits presoaked in cold water - T2 (0.694 mg/100g and 0.486 mg/100g respectively) and fruits kept as control (0.674 mg/100g and 0.473 mg/100g respectively) recorded minimum phenol contents on 9th and 15th day old shelf life, at end of its storage.

4.2.2.6. Rind hardening (kg/cm^2) at 15±1^{0}C

Analysis of data on rind hardening revealed that mangosteen fruits under different treatments stored at 15±1^{0}C varied significantly during all the intervals of storage period (Table 33). Pericarp hardening was very slow at this temperature compared to 5±1^{0}C and10±1^{0}C temperature conditions as there was

Table 32. Effect of treatments on change in phenol content (mg/100g) at 15±1^{0}C

Treatments	*3DAS*	*9DAS*	*15DAS*	*21DAS*	*27DAS*
T1	0.847^{c}	0.764^{ef}	0.707^{def}	0.648^{d}	0.576^{bcd}
T2	0.814^{hi}	0.694^{i}	0.486^{k}	-	-
T3	0.826^{gh}	0.717^{h}	0.687^{ghi}	0.623^{fg}	-
T4	0.838^{cdefg}	0.743^{g}	0.672^{i}	0.615^{g}	-
T5	0.848^{c}	0.764^{ef}	0.721^{d}	0.640^{de}	-
T6	0.844^{cd}	0.771^{e}	0.716^{de}	0.643^{de}	0.607^{bcd}
T7	0.851^{c}	0.784^{d}	0.750^{c}	0.686^{c}	0.615^{bc}
T8	0.842^{cde}	0.767^{ef}	0.771^{b}	0.681^{c}	0.581^{bcd}
T9	0.848^{c}	0.806^{c}	**0.781^{ab}**	0.708^{b}	0.622^{bc}
T10	0.867^{b}	0.825^{b}	**0.784^{ab}**	**0.752^{a}**	**0.709^{a}**
T11	0.851^{c}	0.817^{bc}	**0.777^{ab}**	0.692^{c}	0.627^{b}
T12	**0.882^{a}**	**0.825^{b}**	**0.791^{a}**	**0.747^{a}**	**0.715^{a}**
T13	**0.890^{a}**	**0.851^{a}**	**0.788^{ab}**	**0.742^{a}**	**0.719^{a}**
T14	0.814^{hi}	0.715^{h}	0.679^{hi}	0.614^{g}	0.549^{d}
T15	0.827^{fgh}	0.744^{g}	0.692^{fgh}	0.629^{efg}	0.562^{cd}
T16	0.841^{cdef}	0.759^{ef}	0.703^{efg}	0.641^{de}	0.572^{bcd}
T17	0.832^{defg}	0.757^{f}	0.698^{fg}	0.632^{ef}	0.564^{bcd}
T18	0.830^{efg}	0.763^{ef}	0.692^{fgh}	0.628^{efg}	0.562^{cd}
T19	0.807^{ij}	0.707^{h}	0.564^{j}	-	-
T20	0.797^{j}	0.674^{j}	0.473^{k}	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

no chilling injury. Even after thirty days of storage rind hardness recorded was only12.63kg/cm^2 in T16 – $CaCl_2$ 0.2%. On 15DAS maximum firmness of 10.87kg/cm^2 was noted in control and on 18DAS maximum hardening was found in T19 – fruits covered with dried banana leaves (11.77kg/cm^2).

Rind hardness was minimum throughout storage period in T13 (SA 3%) and T12 (SA 2%). Minimum pericarp hardening with fruit firmness of 6.00kg/cm^2 was found in T13 which was significantly different from all other treatments followed by T12 and T10 (GA_3 600ppm) with 6.27kg/cm^2 and 6.23kg/cm^2 respectively after three days of storage.T12 and T10 were not significantly different on 3DAS. On 6th day of storage T13 had lowest firmness value with 6.37kg/cm^2 followed by T10 (6.53kg/cm^2) which were significantly different. After nine days of storage minimum fruit firmness of 6.93kg/cm^2 was noticed in T13 followed by T12 (7.23kg/cm^2) which differed significantly.

On 12th day of storage T13 (7.97kg/cm^2) and T10 (8.07kg/cm^2) had the lowest fruit firmness and were on par. T13 and T10 were followed by T12 and T9 with 8.33kg/cm^2 firmness which were also on par with each other. During 15th, 18th and 21st days after storage pericarp hardening was minimum in T13 (8.27kg/cm^2, 9.00kg/cm^2 and 9.57kg/cm^2 respectively) followed by T12 (8.57kg/cm^2, 8.87kg/cm^2 and 9.40kg/cm^2 respectively) and were significantly different. After twenty four days of shelf life T13 (9.97kg/cm^2) and T12 (9.87kg/cm^2) had the lowest values which did not differ significantly. All the treatments which retained their shelf life up to 27th day of storage did not significantly differ from each other and the minimum hardening was noted in T13 with 10.60kg/cm^2. At end of storage on 30th day of shelf life T13 (11.63kg/cm^2), T12 (11.50kg/cm^2) and T10 (11.67kg/cm^2) showed lowest values and were on par.

Table 33. Effect of treatments on rind hardening (kg/cm^2) at 15±1^{0}C

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	7.07^{h}	7.57^{gh}	8.03^{i}	8.60^{k}	8.93^{i}	9.70^{j}	10.30^{g}	10.83^{f}	12.37^{a}	-
T2	7.80^{c}	8.07^{d}	8.77^{e}	9.50^{ef}	9.90^{de}	11.37^{b}	-	-	-	-
T3	7.37^{f}	7.87^{e}	8.87^{de}	9.87^{c}	10.47^{c}	11.33^{b}	12.67^{a}	-	-	-
T4	7.57^{d}	7.97^{de}	8.97^{cd}	9.63^{d}e	10.00^{d}	10.43^{ef}	10.70^{f}	11.53^{de}	-	-
T5	6.53^{j}	6.80^{j}	7.87^{j}	9.00^{j}	9.83^{e}	10.20^{h}	10.87^{e}	11.50^{e}	-	-
T6	7.13^{h}	7.77^{fg}	8.43^{fg}	9.30^{gh}	9.67^{f}	10.50^{e}	11.07^{d}	11.73^{bc}	12.07^{a}	-
T7	7.47^{e}	7.90^{e}	8.23^{h}	9.10^{ij}	9.57^{fg}	10.30^{gh}	10.73^{f}	11.67^{cd}	12.03^{a}	-
T8	6.60^{j}	7.07^{i}	7.77^{jk}	8.63^{k}	9.17^{h}	9.70^{j}	10.37^{g}	10.77^{f}	11.50^{a}	-
T9	6.50^{j}	6.97^{i}	7.73^{k}	8.33^{l}	8.90^{i}	9.50^{j}	9.87^{h}	10.60^{g}	11.07^{a}	11.93^{b}
T10	6.23^{k}	6.53^{k}	7.37^{l}	8.07^{m}	8.93^{i}	9.17^{k}	9.70^{i}	10.27^{h}	10.97^{a}	11.67^{c}
T11	6.90^{i}	7.70^{f}	8.47^{fg}	9.17^{hi}	9.43^{g}	9.93^{i}	10.30^{g}	10.87^{f}	11.57^{a}	-
T12	**6.27^{k}**	**6.73^{j}**	**7.23^{m}**	**8.33^{l}**	**8.57^{j}**	**9.00^{l}**	**9.57^{j}**	**9.87^{i}**	**10.83^{a}**	**11.50^{c}**
T13	**6.00^{l}**	**6.37^{l}**	**6.93^{n}**	**7.97^{m}**	**8.27^{k}**	**8.87^{m}**	**9.40^{k}**	**9.97^{i}**	**10.60^{a}**	**11.63^{c}**
T14	7.27^{g}	7.63^{fgh}	8.37^{g}	8.97^{j}	9.47^{g}	10.30^{gh}	10.73^{f}	10.87^{f}	13.44^{a}	-
T15	6.90^{i}	7.53^{h}	8.50^{f}	9.43^{fg}	9.80^{e}	10.37^{fg}	10.70^{f}	11.47^{e}	11.97^{a}	-
T16	7.93^{b}	8.33^{c}	9.20^{b}	10.07^{b}	10.33^{c}	10.77^{d}	11.50^{b}	11.83^{b}	12.30^{a}	12.63^{a}
T17	7.93^{b}	8.27^{c}	9.43^{a}	10.47^{a}	10.67^{b}	11.00^{c}	11.40^{c}	12.03^{a}	12.60^{a}	-
T18	8.10^{a}	8.50^{b}	9.37^{a}	9.77^{cd}	10.43^{c}	10.97^{c}	11.57^{b}	12.03^{a}	12.70^{a}	-
T19	8.00^{b}	8.67^{a}	9.07^{c}	9.87^{c}	10.40^{c}	11.77^{a}	-	-	-	-
T20	7.67^{c}	8.60^{ab}	9.37^{a}	10.47^{a}	10.87^{a}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent (KMnO$_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA$_3$ 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

4.2.3.7. Change in rind colour at 15±1^{0}C

The data related to the mean score of rind colour of fruits under various treatments at 15±1^{0}C are presented in table 34. Mangosteen fruits kept at 15±1^{0}C retained their skin colour up to 6th day of shelf life without any fading. Rind discolouration was noted from 9th day of storage onwards. Fruits treated with salicylic acid 3% (T13), sodium erythorbate 2% (T14), N-acetyl cystene 0.05% (T15), sodium erythorbate 2% + $CaCl_2$ 0.2% (T17), N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) gave best results for retaining rind colour of fruits. In the above superior treatments none to slight colour change was observed on 9DAS (0.00, 0.67, 0.33, 0.00 and 0.33 respectively) and 12DAS (0.67, 1.00, 0.67, 0.67 and 0.67 respectively). Slight to moderate discoloration was seen on 15DAS (1.00, 1.33, 1.33, 1.00 and 1.33 respectively) and 18DAS (1.67, 1.67, 2.00, 1.67 and 2.00 respectively). Moderate to severe damage to fruit rind occurred for these treatments on 21DAS (2.00, 2.33, 2.33, 2.00 and 2.00 respectively), 24DAS (2.33, 3.00, 2.67, 2.67 and 2.33 respectively) and 27DAS (2.67 for T13 and 3.00 for others). In fruits presoaked with cold water (T2) and hot water (T3), fruits treated with 200ppm GA_3 (T8), fruits kept in rattan baskets covered with banana leaves (T19) and control fruits, moderate to severe discoloration was noted within 15DAS and more than 50% of fruit rind got spoiled on 18th day of storage.

4.2.3.8. Change in pulp colour at 15±1^{0}C

Mangosteen fruits in all treatments kept at 15±1^{0}C retained their white colour up to six days of storage. Slight to moderate fading of pulp colour was noticed in some treatments from 9DAS only. The data related to the mean score of pulp colour of fruits under various treatments at 15±1^{0}C are presented in table 35. Fruit pulp colour was retained throughout shelf life in certain good treatments. Fruits treated SA 2% (T12) SA 3% (T13), sodium erythorbate 2% (T14), N-acetyl cystene 0.05% (T15), sodium erythorbate 2% + $CaCl_2$ 0.2% (T17), N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) gave best results without any discolouration of fruit pulp even after nine days of storage . In the above best

Table 34. Effect of treatments on change in rind colour at 15±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	0	0	0.33	1.00	1.67	2.67	3.00	3.00	3.00	-
T2	0	0	1.33	2.00	2.33	3.00	-	-	-	-
T3	0	0	1.00	1.67	2.00	3.00	3.00	-	-	-
T4	0	0	0.33	1.33	1.67	2.33	2.67	3.00	-	-
T5	0	0	1.00	1.67	2.33	2.67	3.00	3.00	-	-
T6	0	0	0.67	1.33	2.00	2.33	3.00	3.00	3.00	-
T7	0	0	0.33	1.00	1.67	2.00	2.33	3.00	3.00	-
T8	0	0	0.67	1.00	2.00	3.00	3.00	3.00	3.00	-
T9	0	0	1.00	1.67	2.00	2.67	3.00	3.00	3.00	3.00
T10	0	0	0.67	1.33	1.67	2.33	2.67	3.00	3.00	3.00
T11	0	0	0.67	1.67	2.00	2.67	3.00	3.00	3.00	-
T12	0	0	0.33	1.00	2.00	2.33	2.67	3.00	3.00	3.00
T13	**0**	**0**	**0.00**	**0.67**	**1.00**	**1.67**	**2.00**	**2.33**	**2.67**	3.00
T14	**0**	**0**	**0.67**	**1.00**	**1.33**	**1.67**	**2.33**	**3.00**	**3.00**	-
T15	**0**	**0**	**0.33**	**0.67**	**1.33**	**2.00**	**2.33**	**2.67**	**3.00**	-
T16	0	0	0.67	1.00	1.67	2.33	3.00	3.00	3.00	3.00
T17	**0**	**0**	**0.00**	**0.67**	**1.00**	**1.67**	**2.00**	**2.67**	**3.00**	-
T18	**0**	**0**	**0.33**	**0.67**	**1.33**	**2.00**	**2.00**	**2.33**	**3.00**	-
T19	0	0	1.00	2.00	2.33	3.00	-	-	-	-
T20	0	0	1.33	1.67	2.33	-	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 35. Effect of treatments on change in pulp colour at 15±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treat-ments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*	*30DAS*
T1	0	0	0.00	0.67	1.00	1.67	2.00	2.67	3.00	-
T2	0	0	1.00	1.67	2.00	3.00	-	-	-	-
T3	0	0	0.67	1.00	1.67	2.67	3.00	-	-	-
T4	0	0	0.00	1.00	1.33	1.33	2.33	3.00	-	-
T5	0	0	0.67	1.33	1.33	2.00	2.67	3.00	-	-
T6	0	0	0.33	1.33	1.67	1.67	2.00	2.33	3.00	-
T7	0	0	0.33	1.00	1.33	1.67	2.33	2.33	3.00	-
T8	0	0	0.67	0.67	1.33	2.00	2.33	2.67	3.00	-
T9	0	0	0.67	0.67	1.00	1.67	2.00	2.00	2.33	2.67
T10	0	0	0.33	0.33	1.33	1.33	2.00	2.33	2.67	2.67
T11	0	0	0.33	0.67	1.00	1.00	1.33	2.00	2.33	-
T12	0	0	**0.00**	**0.33**	**0.33**	**1.00**	**1.67**	**2.33**	**2.33**	2.67
T13	**0**	**0**	**0.00**	**0.00**	**0.67**	**0.67**	**1.33**	**2.00**	**2.33**	2.33
T14	**0**	**0**	**0.00**	**0.00**	**0.33**	**0.67**	**1.33**	**2.00**	**2.67**	-
T15	**0**	**0**	**0.00**	**0.33**	**0.67**	**0.67**	**1.33**	**2.00**	**2.33**	-
T16	0	0	0.67	1.00	1.33	2.00	2.00	2.67	3.00	3.00
T17	**0**	**0**	**0.00**	**0.67**	**0.67**	**1.00**	**1.33**	**2.33**	**2.33**	-
T18	**0**	**0**	**0.00**	**0.33**	**0.67**	**1.00**	**1.00**	**2.33**	**2.67**	-
T19	0	0	1.00	1.67	2.33	3.00	-	-	-	-
T20	0	0	1.00	1.33	2.33	-	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

treatments there was no colour change for T13 and T14 but none to slight variation of pulp colour was noticed in T12, T15, T17 and T18 (0.33, 0.33, 0.67 and 0.33 respectively) on 12DAS. In T12, T13, T14, T15, T17 and T18 none to slight change in pulp colour was noted on 15DAS (0.33, 0.67, 0.33, 0.67, 0.67and 0.67 respectively) and on 18DAS (1.00, 0.67, 0.67, 0.67, 1.00 and1.00 respectively). Slight to moderate pulp colour change occurred on 21DAS (1.67, 1.33, 1.33, 1.33, 1.33 and 1.00 respectively). Moderate to severe pulp colour change on 27DAS (2.33, 2.00, 2.00, 2.00, 2.33 and 2.33 respectively) and on 30DAS (2.33, 2.33, 2.67, 2.33, 2.33 and 2.67 respectively) was recorded in the above treatments. Maximum fruit pulp disclouration with 25 to 50% aril affected was observed in control and T19 (2.33) on 15DAS. Severe pulp discolouration (3.00) was noted in T19 and T2 within eighteen days of storage.

4.2.4. Shelf life at 20±1^{0}C temperature regime

4.2.4.1. Storage life of fruits at 20±1^{0}C

Enhanced shelf life of mangosteen fruits with 24 days of storage life was found at 20±1^{0}C. Significant difference existed between the treatments at 20±1^{0}C (Table 36). Storage life was longest in treatments with $CaCl_2$ 0.2% whole fruit dipping (T16) with 46.67% fruit loss on 24DAS followed by fruits with calyx and stem end dipped in salicylic acid 3% (T13) shown 50% fruit loss. T13 was statistically superior to all other treatments on the 24th day of storage. All other treatments were on par on 24th day. Shortest period of storage at 20±1^{0}C was noted as 12 days in fruits kept in rattan baskets covered with banana leaves (T19) with 50% fruit loss.

4.2.4.2. Physiological loss in weight at 20±1^{0}C

Mangosteen fruits stored at 20±1^{0}C under various treatments also showed significant difference with respect to percentage weight loss on all intervals of shelf life from 6th day of storage onwards (Table 37). In all the treatments physiological loss in weight was noted from 6th day of storage onwards with a slow rate of change in weight loss. Minimum weight loss of 0.23% was

Table 36. Effect of treatments on shelf life (percentage loss of fruits) at 20±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	0	3.33^{cd}	23.30^{abc}	26.70^{bc}	33.33^{bc}	43.30^{bc}	53.30^{a}	-	-
T2	0	3.30^{cd}	23.33^{abc}	26.67^{bc}	36.70^{b}	56.67^{a}	-	-	-
T3	0	13.33^{ab}	26.70^{ab}	30.00^{b}	46.67^{a}	60.00^{a}	-	-	-
T4	0	3.30^{cd}	20.00^{bcd}	26.67^{bc}	26.70^{cde}	40.00^{abc}	53.30^{a}	-	-
T5	0	10.00^{bc}	13.30^{def}	16.70^{def}	26.67^{cde}	26.70^{fgh}	46.67^{a}	56.70^{ab}	-
T6	0	0.00^{d}	16.67^{cde}	20.00^{cde}	20.00^{efg}	23.33^{ghi}	43.33^{ab}	53.33^{ab}	-
T7	0	3.30^{cd}	3.33^{g}	10.00^{f}	20.00^{efg}	16.67^{ij}	36.67^{bc}	53.33^{ab}	-
T8	0	3.33^{cd}	10.00^{efg}	20.00^{cde}	23.30^{def}	33.33^{def}	53.30^{a}	-	-
T9	0	6.67^{bcd}	10.00^{efg}	13.33^{ef}	20.00^{efg}	26.70^{fgh}	50.00^{a}	-	-
T10	0	13.30^{ab}	16.67^{cde}	26.67^{bc}	26.70^{cde}	30.00^{efg}	53.33^{a}	-	-
T11	0	0.00^{d}	6.67^{fg}	13.33^{ef}	16.67^{fg}	20.00^{hij}	50.00^{a}	56.67^{ab}	-
T12	0	6.67^{bcd}	10.00^{efg}	20.00^{cde}	33.33^{bc}	36.67^{cde}	46.67^{a}	53.33^{ab}	-
T13	0	0.00^{d}	6.67^{fg}	10.00^{f}	13.30^{g}	26.67^{fgh}	43.33^{ab}	**50.00^{ab}**	**56.67^{a}**
T14	0	10.00^{bc}	13.33^{def}	20.00^{cde}	23.30^{def}	23.33^{ghi}	53.30^{a}	-	-
T15	0	3.33^{cd}	16.67^{cde}	23.30^{bcd}	30.00^{bcd}	40.00^{abc}	46.70^{a}	60.00^{a}	-
T16	0	3.30^{cd}	10.00^{efg}	26.67^{bc}	23.33^{def}	30.00^{efg}	36.70^{bc}	**46.67^{c}**	**60.00^{a}**
T17	0	6.70^{bcd}	13.33^{def}	20.00^{cde}	23.30^{def}	26.70^{fgh}	36.67^{bc}	53.33^{ab}	**60.00^{a}**
T18	0	3.33^{cd}	13.30^{def}	20.00^{cde}	23.33^{def}	30.00^{efg}	43.30^{ab}	56.70^{ab}	-
T19	0	13.33^{ab}	30.00^{a}	50.00^{a}	-	-	-	-	-
T20	0	20.00^{a}	26.67^{ab}	46.67^{a}	50.00^{a}	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

observed in T13 –salicylic acid 3% and T4 – fruits wrapped in cling film which were not significantly different from each other followed by T12 – 2% salicylic acid (0.29%), T16- $CaCl_2$ 0.2% (0.29%), T10 – GA_3 600ppm (0.31%), T9 – GA_3 400ppm (0.30%) which were on par and were significantly different from T13 and T4. These treatments retained their trend of minimum weight loss till end of post harvest life with 1.57% weight loss in T13 even after 21 days of storage followed by T4 (2.56%) and T16 (2.57%) which were on par with each other and were significantly different with T13 and others. Maximum weight loss of 4.99% was recorded in control fruits within 15 days after storage. Fruits presoaked in cold water (T2) also showed maximum weight loss of 5.76% on 18th day of storage followed by 4.02% in fruits presoaked in hot water (T3) which were significantly different from each other and with rest of treatments. Towards end of post harvest life on 24th day T5- 100ppm BA had maximum weight loss of 6.06% which was significantly different from all the remaining treatments.

4.2.4.3. Change in total soluble solids (TSS) as ^{0}Bx at 20±1^{0}C

Mangosteen fruits stored at 20±1^{0}C under various treatments also showed significant difference with regard to TSS on all intervals of storage (Table 38). Fruits treated with $CaCl_2$ 0.2% (T16) and SA 3% (T13) recorded low TSS values throughout the storage period compared to other treatments. On 3rd day of storage T16 had the lowest TSS value with 17.03^{0}Bx followed by T13 and T10 (GA_3 600ppm) with 17.17^{0}Bx. There was no significant difference between T10 and T13 and were on par with T12 (SA 2%) with 17.23^{0}Bx on 3DAS. Lowest TSS content of 17.33^{0}Bx and 17.30^{0}Bx was noted in T13 and T16 on six days after storage which were on par followed by T10 and T12 with 17.47^{0}Bx. There was no significant difference between T10 and T12 which were on par with T11 (SA 1%) and T17 (Sodium erythorbate 2% + $CaCl_2$ 0.2%) with 17.53^{0}Bx.

After nine days of shelf life, lowest TSS value of 17.47^{0}Bx was found in T16 which was statistically superior to all other treatments followed by T10 and T13 with 17.67^{0}Bx. Both T10 and T13 did not differ significantly and

Table 37. Effect of treatments on weight loss (%) at 20±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	0	0.35^{j}	0.54^{fg}	1.12^{hi}	2.15^{f}	3.07^{f}	4.05^{f}	-	-
T2	0	0.75^{c}	1.63^{b}	2.29^{b}	4.06^{b}	5.76^{a}	-	-	-
T3	0	0.67^{d}	0.74^{c}	1.66^{c}	2.83^{c}	4.02^{b}	-	-	-
T4	**0**	**0.23^{l}**	**0.47^{ghij}**	0.99^{k}	**1.16^{hi}**	1.48^{j}	**2.56^{j}**	-	-
T5	0	0.67^{d}	0.72^{cd}	1.67^{c}	2.52^{d}	3.70^{c}	4.81^{a}	6.06^{a}	-
T6	0	0.61^{ef}	0.64^{de}	1.57^{d}	2.28^{ef}	3.58^{d}	4.33^{de}	5.32^{c}	-
T7	0	0.58^{f}	0.61^{ef}	1.63^{cd}	2.33^{def}	3.26^{e}	4.37^{d}	5.76^{b}	-
T8	0	0.42^{i}	0.48^{ghi}	1.16^{h}	2.27^{ef}	3.27^{e}	4.83^{a}	-	-
T9	0	0.30^{k}	0.45^{hij}	1.39^{ef}	2.47^{de}	3.69^{c}	4.51^{c}	-	-
T10	0	0.31^{k}	0.46^{ghij}	1.34^{fg}	2.75^{c}	3.51^{d}	4.63^{b}	-	-
T11	0	0.35^{j}	0.44^{hij}	1.02^{jk}	1.76^{g}	2.66^{h}	3.69^{g}	4.12^{e}	-
T12	0	**0.29^{k}**	**0.40^{ij}**	**0.91^{l}**	**1.28^{h}**	2.41^{i}	3.08^{i}	3.78^{f}	-
T13	**0**	**0.23^{l}**	**0.39^{j}**	**0.64^{m}**	**0.99^{i}**	**1.12^{l}**	**1.57^{k}**	**2.85^{h}**	**3.31^{c}**
T14	0	0.62^{e}	0.67^{cde}	1.42^{e}	2.50^{d}	3.34^{e}	4.26^{e}	-	-
T15	0	0.50^{gh}	0.64^{de}	1.30^{g}	2.16^{f}	2.89^{g}	3.42^{h}	4.36^{d}	-
T16	0	**0.29^{k}**	**0.41^{ij}**	**0.89^{l}**	**1.01^{i}**	**1.37^{k}**	**2.57^{j}**	**3.37^{g}**	**4.53^{b}**
T17	0	0.51^{g}	0.51^{gh}	1.07^{ij}	1.88^{g}	2.52^{i}	3.37^{h}	4.29^{d}	4.97^{a}
T18	0	0.46^{h}	0.49^{ghi}	1.14^{hi}	2.23^{f}	3.04^{f}	3.60^{g}	4.35^{d}	-
T19	0	0.92^{a}	1.70^{a}	3.46^{a}	-	-	-	-	-
T20	0	0.81^{b}	1.64^{b}	3.42^{a}	4.99^{a}	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 38. Effect of treatments on change in TSS (^{0}Bx) at 20±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	17.37^{ghi}	17.63^{de}	17.87^{cde}	18.23^{e}	18.47^{d}	18.83^{f}	19.20^{de}	-	-
T2	17.67^{ab}	17.93^{ab}	18.33^{a}	18.63^{a}	18.87^{ab}	19.33^{a}	-	-	-
T3	17.57^{cd}	17.77^{c}	18.26^{a}	18.47^{bc}	18.77^{b}	19.13^{cd}	-	-	-
T4	17.43^{fg}	17.70^{cd}	17.97^{bc}	18.27^{de}	18.63^{c}	19.07^{d}	19.47^{b}	-	-
T5	17.67^{ab}	17.90^{ab}	18.33^{a}	18.57^{ab}	18.87^{ab}	19.27^{ab}	19.57^{a}	19.83^{a}	-
T6	17.47^{ef}	17.77^{c}	17.97^{bc}	18.37^{cd}	18.63^{c}	19.10^{cd}	19.37^{c}	19.67^{b}	-
T7	17.40^{fgh}	17.63^{de}	17.93^{bcd}	18.27^{de}	18.57^{cd}	18.83^{f}	19.13^{e}	19.47^{cd}	-
T8	17.63^{bc}	17.87^{b}	18.26^{a}	18.50^{b}	18.77^{b}	19.20^{bc}	19.57^{a}	-	-
T9	17.33^{hij}	17.57^{ef}	17.87^{cde}	18.23^{e}	18.37^{e}	18.83^{f}	19.27^{cd}	-	-
T10	17.17^{l}	17.47^{g}	17.67^{f}	17.87^{g}	18.27^{e}	18.57^{gh}	18.83^{h}	-	-
T11	17.27^{jk}	17.53^{fg}	17.83^{de}	18.03^{f}	18.33^{e}	18.63^{gh}	18.93^{g}	19.33^{e}	-
T12	**17.23^{kl}**	**17.47^{g}**	**17.77^{ef}**	**17.93^{fg}**	**18.27^{e}**	**18.57^{gh}**	**18.80^{hi}**	**19.40^{de}**	-
T13	**17.17^{l}**	**17.33^{h}**	**17.67^{f}**	**17.87^{g}**	**18.27^{e}**	**18.53^{h}**	**18.73^{i}**	**19.07^{f}**	**19.53^{b}**
T14	17.53^{de}	17.77^{c}	18.03^{b}	18.47^{bc}	18.77^{b}	19.13^{cd}	19.37^{c}	-	-
T15	17.43^{fg}	17.67^{d}	17.97^{bc}	18.27^{de}	18.57^{cd}	18.97^{e}	19.27^{cd}	19.53^{c}	-
T16	**17.03^{m}**	**17.30^{h}**	**17.47^{g}**	**17.67^{h}**	**17.83^{f}**	**18.07^{i}**	**18.47^{j}**	**18.77^{g}**	**19.36^{c}**
T17	17.27^{jk}	17.53^{fg}	17.83^{de}	17.93^{fg}	18.33^{e}	18.63^{gh}	19.03^{f}	19.37^{de}	19.67^{a}
T18	17.30^{ijk}	17.57^{ef}	17.87^{cde}	18.16^{e}	18.37^{e}	18.67^{g}	18.97^{fg}	19.33^{e}	-
T19	17.73^{a}	17.93^{ab}	18.33^{a}	18.63^{a}	-	-	-	-	-
T20	17.73^{a}	17.97^{a}	18.37^{a}	18.67^{a}	18.90^{a}	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

was on par with T12 (17.77^{0}Bx). On 12DAS and 15DAS, T16 shown least TSS content with 17.67^{0}Bx and 17.83^{0}Bx respectively followed by T10 and T13 (17.87^{0}Bx and 18.27^{0}Bx respectively). There was no significant difference between T10 and T13 at 12th and 15th days of storage.

Lowest TSS value of 18.07^{0}Bx was observed in T16 on 18DAS followed by T13 (18.53^{0}Bx) and they differ significantly. T13 was on par with T10 (18.57^{0}Bx), T11 (18.63^{0}Bx), T12 (18.57^{0}Bx) and T17 (18.63^{0}Bx). At 21st day of storage lowest TSS value of 18.47^{0}Bx was found in T16 followed by T13 with 18.73^{0}Bx which differed significantly from each other. T13 was on par with T12 (18.80^{0}Bx). At the end of storage on 24DAS and 27DAS also lowest TSS content was noted in T16 with 18.77^{0}Bx and 19.36^{0}Bx respectively followed by T13 with19.07^{0}Bx and 19.53^{0}Bx respectively. On the last day also T16 was significantly superior to T13.

The fruits kept as control (T20) and those packed in rattan baskets with banana leaves (T19) showed a high rate of increase in TSS compared to other treatments. T19 had the highest TSS value of 18.63^{0}Bx on 12DAS at end of its shelf life which did not differ significantly with T2 – fruits presoaked in cold water (18.63^{0}Bx) and control (18.67^{0}Bx) and all these were on par with T5 – BA 100ppm (18.57^{0}Bx).

4.2.4.4. Change in percentage of acidity at 20±1^{0}C

Mangosteen fruits stored at 20±1^{0}C under various treatments also showed significant difference with regard to percentage of acidity on all intervals of storage period (Table 39). Percentage of acidity ranged from 0.377% to 0.277% after completing nine days of storage at 20±1^{0}C which was further reduced to 0.243% on 18th day of shelf life. Best results with highest acidity retention was observed in T16 - $CaCl_2$ 0.2% (0.330% and 0.323% respectively) which was on par with T13 - salicylic acid 3% (0.327% and 0.313% respectively) on 15th and 18th day of shelf life. Towards end of shelf life on 24th day also T13 (0.293%) and

Table 39. Effect of treatments on change in acidity (%) at 20±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	0.326^{jk}	0.313^{jk}	0.307^{ef}	0.300^{gh}	0.297^{efg}	0.280^{ef}	0.270^{de}	-	-
T2	0.310^{l}	0.303^{l}	0.283^{g}	0.290^{i}	0.277^{h}	0.260^{g}	-	-	-
T3	0.317^{kl}	0.310^{kl}	0.300^{f}	0.270^{j}	0.260^{i}	0.243^{h}	-	-	-
T4	0.347^{fgh}	0.333^{h}	0.313^{de}	0.303^{fgh}	0.293^{fg}	0.280^{ef}	0.267^{def}	-	-
T5	0.340^{ghi}	0.337^{gh}	0.310^{def}	0.300^{gh}	0.293^{fg}	0.270^{fg}	0.253^{fg}	0.250^{f}	-
T6	0.343^{gh}	0.333^{h}	0.320^{cd}	0.313^{def}	0.297^{efg}	0.283^{de}	0.267^{def}	0.253^{ef}	-
T7	0.350^{efg}	0.343^{efg}	0.333^{b}	0.317^{de}	0.303^{def}	0.290^{de}	0.270^{de}	0.260^{e}	-
T8	0.330^{ij}	0.317^{ijk}	0.307^{ef}	0.293^{hi}	0.280^{h}	0.263^{g}	0.257^{efg}	-	-
T9	0.336^{hij}	0.323^{i}	0.303^{ef}	0.297^{ghi}	0.283^{gh}	0.270^{fg}	0.250^{g}	-	-
T10	0.363^{bcd}	0.350^{de}	0.337^{b}	0.320^{d}	0.313^{cd}	0.307^{b}	0.300^{abc}	-	-
T11	0.360^{cde}	0.347^{def}	0.333^{b}	0.320^{d}	0.310^{cde}	0.303^{bc}	0.297^{bc}	0.277^{cd}	-
T12	0.370^{abc}	0.360^{bc}	0.350^{a}	0.333^{bc}	0.317^{bcd}	0.310^{b}	0.303^{abc}	0.280^{bc}	-
T13	**0.377^{a}**	**0.363^{ab}**	**0.353^{a}**	**0.343^{a}**	**0.327^{ab}**	**0.313^{ab}**	**0.313^{a}**	**0.293^{a}**	**0.280^{a}**
T14	0.327^{jk}	0.320^{ij}	0.313^{de}	0.307^{efg}	0.297^{efg}	0.290^{de}	0.273^{d}	-	-
T15	0.343^{gh}	0.340^{fgh}	0.330^{bc}	0.313^{def}	0.307^{def}	0.293^{cd}	0.277^{d}	0.270^{d}	-
T16	**0.373^{ab}**	**0.370^{a}**	**0.353^{a}**	**0.340^{ab}**	**0.330^{a}**	**0.323^{a}**	**0.310^{ab}**	**0.290^{a}**	**0.273^{b}**
T17	0.363^{bcd}	0.353^{cd}	0.347^{a}	0.330^{c}	0.323^{abc}	0.313^{ab}	0.307^{abc}	0.287^{ab}	0.260^{c}
T18	0.357^{def}	0.346^{def}	0.330^{bc}	0.317^{de}	0.310^{cde}	0.303^{bc}	0.293^{c}	0.273^{cd}	-
T19	0.313^{l}	0.303^{l}	0.280^{g}	0.267^{jk}	-	-	-	-	-
T20	0.307^{l}	0.293^{m}	0.277^{g}	0.260^{k}	0.247^{j}	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

T16 (0.290%) had maximum percentage of acidity which were not significantly different. On the last day of its shelf life (27DAS) T13 had 0.280% and T16 had 0.273% of acidity which were significantly different. Control fruits showed a faster reduction in acidity with lowest acidity percentage of 0.247% on 15th day of storage itself which was significantly different from others. It was followed by T2 (fruits presoaked in cold water) with 0.243% on 18th day of storage which was also significantly different from others.

4.2.4.5. Change in phenol content (mg/100g) at 20±1^{0}C

Mangosteen fruits stored at 20±1^{0}C under various treatments had significant difference with regard to total phenol contents during all stages of storage (Table 40). At 20±1^{0}C fruits treated with salicylic acid 3% (T13) retained maximum phenol content at all intervals of storage which was significantly superior to all other treatments. T13 had 0.898 mg/100g on 3rd day followed by T1 (with $KMnO_4$), T12 (2% salicylic acid), T10 (GA_3 600ppm) and T9 (GA_3 400ppm) with 0.850 mg/100g, 0.845 mg/100g, 0.839 mg/100g and 0.838 mg/100g respectively which were on par with each other. After 15DAS and 21DAS also T13 had maximum phenol content of 0.823 mg/100g and 0.768 mg/100g respectively followed by T12 (0.765 mg/100g and 0.717 mg/100g respectively) and T1 (0.759 mg/100g and 0.703 mg/100g respectively) which were on par. Minimum phenol content of 0.710 mg/100g was noticed in T19 (fruits kept in rattan baskets) and T2 (presoaked in cold water) with 0.714 mg/100g on 3rd day of storage. T19 had lowest phenol content of 0.593 mg/100g on 9th day, at end of its storage period. Control fruits also had minimum phenol content with 0.542 mg/100g on last day of its post harvest life (15DAS).

4.2.4.6. Rind hardening (kg/cm^2) at 20±1^{0}C

Mangosteen fruits stored at 20±1^{0}C under various treatments also showed significant difference with regard to rind hardening on all intervals of storage period (Table 41). Even though rind hardness increased as shelf life progressed, at 20±1^{0}C fruits had only a slow rate of rind hardening. Highest

Table 40. Effect of treatments on change in phenol content (mg/100g) at 20±1^{0}C

Treatments	*3DAS*	*9DAS*	*15DAS*	*21DAS*
T1	**0.850^{b}**	**0.787^{b}**	**0.759^{b}**	**0.703^{b}**
T2	0.714^{h}	0.657^{j}	0.589^{i}	-
T3	0.763^{fg}	0.681^{i}	0.599^{i}	-
T4	0.836^{bc}	0.767^{cd}	0.707^{de}	0.654^{c}
T5	0.762^{fg}	0.711^{h}	0.657^{fg}	0.534^{f}
T6	0.764^{fg}	0.720^{h}	0.648^{gh}	0.525^{f}
T7	0.775^{ef}	0.722^{gh}	0.698^{e}	0.632^{cd}
T8	0.820^{c}	0.735^{fg}	0.697^{e}	0.563^{e}
T9	**0.838^{b}**	0.744^{ef}	0.702^{e}	0.622^{d}
T10	**0.839^{b}**	0.769^{c}	0.730^{c}	0.620^{d}
T11	0.819^{c}	0.758^{cde}	0.712^{de}	0.632^{cd}
T12	**0.845^{b}**	0.770^{c}	**0.765^{b}**	**0.717^{b}**
T13	**0.898^{a}**	**0.847^{a}**	**0.823^{a}**	**0.768^{a}**
T14	0.776^{ef}	0.725^{gh}	0.670^{f}	0.525^{f}
T15	0.762^{fg}	0.711^{h}	0.638^{h}	0.563^{e}
T16	0.834^{bc}	0.759^{cde}	0.727^{cd}	0.626^{d}
T17	0.796^{d}	0.750^{e}	0.701^{e}	0.621^{d}
T18	0.781^{de}	0.754^{de}	0.699^{e}	0.632^{cd}
T19	0.710^{h}	0.593^{l}	-	-
T20	0.751^{g}	0.625^{k}	0.542^{j}	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

rind hardness of 11.73kg/cm^2 and 11.67kg/cm^2 was found in T17 (sodium erythorbate 2% + $CaCl_2$ 0.2%) and T16 ($CaCl_2$ 0.2%) respectively which did not differ significantly even after 27 days of storage. On 21st and 24th days after storage T5 (BA 100ppm) showed maximum pericarp hardening with firmness of 11.73kg/cm^2 and 12.53kg/cm^2 respectively and was significantly different from all other treatments. T2 (presoaked in cold water) showed maximum firmness of 11.70kg/cm^2 and 12.47kg/cm^2 respectively on 15th and 18th days after storage and was significantly varied from all other treatments.T2 and control were on par with firmness of 11.70kg/cm^2 on 15DAS which was the end of its storage life.

Fruits treated with GA_3 600ppm (T10) had the minimum fruit firmness on 3rd and 6th day of storage with 6.00kg/cm^2 and 6.67kg/cm^2 respectively which was significantly different from other treatments. T10 was followed by T13 – SA 3% (6.43kg/cm^2 and 7.00kg/cm^2 respectively) and T12 – SA 2% (6.40kg/cm^2 and 6.97kg/cm^2 respectively) which were not significantly different from each other. After nine days of shelf life T10 and T13 had the lowest firmness with 7.50kg/cm^2 and 7.60kg/cm^2 which were on par. On 12th day of shelf life minimum firmness of 8.00kg/cm^2 was noted in T13 followed by 8.13kg/cm^2 in T10 which were significantly different from each other and from other treatments.

After fifteen days of storage T13 had the lowest firmness value of 8.47kg/cm^2 which was significantly different from others followed by T12 (8.87kg/cm^2) and T10 (8.97kg/cm^2). T12 and T10 were on par with each other. On 18th day of shelf life minimum firmness of 8.80kg/cm^2 was noted in T13 followed by T10 (9.33kg/cm^2) which were significantly different from each other and with others. Towards end of post harvest period T13 showed lowest fruit firmness of 9.37kg/cm^2 and 9.87kg/cm^2 respectively on 21 and 24 days after storage followed by T12 (9.83kg/cm^2 and 10.33kg/cm^2 respectively) which were significantly different from each other and with other treatments.

Table 41. Effect of treatments on rind hardening (kg/cm^2) at 20±1^{0}C

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	7.57^{ef}	8.00^{ef}	8.57^{i}	8.93^{j}	9.47^{gh}	9.87^{i}	10.40^{gh}	-	-
T2	8.00^{c}	8.63^{c}	9.60^{cd}	10.37^{bc}	11.70^{a}	12.47^{a}	-	-	-
T3	7.50^{f}	8.43^{d}	9.53^{d}	10.27^{c}	10.67^{b}	11.73^{b}	-	-	-
T4	7.13^{ij}	8.10^{e}	8.97^{g}	9.37^{g}	9.97^{de}	10.77^{cde}	11.60^{b}	-	-
T5	7.83^{d}	8.37^{d}	9.13^{f}	9.50^{f}	10.10^{d}	10.80^{cd}	11.73^{a}	12.53^{a}	-
T6	7.30^{h}	7.93^{f}	8.83^{gh}	9.27^{gh}	9.70^{f}	10.43^{g}	10.90^{de}	11.73^{c}	-
T7	7.20^{i}	8.00^{ef}	8.73^{h}	9.17^{hi}	9.87^{e}	10.57^{fg}	11.50^{bc}	12.33^{b}	-
T8	6.73^{k}	7.50^{h}	8.13^{k}	8.53^{k}	9.37^{h}	9.93^{i}	10.67^{f}	-	-
T9	6.67^{k}	7.37^{i}	8.00^{kl}	8.60^{k}	9.00^{i}	9.70^{j}	10.50^{g}	-	-
T10	**6.00^{m}**	**6.67^{l}**	**7.50^{m}**	**8.13^{m}**	**8.93^{i}**	**9.33^{k}**	**10.30^{h}**	-	-
T11	7.10^{j}	7.80^{g}	8.33^{j}	8.93^{j}	9.50^{gh}	9.93^{i}	10.63^{f}	11.27^{e}	-
T12	**6.40^{l}**	**6.97^{k}**	**7.97^{l}**	**8.37^{l}**	**8.87^{i}**	**9.67^{j}**	**9.83^{i}**	**10.33^{f}**	-
T13	**6.43^{l}**	**7.00^{k}**	**7.60^{m}**	**8.00^{n}**	**8.47^{j}**	**8.80^{l}**	**9.37^{j}**	**9.87^{g}**	**10.50^{b}**
T14	7.40^{g}	7.77^{g}	8.70^{hi}	9.27^{gh}	9.97^{de}	10.63^{ef}	11.03^{d}	-	-
T15	6.73^{k}	7.20^{j}	8.77^{h}	9.10^{i}	9.57^{g}	10.23^{h}	10.83^{e}	11.53^{d}	-
T16	8.07^{bc}	8.97^{a}	9.47^{de}	9.97^{de}	10.30^{c}	10.63^{ef}	10.93^{de}	11.40^{de}	11.67^{a}
T17	7.90^{d}	8.77^{b}	9.73^{bc}	10.00^{d}	10.30^{c}	10.67^{def}	10.97^{de}	11.27^{e}	11.73^{a}
T18	7.60^{e}	8.43^{d}	9.33^{e}	9.87^{e}	10.37^{c}	10.87^{c}	11.40^{c}	11.77^{c}	-
T19	8.13^{b}	8.93^{a}	9.90^{a}	10.47^{b}	-	-	-	-	-
T20	8.37^{a}	8.97^{a}	9.87^{ab}	10.77^{a}	11.70^{a}	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

4.2.4.7. Change in rind colour at 20±1^{0}C

The data showing mean score of rind colour of fruits under various treatments at 20±1^{0}C are presented in table 42. Fruits stored at 20±1^{0}C also retained their skin colour without any deterioration up to 6th day of shelf life. Fruit rind discolouration started on 9th day of storage and moderate to severe damage was expressed on 18DAS onwards. Fruits treated with salicylic acid 2% (T12), salicylic acid 3% (T13), N-acetyl cystene 0.05% (T15) and N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) showed good colour retaining trend at 20±1^{0}C. Rind colour change was visualised from 9th day of storage onwards with slight rind damage (0.67, 0.33, 0.33 and 0.33 respectively). On 12th day after storage also only slight colour change (1.00, 0.67, 0.67 and 0.67 respectively) was observed. Slight to moderate discolouration was noted on 15DAS (1.67, 1.00, 1.33 and 1.00 respectively) and 18DAS (2.00, 1.33, 1.67 and 1.67 respectively). Moderate to severe loss in rind colour was observed on 21DAS (2.33, 2.00, 2.33 and 2.00 respectively) and 24DAS (3.00, 2.33, 2.67, 2.33 respectively). Fruits kept in rattan baskets covered with banana leaves (T19) showed moderate to severe rind colour change (2.33) on 12th and 15th day of storage followed by fruits dipped in $CaCl_2$ 0.2% (T16), those presoaked in cold water (T2) and control.

4.2.4.8. Change in pulp colour at 20±1^{0}C

There was no discolouration of mangosteen fruit pulp after six days of storage at 20±1^{0}C in all treatments. The data showing mean score of pulp colour of fruits under various treatments at 20±1^{0}C are presented in table 43. Fruit pulp colour change was noticed on 9th day of storage onwards only. Fruits treated with salicylic acid 2% (T12), salicylic acid 3% (T13), N-acetyl cystene 0.05% (T15) and N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) retained pulp colour at 20±1^{0}C for a long period. T12 and T13 had no discolouration on 9DAS but T15 and T18

Table 42. Effect of treatments on change in rind colour at 20±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	0	0	0.33	0.67	1.67	2.33	3.00	-	-
T2	0	0	1.33	2.33	2.67	3.00	-	-	-
T3	0	0	1.00	2.00	2.33	3.00	-	-	-
T4	0	0	0.33	1.33	1.67	2.00	2.33	-	-
T5	0	0	1.00	2.00	2.33	3.00	3.00	3.00	-
T6	0	0	0.33	1.00	2.33	3.00	3.00	3.00	-
T7	0	0	1.00	1.67	2.00	2.67	3.00	3.00	-
T8	0	0	1.00	1.33	1.67	2.00	2.67	-	-
T9	0	0	1.00	1.67	2.00	2.67	3.00	-	-
T10	0	0	0.33	0.67	1.67	2.33	3.00	-	-
T11	0	0	1.00	1.33	2.00	2.67	3.00	3.00	-
T12	**0**	**0**	**0.67**	**1.00**	**1.67**	**2.00**	**2.33**	**3.00**	-
T13	**0**	**0**	**0.33**	**0.67**	**1.00**	**1.33**	**2.00**	**2.33**	3.00
T14	0	0	0.67	1.00	2.00	2.67	3.00	-	-
T15	**0**	**0**	**0.33**	**0.67**	**1.33**	**1.67**	**2.33**	**2.67**	-
T16	0	0	1.00	2.00	2.67	3.00	3.00	3.00	3.00
T17	0	0	0.67	1.00	2.00	2.33	2.67	3.00	3.00
T18	**0**	**0**	**0.33**	**0.67**	**1.00**	**1.67**	**2.00**	**2.33**	-
T19	0	0	1.33	2.33	-	-	-	-	-
T20	0	0	1.33	2.00	2.67	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 43. Effect of treatments on change in pulp colour at 20±1^{0}C

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*	*24DAS*	*27DAS*
T1	0.00	0.00	0.33	0.33	0.67	1.67	2.33	-	-
T2	0.00	0.00	1.00	1.67	2.67	3.00	-	-	-
T3	0.00	0.00	0.67	1.67	2.00	2.67	-	-	-
T4	0.00	0.00	0.33	0.67	1.00	1.67	2.33	-	-
T5	0.00	0.00	0.33	1.00	1.67	2.00	2.00	2.67	-
T6	0.00	0.00	0.33	0.67	0.67	2.33	2.33	2.67	-
T7	0.00	0.00	0.67	1.00	1.33	1.67	2.67	3.00	-
T8	0.00	0.00	0.67	0.67	1.00	1.67	2.33	-	-
T9	0.00	0.00	0.67	1.33	2.00	2.00	2.67	-	-
T10	0.00	0.00	0.33	0.33	0.67	1.33	2.33	-	-
T11	0.00	0.00	0.67	1.00	1.00	1.67	2.33	3.00	-
T12	**0.00**	**0.00**	**0.00**	**0.67**	**0.67**	**1.67**	**1.67**	**2.33**	-
T13	**0.00**	**0.00**	**0.00**	**0.33**	**0.67**	**1.33**	**2.00**	**2.33**	3.00
T14	0.00	0.00	0.67	0.67	1.33	2.33	3.00	-	-
T15	**0.00**	**0.00**	**0.33**	**0.67**	**0.67**	**1.33**	**2.00**	**2.33**	-
T16	0.00	0.00	0.67	0.67	1.33	1.67	2.33	2.67	3.00
T17	0.00	0.00	0.67	1.00	1.00	2.00	2.67	3.00	3.00
T18	**0.00**	**0.00**	**0.33**	**0.33**	**0.67**	**1.67**	**2.00**	**2.33**	-
T19	0.00	0.00	1.33	2.33	-	-	-	-	-
T20	0.00	0.00	1.33	2.00	2.67	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

showed none to slight change in pulp colour (0.33). None to slight colour change (0.67, 0.33, 0.67 and 0.33 respectively) on 12DAS and 0.67 score for all these treatments on 15DAS was observed. Slight to moderate discolouration was noted on 18DAS (1.67, 1.33, 1.33 and 1.67 respectively) and 21DAS (1.67, 2.00, 2.00 and 2.00 respectively). Moderate to severe loss in pulp colour with 2.33 mean score was observed for all these best treatments on 24DAS. In control as well as fruits kept in rattan baskets covered with banana leaves (T19) severe pulp discolouration (2.33 and 2.00 respectively) was observed on 12DAS. On 15th day of storage control and those fruits presoaked in cold water (T2) also expressed moderate to severe pulp colour change (2.67).

4.2.5. Shelf life at room temperature

4.2.5.1. Storage life of fruits at room temperature

At room temperature, storage life was limited to 18-21 days only. There was significant difference between treatments at room temperature (Table 44). Longest shelf life of 21days was recorded in fruits with salicylic acid 3% (T13) followed by $CaCl_2$ 0.2% (T16) treatments with 50% fruit loss which were statistically on par. Fruits with ethylene absorbent $KMnO_4$ (T1) also shown comparatively long shelf life of 18 days with 46.67% fruit loss which was statistically on par with fruits wrapped with cling film (T4) and those fruits treated N-acetyl cystene 0.05% (T15) with 50.00% fruit loss. Shortest storage period of 6 days was recorded in control with 50.00% fruit loss.

4.2.5.2. Physiological loss in weight at room temperature

As compared to other temperature regimes faster rate of weight loss was noticed in fruits stored at room temperature and all treatments varied significantly with respect to physiological weight loss on different intervals of shelf life as given in table 45. Fruits treated with salicylic acid 3% (T13) and $CaCl_2$ 0.2% had minimum weight loss of 0.43% and 0.45% respectively which were significantly different from each other and with rest of treatments. These

Table 44. Effect of treatments on shelf life (% loss of fruits) at room temperature

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	3.33^{cd}	10.00^{fgh}	20.00^{gh}	26.67^{ef}	36.70^{ef}	**46.67^{ab}**	53.30^{a}
T2	13.30^{ab}	33.33^{b}	46.67^{b}	60.00^{a}	-	-	-
T3	3.33^{cd}	26.70^{bc}	36.67^{cd}	53.30^{ab}	-	-	-
T4	0.00^{d}	3.33^{h}	23.30^{fg}	30.00^{ef}	36.67^{ef}	**50.00^{ab}**	-
T5	10.00^{bc}	26.67^{bc}	40.00^{bc}	46.70^{bc}	53.30^{a}	-	-
T6	3.30^{cd}	20.00^{cde}	26.67^{efg}	33.30^{def}	53.33^{a}	-	-
T7	3.33^{cd}	20.00^{cde}	36.70^{cd}	43.33^{bcd}	50.00^{abc}	-	-
T8	13.30^{ab}	26.70^{bc}	33.33^{cde}	43.30^{bcd}	53.30^{a}	-	-
T9	10.00^{bc}	23.33^{cd}	36.67^{cd}	53.30^{ab}	56.70^{a}	-	-
T10	3.30^{cd}	26.67^{bc}	30.00^{def}	36.70^{cde}	43.33^{cde}	53.30^{a}	-
T11	6.67^{bcd}	16.70^{def}	26.67^{efg}	30.00^{ef}	50.00^{abc}	-	-
T12	6.70^{bcd}	13.30^{efg}	20.00^{gh}	23.33^{fg}	36.70^{ef}	53.33^{a}	-
T13	0.00^{d}	6.67^{gh}	20.00^{gh}	23.30^{fg}	33.30^{f}	**46.67^{ab}**	**50.00^{ab}**
T14	6.70^{bcd}	20.00^{cde}	30.00^{def}	43.30^{bcd}	56.67^{a}	-	-
T15	3.30^{cd}	13.33^{efg}	33.30^{cde}	36.67^{cde}	46.70^{bcd}	**50.00^{ab}**	-
T16	0.00^{d}	3.33^{h}	13.30^{h}	16.70^{g}	33.30^{f}	**43.30^{c}**	**50.00^{ab}**
T17	6.70^{bcd}	10.00^{fgh}	26.67^{efg}	36.67^{cde}	40.00^{def}	53.33^{a}	-
T18	3.30^{cd}	16.67^{def}	23.30^{fg}	30.00^{ef}	43.30^{cde}	53.30^{a}	-
T19	13.30^{ab}	46.07^{a}	66.67^{a}	-	-	-	-
T20	20.00^{a}	50.00^{a}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

superior treatments retained this slow rate till end of storage life with 14.88% and 16.22% weight loss even after 18th day of storage which were significantly different from each other and with remaining treatments. In the treatments on 18th day, the loss in weight was as high as 22 to 26%. Fruits kept in rattan baskets had maximum weight loss of 17.07% within nine days after storage which was significantly different from others. Fruits presoaked in cold water (T2) and hot water (T3) also showed high rate of weight loss with 28.00% and 27.60% on 12th day of storage itself.

4.2.5.3. Change in total soluble solids (TSS) as ^{0}Bx at room temperature

Fruits kept at room temperature also showed increase in TSS as storage period progressed. At all intervals of shelf life except on 12DAS all treatments varied significantly as given in table 46. Fruits treated with $CaCl_2$ 0.2% (T16), SA 3% (T13) and those packed with ethylene absorbent $KMnO_4$ (T1) expressed slow rate of TSS change. On 3rd day of storage lowest TSS content of 16.97^{0}Bx was noted in T16 followed by T1 with 17.00^{0}Bx which did not differ significantly and were on par with T13 (17.03^{0}Bx). After six days of storage lowest TSS content was found in T16 with 17.23^{0}Bx which was on par with T1 (17.27^{0}Bx), T13 (17.33^{0}Bx) and T17- sodium erythorbate 2% + $CaCl_2$ 0.2% (17.33^{0}Bx).After nine days of shelf life T16 with lowest TSS of 17.37^{0}Bx was followed by T1 with 17.47^{0}Bx.

Lowest TSS content of 17.60^{0}Bx was observed in T1 and T16 on 12DAS which did not significantly differ from all other treatments except those with highest TSS values including T2 (presoaked in cold water), T3 (presoaked in hot water), T5 (BA 100ppm) and T8 (GA_3 200ppm) with 18.93^{0}Bx, 18.90^{0}Bx, 18.73^{0}Bx and 18.77^{0}Bx respectively. There was no significant difference between T2, T3, T5 and T8 and were on par with all other treatments. On 15th day of storage T16 having lowest TSS value with 17.96^{0}Bx was followed by T1 with 18.23^{0}Bx which differed significantly. T1 was on par with T13 (18.27^{0}Bx). Towards the end of storage on 18DAS and 21DAS lowest TSS value of 18.20^{0}Bx

Table 45. Effect of treatments on weight loss (%) at room temperature

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	0.66^{f}	5.00^{g}	10.87^{h}	16.67^{h}	17.07^{i}	18.86^{d}	20.04^{a}
T2	0.73^{d}	8.33^{b}	16.60^{b}	28.00^{a}	-	-	-
T3	0.80^{c}	9.03^{a}	15.10^{c}	27.60^{a}	-	-	-
T4	0.49^{jk}	4.90^{g}	9.17^{j}	15.53^{i}	17.21^{i}	19.10^{d}	-
T5	0.79^{c}	8.23^{b}	14.97^{c}	19.23^{d}	22.99^{c}	-	-
T6	0.70^{e}	6.03^{e}	14.43^{d}	20.90^{c}	23.52^{b}	-	-
T7	0.60^{h}	7.30^{c}	14.93^{c}	17.60^{fg}	21.35^{e}	-	-
T8	0.57^{i}	6.00^{e}	13.00^{f}	20.67^{c}	21.97^{d}	-	-
T9	0.63^{g}	7.17^{c}	12.47^{g}	18.77^{de}	19.96^{f}	-	-
T10	0.55^{i}	6.50^{d}	12.30^{g}	17.70^{gh}	19.90^{f}	22.41^{c}	-
T11	0.60^{h}	5.50^{f}	10.37^{i}	15.50^{i}	18.74^{g}	-	-
T12	0.48^{k}	5.00^{g}	8.33^{k}	12.73^{j}	**14.47^{j}**	16.08^{e}	-
T13	**0.43^{m}**	**3.53^{h}**	**6.42^{m}**	**11.50^{k}**	**13.09^{k}**	**14.88^{f}**	**16.79^{c}**
T14	0.72^{d}	8.17^{b}	13.87^{e}	16.53^{h}	19.03^{g}	-	-
T15	0.70^{e}	7.20^{c}	14.17^{de}	22.60^{b}	24.41^{a}	26.28^{a}	-
T16	**0.45^{l}**	**2.50^{i}**	**7.87^{l}**	**12.15^{jk}**	**14.55^{j}**	**16.22^{e}**	18.10^{b}
T17	0.50^{j}	4.90^{g}	9.07^{j}	15.17^{i}	17.94^{h}	18.89^{d}	-
T18	0.66^{f}	5.50^{f}	12.30^{g}	18.30^{ef}	20.04^{f}	24.60^{b}	-
T19	1.70^{b}	9.37^{a}	17.07^{a}	-	-	-	-
T20	2.00^{a}	8.27^{b}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 46. Effect of treatments on change in TSS (^{0}Bx) at room temperature

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	17.00^{i}	**17.27^{ij}**	**17.47^{j}**	**17.60^{ab}**	**18.23^{k}**	**18.43^{f}**	**18.77^{b}**
T2	17.67^{bc}	18.27^{ab}	18.73^{b}	18.93^{a}	-	-	-
T3	17.63^{c}	18.23^{b}	18.57^{c}	18.90^{a}	-	-	-
T4	17.13^{fg}	17.40^{gh}	17.63^{i}	17.97^{ab}	18.37^{hi}	18.77^{bcd}	-
T5	17.47^{d}	18.03^{c}	18.37^{d}	18.73^{a}	19.37^{b}	-	-
T6	17.37^{e}	17.77^{d}	18.27^{e}	18.63^{ab}	19.27^{c}	-	-
T7	17.33^{e}	17.63^{e}	18.23^{e}	18.63^{ab}	19.20^{cd}	-	-
T8	17.53^{d}	18.03^{c}	18.43^{d}	18.77^{a}	19.50^{a}	-	-
T9	17.17^{fg}	17.43^{gh}	17.83^{h}	18.13^{ab}	18.67^{f}	-	-
T10	17.10^{gh}	17.37^{ghi}	17.63^{i}	17.83^{ab}	18.37^{hi}	18.73^{cd}	-
T11	17.20^{fg}	17.47^{fg}	18.07^{f}	18.47^{ab}	19.03^{e}	-	-
T12	17.17^{fg}	17.43^{gh}	17.70^{i}	17.97^{ab}	18.43^{h}	18.80^{bc}	-
T13	**17.03^{hi}**	**17.33^{hij}**	**17.63^{i}**	**17.73^{ab}**	**18.27^{jk}**	18.60^{e}	19.07^{a}
T14	17.23^{f}	17.57^{ef}	18.13^{f}	18.47^{ab}	19.17^{d}	-	-
T15	17.20^{fg}	17.47^{fg}	17.93^{g}	18.27^{ab}	19.00^{e}	19.33^{a}	-
T16	**16.97^{i}**	**17.23^{j}**	**17.37^{k}**	**17.60^{ab}**	**17.96^{l}**	**18.20^{g}**	**18.63^{c}**
T17	17.10^{gh}	17.33^{hij}	17.63^{i}	17.77^{ab}	18.33^{ij}	18.67^{de}	-
T18	17.17^{fg}	17.43^{gh}	17.73^{i}	18.03^{ab}	18.53^{g}	18.87^{b}	-
T19	17.83^{a}	18.37^{a}	18.83^{a}	-	-	-	-
T20	17.73^{b}	18.33^{ab}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^{0}C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

and 18.63^{0}Bx respectively were recorded in T16 followed by 18.43^{0}Bx and 18.77^{0}Bx respectively in T1, and T16 was significantly superior to T13 on both days.

Highest TSS content of 18.37^{0}Bx was noted in fruits kept in rattan baskets covered with dried banana leaves (T19) within six days of storage which was on par with T2 (18.27^{0}Bx) and control (18.33^{0}Bx). On nine days after storage T19 had the maximum TSS value of 18.83^{0}Bx at the end of its shelf life followed by T2 with TSS content of 18.73^{0}Bx.

4.2.5.4. Change in percentage of acidity at room temperature

Faster rate of reduction was found in mangosteen fruits stored at room temperature and all treatments varied significantly with respect to percentage of acidity on different intervals of shelf life as given on table 47. Percentage of acidity ranged from 0.356% to 0.260% on 3rd and 6th day of storage which further decreased up to 0.230% on 12th day itself in T3 (fruits presoaked in hot water). T1 – fruits packed with ethylene absorbent ($KMnO_4$) and T13 – salicylic acid 3% showed maximum retention in acidity with 0.320% and 0.300% respectively on 12th and 15th days after storage and were on par. Towards end of storage period on 18th day T1 had maximum acidity of 0.283% which was on par with T13 and T16 ($CaCl_2$ 0.2%) with 0.277%. T13 and T16 showed same values of acidity on 18DAS. On 21st day at end of storage T13 had maximum acidity of 0.270% which was on par with T1 (0.260%). Minimum percentage of acidity with 0.233% was recorded in T19 (fruits kept in rattan baskets) followed by T2 – fruits presoaked in cold water (0.240%) on 9th day of storage which were not significantly different. Minimum percentage acidity was also recorded in T3 (0.230%) on 12th day of shelf life which was on par with T2 (0.233%).

4.2.4.5. Change in phenol content (mg/100g) at room temperature

At room temperature also various treatments showed significant difference with regard to total phenol content at all intervals of storage period (Table 48). As in the case of different low temperature storages in the room

Table 47. Effect of treatments on change in acidity (%) at room temperature

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	**0.357^{a}**	**0.340^{ab}**	**0.337^{a}**	**0.320a**	**0.300^{a}**	**0.283^{a}**	**0.260^{ab}**
T2	0.293^{hi}	0.263^{h}	0.240^{j}	0.233^{jkl}	-	-	-
T3	0.300^{gh}	0.267^{gh}	0.253^{i}	0.230^{kl}	-	-	-
T4	0.340^{bc}	0.330^{bc}	0.307^{d}	0.277^{de}	0.263^{c}	0.253^{c}	-
T5	0.300^{gh}	0.277^{fg}	0.257^{hi}	0.246^{hij}	0.237^{defg}	-	-
T6	0.303^{fgh}	0.283^{f}	0.260^{ghi}	0.237^{ijk}	0.227^{ghi}	-	-
T7	0.310^{efg}	0.280^{f}	0.267^{fgh}	0.247^{hij}	0.237^{defg}	-	-
T8	0.313^{def}	0.300^{d}	0.277^{ef}	0.250^{ghi}	0.233^{efg}	-	-
T9	0.323^{d}	0.303^{d}	0.283^{e}	0.267^{ef}	0.240^{defg}	-	-
T10	0.350^{ab}	0.336^{abc}	0.320^{bc}	0.293^{bc}	0.270^{c}	0.250^{c}	-
T11	0.337^{c}	0.327^{c}	0.303^{d}	0.287^{cd}	0.250^{d}	-	-
T12	0.350^{ab}	0.337^{abc}	0.310^{cd}	0.303^{b}	0.287^{b}	0.263^{bc}	-
T13	**0.353^{a}**	**0.343^{a}**	**0.330^{ab}**	**0.320^{a}**	**0.300^{a}**	**0.277^{ab}**	**0.270^{a}**
T14	0.310^{efg}	0.287^{ef}	0.260^{ghi}	0.247^{hij}	0.230^{fgh}	-	-
T15	0.307^{fg}	0.300^{d}	0.270^{fg}	0.263^{efg}	0.243^{def}	0.233^{d}	-
T16	**0.356^{a}**	**0.340^{ab}**	**0.323^{b}**	**0.303^{b}**	**0.290^{ab}**	**0.277^{ab}**	**0.257^{b}**
T17	0.320^{de}	0.303^{d}	0.283^{e}	0.260^{fgh}	0.250^{d}	0.233^{d}	-
T18	0.313^{def}	0.297^{de}	0.273^{ef}	0.240^{ijk}	0.247^{de}	0.230^{d}	-
T19	0.287^{i}	0.267^{gh}	0.233^{j}	-	-	-	-
T20	0.273^{j}	0.260^{h}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

temperature also, fruits treated with salicylic acid 3% (T13) retained maximum phenol throughout storage period and was significantly superior to all other treatments. T13 had 0.896 mg/100g on 3rd day followed by T1 (with $KMnO_4$) and T12 (salicylic acid 2%) with 0.846 mg/100g and 0.844 mg/100g respectively. T1 and T12 were not significantly different from each other and were on par with T10 –GA_3 600ppm (0.839 mg/100g). Towards the end of storage also T13 had 0.776 mg/100g and 0.751 mg/100g respectively on 15th and 21st day followed by T1 with 0.798 mg/100g on 15th day which were significantly different from each other and with rest of treatments. Minimum phenol content of 0.700 mg/100g was observed on 3rd day itself in fruits kept in rattan baskets (T19) which was on par with control (0.710 mg/100g). T19 on 9th day, at end of its storage life recorded the lowest phenol content of 0.521 mg/100g was recorded followed by T2 – fruits presoaked in cold water (0.535 mg/100g) and T3 – fruits presoaked in hot water (0.538 mg/100g) which were on par.

4.2.5.6. Rind hardening (kg/cm^2) at room temperature

Mangosteen fruits stored at room temperature also showed hardening of pericarp during storage period and all treatments varied significantly with respect to rind hardness at different intervals of shelf life as given in table 49. Towards end of storage period at room temperature, maximum fruit firmness of 12.93kg/cm^2 and 12.63kg/cm^2 respectively was noted in T16 ($CaCl_2$ 0.2%) on 18th and 21st days after storage. T5 (BA 100ppm) had the highest firmness value of 12.73kg/cm^2 on fifteen days after storage and was significantly different from all other treatments on 15DAS. T2 (presoaked in cold water), T3 (presoaked in hot water) and T6 (BA 200ppm) showed maximum firmness of 11.93kg/cm^2, 11.87kg/cm^2 and 11.93kg/cm^2 respectively on 12th day of shelf life and were on par with each other.

Fruits treated with SA 3% (T13) had the minimum firmness of 7.07kg/cm^2 on third day of storage followed by those fruits packed with ethylene absorbent – $KMnO_4$ (T1) with 7.23kg/cm^2 which were significantly different from each other

Table 48. Effect of treatments on change in phenol content (mg/100g) at room temperature

Treatments	*3DAS*	*9DAS*	*15DAS*	*21DAS*
T1	**0.846^{b}**	**0.772^{c}**	**0.758^{b}**	**0.691^{b}**
T2	0.725^{i}	0.535^{h}	-	-
T3	0.719^{ij}	0.538^{h}	-	-
T4	0.813^{e}	0.732^{d}	0.624^{f}	-
T5	0.761^{gh}	0.714^{d}	0.520^{h}	-
T6	0.755^{h}	0.688^{e}	0.549^{g}	-
T7	0.769^{fgh}	0.680^{e}	0.556^{g}	-
T8	0.767^{fgh}	0.765^{c}	0.680^{de}	-
T9	0.828^{cd}	0.762^{c}	0.670^{e}	-
T10	**0.839^{bc}**	**0.792^{b}**	0.695^{cd}	-
T11	0.839^{bc}	0.769^{c}	0.683^{cd}	-
T12	**0.844^{b}**	**0.795^{b}**	**0.698^{c}**	-
T13	**0.896^{a}**	**0.865^{a}**	**0.776^{a}**	**0.751^{a}**
T14	0.759^{gh}	0.640^{f}	0.556^{g}	-
T15	0.754^{h}	0.615^{g}	0.622^{f}	-
T16	0.822^{de}	0.755^{c}	0.686^{cd}	0.530^{c}
T17	0.773^{fg}	0.673^{e}	0.623^{f}	-
T18	0.779^{f}	0.719^{d}	0.637^{f}	-
T19	0.700^{k}	0.521^{h}	-	-
T20	0.710^{jk}	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

and with other treatments. T1 was on par with T12 – SA 2% (7.30kg/cm^2). After six days of storage lowest firmness was noticed in T13 and T1 with 7.87kg/cm^2 and 7.93kg/cm^2 which did not significantly differ from each other followed by T10 – GA_3 600ppm (8.17 kg/cm^2) and T12 –SA 2% (8.13 kg/cm^2). T12 and T10 were on par. On 9th day of shelf life minimum firmness of 8.63kg/cm^2 was found in T13 followed by T1 (8.80kg/cm^2) which were not significantly different and were on par with T12 (8.83kg/cm^2) and T10 (8.90kg/cm^2) .

After 12th and 15th days of storage minimum rind hardening was recorded in T13 (9.50kg/cm^2 and 10.47 kg/cm^2 respectively) and T1 (9.53kg/cm^2 and 10.50kg/cm^2 respectively). T13 and T1 were followed by T10 (9.77kg/cm^2 and 10.77kg/cm^2 respectively) and T12 (9.70kg/cm^2 and 10.73kg/cm^2 respectively) and were on par. On 18th day T13 had minimum firmness of 11.27 kg/cm^2 which was on par with T1 (11.43kg/cm^2). On the last day of storage, the 21st day T1 had minimum firmness of 12.20kg/cm^2 followed by T13 with 12.37kg/cm^2 which were significantly different from each other.

4.2.5.7. Change in rind colour at room temperature

Rind colour deterioration of mangosteen fruits kept at room temperature started from 3rd day of storage. The data pertaining to the mean score of rind colour of fruits under various treatments at room temperature are furnished in table 50. Moderate to severe rind colour damage happened on 9DAS in most of treatments. But the fruits packed with ethylene absorbent –KMnO4 (T1), fruits packed in cling film (T4), those fruits treated with salicylic acid 3% (T13), sodium erythorbate 2% (T14), N-acetyl cystene 0.05% (T15), and N-acetyl cystene 0.05% + $CaCl_2$ 0.2% (T18) showed comparatively good colour retention pattern at room temperature. None to slight colour change only was observed in the above mentioned treatments on 3DAS (0.00, 0.00, 0.00, 0.33, 0.00 and 0.00 respectively) and 6DAS (0.67, 0.33, 0.33, 1.00, 0.67 and 0.67 respectively); slight to moderate colour fading on 9th day (1.33, 1.00, 1.00, 1.33, 1.33 and 1.00 respectively) and 12th day (2.00, 1.67, 1.67, 2.00, 1.67 and1.33 respectively) of shelf life. After fifteen days of shelf life moderate to severe rind discolouration of

Table 49. Effect of treatments on rind hardening (kg/cm^2) at room temperature

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	**7.23^{l}**	**7.93^{k}**	**8.80^{j}**	**9.53^{k}**	**10.50^{g}**	**11.43^{de}**	**12.20^{c}**
T2	8.60^{b}	9.60^{b}	10.77^{b}	11.93^{a}	-	-	-
T3	8.50^{bc}	9.57^{b}	10.67^{bc}	11.87^{a}	-	-	-
T4	7.73^{h}	8.57^{gh}	9.50^{fg}	10.47^{gh}	11.60^{de}	12.33^{b}	-
T5	8.23^{e}	8.97^{d}	9.80^{e}	11.20^{c}	12.73^{a}	-	-
T6	8.43^{cd}	9.30^{c}	10.47^{c}	11.93^{a}	12.50^{b}	-	-
T7	8.00^{f}	8.77^{ef}	9.67^{efg}	10.77^{de}	12.47^{b}	-	-
T8	8.37^{d}	9.17^{c}	10.10^{d}	11.70^{b}	12.00^{c}	-	-
T9	7.97^{fg}	8.70^{fg}	9.53^{efg}	10.63^{ef}	11.67^{d}	-	-
T10	7.40^{jk}	**8.17^{j}**	**8.90^{hij}**	**9.77^{j}**	**10.77^{f}**	**11.53^{d}**	-
T11	8.07^{f}	8.87^{de}	9.77^{ef}	10.90^{d}	11.90^{c}	-	-
T12	**7.30^{kl}**	**8.13^{j}**	**8.83^{ij}**	**9.70^{j}**	**10.73^{f}**	**11.50^{d}**	-
T13	**7.07^{m}**	**7.87^{k}**	**8.63^{j}**	**9.50^{k}**	**10.47^{g}**	**11.27^{e}**	**12.37^{b}**
T14	8.03^{f}	8.80^{ef}	9.67^{efg}	10.83^{d}	12.53^{b}	-	-
T15	7.73^{h}	8.57^{gh}	9.40^{g}	10.37^{h}	11.53^{de}	12.33^{b}	-
T16	7.87^{g}	8.67^{fg}	9.50^{fg}	10.60^{fg}	11.63^{de}	12.63^{a}	12.93^{a}
T17	7.53^{i}	8.50^{hi}	9.13^{h}	10.00^{i}	11.47^{e}	11.97^{c}	-
T18	7.47^{ij}	8.40^{i}	9.10^{hi}	9.93^{i}	10.80^{f}	11.60^{d}	-
T19	8.73^{a}	9.63^{b}	11.03^{a}	-	-	-	-
T20	8.73^{a}	10.00^{a}	-	-	-	-	-

Treatment means having similar alphabets in superscript, do not differ significantly

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Table 50. Effect of treatments on change in rind colour at room temperature

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	**0.00**	**0.67**	**1.33**	**2.00**	**2.33**	**3.00**	**3.00**
T2	1.00	2.00	2.67	3.00	-	-	-
T3	1.00	1.67	2.67	2.67	-	-	-
T4	**0.00**	**0.33**	**1.00**	**1.67**	**2.33**	**3.00**	-
T5	0.67	1.33	2.67	3.00	3.00	-	-
T6	1.00	1.67	2.67	3.00	3.00	-	-
T7	0.33	1.00	1.67	2.67	3.00	-	-
T8	0.67	1.33	2.33	3.00	3.00	-	-
T9	1.00	2.00	2.00	3.00	3.00	-	-
T10	0.67	1.33	1.67	2.33	2.67	3.00	-
T11	0.67	1.67	2.33	3.00	3.00	-	-
T12	0.33	1.00	1.67	2.00	2.67	3.00	-
T13	**0.00**	**0.33**	**1.00**	**1.67**	**2.33**	**3.00**	**3.00**
T14	**0.33**	**1.00**	**1.33**	**2.00**	**2.67**	**-**	-
T15	**0.00**	**0.67**	**1.33**	**1.67**	**2.33**	**2.67**	-
T16	0.67	1.33	2.00	2.33	2.67	3.00	3.00
T17	**0.00**	**0.67**	**1.00**	**1.33**	**2.33**	**2.67**	-
T18	0.33	1.00	1.67	2.33	3.00	3.00	-
T19	1.00	2.00	3.00	-	-	-	-
T20	1.33	2.33	-	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

the above best treatments (2.33, 2.33, 2.33, 2.67, 2.33, 2.33 respectively) were noted. Control fruits showed moderate to severe fruit damage (2.33) within 6th day of storage at room temperature.

4.2.5.8. Change in pulp colour at room temperature

At room temperature discolouration of pulp started from 3rd day of storage. The data depicting the mean score of pulp colour of fruits under various treatments at room temperature are furnished in table 51. Fruits packed with ethylene absorbent –$KMnO_4$ (T1), fruits packed in cling film (T4), those fruits treated with salicylic acid 3% (T13), sodium erythorbate 2% (T14), N-acetyl cystene 0.05% (T15), and sodium erythorbate 2% + $CaCl_2$ 0.2% (T17) showed good pulp colour retention at room temperature. There was no discolouration of pulp after three days of storage in these treatments. None to slight colour change was observed on 6DAS (0.00, 0.33, 0.00, 0.33, 0.67 and 0.33 respectively) and 9DAS (0.67, 0.33, 0.67, 0.67, 1.00 and 0.67 respectively). Slight to moderate colour fading (1.00, 0.67, 1.33, 1.33, 1.67 and 1.00 respectively) was noticed on twelve days after storage whereas moderate to severe pulp colour change (2.00, 2.00, 2.00, 2.33, 2.33 and 2.00 respectively) was found on 15th day of shelf life in the above treatments. T1, T4, T13, T15 and T17 retained 25-50% of pulp colour (2.00, 2.33, 2.33, 2.67 and 2.33 respectively) on 18DAS where the shelf life ended. Severe change in pulp colour at room temperature was observed in control fruits with moderate to severe fruit damage (2.33) within 6DAS at room temperature.

Table 51. Effect of treatments on change in pulp colour at room temperature

Scale:- 0-None, 1-Slight (<25% skin area), 2-Moderate (25-50% skin area), 3-Severe (>50% skin area)

Treatments	*3DAS*	*6DAS*	*9DAS*	*12DAS*	*15DAS*	*18DAS*	*21DAS*
T1	**0.00**	**0.00**	**0.67**	**1.00**	**2.00**	**2.00**	**2.33**
T2	0.67	1.67	2.33	3.00	-	-	-
T3	1.00	1.33	1.67	2.67	-	-	-
T4	**0.00**	**0.33**	**0.33**	**0.67**	**2.00**	**2.33**	-
T5	0.33	1.00	1.67	2.33	3.00	-	-
T6	**0.00**	**0.67**	**1.67**	**2.00**	**2.67**	-	-
T7	**0.00**	**0.67**	**1.00**	**1.67**	**2.33**	-	-
T8	0.33	1.00	1.33	2.00	3.00	-	-
T9	0.33	1.00	1.67	1.67	2.67	-	-
T10	**0.00**	**0.67**	**1.33**	**2.00**	**2.33**	**2.67**	-
T11	0.33	1.00	1.33	2.33	3.00	-	-
T12	0.33	0.67	1.00	2.00	2.67	3.00	-
T13	**0.00**	**0.00**	**0.67**	**1.33**	**2.00**	**2.33**	**3.00**
T14	**0.00**	**0.33**	**0.67**	**1.33**	**2.33**	-	-
T15	**0.00**	**0.67**	**1.00**	**1.67**	**2.33**	**2.67**	-
T16	0.67	1.00	1.00	2.00	2.00	2.33	3.00
T17	**0.00**	**0.33**	**0.67**	**1.00**	**2.00**	**2.33**	-
T18	0.33	0.67	1.00	1.67	2.00	2.67	-
T19	1.00	1.67	2.67	-	-	-	-
T20	1.00	2.33	-	-	-	-	-

T1 – Ethylene absorbent ($KMnO_4$)

T2 – Presoaking in cold water

T3– Presoaking in hot water (50^0C)

T4 – Cling film wrapping

T5 to T7– BA 100 ppm, 200 ppm and 300 ppm

T8 to T10 – GA_3 200 ppm, 400 ppm and 600 ppm

T11 to T13– Salicylic acid 1%, 2% and 3%

T14– Sodium erythorbate 2%

T15– N – acetyl cystene 0.05%

T16– Calcium chloride 0.2%

T17– Sodium erythorbate 2% + Calcium chloride 0.2%

T18– N – acetyl cystene 0.05% + Calcium chloride 0.2%

T19– Farmer's practice

T20– Control

Discussion

5. DISCUSSION

Mangosteen (*Garcinia mangostana* L.) is a unique tropical fruit rich in vitamins and minerals. It is gaining demand in international markets mainly due to its much acclaimed health benefits such as antioxidant properties and prophylactic action on many of degenerative diseases. Demand always exceeds production and hence the crop fetches a premium price in local markets. Fruit defects including fruit-cracking, rough surface, pericarp hardening, translucent flesh, gummosis and decay are typically found at retail level and often reduce consumer demand for the fruit. Major problems limiting profitable mangosteen production is the occurrence of translucent flesh disorder (TFD) and gamboge disorder (GD).

Mangosteen is an important economic fruit with a high market value but with a relatively short shelf life. The fruit rapidly changes its pericarp (rind) colour and shows shrinkage of both the attached stem end and sepals (calyx). Low temperatures induce chilling injury, pericarp hardening, browning and shrinkage of both the stem end and calyx, browning of the fruit flesh and develop an off-flavour (Choehom *et al.*, 2003).

The present investigation was envisaged to develop techniques for improving fruit quality, reduce flesh disorders like gamboge and translucent flesh disorder, and to enhance shelf life of mangosteen. The results of the study are discussed in the ensuing pages.

5.1. IMPROVING FRUIT QUALITY AND MINIMISING FLESH DISORDERS

An experiment was conducted to find out the effect of foliar nutrient application at 4^{th}, 8^{th} and 12^{th} weeks after bloom on quality improvement of mangosteen fruits together with reduction in flesh disorders. A foliar spray at fruit development stage is more effective than applying fertilizer to the soil.

5.1.1. Fruit characters

Mangosteen fruit quality was studied from the very beginning of anthesis. In this investigation, fruit characters were assessed in terms of fruit set and development, percentage of fruit retention, days to maturity of fruit from the day of anthesis to harvest, percentage occurrence of TFD and GD, position of fruits affected with flesh disorders on tree canopy and fruit physical and chemical properties.

Mangosteen trees selected for the experiment on fruit quality improvement flowered during 2nd and 3rd week of February 2011. As per Chutinunthakun, 2001 flowering in mangosteen was during February to early March.

Significant differences were noticed with regard to fruit retention due to foliar application of various nutrients (Fig. 2). Highest percentage of fruit retention (88.49%) was found in trees treated with 2% $CaCl_2$ foliar application followed by 1% $CaCl_2$ (81.42%). The above mentioned results are in agreement with those findings of Singh and Ram, 1983, where fruit retention of many other fruit trees have been improved under similar applications with calcium. A tentative explanation for the increased fruit retention percentage due to calcium sprays may be due to improvement in the formation of cellulose and lignin. These materials are required for building up of cell structure or preventing the abscission layer formation and consequently, the reduction in pre-harvest fruit dropping (Nijjar, 1985).

Trees sprayed with combinations of calcium chloride and boron also showed comparatively positive results (74-75%) with respect to fruit retention. The results obtained go in line with the findings of Sarrwy *et al.,* 2012 where the highest fruit retention percentage of cv. Amhat date palm was obtained by spraying boric acid at 500ppm combined with calcium nitrate at 2 per cent followed by spraying boric acid at 250ppm combined with calcium nitrate at 2 per cent concentration. 0.5% KH_2PO_4 spray also increased fruit retention. It may be

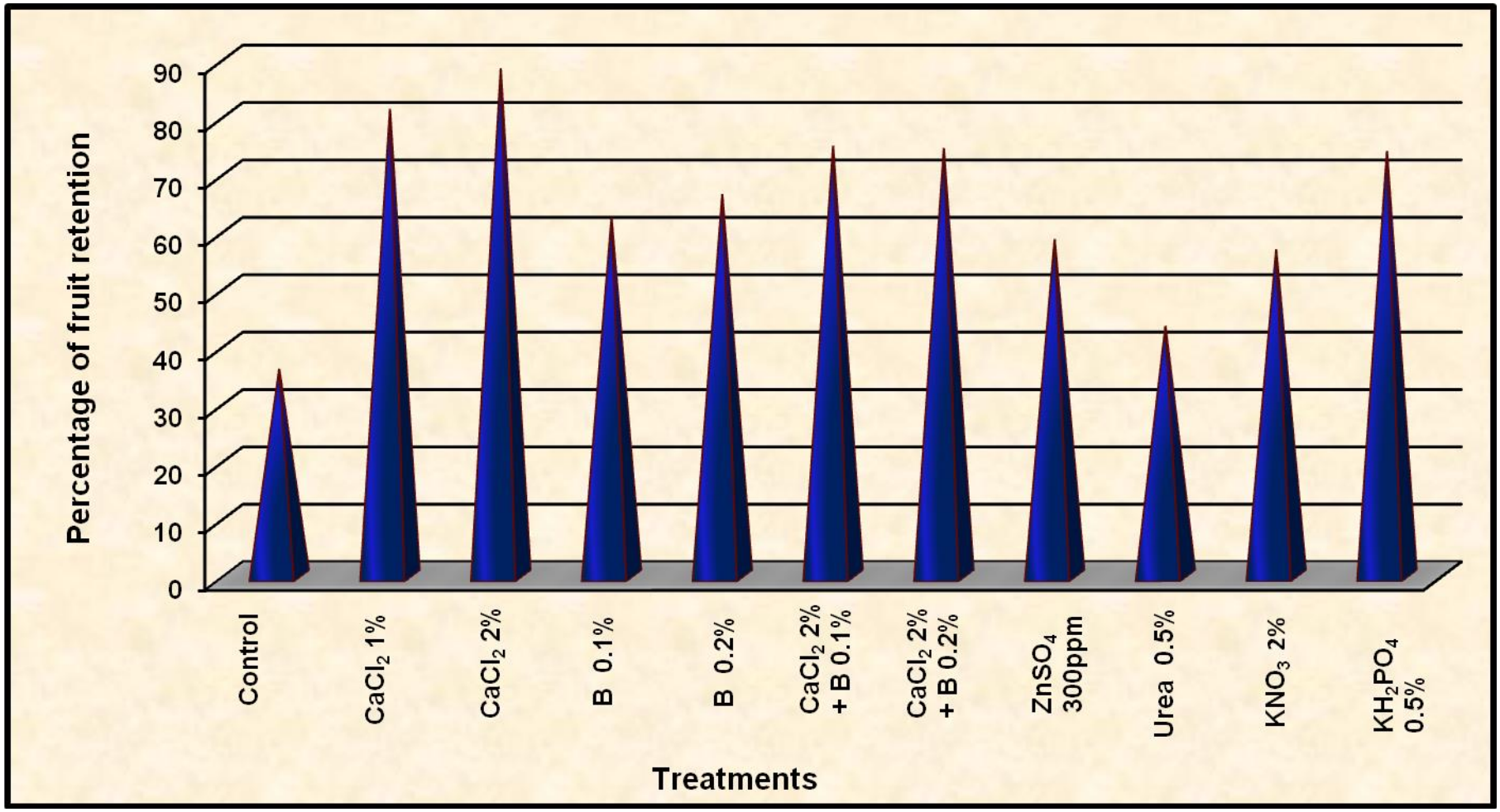

Fig 2 – Effect of treatments on percentage of fruit retention

concluded that foliar spray of $CaCl_2$ 1-2% or calcium combination with boron 0.1-0.2% and 0.5% KH_2PO_4 reduced fruit drop in mangosteen when applied at monthly interval for 3 months starting from full bloom.

The number of days from flowering to fruit maturity should be less so that harvesting can be done before monsoon showers. Normally mangosteen takes more than 100 days for maturity. An early harvest is highly essential for the mangosteen growers to get premium price for their produce before the rainy season starts. Once rains occur the quality of fruits will be affected and market demand also comes down. In the present study lowest number of days for harvest was recorded in trees applied with KH_2PO_4 (84 days) followed by those treated with KNO_3 (85 days). The positive effect of mono potassium phosphate on reduction in fruit maturity was indicated by Chapagain and Wiesman (2003) who clearly suggested that spraying of mono potassium phosphate could provide tomato growers with an early crop. The stimulatory effect of mono potassium phosphate on ripening, as reflected in the significantly shorter time to fruit maturity (anthesis to picking of the fruits) in all the sprayed plants, may be attributed to the P component of the spray. Several studies have clearly demonstrated the effect of potassium and phosphrous salts on the maturation of olive and citrus fruits.

Early maturity obtained by KNO_3 spray in the present study is in concordance with the findings of Lester *et al*., 2005. They reported that muskmelon fruits from plants receiving supplemental foliar potassium matured on an average 2 days earlier than those from control plants in experiments conducted during spring 2003 and 2004. The present study revealed that foliar application of 0.5% KH_2PO_4 and 2% KNO_3 could enhance maturity by two weeks so that harvest can be completed before the rains (Fig. 3).

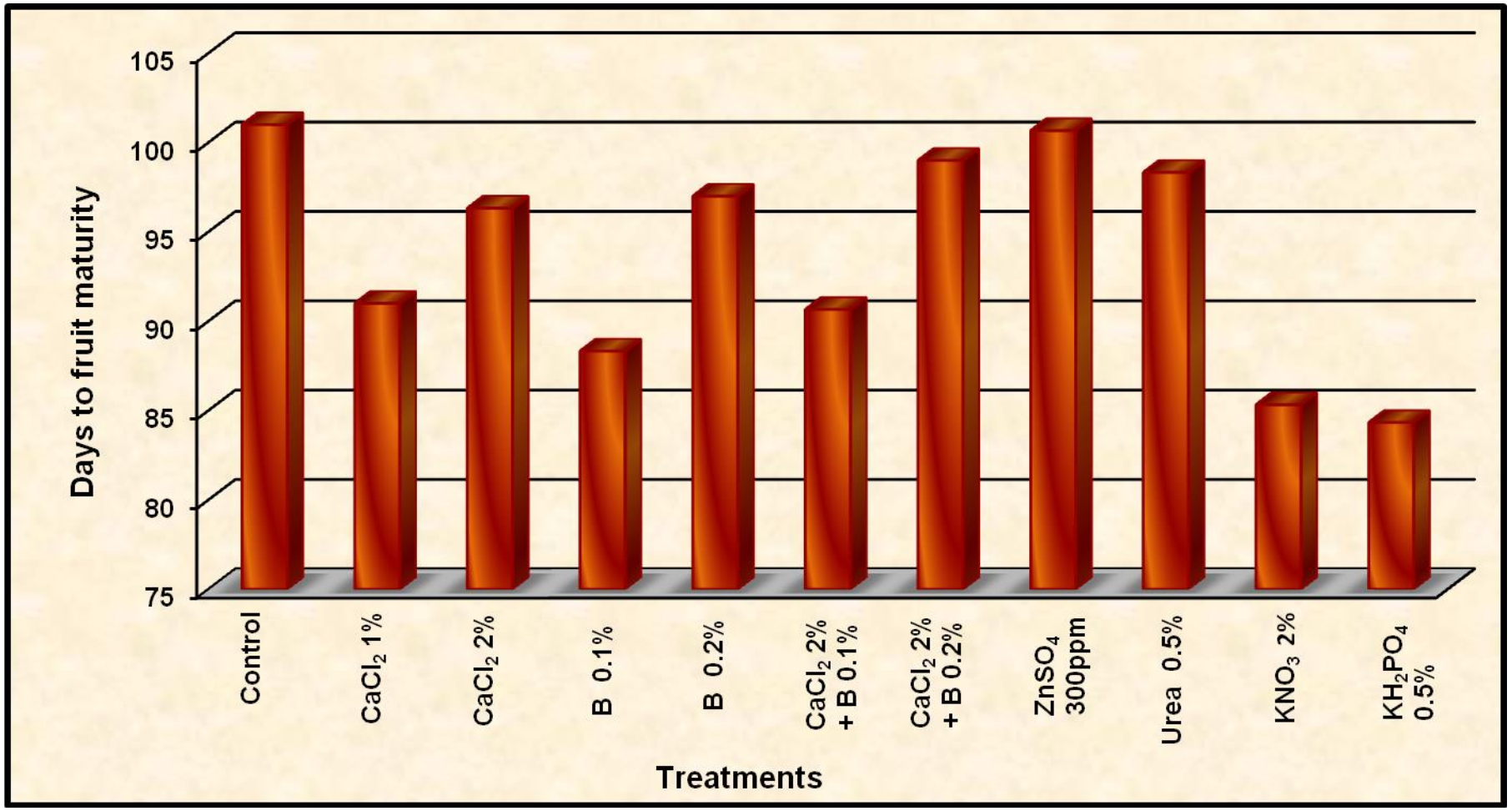

Fig 3 – Effect of treatments on days to harvesting maturity

5.1.1.1. Physiological disorders- TFD and GD

According to Poerwanto *et al.,* 2009 physiological disorders like gamboge disorder (GD) and Translucent flesh disorder (TFD) were rectifiable by application of adequate calcium nutrient to mangosteen trees. Calcium as one of the important components of the middle lamella in the form of calcium pectate that binds together the contiguous cell walls is a major factor in withstanding such pressure. Hence application of dolomite fertilizer at rate of 18-24 tons/ha has been reported to improve calcium content in the exocarp and leaves; and at the same time, it effectively reduced gamboge (GD). Also, it was reported that applications of $CaCl_2$ spray effectively reduced yellow spots either on the pericarp or the aril of mangosteen. Results obtained in the present study are supported by the above findings. It was found that translucent flesh disorder (TFD) and gamboge disorder (GD) were significantly reduced in trees treated with calcium foliar nutrition as $CaCl_2$ in the current research.

Calcium chloride 1% and 2% were equally good to bring down GD to a level of 9 to 10%. $CaCl_2$ 2% along with boron 0.1% or 0.2% also could reduce GD to 10-11%. $CaCl_2$ 1 to 2% alone or in combination with 0.1% and 0.2% boron were the best treatment to reduce TFD. Unlike in the case of GD, TFD could be brought down to a level of 12-13% with boron spray alone at 0.1 to 0.2%. The present study therefore revealed that calcium and boron play a prominent role in reducing physiological disorders in mangosteen. $CaCl_2$ 1 or 2% alone or $CaCl_2$ 2% in combination with boron 0.1% and 0.2% sprays can minimise GD which can be adopted by mangosteen growers to improve fruit quality. To reduce TFD either $CaCl_2$ 1 or 2% alone, boron 0.1 to 0.2% alone or combination of $CaCl_2$ 2% with boron 0.1 to 0.2% are the promising treatments which can be successfully be tried by the farmers to improve quality production (Fig. 4).

The result of the nutrient analysis carried in the standard leaf, rind and fruit pulp of these superior treatments involving calcium and boron also reveals the role of these elements in reducing the physiological disorders.

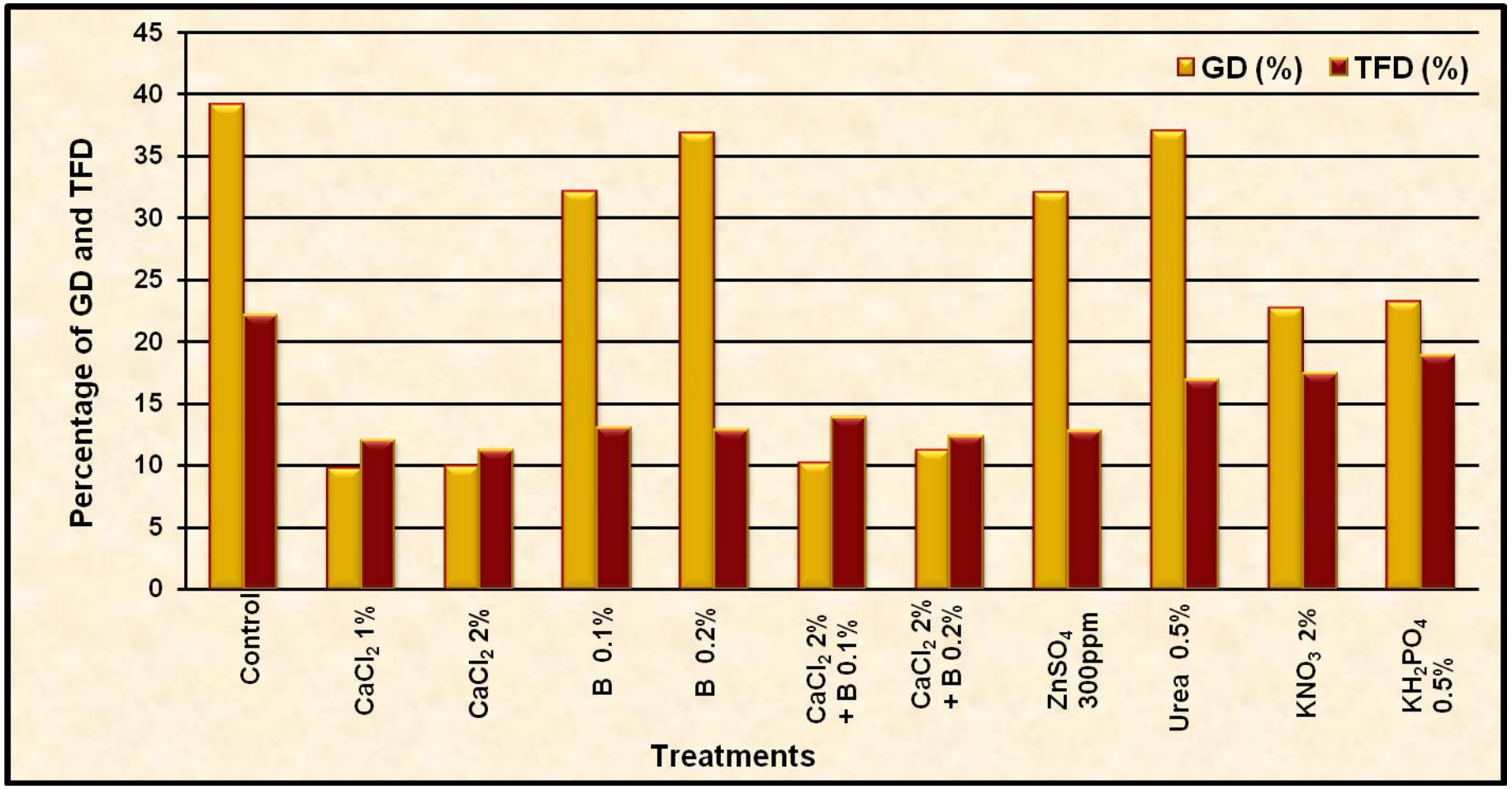

Fig 4 – Effect of treatments on percentage occurrence of GD and TFD

Treatments with $CaCl_2$ 1 and 2% and $CaCl_2$ 2% along with boron also showed very high amounts of calcium in the standard leaf, fruit rind and fruit pulp. Treatments with boron alone or in combination with $CaCl_2$ had large quantity of boron in the standard leaf, fruit rind and pulp.

It may be concluded that foliar sprays with calcium and boron help the trees to absorb more of calcium and boron and accumulate them in the fruit rind and pulp which might have helped to reduce the incidence of the physiological disorders in mangosteen.

Limpun-Udom (2001) found that Ca and B concentrations in the peel and Ca concentration in the flesh of normal mangosteen fruit (NF) were high compared with TFD and GD fruits, whereas B concentration in the flesh of NF fruits were lower than those of TFD and GD fruits. An important role of B is to support Ca function in plant (Lim *et al.,* 2001). The present research findings also indicate that combinations of calcium and boron also have positive relationship on reduction of TFD and GD. In the application of $CaCl_2$ and H_3BO_3, accumulation of Ca was higher than the application of $CaCl_2$ alone, as reported by Poowarodom *et al.,* 2002. Mangosteen fruits with low calcium were susceptible to translucent flesh and gamboge disorders. Gamboge disorder was associated with imbalanced calcium-boron ratio (Poovarodom, 2009).

According to Pechkeo *et al.,* 2007 mangosteen fruit qualities were not significantly different between the outer and inner canopy fruits. Likewise, most of the plant nutrients accumulation in mangosteen leaf, peel and flesh were not significantly different between two fruit positions. The comparison of fruit quality between NF or TFD or GD fruits and among them, of outer and inner canopy fruits was not significantly different. In contradiction to the above results, the present study revealed that more gamboge and TFD affected fruits were found in the outer canopy than inner canopy of the trees in all the treatments including the control. Over exposure to bright sunlight in the outer canopy might have

accelerated the occurrence of high numbers of TFD and GD affected fruits in the outer canopy.

5.1.2. Fruit physical characters

Sdoodee and Chiarawipa (2005) noted that mangosteen fruit diameter increased steadily from 1st week to 13th week after bloom and it tended to decrease from 9th week to 13th week after bloom that it was evident in the marked decrease in fruit growth rate. In the present study also fruit diameter increased steadily and growth rate reduced from 8th week to 12th week after bloom. At 12th week urea 0.5% treatment had maximum fruit diameter of 6.17cm.

In the present study fruit physical characters of the fruit including length, breadth, circumference and average fruit weight were found to be maximum under foliar nutrition with urea 0.5% concentration followed by KNO_3 2% and KH_2PO_4 0.5% (Fig. 5). Shinde (2007) also noticed significant increase in fruit length, breadth and circumference in kokum under konkan conditions with foliar nutrition of urea. With respect to the physical characteristics of the fruit, the present results are in accordance with those of Gupta and Brahmachari (2004) who found that the foliar applications of urea and KNO_3 were effective in improving the fruit characteristics of mango.

In the present study rind-pulp ratio was lowest in 2% KNO_3, 0.5% urea and 0.5% KH_2PO_4 foliar applications. It may be concluded that not only for increasing the fruit size but also for maximising the edible pulp content these foliar treatments can be recommended. Highest number of segments and maximum number of viable seeds per fruit were found in 0.5% urea (Plate 9), 0.5% KH_2PO_4 and 2% KNO_3 foliar applications which may be the reason behind large sized fruits in these treatments.

In this study maximum fruit firmness was noted in fruits treated with $CaCl_2$ foliar nutrition. Similar results were reported by Subbiah (1994) that application of 0.5% $CaCl_2$ sprays significantly increased firmness index of tomato fruits. Positive relationships between fruit Ca and firmness retention were

Plate 9 – Biggest fruits with more no. of segments by foliar application of 0.5% urea

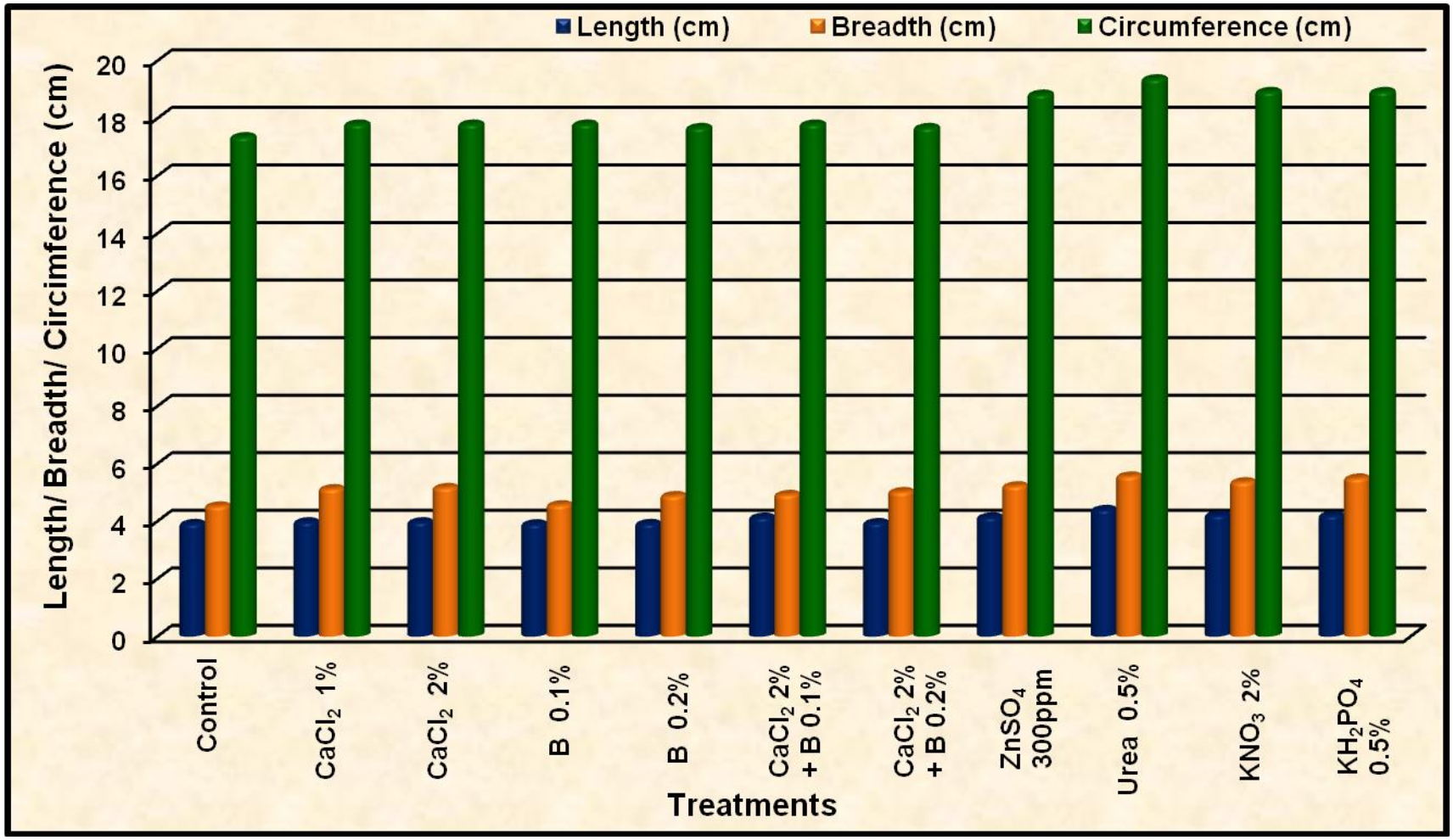

Fig 5 – Effect of treatments on physical characters of fruit

observed in many fruits (Saftner *et al*. 2003; Omaima and Karima, 2007). The role of calcium in developing the resistance of fruit tissue to softening is attributed to the stabilization of membrane systems and the formation of calcium pectates, which increases rigidity of middle lamella (Siti *et. al.* 2010).

There was a negative relation between specific gravity, gamboges and translucent flesh disorder. In the present study lowest specific gravity (less than one) was observed in treatments with calcium chloride foliar application in which percentage of GD and TFD were also comparatively low. Poonnachit *et al*. 2005 illustrated that specific gravity of translucent flesh fruit is equal to one during period of normal rainfall before harvesting and equal to 1.02-1.04 during the periods of heavy rainfall before harvesting. Pankasemsuk *et. al.* 1996 revealed that the specific gravity of translucent flesh fruit was greater than one and that of normal flesh was less than one. Chaisrichonlathan and Noomhorm, 2011 reported that specific gravity mean values of normal, mild translucent and moderate to severe translucent flesh mangosteen fruits were 0.97, 1.00 and 1.01 respectively. In accordance with these findings, results obtained in the present research ranges between 0.970 - 1.017.

In the control where GD and TFD were maximum, the specific gravity of fruit was 1.013. In treatments with $ZnSO_4$ and urea also GD as well as specific gravity was high. Even though it is very difficult to make out whether a fruit is affected with GD or TFD from its external appearance, it will be possible to identify such fruits if they get immersed in water. Only the normal fruits float on the surface and the fruit which sink in water may be affected with GD or TFD.

5.1.3. Yield attributes

In this study average fruit weight was highest in trees treated with urea 0.5% spray followed by KNO_3 2%. This was in conformity with the findings of Gupta and Brahmachari (2004) who observed that foliar application of 4 per cent urea and 4 per cent KNO_3 increases fruit weight in mango Cv. Bombai. Shinde (2007) reported significantly maximum fruit weight with 0.5 per cent urea

foliar application in kokum under konkan conditions. Wahdan *et.al*, 2011 also recorded highest value of fruit weight with the urea 2% at one month after full bloom in mango cv.“Succary Abiad.”Highest per cent of big sized fruits with more than 100g weight (60% of total fruits/tree) was also observed in treatment with 0.5% urea foliar nutrition in the present investigation. Therefore, for enhancing the fruit size urea foliar application can be adopted by the farmers.

Marked increase in fruit yield was also observed due to foliar nutrient applications. Maximum average fruit weight of 113.17g with comparable number of fruits per tree of 184 fruits in 0.5% urea foliar application resulted in highest fruit yield per tree (Fig. 6). Similar results of increased fruit yield with foliar application of urea was reported in guava cv. Sardar and in mango by Jain (2006).

Treatments with 1% and 2% concentrations of $CaCl_2$ with 50% of medium sized fruits of 75-100g weight, combined foliar spray of 2% $CaCl_2$ with 0.1% and 0.2% boron with 60% of small sized fruits (50-75g) and 0.5% KH_2PO_4 foliar application with 40% of big sized fruits (>100g) produced higher number of fruits per tree (198-201). The higher number has also contributed to higher yield per tree but next to 0.5% urea treatment. This higher number of fruits per tree might be due to higher percentage fruit retention and minimum fruit drop obtained by the treatments involving calcium, boron, and their combinations (Plate 10) followed by KH_2PO_4.

5.1.4. Fruit quality characters

The fruit quality parameters like moisture content, TSS, acidity, ascorbic acid and total sugars were also influenced by foliar nutrient application. Highest moisture percentage was observed in treatments with 0.5% urea foliar application. Shinde (2007) also reported similar results in kokum under Konkan conditions.

Marked increase in TSS and total sugars were noticed in treatments with foliar spray of mono potassium phosphate and potassium nitrate. Increased

Plate 10 – High no. of fruits/tree with calcium chloride treatment

Plate 11 – Quality fruits with KNO_3 2% foliar application

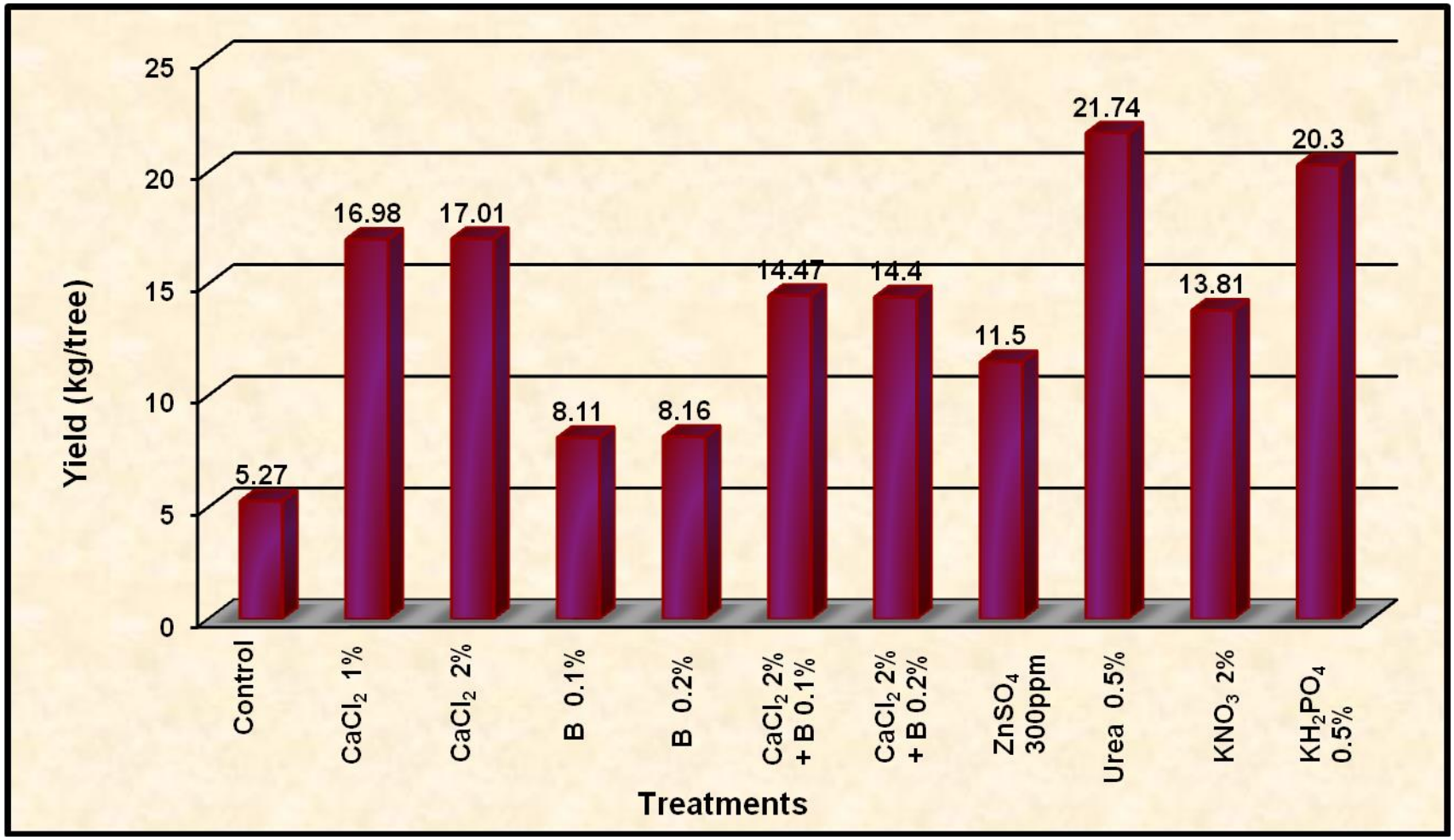

Fig 6– Effect of treatments on fruit yield

TSS was also found in 300ppm $ZnSO_4$ treatment. In this aspect, Hassona (1967) stated that, phosphoric acid has a major role in the biosynthesis of nucleic acid, ATP molecules and act as co enzyme for many enzymes. Shinde (2007) reported that 0.5% mono potassium phosphate foliar application gives highest TSS and total sugars. These results are in general agreement with those of Kassem *et. al*. (2010) working on Costata persimmon trees who reported that pre harvest foliar sprays of phosphoric acid recorded the highest value of TSS and total sugars.

In the present investigation the lowest percentage of fruit acidity was indicated by pre harvest foliar application of 0.5% urea and 2% potassium nitrate. In the organoleptic evaluation of fruits also maximum overall acceptability was found in KNO_3 2% (Plate 11) followed by urea 0.5%. These findings go in line with results obtained by Gupta and Brahmachari (2004) who reported that foliar application of 4 per cent urea and 4 per cent KNO_3 resulted in decrease in fruit acidity compared to control in mango cv. Amrapali. Highest percentage of ascorbic acid content in fruits was found in foliar treatments with 300ppm zinc sulfate, 0.5% mono potassium phosphate and 0.2% boron.

From the present experiment it can be stated that for improving the sweetness in terms of high TSS, total sugars and reducing acidity KNO_3 2% was the best treatment. To enhance ascorbic acid content and thereby the acidity, along with high TSS and sugars, KH_2PO_4 0.5% was a better treatment.

5.1.5. Keeping Quality

Balanced nutrient supply is necessary not only for obtaining higher and regular yield of better quality fruits but also for increasing shelf life of fruits. Increasing shelf life and minimizing post harvest losses will go a long way in increasing fruit production indirectly. Keeping quality was highest in fruits with foliar application of calcium chloride. The results are in accordance with those obtained by Robson *et al.* (1989) who states that foliar applications of calcium to peach trees throughout the growing season can have a positive effect on peach fruit quality in storage. Calcium treated fruits maintained their quality longer than

non-treated fruits. Pre-harvest calcium applications have been used to delay aging or ripening, to reduce post-harvest decay, and to control the development of many physiological disorders in fruits and vegetables (Conway *et. al.* 1994).

5.1.6. Nutrient analysis

"For every nutritional problem there is a horticultural solution". Hidden in this is the understanding of the dynamics of nutrients in horticulture. A due importance to nutrients is essential as they affect the productivity, quality and profitability (Ganeshamurthy *et al*., 2011). Based on this concept efficient nutrient management through foliar nutrient application in mangosteen fruits was studied in this research work. Analysis of nutrient content in the standard leaves before foliar treatment and after harvest of fruits along with fruit rind and pulp analysis at harvest revealed the fact that all nutrient sprays contributed considerable increase of corresponding nutrient content in the fruit rind, pulp and standard leaf.

The experiment trees were given only organic manures such as cow dung and no other chemical fertilizer was applied in the soil. In the current investigation variation in the nutrient status of soil, in the experiment field before foliar treatments and after harvest of fruits was very meager. Nitrogen, phosphorus, calcium, magnesium, zinc and boron contents in the soil were reduced a little once fruits reach maturity stage whereas potassium content in the soil had a slight increase. However there was not much difference in soil nutrients before foliar spray and after harvest of fruits which indicated that the trees utilised nutrients applied through foliar spray to satisfy the nutritional requirements during the fruit development and the foliar nutrition had little effect on soil nutrient content.

Foliar application of urea resulted in significant increase of nitrogen content in the standard leaf of mangosteen along with increased uptake of phosphorus, calcium, magnesium and zinc contents in the leaves. Fruit rind and pulp nitrogen contents were also significantly high on trees treated with 0.5% urea foliar spray. Phosphorus content in fruit pulp also increased by urea application.

El-Fouly *et al.* (1990) stated that foliar application of urea improved the uptake of micronutrients. Johnson *et al.* (2001) reported that urea applied to leaves increased the N content of tissues and improved leaf colour and shoot growth. Apparently urea spray enriches nitrogen sources in both leaves and fruits which affect the rate of CO_2 assimilation and the activity of enzymes involved in photosynthesis resulting in increased quantitative parameters including fruit size, weight and per tree yield of mangosteen. In agreement with the present finding Ramezanian *et al.* (2009) reported increased amount of nitrogen in pomegranates treated with foliar spray of urea at full bloom and one month after full bloom. He also found increased fruit length, breadth and aril weight by foliar application of urea.

Phosphorus, potassium and magnesium contents in the standard leaves were found high in trees treated with mono potassium phosphate. Increased uptake of nitrogen and boron in leaves was also noted by 0.5% KH_2PO_4 foliar spray. Rind and pulp phosphorus and magnesium contents were considerably increased by mono potassium phosphate spray. Potassium content in the fruit pulp was also found high. It has been reported that foliar spraying of citrus trees with mono potassium phosphate increased total soluble solids, phosphate and potassium concentration in the fruit (Lavon *et al*., 1996). In the present study also trees treated with 0.5% KH_2PO_4 had very good quality fruits with high values of TSS, total sugars, acidity and ascorbic acid along with reduced days to harvest. Similar to the present findings Chapagain and Weisman (2003) reported significantly higher potassium, phosphate and magnesium contents in leaves and fruits of tomato plants sprayed with mono potassium phosphate with superior quality fruits of short fruit maturity period.

Foliar treatment of 2% KNO_3 significantly increased potassium content in the standard leaf with slight increase in uptake of nitrogen, phosphorus and boron. Potassium content in the fruit rind and pulp was also significantly high. Hamza *et al.* (2012) reported increased potassium concentration in the leaves of potassium nitrate foliar fertilized Clementine citrus var. *cadoux* with

quality fruits of high TSS and good yield. In the current research fruits from trees foliar sprayed with potassium nitrate had high TSS, total sugars and fruit weight with reduced days to fruit maturity. Accordingly Lin *et al.* (2004) found that increasing the K supply from 120-240 mg L^{-1} in a hydroponics system resulted in higher musk melon fruit sugar concentrations.

Calcium content in the standard leaf was found highest in trees treated with 2% $CaCl_2$. High calcium concentrations was also found in standard leaves of trees sprayed with combination spray of 2% $CaCl_2$ + 0.2% boron, 2% $CaCl_2$ + 0.1% boron and 1% $CaCl_2$ foliar spray. An important role of boron is to support Ca function in plant (Lim *et al*., 2001). These treatments also improved uptake of nitrogen in leaves considerably along with slight increase in magnesium content. Calcium content in the rind and pulp was also found at higher level in the above mentioned treatments. In the present investigation physiological disorders including gamboge and translucent flesh disorders of mangosteen fruits were significantly reduced by foliar spray of calcium chloride at 1% and 2% followed by combination sprays of calcium and boron. The present finding is supported by Dorly *et al*. (2011) who reported that pre harvest foliar application 22.5g/l calcium chloride on 16^{th} weeks after anthesis in mangosteen resulted in high calcium content in the exocarp, mesocarp and endocarp of fruits with reduced yellow latex spots both on the outer part of fruit and in the aril.

Boron content in the standard leaves was found highest in combination spray of 0.2% boron + 2% calcium chloride followed by foliar application of 0.2% boron alone. Boron foliar nutrition increased nutrient uptake of phosphorus, potassium, calcium and magnesium contents in standard leaf. Fruit rind and pulp with highest boron content was also found in trees treated with 0.2% boron alone. It was found that foliar application of zinc sulfate significantly increased zinc content in standard leaf, fruit rind and pulp of mangosteen. In agreement with this Bahadur *et al.* (1998) reported that zinc uptake rate was faster in mango trees when zinc sulfate was foliar applied as compared with its soil

application. Hasani *et al.* (2012) also reported that foliar spray of $ZnSO_4$ appreciably increased zinc concentrations in the leaves of pomegranates.

5.2. ENHANCING SHELF LIFE

Even though mangosteen (*Garcinia mangostana* L.) being a highly appreciated fruit by consumers due to its excellent taste, it faces issues of post harvest life. Short shelf life when associated with inadequate handling, results in post harvest losses. Therefore it is necessary to develop technology which enables to extend the post harvest life of mangosteen, reaching the consumer with its sensory qualities minimally altered and at compensatory prices. Mangosteen is a climacteric fruit. After harvest rapid ripening in mangosteen fruits is responsible for short shelf life and represents a serious constraint for efficient handling and transportation. Though post harvest quality of a produce after harvest cannot be improved, it is possible to reduce the rate of quality loss. Surface treatments with various growth regulators and anti browning agents along with proper packaging methods delay physiological decay in fruit tissues, stabilize the fruit surface and prevent degradation that affect the quality of product (Akhtar *et al.* 2010).

The main objective of storage study was to find out best combination of post harvest treatment, packaging and temperature for enhanced shelf life of mangosteen fruits. In the present investigation fruits at commercial maturity were treated with various post harvest applications (Plate 12 and 13) like presoaking in cold and hot water, dipping calyx and stem end of fruit in BA at 100ppm, 200ppm and 300ppm, GA_3 at 200ppm, 400ppm, 600ppm, salicylic acid at 1%, 2% and 3% concentrations, whole fruit dipping in sodium erythrobate 2%, N-acetyl cystene 0.05%, $CaCl_2$ 0.2% and combinations of sodium erythrobate and N-acetyl cystene with $CaCl_2$. After treatments the fruits were packed in 0.05mm LDPE bags (Plate 14). Apart from the above post harvest treatments cling film wrapping and farmers' practice of packing in rattan baskets with dried banana leaves were tried (Plate 15). Fruits were then kept at five temperature conditions of 5 ± 1^0C, 10 ± 1^0C, 15 ± 1^0C, 20 ± 1^0C and ambient temperature.

Plate 12 – Fruits at commercial maturity were selected for storage

Plate 13 – Post harvest treatment with growth regulators before packing in LDPE bags

Plate 14 – Fruits packed in 0.05mm LDPE bags

Plate 15 – Fruits in rattan baskets covered with banana leaves

5.2.1. Change in fruit quality during storage

The fruits stored at different temperature regimes with various treatments varied considerably with respect to storage life and expressed as percentage loss of fruits. Percentage loss of fruits increased as storage period progressed. Various observations were taken till 50% fruits were lost out of 20 fruits in each treatment. The fruit quality was assured in terms of physiological loss of weight, TSS, acidity, phenol, rind hardness, and rind and pulp colour during storage period. Even though physiological loss of weight expressed in percentage was found increasing as post harvest life proceeded at all temperature conditions under study, only slight increase in percentage weight loss was noticed in fruits stored at very low temperatures of 5 ± 1^0C and 10 ± 1^0C, irrespective of treatments. Faster rate of weight loss was found in fruits kept at ambient temperature which might be due to faster rate of respiration and transpiration loss in fruits at higher temperatures compared to low temperature conditions.

Total soluble solid contents of fruits during storage is considered as an index of fruit ripening and an increase in TSS corresponds to conversion of starch into soluble sugars. In the present study, total soluble solids of stored mangosteen fruits progressively increased during storage irrespective of storage temperature. As TSS are commonly thought to be related to sugars, these results may indicate, the conversion of remaining starch to sugars or stored sucrose to reducing sugars during tissue ripening. The reduced rate of change of TSS value of some superior treatments like salicylic acid 3% and 2% at varying temperature conditions was probably due to slowing down of respiration and metabolic activity, hence retarding the ripening process. The slower respiration also slows down the synthesis and use of metabolites resulting in lower TSS due to slower change from carbohydrates to sugars.

Titratable acidity is directly related to the concentration of organic acids present in the fruit which is an important parameter in maintaining the quality of fruits. Titratable acidity in mangosteen fruits had a declining trend as

the storage period progressed at all temperatures. Some of the superior treatments retained acidity of fruits for a longer period. It might be due to slow rate metabolic changes of organic acid into carbon dioxide and water.

Mangosteen fruit is a rich source of phenols such as xanthones and anthocyanins. The total phenol content in mangosteen was found reducing as storage period enhanced at all temperature conditions. This might be due to incorporation of phenols into lignin synthesis pathway resulting in increased pericarp hardness. Mangosteen fruits have hard rind and its hardness increases as storage period progresses at all temperature regimes. But at very low temperature conditions mangosteen showed pericarp hardening at a faster rate compared to other temperature conditions irrespective of treatments as a result of chilling injury.

Fruit colour including both rind and pulp colour is an important marketing attribute of mangosteen, which influences both consumer acceptance and sales. The attractive purplish red colour of mangosteen is mainly due to anthocyanin. The total anthocyanin content increased continuously during maturation and reaching a maximum value at fully ripe stage (Ratanamarno *et al.*1999). In the storage experiments, the fruits kept at varying temperature regimes shown a transition of rind colour from mean score of 0 to 3 (Plate 16). Accordingly Ratanamarno *et al.* (2005) also reported that anthocyanin contents in mangosteen fruit pericarp stored at different temperatures 15^0, 25^0, 30^0 and 35^0 increased from light purple stage to dark black stage with non-statistical difference.

Mangosteen fruit pulp is white in colour and its colour would fade to dull white, cream and light brown at later stages of storage. Brown discolouration would appear when fruits start decaying. In the present study it was found that even though rind colour changed, pulp colour and quality were not affected proportionately during storage period. This might be due to hard pericarp of mangosteen. In agreement with this result Augustin and Azudin (1986)

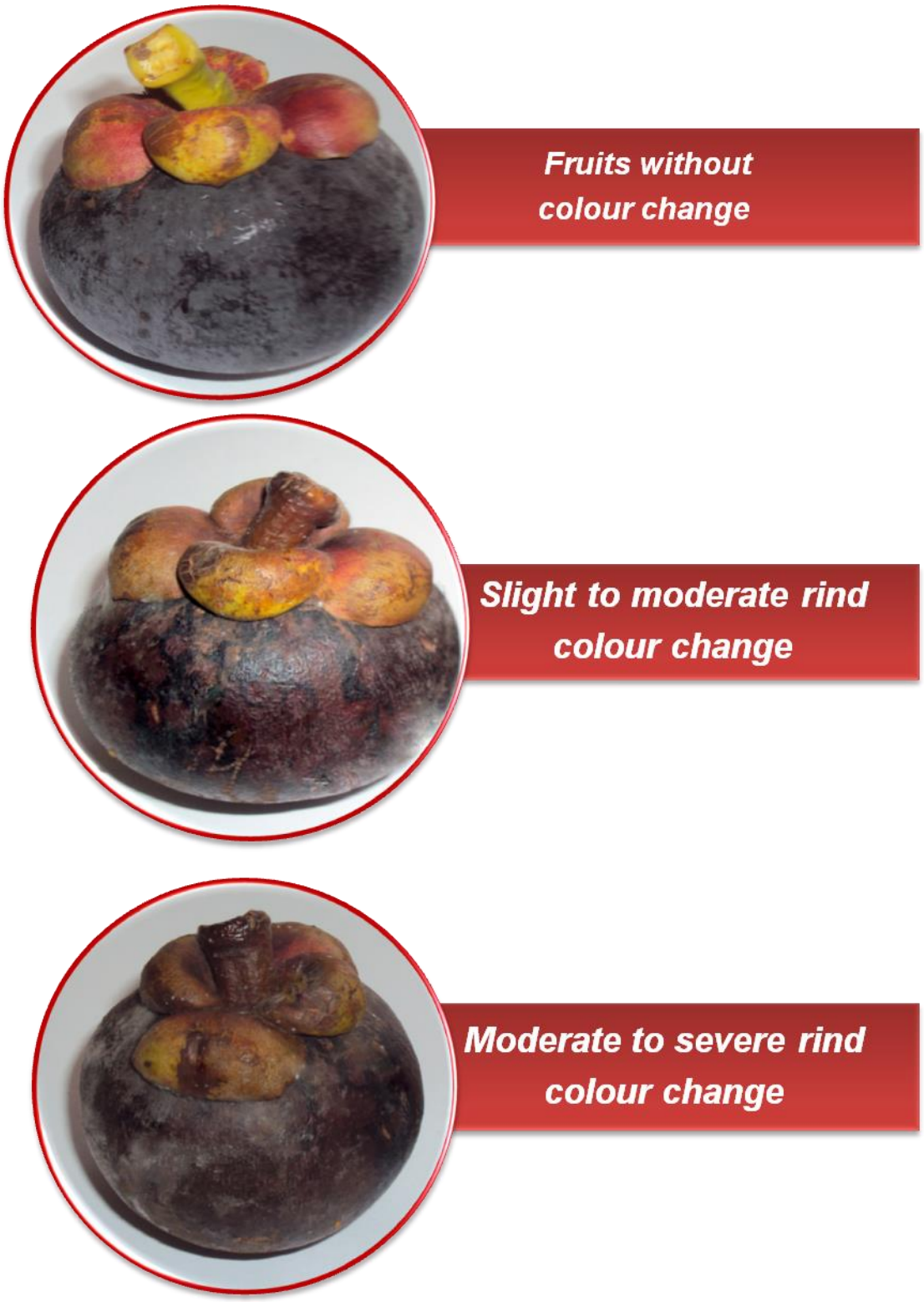

Plate 16- Deterioration of rind colour of mangosteen in storage

reported that damage to fruit skin does not affect senescence of the aril, but 25% of the skin damaged fruit become inedible.

5.2.2. Chilling injury of fruits at 5±1^{0}C and 10±1^{0}C temperatures

In the present study it was found that very low temperatures of 5±1^{0}C and 10±1^{0}C resulted in chilling injury of fruits irrespective of treatments which had only 9-12 days of storage even with superior treatments of salicylic acid and GA_3 (Fig. 7 and 8). Low temperature storage is commonly used to maintain quality and shelf life of many fruits but it induced chilling injury in mangosteen. Chilling injury symptoms appeared as shriveling of calyx, brown patches in rind with hardened pericarp and pink or orange coloured flesh with bitter taste and off flavor (Plate 17). In agreement with these findings Kosiyachinda (1986) reported that mangosteen fruits stored at 1^{0}C showed chilling injury symptoms within 3-4 days and these symptoms become more prominent upon transfer to room temperature. Augustin and Azudin (1986) also reported that storage of mangosteen fruits at 4^{0}C and 6^{0}C could prolong shelf life but pericarp hardening reduced fruit acceptability.

Fruits with calyx and stem end dipped in salicylic acid 2% and 3%, GA_3 600ppm and calcium chloride 0.2% treatments showed comparatively less percentage of fruit loss, having fairly good fruit quality with slow rate in TSS change, acidity decline and phenol degradation up to 9 days at 5±1^{0}C and 12 days at 10±1^{0}C. It has been reported that in CI sensitive fruits like peaches, pre-treatment with salicylic acid reduced chilling injury (Wang *et al*., 2006). Salicylic acid is a well known phenol that can prevent chilling injury and thereby reduce tissue browning in fruits. Sayyari *et al.* (2009), also reported similarly that salicylic acid treatments especially at 2mM concentration were highly effective in reducing CI and electrolyte leakage in pomegranates at 2^{0}C and 85% RH.

The results obtained in current research of skin browning and surface pitting of fruits due to chilling injury are in agreement with Salunkhe and Desai (1984) who reported that low temperature induces hardening and browning

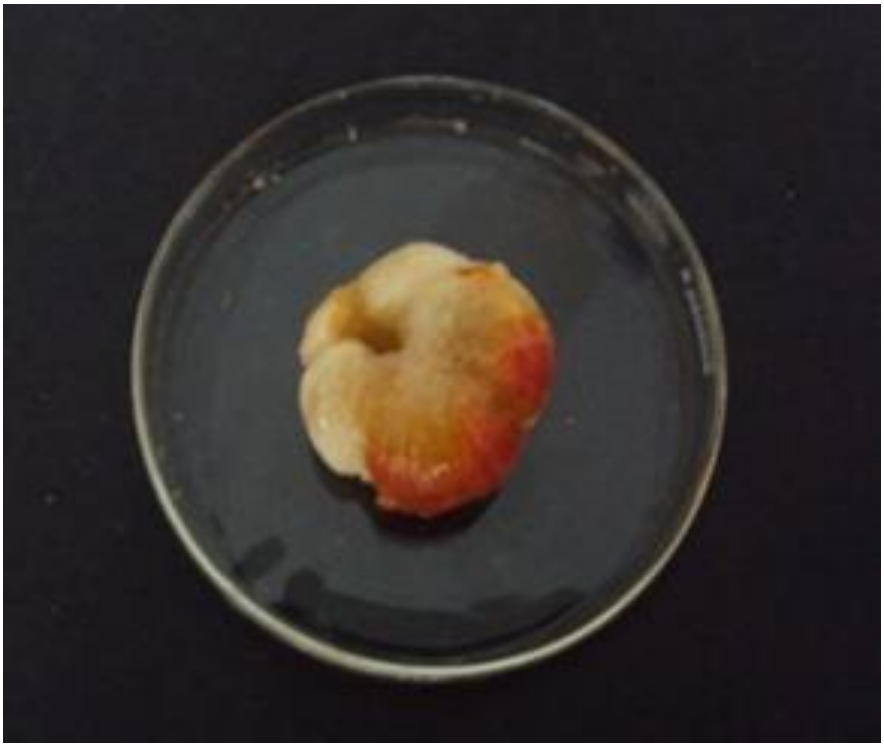

Plate 17 – Chilling injury at 5 ± 1^0C and 10 ± 1^0C

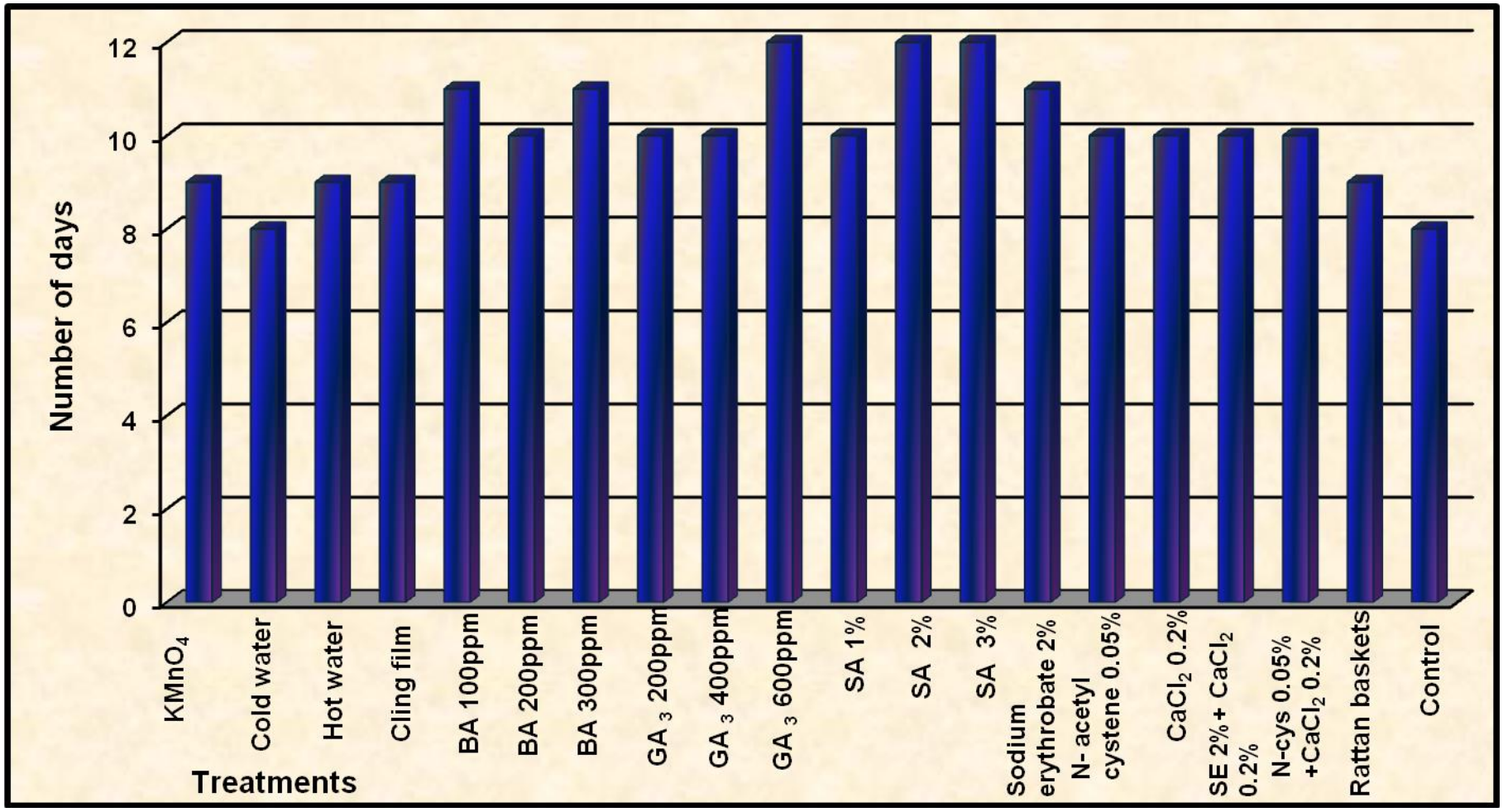

Fig 7– Effect of treatments on shelf life of fruits at 5±1^{0}C

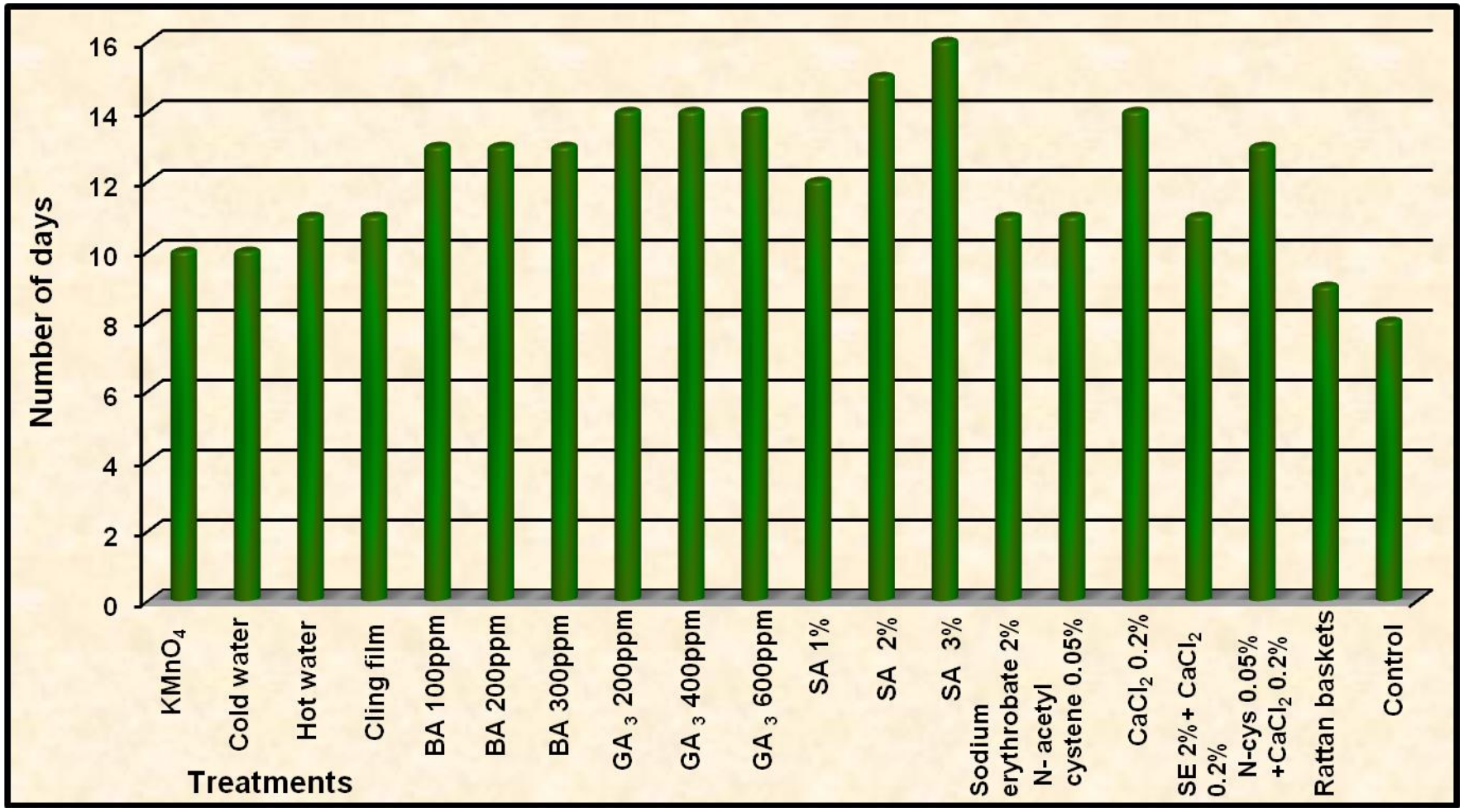

Fig 8– Effect of treatments on shelf life of fruits at 10±1^{0}C

of the mangosteen fruit, rendering it unmarketable. According to Kondo *et al*. (2003) browning and hardening of skin was observed at 7^0C but not at 13^0C suggests that these phenomena may be a kind of CI symptom in mangosteen. In the present study pericarp hardening and degradation of phenol was found faster at very low temperatures (5 ± 1^0C and 10 ± 1^0C) compared to other temperature conditions. Similar to this finding Uthairatanakij and Ketsa (1996) found that pericarp hardening can occur when the mangosteen fruit if stored at chill temperatures for a prolonged period and pericarp firmness of fruit stored at 6^0C was higher than those stored at 12^0C. Choehom *et al.* (2003) also reported that unacceptable chilling injury symptoms of hardened rind found within 5 days at 3^0C and 6^0C. According to Bunsiri *et al*. (2003) decrease in total phenol and increase in lignin contents occurred before pericarp hardening in fruit stored at low temperatures suggested that phenols were incorporated into lignin biosynthesis resulting in hardened pericarp.

5.2.3. Enhanced shelf life at 15 ± 1^0C and 20 ± 1^0C temperatures

In the present study 15 ± 1^0C had excellent storage life up to one month (Fig. 9) followed by 20 ± 1^0C with post harvest life of 3 weeks (Fig. 10). At these temperatures even control fruits without any treatments and fruits kept as farmer's practice in rattan baskets also showed shelf life up to two weeks with satisfactory quality. According to Choehom *et al*. (2003) eating quality of mangosteen fruits stored at 12^0C was better than that of fruits stored at 3^0C and 6^0C.

In both temperature conditions salicylic acid treatment with 3% concentration was the best and was closely followed by calcium chloride 0.2%, salicylic acid 2% and gibberllic acid treatments with 600ppm and 400ppm concentrations. The fruits in these treatments could be stored for a period of 3-4 weeks and had outstanding quality parameters during storage period with low rate of change in TSS and reduction in acidity, slow rate of pericarp hardening and weight loss, reduced degradation of phenol and they retained comparatively good rind and pulp colour. Retention of the quality parameters in these treatments

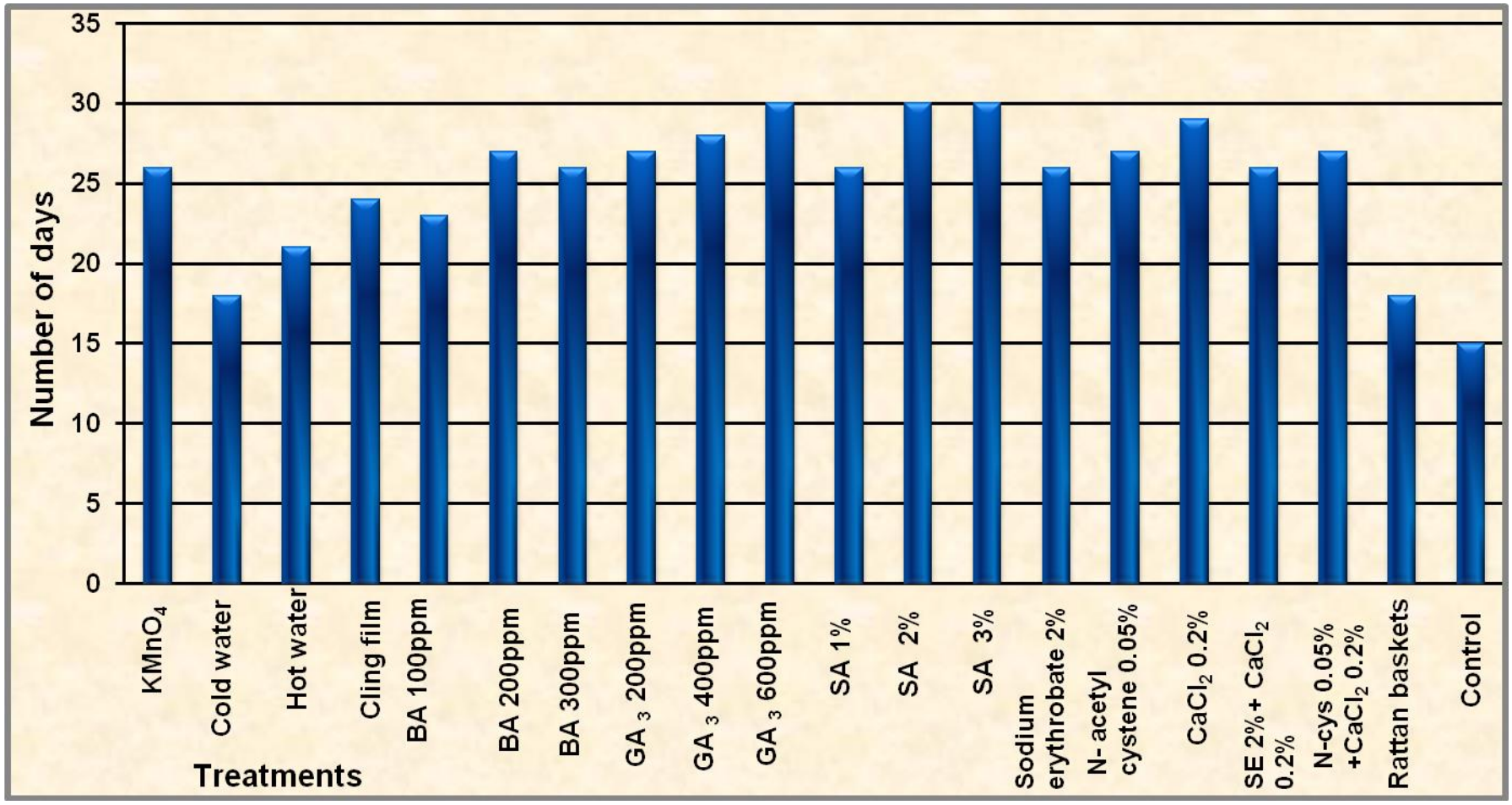

Fig 9– Effect of treatments on shelf life of fruits at 15±1^{0}C

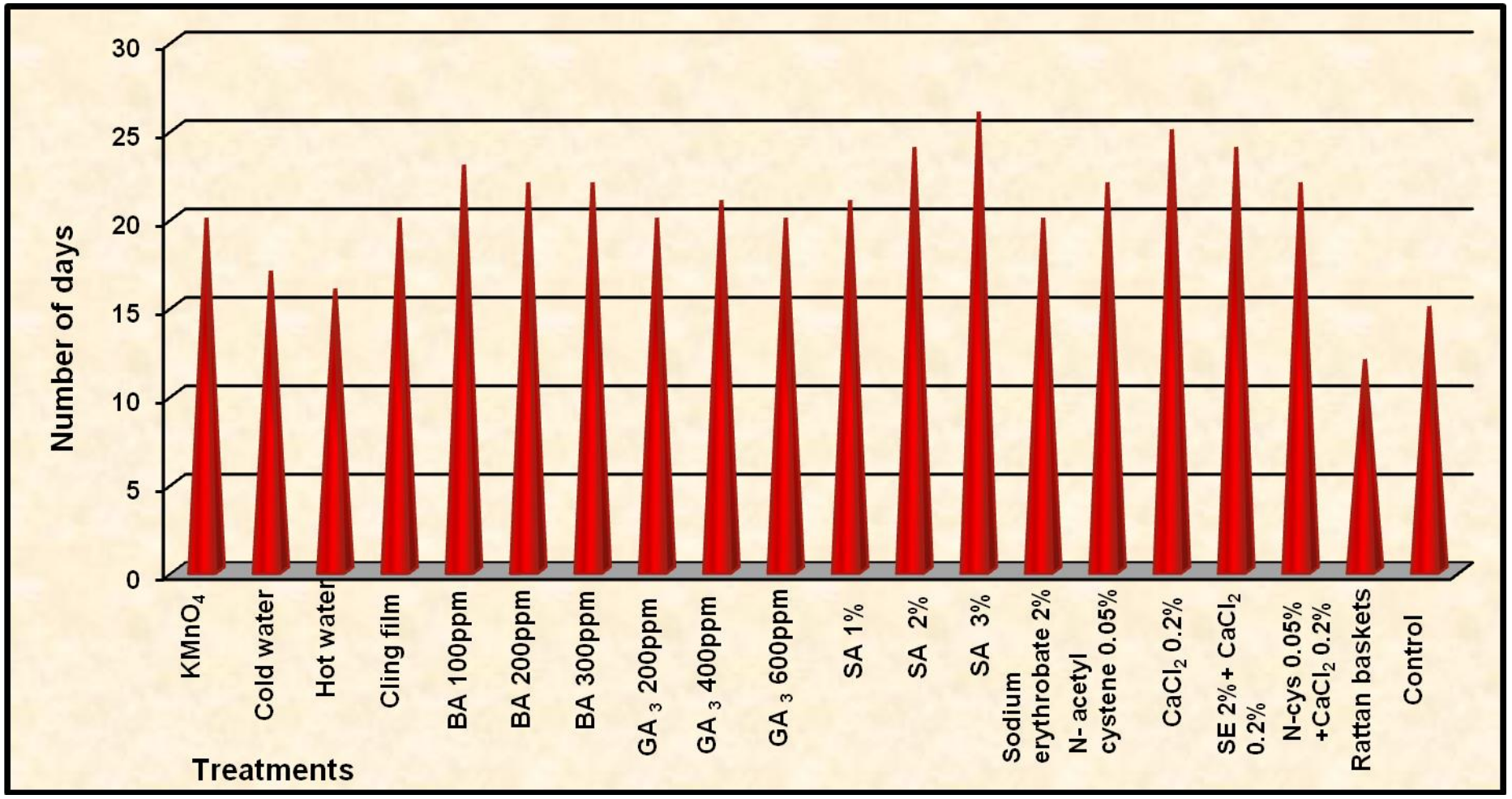

Fig 10– Effect of treatments on shelf life of fruits at 20±1^{0}C

might be due to the anti-senescent action of salicylic acid, calcium chloride and gibberllic acid. In agreement with these findings, Lam *et al.* (1987) stated that salicylic acid as an anti transpirant chemical can retard moisture loss associated pericarp browning of fruits. Senescent changes resulting in losses of physicochemical characters and nutritional qualities can also be inhibited. The finding of the present study tally with reports Wills *et al.* (1998) who advocated that post harvest dipping of fruits in GA_3 delayed the conversion of starch to sugars, reduced peroxidase activity and ethylene production. GA_3 treatment caused the decrease in the tissue permeability and thereby reducing the rate of water loss, leads to delayed fruit ripening.

Other treatments including ethylene absorbent, benzyl adenine at various concentrations, 1% salicylic acid and 200ppm GA_3, also retained fare fruit quality till 15-18 days. Choehom et al. (2003) reported that post harvest dipping of calyx and stem end of mangosteen fruits in benzyl adenine and gibberellic acid either alone or in combination delayed calyx and stem shriveling during storage thereby allowing at least 25 days of storage at 12^0C.

5.2.4. Shelf life of fruits at room temperature

At room temperature, longest shelf life obtained was 21 days in fruits dipped in 0.2% $CaCl_2$ and also in fruits with calyx and stem end dipped in 3% salicylic acid (Fig. 11). These superior treatments showed reduced TSS change, weight loss and slowed down degradation of acidity and phenol. Post harvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism, extending storage life of fresh fruits (Picchioni *et al*, 1998). Salicylic acid is a plant hormone inhibiting ethylene biosynthesis and delaying senescence (Ozeker, 2005) which is also involved in local and systemic resistance to pathogens. Therefore at farmers' level application of calcium chloride 0.2% or salicylic acid 3% can be of great help to improve shelf life, maintain sweetness and acidity, and reduce post harvest loss of mangosteen even at ambient conditions.

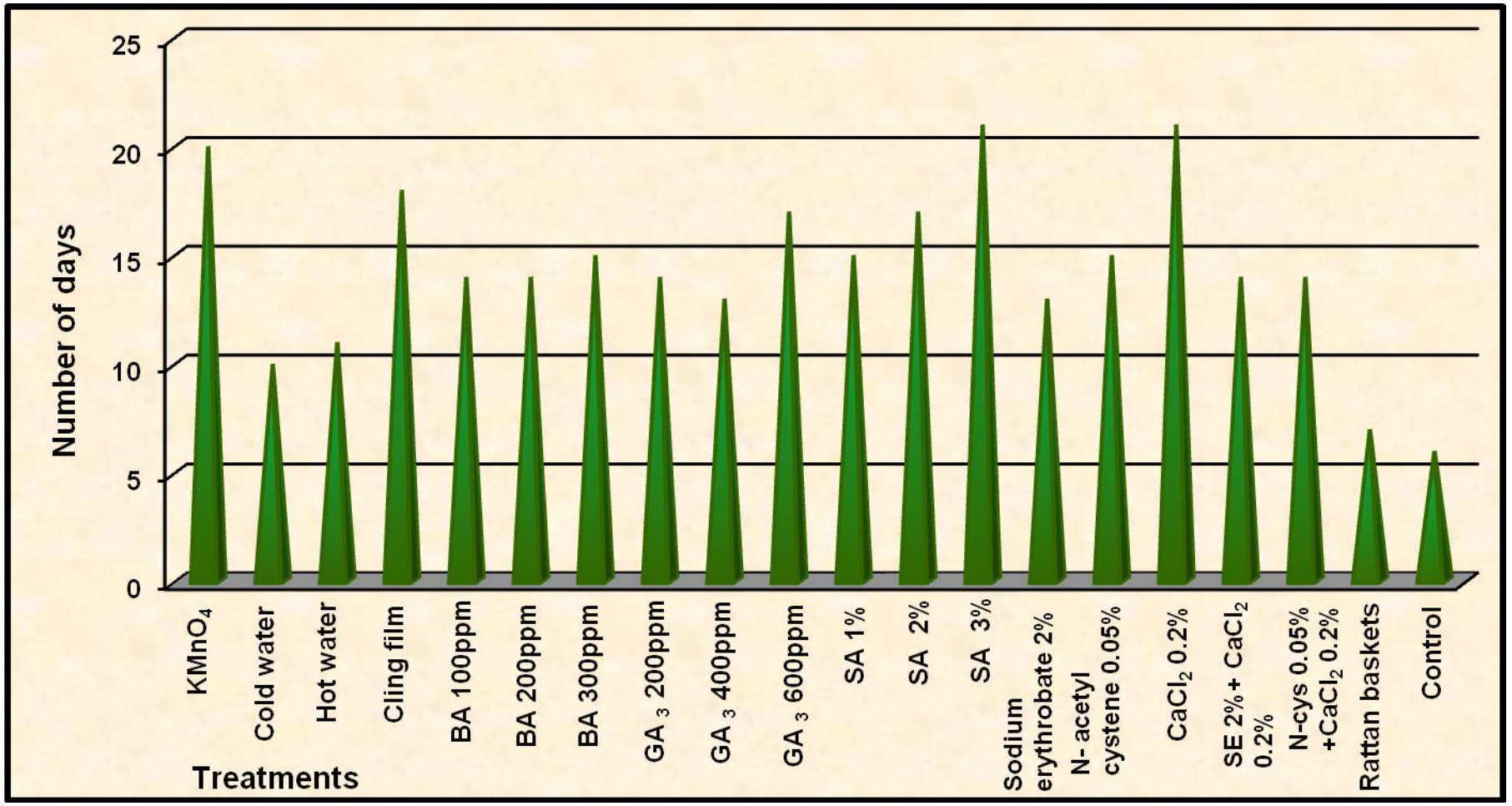

Fig 11– Effect of treatments on shelf life of fruits at room temperature

Fruits packed with ethylene absorbent ($KMnO_4$) and those wrapped with cling film also had good shelf life of 18 days at room temperature with low rate of TSS change good retention of acidity and phenol with less pericarp hardening and weight loss. In accordance with this result Abanesa and Capirig (2000) reported that cling wrap extends shelf life of mangosteen up to two week. Similarly the use of PVC film to create modified atmosphere has shown satisfactory results for many fruits like guava and passion fruit and has reduced loss of fresh weight. Accordingly Correa *et al*. (2005) reported that $KMnO_4$ application delay fruit softening and increase post harvest life. Ethylene absorber – $KMnO_4$ also enhanced storage period at room temperature. Removal of ethylene from storage condition is important for climacteric fruits.

5.2.5. Effect of superior treatments on fruit quality

Salicylic acid 3% and 2% concentrations had a positive effect on all quality parameters by retaining TSS, acidity and phenol with minimum weight loss and rind hardening and good colour of rind and pulp, hence it improved shelf life at all temperature ranges including low temperatures. Salicylic acid ($C_7H_6O_3$), the active ingredient of aspirin, has been reported to regulate a number of processes in plants. It was also proposed that, salicylic acid has an antagonistic effect on ethylene biosynthesis and/or ethylene action (Raskin 1992). In the present study at very low temperatures of 5^0C and 10^0C also salicylic acid had good effect on alleviating chilling injury and to maintain quality up to 9-12 days. In agreement with above results Ding *et al*., 2001 reported that post harvest salicylic acid treatment could be used to reduce quality deterioration and chilling injury in number of fruits and vegetables. Salicylic acid has been found to delay the senescence of fruits (Hassan *et al.* 2007).

Even though pericarp hardening was higher in calcium chloride treatment compared to other superior ones it did not affect fruit quality considerably. At room temperature as well as at 20^0C calcium chloride 0.2% minimised the rate of change in TSS and enhanced shelf life up to 27 days. At

10^0C, 15^0C, 20^0C, $CaCl_2$ 0.2% helped to retain the acidity level and the rate of change was minimal. Cheour *et al.* (1990) stated that the application of calcium increased fruit calcium content and influenced several post harvest senescence changes involving free sugars, organic acids and texture of fruits. Cheour *et al.* (1991) also reported that concentration of free sugars progressively increased with storage and this increase was quite markedly delayed by calcium treatment. In the present study also calcium chloride delayed the conversion of sugars and acids and thus helped the fruits to retain its quality up to 27 days at 20^0C. Hewajulige *et al.* (2003) reported that calcium concentrations resulted in decreased flesh browning symptoms which were directly associated with calcium content of fruits. But in the present experiment, the application of $CaCl_2$ 0.2% alone did not help much to retain its pulp and rind colour at any of storage temperatures. Instead $CaCl_2$ 0.2% in combination with sodium erthrobate or N-acetyl cystene helped the fruits to retain its colour for a longer period.

In this study, cling film wrapping had a very good affect on reducing physiological loss in weight at all temperatures. It might be due to reduced water loss by transpiration of fruit wrapped with individual cling film. In the present investigation, it was also found that N-acetyl cystene and sodium erythrobate alone or their combinations with calcium chloride noticeably retained rind and pulp colour at all temperatures. According to Lei *et al.* (2004) N-acetyl cystene have been found very effective to reduce the browning and to prevent the postharvest decay of fruits and vegetables by decreased polyphenol oxidase activity. Anti browning agents like N-acetyl cystene and sodium erythrobate might have been found to be effective in retarding enzymatic browning of mangosteen fruits as observed by Sapers and Miller (1998). Similarly Manurakchinakorn *et al.* (2010) reported that tissue browning, due to oxidation of phenolic compounds by polyphenol oxidase (PPO) was inhibited by dipping of mangosteen fruits in sodium erythorbate and N-acetyl cystene and calcium chloride acted as an agent for maintaining tissue firmness. In the present experiment however calcium chloride did not retain the softness of mangosteen

rind in the storage. Even those fruits treated with $CaCl_2$ in combination with N-acetyl cystene and sodium erythrobate had hard rind towards the end of storage.

On considering all the temperature conditions 15 ± 1^0C was found the best temperature for mangosteen storage with 24-27 days followed by 20 ± 1^0C with 18-21 days of post harvest life when fruits are packed in 0.05mm LDPE bags and treated with salicylic acid 3% and 2%, $CaCl_2$ 0.2% and GA 600ppm. Very low temperature conditions of 5 ± 1^0C and 10 ± 1^0C resulted in chilling injury of fruits within short period (9-12 days) in almost all treatments including superior ones. At room temperature, fruits without any treatments perished within 6-9 days but specific treatments with salicylic acid 3%, calcium chloride 0.2% ethylene absorbent ($KMnO_4$) and cling film packaging gave enhanced shelf life of 18-21days. In general post harvest treatment with salicylic acid at 3% and 2% concentrations and 0.2% calcium chloride have shown good results in almost all temperature conditions followed by GA_3 600ppm and 400ppm concentrations considering all quality parameters under study during the post harvest period of mangosteen.

Therefore it can be concluded from this study that mangosteen fruits treated with salicylic acid 3% together with LDPE packing at 15^0C temperature enhances the storage life up to one month with optimum fruit quality (Plate 18). Also, post harvest treatments of calcium chloride 0.2% and GA_3 600ppm can be used instead of salicylic acid. At farmers level they can effectively enhance shelf life of mangosteen up to two weeks at room temperature by packing in LDPE bags after treating with salicylic acid 3% or $CaCl_2$ 0.2%.

5.3. FUTURE LINE OF WORK

In the present studies it was found that urea 0.5% had effect on fruit quantitative characters, hence higher concentrations of urea to be studied for more improved physical characters and yield. Fruits from calcium chloride 2% and 1% alone and combinations of calcium chloride 2% with boron 0.1% and

Plate 18 – Quality fruits with SA 3% at 15^0C after 24 days

0.2% reduced physiological disorders considerably, so more effective combination and concentration of both calcium and boron to be identified. Combinations of urea and calcium chloride also to be experimented to get increased yield along with reduced physiological disorders. Mangosteen trees had good response to nutrient application with respect to both quality and quantity characters; hence package of practices with soil fertilizer application to be standardised under Kerala condition to enhance yield and quality of fruits. In the storage salicylic acid 3% had very good effect on all temperature regimes, so higher concentrations of salicylic acid to be studied to enhance shelf life with quality fruits.

Summary

6. SUMMARY

The present investigation on 'Improving quality and shelf life of mangosteen (*Garcinia mangostana* L.)' was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 2010-2011 with the objective of improving fruit quality along with reducing gamboge and translucent flesh disorders and enhancing shelf life of mangosteen.

The study comprised of two experiments. First experiment was to study the effect of foliar application of nutrients at 4^{th}, 8^{th} and 12^{th} weeks after bloom on improving fruit quality and reducing physiological disorders. Second one was a storage study at five different temperature regimes along with growth regulator/ nutrient treatments on fruits packed in 0.05mm LDPE bags to identify most efficient storage condition for mangosteen.

The salient findings of the study are summarised as follows:

1. Highest percentage of fruit retention was obtained in $CaCl_2$ 2% (88.49%) followed by $CaCl_2$1% (81.42%). High fruit retention was also recorded in combinations of $CaCl_2$ 2% with boron 0.1% and 0.2%, and KH_2PO_4 0.5% with 74-75% of fruit retention.

2. Days to harvesting maturity was reduced by KNO_3 and KH_2PO_4 0.5% to 84-85 days compared to 101 days in the control.

3. Gamboge disorder was significantly reduced to 9.83% and 9.97% respectively by $CaCl_2$ 1% and 2% foliar spray. Combinations of $CaCl_2$ 2% with boron 0.1% and 0.2% also reduced gamboges to 10-11%.

4. Translucent flesh disorder was reduced to 11-12% by $CaCl_2$ 2% and 1% alone as well as combination of $CaCl_2$ 2% with boron

0.2%. Foliar spray of boron 0.1% and 0.2% alone and $ZnSO_4$ 300ppm also reduced TFD to 12-13%.

5. Maximum percentage of fruits affected with physiogical disorders was noticed in the outer canopy (56-64%) than the inner canopy (34-40%) in all treatments

6. Maximum fruit diameter was found in 0.5% urea (6.17cm), 2% KNO_3 (6.03cm) and 0.5% KH_2PO_4 (6.03cm). Fruit physical parameters including fruit length, breadth, circumference and average fruit weight were also high in treatments with 0.5% urea followed by 2% KNO_3 and 0.5% KH_2PO_4.

7. Maximum number of segments/fruit (6.7-7), number of viable seeds/fruit (1.7 -1.3) and minimum rind/pulp ratio (1.77-1.87) were found in treatments with urea 0.5% followed by KH_2PO_4 0.5% and KNO_3 2%.

8. Highest number of big sized fruits with >100gms weight was found in foliar sprays with urea 0.5% (60% of total fruits), maximum medium sized fruits with 75-100gms in $CaCl_2$ 1% and 2% (60-62% of total fruits), small fruits with 50-75gms in $CaCl_2$ 2% and boron 0.1% and 0.2% (60-62% of total fruits) and very small fruits (11% of total fruits) with <50gms in 1% $CaCl_2$ treatment.

9. Number of fruits per tree was highest (201no.s) in $CaCl_2$ 1% and 2% treatments, followed by 198 fruits in combination of $CaCl_2$ 2% with boron 0.1% and 0.2% and KH_2PO_4 0.5%.

10. Highest yield per tree was recorded in treatments with urea 0.5% with 21.74kg/tree followed by 20.30kg/tree in KH_2PO_4 0.5%.

11. Firmness of fruits was maximum (8-9kg/cm^2) and specific gravity was minimum (0.97-0.98) in $CaCl_2$1% and 2% followed by combination of $CaCl_2$ 2% with boron 0.1% and 0.2%.

12. Moisture content in fruit was found highest in urea 0.5% with 70.87%. Maximum TSS, total sugars, organoleptic quality and minimum acidity was found in KNO_3 2% which resulted in superior quality. High values of TSS were also noticed in $ZnSO_4$ 300ppm and KH_2PO_4 0.5%. Total sugars was also high in KH_2PO_4 0.5%. Ascorbic acid content was high in boron 0.1%, $ZnSO_4$ 300ppm and KH_2PO_4 0.5%.

13. Longest period of shelf life was obtained in foliar sprays of $CaCl_2$ 2% with 21 days followed by $CaCl_2$ 1% with 20 days.

14. Nutrient analysis of standard leaves, fruit rind and pulp revealed that all nutrient sprays significantly increased corresponding nutrient content in the standard leaf, rind and pulp along with positive effects on uptake of other elements too.

15. In the studies, longest shelf life was recorded in fruits stored at 15 ± 1^0C with 27- 30 days followed by 20 ± 1^0C with 24-27 days. Even fruits without any treatments had shelf life of 15 days at 15^0C and 20^0C only because of temperature effect.

16. At 15 ± 1^0C and 20 ± 1^0C salicylic acid 3% and 2%, $CaCl_2$ 0.2%, GA_3 600ppm and 400ppm were the best treatments with low rate of change in TSS, slow degradation of acidity and phenol, physiological loss in weight and pericarp hardening up to last stage of its storage (3-4weeks) .

17. Fruits kept at very low temperatures showed only short storage life with 9 days in 5 ± 1^0C and 12 days in 10 ± 1^0C mainly due to chilling injury.

18. Chilling injury symptoms appeared as shriveling of calyx, brown patches in rind with hardened pericarp and pink or orange coloured flesh with bitter taste and off flavour.

19. N-acetyl cystene 0.05% and sodium erythrobate 2% alone, and their combinations with calcium chloride 0.2% retained rind and pulp colour at all temperatures. Cling film wrapping of individual fruits reduced physiological loss in weight considerably at all temperatures.

20. Treatments with 2% and 3% salicylic acid, 0.2% $CaCl_2$ and 600ppm GA_3 retained comparatively good storage quality of fruit with slow degradation of phenol and acidity, less pericarp hardening and weight loss with lower rate of change in TSS at all temperature conditions.

21. At room temperature control fruits had only 6 days of storage where as superior treatments with 0.2% $CaCl_2$, 3% salicylic acid, ethylene absorbent ($KMnO_4$) and cling film extended the shelf life up to 18-21days.

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Appendices

APPENDIX I

Weather data of the experimental site

Hours of observation: I-0700 hrs LMT (07:25 IST); II- 1400 hrs LMT (14:25 IST)

February to June 2011 weekly weather data

Week	Temperature (^{0}C)		Relative humidity (%)		Sun shine (hrs/day)	Rainfall (mm)
	Maximum	Minimum	I	II		
February 1st week	33.50	21.75	57.17	26.00	9.42	0.00
February 2nd week	34.40	21.61	64.57	25.43	9.57	0.00
February 3rd week	33.54	20.76	87.57	45.43	8.99	0.00
February 4th week	33.30	23.39	89.57	51.43	6.10	11.07
March 1st week	34.84	23.10	73.14	31.14	9.99	0.00
March 2nd week	35.69	23.54	91.423	37.14	9.23	1.43
March 3rd week	34.80	23.43	80.71	37.86	9.33	0.00
March 4th week	33.97	24.86	89.14	58.14	6.97	0.00
March 5th week	34.09	24.86	91.00	58.14	7.14	0.31
April 1st week	34.83	24.34	86.86	52.57	8.20	0.00
April 2nd week	35.01	24.80	85.43	54.00	8.04	1.03
April 3rd week	34.34	23.83	90.29	61.86	5.23	21.17
April 4th week	32.97	24.81	89.86	63.29	5.34	7.07
May 1st week	33.06	24.81	90.29	61.00	7.96	16.17
May 2nd week	32.79	24.90	89.14	63.14	8.33	0.00

Week	Temperature (^{0}C)		Relative humidity (%)		Sun shine (hrs/day)	Rainfall (mm)
	Maximum	Minimum	I	II		
May 3rd week	33.51	25.49	89.43	61.71	6.00	0.00
May 4th week	33.27	25.06	92.14	63.14	5.41	9.51
June 1st week	28.57	23.96	94.71	86.14	1.34	38.96
June 2nd week	30.13	24.11	95.29	82.33	3.09	23.03
June 3rd week	28.43	23.42	96.00	84.86	1.59	31.90
June 4th week	29.76	23.49	95.71	78.28	3.10	16.33
July 1st week	30.64	23.20	95.14	73.43	4.80	7.87

Appendix –II

Organoleptic evaluation of fruits

Treatments	*Taste*	*Flavour*	*Colour*	*Texture*	*Overall acceptability*
T1	6.07^{e}	5.23^{f}	6.77^{c}	6.27^{c}	24.33^{g}
T2	6.16^{e}	6.07^{e}	6.97^{bc}	6.17^{cd}	25.23^{f}
T3	6.67^{d}	5.30^{f}	6.90^{bc}	6.17^{cd}	25.03^{f}
T4	7.10^{c}	6.83^{d}	6.03^{d}	6.93^{b}	26.90^{e}
T5	7.13^{c}	7.77^{b}	7.10^{b}	7.10^{b}	29.10^{c}
T6	7.17^{c}	7.03^{cd}	6.97^{bc}	7.00^{b}	28.17^{d}
T7	7.57^{b}	7.03^{cd}	7.00^{bc}	7.03^{b}	28.63^{c}
T8	7.17^{c}	7.17^{c}	6.97^{bc}	7.03^{b}	28.34^{d}
T9	8.13^{a}	7.80^{b}	8.07^{a}	7.73^{a}	31.73^{b}
T10	8.27^{a}	8.23^{a}	8.10^{a}	7.80^{a}	**32.40^{a}**
T11	7.57^{b}	7.17^{c}	7.00^{bc}	7.03^{b}	28.77^{c}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-Control ***T4-Boron 0.1%*** ***T7-$CaCl_2$ 2% + Boron 0.2%*** ***T10-KNO_3 2%***

T2-$CaCl_2$ 1% ***T5- Boron 0.2%*** ***T8-$ZnSO_4$ 300ppm*** ***T11-KH_2PO_4 0.5%***

T3-$CaCl_2$ 2% ***T6- $CaCl_2$ 2% + Boron 0.1%*** ***T9-Urea 0.5%***

IMPROVING QUALITY AND SHELF LIFE OF MANGOSTEEN (*Garcinia mangostana* L.)

By

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ABSTRACT OF THESIS

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ABSTRACT

Mangosteen (*Garcinia mangostana* L.) is a unique tropical fruit rich in vitamins and minerals. It is gaining demand in international markets mainly due to its much acclaimed health benefits such as antioxidant properties and prophylactic action on many of degenerative diseases. Major problems limiting profitable mangosteen production is the occurrence of translucent flesh disorder (TFD), gamboge disorder (GD) and short shelf life. Therefore an attempt was made to improve fruit quality and reduce flesh disorders through foliar nutrition at 4^{th}, 8^{th} and 12^{th} week after bloom.

Foliar application of $CaCl_2$ (1 and 2%) alone, combinations of $CaCl_2$ 2% and boron (0.1% and 0.2%) and KH_2PO_4 0.5% gave high fruit retention of 75-88 per cent. Days to maturity was reduced to 84-85 days by KH_2PO_4 0.5% and KNO_3 2%. Gamboge and translucent flesh disorders were significantly reduced by $CaCl_2$ (1 and 2%) alone and combination of $CaCl_2$ 2% with boron (0.1 and 0.2%). Incidence of physiological disorders was minimum in the inner canopy (34-40%) compared to the outer canopy (56-66%) in all treatments.

Biggest fruit size with maximum fruit weight of 113.17g in foliar nutrition with urea 0.5%. Highest yield of 20-22kg/tree was in urea 0.5% and KH_2PO_4 0.5% treatments. Highest number of fruits per tree (198-202 no.) was found in $CaCl_2$ 1% and 2%, combination of $CaCl_2$ 2% and boron (0.1 and 0.2%), and KH_2PO_4 0.5%. Highest number of biggest fruits with >100g weight was found in urea 0.5% treatment, followed by KNO_3 2%. Maximum number of segments/fruit (6.7-7), number of viable seeds/fruit (1.7 -1.3) and minimum rind/pulp ratio (1.77-1.87) were found in treatments with urea 0.5% followed by KH_2PO_4 0.5% and KNO_3 2%. Fruit firmness was maximum (8-9kg/cm^2) and specific gravity was minimum (0.97-0.98) in $CaCl_2$ 1% and 2% followed by combination of $CaCl_2$ 2% with boron 0.1% and 0.2%.

TSS, total sugars and organoleptic qualities were maximum and acidity low in treatments with KNO_3 2%. Moisture content in fruit was highest in urea 0.5% with 70.87%. High values of TSS were also noticed in $ZnSO_4$ 300ppm and KH_2PO_4 0.5%. Total sugars was also high in KH_2PO_4 0.5%. Ascorbic acid content was high in boron 0.1%, $ZnSO_4$ 300ppm and KH_2PO_4 0.5%. Longest post harvest life of 21 days was obtained in $CaCl_2$ 2% treatment. Nutrient analysis revealed that all nutrient sprays significantly increased corresponding nutrient content in the leaf, rind and pulp along with positive effects on the uptake of elements.

Mangosteen fruits have a storage and marketable life of not more than one week under tropical ambient conditions. Hence in the second experiment to extend shelf life, fruits kept at 5 ± 1^0C, 10 ± 1^0C, 15 ± 1^0C, 20 ± 1^0C and ambient temperature conditions after nutrient/growth regulator treatments and packing in 0.05mm LDPE bags. In the storage study, longest post harvest life of 24- 27 days was recorded in 15 ± 1^0C followed by18-21days in 20 ± 1^0C. Salicylic acid 3% and 2%, $CaCl_2$ 0.2% and GA_3 600ppm were the best treatments in 15 ± 1^0C and 20 ± 1^0C temperatures with low rate of change in TSS, slow degradation of acidity and phenol, less weight loss and low pericarp hardening up to last stage of fruit storage. Fruits kept at very low temperatures showed only short storage life with 6 days in 5 ± 1^0C and 10 ± 1^0C without any treatments mainly due to chilling injury. But salicylic acid (3% and 2%) and GA_3 600ppm treatments extended shelf life of mangosteen to 12-15 days. At ambient temperature superior treatments were salicylic acid 3%, $CaCl_2$ 0.2%, ethylene absorbent ($KMnO_4$) and cling film with shelf life of 18-21 days. In all temperature regimes treatments with salicylic acid 2% and 3%, $CaCl_2$ 0.2% and 600ppm GA_3 retained comparatively good storage quality of fruit with slow rate of senescence. N-acetyl cystene 0.05% and sodium erythrobate 2% alone and their combinations with calcium chloride 0.2% retained rind and pulp colour, and cling film wrapping of individual fruits reduced physiological loss in weight at all temperature conditions.