EFFECT OF PRE-HARVEST TREATMENTS ON POST-HARVEST QUALITY AND SHELF LIFE OF MANGO

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CERTIFICATE

This is to certify that the thesis entitled, **EFFECT OF PRE-HARVEST TREATMENTS ON POST-HARVEST QUALITY AND SHELF LIFE OF MANGO** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural university, Dhaka, in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE IN HORTICULTURE** *embodies the results of a piece of bona fide research work carried out by* ***MD. TOUHID IQBAL,*** *bearing Registration No.* ***18- 09227*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: DECEMBER, 2020

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Dedicated

To

My Beloved Parents

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EFFECT OF PRE-HARVEST TREATMENTS ON POST-HARVEST QUALITY AND SHELF LIFE OF MANGO

ABSTRACT

Pre-harvest management that extends the shelf life of mango is limited in developing countries like Bangladesh. An experiment was carried out to investigate the effect of pre-harvest treatments on shelf-life and quality of mango fruits cv. Amrapali. at 20 and 10 days before harvesting (DBH), mango trees were sprayed with different treatments; water spray (control), 2% calcium chloride ($CaCl_2$), 1% potassium sulphate (K_2SO_4), 75 ppm gibberellic acid (GA_3), and 200 ppm salicylic acid (SA). Fruit trees sprayed with 75 ppm GA_3 and 200 ppm SA at 20 DBH increased the time to ripen (12 and 11 days after harvesting, respectively) than control trees (6 days). When fruits were sprayed with 75ppm GA_3 at 20 DBH, they had the longest shelf life (17 days), followed by 200 ppm SA at 20 DBH (16 days), compared to control (9 days). Among the treatments, 75 ppm GA_3 at 20 DBH reduced weight loss, pH, disease severity, total soluble solid (percent Brix), and enhanced ascorbic acid, β--Carotene, and titratable acidity. Therefore, 75 ppm GA_3 at 20 DBH is suitable for extending the shelf life and improves the quality of mango.

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LIST OF ABBREVIATIONS OF TECHNICAL SYMBOLS AND TERMS

Full Word	**Abbreviation/ Symbol**
Analysis of Variance	ANOVA
And Others	*et al.*
Physiological Loss of Weight	PLW
Coefficient of Variation	CV
Total Soluble Solid	TSS
Completly Randomized Block Design	RCBD
Titratable Acidity	TA
Days After Storage	DAS
Modified Atmosphere Packaging	MAP
Relative Humidity	RH
Food and Agriculture Organization	FAO
Degree of Freedom	DF
High Density Polyethylene	HDPE
Journal	*J.*
Least Significant Difference	LSD
Negative Logarithm of Hydrogen Ion Conc.	pH
World Health Organization	WHO
Percentage of Disease Incidence	% DI
Sher-e-Bangla Agricultural University	SAU
That is	i.e.
Percentage of Disease Severity	%DS

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) fruit belongs to dicotyledonous family of Anacardiaceae and it is recognized as one of the choicest and well accepted fruits all over the world due to its luscious flavor, taste and high nutritive value. It provides about 64-86 calories per 100 grams of ripe fruits (Rathore *et al.,* 2007) and it contains adequate quantity of appreciable β-carotene, vitamin C, and dietary fiber (Amin and Hanif, 2002; Pal, 1988). It is commercially grown in more than 80 countries of the world and Bangladesh produces 1.22 million tons of mangoes from 0.95 lakh hatres lakh acres which is the 7th largest mango producer in the world (BBS, 2019).

The leading mango growing districts are Rajshahi, Chapainawabgonj and greater Dinajpur. It is a seasonal cash crop which dominates the economy of Rajshahi and Chapainawabgonj district (Ali *et al.,* 2019). Mango has rich diversity with many cultivated varieties and hybrids. Among the promising mango hybrids, Amrapali is a well-known late maturing and regular bearer dwarf hybrid variety. It was evolved as a result of a cross between „Dasheheri (alternate bearer) and Neelum (regular bearer)" varieties of mango species Indica at IARI, New Delhi, in 1978. The fruit is oblong in shape. It is excellent in taste and is regarded as a good table variety. Due to dwarf nature the cultivar is recommended for high density planting and kitchen gardens (Ray, 1999).

Mango as the climacteric fruit generally harvested green, which ripens during the marketing process (transport, storage etc.) with an irregular storage period from harvest to consumption. However, similar to other tropical fruits, it has little amounts of endogenous ethylene until maturity, physiologically and biologically active even after harvest which makes it being a highly perishable fruit and possesses a shorter shelf life about one week at ambient temperature. Postharvest losses are also a topic of concern (Patil *et al*. 2013, Luo *et al.* 2015). Once fruits are harvested, these processes along with other bio-chemical deterioration, decrease the fruit quality and shelf life very quickly which affects its marketability, becomes highly susceptible to postharvest losses (Roy 1993, Wills *et al*. 2007, Jha *et al*. 2015) which accounts of 25-40% from harvesting to consumption stage. It is also susceptible to post harvest diseases due to its harvesting in rainy season, improvement in the shelf life and maintaining good quality after the post-harvest has become resulting in excess

post-harvest losses (Jakhar & Pathak 2016). However, high perishability is not only a serious problem of Amrapali growers and traders in Bangladesh, but also present time an emerging issue.

The importance of maintaining the fruit quality and shelf life during post-harvest has been long interest to the growers, therefore, some pre and post-harvest mechanism are developed to ensure supply of quality mango fruits for longer period on domestic and distant market. These treatments are applied to delay the ripening (Suhardi, 1992), extending storage life, minimizing weight loss, reduction in rate of respiration, transpiration and rotting percentage (Singh *et al.,* 1998) and to ensure good market price of mango (Hossain *et al.,* 2020). For this purpose, several pre-harvest and post-harvest treatments are applied during the fruit development that influence the postharvest quality such as weight loss, moisture content, ripening time, TSS, vitamin contents, pH, β-carotene content of fruits (Taduri *et el*., 2017; Lechaudel and Joas, 2007). Among the treatments, pre-harvest treatments are regarded as best methods because of its combining performance with the tree mechanism and it 's fewer side effects.

Exogenous application of various pre-harvest synthetic chemicals, viz. cycloheximide, aminoethoxyvinyl glycine (AVG), silver nitrate, benzothiadiazole, sodium nitroprusside etc., were in vogue for inhibition of ethylene biosynthesis. But due to raising concerns of consumers regarding synthetic chemicals (Sharma *et al*., 2010), the research paradigm has shifted towards natural plant growth regulators viz. gibberellic acid, salicylic acid, NAA, putrescine etc. The discovery of new plant hormones and their ability to regulate all aspects of growth and development were defining moments in horticulture (Greene 2010). Some of them were tried and proven to be effective in extending shelf-life and reducing post-harvest losses by delaying ripening and senescence or by preventing pathogenic infections in many fruit species (Lurie *et al.* 2010). Chemicals such as $CaCl_2$ (Ranjbar *et al.,* 2018; Karemera *et al.,* 2013; Goutam *et al.,* 2010, Ramezanian *et al.,* 2009; Singh *et al.,* 1993), K_2SO_4 (Mandal *et al.,* 2012), GA_3 (Talat *et al.,* 2020; Rokaya *et al.,* 2016; Ozkan *et al.,* 2016; Zahedi, *et al.,* 2013; Khader 1991), salicylic acid (Lu *et al.,* 2011; Babalar *et al*., 2007; Yao *et al.,* 2005) are frequently used as pre-harvest period. Pre harvest spray of calcium increases the productivity, storability of mango (Wahdan *et al*., 2011; Kumar *et al.,* 2006) Calcium, as a constituent of the cell wall, plays an important role in forming crossbridges, which influence cell wall strength and regarded as the last barrier before cell separation (Fry, 2004). Calcium compounds (chloride and nitrate) treatments have been found to have some beneficial effect

like prevention of decline in ascorbic acid (Kwon *et al.,* 1999), phenol content (Sharma *et al.,* 1996) and reduce softness of pulp adhering stone etc for improving the quality and shelf life of mango fruits. Whereas Gibberellins enhances fruit storability and marketability through its action on cell juvenility and retardation of senescence, fruit coloration and softness (Macleod and Millar, 1962). Another plant growth regulator compound is salicylic acid (SA) which plays an important role in regulating a variety of physiological processes in plants. The effect of SA on delaying fruit ripening, softening, and reducing disease resistance and reducing disease incidence were discussed by various researchers (Raskin, 1992). Potassium treatments improve the productivity of several mango cultivars in terms of fruit size and weight (Jakhar and Pathak, 2016).

Most researchers conducted studies on the effect of various pre-harvest treatments on the fruit quality and shelf life of mango. While less concerns had been focused to determine among which treatment is comparatively better in terms of improving various fruit quality parameters and fruit shelf life. Therefore, the present study was done to fulfill the following objectives:

i. To extend the shelf-life of fruits and delay the ripening process by various pre-harvest treatments.

i. To evaluate the quality parameters of mango fruits after storage

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CHAPTER II

RIVEW OF LITERATURE

Mango is a climacteric and highly perishable fruit since it easily ripens after harvest or during transport. Moreover, it is susceptible to some postharvest diseases that also cause a decline in its quality and consumer acceptability.

This review will focus on the causes of quality loss of mango and the widely used pre harvest treatments for preservation of mango of Amrapali variety by using available resources treatments to alleviate or solve it. A considerable amount of researches works on pre harvest treatments and quality of treated Mango as influenced by different postharvest treatments has been extensively investigated by a plethora of scientists of the world. Storage is essential for extending the consumption period of fruits, regulating their supply to the market and also for transportation to long distances.

2.1 Effect of pre -harvest treatments

Postharvest physiological, chemical, biochemical and microbiological qualities of fruits partly depend upon various pre-harvest factors such as genetic, climatic, biotic, edaphic, chemical, and hormonal factors, as well as combinations of these (Leonardi *et al*. 2000). Five major classes of plant hormones are generally recognised: auxin, gibberellin, cytokinin, abscisic acid and ethylene gas (Davies 1995), which may change the rate of biological and biochemical changes in fruits. Therefore, various chemicals have been used to hasten or delay ripening, to reduce losses and to improve and maintain the colour and quality by slowing down the metabolic activities of the fruit. These chemicals arrest the growth and lead to an increased shelf life and maintain the marketability of the fruit for a longer period (Sudha *et al*., 2007).

2.1.1 Gibberellic Acid (GA_3)

Gibberellins as a pre-harvest treatment is an efficient growth regulator in enhancing fruit storability and marketability through its action on cell juvenility and retardation of senescence, fruit coloration and softness (Macleod and Millar, 1962). Pre-harvest applications of gibberellic acid decreasing the tissue permeability there by reducing the rate of water loss leading to delayed fruit ripening (Wills *et al.*, 1998) and it showed the inhibitory effect on ethylene biosynthesis and retarded the activity of enzymes responsible for ripening and through creation of resistance to pathogen entry, hence cell degradation was prevented

which in turn facilitated the reduced moisture loss and lesser respiratory gas exchange, results in delay of ripening.

Monika *et al.* (2017) conducted a study to investigate the effect of various pre-harvest treatments on shelf-life and quality of mango cv. Amrapali fruits during storage condition. The result showed that 75 ppm GA_3 at 20 DBH took the highest number of days for ripening (16.3 and 16.0 days) and showed shelf life up to 21.0 days.

Surendar and Madhavan S. (2019) was conducted an experiment to investigate the effect of post-harvest treatments on shelf-life and quality of Mango cv. Banglora. The fruits were sprayed with 0.5 and 1.5 % $CaCl_2$ and 200 and 300 ppm GA_3 and wrapping with newspaper and perforated polyethylene bags. They observed that fruits sprayed with GA_3 @ 200 ppm + wrapping with Newspaper showed the highest shelf life up to 18.24 days.

Khader *et al.* (1990) found that Gibberellic acid (GA_3) was applied as a foliar spray to the mango (*Mangifera indica* L.) cultivar „Dashehari" retarded the ripening of mango fruits for up to 6 days of storage under ambient temperatures between 36 ± 2 and 40 ± 3°C. With increasing concentrations of GA_3, postharvest ripening during the first 6 days was delayed significantly.

2.1.2 Effect of Calcium Chloride ($CaCl_2$)

Calcium, as a constituent of the cell wall, plays an important role in forming cross bridges, which influence cell wall strength and regarded as the last barrier before cell separation (Fry, 2004). The role of calcium in the physiology of plant tissue is well established (Chaplin and Scott, 1980). In addition to its involvement in cell wall membrane and chromosome, metabolism it contributes to the maintenance of configuration of specific enzymes. Addition of calcium improves rigidity of cell walls and obstruct enzymes such as polygalcturonase from reaching their active sites, thereby retarding tissue softening and delaying ripening. Calcium inhibits the ripening of tomato and pineapples (Gofure, *et al.,1997* and Wills *et al.,* 1997). Its role in physiological disorders is related to shelf life, ripening and fruit quality (Wilnwright and Burbage, 1989).

Pre harvest spray of calcium increases the productivity of mango due to reduction of abscission and it enhances the fruit quality by increasing the fruit firmness and by maintaining the turgidity of middle lamella cells (Kumar *et al.,* 2006). The calcium salts in different concentrations have either been used as pre-harvest sprays or infiltrated into

harvested fruits. Calcium compounds (chloride and nitrate) treatments have been found to have some beneficial effect like prevention of decline in ascorbic acid (Kwon *et al.,* 1999). The pre-harvest spray of $CaCl_3$ reduces the weight loss, delays the ripening of fruits, increases the shelf life, physio-chemical parameters, and organoleptic quality of mango fruits (Karemera and Habimana, 2014). It also improves the productivity of several mango cultivars in terms of fruit size and weight. Fruits storability is also improved by $CaCl_2$ under cold storage (Wahdan *et al.,* 2011). Calcium carbide has been frequently used since long times to enhance ripening process of mango fruits (Paj, 1998; Sive and Resnizky, 1985).

Madani *et al.* (2003) reported that the pre harvest pre-harvest application of 2% calcium chloride improves the quality and decreases the enzymatic activity in papaya fruits during the storage.

Treatment with calcium nitrate and calcium chloride delayed ripening after harvest, lowered weight loss, and reduced respiration rates (Bender, 1998).

Pre-harvest treatment of 1% potassium sulfate have resulted in improving the fruit quality parameters i.e. juice content, total soluble solids, ascorbic acid, total sugars, and reducing the weight loss during the storage. Sulfate compound can also reduce the infection of diseases (Burondkar *et al.,* 2009).

Jakhar and Pathak (2016) conducted an experiment to study the effect of pre-harvest bagging and spray of $CaCl_2$ and K_2SO_4 on quality and shelf life of mango fruits cv. Amrapali during two succeeding years. The result of that experiment revealed that the pre-harvest treatment of 2% $CaCl_2$+1% K_2SO_4+bagging was found superior to improve the quality of fruits in respect of highest fruits weight, firmness, TSS, ascorbic acid, total sugars, and β-carotene content with minimum black spotted fruits percent, maintained it throughout the storage period up to 18 days and showed shelf life up to 12 days with lowest weight loss and highest organoleptic quality.

Madani, *et al.* (2017) carried an investigation on the effect of pre harvest spraying of calcium chloride and calcium nitrate on shelf life and quality attributes of mango cv. Dashehari and Amrapali. Results indicated that different pre harvest spraying of calcium compounds were significantly enhanced the fruit quality and shelf life of both the mango cultivars compared to control. Double sprays of Ca $(NO_3)_2$ (1%), showed an extended shelf-life of 7 and 7.4 days in Dashehari and Amrapalli, respectively.

Dhillon and Sukhjit Kaur (2013) conducted an experiment to assess the effect of postharvest application of Calcium Chloride on the storage life of mango (*Mangifera indica* L.) var. Dushehari fruits. The results showed that postharvest application of Calcium Chloride (6%) had proved quite effective in enhancing the shelf life of Dushehari mango fruits up to 12 days at room temperature.

2.1.3 Effect of Potassium: Sulphate (K_2SO_4)

The potassium treatments improve the productivity of several mango cultivars in terms of fruit size and weight. Pre-harvest treatment of 1% potassium sulfate have resulted in improving the fruit quality parameters i.e. juice content, total soluble solids, ascorbic acid, total sugars, and reducing the weight loss during the storage. Sulfate compound can also reduce the infection of diseases Burondkar *et al.(* 2009).

El-Dengawy *et al.,* (2019) stated that applying the combination treatment of 1.5 % K_2SO_4 and 2% $CaCl_2$ showed the highest values of vitamin C, acidity and total sugars%, anthocyanin and pectin substances contents as well as the lowest value of TSS/acid ratio and weight loss% of fruit and it also assists in maintaining physical and chemical qualities of peach fruits during cold storage up to 24 days.

2.1.4 Effect of Salicylic acid (SA)

Salicylic acid (SA) plays an important role in regulating a variety of physiological processes in plants. The effect of SA on delaying fruit ripening, softening, and reducing disease resistance and reducing disease incidence were discussed by various researchers (Raskin, 1992).

Vijay *et al.* (2016) carried an experiment to study effect of pre-harvest application of salicylic acid on the postharvest fruit quality of the Amrapali mango (*Mangifera indica* L.) and found that the shelf-life of mango (*Mangifera indica* L.) fruits is only 5 to 6 days under ambient conditions, which can be increased efficiently, if the rates of biological activities and/or changes are reduced by pre and/or post-harvest treatments. Among various concentrations of SA, the SA (200 ppm) was found most effective in delaying the ripening processes and better retention of soluble solid concentrates (SSC) (27.72°B), titratable acidity (0.53 %), ascorbic acid (32.52 mg/100g) and total antioxidant content (11.85 µmol Trolox/g Fresh Weight) etc.

Singh *et al*. (2003) undertook a study to evaluate the pre and postharvest application of salicylic acid on storage life and quality of mango cultivar 'Kensington Pride'. Fruits were harvested at

full mature stage (shoulder development) and treated with $CaCl_2$ (2g) to initiate the ripening process. The findings showed that fruit weight loss significantly reduced in all treated fruits as compared to control. It was also observed that SA 16 mm showed minimum reduction in TSS, vitamin C, reducing, non-reducing, total sugars, total antioxidants, total phenolic and total flavonoids.

A field experiment was carried out by Gonchikari *et al*. (2020) to assess the effect of salicylic acid and potassium silicate on fruit quality and shelf life in mango (*Mangifera indica* L.) cv. Alphonso. The findings of that study revealed that foliar application of salicylic acid @ 200 ppm + potassium silicate @ 0.2% (T_8) found to improve fruit quality attributes like TSS (19.70oBrix), Ascorbic acid content (57.35 mg/100 g), reducing sugars (4.20%). This treatment also enhances shelf life of fruits (15.10 days), marketable fruits percentage (88.94%), firmness (4.97 kg/cm^2) and reduces physiological loss in weight during storage period.

2.2 Postharvest physiological changes of mango

The postharvest ripening changes in the quality characteristic of ripe mangoes were correlated among treatments and compared with similar changes in other mango varieties. Changes such as formation of sugars, decreased acidity, and increased carotene reflected the most significant chemical changes in ripeness stage (Peter *et al.,* 2007).

Fruit flesh taste is highly dependent on the balance between organic acids and soluble sugars, which are predominantly represented in mango by citric and malic acids, and sucrose, fructose and glucose, respectively (Medlicott and Thompson, 1985).

2.2.1 Ripening of fruit

The ripening time is very important because it is related with the marketing value of mango. Some more information on change in color is cited below:

Pre-harvest applications of gibberellic acid decreasing the tissue permeability there by reducing the rate of water loss leading to delayed fruit ripening (Wills *et al.,* 1998). It showed the inhibitory effect on ethylene biosynthesis and retarded the activity of enzymes responsible for ripening and through creation of resistance to pathogen entry, hence cell degradation was prevented which in turn facilitated the reduced moisture loss and lesser respiratory gas exchange, results in delay of ripening. The delay of ripening by $CaCl_2$ may be attributed to

higher fruit calcium levels that lead to the reduction of respiration and ethylene production rates (Singh *et al.,* 2003).

Jayawic *et al.* (2006) conducted an experiment to find out the effect of ethrel on papaya ripening. They observed that fruits at ambient temperature (28±1°C) took 7 days to ripe, but on the other hand when the fruits were treated with ethrel solution (250 ppm) under similar condition it was found to ripen in 4 days.

Kumar and Dhawan (1995) conducted an experiment with different concentrations of ethrel solution (250, 500, 1000 ppm) on mango fruit ripening. They found that the ripening rate progressively increased with the increase in concentration.

In Sydney Postharvest Laboratory, Kumar and Dhawan (1995) showed that the concentration of ethylene required for the ripening of different products varies. The concentration applied is within the range of 1 and 100 ppm. The time and temperature of treatment also influences the rate of ripening with fruit being ripened at temperatures 15 to 21°C and relative humidity of 85 to 90%.

An experiment was conducted by Kumar and Dhawan (1995) to study the effect of postharvest treatment on the enhancement of ripening of mango fruit (cv. Dashchari). Experiments with ethrel (ethylene releasing chemical) on different cultivars of banana have indicated that 100 to 250 ppm of ethrel is required to get optimum qualities in the ripe banana fruit (Krishnamurthy, 1993).

2.2.2 Percentage of total weight loss

Weight loss of stored mango is an issue where it reduces the overall quality of mango and consumable shelf life. That could be due to the fact that pre-harvest applications are more successful early in the development of fruits rather than when they are applied late just before harvest.

The appreciable improvement in fruit weight has also been earlier reported with the pre-harvest application of 1.5% $CaCl_2$ by Karemera and Habimana (2014) and 1% K_2SO_4 by Burondkar *et al.* (2009) in mango fruits.

Taduri *et al*. (2017) concluded that weight of fruit and pulp weight of fruit was maximum when trees were sprayed with 75 ppm GA_3 at 20 days before harvest and minimum weight loss when compared with other treatments.

Richard (2006) reported that gibberellic acid promoted growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation.

Karemera and Habimana (2014) also reported that the mango fruits cv. Alphonso treated with 1.5% $CaCl_2$ spray showed the minimum weight loss during storage.

Manzano *et al*. (1997) observed that 6.2 percent fresh weight loss of mango occurred when stored at 25°C temperature for 20 days.

Reddy and Haripriya (2002) reported that mango fruits treated with GA_3 and stored in polythene bags with ethylene absorbent significantly reduced physiological weight loss. Physiological weight loss was reduced in mango fruits cv. 'Kensington pride' which were wrapped with polythene bags and stored in 13°C (Zora, 2001).

2.2.3 Fruit Length and Breadth (mm)

Richard (2006) stated that gibberellic acid promoted growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars that reduces the cell water potential, resulting in the entry of water into the cell and causing elongation. The improvement observed in the fruit quality due to calcium chloride could be attributed to its effects in influencing formation and changes of carbohydrates and carbohydrate enzymes, others reasons might be the reduction of abscission and the calcium influence in maintaining the middle lamella cells Wahdan *et al.* (2011)

2.2.4 Moisture content

Srivastava (1967) reported that the green mango contained higher percentage of moisture as compared to ripe mangoes.

Shahajahan (1994) studied that the moisture content of pulp of mature hard 'Fazli' mango was 79.95% but found it as 91% and in ripe mango 78-86%. Salunkhe and Desai (1984) observed that mango pulp contains 81% moisture.

Absar *et al*. (1993) stated that moisture content at the early stage of development varied from 87.4% to 90.1%, gradually decreased as the maturity advanced and at ripening stage it varied from 71.22 to 79.4%. They also observed that the decreasing tendency of moisture content with the advancement of maturity of varieties Gopalbagh (82.13 to 79.23%), Khirsapat (82.1 to 79.25%), Langra (81.75 to 78.29%) and Fazli (82.30 to 79.95%).

Mollah and Siddique (1973) conducted an experiment with 12 varieties of mango and found that moisture content of the pulp of all the varieties of mango ranged from 81.03 to 87.12%. They also studied the fruits of ten varieties of mango. The moisture percentage was the highest (87.55) in Ranibhog whereas it was the lowest (78.96%) in Misribhog. This trait for the different varieties under consideration ranged from 78.96 to 87.55%.

2.2.5 Disease incidence and severity on shelf life and quality of mango

The control of postharvest disease in mango is generally achieved through proper pre-harvest and postharvest management practices such as strict orchard hygiene management, application of fungicides and temperature management during storage and shipping (Johnson and Hofman, 2009; Sivakumar, 2011).

Absar *et al*. (1993) this study investigated treatment of mango (*Mangiferaindica L*.) fruit with 2 host deference promoting compounds for suppression of anthracnose disease (*Colletotrichum gloeosporioides*). The findings revealed that potassium phosphonate or salicylic acid. Applications were by various combinations of pre and postharvest minimizes the occurrence of anthracnose disease. The shelf life of mango could be extended up to 5 days by hot water treatment and packed in corrugated fiber board carton compared to others. The color and quality of mango was very better in treated fruits compared to non-treated fruits.

Hofinan *et al*. (1999) observed that the effect of bagging of mango (*Mangifera indica* L.) fruit was evaluated in order to improve fruit quality of late maturing cultivars. Fruit calcium concentrations were reduced by bagging for 56 days or less in the 1994/1995 trial, but not by longer bagging times (82131 days). Percent dry matter (% DM) was higher, and days to ripen shorter, in bagged fruit from one orchard during 1993/1994. Fruit-mass, flesh color, total soluble solids, acidity and eating quality were generally not affected by bagging. These results indicate that bagging can improve fruit quality through reduction in disease, and this benefit outweighs the negative effects of bagging on skin color in the 'Keitt' cultivar.

The botanical materials evaluated were neem (*Azadirachta indica* A. Juss), 'Malunggay' (*Moringa oleifera* L.), and garlic (*Allium sativum*). The effect of the botanical extracts was compared with those of untreated plants and fungicide-treated plants. The botanical plants were weighed and washed with 10% sodium hypoclorite for 5 minutes and rinsed thrice with distilled water. These were placed in Waring blender and for every kilogram of plant materials; 1 L of water was added until a homogenous mixture was attained. The crude extract was filtered using a clean muslin cloth. Ten healthy mango seedlings per treatment

with three replications were assigned. Seedlings were sprayed with the appropriate treatments when they started to produce new leaves. Each seedling was sprayed with 40 ml botanical extract and for the fungicide; manufacturer's recommendation was followed using an atomizer.

2.3 Post harvest Biochemical changes of mango

The postharvest ripening changes in the quality characteristic of ripe mangoes were correlated among treatments and compared with similar changes in other mango varieties. Changes such as formation of sugars, decreased acidity and increased carotene reflected the most significant chemical changes in ripeness stage (Peter *et al.,* 2007).

Fruit flesh taste is highly dependent on the balance between organic acids and soluble sugars, which are predominantly represented in mango by citric and malic acids, and sucrose, fructose and glucose, respectively

Aina (1990) studied on effect on treatments on fruit ripening of mature green African mango fruits (Irvingiaga bonensis Baill). He observed changes in fruit weight, texture and color reflected the most significant chemical changes in the fruit such as starch degradation, formation of sugars and increase in total carotenoids.

2.3.1 Total soluble solids (TSS)

Mohamed and Abu-Goukh (2003) conducted an experiment with different concentrations of ethrel solution (250, 500, 1000 ppm) on mango fruit. They analyzed three varieties of mango for chemical composition and reported that ethrel treatments significantly increased TSS compared to untreated fruits.

A delayed increase in TSS of SA treated fruits was reported in kiwi fruit (Kazemi *et al*. 2011a), apple (Kazemi *et al*. 2011), peach (Khademi and Ershadi, 2013) and persimmon (Khademi *et al.* 2012).

Wahdan *et al*. (2011) recorded that significantly higher TSS of fruit (21.660Brix), significantly higher percentage of total sugars (16.24 %), and reducing sugar (9.26 %) and minimum percentage of titratable acidity (0.14%) was observed when trees were sprayed with 75 ppm GA_3 at 20 days before harvest.

Monica *et al.* (2013) reported that the change of acid into sugars under enzyme invertase influence during storage period. GA_3 induced reduction in acidity, may be linked with

hormonal stimulation of assimilates translocation. Similar changes have been reported by in litchi cv. Dehradun the increase in sugars content of mango fruits could be due to normal ripening process that leads to senescence and to the transformation of some carbohydrates components as starch to sugars by the enzymatic activities. $CaCl_2$ and GA_3 treatments significantly increased total sugars during storage of mango fruits. The increase in the sugars of fruits has been recorded by Wahdan *et al.* (2011).

Pinaki *et al.* (1997) conducted an experiment with hot water treatment and artificial ripening of mango. They observed that the differences between treated and controlled mangoes in taste and the appearance are large and TSS content is higher than the non-treated fruit.

Nyanjage *et al.* (1998) observed that mango treated with hot water at 46.5°C for 45 minutes in combination with intermittent warming (34°C) during 12 days of cool storage (13°C) showed higher TSS and better general appearance than those of non-hot treated fruits.

Singh *et al*. (1998) carried out an experiment on mango cv. Amrapali and found that TSS contents at mature and ripe stage were 8.12 and 20.05 percent respectively. Hossain and Ahmed (1994) recorded 18.3% TSS in Aswina'.

Absar *et al*. (1993) reported that the total soluble solid content was increased with maturity of fruit. They found that Langra' showed the highest (22.2%) and Fonia' the lowest (16.8%) TSS content at ripen stage.

Lou *et al*. (2015) analyzed eight varieties of mango where TSS ranged from 15.40% (Totapuri) to 21.40% (Bombay green). On the other hand, Palaniswamy *et al*. (1974) observed 11.8-26.8% TSS in South Indian mango cultivars.

Mollah and Siddique (1973) reported that TSS of mango cultivars Fazli and Langra were 7.70 to 14.8% and 12.15 to 18.00%, respectively. Increase in the percentage of total soluble solids during storage was recorded in mango (19.68) by Srivastava (1967). He found that total soluble solids increased while the acidity of the fruit generally decreased Popenoe (1964) made a report on the chemical composition of different varieties of mango and noted that TSS was more than 20%.

2.3.2 Titratable acidity (TA)

According to Hossain *et al.* (1999) titratable acidity was decreased during storage and ripening. Titratable acidity was declined slowly when mango fruits were stored at 13°C temperature.

Similarly, Taduri (2004) stated that titratable acidity decreased during storage in a refrigerated room. According to Hossain *et al,* (1999) titratable acidity was decreased during during later growth stage on attainment of maturity and ripening.

Medlicott *et al.* (2000) also observed that acidity was reduced during later growth stage on attainment of maturity and ripening.

Jana *et al.* (1998) studied the 20 mango varieties of West Bengal, India and found that variety Daudia had the highest titrable acids (0.58%). They also carried out an experiment with 21 mango cultivars and chemical analysis was performed. They narrated that titrable acidity of mango varieties differed 23 greatly. It was the maximum (0.59%) in Himsagar and the minimum (0.14%) in Jahangir.

Shahjahan *et al.* (1994) revealed that acidity of mango was decreased gradually at the time of storage and ripening. Shahjahan *et al.* (1994) also performed an experiment to find out the effect of ethrel concentrations (250,500, 1000, and 1500 ppm) on shelf life of mango. They reported that ethrel treatments significantly reduced the acid content compared to untreated fruits. After cold storage and ripening, heated fruits had a lower incidence of disease and developed less chilling injury than non-heated fruits. Non-heated fruits stored at 4°C also developed off-flavor whereas the heated fruits did not. Heat treatment did not inhibit ripening Tripathi and Upadhyay (1985). Titratable acidity was declined slowly when mango fruits were stored at 13°C temperature. Similarly,

2.3.3 pH

Literature is not available that deals with the changes in pH content of mango fruits during storage. However, Davies P.J. (1995) and Wani *et al.* (2014) reported that the pH content of mango fruit observed lowest in case of SA and GA_3 treatment.

2.3.4 Ascorbic acid

Mango is a good source of vitamin C at early stages of development, which decreases rapidly 5-7 weeks after fruit set as reported by Gofur *et al.* (1994). They also reported that at 12 weeks after fruit set ascorbic acid content was 105.2, 65.7 and mg/100 g in Langra, Ashwini

and Fazli varieties, respectively. They also reported that ascorbic acid decreased with increased of storage duration.

The ascorbic acid content of mango fruits significantly decreased with the advancement of storage period, probably due to the rapid conversion of L-ascorbic acid into dehydro-ascorbic acid in the presence of ascorbinase enzyme (Mapson, 1970).

The increase in ascorbic acid content during ripening was attributed to the increase in lipid peroxidation considering that fruit ripening is an oxidative phenomenon requiring turnover of active oxygen species (Jimenez *et al.* 2002).

The green fruits stored at 10-12°C temperature for 7 weeks had little change on vitamin C content. Maximum portion vitamin C was lost when the fruits were stored at room temperature (20-30°C). In addition, reduction in vitamin C with progress of fruit maturity and ripening was found in cv. Gopalbhog', Khirshapat', Langra' and Fazli' described by Shahjahan *et al*. (I994).

There was a tendency for ascorbic acid content to be higher in cold storage. The same, fact also verified. They reported that higher ascorbic acid content was obtained in the mango fruits stored in cool chamber.

An experiment was conducted by Singh *et al*. (1993) with GA_3 and ethrel and found to enhance the ripening and improve the quality of mango (cv. Amrapali). They found that ethrel at 500 ppm was very effective to improve the quality in terms of ascorbic acid content.

Reduction in ascorbic acid with advancement of maturity and ripening was observed in cv. Gopalbhog, Khirshapat, Langra and Fazli (Shahjahan *et al.* 1994).

2.3.5 β-carotene content

Jhakar and Pathak (2016) in their study on the effect of pre-harvest nutrients application and bagging on quality and shelf life of mango (*Mangifera indica* L.) fruits cv. Amrapali concluded that the pre-harvest treatment of 2% $CaCl_2$+1% K_2SO_4+bagging was found superior to improve the quality of fruits in respect of highest fruits β-carotene content.

2.3.6 Shelf life

Shelf life is the most important aspect in loss reduction biotechnology of fruits. There is a natural tendency of fruits to degrade to the simpler inorganic compound such as CO_2, H_2O and NH_3 from which they were synthesized in the first place through spontaneous bio-chemical reaction which occur with the decreased in free energy and increase in the randomness (entropy) of the system, consequently reduce the shelf life as well as other qualities of fruits (Salunkhe and Desai, 1984).

Cuaresma (2007) reported that the large-scale, long distance shipment of fresh mangoes from the Philippines is not yet feasible because the fruits ripen seven days after harvest. Because of this, exportable, good quality fruits barely reach 50% of the total harvest. Moreover, mango is susceptible to postharvest diseases such as anthracnose and stem-end-rot which causes considerable losses.

Pinaki *et al*. (1997) found that matured banana fruits of uniform sites were dipped into gibberellic acid (GA_3) at 150 ppm were most effective treatment for prolonging the shelf life of mango.

Kumar and Singh (1993) conducted an experiment with GA_3 and found that the quality and shelf life of mango cv. Amrapali were improved.

Giami and Ali (1994) conducted an experiment on the unripe fruit had relatively low polyphenol oxidase (catechol oxidase) activity and low total polyphenol content but had huge ascorbic acid and carotenoid contents and showed the least browning potential.

From the above reviews, it is quite clear that a large volumes of works have been done in various parts of the world. Various issues related to the physiochemical changes, shelf life extension, and diseases have been mentioned above. Similar statements are scanty in Bangladesh. Very little information is present in Bangladesh regarding the use of chemical treatments a postharvest physiochemical and biochemical changes shelf life and quality of mango.

CHAPTER III

MATERIALS AND METHODS

This chapter is comprised of a brief description about experimental period, Experimental location storage room, its controlled condition, treatments used in this experiment, experimental design, data collection and statistical analysis.

3.1 Experimental location

This experiment was conducted from June to July 2019 in a 5 years old mango orchard at the village of Khangaon Shahapara under the upazila of Pirganj in Thakurgaon district **(plate 1)** and the post-harvest laboratory of Horticulture Department at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Plate. 1: Mango orchard in Thakurgaon district

3.2 Experimental materials

Mature, green mangoes (cv. Amrapali) were collected from 27 mango trees of a renowned orchard in Thakurgaon district, Bangladesh. Uniform sized, free from diseases, undamaged fruits were selected and transferred to the central laboratory, Sher-e-Bangla Agricultural University as early as possible with careful handling to avoid injury.

3.3 Pre-harvest Treatments of the experiment

T_0: Control (Water spray)

T_1: 2% Calcium Chloride ($CaCl_2$) spray at 10 Day before Harvest (DBH)

T_2: 1% Potassium Sulphate (K_2SO_4) spray at 10DBH

T_3: 75 ppm Gibberellic Acid (GA_3) spray at 10DBH

T_4: 200 ppm Salicylic Acid (SA) spray at 10DBH

T_5: 2% Calcium Chloride ($CaCl_2$) spray at 20DBH

T_6: 1% Potassium Sulphate (K_2SO_4) spray at 20DBH

T_7: 75 ppm Gibberellic Acid (GA_3) spray at 20DBH

T_8: 200 ppm Salicylic Acid (SA) spray at 20DBH

3.4 Experimental Design

A Randomized Completely Block Design (RCBD) was used with nine treatments and three replications. Trees were spaced 2.5×2.5 m and received uniform pruning and cultural operations. Twenty seven (27) selected trees were subjected to nine pre-harvest treatments including Control with three replications. One tree was taken as a unit for a replication of treatment.

3.5 Preparation and Application of Treatment

Preparation of plant growth regulators (SA and GA_3) and chemical salt ($CaCl_2$ and KSO_4) were prepared following the procedure mentioned below and spraying was done during noon by using a hand sprayer. Twin-20 was used as spreader in spray solution for increasing the surface adhesiveness and applied on trees.

3.5.1 GA_3 and SA solution preparation

1 ppm GA3 and SA solution was prepared by dissolving 1 mg GA_3 and 1 mg SA powder with each 10 ml Ethyle Alcohol and the volume was made 1000 ml by adding distilled water in a volumetric flask. So, 75 ppm GA_3 and 200 ppm SA solution were prepared in the similar way.

Preparation of 75 ppm GA_3 solution: 75 mg GA_3 powder were measured by an electrical balance and used 10 ml Ethyle Alcohol for dissolving the GA_3 powder and the volume was made 1000 ml by adding water in a volumetric flask.

Preparation of 200 ppm SA solution: 200 mg SA powder were measured by an electrical balance and used 10 ml Ethyle Alcohol for dissolving the SA powder and the volume was made 1000 ml by adding water in a volumetric flask.

Preparation of 2% $CaCl_2$ solution: 20 g $CaCl_2$ were measured by an electrical balance and then dissolved in water and the volume was made 1000 ml by adding distilled water in a volumetric flask.

Preparation of 1% K_2SO_4 **solution:** 10 g K_2SO_4 **were** measured by an electrical balance and then dissolved in water and the volume was made 1000 ml by adding distilled water in a volumetric flask.

3.5.2 Application of Treatment

Trees of mango cv. Amrapali trees were sprayed with 2% $CaCl_2$, 1.0% K_2SO_4, 75 ppm GA_3 and 200 ppm SA at 20 and 10 days before the commercial harvest and it was done on all sides of the fruit as well as to the foliage surrounding to the fruit. Control trees were sprayed with water.

A. Preparation of GA_3 solution by adding Ethyle Alcohol

B. Mango trees are sprayed by hand sprayer

Plate 2: Application of pre-harvest treatment in orchard

3.6 Fruit Harvest and Storage

Fruits of all trees were separately harvested at same days in optimum maturity stage by hand with 1.0 cm stalk to escape any damage of fruit. Harvesting was done in the morning. The field heat of harvested fruits was removed by dipping in fresh water and then carefully sorted and graded as fresh and uniform sized fruits. These fruits were transported from orchard to the laboratory without any type of physical damage including bruising. In the laboratory, fruits were washed in running tap water and cleaned with muslin cloth. Weather data during the trial from 1th June to 31st June, 2019 are given in (Appendix 1). An average of 5 fruits per tree was considered for calculating the external and internal fruit attributes, physiochemical properties such as total weight loss, ripening percentage, moisture content, pH, total soluble solid content, Ascorbic acid, β-carotene content, Visual scoring of mango skin on the basis of disease severity and shelf life. Weight after harvesting was taken and expressed in grams. The fruits were stored at 25 (± 2) degree centigrade with relative humidity 80-85% until the end of shelf life.

A. At the day of harvest time

B. Cleaning of mangoes by ozone water

C. Storage in post harvest laboratory

Plate. 3: Mango harvest, cleaning by ozone water and storage

3.7 Parameters studied

In this experiment the following parameters were studied:

3.7.1 Physical parameters

1. Weight loss (%)
2. Ripening (%)
3. Fruit Length and Breadth (mm)
4. Moisture content (%)

3.7.2 Chemical parameters

1. TSS (Total soluble solid)
2. TA (Titratable acidity)
3. Vitamin C
4. pH
5. β-carotene content

3.7.3 Microbial characters

1. Disease severity (%)

3.7.4 Shelf life

1. Duration (Days)

3.8 Observation and Data collection

During the entire postharvest storage period the experimental fruits were keenly observed every day to find out any kind of special change. Physical observations (weight loss %, ripening %, moisture content %, browning/black spot % and disease severity %) were recorded at an interval of 3 days during storage influenced by pre harvest treatment. For estimating chemical analysis total soluble solids (TSS), titratable acidity (TA), β-carotene, ascorbic acid and pH of each samples were drawn at the end of shelf life.

3.9 Methods of studying parameters listed earlier

3.9.1 Physical parameters

3.9.1.1 Estimation of total weight loss percentage

The fruits of each treatment were individually weight by using electric balance and kept for storage. Physiological lossin weight of mango fruits as influenced by pre-harvest treatment were recorded periodically at 3rd, 6th, 9th, 12th and 15th days during the storage by using the following formula:

Weight loss (%) = $\frac{IW-FW}{FW} \times 100$ Where,

IW = Initial fruit weights (g) and FW= Final fruit weight (g)

3.9.1.2 Ripening percent

The ripening of fruit was judged on the basis of visual observations of change in color from greenish to yellow and by feeling softness in texture and flavor. The number of fruits having change in color from greenish to yellow were measured by using numerical rating scale of 1-5, where 1 = green, 2 = one-quarter-yellow (< 25%), 3 = two-quarter fruit skin yellow (<50%),4 = three quarter yellow (5 = fully yellow (75-100%). The ripen fruits were counted and expressed as percentage over total number of fruits. Mango fruits with more than 50 percent yellowing of skin colour were counted at specific intervals of storage was considered ripened.

3.9.1.3 Fruit length and breadth (mm)

The length of the fruit from stalk end to the apex of the fruit was determined after harvest with the help of vernier caliper and expressed in millimeters. The breadth of fruit was determined as the maximum linear distance between two shoulders of the fruit with the help of vernier caliper and expressed in millimeters.

3.9.1.4 Estimation of moisture content

Fifty gram of fruit pulp was weighed in a porcelain crucible (which was previously cleaned, dried and weighed) from each treatment and replications. At the end of shelf life he crucible was placed in electric oven at 80°C for 72 hours until the weight became constant. It was then cooled in desiccators and weighed again.

Percent moisture content was calculated by using the formula:

Moisture content (%) = $\frac{IW-DW}{IW} \times 100$

Where,

IW = Initial weight of fruit pulp (g) and

DW= Dry weight of fruit pulp (g)

3.9.3 Chemical parameters

3.9.3.1 TSS (Total soluble solids)

Total soluble solids content of mango pulp was estimated by using hand refract meter. A drop of mango juice squeezed from the fruit pulp on the prism of the refract meter. In each treatment three readings were taken and their average value was considered. The results were expressed as percentage.

3.9.3.2 TA (Titratable acidity)

Fruit acidity was estimated by titrating the fruit pulp extract with 0.1 N sodium hydroxide using phenolphthalein as indicator (Rangana, 2004). From mango fruit 5 gram of fruit pulp was chopped, blended by mortar and pestle Then the juice was filtered by sieve in a beaker. The volume was made up to 50 ml by adding distilled water, then 2 drops phenolphthalein indicator was added. From this 10 ml solution was taken in a conical flask and titrated against 0.1N NaOH until a pink color was obtained. The reading was taken for 3 times. The acid content of the mango sample was calculated using the following formula:

TA% = $\frac{\text{Titrate} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{equivalent wt. of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{Wt.of sample taken} \times 1000}$

0.1N NaOH solution preparation: 4.0 g of sodium hydroxide was added in water. Then the volume made up to 1 liter.

Phenolphthalein indicator preparation

To prepare phenolphthalein indicator 0.5g phenolphthalein was weighted. 50% ethanol was prepared by adding 50 ml ethanol and 50 ml distilled water. Then 0.5 g phenolphthalein was dissolved in 50% ethyl alcohol solution.

3.9.3.3 Ascorbic acid content

Ascorbic acid content (ascorbic acid) was estimated by using 2,6- Dichloro phenol indophenol (DCPIP) visual titration method (Rangana, 2004). 28 5gm mango fruit sample was blended, juice was filtered by sieve. Volume was made up to 100 ml by adding oxalic acid.10 ml from solution was taken in conical flask and titrated against DCPIP (Standard dye) to a pink end point which should persist for at least 15 seconds. Ascorbic acid content in terms of mg/100 g pulp weight was calculated using the following formula:

**Ascorbic acid (mg/100g)

$$= \frac{\text{Titrate value} \times \text{diefactor} \times \text{volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{wt.of sample taken for estimation}}$$

5% Oxalic acid solution preparation

It was prepared by dissolving 50g oxalic acid powder in 1000 ml distilled water. Standard ascorbic acid solution: 10 mg of L-ascorbic acid was dissolved with 100 ml of 5% oxalic acid solution. Then 10 ml of this solution was taken in a volumetric flask with 90 ml of 5% oxalic acid solution to prepare standard ascorbic acid solution.

Dye solution preparation

It was prepared by dissolving 260 mg of the sodium salt of 2,6-dichlorophenol indophenol in approximately 1000 ml of hot distilled water containing 210 mg of sodium bicarbonate. Standardization of dye solution: Ten milliliters (10 ml) of standard ascorbic acid solution was taken in a conical flask and 5 ml of oxalic acid was added to it. A micro burette was filed with the dye solution. The content of the conical flask was titrated with dye solution. The content of conical flask was titrated with dye till the pink colored end point appeared. The milliliters of dye solution required to complete the titration was recorded. Dye factor was calculated using the following formula: Dye factor = 0.5/ titrate value 29 3.9.3.4

3.9.3.4 pH

pH was measured using a phs-25 p H meter (Plate 4). An electrolytic cell comprise of two electrodes (calomel electrode and glass electrode) was standardized with buffer solution of pH 4. Then the electrodes were dipped into the test sample. A voltage corresponding to the pH of the solution was identified by the instrument. For preparing sample solution of fruits,

mangoes were chopped into small pieces and ground into a fine paste by mortar and pestle. The mango juice was transferred into a test tube and the pH of the paste was determined by inserting the electrodes into the paste and stabilized readings were recorded.

3.9.3.5 β-carotene content

β-carotene in mango pulp was determined according to the method of (Nagata and Yamashita, 1992). One gram of pulp was mixed with 10 ml of acetone: hexane mixture (4:6) and vortex for 5 minutes. The mixture was filtered and absorbance was measured at 453nm, 505nm and 663nm wave length. The calculation was done by following method: β-carotene (mg/100gm) = 0.216 A663-0.304 A505+0.452 A453.

3.9.4 Microbial characters

3.9.4.1 Assessment of percentage disease severity

The percentage of disease severity was recorded from 6th day of storage as visual symptom like black sunken lesions of *Colletotrichum gloeosporioides* or mycelial development (Gray mold disease) on the surface of fruit caused by *Botrytis cinerea* was visible. Fruits were stored till >25% fruit skin considered commercially unacceptable. All the infected fruits were selected to determine percent of fruit area infected. These parameters were taken by eye estimation, for this visual scoring of mango skin was done on the basis of disease severity. In case of disease severity 0= no disease, 1=1-10% disease, 2=>10-20% disease, 3=>20- 30% disease, 4=>30-40% disease, 5=>40% disease.

3.9. Shelf life

Shelf life of fruits were calculated from daily estimation of disease severity on the same fruits from each replication and considered as ended when the fruits had little or no commercial viability (disease severity more than 25%) as estimated by Rashid *et al*. (2015).

3.10 Statistical analysis

The collected data were statistically analyzed by MSTAT-C software. The significance of difference between the pairs of treatment means were separated and compared using least significant difference (L.S.D) at 0.01 level of probability according to Steel and Torrie (1980).

A.Weight measurement of mango

B. Mango Pulp dry for moisture determation

C. Determination of pH

D. Titration for TA and

Plate 4: Physical and chemical analysis of mango pulp

CHAPTER IV

RESULTS AND DISCUSSION

This chapter accounts for the presentation of the results acquired from the present study. The results of the study on physico-chemical changes during post-harvest losses of "Amrapali" mango variety are represented and discussed from (Table 1 to Table 8) and (Figure 1 to Figure 3) in this chapter. These results are explained under the following headings:

4.1 Weight loss (%)

The fruits weight gradually decreases with the advancement of storage period. It might be due to evapo-transpiration of water, respiration, and degradation processes. The weight loss percentage calculating foreach showed significant difference (Table 1, Appendix II).

The maximum weight loss (5.11%, 9.65%, 12.80%, 14.73% and 20.71% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was recorded in T_0 (control treatment) followed by T_2 (1% K_2SO_4 spray at 10DBH), where weight loss was (4.81%,8.83%, 10.06%, 12.51% and 17.14% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) and the minimum (1.93%, 3.03%, 4.86%, 6.10% and 7.08% at 3^{rd}, 6^{th}, 9^{th}, 12^{th} and 15^{th} day of storage, respectively) was found in T_7 (75 ppm GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH) where weight loss was (2.6%, 3.89%, 5.48%, 6.98%, 8.12% at 3rd, 6th, 9th, 12th and 15th day of storage, respectively).

This was mainly gibberellic acid promoted growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation (Richard, 2006). Similar findings were observed by Taduri *et al.* (2017) who reported that weight of fruit and pulp weight of fruit was maximum when trees were sprayed with 75 ppm GA_3 at 20 days before of harvest. Reddy and Haripriya (2002) also find similar results that mango fruits treated with GA_3 and stored in polythene bags with ethylene absorbent significantly reduced physiological weight loss.

The similar fruit weight loss has also been supported the findings with the pre-harvest application SA might have reduced respiration and transpiration, which concomitantly delayed senescence of the treated mango fruits Singh and Tiwari (2016).

The fruit weight loss was observed in case of $CaCl_2$ because it effects formation and changes of carbohydrates and carbohydrate enzymes, reduces abscission and maintains the middle lamella cells (Wahdan *et al.,* 2011). Karemera and Habimana (2014) also showed that the mango fruits cv. Alphonso treated with 1.5% $CaCl_2$ spray showed the minimum weight loss during storage. The similar results were also observed by Mathooko *et al.* (2011).

The similar fruit weight loss has also been supported the findings with the pre-harvest application of 1.5% CaCl by Karemera and Habimana (2014) and 1% K_2SO_4 by Burondkar *et al.* (2009) in mango fruits. Chonhenchob *et al.* (2011).

Table 1: Effect of pre-harvest treatments on weight loss (%) of mango at different days after storage (DAS)

	Weight loss (%)				
Treatments	**DAY 3**	**DAY 6**	**DAY 9**	**DAY 12**	**DAY 15**
T_0	5.11 a	9.65 a	12.80 a	14.73 a	20.71 a
T_1	3.82 b	8.10 bc	9.91 bc	11.48 bc	16.30 c
T_2	4.81 a	8.83 ab	10.06 bc	12.51 b	17.14 b
T_3	3.16 cd	6.74 d	9.24 cd	10.85 cd	13.18 e
T_4	3.56 bc	7.37 cd	10.38 b	12.06 bc	13.99 d
T_5	3.06 de	6.49 d	8.64 d	10.02 d	11.95 f
T_6	3.83 b	8.07bc	9.89 bc	11.89 bc	14.05 d
T_7	1.93 f	3.03 e	4.86 e	6.10 e	7.08 h
T_8	2.6 e	3.89 e	5.48 e	6.98 e	8.12 g
LSD	0.4547	1.205	0.8063	1.173	0.7364
CV %	7.38	10.08	5.16	6.31	3.12

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest.

4.2 Ripening (%) of mango

There was significant difference between the treatments and the number of days taken for ripening of fruits (Figure 1, Appendix III).

The value indicated that treatment fruits significantly delayed the ripening process over untreated fruits irrespective of storage condition and not fully ripen up to 12^{th} day of storage. The maximum (33.33%, 57.33%, 81.67%, and 100.00% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) value was recorded from control (untreated fruits) and minimum (0.00%, 17.33 %, 37.67 % and 56.67% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS) value was obtained from T_7 (75 ppm GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH) where value was (0.00%, 19%, 41.67%, 61.33%at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS)

The results showed that the untreated mangoes had early ripeness whereas the treated mangoes had a significantly delayed ripening. The probable reason might be that pre-harvest applications of gibberellic acid decreasing the tissue permeability there by reducing the rate of water loss leading to delayed fruit ripening (Wills *et al.,* 1998) and it showed the inhibitory effect on ethylene biosynthesis and retarded the activity of enzymes responsible for ripening and through creation of resistance to pathogen entry, hence cell degradation was prevented which in turn facilitated the reduced moisture loss and lesser respiratory gas exchange, results in delay of ripening. The delay of ripening by $CaCl_2$ may be attributed to higher fruit calcium levels that lead to the reduction of respiration and ethylene production rates (Singh *et al.,* 2003).

Reddy and Sharma (2016) showed similar results where they found that application of salicylic acid influences the ripening behavior of the Amrapali mango fruits during storage at ambient conditions (30±5°C and 50±5 % RH) and the SA (200 ppm) was found most effective in delaying the ripening of mango fruit.

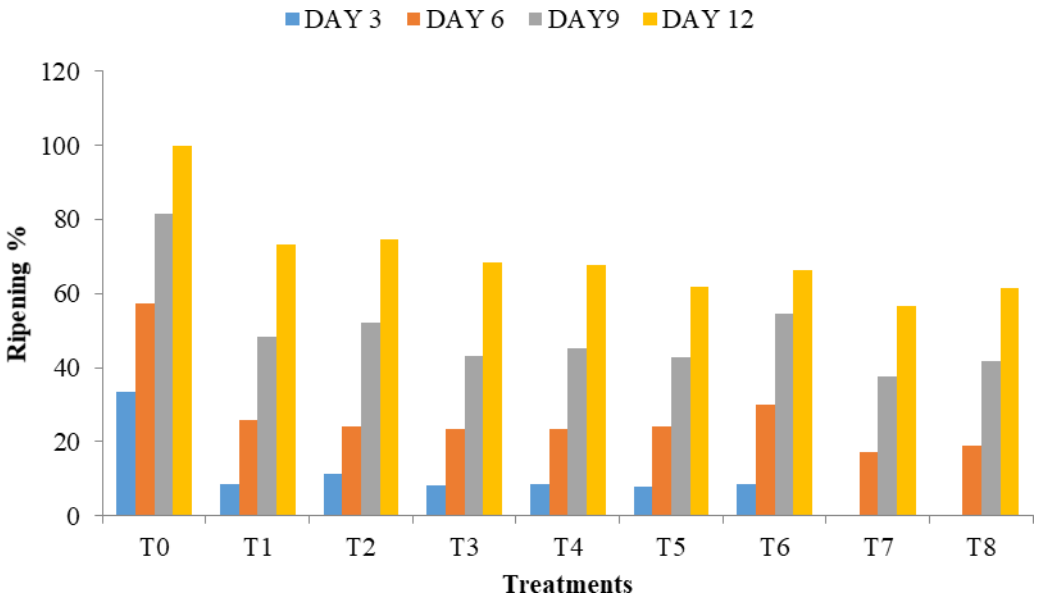

Figure 1: Effect of pre-harvest treatments on ripening (%) of mango at different days after storage (DAS)

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH

4.3 Physical parameters of fruits (length and breadth)

Physical parameters (length and breadth) of fruits was accounted at the end of shelf life. The data on Physical parameters of fruits were significantly influenced by pre harvest treatment (Table 2, Appendix IV).

Higher fruit length (96.00 mm) and breadth (65.00 mm), was recorded in treatment of T_7 (75 PPM GA_3 spray at 20DBH) when compared with other treatments statistically similar with T_8, T_1, and T_5 respectively 200 PPM SA spray at 20DBH in which data recorded length (95 mm) breadth (62.33mm). On the contrary, minimum length and breadth was found in T_0 (control) in which data recorded length (85.33 mm) breadth (54.00 mm)

It is because Gibberellic acid promoted growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation (Richard, 2006) and its mediating process for faster translocation and mobilization of photosynthetic from source.

These findings are in agreement with the reports of (Singh *et al. 2003)* in pear, and (Pal *et al.1997)* in kinnow man (P. R. Rokaya *et al.2016)*

The improvement observed in the fruit quality due to calcium chloride could be attributed to its effects in influencing formation and changes of carbohydrates and carbohydrate enzymes, others reasons might be the reduction of abscission and the calcium influence in maintaining the middle lamella cells (Wahdan *et al.,* 2011). Calcium applications have been known to play a role in membrane functionality and maintenance. Karemera and Habimana (2014) also recorded significantly higher fruit length (9.81 cm), breadth (8.50 cm), thickness (8.16 cm), volume (311.66 ml), weight of fruit (315.23 g) and pulp weight of fruit (205.33 g) when trees were sprayed with 1.50% CaC_{12} at 30 days before harvest while those results were low in no sprayed trees. That could be due to the fact that pre-harvest applications are more successful early in the development of fruits rather than when they are applied late just before harvest.

Table 2. Effect of pre-harvest treatments on length (mm) and breadth of mango (mm)

Length and Breadth of mango (mm)		
Treatments	**Length (mm)**	**Breadth (mm)**
T_0	85.33 d	54.00 d
T_1	94.00 abc	62.00 ab
T_2	92.33 bc	53.67 d
T_3	92.00 bc	62.67 ab
T_4	90.67 c	59.00 bc
T_5	92.67 abc	55.33 cd
T_6	92.00 bc	57.00 cd
T_7	96.00 a	65.00 a
T_8	95.00 ab	62.33 ab
LSD	3.232	4.190
CV %	2.02	4.10

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1%K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.4 Moisture content (%) of mango pulp

Significant variation was observed in respect of moisture content (%) of mango pulp by pre-harvest treatment of mangoes at the end of shelf life (Table 3, Appendix V).

The maximum (85.09%) moisture content was noticed in T_7 (75 ppm GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH) where moisture content was 83.88%.The minimum (73.20%) moisture content was found in T_0 (control).

Absar *et al.* (1993) reported that moisture content at the early stage of development varied from 87.4% to 90.1%, gradually decreased as the maturity advanced and at ripening stage it varied from 71.22 to 79.4%. Srivastava (1987) described that green unripe mangoes contained higher percentage of moisture as compared to ripe mangoes. Bhatnargar and Subramanyam (1973) stated that 90% moisture content present in green ripe mango whereas pulp of ripe mango held 81% moisture. The similar results were also observed bypre-harvest applications of gibberellic acid Reddy and Haripriya (2002).

Table 3: Effect of pre-harvest treatments on moisture content (%) of mango pulp at the end of shelf life.

Treatments	Moisture content (%) of mango pulp
T_0	73.20 g
T_1	80.98 e
T_2	79.39 f
T_3	82.62 cd
T_4	82.86 bc
T_5	81.63 de
T_6	79.70 f
T_7	85.09 a
T_8	83.88 b
LSD	1.063
CV %	0.76

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.5 Total soluble solids (TSS) content

Significant variation in TSS content of mango pulp was found during the storage period because of various pre-harvest chemical treatment (Table 4, Appendix V). The fruits treated with T_7 (75 ppm GA_3 spray at 20DBH) maintained the lowest TSS value (15.33%) statistically similar with T_8 and T_5 while un-treated control fruits (T_0) maintained the highest TSS value (19.00%) statistically similar with T_2 and T_3 treatments.

The rapid and higher TSS in control fruits might be due to faster ripening and the hydrolysis of starch into simple sugars. The quicker decline may be due to higher respiration rate of untreated mango fruits than treated fruits, which utilizes the simple sugars initially and the organic acids thereafter (Taduri *et al.*, 2017, Koksal *et al.,* 1994). The delayed increase of TSS in SA treated fruits might be due to slower ripening in such fruits, caused by inhibition of ethylene biosynthesis. A delayed increase in TSS of SA treated fruits was reported in kiwi fruit (Kazemi *et al.,* 2011), apple (Kazemi *et al.* 2011b), peach (Khademi and Ershadi, 2013) and persimmon (Khademi *et al.* 2012). On the other hand, GA_3 induced reduction in acidity, may be linked with hormonal stimulation of assimilates translocation. Similar changes have been reported by Monica *et al.* (2013) in litchi cv. Dehradun.

Table 4: Effect of pre-harvest treatments on TSS (%) of mango pulp at the end of shelf life.

Treatments	TSS (%) of mango pulp
T_0	19.00 a
T_1	17.00 bcd
T_2	18.33 ab
T_3	17.67 abc
T_4	16.33 cde
T_5	16.00 de
T_6	17.00 bcd
T_7	15.33 e
T_8	16.00 de
LSD	1.48
CV %	5.04

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.6 Titratable acidity (TA)

The present investigation showed that application of Pre-harvest treatment had significant variation on titratable acidity of mango pulp (Table 5, Appendix V).

The maximum value (0.23%) of titratable acidity for mango fruits was recorded for T_7 (75 ppm GA_3 spray at 20DBH) statistically similar with T_5 and T_3 and T_4 treatments respectively where the value was (0.20%) and the minimum (0.09%) value was recorded in case of control (T_0, untreated fruits) and T_2 treatment.

Similar increase in acidity values in treated mangoes pulp was observed by Yousef *et al.* (2002) and Harder *et al.* (2009). Besides the decrease in acid content of fruits with the increase in storage period could be attributed to the use of organic acids in respiratory process by the fruit cells and conversion of acids into total sugars. So, it may be concluded that interaction effect of treatment reduced physiological process, delayed ripening process which in turns slowed down the conversion rate of acids into sugar. For this, reason titratable acidity percent reduction was slower in the treated fruits than the control.

Table 5: Effect of pre-harvest treatments on TA (%) of mango pulp at the end of shelf life.

Treatments	TA (%) of mango pulp
T_0	0.09 d
T_1	0.15 bc
T_2	0.13 cd
T_3	0.17 abc
T_4	0.18 abc
T_5	0.18 abc
T_6	0.16 bc
T_7	0.23 a
T_8	0.20 ab
LSD	0.05
CV %	6.51

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.7 pH

The pH value was affected by variety, maturity stage of mango, their storage condition and so on. The pH value continuously increasing during the entire period of storage as acidity get lower day by day due to advancement of ripening. Variations in pH of mangoes under different pre harvest treatment were observed during successive days of storage (Table 6, Appendix VI). The pH value of pre harvest treated fruits showed significant differences.

The highest (5.69) pH value was recorded in T_0 (Control)) followed by T_2 (1.0% K_2SO_4 spray at 10DBH) fruit was (5.46). The lowest (4.31) value was found in T_8 (200 PPM SA spray at 20DBH) which is statistically identical to T_7 (75 PPM GA_3 spray at 20DBH) also showed lower pH value and that was (4.49)

This reduction of acidity content might be due to the change of acid into sugars under enzyme invertase influence during storage period. Moreover, acids are partially a respiratory substrate and its consumption in respiratory increase with the progresses of storage periods. GA_3 induced reduction in acidity, may be linked with hormonal stimulation of assimilates translocation. Similar changes have been reported by Monica *et al.,* (2013) in litchi cv. Dehradun. Similar findings were also found by Wani *et al.* (2014).

Table 6: Effect of pre-harvest treatments on pH of mango pulp at end of shelf life.

Treatments	pH
T_0	5.69 a
T_1	5.21 abc
T_2	5.46 ab
T_3	5.06 bc
T_4	4.85 cd
T_5	4.79 cd
T_6	5.11bc
T_7	4.49 d
T_8	4.31 d
LSD	0.50
CV %	5.85

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1%K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.8 Ascorbic acid content (mg/100g)

The significant variation was observed in variations in ascorbic acid content of mangoes under different pre harvest treatment during successive days of storage (Table 7, Appendix V).

The highest value (30.78 mg/100g) was recorded in T_7 (75 PPM GA_3 spray at 20DBH) treatments which was statistically similar with T_8 and T_3 and the minimum (18.34mg/100g) value was recorded in case of Control (T_0, untreated fruits).

The increase in ascorbic acid content during ripening was attributed to the increase in lipid peroxidation considering that fruit ripening is an oxidative phenomenon requiring turnover of active oxygen species (Jimenez *et al.*, 2002). However, the loss of ascorbic acid is very much common in naturally riches source of ascorbic acid contained fresh fruits. It is very responsive to degradation due to its oxidation compared to other nutrient during food processing, preservation and storage. The level of acid gradually decreased as the fruits proceed towards ripening process. In general, a gradual decline was observed both treated and untreated controlled mango fruits.

The ascorbic acid content (AAC) of Amrapali mango fruits had increased gradually up to certain period and then decreased progressively with increase in storage period. However, in the fruits treated with SA (200 ppm), the AAC has showed a continual increasing trend towards the end of storage life.

The ascorbic acid content of mango fruits significantly decreased with the advancement of storage period, probably due to the rapid conversion of L-ascorbic acid into dehydro-ascorbic acid in the presence of ascorbinase enzyme (Mapson, 1970).The above results are very close to the findings of Sharma *et al.* (1990) and Wavhal. (1989) in mango.

Table 7: Effect of pre-harvest treatments on Ascorbic acid content (mg/100g) of mango pulp at the end of shelf life.

Treatments	Ascorbic acid (mg/100g)
T_0	18.34 f
T_1	25.50 d
T_2	21.68 e
T_3	28.95 ab
T_4	28.21 bc
T_5	26.32 cd
T_6	22.43 e
T_7	30.78 a
T_8	29.36 ab
LSD	1.97
CV %	4.44

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.9 β-carotene content of mango pulp (mg/100g)

The carotenoids of fruits are usually fat-soluble and are associated with lipid portions of human tissues, cells, and membranes. β-carotene of mango pulp showed significant variation incase of Pre harvest treatment (Table 8, Appendix VI).

β-carotene content was found to be the highest (5.56 mg/100g) at the end of shelf life in case of T_7 (75 PPM GA_3 spray at 20DBH) treatments which was statistically similar with T_8 and T_3 and the lowest value (4.42 mg/100g) was recorded in T_0 (control fruit).

The β-carotene content of mango fruits significantly increased with the advancement of storage period, likely due to the breakdown of chlorophyll and increase in carotenoids content by chlorophyllase enzyme during the storage. Analogous observations to these findings have also been earlier reported in mango (Singh *et al.*, 1998; Babu and Krishnamurthy, 1993).

Table 8: Effect of pre-harvest treatments on β-carotene content of mango pulp at the 9 days after storage.

Treatments	β-carotene content (mg/100g)
T_0	4.42 e
T_1	5.06 cd
T_2	4.84 d
T_3	5.29 abc
T_4	5.16 dcd
T_5	5.26 abc
T_6	5.28 abc
T_7	5.56 a
T_8	5.51 ab
LSD	0.35
CV %	3.94

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH, Means with different letters significantly differ at LSD‟ s test at $P \leq 0.01$; CV: Coefficient of Variation; LSD: Least Significant Difference, DBH = Day before harvest

4.10 Disease severity (%)

The data on disease severity (%) of mango (at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) significantly influenced by pre-harvest treatment (Figure 2, Appendix VII).

The maximum disease severity (%) (14.00%, 24.00%, 32.00%, and 43.00% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value was recorded from T_0 (control). On the contrary, minimum disease severity (%) (0.00%, 3.33%, 7.00% and 15.33% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS) value was obtained from T_7 (75 PPM GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH.) in which data recorded (0.00%, 3.66%, 8.33% and 17.67% at 6^{th}, 9^{th}, 12^{th} and 15^{th} DAS). From the above discussion it is revealed that severity of disease on mango fruits increased with the advancement of time. Fungal diseases account for one of the main reasons of loss during commercialization of tropical fruits.

The lesser disease percentage in GA_3 treated fruits could be due to anti senescent and anti respirant properties of the gibberellins which prevent the cellar disintegration with enhancing

resistant ability in the fruit. Similar results were reported by Brahmachari and Rani (2005) in guava, Sindhu and Singhrot (1993) in lemon, Ladaniya (1997) in Nagpur mandarin and Ahlawat *et al.* (1984) in kinnow mandarin.

Black spotting in stored mango is mainly due to the infection of anthracnose caused by *Coletotrichum gloeosporioides* and stem-end rot caused by *Diplodo dianetalensis* (Yadav *et al.*, 2013). Similarly, pre-harvest fruit treatment has been reported to reduce the incidence of anthracnose and stem-end rot in mango. It also improves the physical quality i.e., the incidence of black spots, which increased their market appeal (Sarker *et al.*, 2009; Chonhenchob *et al.*, 2011) and Burondkar *et al.* (2009).

Sharma *et al.*, *(*2017) reported that At 10 DAH minimum anthracnose infestation percentage of 9.87 was recorded in 4% $CaCl_2.6H_2O$ treatment and maximum anthracnose infestation percentage of 11.07 was recorded in control. At 15 DAH minimum anthracnose infestation percentage of 10.08 was recorded in 2% $CaCl_2.6H_2O$ and 2% K_2SO_4 treatments and maximum anthracnose infestation percentage of 11.25 was recorded in control. At 20 DAH minimum anthracnose infestation percentage of 10.23 was recorded in 2% $CaCl_2.6H_2O$ treatment and maximum anthracnose infestation percentage of 11.41 was recorded in control.

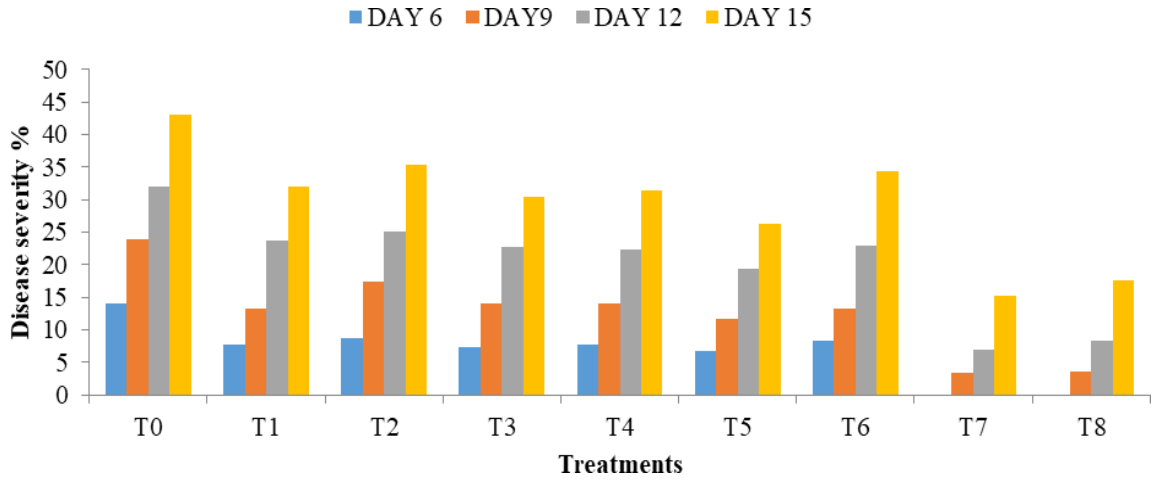

Figure 2. Effect of pre-harvest treatments on disease severity (%) of mango at 9 days after storage

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1%K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH

A. Disease severity % at 6 days after storage **(T_0)**

B. Disease severity % at 9 days after storage **(T_0)**

C. Disease severity % at 6 days after storage (T_7)

D. Disease severity % at 15 days after storage (T_7)

.

E. Disease severity % at 6 days after storage **(T_8)**

F. Disease severity % at 15 days after storage **(T_8)**

Plate 5: Comparison of disease severity (%) among the pre-harvest treatment of mango

4.11 Shelf life (Days)

The shelf life of fruits was accounted from the date of harvesting to the shelf life expiration date. The data on shelf life of fruits were significantly influenced by pre harvest treatment (Figure 3 Appendix VIII).

Significantly long shelf-life of fruit was recorded in Cv. Amrapali when trees were sprayed with 75 ppm GA_3 spray at 20 days before harvest (17 days) followed by 200 ppm SA spray at 20 DBH (16 days). The shelf-life of fruits was minimum (9 days) in control trees.

Extending the shelf life due to application of GA_3 might be because of delaying in conversion of starch to sugars there by reducing the peroxidase activity and ethylene (Taduri *et. al.,* 2017). Application of salicylic acid as a pre-harvest spray, one week prior to harvest could effectively modulate the ripening behavior of the Amrapali mango fruits during storage at ambient conditions (30±5 °C and 50±5 % RH). Also, this SA treatment influenced the pectin methyl esterase activity as well as the lipid per oxidation during storage in order to extend the fruit shelf life by 3 days. Also, this SA treatment influenced the pectin methyl esterase activity as well as the lipid per oxidation during storage in order to extend the fruit shelf life by 3 days (Raddy and Sharma, 2016). However, the extended shelf life in $CaCl_2$ treatment may be due to the fact that calcium enhances fruit firmness relative to control which leads to slower hastening and extends the shelf-life. The above results are very close to the findings of Karemera and Habimana (2014) and they had also reported that the trees sprayed with 1.50% $CaCl_2$ at 30 days before harvest extended the shelf life of mango cv. Totapuri up to 25.89 days and physio-chemical proprieties were also improved compared to fruits from non-sprayed trees.

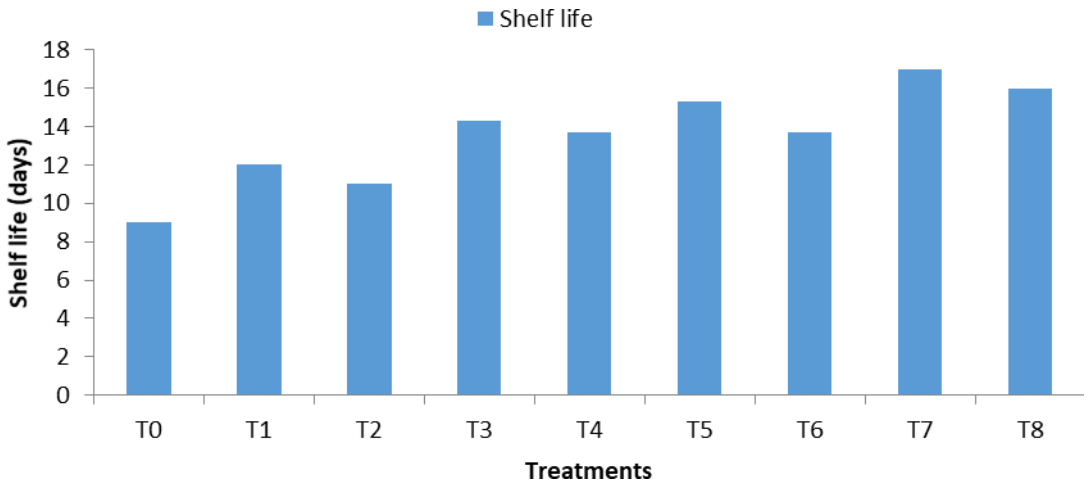

Figure 3. Effect of pre-harvest treatments on Shelf life of mango

T_0: Control (water spray), T_1: 2 % $CaCl_2$ spray at 10DBH, T_2: 1.0% K_2SO_4 spray at 10DBH, T_3: 75 PPM GA_3 spray at 10DBH, T_4: 200 PPM SA spray at 10DBH, T_5: 2% $CaCl_2$ spray at 20DBH, T_6: 1% K_2SO_4 spray at 20DBH, T_7: 75 PPM GA_3 spray at 20DBH and T_8: 200 PPM SA spray at 20DBH,

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted from June to July 2019 in a renowned orchard at the village of Khangaon Shahapara under the upazila of Pirganj in Thakurgaon district and the postharvest Laboratory of Horticulture Department at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

The objectives of the present study were to investigate the effect of pre harvest treatment on shelf life and quality attributes of mango cv. "Amrapali" after storage. Nine pre harvest treatment of different nutrients (PGRs and chemical) i.e. T_0: Control (Water spray),T_1: 2% Calcium Cholride ($CaCl_2$) spray at 10 Day Before Harvest (DBH), T_2: 1% Potassium Sulphate (K_2SO_4) spray at 10 DBH, T_3:75 ppm Gibberellic Acid (GA_3) spray at 10 DBH, T_4: 200 ppm Salicylic Acid (SA) spray at 10 DBH, T_5: 2% $CaCl_2$ spray at 20 DBH, T_6: 1% K_2SO_4 sprayat20 DBH, T_7: 75 ppm Gibberellic Acid (GA_3) spray at 20 DBH,T_8: 200 ppm Salicylic Acid (SA) spray at 20 DBH were used in this experiment. The experiment was laid out in Randomized Completely Block Design (RCBD). In this study observations were made on external and internal fruit attributes, physiochemical properties such as total weight loss, ripening percentage, moisture content, pH, total soluble solid content, Ascorbic acid, β-carotene content, Visual scoring of mango skin on the basis of disease severity and shelf life. In this research work mango of each treatments were collected randomly at three, six, nine, twelve and fifteen days after harvest for physiochemical studies. The data were statistically analyzed and evaluated. The results of the experiment expressed that almost all the parameters studied were significantly influenced by the above factors. Nutrients (PGRs and chemical) were applied in this experiment along with untreated fruit marked as control (water spray). Among all those treatments The maximum weight loss (5.11%, 9.65%, 12.80%, 14.73% and 20.671% at 3rd, 6th, 9th, 12th and 15th day of storage, respectively) was observed in T_0 (control treatment) followed by T_2 (1% K_2SO_4 spray at 10DBH), where weight loss was (4.81%,8.33%,10.06%,12.51% and 17.14% at 3rd, 6th, 9th, 12th and 15th day of storage, respectively) and the minimum (1.93%, 3.03%, 4.86%, 6.10% and 7.08% at 3rd, 6th, 9th, 12th and 15th day of storage, respectively) was found in T_7 (75 ppm GA_3 spray at 20DBH)) followed by T_8 (200 ppm SA spray at 20DBH) where weight loss was (2.6%, 3.89%, 5.48%, 6.98%, 8.12% at 3rd, 6th, 9th, 12th and 15th day of storage, respectively).

The maximum ripening value was (33.33%, 57.33%, 81.67%, and 100.00% at 3rd, 6th, 9th and 12th DAS) value was recorded from control (untreated fruits) and minimum (0.00%, 17.33 %, 37.67 % and 56.67% at 3rd, 6th, 9th and 12th DAS) value was obtained from T_7 (75 ppm GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH) where value was (0.00%, 19%, 41.67%, 61.33% at 3^{rd}, 6^{th}, 9^{th} and 12^{th} DAS).

The untreated mangoes had early ripeness whereas treated mangoes had a significantly delayed ripening. The higher fruit length (96.00 mm) and breadth (65.00 mm), was recorded in treatment of T_7 (75 PPM GA_3 spray at 20DBH) when compared with other treatments followed by T_8:200 PPM SA spray at 20DBH in which data recorded length (95 mm) breadth (62.33mm). On the contrary, minimum length and breadth was found in T_0 (control) in which data recorded length (85.67 mm) breadth (54.00 mm).

The maximum (85.09%) moisture content was noticed in T_7 (75 PPM GA_3 spray at 20DBH) followed by T_8 (200 PPM SA spray at 20DBH) where moisture content was 83.88%.The minimum (73.20%) moisture content was found in T_0 (control). TSS value which was an important quality parameter of mango, the fruits treated with T_7 (75 ppm GA_3 spray at 20DBH) maintained the lowest TSS value (15.33%) followed by T_8 (200 ppm SA spray at 20DBH) where the value (16.00%), while un-treated control fruits (T_0) maintained the highest TSS value (19.00%).

The maximum value (0.23%) of titratable acidity for mango fruits was recorded for T_7 (75 ppm GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH) where The value, the value was 0.20% and the minimum (0.09%) value was recorded in case of Control (T_0, untreated fruits).

The highest (5.69) pH value was recorded in T_0 (Control)) followed by T_2 (1.0% K_2SO_4 spray at 10DBH) fruit was (5.46). The lowest (4.31) value was found in T_8 (200 PPM SA spray at 20DBH) which is statistically identical to T_7 (75 PPM GA3 spray at 20DBH) also showed lower pH value and that was (4.49).

The highest ascorbic acid value (30.78 mg/100g) was recorded in 75 PPM GA_3 (T_7) followed by 200 ppm SA treated fruit (T_8), the value was 29.36% and the minimum (18.34%) value was recorded in case of Control (T_0, untreated fruits) at the end of shelf life. β-carotene content was found to be the highest (5.55 mg/100g) at the end of shelf life in case of T_7 (75 PPM GA3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH), where the value was (5.51 mg/100g) and the lowest value (4.42 mg/100g) was recorded in T_0 (control fruit).

The maximum disease severity % (14.00%, 24.00%, 32.00%, and 43.00% at 6th, 9th, 12th and 15th DAS) value was recorded from T_0 (control). On the contrary, minimum disease severity % (0.00%, 3.33%, 7.00% and 15.33% at 6th, 9th, 12th and 15th DAS) value was obtained from T_7 (75 PPM GA_3 spray at 20DBH) followed by T_8 (200 ppm SA spray at 20DBH.) in which data recorded (0.00%, 3.66%, 8.33% and 17.67% at 6th, 9th, 12th and 15th DAS). Above parameter indicated that significantly long shelf-life of fruit was recorded in Cv. Amrapali when trees were sprayed with 75 ppmGA_3at 20 days before harvest (17.0 days) and 200 ppm SA at 20 DBH (16.00days). The shelf-life of fruits was minimum (9.00 days) in control trees.

Conclusion

So, it can be concluded that fruit of Amrapali mango pre-harvest treated with 75 ppm GA_3 and 200 ppm SA at 20 DBH perform the best but 75 ppm GA_3 at 20 DBH being the most effective treatment to increase the shelf life & maintained better quality of physico-chemical parameters of mango fruits.

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APPENDICES

Appendix I: Daily temperature, relative humidity and rainfall of Thakurgaon district from June 2019.

Year - 2019 Month – June

Date	Temperature °C		Relative humidity (%)		Rainfall (mm/day)
	Maximum	Minimum	Morning	Afternoon	
1	30.0	25.7	85	60	2.2s
2	30.8	25.0	87	57	2.0
3	29.8	25.2	83	60	-
4	30.4	25.0	79	75	27
5	30.5	24.8	75	58	35
6	31.0	25.2	80	60	12
7	29.8	23.4	80	57	32
8	28.9	22.6	80	55	26-
9	30.2	24.0	83	63	40
10	32.00	28.0	84	66	-
11	29.5	22.5	92	75	-
12	29.2	22.2	90	72	-
13	30.1	24.0	86	64	60.0
14	30.3	22.6	88	65	15.0
15	30.4	23.0	81	67	30
16	33.0	26	80	56	-
17	29.3	21.6	84	63	-
18	29.6	22.4	84	62	-
19	31.0	22.0	84	69	47
20	30.9	25.0	80	60	25
21	29.5	24.0	81	66	13
22	30.4	22.8	77	52	-
23	28.6	24.9	81	67	-

24	30.8	22.5	79	54	60
25	30.2	22.3	85	67	-
26	29.3	21.8	85	70	65
27	29.0	22.6	79	58	35
28	28.0	22.2	94	73	-
29	30.6	24.0	90	70	-
30	30.2	23.5	78	55	5
31	29.0	22.4	78	66	33

Appendix II: Effect of pre-harvest treatments on weight loss (%) of mango at different days after storage (DAS)

Mean square	**Degrees of freedom**	**Mean square of weight loss at different days after storage(DAS)**				
		3	**6**	**9**	**12**	**15**
Replication	2	0.044	2.272	0.513	0.708	0.476
Factor	8	3.015**	14.472**	18.292**	22.051**	54.779**
Error	16	0.069	0.485	0.217	0.459	0.181

**Significant at 1% level of significance

Appendix III: Effect of pre-harvest treatments on ripening (%) of mango at different days after storage (DAS)

Mean square	**Degrees of freedom**	**Mean square of ripening (%) at different days after storage (DAS)**			
		3	**6**	**9**	**12**
Replication	2	0.111	0.593	0.111	0.444
Factor	8	284.000**	424.593**	516.167**	478.833**
ERROR	16	0.361	1.343	1.278	0.903

**Significant at 1% level of significance

Appendix IV: Effect of pre-harvest treatments on length and breadth of mango

Mean square	**Degrees of freedom**	**Mean square of length and breath**	
Replication	2	1.444	3.444
Factor	8	28.250**	52.667**
ERROR	16	3.486	5.861

**Significant at 1% level of significance

Appendix V: Effect of pre-harvest treatments on moisture (%), TSS, TA, Ascorbic acid of mango the end of shelf life

Mean square	**Degrees of freedom**	**Mean square at the end of shelf life**			
		TSS	**TA**	**Vitamin c**	**moisture**
Replication	2	0.481	0.000	0.346	0.472
Factor	8	4.287**	0.005**	51.605**	36.245**
ERROR	16	0.731	0.001	1.304	0.377

**Significant at 1% level of significance

Appendix VI: Effect of pre-harvest treatment on p^H and β-carotene content of mango at the end of shelf life

Mean square	Degrees of freedom	Mean square at the end of shelf life	
		pH	**β-carotene**
Replication	2	0.036	0.39
Factor	8	0.581**	3.364**
ERROR	16	0.085	0.041

**Significant at 1% level of significant

Appendix VII: Effect of pre-harvest treatments on disease severity (%) of mango at differentdays after storage (DAS)

Mean square	Degrees of freedom	Mean square of disease severity (%) at different days after storage (DAS)			
		6	**9**	**12**	**15**
Replication	2	0.148	0.259	1.037	2.926
Factor	8	56.954**	121.398**	190.620**	225.259**
ERROR	16	0.356	0.843	0.954	0.426

**Significant at 1% level of significance

Appendix VIII : Effect of pre-harvest treatments on shelf life of mango

Mean square	**Degrees of freedom**	**Mean square of shelf life**
Replication	2	0.444
Factor	8	19.250**
ERROR	16	0.611

**Significant at 1% level of significance