

**EFFECT OF ETHREL TREATMENT ON
RIPENING AND POSTHARVEST QUALITY OF
MANGO (*Mangifera indica* L.)**

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EFFECT OF ETHREL TREATMENT ON RIPENING
AND POSTHARVEST QUALITY OF MANGO
(*Mangifera indica* L.)

HSU MYAT MON

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Division of Postharvest Technology
Advanced Center for Agricultural Research and
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The thesis attached here to, entitled “**Effect of Ethrel Treatment on Ripening and Postharvest Quality of Mango (*Mangifera indica* L.)**” was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and the board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science in Food Engineering and Technology**.

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DECLARATION OF ORIGINALITY

This thesis represents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree or to any other University.

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ABSTRACT

The experiment was carried out to evaluate the effect of ethrel treatments on ripening and postharvest quality of Sein Ta Lone and Yin Kwe mango (*Mangifera indica* L.) at ambient condition. It was conducted at the Laboratory of Postharvest Technology Division, ACARE, Yezin Agricultural University (YAU) from May to August, 2019. Factorial arrangement with RCB design was laid out for four replications. The first factor was dipping for 5 minutes in ethrel concentrations of (0, 500, 1000, 1500) ppm and the second was the variety of Sein Ta Lone, which was collected from Myanadi mango orchard, Department of Agriculture, Myittha Township, Mandalay Region and Yin Kwe variety, which were collected from Horticulture Section, Department of Agricultural Research (DAR). The data on physiological loss in weight (%), total soluble solid (TSS%), total titratable acidity (TTA%), ascorbic acid content (mg/ 100g), skin and pulp firmness (N), color development, respiration rate (ml CO₂/kg/h) and ethylene production rate (μl/ kg/h) were collected and observation were recorded daily. In both varieties, there were no significant differences in TSS%, skin and pulp firmness, color development, TTA% and ascorbic acid content of the fruits treated with 1000 ppm and 1500 ppm ethrel. Among the treatments, fruits treated with 1000 ppm and 1500 ppm not only considerably decreased in TTA% and ascorbic acid content but also remarkably increased in fruit ripening characters of color development and TSS% with soft skin. Regardless of ethrel concentrations, the ethylene production rate of Sein Ta Lone was significantly higher than that of Yin Kwe. Thus, ethrel dipping was more effective in ripening characteristics of Yin Kwe compared to Sein Ta Lone. The results from this study revealed that 1000 ppm was the most suitable concentration to be both mango varieties to be uniform in ripening and early market access.

Keywords: ethrel dipping, Sein Ta Lone and Yin Kwe mangoes, ripening and postharvest quality

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CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most favored specialty fruits and is very popular world-wide. It belongs to the family Anacardiaceae and it is one of the most important tropical and subtropical fruits of the world particularly in Asia. Mango is the 'King of fruits' because of its attractive color, excellent taste, excellent flavor, nutritive value, its delicacy for the table which provides employment to the millions of poor people during summer (Doke, Dhemre & Kad, 2018). According to FAOSTAT (2007), the production of mango has increased by nearly 2-3 times in these days. According to the FAOSTAT (2010), mango is the main fruit crop in world production with 38.67 million tons and over 90 countries produce mango around the world. In FAOSTAT (2012), the largest mango producing country among the mango producers was India, accounting for 42.25% of global production in 2010 with a yield of 14.3 million metric tons followed by China and Thailand about 4.35 million metric tons (11.25%) and 2.55 million metric tons (6.60%), respectively.

Mangoes are important sources of pro-vitamin A (carotenoids), especially β -carotene. These also include carbohydrates, fatty acids, minerals, organic acids, protein and vitamins (Rodriguez, 2001). Ripe mango includes moderate level of vitamin C, but are moderately rich in vitamin A, vitamin B₁ and B₂ (Palozza, 1992). The ripe mango has 6.8-38.8 mg/100g ascorbic acid, 12.0-23.0 TSS% and 0.12-0.38 percent acidity.

Myanmar is the 6th largest country of mango production in Asia with annual growth rate of 19.8% in 2000. The variation of mango harvest period occurs in Myanmar due to the different climatic conditions and ecological zones. Mango is the main commercial fruit in Myanmar. According to Naing (2003) and Soe (2008), there are about 300 varieties of mango in Myanmar. The harvest period of mango fruit commences from February to March in Tanintharyi Region and Mon State, April to May in Ayeyarwaddy, Yangon and Bago Regions, and April to July in Mandalay, Sagaing and Magway Regions. Major mango producing areas are Ayeyarwaddy, Bago and Yangon, in the central Regions of Mandalay, Sagaing and in the Southern Shan State.

Ethrel is widely used for ripening of mango in various ways all over the world. Various methods have been developed to induce postharvest ripening of mangoes by ethrel treatment. It is used to initiate fruit ripening by placing containers of ethrel in a

gas-tight room containing the fruit. In commercial ripening rooms, buckets of ethrel are placed throughout the ripening rooms that resulted in instant release of ethylene gas into the room and measured amount of ethylene (Chandel, 2014). Another widely acceptable method involves the use of ethylene gas but lack of infrastructural facility limited its use (Singh, Kumar & Malik, 2012).

Artificial ripening of mango is very recent concept in postharvest technology in Myanmar but it has great importance especially in export of mango. Ethylene and commercial ethylene-releasing compounds such as ethrel (2-chloroethyl-phosphonic acid, $C_2H_6ClO_3P$) have been used successfully for uniform ripening of fruits e.g. mango, banana, papaya and also for degreening of citrus. Ethrel is used for induction of early and uniform ripening in a number of fruits including mango. The ethrel treatment brings about postharvest physiological and chemical changes such as softening, sweetening and color changes which are associated with ripeness (Godambe, 2012). The main purpose of early ripening of mango is to catch the early market with uniformly ripe fruit having good sensory attributes.

The principal factors affecting mango ripening are the cultivar, the dosage of ethrel, ethrel treatment types and storage conditions (Chandel, 2014). There is needed to standardize the method for ripening of mango by the use of safe chemicals so that uniform ripe mango can fetch remunerative price in the domestic and export markets. The color and ripening stage are important considerations on quality of mango to the commercial growers. Mango var. Yin Kwe, despite its satisfactory ripening, pleasant flavor, correct pulp color and general acceptance, shows a skin without the characteristic red yellow color of the regular ripe fruit. Yin Kwe remains green and this makes it slightly unattractive to the consumer. Sein Ta Lone is a popular variety for both domestic consumption and export market. It gets the greatest consumers' preference because of its sweetness level (nearly TSS% 24) and less fiber content (Soe, 2008). During the growth and development, there are many chemical and physical changes occur in mango that have an impact on fruit quality and ripening behavior after harvest. Moreover, the changes that occur during ripening of mango its external appearance as well as other characteristics such as quality, color, texture and flavor. These changes depend upon greatly for each variety, and ecological conditions of grow including watering, fertilization, temperature, etc.

In Myanmar, there were some information available on postharvest characteristics and storage life of Sein Ta Lone by the use of modified atmosphere

packaging, coating and pretreatment using chemicals to prolong shelf life and different storage temperatures and conditions (Naing, 2003 & Kyaw, 2011). Similarly, academic information on postharvest storage of Yin Kwe mango by the use of coating materials and different temperatures are also available. However, there was no systematic information on ripening and postharvest quality of Sein Ta Lone and Yin Kwe mango by the use of different ethrel concentrations. Therefore, this study was conducted to investigate the following objective:

1. To examine the effect of ethrel treatment on ripening and postharvest characteristics of mango, Sein Ta Lone and Yin Kwe varieties

CHAPTER II

LITERATURE REVIEW

2.1 Origin and History of Mango

Mango is native to Indo-Myanmar region and it has been cultivated for more than 4000 years (Narong Chomchalow, 2008). India, Mexico, Thailand, Brazil and Pakistan produced the largest amount of fresh mango for export among the mango growing countries. In fact, Asia was the main exporter with 46.27% of global mango production in 2009 (FAOSTAT, 2012).

2.2 World Mango Production

Worldwide mango production is spread over 100 countries. In 2009, the volume of mango trade has been increasing continuously since the late 1990s (FAOSTAT, 2012). Asia had the most mango production approximately with 76.49 % followed by Americas and Africa with 12.62% and 10.77%, respectively in 2010 (FAOSTAT, 2012). Mango production is concentrated in certain countries with the top ten countries producing almost 77% of worldwide quantity. India is the world's largest producer of mangoes and accounts for nearly 40% of world production (Kaung, 2012).

Mango (*Mangifera indica*) is considered as one of the most consumed fresh fruits in the world, with extensive marketing and production taking place in 115 countries. The global area of mangoes harvested is approximately 5.41 million hectares and its global production is 42.66 million metric tons. Ecuador, with a global area of mangoes harvested of 13,300 hectares and a production of 61,300 metric tons, is the second and sixth mango exporter to USA and to worldwide, respectively, being an important fruit in the Ecuadorian economy. Mexico is the leading global exporter of mangoes, and the 'Ataulfo', 'Tommy Atkins', 'Hayden', and 'Kent' varieties account for 60% of the mangoes produced nationally. In 2017, global production of mangoes was 50.6 million tons, led by India with 39% (19.5 million tons) of the world. China and Thailand were the next largest producers (FAOSTAT, 2007)

Table 2.1. Mango Producing Countries in 2016

No.	Country	Production (ton)
1.	India	18,779,000
2.	China	4,771,038
3.	Thailand	3,432,129
4.	Mexico	2,197,313
5.	Indonesia	2,184,399
6.	Pakistan	1,606,091
7.	Brazil	1,417,149
8.	Egypt	1,277,008
9.	Bangladish	1,161,685
10.	Nigera	917,617

Source: International Trade Centre (ITC, 2016)

2.3 Myanmar Mango Production and Market

Since mango is a kind of native fruit in Myanmar, it can grow well throughout the country over the wide range of climatic conditions. It is the first major fruit crop in Myanmar and 11.85% of the total fruit production of the country followed by cashew nut (DOA, 2011). Annual growth rate of mango production is 19.8% (DOA, 2018). Total growing area is 104,341 hectares and total harvested area was 91,196 hectares (DOA, 2018). Major mango producing areas in Myanmar are Ayeyarwaddy Region, Bago Region, Yangon Region, Mandalay Region, Sagaing Region and Southern Shan State with the average yield of 5.1 ton/ha (DOA, 2018). There are about 300 varieties of mango in Myanmar. Among them, only a few varieties such as Sein Ta Lone, Shwe Hin Thar, Yin Kwe and Mya Kyauk are exported due to high degree of sweetness, good quality and high yield production (Naing, 2003) (Soe, 2008).

2.4 Ripening Regulators of Mango

Ripening regulators are substances used to hasten the ripening process in fruits. Since the fruits are sent to distant places, requiring several days at ordinary or refrigerated transportation, only firm, but mature fruits are least damaged during transportation and marketing. Artificial ripening of fruits for the commercial purpose is achieved by using different chemicals as ripening regulators. Thus, ripening agents allow many fruits to be picked at optimum maturity prior to ripening. Various chemicals generally employed as ripening regulators are ethylene gas, ethephon or ethrel, and calcium carbide for fruits in commercial scale. Artificial ripening of mango has great importance especially in export (Chandel, 2014). Ethylene and commercial ethylene releasing compounds such as ethrel (2-chloroethyl-phosphonic acid) have been used successfully for uniform ripening of fruits and also for degreening of citrus (Kadar & Kasmire, 1984). The toxicity of ethephon is very low and any ethrel used on the plant gets converted very quickly to ethylene.

2.5 Enhancing Ripening Process in Market Access

Mango is a climatic fruit with the short shelf life that can ripen after being picked and produce much more ethylene. When mango fruits ripen, they become softly and deteriorate in short time. As the matter of this, it is difficult to deliver ripe mango to large market in big cities and hence, reduces the chance for better profit to farmers. Meanwhile, green mature mango is firm enough and can maintain its appearance during

transportation and ethrel application can hasten fruit ripening. This brings more advantages to distribute to distant market places (Hai, Huong, Sruamsiri, & Hegele, 2009).

Ethylene gas, acetylene gas liberated from calcium carbide and ethephon are some of the commercial ripening agents used successfully in the trade by initiating and accelerating the ripening process and fruit quality. But, calcium carbide contains impurities of arsenic and phosphorus hydride, which are toxic to human health. Instead of using calcium carbide, it is widely used ethrel as a ripening regulator in most fruits. Lauryl alcohol is an organic compound produced industrially from coconut oil or kernel oil. It is fatty alcohol and widely used as a ripening agent for bananas (Maduwanthi & Marapana, 2019). Mango fruits ripen unevenly on the tree while the natural ripening process after harvest is also very slow and unpredictable. To overcome such problem, fruits can be ripened by exposing them to ethrel, which initiate the early and uniform ripening process. Nowadays, mango traders widely use ethrel of ethephon to enhance ripening process for market demand.

2.6 Role of Ethylene Source in Fruit Ripening

Ethylene is a natural ripening agent of fruits and it can stimulate fruit ripening and it has gained recognition as a ripening hormone. When the mature fruits are dipped in ethrel, it enters fruits cells, releases ethylene and hastens the ripening process (Dharmasena & Kumari, 2005). Mehta et al., (1980) and Singh (2012) said that changes in ascorbic acid content may occur with ethrel spray which influences the carbohydrate metabolism in related fruits. Ethrel promotes ripening and increases ethylene production in tissues which improve normal ripening process and may affect storage quality. Exogenous application of chemicals including growth regulators significantly decreased postharvest disease incidence leading to increase in postharvest fruit quality and shelf life (Jatinder et al., 2012).

Fruit ripening with certain chemicals is permissible up to a limited concentration. In FSSAI (2011), the government of India has allowed the use of ethylene for fruits ripening as it is not harmful. In the case of ethephon, the ripening is slightly cumbersome; the fruit sellers have to either dip the fruits in a ethephon solution or pass fumes of this chemical through the fruits (Siddiqui & Dhua , 2009). The chemical is mainly used to ripen mango, papaya, banana etc. Siddiqui (2008) and Kulkarni, Kudachikar, and Vasantha (2004) found that the fruits ripened with ethrel

had more acceptable color than naturally ripened fruits and calcium carbide treated fruits. The ethrel dose of 500 ppm for Himsagar mango, to impart good acceptable color with up to 5-6 days of storage (Siddiqui & Dhua , 2009).

Ethrel (2-chloroethyl phosphonic acid) is strongly acidic in water solution. When in solution above a pH of about 5, the ethrel molecules spontaneously hydrolyses, liberating ethylene (Thompson, 1985). The amount of ethylene will increase as pH and/or relative humidity increases. Ethrel is commercially available (ethephon, floral, cepa) and used for enhancing postharvest ripening (Singh, 2012). The benefits of ethylene treated fruits are better color and aroma before releasing them to the market. At the onset of climacteric fruit ripening, changes in color, aroma, texture and flavor is mainly initiated by the sharp increase in ethylene production (Hai, 2012).

Mango is a climacteric fruit and it is picked at mature green but unripe stage. The harvested green mature mango fruits are hard in texture; possess low soluble solids contents, high acidity resulting poor edible quality. Respiration involves a larger set of reactions, such as the enzymatic breakdown of more complex substances to glucose (Vigneault, et al., 2003). During climacteric rise in respiration, there is a massive increase in CO₂ release followed by a decrease. The climacteric rise in ethylene production precedes the climacteric rise in CO₂ production, suggesting that ethylene is the hormone that triggers the ripening process. The respiration passes through a maximum referred to as the climacteric peak and then decline. This respiratory peak is proceeded by a rise in ethylene production during fruit ripening (Soe, 2008). The increase of respiratory activity is accompanied by rapid modifications in its chemical composition, which alter the taste, aroma, firmness of the pulp and skin color. In turn, the rate of respiration is governed by the interaction of the genetic nature of the produce, its physiological status, temperature and the influence of ethylene, oxygen and carbon dioxide concentrations (Jiang & Joyce, 2000). The ripening process of mango fruit involves a series of metabolic activities that cause chemical changes, increased respiration, change in structural polysaccharides causing softening of fruits, degradation of chlorophyll and carotenoids biosynthesis, hydrolysis of starch into sugars, thus leading to ripening of mango fruit with softening of texture to acceptable quality (Herianus, Singh and Tan, 2003).

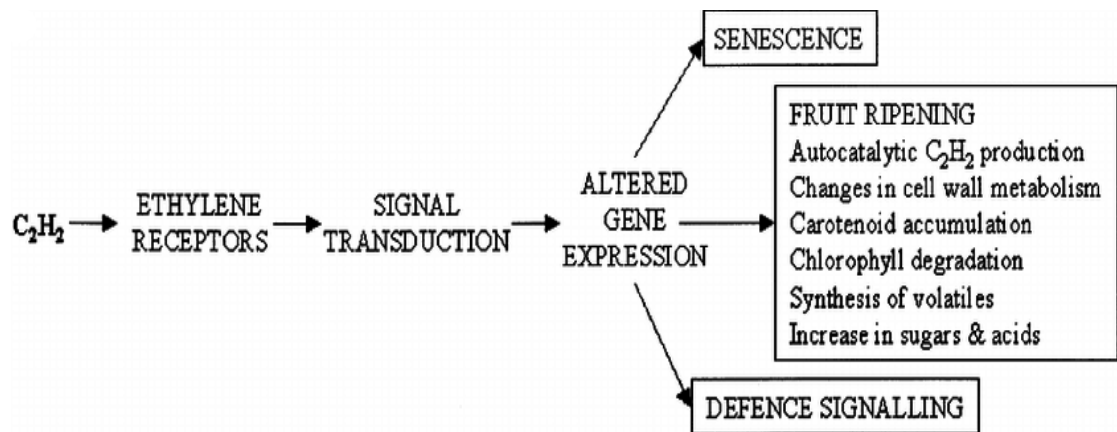


Figure 2.1 Fruit ripening process by ripening growth regulator

2.7 Effect of Ethrel on Quality Characteristics of Mango Fruit

2.7.1 Color development

The uniform and sustainable color development of the fruit during ripening may be associated with faster degradation of chlorophyll and functional activity of ethylene as a degreening agent (Doke, Dhemre, & Kad, 2018). The application of ethrel improved substantially skin color at 12°C and 20°C when compared to untreated fruits (Hai, 2012). Significant change in skin color of greenish yellow to deep yellow with increase in ethrel concentration from 250 ppm to 1250 ppm could be observed during ripening of mango. In untreated fruits, yellowish green to yellow color was noticed till the end of storage. It was said that the color development was better due to rapid degradation of chlorophyll and higher synthesis of carotenoids and other pigments in ethrel treatments (Kaur, 2017).

The fruits treated with ethylene gas or ethephon solution resulted in the development of color in tomato fruits from green to red (Singh, 2012). The ethylene gas and ethephon treatments was known to accelerate the chlorophyll degradation or synthesis of carotenoids by stimulating the synthesis of chlorophyllase enzyme.

2.7.2 Fruit firmness

Many researchers observed that optimum dose of ethrel induce ethylene production, respiration rate and ripening phenomenon which promote the ripening process with significant decrease in firmness of fresh fruits. The fruit firmness declined during ripening period in all treatments when the mango fruits were exposed with various concentrations of ethrel (250, 500, 750, 1000 ppm) in aqueous solution each for five minutes (Godambe, 2012). Untreated fruits were significantly hard and remained unripe. Fruits treated with 500 ppm exhibited significantly the highest firmness among the ethrel or ethylene treated fruits. The ethrel or ethylene treated fruits triggered the ripening process and became soft than the untreated fruits with the advancement in the ripening period (Godambe, 2012 & Singh, 2012). Among the different concentrations, the fruits treated with 1500 ppm ethrel showed the faster loss of firmness during ripening period, thereby leading to excess softening and shriveling of fruits (Singh, 2012). Low dose of ethrel maintained better fruit firmness on ripening of Dushahari mango. It was reported that more loss of electrolyte due to high dosage (1500 ppm) of ethrel treatment causes in fruit firmness loss in mango during ripening (Pal, 1998a).

2.7.3 Physiological loss in weight

Many researchers observed that fruits treated with ethrel had higher weight loss as compared to untreated fruits. The maximum weight loss was recorded towards the ripe stage as compared to the harvest stage due to several physiological and metabolic activities during fruit ripening such as respiration, ethylene production. Physiological loss in weight of pear was significantly higher in all the ethylene treated fruits at ambient temperature as compared to untreated fruits (Dhillon & Mahajan, 2011). It also significantly increased after each storage interval during storage period. More than 5 percent moisture loss leads to shriveling of fruits.

The effect of exposure to ethylene gas (150 ppm) for 24 hours in ripening chamber and dipping in different concentrations of ethephon (250, 500, 750, 1000 ppm) solution each for 5 min in fruits. Fruits treated with ethephon 1000 ppm showed the highest PLW during ripening period which was followed by ethephon 750 ppm. Control fruits showed the lowest physiological loss in weight and these fruits were still green and hard in texture (Chauhan, Sandeep, Singh, & Jawa, 2012). During different ripening period, untreated fruits recorded the lowest weight loss and ethrel 1500 ppm treated fruits showed the highest PLW during the same interval (Singh, 2012). There was significant variation in physiological loss in weight of Alphonso mango fruits due to the ethylene treatments during storage (Godambe, 2012).

As the similar observations in orange fruits, ethrel-treated fruits resulted in shriveling, softening and over ripening of fruits. Ethylene gas (100 ppm) and ethephon (500 ppm) resulted in adequate degreening and softening of oranges. The lowest physiological loss in weight was observed in untreated fruits with green and hard texture (Jatinder et al., 2018).

2.7.4 Total soluble solid

The increase in soluble sugars or total soluble solid (TSS) is a major change during mango fruit ripening and the most important compositional change related to flavor. It was reported that TSS content increased with the increase in concentration of ethephon (500-1500 ppm). There was increase in all the treatments during the ripening period. All the ethephon treatments showed nonsignificant difference among themselves (Hai, 2012). The refrigerated storage restricted ripening and limited the effect of ethrel to ripening in mango cv. 'Tron' and 'Hoi' fruits. Increasing ethrel concentrations within five days at 12°C and three days at 20°C induced accumulation

of high soluble solids contents (Hai, 2012). Singh, Kumar and Malik, (2012) found significant differences among the treatments given to mango cv. Amrapali with ethrel 750 and 1000 ppm increased TSS level. During ripening of mango, starch content increases in chloroplasts and it is almost completely hydrolysed to simple sugars (Ito, Sasaki & Yoshida, 1997). This may be due to advanced ripening stage which resulted in the substantial utilization of sugars and hence the reduced TSS was observed (Dhall & Singh, 2013). Ripe mango contains up to 10-20% total sugars on a fresh weight basis depending on the cultivar and the stage of ripeness.

In similar findings, the tomato fruits treated with 1500 ppm ethephon showed the maximum average TSS content. Total soluble solid content slowly and steadily increased in all the treatments during ripening period whereas the lowest TSS content was in untreated fruits. In all the ethephon treatments, there was decrease in TSS content after reaching maximum TSS content.

2.7.5 Total titratable acidity

According to Medlicott and Thompson (1985), organic acids are important sources for respiratory activity and flavor constituents of fruits. During ripening, mango fruit has a substantial loss of organic acids. The predominant acids in matured mango are citric acid, succinic, malic and tartaric acid. Citric acid has the highest concentration and tartaric acid is the lowest in mature mango. The acid content in fruits decreased significantly during ripening under all the ethephon treatments with prolongation of ripening period. In control fruits, the acid content decreased up to 8 days and slightly increased after 16 days of ripening interval at ambient condition. The lowest acidity level was recorded in ethephon treatment at 20°C, while it was the highest in control fruits at ambient temperature after 4 days (Dhillon & Mahajan, 2011).

The acidity of mango fruit was decreased by postharvest application of ethrel and the response varied with the concentrations. All ethrel-treated fruits showed lower acidity content than the untreated fruits whereas all the treatments were non-significant from each other. The minimum mean acidity was observed in the untreated fruits (Singh, 2012).

2.7.6 Ascorbic acid

The ascorbic acid of mango fruits decreased during the ripening period at room temperature (Othmman & Mbogo, 2009). The ascorbic acid content decreased with the advancement of storage time and increase in ethrel concentration in fruits

(Moniruzzam, Khatoon, Hossan, Rahman, & Alam, 2015). The reduction in ascorbic acid content was more pronounced in ethrel treated mango fruit than that of untreated fruit. The reason may be treated ethrel could enhance ripening process with more utilization of ascorbic acid that resulted in reduction of ascorbic acid (Godambe, 2012). The ethrel-treated fruits 500 ppm and 750 ppm were found at par with each other, however, the lowest ascorbic acid content was observed in 1000 ppm treated fruit (Rao & Shrinath, 1989). It was observed that 500 ppm of ethrel-treated fruits showed the highest ascorbic acid content while 1000 ppm ethrel-treated fruits showed the lowest ascorbic acid content (Bal & Kok, 2007). Alphonso mangoes treated with ethrel dipping for 5 minutes and storage at ambient conditions recorded lower ascorbic acid content as compared to untreated fruits (Das, Balamohan, Auxilia, & Nalina, 2011).

2.7.7 Ethylene production and respiration rate

Ethylene production and respiration rate increased with the increase in ethylene concentrations. Ethylene released from ethrel-treated fruits at 250, 500 and 1000 ppm exhibited the climacteric peak at respective day at 1 day, 3 to 4 days and 4 to 5 days earlier than the untreated fruits (Goukh & Ali, 2003). The respiratory peak in Sein Ta Lone mango was observed at 6 days after storage and the fruit ripens within 6 or 7 days at ambient condition (Leiyi, Soe, Yamamoto and Myint, 2019). It was observed that mango fruits stored at low temperature showed lower the respiration and ethylene production rate than higher temperature storage. Fruits treated with ethrel reached their climacteric peak 3 days earlier than untreated fruits (Nour & Goukh, 2010).

It was observed that ethrel was effective in triggering fruit ripening in three mango cultivars. Ethylene production and respiration rate was significantly higher in ethrel-treated fruits compared to untreated fruits (Nour & Goukh, 2010). It was also reported that ethylene production and respiration rate increased with the increase in ethrel concentrations. While the fruits treated with ethrel in aqueous solution, the fruits reached the climacteric peak 2-3 days earlier than the untreated fruits. Fruits treated with ethrel 1000 ppm was higher respiration rate than that of untreated fruits. It was reported that the higher the concentration, the higher the ethylene production and respiration rate (Goukh & Mohamed, 2003).

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site and Period

The experiment was conducted at the laboratory of Postharvest Technology Division, Advanced Centre for Agricultural Research and Education (ACARE), Yezin Agricultural University, Naypyidaw from May to August, 2019.

3.2 Experimental Design

This experiment was arranged in factorial randomized complete block design (RCBD) with four replications (Plate 1). There were 320 fruits for each variety and total fruits were 640 fruits for this study. Each variety was divided into four groups for dipping 5 minutes in different ethrel concentrations (500, 1000, 1500 ppm) and each treatment consisted of 80 fruits. Treatment combinations were as follows:

Factor (A) - Ethrel concentrations

1. 500 ppm
2. 1000 ppm
3. 1500 ppm
4. 0 ppm (Control)

Factor (B) - Varieties

1. Sein Ta Lone (STL)
2. Yin Kwe (YK)

3.3 Procurement of Experimental Materials

Physiologically matured Sein Ta Lone mango fruits (110 days after flowering) were collected from Myanadi Orchard, Myittha Township, Mandalay Region. Yin Kwe mangoes (105 days after flowering) were collected from Department of Agricultural Research (DAR), Yezin, Naypyidaw. Uniform fruits without any defects like mechanical damage, blemish and visual spots were selected for this study. Then, these were cleaned, washed with a washing machine and dried for a while.

Before giving treatment to mango fruits, concentration of ethrel was prepared for accurate amount for different treatment of mango fruits (Plate 2). The market brand DIMEI with ethrel 40% of plant growth regulator was prepared concentration for part per million (ppm) according to the treatments. The stock solution of ethrel was prepared by using the following formula.

$$C_1 V_1 = C_2 V_2$$

C_1 = known concentration of ethrel

V_1 = required Volume of ethrel

C_2 = required concentration of ethrel

V_2 = required Volume of water

3.4 Data Collection

From each treatment, eight fruits of non-destructive sample were used to assess the data on weight loss, color development, ethylene production rate and respiration rate. Eight destructive sample fruits from each treatment were used for the data such as firmness, total soluble solid (TSS%), total titratable acidity (TTA%) and ascorbic acid (mg/100g). The data were daily collected from the beginning to the end of the experiment.

3.4.1 Measurement of physiological loss in weight

The weight of sample fruits were measured daily with electronic digital balance. The physiological loss in weight was calculated on fresh weight basis and presented as percent (%).

$$\text{Weight loss (\%)} = \frac{\text{Initial fruit weight} - \text{Weight at intended time}}{\text{Initial fruit weight}} \times 100$$

3.4.2 Measurement of fruit firmness

The skin and pulp firmness of selected sample fruits were measured daily by using Texture Analyzer (TA. XT. Plus100) with probe of 5mm diameter and results were expressed as Newton (N) of force. The fruits were peeled to determine the pulp firmness. Firmness tester is a fruit destructive device that incorporated in force (Plate 3). The value was measured at four places of equatorial portion of the fruits and calculated by the average mean.

3.4.3 Fruit color

The color of the fruit was measured at three places by using colorimeter (Mini Scan XE Plus, Hunter Lab, USA). Color values were recorded by L^* , a^* , b^* and analyzed. As a result, single value (b^*) can be used to describe the yellow/blue attributes. The coordinate L^* is called the lightness. The coordinate a^* defines the deviation from the achromatic point corresponding to lightness, to red when it is

positive and to green if negative. Similarly, the coordinate b^* defines the turning to yellow if positive and to blue if negative.

3.4.4 Measurement of total soluble solid

The total soluble solid (TSS%) of mango was determined by using a portable digital refractometer (J47 automatic, Tokyo, Japan) by squeezing the juice from mango pulp (Plate 4). The reading value was expressed as percent (%) and three times were recorded and the average value was calculated.

3.4.5 Measurement of total titratable acidity

Total titratable acidity (TTA%) of mango juice was determined by the acid base titration method (AOAC, 1990). A known volume of fruit juice sample was blended on electric stirrer with distilled water. It was then transferred to 100 ml volumetric flask, made up the volume and filtered. The aliquot of (20 ml) was titrated against 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator so that the end point can be easily observed. The titrated value was noted and total titratable acidity was measured as percentage according to the following equation.

$$\text{TTA}\% = \frac{(\text{ml}) \text{ NaOH} \times 0.1 \text{ N NaOH} \times \text{Volume make up}(\text{ml}) \times 0.067 \times 100}{\text{Volume of Juice taken}(\text{ml}) \times \text{Weight of sample} \times 1000}$$

Whereas, 0.067 = constant value for malic acid in ripe mango

3.4.6 Measurement of ascorbic acid

The estimation of ascorbic acid content in fruit pulp was determined by titrimetric method (AOAC, 1990) (Plate 5). About 10 gm of sample was taken and made up to a volume of 100 ml with 3% metaphosphoric acid solution. After 30 minutes, the suspension was filtered by using Whatman No.1 filter paper. The 2, 6-dichlorophenol indophenol dye solution was standardized by titrating against standard ascorbic acid solution and the dye factor was calculated before actual titration. About 10 ml of the juice was taken from the filtrate and titrated against standardized dye solution through a burette. Titration was continued till the pink color persisted for 15 seconds. Ascorbic acid content was determined by using the following formula the results were expressed as mg/100g.

$$\text{Ascorbic Acid} = \frac{\text{Titre acid (ml)} \times \text{Dye Factor} \times \text{Volume make up (ml)} \times 100}{\text{Volume of Juice taken (ml)} \times \text{Weight of sample (10g)}}$$

3.4.7 Measurement of ethylene production and respiration rate

Ethylene production and respiration rate was determined using (F-900, Portable ethylene analyzer) (Plate 6). It is a versatile ethylene analyzer available with the ability to measure ethylene flux directly from a single fruit non-destructively. It includes a patented Polar Cept water filter that removes interfering gases and hydrocarbons which would otherwise lead to an artificially elevated readings on the electrochemical sensor. The sample fruits were sealed in 1250 ml of plastic container for 6 hours for ethylene and respiration analysis before each measurement. The 5 ml of sample gas was injected into the machine through the injection port by using syringe.

3.4.8 Statistical analysis

All collected data were statistically subjected to analysis of variance (ANOVA) using Statistix 8.0 version software and treatment means were compared using Least Significant Difference (LSD) test at 5% level of significance ($P \leq 0.05$).



(a) Sein Ta Lone mango



(b) Yin Kwe mango

Plate 1 Experimental layout of two mango varieties as affected by different ethrel concentrations at ambient condition



Plate 2 Preparation for ethrel dipping of mango

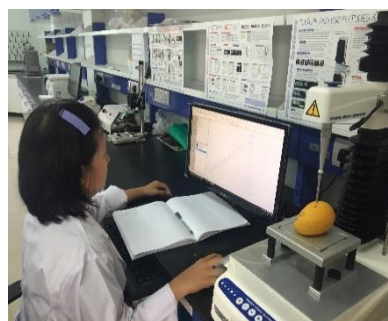


Plate 3 Measurement of fruit firmness



Plate 4 Measurement of total soluble solid (TSS%) by using automatic refractometer

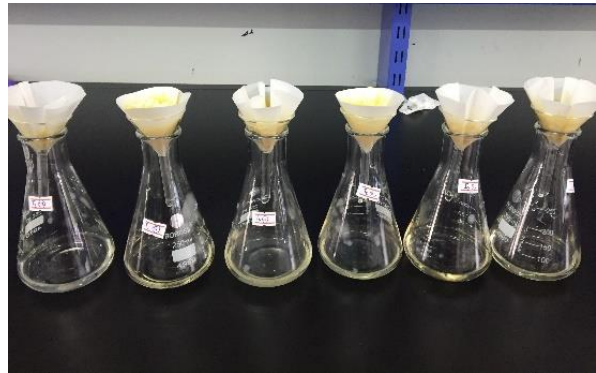


Plate 5 Measurement of ascorbic acid content



Plate 6 Measurement of ethylene production and respiration rate by using portable ethylene analyzer

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Physiological Loss in Weight

The data on physiological loss in weight (PLW) as affected by different ethrel concentrations and two varieties of Sein Ta Lone and Yin Kwe varieties is presented in Figure (4.1). In general, physiological loss in weight increased with the increase in ethrel concentrations. The lowest physiological loss in weight was noticed in untreated fruits which was statistically significant as compared to ethrel-treated fruits (Appendix 3). On the other hand, the highest physiological loss in weight was observed in fruits treated with 1500 ppm ethrel and followed by 1000 ppm and 500 ppm (Appendix 3). The interaction between ethrel treatments and varieties were found to be highly significant.

The data on physiological loss in weight as affected by different ethrel concentrations and ripening period is shown in Figure (4.2). It was observed that physiological loss in weight increased with the increase in ethrel concentrations and also with the advancement in storage days in both varieties. The PLW during ripening may be attributed to increased rate of respiration which is positively correlated with the increase in ethrel concentrations. There was no interaction between ethrel treatment and ripening period.

The data on physiological loss in weight as affected by two varieties and ripening period is presented in Figure (4.3). From the findings, PLW increased progressively during storage. It was also noticed that PLW of var. Yin Kwe significantly recorded higher value than that of var. STL during 2 days. After that, there was no significant difference in PLW between two varieties but PLW of var. STL was slightly higher than var. Yin Kwe. This might be due to ripening nature and ethylene production of var. Sein Ta Lone. The interaction between two varieties and ripening days was noticed to be highly significant difference.

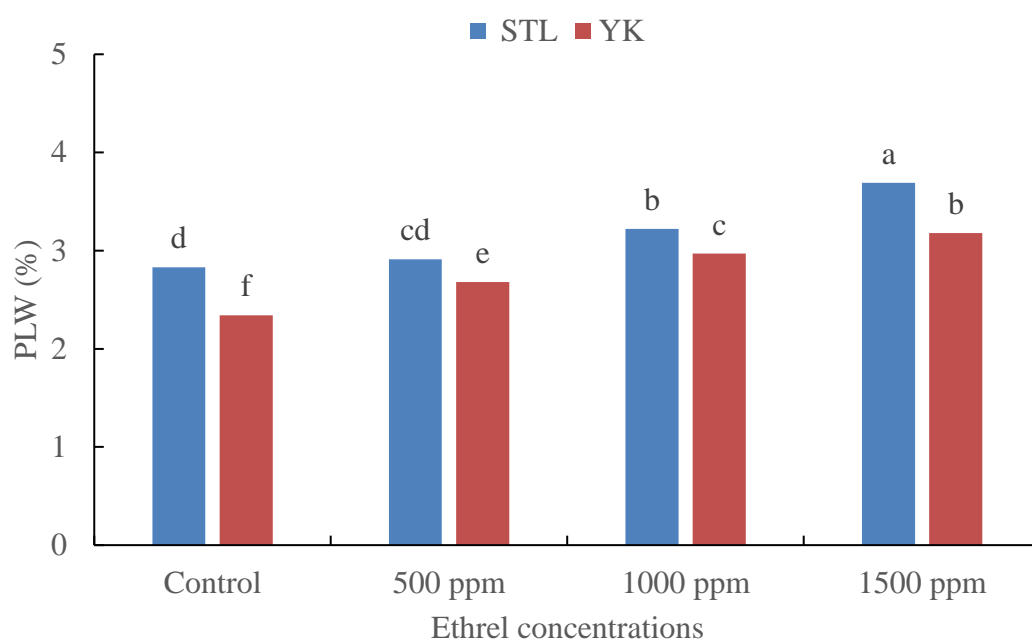


Figure 4.1 Physiological loss in weight of two mango varieties as affected by different ethrel concentrations during storage period

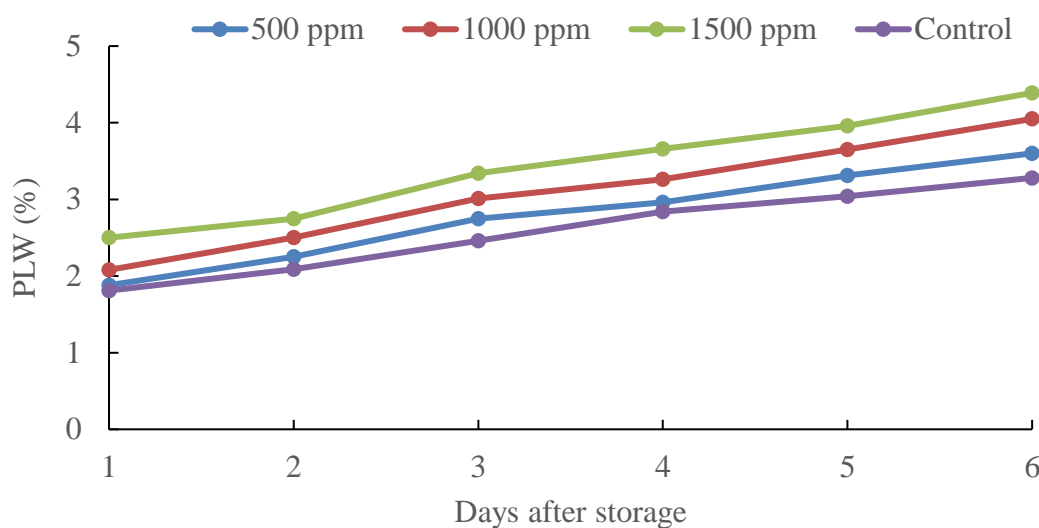


Figure 4.2 Progressive changes in physiological loss in weight of two mango varieties as affected by different ethrel concentrations during storage period

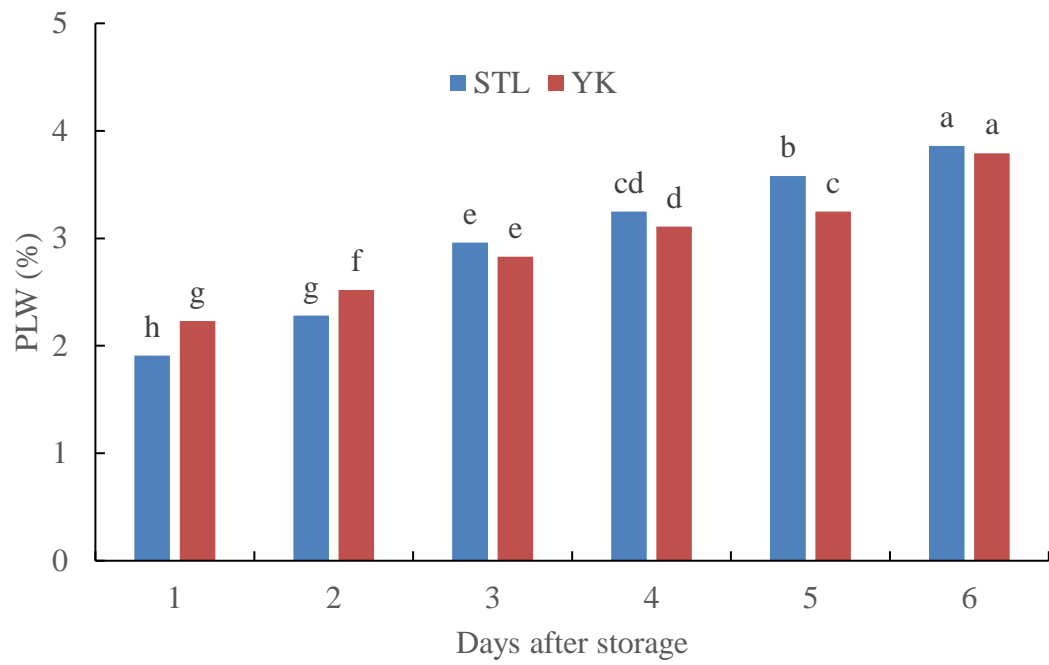


Figure 4.3 Physiological loss in weight of two mango varieties during storage period

4.2 Skin Firmness

Data presented in Figure (4.4) reveals the effect of different ethrel concentrations on skin firmness of two mango varieties of Sein Ta Lone and Yin Kwe. The ethrel-treated fruits drastically reduced the skin firmness when compared with untreated fruits. Effect of ethrel-treated fruits by 1000 and 1500 ppm on skin firmness were found to be at par with each other, however, the skin firmness of Sein Ta Lone was found to be significantly lower than Yin Kwe variety in all the treatments. The similar observation was made by Singh (2012) who also reported that the ethrel-treated fruits became soft with low skin pulp firmness than the untreated fruits due to triggering of ethylene production during the ripening process.

The skin firmness progressively decreased along the storage period. The rate of change in skin firmness was slow in control whereas it rapidly decreased in ethrel-treated fruits along the storage days (Figure 4.5). The differences among the treatments with respects to storage days were at par with each other. In this study, the higher the ethrel treatments, the hasten the ripening process.

The skin firmness of two mango varieties during ripening period is shown in Figure (4.6). Skin firmness of Sein Ta Lone variety showed lower values than that of var. Yin Kwe variety throughout the ripening period. Skin firmness of both varieties gradually decreased during the ripening period. The decrease in firmness during ripening may be due to breakdown of insoluble into soluble pectin or by cellular disintegration leading to membrane permeability (Brinston, Dey, Tohn & Pridhan, 1988). The similar observations were recorded by Dhillon and Mahajan (2011) in pear fruits and Hai et al. (2009) in Tron and Hai mangoes.

4.3 Pulp Firmness

The pulp firmness of two mango varieties as affected by different ethrel concentrations is presented in Figure (4.7). In general, pulp firmness of both varieties treated with ethrel was significantly reduced when compared with untreated fruits. The untreated fruits maintained the highest mean firmness followed by 500 ppm ethrel-treated fruits at the end of the experiment (Appendix 1). Pulp firmness of ethrel treated with 1500 ppm and 1000 ppm were at par with each other. Pulp firmness in both varieties decreased with the increase in ethrel concentrations. However, pulp firmness of var. Yin Kwe was found to be significantly higher than that of var. Sein Ta Lone.

Figure (4.8) depicts the progressive changes in pulp firmness of two mango varieties during ripening. The data revealed the firmness of the fruits during ripening period was significantly affected by different ethrel treatments. The pulp firmness of ethrel-treated fruits suddenly decreased during two days compared to untreated ones with the advancement of ripening period. As trigger the ripening process, the ethrel-treated fruits become soft, lower in both skin and pulp firmness than untreated fruits (Singh, 2012). However, the differences in pulp firmness among ethrel treatments on progressive change was found non-significant from 3rd day onwards.

Data presented in Figure (4.9) reveals pulp firmness of two mango varieties with the advancement of ripening. It was observed that mango var. Yin Kwe with ethrel treatment recorded higher pulp firmness during ripening as compared to var. Sein Ta Lone up to 4 days. However, there was non-significant difference in pulp firmness between the varieties at five day after storage.

4.4 Fruit Color

The fruit color development of mango vars. Sein Ta Lone and Yin Kwe is presented in Figure (4.10). It was found that ethrel treatment significantly enhanced the color development of both varieties. There was no significant difference in value of color development between 1000 ppm and 1500 ppm ethrel treatments. Between the two varieties, var. Sein Ta Lone developed significantly higher value of yellow color as compared to var. Yin Kwe (Appendix 1).

Fruit color due to ethrel treatments during ripening is presented in Figure (4.11). All fruits showed slightly increased in color development value with the advancement of ripening but fruits treated with 1000 ppm and 1500 ppm showed the higher value in yellow color than 500 ppm and control fruits. (Appendix 1). In Yin Kwe variety, yellow color did not develop until two days after storage. Fruits treated with 1000 ppm and 1500 ppm showed yellow color at three days after treatment with ethrel. Kyaw (2011) described that the increase in peel color during storage was probably due to the degradation of chlorophyll and increase in carotenoid pigments during ripening.

The data on fruit yellow color as affected by different varieties during ripening days is presented in Figure (4.12). The color development of var. STL was significantly higher than that of var. Yin Kwe (Plate 8 and 10).

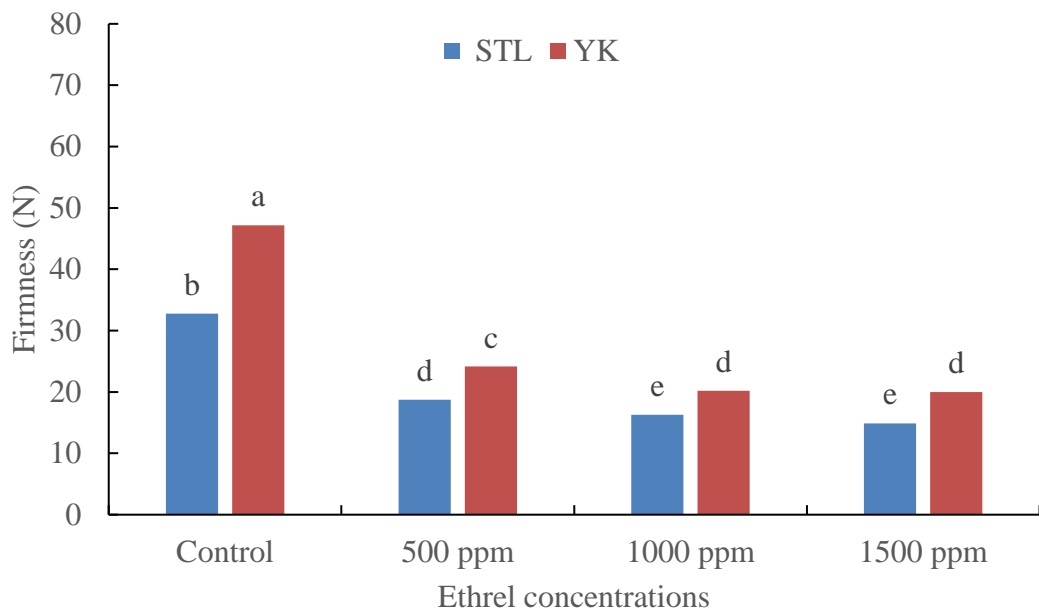


Figure 4.4 Skin firmness of two mango varieties as affected by different ethrel concentrations during storage period

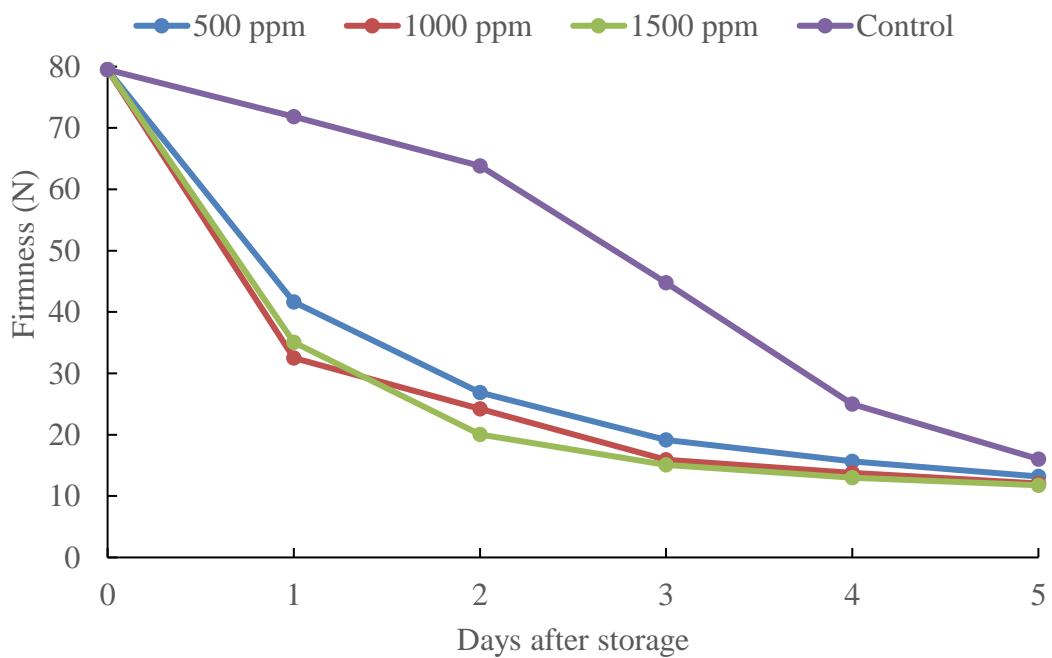


Figure 4.5 Progressive changes in skin firmness of two mango varieties as affected by different ethrel concentrations during storage period

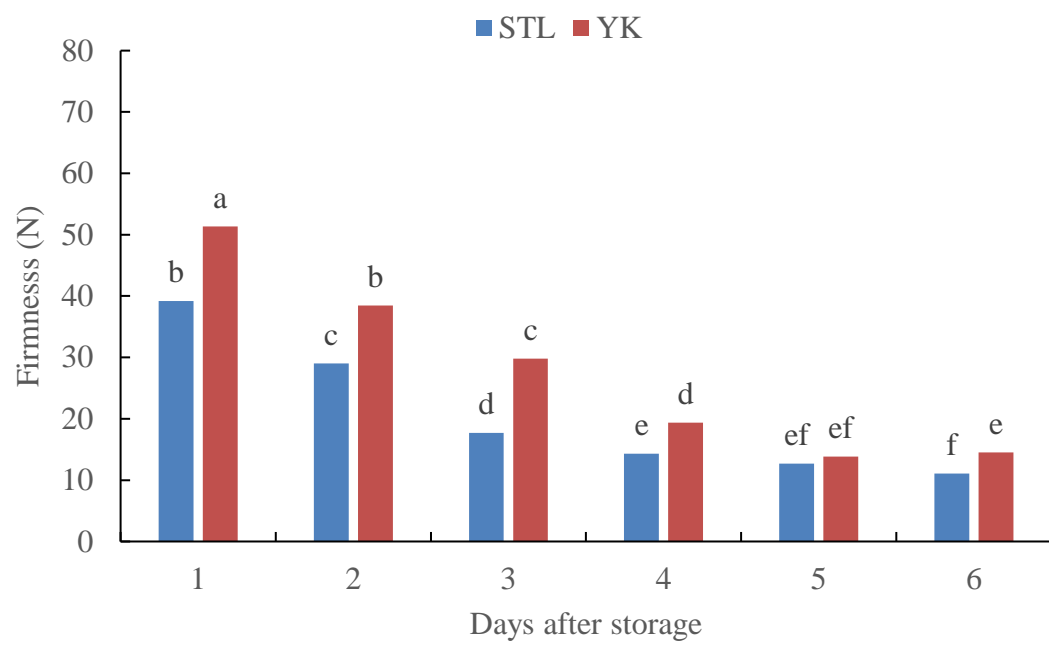


Figure 4.6 Skin firmness of two mango varieties during storage period

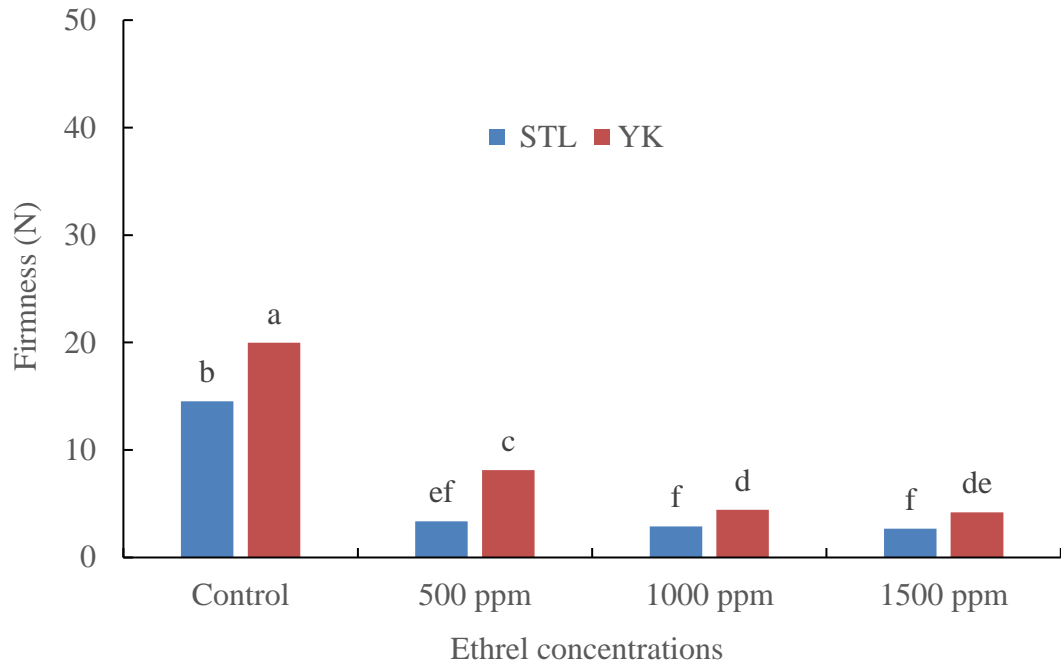


Figure 4.7 Pulp firmness of two mango varieties as affected by different ethrel concentrations during storage period

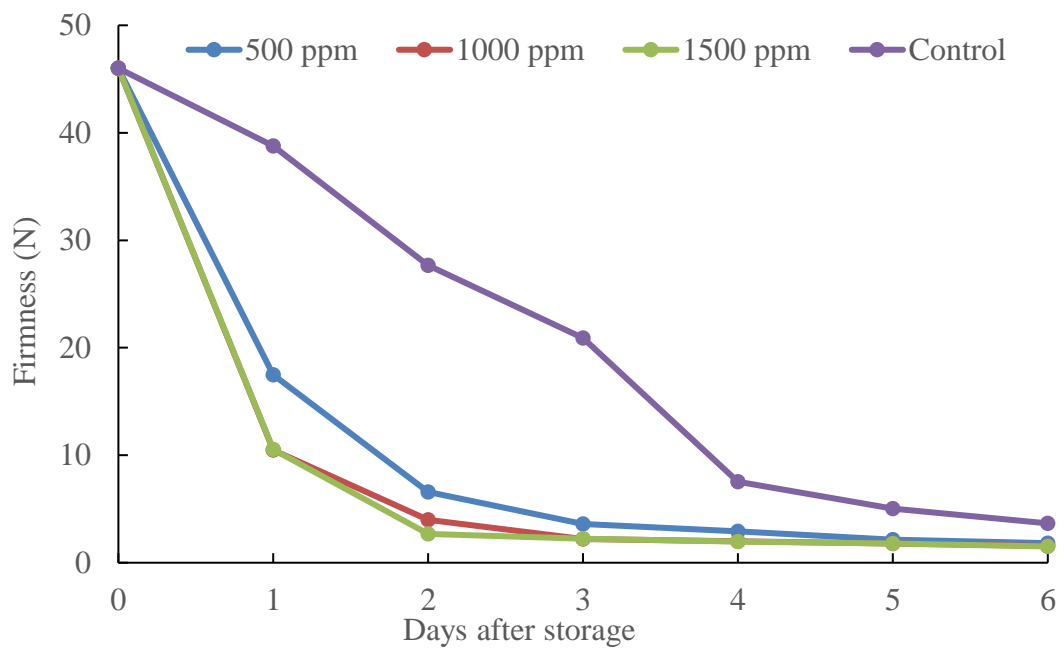


Figure 4.8 Progressive changes in pulp firmness of two mango varieties as affected by different ethrel concentrations during storage period

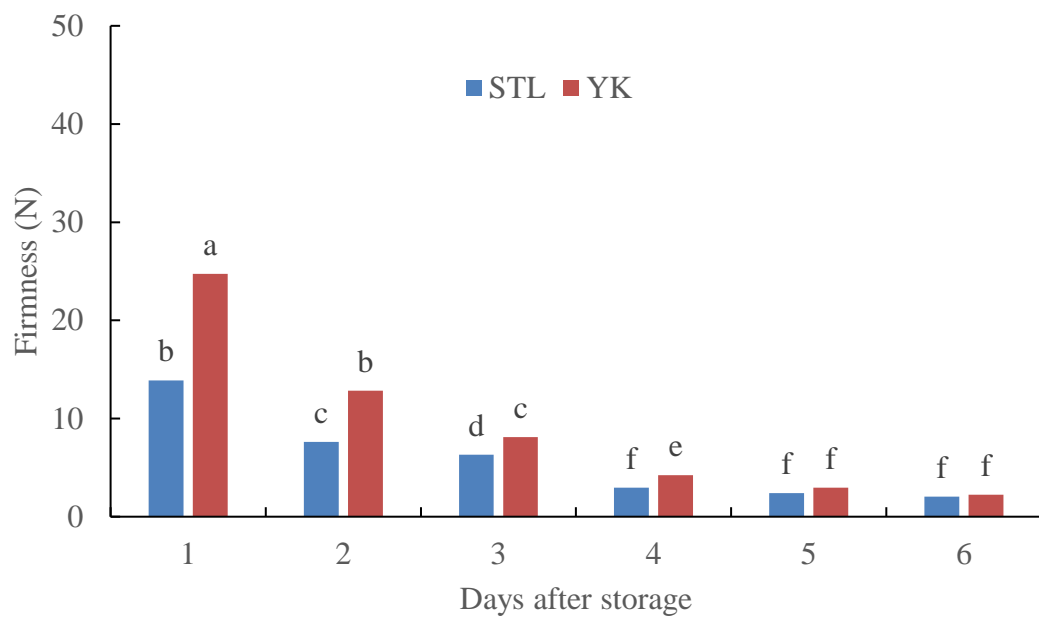


Figure 4.9 Pulp firmness of two mango varieties during storage period

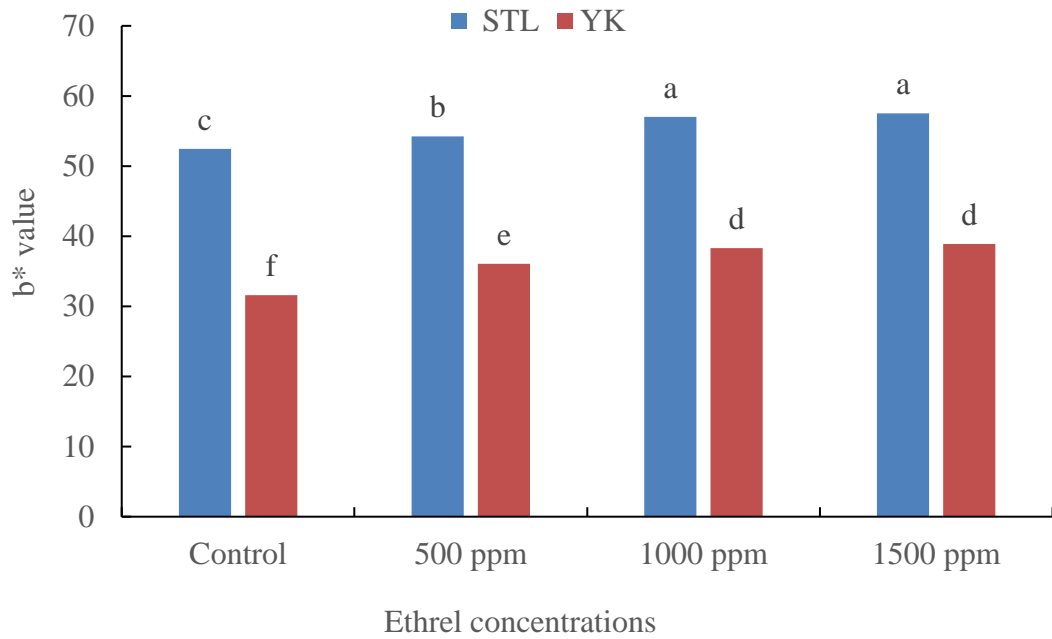


Figure 4.10 Color development of two mango varieties as affected by different ethrel concentrations during storage period

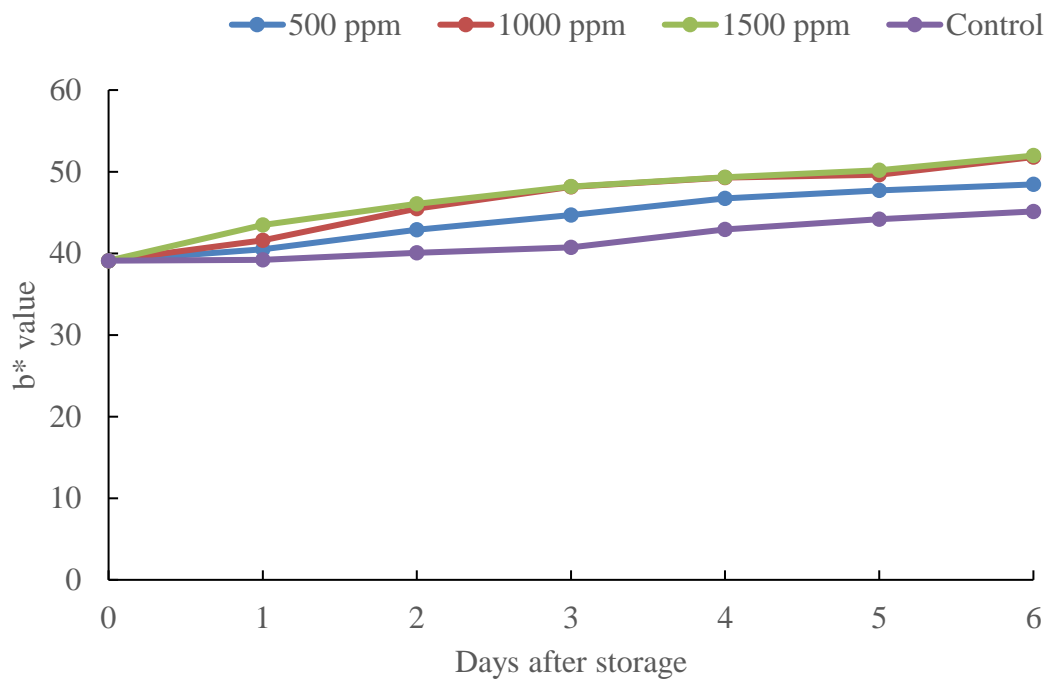


Figure 4.11 Progressive changes in color development of two mango varieties as affected by different ethrel concentrations during storage period

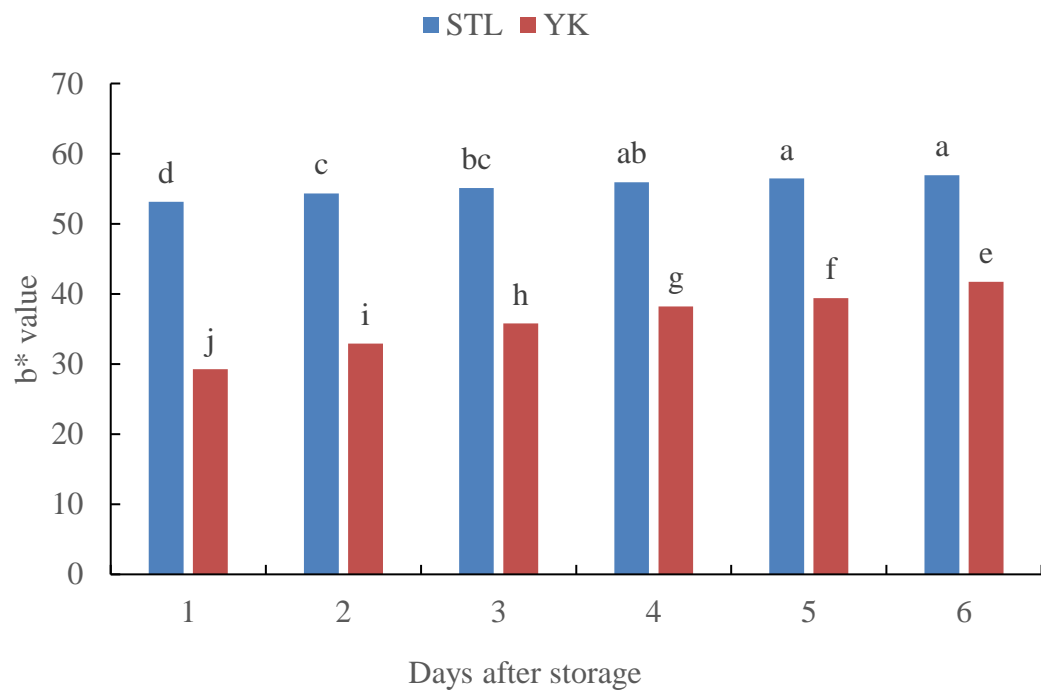


Figure 4.12 Color development of two mango varieties during storage period



500 ppm



1000 ppm



1500 ppm



Untreated

Plate 7 Color appearance of Sein Ta Lone variety as affected by different ethrel concentrations at 0 day after storage



500 ppm



1000 ppm



1500 ppm



Untreated

Plate 8 Color appearance of Sein Ta Lone variety as affected by different ethrel concentrations at 6 days after storage



500 ppm



1000 ppm



1500 ppm



Untreated

Plate 9 Color appearance of Yin Kwe variety as affected by different ethrel concentrations at 0 day after storage



500 ppm



1000 ppm



1500 ppm



Untreated

Plate 10 Color appearance of Yin Kwe variety as affected by different ethrel concentrations at 6 days after storage

4.5 Total Soluble Solid

Total soluble solid content is one of the most important quality attributes of ripe mango. The data presented in Figure (4.13) reveals total soluble solid content of two mango varieties as influenced by ethrel treatments. The untreated fruits showed the lowest TSS content and it was significantly lower than that of ethrel-treated fruits (Appendix 2). It was observed that ethrel treatments had significant effect on TSS of both Sein Ta Lone and Yin Kwe varieties. Fruits treated with ethrel 1500 ppm showed the highest TSS value which was closely followed by 1000 ppm ethrel-treated fruits in both varieties. However, TSS content of ethrel treated Yin Kwe variety was significantly lower than that of Sein Ta Lone. It can be assumed that ethrel-treated fruits hastened the physiological changes (PLW, respiration and ethylene production) that resulted in hastening of ripening process and hydrolysis of starch to sugar formation. The interaction between ethrel concentration and two varieties was also found to be highly significant which may be attributed to the genetic make-up.

It is evident from the Figure (4.14) that there was greatly influenced by ethrel concentrations on two mangoes varieties during storage days. The increase in TSS% was observed with the advancement of the ripening days. It was further observed that TSS content of both varieties increased slowly and steadily in all treatments during ripening period. This result is similar to the findings of Dhillon and Mahajan (2011). It was also observed that the increase in TSS during ripening was rapid up to 5th day and thereafter it remained almost steady.

It is evident from the data on Figure (4.15) that total soluble solid content of two mango varieties significantly increase with the advancement of the ripening days. There was not significant difference in TSS content of both varieties at the 1st day of the storage. However, the TSS content of Sein Ta Lone and Yin Kwe was significantly increased from the 2nd day to 6th day of the storage.

4.6 Total Titratable Acidity

The effect of ethrel treatments on total titratable acidity of mango var. Sein Ta Lone and Yin Kwe is presented in Figure (4.16). Total titratable acidity declined with the increase in ethrel treatment. Decline of TTA% was more in 1500 ppm compared to 500 ppm ethrel treatments. The lowest value of total titratable acidity was observed in 1500 ppm followed by 1000 ppm ethrel-treated fruits which were at par with each other (Appendix 2). In comparison of two varieties, var. Sein Ta Lone had low TTA%

compared to var. Yin Kwe. There was significant difference in TTA% among the ethrel-treated fruits.

The total titratable acidity progressively decreased with the advancement of storage period. The rate of change in total titratable acidity was slow in control fruits whereas it was rapidly decrease in ethrel-treated fruits with the advancement of storage days. Singh (2012) described that this was possibly due to hastening of ripening and faster respiration activities inside the fruit tissue by ethrel treatment. There was a significant difference in the total acid content of the fruits during the ripening days (Figure 4.17). This is agreed with the findings of Dhillon and Mahajan (2011) stated that the acid content in pear decreased significantly all the ethephon treatments during ripening.

According to the data presented in Figure (4.18), the amount of acidity in both varieties gradually decreased during the ripening period. Total titratable acidity in var. Yin Kwe is higher than that of var. Sein Ta Lone along the storage period. That might be due to genetic make-up.

4.7 Ascorbic Acid Content

Data presented in Figure (4.19) reveals the effect of different concentrations of ethrel treatment on ascorbic acid content of two mango varieties namely Sein Ta Lone and Yin Kwe. It was observed that ascorbic acid content declined by ethrel treatment. In general, the ascorbic acid content decreased in 500 ppm ethrel treatment. The decline in ascorbic acid content in 1000 and 1500 ppm was not significant irrespective to varieties. Mango var. Yin Kwe exhibited more loss of ascorbic acid due to ethrel treatment as compared to var. Sein Ta Lone. Different treatments showed a significant difference with untreated fruits with regard to ascorbic acid but not significant in varieties. In Sein Ta Lone variety, fruits treated with ethrel 500 ppm showed the highest ascorbic acid content among the treatments. Fruits treated with ethrel 1000 ppm and 1500 ppm were at par with each other in ascorbic acid content. In Yin Kwe variety, the lowest ascorbic content was observed in 1500 ppm ethrel-treated fruits, which was closely followed by 1000 ppm ethrel-treated fruits (Appendix 2). In this variety, ascorbic acid content was significantly higher in untreated fruits. The similar findings was that the low ascorbic acid in ethrel treated Alphonso mango could be due to triggering of ripening process with more utilization of ascorbic acid in the respiration process (Godambe, 2012).

The ascorbic acid content remarkably decreased with the advancement of the ripening period. There were significant differences in ascorbic acid content among ethrel treatments but no significant difference between two varieties (Figure 4.20). Orzolek and Argel (2011) also described that reduction in ascorbic acid content with the advancement of storage days might be due to rapid oxidation phenomenon of organic acid at ambient condition.

The data regarding the ascorbic acid content as affected by two varieties of Sein Ta Lone and Yin Kwe during ripening days is presented in Figure (4.21). Ascorbic acid content of both varieties was found to be significantly different up to 3 days after storage. After that it was not significant difference among them. With the advancement of ripening days, ascorbic acid content of both varieties gradually decreased. The interaction among the varieties and storage period significantly behaved with respect to ascorbic acid content.

4.8 Ethylene Production Rate

The data on the rate of ethylene evolution of two mango varieties as affected by different ethrel concentrations is presented in Figure (4.22). In general, var. Sein Ta Lone was observed to liberate more ethylene as compared to var. Yin Kwe. The ethylene evolution rate of both varieties increased with the increase in ethrel concentration. There were significant differences in ethylene production rate of both varieties in all the treatments. The highest ethylene production rate was observed in fruits treated with ethrel 1500 ppm which was followed by fruits treated with 1000 ppm whereas the lowest ethylene production rate was found in untreated fruits (Appendix 3). There was no significant difference on the rate of ethylene evolution between 1000 and 1500 ppm ethrel treated fruits in Yin Kwe variety whereas 500 and 1000 ppm in var. Sein Ta Lone (Figure 4.22). James (2007) described that increased ethylene synthesis at the onset of ripening is required for the normal ripening of many fruits.

The data pertaining with the ethylene evolution rate as affected by different ethrel concentrations during ripening days is presented in Figure (4.23). It was evident that ethylene production rate of all treatments increased with the advancement of the ripening days. Ethrel-treated fruits showed the highest ethylene production rate while untreated fruits showed the lowest rate. Ethylene liberation rate gradually increased up to 3 days after storage, after that it increased rapidly.

The data regarding the changes in the rate of ethylene evolution as affected by two varieties of Sein Ta Lone and Yin Kwe during ripening days is presented in Figure (4.24). From the findings, the ethylene evolution rate exhibited a steady increase up to 3rd day in both varieties. It was considerably lower in ethylene production rate in var. Yin Kwe compared to var. Sein Ta Lone. The var. Sein Ta Lone exhibited a sharp increase in ethylene evolution rate from 4th day onwards whereas gradual increase rate was observed in var. Yin Kwe on 5th day onwards. It can be assumed that the triggering of ethylene evolution was appeared 2 days after storage and that may result in more PLW for STL mango than var. YK. The trend of such increase in ethylene evolution with the advance of ripening is quite normal in mango due to its climacteric nature of respiratory metabolism (Soe, 2008). Significantly lower rate of ethylene evolution by var. Yin Kwe as compared to var. Sein Ta Lone has been observed as an important finding.

4.9 Respiration Rate

According to the Figure (4.25), respiration rate increased with the increase in ethrel concentrations. The var. Sein Ta Lone recorded significantly higher value of respiratory rate as compared to var. Yin Kwe when treated with ethrel with 1000 and 1500 ppm. Respiration rate was significantly higher in 1500 ppm ethrel treated fruits which was followed by 1000 ppm ethrel-treated fruits in both Sein Ta Lone and Yin Kwe varieties. Untreated fruits showed the lowest respiration rate compared to ethrel-treated fruits. Ethrel treated Sein Ta Lone variety showed the higher respiration rate than that of ethrel treated Yin Kwe variety (Appendix 3). This is similar to the findings of Goukh and Mohamed (2003) where untreated mango fruits showed the lowest respiration rate than ethrel treated ones. The interaction between ethrel concentrations and varieties was found to be highly significant.

The data related to progressive changes in respiration rate of mango as affected by different ethrel concentrations during ripening is presented in Figure (4.26). All treatments increased in respiration with the advancement of the ripening days. Khan and Raza (2013) described that respiration rate increased as fruit ripening period progressed. Fruits treated with ethrel 1500 ppm showed the highest respiration rate along the ripening days and untreated fruits showed the lowest respiration rate. The interaction between ethrel treatments and ripening days was found to be highly significant.

The data related to respiration rate of mango as affected by two varieties of Sein Ta Lone and Yin Kwe during ripening days is presented in Figure (4.27). In all ripening days, respiration rate of two varieties showed highly significant difference. Respiration rate of both varieties increased with the increased in the advancement of the ripening days. Respiration rate of var. Sein Ta Lone was higher than that of var. Yin Kwe along the ripening period.

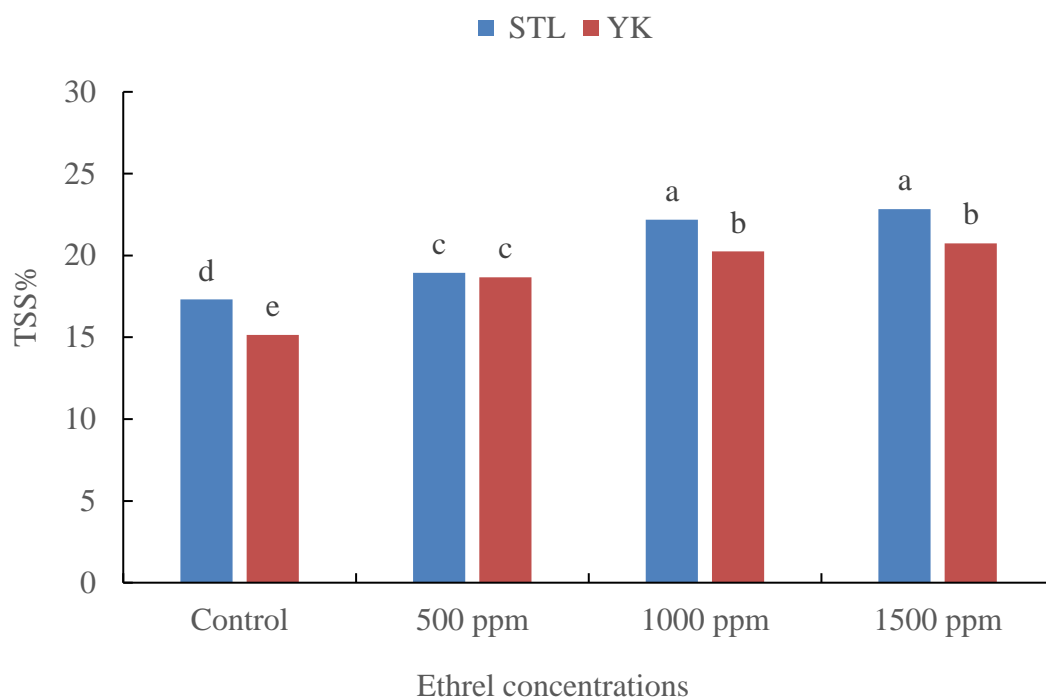


Figure 4.13 Total soluble solid content of two mango varieties as affected by different ethrel concentrations during storage period

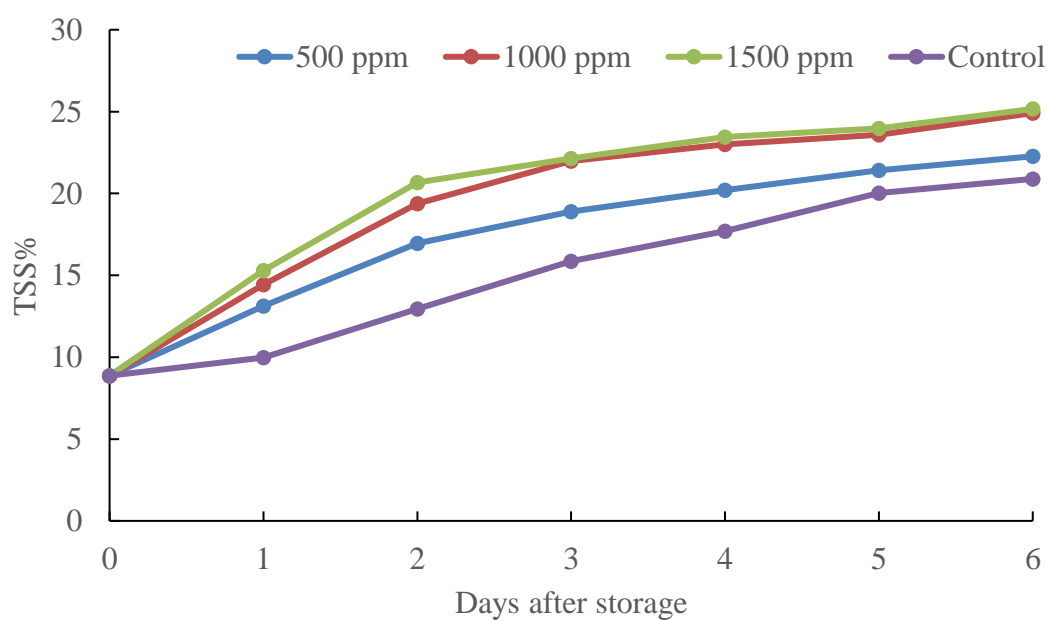


Figure 4.14 Progressive changes in total soluble solid content of two mango varieties as affected by different ethrel concentrations during storage period

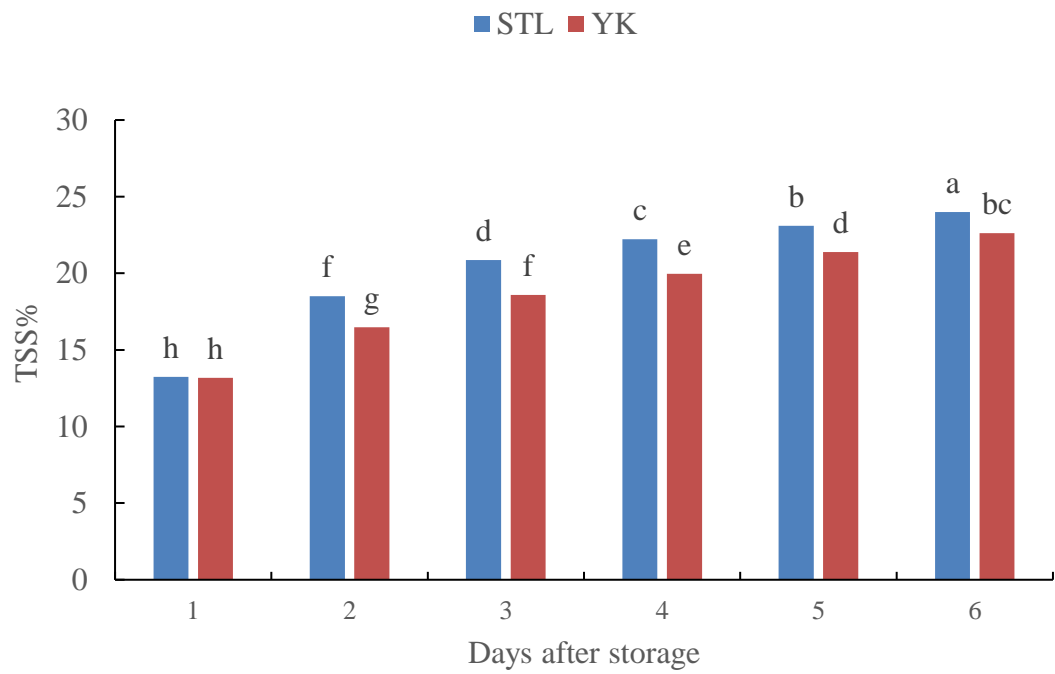


Figure 4.15 Total soluble solid content of two mango varieties during storage period

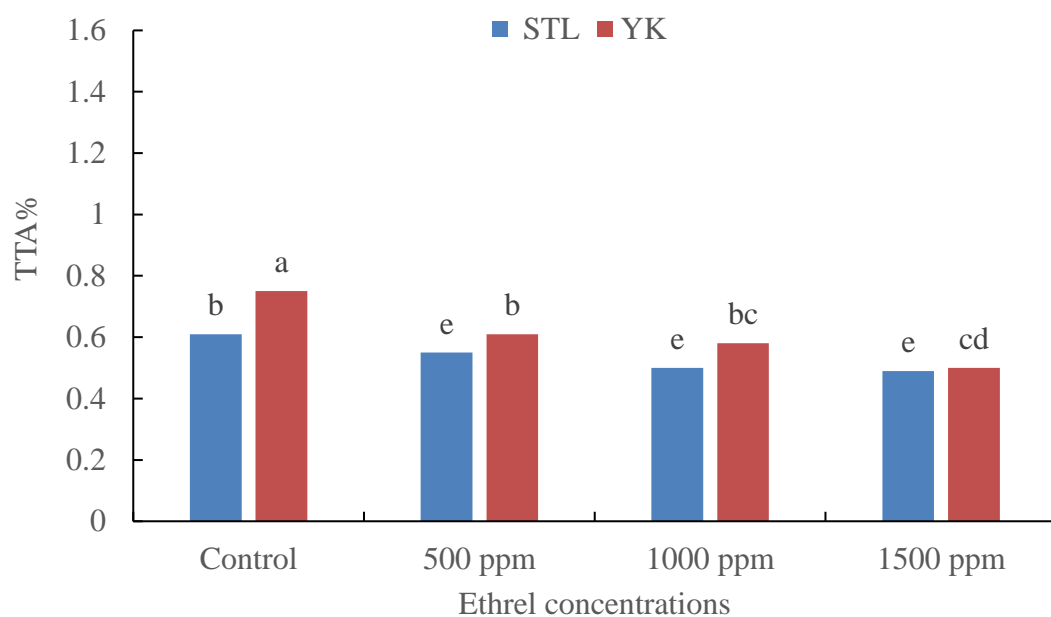


Figure 4.16 Total titratable acidity of two mango varieties as affected by different ethrel concentrations during storage period

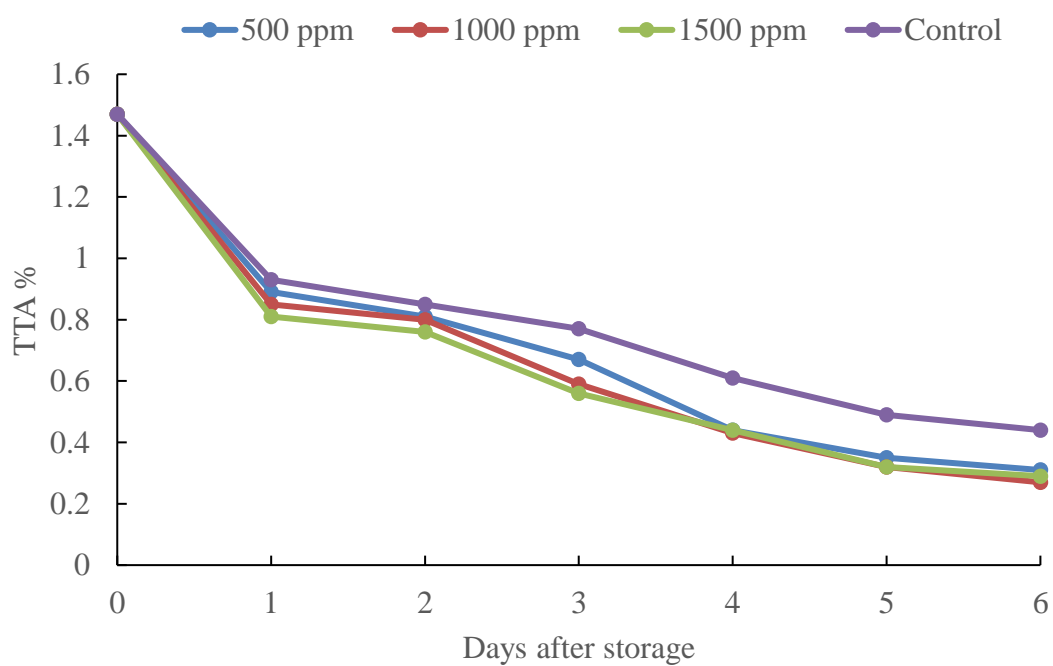


Figure 4.17 Progressive changes in total titratable acidity of two mango varieties as affected by different ethrel concentrations during storage period

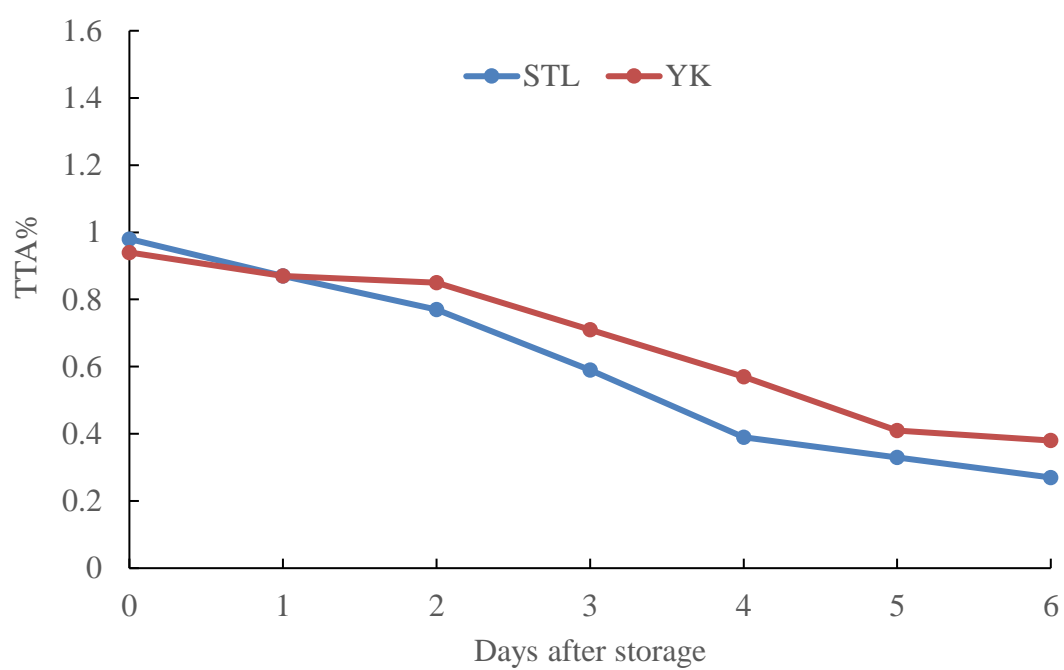


Figure 4.18 Total titratable acidity of two mango varieties during storage period

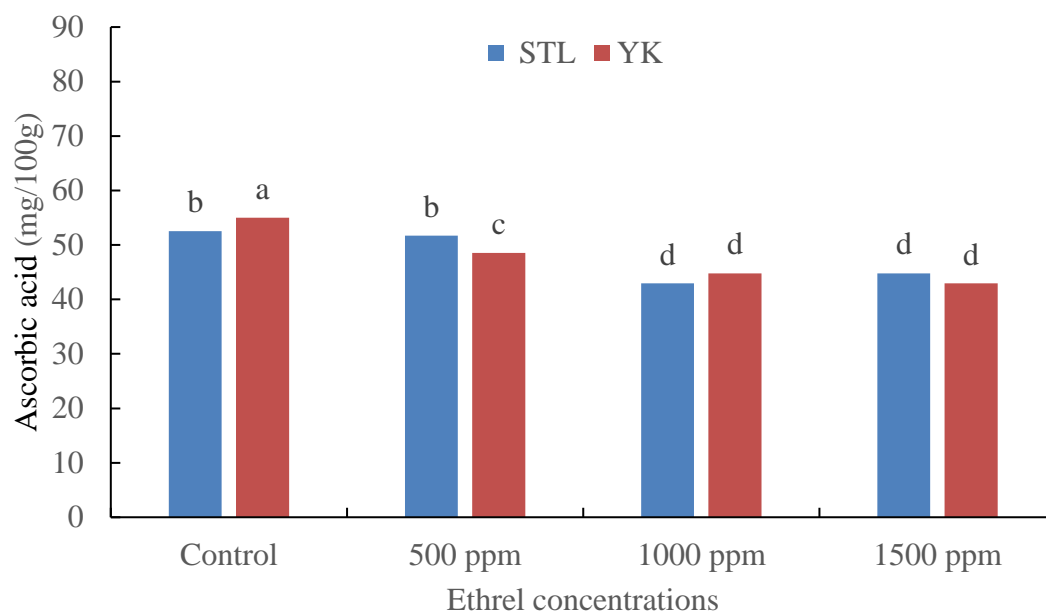


Figure 4.19 Ascorbic acid content of two mango varieties as affected by different ethrel concentrations during storage period

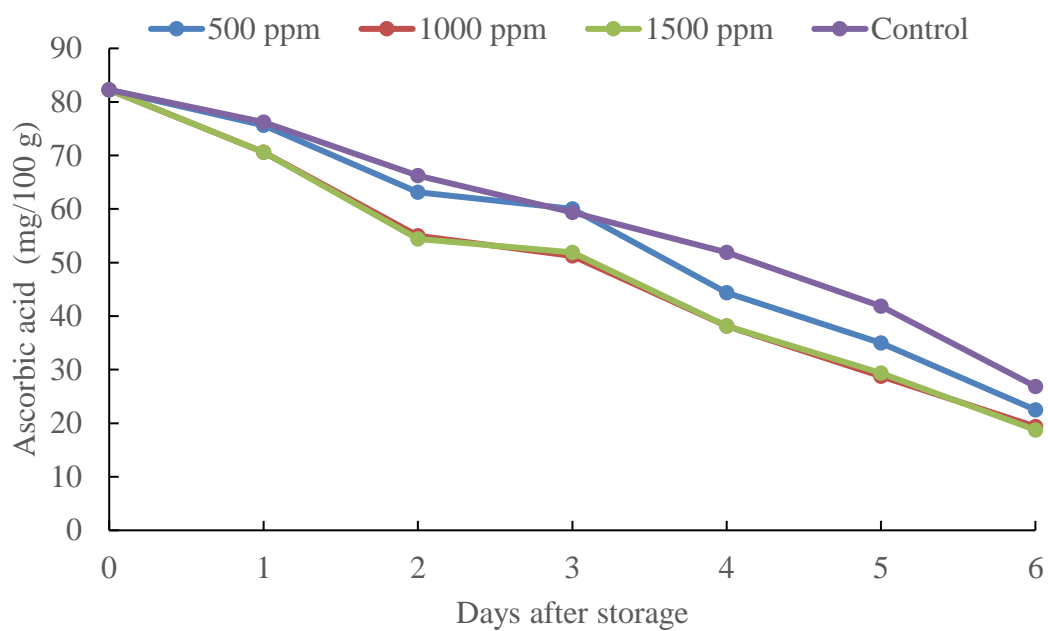


Figure 4.20 Progressive changes in ascorbic acid content of two mango varieties as affected by different ethrel concentrations during storage period

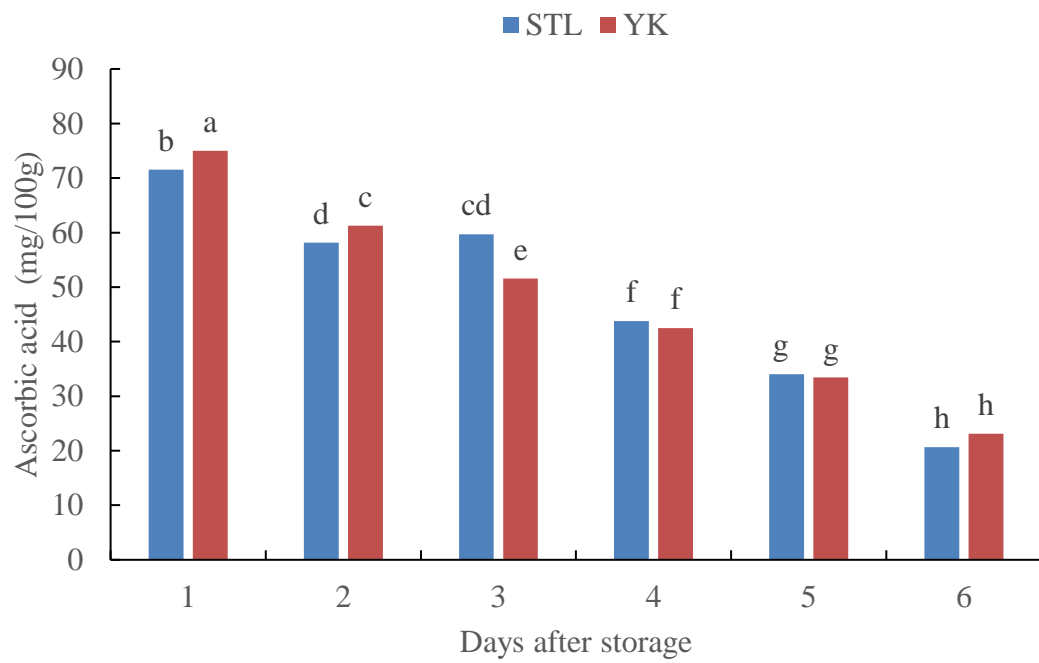


Figure 4.21 Ascorbic acid content of two mango varieties during storage period

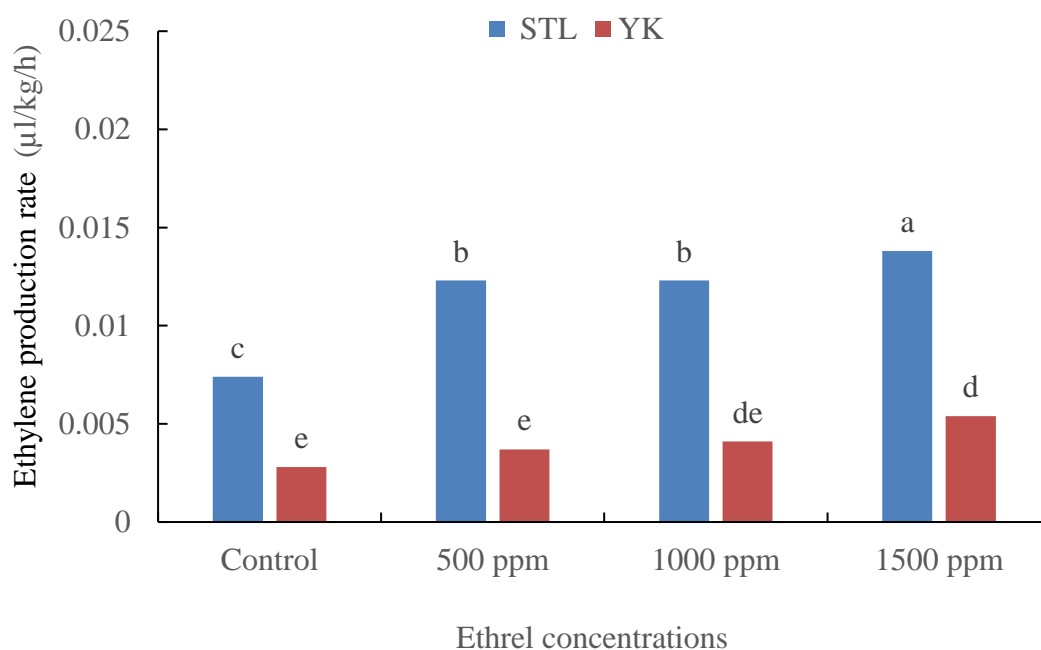


Figure 4.22 Ethylene production rate of two mango varieties as affected by different ethrel concentrations during storage period

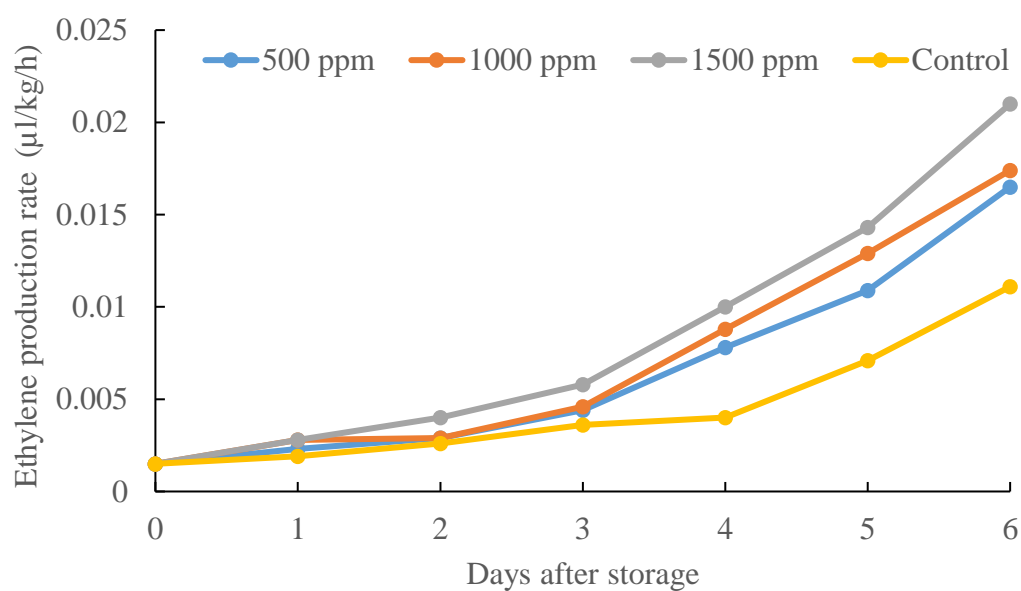


Figure 4.23 Progressive changes in ethylene production rate of two mango varieties as affected by different ethrel concentrations during storage period

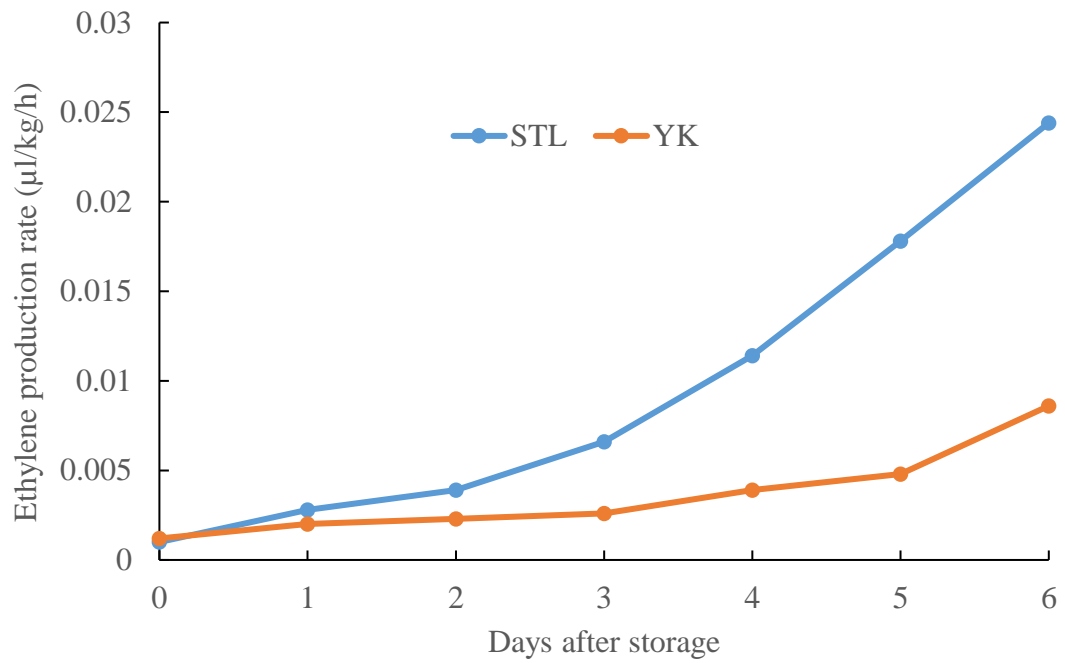


Figure 4.24 Ethylene production rate of two mango varieties during storage period

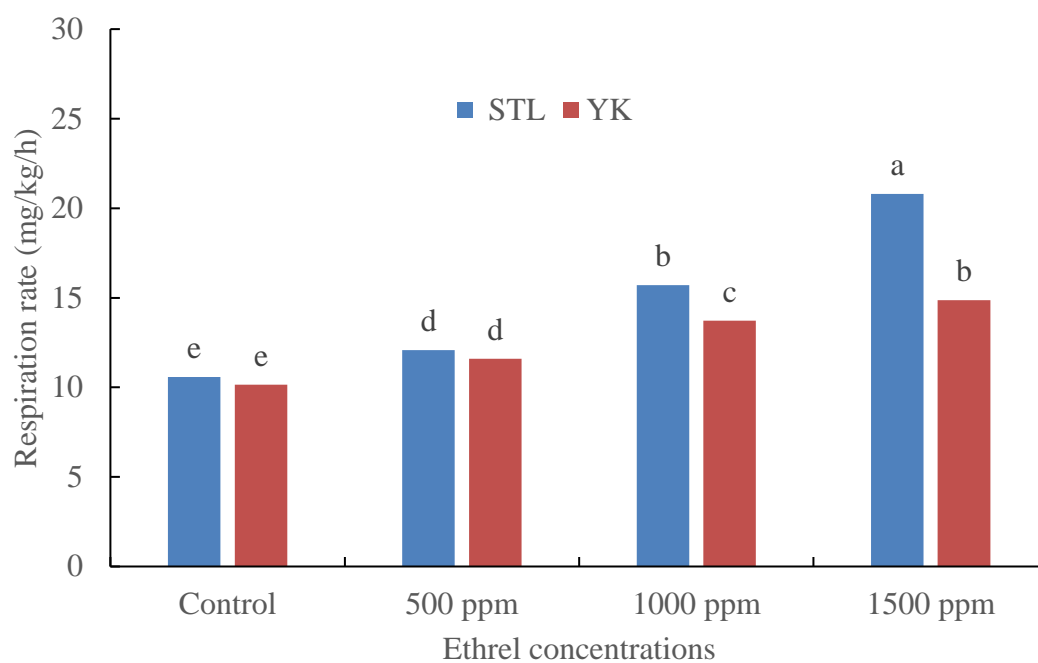


Figure 4.25 Respiration rate of two mango varieties as affected by different ethrel concentrations during storage period

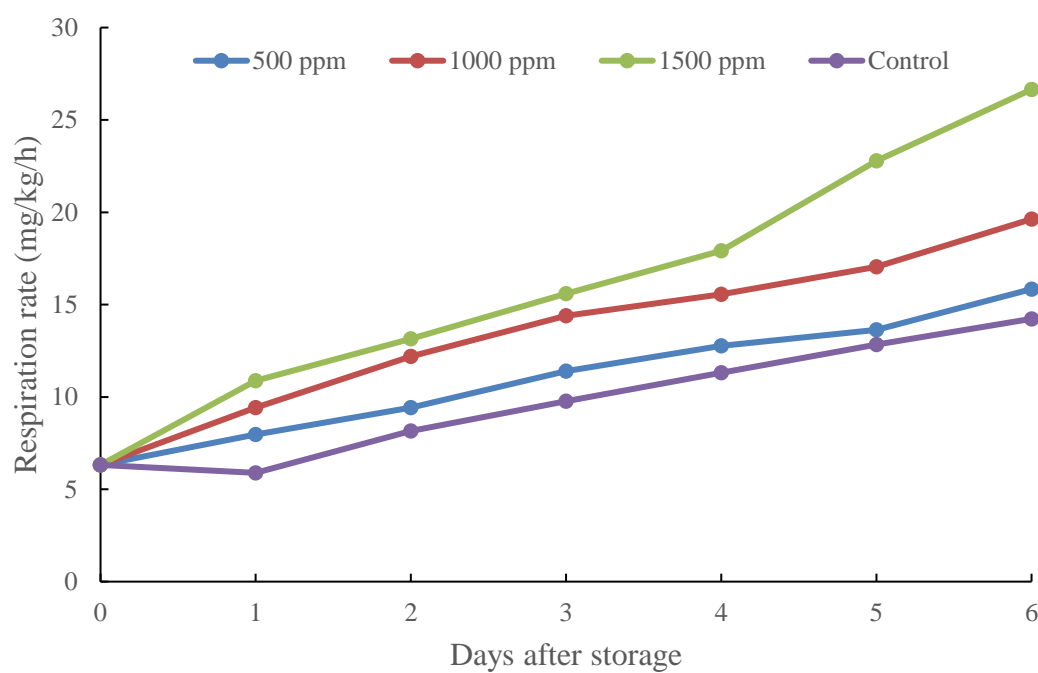


Figure 4.26 Progressive changes in respiration rate of two mango varieties as affected by different ethrel concentrations in mango

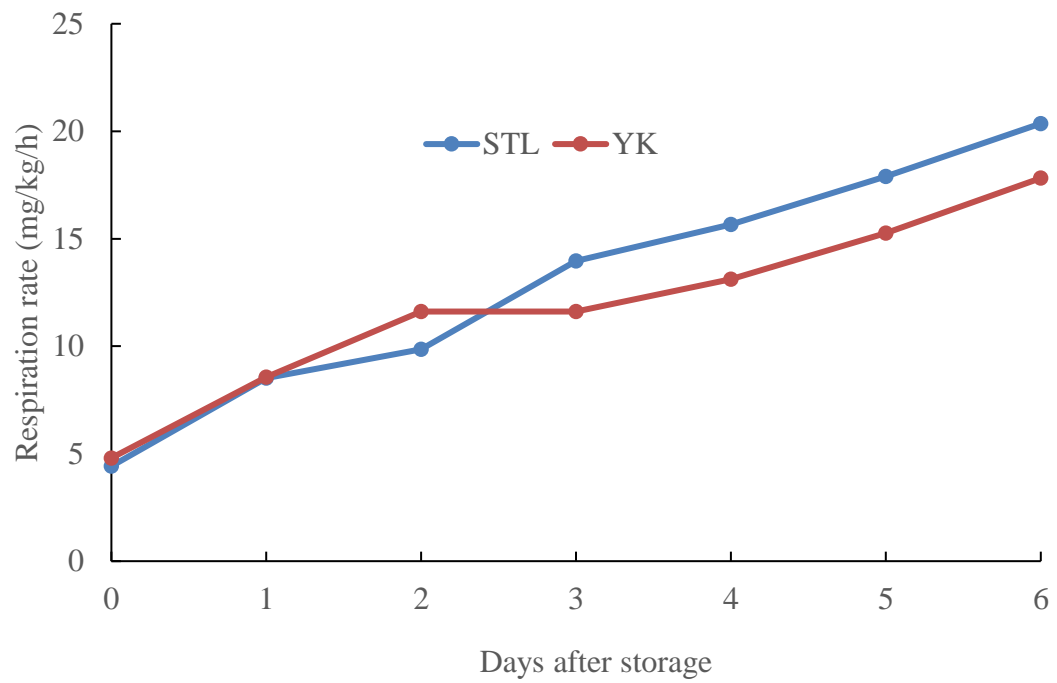


Figure 4.27 Respiration rate of two mango varieties during storage period

CHAPTER V

CONCLUSION

Nowadays, most of the sellers and traders widely use ethrel (2-chloroethyl phosphonic acid) as a ripening regulator for mango fruits to meet the early market demand. However, most of the sellers have poor knowledge on the use of regulators without limitation of dosage and concentration. This causes lack of food safety aspects, uneven ripening of fruits and postharvest losses. The present study revealed that the effective use of ethrel concentrations on the ripening process and quality of Sein Ta Lone and Yin Kwe mango varieties at ambient condition. Among the ethrel-treated fruits, 1000 ppm (2.5 ml/liter) and 1500 ppm (3.75 ml/ liter) not only considerable increased in color development and total soluble solid content with soft skin but also decreased total titratable acidity and ascorbic acid content. In the mango fruits treated with 1000 ppm ethrel, market acceptable fruits were observed at one day after storage in Sein Ta Lone and two days after storage in Yin Kwe. Untreated Yin Kwe mango failed to ripe uniformly and remained mature green stage at 5 days after storage. In this regard, 1000 ppm of ethrel treated Yin Kwe mango enhanced fruit ripening process for three days earlier than untreated fruits. The ethylene production rate of Yin Kwe variety was significantly lower than that of Sein Ta Lone variety regardless of ethrel concentrations. Thus, it could be assumed that the application of ethrel was more effective in ripening of Yin Kwe mango than Sein Ta Lone mango at ambient condition.

The use of high ethrel concentrations causes uneven ripening, postharvest losses and even health hazards. Therefore, ethrel dipping with 1000 ppm (2.5 ml/liter) was the most suitable concentration for both mango varieties due to less concentration of ethrel for food safety aspects and early market access. The beneficial effect of the present study is to overcome the problem of uneven and late ripening of Yin Kwe mango and to develop typical fruit flavor with marketable quality. Further research should be conducted in order to study the ripening characters of mango fruits by evaluating the ethylene gas in ripening chamber.

REFERENCES

- AOAC, 1990. Official Methods of Analysis. Association of Analytical Chemists. 15th Ed. Arlington, Virginia, 22201, USA.
- Bal, E. & Kok, D. (2007). The Effect of Glycerin Added Ethephon Treatment on Charactrists of *Actinidia deliciosa* Var. Hayward. Bulgarian. *Journal of Agricultural Science*, Vol. 13, 291-300.
- Brinston, K, Dey, P. M., John, M. A. and Pridhan. J, B. (1988). Post Harvest Changes in *Mangifera Indica* L. Mesocarp Wall and Cytoplasmic Polysaccharides. *Phytochem*, 27: 719-23.
- Chandel, R. (2014). Development of a Method for Safe Ripening and Removal of Calcium Carbide Residues in Traditionally Ripened Mango Frutis. College of Horticulture, University of Horticulture and Forestry, Nauni, India.
- Chauhan, Sandeep, k., Singh, P. & Jawa, N. K. (2012). Studies on the Standardization of Ripening Techniques for Oranges. *Journal of Stored Products and Postharvest Research*, Vol.3(8), 117-121.
- Das, S., Balamohan, T., Auxcilia, J. & Nalina, L. (2011). Early and Uniform Ripening of Mango var. Alphonso with Ethrel Treatement. *Journal of Horticulture*, Vol.6, No.1: 189-190.
- Dhall, R. & Singh, P. (2013). Effect of Ethephon and Ethylene Gas on Ripening and Quality of Tomato (*Solanum Lycopersicum* L.) during Cold Storage. *Journal of Nutrition and Food Sciences*, 3-6.
- Dharmasena, D. N. & Kumari, A. (2005). Suitability of Charcoal Cement Evaporative Passive Cooler for Banana Ripening. *Journal of Agricultural Science*, Vol.1(1): 19-30.
- Dhillon, S. W. & Mahajan, B. C. (2011). Ethylene and Ethephon Induced Fruit Ripening in Pear. *Journal of Stored Products and Postharvest Research*, Vol.2(3).45-51.
- DOA. (2011). Department of Agriculture, Myanmar Horticultural Crops Production Report. Ministry of Agriculture, Livestock and Irrigation:.
- DOA. (2018). Myanmar Horticultural Crops Production Report. Ministry of Agriculture, Livestock aand Irrigation: Department of Horticulture.

- Doke, N. D., Dhemre, J. K. & Kad, V. P. (2018). Effect of Ethylene on Qualitative Changes during Ripening of Mango (*Mangifera indica* L.) var. Kesar. *Journal of Current Microbiology and Applied Sciences*, Vol.7(2):1563-1571.
- FAOSTAT. (2007). Food and Agriculture Organization of the United Nations Database. Retrieved from <http://faostat.fao.org>.
- FAOSTAT. (2010). Food and Agriculture Organization of the United Nations Database. Retrieved from <http://faostat.fao.org>.
- FAOSTAT. (2012). Food and Agriculture Organization of the United Nations Database. Retrieved from <http://faostat.fao.org>.
- FSSAI. (2011). Food Safety and Standard Act 2006, Rules 2011, Regulations, 2011. 7th Edition, International Law Book Company, Delhi pp.643.
- Godambe, S. A. (2012). Studies on Effect of Ethrel on Ripening Behaviour of Mango (*Mangifera indica* L.) var. Alphonso. Department of Postharvest Management of Fruit, Vegetable and Flower Crops, Post Graduate Institute of Post Harvest Management, Dapoli.
- Goukh, A. & Ali, A. B. (2003). Changes in Pectic Enzymes and Cellulase Activity during Guava Fruit Ripening. *Journal of Food Chemistry*, 213-218.
- Goukh, A. & Mohamed H. E. (2003). Effect of Ethrel in Aqueous Solution and Ethylene Released from Ethrel on Mango Fruit Ripening, *Journal of Horticultural Science & Biotechnology*, 78 (4) 568-573.
- Hai, V. T. (2012). The Effect of Picking Time and Postharvest Treatments on Fruit Quality of Mango (*Mangifera indica* L.). Degree of Doctor of Philosophy, Institute of Crop Science, University of Hohenheim, Vietnam.
- Hai, V. T., Huong, P. T., Sruamsiri, P. & Hegele, M. (2009). Effect of Ethrel Postharvest Applications on Ripening of "Tron" and "Hoi" Mangoes. Conference on International Research on Food Security, Natural Resource Management and Rural Development.
- Herianus, J.D., Singh, L.Z, Tan, S. C. (2003). Aroma Volatiles Production during Fruit Ripening of Kensington Pride Mango. *Postharvest Biology and Technology*. 27:323–336.
- ITC. (2016). International Trade Centre, Global Import and Export Data.
- Ito, T., Sasaki, K. and Yoshida, Y. 1997. Changes in Respiration Rate, Saccharide and Organic Acid Content during the Development and Ripening of Mango Fruit

- (*Mangifera indica* L. 'Irwin') Cultured in a Plastic House. *Journal of Horticultural Science*. 66:629-635.
- James, J. G. (2007). Ethylene and Fruit Ripening. *Journal of Plant Growth Regulation*, 143-159.
- Jatinder, Singh, Bal, J. S., Singh, Sukhdip; Mirz & Snis;. (2018). Assessment of Chemicals and Growth Regulators on Fruit Ripening and Quality: A review. *Plant Archives*, 18(2), 1215-1222.
- Jiang, Y. & Joyce, D. (2000). Effect of 1-methylcyclopropene Alone and in Combination with Polyethylene Bags on the Postharvest Life of Mango Fruit. 137:321-327.
- Kadar, A. & Kasmire, R. (1984). Accelerated Ripening of Aphonso Mangoes by Application of Ethrel. *Journal of Tropical Science*, 17:95-101.
- Kaung, M. (2012). Export Conditions of Myanmar Mango: Hindrances and Opportunities in the Supply Chain. International Master in Horticultural Science.
- Kaur, S. (2017). Effect of Different Treatments of Ethrel on Ripening and Postharvest Quality of Mango (*Mangifera indica* L.) during Storage. *Journal of Applied and Natural Science*, Vol. 9 (1), 85-93.
- Khan, A. S. & Raza, S. A. (2013). Respiration Rate, Physico-chemical Fruit Quality and Consumer Acceptability for Fajri Mango under Different Storage Temperatures. *Journal of Agricultural Science*, Vol.50 (4), 585-590.
- Kulkarni, S. G., Kudachikar, V. B. & Vasantha, M. S. (2004). Studies on Effect of Ethrel Treatment on the Ripening Behaviour of Mango (*Mangifera indica* L.) variety 'Neelum'. *Journal of Food Science and Technology*, 41(2):216-220.
- Kyaw, P.N. (2011), Effect of Wrapping Materials and Potassium Permanganate on Postharvest Characteristics of Mango (*Mangifera indica* L.), M.Sc Thesis, Department of Horticulture, Yezin Agricultural University.
- Lei Yi, P.P., Soe, T.T., Yamamoto.Y. & Myint, K.T.D. (2019), Influences of Different Storage Conditions on Postharvest Quality of Mango (*Mangifera indica* L. cv. Sein Ta Lone), *Journal of Advances in Nutrition and Food Science*, Department of Food Science and Technology, Yezin Agricultural University, Naypyidaw, Myamar.
- Maduwanthi, S. & Marapana, R. (2019). Induced Ripening Agents and Their Effect on Fruit Quality of Banana. *International Journal of Food Science*.

- Medlicott, A. & Thompson (1985). Analysis of Sugar and Organic Acids in Ripening Mango Fruit (*Mangifera indica* var. Keitt) by High Performance Liquid Chromatography. *Journal of Science, Food and Agriculture*. 36: 561-566.
- Mehta P. M., Suma, T. K. & Prasad, T. K. (1980). Effect of Ethrel Treatment on the Treatment on the Postharvest Changes on the Turnover of Ascorbic Acid and Reducing Sugar in Achrassapota Fruits. *Journal of Biosciences*, 2(4):305-310.
- Moniruzzam, M., Khatoon, R., Hossan, M. F., Rahman, M. & Alam, S. (2015). Influence of Ethephon on Ripening and Quality of Winter Tomato Fruit Harvested at Different Mature Stages. Bangladesh. *Journal of Agricultural Science*, 40 (4):, 567-580.
- Naing, W. (2003). Effect of Modified Atmosphere Packaging (MAP) with and without Chemicals on Postharvest Characteristics of Mango (*Mangifera indica* L.) var. Sein Ta Lone. Master Thesis Dissertation. Department of Horticulture, Yezin Agricultural University, Nay Pyi Taw, Myanmar.
- Narong Chomchalow, S. S. (2008). Marketing and Export of Major Tropical Fruits from Thailand. *Journal of Agriculture*, 133-143.
- Nour, I., & Goukh, A. (2010). Effect of Ethrel in Aqueous Solution and Ethylene Released from Ethrel on Guava Fruit Ripening. *Journal of Agriculture and Biology*, North America.
- Orzolek, M., & Argel, F. (2011). Effect of Ethephon on Ascorbic Acid and Soluble Solids in Processing Tomato Varieties. *Journal of Horticultural Science*.
- Othmman, & Mbogo. (2009). Physico-chemical Characteristics of Storage Ripened Mango Fruit Varieties of Eastern Tanzania. *Journal of Science*. Vol 35.
- Pal, R. K. (1998a). Influence of Ethrel and Calcium Carbide on Respiration on Respiration Rate, Ethylene Evolution, Electrolyte Leakage and Firmness of Dashehri Mango (*Mangifera indica* L.). *Indian Journal of Agricultural Science*, 68 (4): 201-203.
- Palozza, N. (1992). Antioxidant Effect of Carotenoids in vivo and in vitro: An Overview on Methods of Enzymology. 213: 403-420.
- Rao, M., & Shrinath, M. (1989). Heat Unit Requirement for the Maturation of Mango Variety. Baneshan Syn. Banganpalli. *Indian Journal of Horticulture*, 24: 156-159.
- Rodriguez, D. A. (2001). A Guide to Carotenoid Analysis in Foods (Vol. 71): ILSI Press, Washington.

- Siddiqui, M. W., & Dhua, R. S. (2009). Standardization of Ethrel Treatment for Inducing Ripening of Mango var. 'Himsagar'. In Proceedings of International Conference on Horticulture (ICH-2009), Bangalore, 1641-1648.
- Siddiqui, M. W. (2008). Studied on Some Aspects of Mango Ripening . Department of Post-Harvest Technology of Horticultural Crops. Mohanpur, Nadia, India.
- Singh, P. D. (2012). Effect of Ethephon and Ethylene Gas on Ripening and Quality of Winter Tomato. Ludhiana, India: Department of Vegetable Science, College of Agriculture, Punjab Agricultural University.
- Singh, P., Kumar, V. & Malik, S. (2012). Effect of Physico-chemical Treatments on Ripening Behavior and Postharvest Quality of Amrapali Mango during Storage. *Journal of Environmental Biology*. 227-232.
- Soe, T. T. (2008). Studies on Improved Methods of Postharvest Storage of Mango Fruits. Tokyo University of Agriculture, Japan: Ph.D Thesis Dissertation, Department of International Agricultural Development, Graduate School of Agriculture.
- Thompson, A. K. (1985). Postharvest Losses of Bananas, Onions and Potatoes in PDR Yemen. Tropical Development and Research Institute, London, United Kingdom Contract Services Report CO 485, 41 pp.
- Vigneault, C., Raghavan, G., Markarian, N., De-Ell, J., Gariepy, Y. & Goyette, B. (2003). Techniques of Modified and Controlled Atmosphere Storage for Fresh Fruits and Vegetables. In: Dris, R., Niaskanen, R. and Jain, S. M. (eds.) Crop Management and Postharvest Handling of Horticultural Products. Vol. II. Fruits and Vegetables. USA, pp. 23-64: Science Publishers, Inc. Enfield (NH).

APPENDICES

Appendix 1 Mean comparison of peel color, skin firmness and pulp firmness

Treatment	Color	Skin Firmness	Pulp Firmness
Ethrel			
500 ppm	45.16 b	21.44 b	5.75 b
1000 ppm	47.65 a	18.24 c	3.67 c
1500 ppm	48.19 a	17.43 c	3.45 c
Control	42.03 c	39.96 a	17.26 a
LSD _{0.05}	0.66	1.66	0.67
P > F	**	**	**
Variety			
STL	55.31 a	20.66 b	5.87 b
YK	36.21 b	27.88 a	9.19 a
LSD _{0.05}	0.46	1.18	0.48
P > F	**	**	**
Day			
1	41.19 f	45.25 a	19.32 a
2	43.62 e	33.73 b	10.23 b
3	45.44 d	23.73 c	7.24 c
4	47.07 c	16.85 d	3.60 d
5	47.91 b	13.27 e	2.69 e
6	49.33 a	12.78 e	2.14 e
LSD _{0.05}	0.81	2.04	0.82
P > F	**	**	**
P > F			
Concentration x Variety	**	**	**
Concentration x Day	ns	**	**
Variety x Day	**	**	**
CV%	3.6	17.03	22.1

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$. * = significant at 5% level ** = significant at 1% level, ns = non-significant

Appendix 2 Mean comparison of total soluble solid (TSS%), total titratable acidity (TTA%) and ascorbic acid

Treatment	TSS %	TTA%	Ascorbic Acid
Ethrel			
500 ppm	18.81 b	0.58 b	50.10 b
1000 ppm	21.21 a	0.54 c	43.85 c
1500 ppm	21.78 a	0.53 c	43.85 c
Control	16.23 c	0.68 a	53.75 a
LSD _{0.05}	0.47	0.02	1.57
P > F	**	**	**
Variety			
STL	20.32 a	0.54 b	47.96 a
YK	18.7 b	0.63 a	47.81 a
LSD _{0.05}	0.33	0.02	1.11
P > F	**	**	ns
Day			
1	13.2 f	0.87 a	73.28 a
2	17.49 e	0.81 b	59.67 b
3	19.72 d	0.65 c	55.63 c
4	21.09 c	0.48 d	43.13 d
5	22.25 b	0.37 e	33.75 e
6	23.31 a	0.33 f	21.88 f
LSD _{0.05}	0.57	0.03	1.93
P > F	**	**	**
P > F			
Concentration x Variety	**	**	**
Concentration x Day	**	**	*
Variety x Day	**	**	**
CV%	5.92	9.05	8.15

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$. * = significant at 5% level ** = significant at 1% level, ns = non-significant

**Appendix 3 Mean comparison of physiological loss in weight (PLW%),
respiration rate and ethylene production rate**

Treatment	PLW%	Respiration Rate	Ethylene Production Rate
Ethrel			
500 ppm	2.79 c	11.84 d	0.033 b
1000 ppm	3.09 b	14.71 b	0.035 b
1500 ppm	3.43 a	17.83 a	0.042 a
Control	2.59 d	10.36 d	0.010 c
LSD _{0.05}	0.09	0.62	1.09
P > F	**	**	**
Variety			
STL	2.97 a	14.67 a	0.011 a
YK	2.98 a	12.70 b	0.004 b
LSD _{0.05}	0.06	0.44	7.14
P > F	ns	**	**
Day			
1	2.07 f	8.54 f	0.0024 e
2	2.40 e	10.73 e	0.0031 e
3	2.89 d	12.79 d	0.0046 d
4	3.18 c	14.34 c	0.0076 c
5	3.49 b	16.58 b	0.0113 b
6	3.83 a	19.09 a	0.0165 a
LSD _{0.05}	0.1	0.76	1.24
P > F	**	**	**
P > F			
Concentration x Variety	**	**	**
Concentration x Day	**	**	**
Variety x Day	ns	**	**
CV%	7.23	11.22	32.99

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$. * = significant at 5% level ** = significant at 1% level, ns = non-significant

Appendix 4 Daily record of minimum, maximum temperature and relative humidity at ambient condition

Date	Temperature (°C)		Relative humidity (RH)
	Minimum	Maximum	
1.5.2019	32	36	34
2.5.2019	33	36	36
3.5.2019	33	36	45
4.5.2019	33	36	46
5.5.2019	32	36	56
6.5.2019	31	35	50
7.5.2019	32	36	51
8.5.2019	31	35	48
9.5.2019	33	36	49
10.5.2019	32	37	44
11.5.2019	33	36	49
12.5.2019	32	36	49
13.5.2019	33	36	47
14.5.2019	33	36	51
15.5.2019	33	36	51
16.5.2019	33	36	48
17.5.2019	33	36	44
18.5.2019	33	37	54
19.5.2019	33	37	49