EFFECT OF DIFFERENT BAGGING MATERIALS ON QUALITY OF MANGO (*Mangifera indica* L. cv. Sein Ta Lone)

EI HAY MAN

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A thesis presented by

EI HAY MAN

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The thesis attached hereto, entitled **"Effect of Different Bagging Materials on Quality of Mango (*Mangifera indica* L. cv. Sein Ta Lone)"** was prepared under the direction of chairperson of the candidate's supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **MASTER OF AGRICULTURAL SCIENCE (HORTICULTURE).**

Dr. Than Than Soe
Chairperson of Supervisory Committee
Lecturer
Department of Horticulture
Yezin Agricultural University
Yezin, Nay Pyi Taw

Dr. Nyo Nyo
External Examiner
Supervisory Committee
Professor and Head (Retired)
Department of Horticulture
Yezin Agricultural University
Yezin, Nay Pyi Taw

Dr. Nyein Nyein Htwe
Member of Supervisory Committee
Lecturer
Department of Agronomy
Yezin Agricultural University
Yezin, Nay Pyi Taw

Dr. Yi Yi Soe
Member of Supervisory Committee
Assistant Lecturer
Department of Horticulture
Yezin Agricultural University
Yezin, Nay Pyi Taw

Dr. Khin Thida Myint
Professor and Head
Department of Horticulture
Yezin Agricultural University
Yezin, Nay Pyi Taw

This thesis was submitted to the Rector of the Yezin Agricultural University and was accepted as a partial fulfillment of the requirements for the degree of **MASTER OF AGRICULTURAL SCIENCE (HORTICULTURE).**

Dr. Tin Htut

Rector

Yezin Agricultural University

Yezin, Nay Pyi Taw

Date------------------------

DECLARATION OF ORIGINALITY

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

Ei Hay Man

Date------------------------

DEDICATED TO MY BELOVED PARENTS,

U SAN MYINT AND DAW MYINT MYINT OO

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ABSTRACT

Dr. Than Than Soe Ei Hay Man

The two experiments were carried out to evaluate the effect of different pre-harvest bagging materials on fruit quality of mango (*Mangifera indica* cv. Sein Ta Lone). They were conducted at the mango orchard of Department of Agricultural Research (DAR), Yezin during bearing season of 2011.

Fruits were bagged on 18-year-old Sein Ta Lone trees as the first experiment and 6-year-old trees as the second experiment. Randomized complete blocked design (RCBD) with ten replications was used in both experiments. Bagging materials were double-layer brown paper bag (Thai bag - TB), single-layer brown paper bag (China bag - CB), journal paper bag (JB), journal paper bag coated with glue (JBC), newspaper bag (NB) and unbagged fruits were treated as control. The data on fruit drop, fruit weight, fruit area, peel color, Brix % and defective fruit % were collected at harvest time. The fruits were stored to determine shelf life by the days at the end of the experiments.

In both experiments, bagging materials had significantly affected on peel color, defective fruit % and shelf life of Sein Ta Lone mango. Fruits bagged with bagging of JB, JBC and NB showed significantly lower defective fruit % than control fruits. Fruits treated with bagging of TB and CB not only improved peel color but also extended the shelf life (1-3 days) by reducing defective fruit %. These results indicated that bagging produced an unblemished and high quality fruit with preferable color leading to export market with higher prices for mango growers. Among the bagging materials, TB was the suitable one for bagging of Sein Ta Lone mango because it gave significantly the longest shelf life and better color development than others.

Key words: bagging materials, color development, defective fruit, shelf life, Sein Ta Lone mango

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1. INTRODUCTION

The mango (*Mangifera indica* L.), which belongs to the family Anacardiaceae, is one of the most important tropical and subtropical fruits of the world. The mango is indigenous to North-East India and North Burma, in the foot hill of Himalayas and is said to have originated in the Indo-Burma region (De Candolle 1904 and Popenoe 1920). It was found throughout South-East Asia and the Malay Archipelago in the early days. The cultivation of mango began at least 4000 years ago in India (De Candolle 1886) and its production has increased by nearly 2-3 times in these days (FAOSTAT 2007).

Mango has become a major fruit crop of the tropics and subtropics particularly in Asia where it has been considered the king of fruits (Purseglove 1972). Mango is an important fruit crop with world production being 38.67 million tons (FAO 2010). Worldwide mango production occurs in over 90 countries. Asia accounts for approximately 76.49 % of global mango production and the America and Africa account for approximately 12.62 % and 10.77%, respectively in 2010 (FAOSTAT 2012).

India was the largest producer among the mango producing countries, accounting for 42.25% of global production in 2010 with a yield of 14.34 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. Other leading mango producing countries and their respective share of world producing in 2010 include Pakistan (4.61%), Mexico (4.22%), Indonesia (3.40%), Brazil (3.07%), Bangladesh (2.71%), Philippines (2.14%), Nigeria (2.04%), Egypt (1.31%) and Peru (1.18%), respectively (FAOSTAT 2012).

Myanmar is the 6th largest country in mango production in Asia with annual growth rate of 19.8% in 2000. Mango is the most important commercial fruit in Myanmar. The variation of mango harvest period occurs in Myanmar due to the different climatic conditions and ecological zones. The harvest period of mango fruit could be available starting 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 (Soe 2008). Major mango producing areas are observed in the Regions of Ayeyarwaddy, Bago and Yangon, in the central Regions of Mandalay, Sagaing and in the Southern Shan State.

Mangoes are important sources of pro-vitamin A (carotenoids), particularly β-carotene (Rodriguez-Amaya 2001). These have diverse roles and benefits for human health including antioxidant activity, cell communication, immune function enhancement and UV skin protection (Palozza and Krinsky 1992). Apart from their importance in enhancing nutrition and food security, the mango fruits are increasingly being cultivated also for commercial purposes. Different cultivars of mango fruits are sold and consumed at different stages of maturity.

According to the Myanmar Mango Association, 40,000 tons of mangoes were exported mainly to China followed by Singapore and Bangladesh in 2009. The demand for mango in the world market is increasing day by day. The expansion of mango trade has been possible because of successful post-harvest management strategies to control diseases and pests (David and Dudandanrui 2010).

There are about 300 varieties and 20 kinds of mango species in Myanmar. Among them, there are only a few cultivars such as Sein Ta Lone, Yin Kwe, Shwe Hin Thar and Mya Kyauk which have exportable quality including sweetness level (Naing 2003, Soe 2008 and Myat 2012). Among these varieties, Sein Ta Lone possesses maximum total soluble solid (Brix%) 20-24, no fiber, very good flavor, proper shelf life and attractive yellow skin color (Ram 2002). Sein Ta Lone is not only a high quality variety but also probably one of the promising ones to be exported. It is grown virtually throughout the country on commercial scale not only for local consumption but also for export. In 2009, the mangoes were planted in Shan State and Mandalay Region 20,000 acres and 18,000 acres, respectively (David and Dudandanrui 2010). Despite having excellent eating quality, market potential is limited due to the appearance of black spots on skin reduces the fruit quality and the marketable fruits are lost by fruit flies.

In the international market, the quality of Myanmar mango is better than that of other countries (David and Dudandanrui 2010). Therefore it is essential to get high quality fruits for international markets. External appearance, internal quality and market quality of mango are influenced by several factors including pre-harvest production practices. The external appearance includes key attributes such as color, shape, size and free from any defect. The internal attributes such as taste, texture, sweetness, aroma, acidity, flavor, nutritional values and shelf life of the fruit are important for consumers. The physical appearance of the peel is especially important in the highly competitive export markets and in some local markets like the supermarkets. Buyers in these markets require consistent supplies of uniform colored fruit with blemish-free peels.

One of the most important constraints in mango production and export is pest infestation especially for fruit-fly. Fruit flies are particularly important in the fruit production for domestic consumption and export. The mango producers suffer significant direct economic losses (larval feeding renders fruit unmarketable) and indirect economic losses (quarantine restrictions hindering exports) resulting from the presence of fruit flies (Aluja and Mangan 2008). Allwood (1997) indicated that fruit fly damage can result in crop losses of as high as 20-25% in mango.

Fruit bagging is one of the best solutions to prevent the attack of fruit fly in mango and other tropical fruits (Yin 2010). Bagging of mango fruits during their development on the tree can reduce insect and disease damage (Hofman et al. 1999). Nowadays, bagging materials are used in apple, pear, peach, grape, banana, mango, longan, dragon fruit, litchi, carambola, custard apple, dragon fruit, Indian jujube, guava and citrus.

Fruit bagging may also enhance fruit appearance by providing protection from temperature extremes and from fruit abrasion. Market returns for mango in international markets are generally greatest for large fruit that are blemish-free (Johns 1996). The supply of blemish-free fruit is difficult due to various types of mechanical injury and insect damage imparted on the peel surface during growth and development due to wind and insects which are the principal agents of this damage (Anon 2003).

Bagging fruits are harvested without any disease and fruit fly infestation. The shelf life of such fruits also increases by two to three days (Pathak 2009). Fruit bagging is eco-friendly by reducing spraying insecticides and gives less hazardous to the consumers. Bagging is effective not only in controlling diseases and insects but also enhancing the appearance of the fruits and reduces chemical residues (Kitagawa et al. 2009). The bagging time for mango fruits is at 55 to 60 days from flower bloom or at the size of a chicken egg (Billah 2009).

In Myanmar, there are a few research papers about the effect of bagging materials on quality of Sein Ta Lone mango. These experiments were carried out with the following objectives:

(1) to evaluate the effect of different bagging materials on quality of Sein Ta Lone mango

(2) to examine the most suitable bagging material for commercial production of Sein Ta Lone mango

2. LITERATURE REVIEW

2.1 Origin and History of Mango

Mango is originated in the Indo-Burma region (Verheij 1991) and it is most likely originated in the South-East Asia, particularly in the Malay Archipelago (Mukherjee 1997). The domestication centers of mangoes are suggested in two main areas; one is in India and Myanmar with mono-embryonic mangoes and the other is eastern part of Assam with poly-embryonic mangoes (Bompart and Schnell 1997). De Candolle (1886) estimated that mango cultivation might have begun at last 4,000 years ago. There are many evidences of trade of mango in first countries of A.D. by Buddhist monks from India to Malay Peninsula (Opeke 1982). Bompard and Schnell (1997) revealed that mango had also spread via sea-trade between mainland and insular of South-East Asia.

2.2 Worldwide Mango Production

Worldwide mango production occurs in over 100 countries. The production covers approximately 4.2 million hectares and almost 80% of them are in Asia. The main mango producing countries in the world consisted in South Asia (India and Pakistan), South-East Asia (Thailand, Indonesia and Philippines), Africa (Nigeria and Sudan) and Central and South America (Mexico and Brazil). India is the highest producing country with 11 million tons followed by China and Pakistan, 3.6 million tons and 2.2 million tons respectively (FAOSTAT 2007). Within South-East Asia countries, Thailand is the biggest mango producer and the annual cultivation area is 6.5 million hectares in 2005. Mango cultivated in South-East Asia countries in 2005 were shown in Table 2.1.

Table 2.1 The cultivated area of mango in South East Asia

Country	Cultivated area (ha)	Country	Cultivated area (ha)
Thailand	684,000	Vietnam	127,200
Indonesia	656,256	Malaysia	12,240
Philippines	384,000	Cambodia	8,400
Myanmar	150,031	Laos	840

(Source; Htu 2007)

The Food and Agriculture Organization of the United Nations estimates worldwide production is nearly 35,000,000 tons (39,000,000 short tons) in 2009 (Table 2.3). The total production of the top 10 countries is responsible for roughly 80% of worldwide production. India is the biggest producer of mangoes. World mango production from 2005 to 2010 was described in Table 2. 2.

Table 2.2 The production of mango in the world (,000 ton)

Country	2005	2006	2007	2008	2009	2010
India	10,500	9,854	13,501	13,649	13,557	16,337
China	4,250	4,091	3,715	3,977	4,140	4,352
Thailand	1,803	2,094	2,303	2,374	2,470	2,551
Indonesia	1,413	1,622	1,819	2,105	2,243	1,314
Pakistan	1,674	1,754	1,719	1,754	1,728	1,784
Mexico	1,680	2,046	1,911	1,855	1,509	1,633
Brazil	1,002	1,217	1,272	1,155	1,198	1,189
Philippines	1,003	919	1,024	884	771	826
Egypt	380	597	532	466	534	506
Kenya	180	249	385	449	475	554
Peru	235	320	294	323	167	454
Colombia	185	184	193	175	187	243

Source: FAO (2010)

Table 2.3 Top producers of mangoes, mangosteens, guavas (2010-2011)

Country	Production (million tons)
India	16.34
China	4.35
Thailand	2.55
Pakistan	1.78
Mexico	1.63
Indonesia	1.31
Brazil	1.19
Bangladesh	1.05
World total	38.6

Source: UN FAOSTAT 2011

2.3 Mango Production in Myanmar

As a kind of native fruit in Myanmar, mango can grow well throughout the country under the various climatic conditions. It plays as the first major fruit crop in Myanmar and shares 11.85 % of the total fruit production of the country followed by cashew nut (DOA 2011). Soe (2008) mentioned that the majority (45%) of mango farms in the country was occupied by large farmers, followed by (25%) of the government estate and (30%) of the backyard farms and small farmers (3 ha and below). The maximum area is used for mango cultivation which is over 93, 890 hectares, harvested area was 76,313 hectares and the production was over 524,654 tons and the average yield was 6.88 ton per hectare (DAP 2013). Mango yield per hectare is still very low comparing to ASEAN and neighbor countries.

2.3.1 Varieties

There are many varieties of mango in Myanmar. At least two hundred varieties are recognized in the country. Names of the popular varieties are Aung Din, Bingalar-hteik-ni, Bingalar, Daw-tha-phyu, Hteik-ni, Ma-chit-su, and Mandalay- yin-kwe, Mya-kyauk, Maung-yin-pan-swe, Ma-soemin, Manaw-nwe, Moot-the, Ma-thi, Oo-cheik, Oo-shit, Pan-swe, Pya-yae-san, Pya-yae, Sai, Shwe-wine, Shwe-ni, Shwe-hin-thar, Sin-swe, Sein-sa, Thone-lone-ta-taung, Tha-Kyar, Wa-so, Shwe-pha-lar, Sin-paung, Ngwe-thaw, Mandalay-sein-ta-lone, Pata-mya and Mataya- khaung-choe (MAS 2005).

Sein Ta Lone is the famous and popular mango among hundreds of varieties in Myanmar. Sein Ta Lone means solitary diamond. It means this mango is precious like a diamond for the mango lovers because of its flavor, aroma and color. Sein Ta Lone is fiber-less pulp with yellowish color. It has lovely appearance with pointed part like a beak. Nowadays, Sein Ta Lone is the most important cultivar commercially grown in Myanmar (MAS 2005).

2.3.2 Export market

In Myanmar, mango production was increased year by year and have been exported oversea since 1985-1986. Sein Ta Lone, Mya Kyauk and Shwe Hin Thar are the most popular varieties for oversea export. Myanmar mango is largely exported to China, Singapore and recently for some European countries (Mon 2003). The main production areas of mango varieties for export are Sagaing and Monywa, Mandalay, Taunggyi, Pyay, Taungoo, Ayeyarwady and Yangon. The exportable quality mangoes were produced from Mandalay Region was sent to China by truck via Muse border trade and to Singapore via Yangon International airport. Myanmar mangoes were sent to Malaysia and Singapore with 1.3 ton in 1997-1998 (Wai 2004). China is currently the main importing country for Myanmar mango with attempt to increase export market and which was reconnected to Singapore in 2010 (Myat 2012). The exported volumes, average price and value of fresh mango from Myanmar (2007 to 2012) are shown in Table 2.4.

Table 2.4 Exported volumes, price and value of fresh mango from Myanmar (2007-2012)

No.	Year	Export volume (000 MT)	Value (million US$)	Major country
1	2007-2008	16.70	6.99	China
2	2008-2009	21.76	6.62	China
3	2009-2010	44.361	11.94	China
4	2010-2011	34.28	10.73	China, Singapore
5	2011-2012	39.91	13.48	China, Singapore, Thailand

Source: MFFVPEA (2012)

2.4 Morphological Structures of Mango Fruit

Mango fruit is different in size, shape, color, fiber content, aroma, flavor and taste depending on cultivars. Mango fruit is a large fleshy drupe containing mesocarp of varying thickness. The fruit can be divided into three parts, i.e. exocarp, mesocarp and endocarp (Figure 2.1). The exocarp is the part that protects the fruit that is initially green and later changes to yellow or reddish depending on the cultivar and stage of ripening and waxy. The mesocarp is the fleshy edible portion or the pulp which is always yellow due to the presence of carotenoids. The endocarp is a thick and leathery covering of the seed. The fruit has a single seed in the middle of the fruit which is large, flat, and ovoid-oblong shaped (Tharanathan et al. 2006).

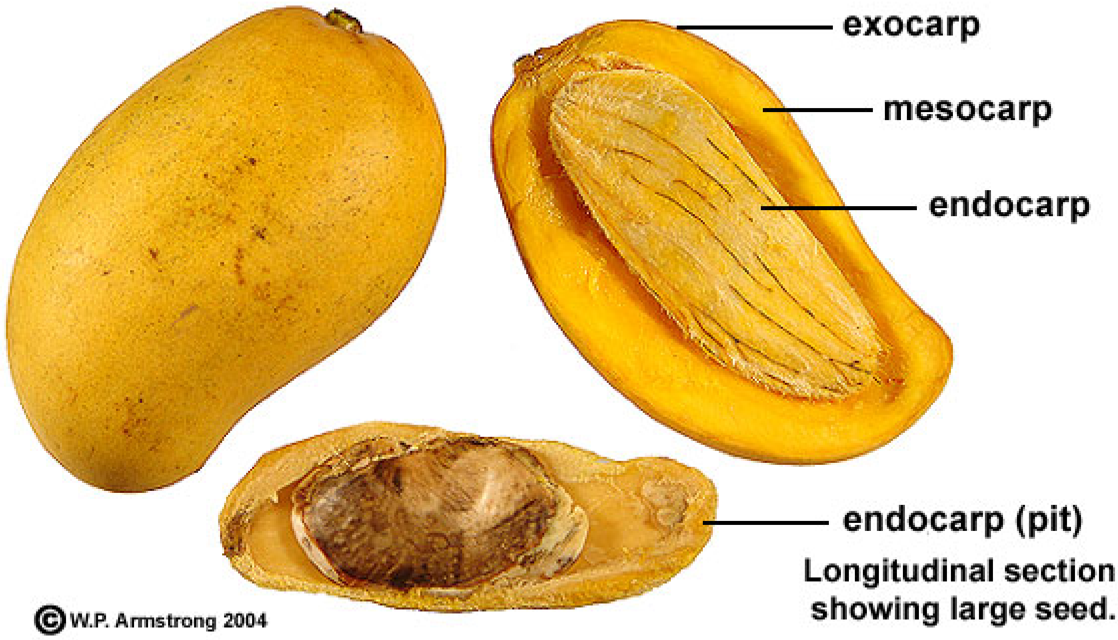


Plate 2.1 Morphological structure of mango fruit

2.5 Mango Fruit Anatomy

The anatomical characters such as nature of fruit wall and nature of dermal system vary depending on kinds of fruits. The fruit wall greatly influences the effect of the environment on the organs and its susceptibility to mechanical damage, insects and diseases. In mango fruit, the fruit wall is composed of very compact parenchyma cells which mean less intercellular spaces for gas exchange between the fruit and the atmosphere unlike banana, which has loosely arranged cells (Nuevo et al. 1984).

The nature of the dermal system accounts for a lot of the observed post-harvest behavior of fresh produce since it regulates many processes such as moisture loss, penetration of microorganisms and chemicals, volatilization of aromatic compounds, textural changes, flavor deterioration, absorption of chemicals and gas exchange. Parts of dermal system inside the epidermal layer, cuticle, stomata and lenticels and emergences such hair and spines (Pantostico et al. 1975).

In post-harvest discoloration of mango fruit, lenticel is a major problem and detracts from the aesthetic value of the fruit. It is unacceptable to consumers, consequently depreciating the economic value of the fruit.

Lenticels are microscopic openings occurring on stems, pedicels, old roots where the periderm (cork) has formed and on several fruit types including apples, pears, avocados and mangoes (Dietz et al. 1988).

Lenticels differentiate from existing stomata that lose their function and protrude above the fruit surface as a result of rapid cell divisions in the epidermis of the exocarp. An interaction between naturally occurring pigments and sap from the resin ducts in the exocarp appears to be another reason for lenticels discoloration (Bezuidenhout et al. 2004). Dietz et al. (1988) maintained that lenticels may originate in one of two ways: from a preformed stoma, or by shearing of the fruit epidermis as a result of rapid fruit growth.

Lenticel spot is characterized by the development of small spots of corky tissues in the skin lenticels that darken as the fruit changes color during ripening, which makes the fruit unmarketable. The causes are not entirely uncertain but it is most often associated with incorrect postharvest practices including low storage temperatures, high humidity of the storage atmosphere, excessive immersion time in postharvest dips and excessive detergent in wash water (Mauseth 1998).

O'Hare and Prasad (1992) showed that one of the most important causes of lenticel discoloration was leakage of sap from associated resin ducts into the lenticels. The sap in mango fruit is under high pressure and it is well-known that large amounts of sap exuded from the cut petiole after the fruit has been picked. Mango sap consists of two distinct components, an oil fraction and a protein-polysaccharide fraction (Joel and Fahn 1980). Moreover, Loveys et al. (1992) found that the sap came into the fruit skin, these two components separated and the oil component that was responsible for lenticel discoloration.

To determine the causes and timing of fruit lenticel discoloration, fruit anatomy from anthesis up to maturity was examined microscopically (Tamjinda et al. 1992). Initially, lenticel discoloration occurred in the form of a light purple spot surrounding the lenticel and seen in transverse section, this particular type of lenticel had vacuolar accumulation of pigmentation (Plate 2.2: A-C). In black, discolored lenticels there was no vacuolar pigmentation but the cell walls were discolored by natural pigmentation. (Plate 2.2: D).

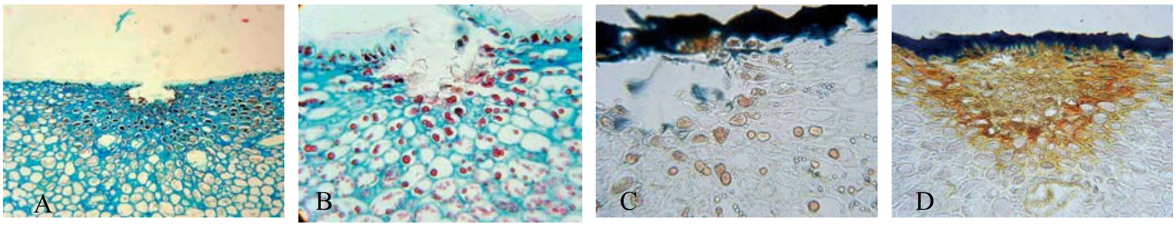


Plate 2.2 Transverse sections of exocarp of mature Tommy Atkins mango: (A and B) lenticels subtended by cell containing pigments that stained red, (C) staining of cuticle and (D) natural pigmentation of the lenticels walls in the absence of chemical staining

Source: Bezuidenhout et al. 2004

Stomatal guard cells were still functional at this stage but, due to increased anticlinal cell division and radial elongation of epidermal cells in fruit up to 6 mm in length (Plate 2.3 A), most stomata were present in the top half of the epidermis. Continued anticlinal cell division of epidermal cells resulted in the fruit surface adopting an undulating appearance (Plate 2.3 B, C) and stomatal guard cells became elevated above the fruit surface resulting in volcano-like protuberances on the fruit surface in fruit up to 13 mm in length. As fruit continued growing up to 20 mm in length, there was a marked decline in anticlinal cell division of epidermal cells concurrent with enlargement of the sub-epidermal cells, resulting in rupturing of the stomata (Plate 2.3 D) and loss of undulation of the epidermis.

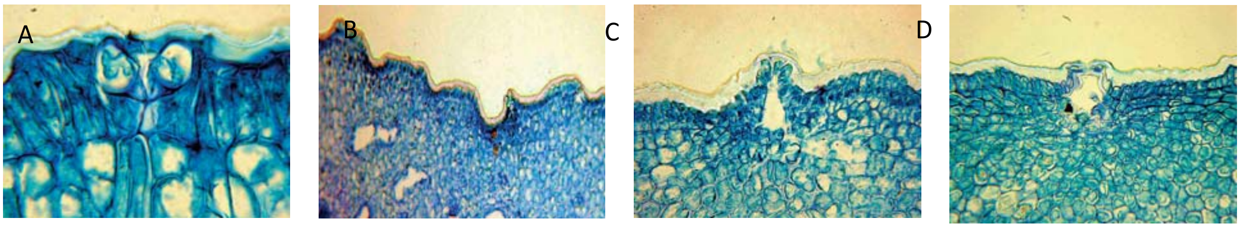


Plate 2.3 Cross-sections of exocarp of Tommy Atkins mango: (A) intact stomatal guard cell (B) sotmatal guard cells are forced upwards (C) stomatal guard cells are forced upwards and (D) stomatal guard cells eventually become raised above the epidermis at 20 mm in fruit diameter and rupture resulting in an atypical lenticels

Source: Bezuidenhout et al. 2004

2.6 Chemical Composition of Mango Fruit

Mango is a fleshy fruit containing more than 80% water (Lakshimnarayana et al. 1970). Its size depends on the accumulation of water and dry matter in the various compartments during fruit growth. Dry matter in mango fruits mainly consists of carbohydrates, 60% of which are sugars and acids (Ueda et al. 2000), the main compounds contributing to fruit sweetness and acidity (Malundo et al. 2001).

The edible portion contains mainly glucose, fructose and sucrose and the total sugar content of mangoes can vary from 11.5 to 25% depending on the type of mango and stage of ripeness. Different organic acids such as oxalic, citric, malic, succinic, pyruvic, adipic, galacturonic, glucuronic and mucic acids were reported to be produced by mango fruit, and citric is the major acid (Jain et al. 1959).

Mangoes are an excellent source of vitamins A and C, (both are) important antioxidant nutrients. Vitamin C promotes healthy immune function and collagen formation. Vitamin A is important for vision and bone growth. Mangoes are a good source of dietary fiber, therefore, it is associated with a reduced risk of some types of cancer, protecting against heart disease and cholesterol build up. Mangoes contain over 20 different vitamins and minerals (Bhushan 2012).

Mango fruits contain phytochemicals such as polyphenols, ascorbic acid and carotenoids, revealing health promoting properties mainly due to their antioxidant properties. The nutrient content in mango is shown in Table 2.5.

The skin color changes are due to the disappearance of chlorophyll and the appearance of other pigments (carotenoids and/or anthocyanins). At maturity and ripening stage, chlorophyll content declines and carotenoids and/or anthocyanins tend to increase (Tharanathan et al. 2006). Carotenoids are responsible for the attractive flesh color (Medlicott and Thompson 1985) and the predominant pigments in yellow cultivars. Skin color changes from dark green to reddish or yellow during ripening.

Chloroplasts are transformed to chromoplasts containing yellow or red pigments (Lizada 1993). In yellow cultivars, carotenoids and xanthophylls are the predominant pigments. During fruit ripening, chlorophyll concentration decreases substantially in Keitt while carotenoid concentration increases and anthocyanin decreases gradually in Tommy Atkin (Medlicott and Thompson1985). Presence of the anthocyanin has been reported in the skin of some types of cultivars such as Tommy Atkins (Proctor and Creasy 1969).

Mango flavor properties depend on the interaction among volatile compounds with sugars and acids. From the 150 volatile compounds isolated from mango, it is probable that only a few are critical in mango flavor (Malundo et al. 1996). Sugars and acids enhance consumers' perception of specific flavor in mango, including aromatics (Malundo et al. 2001).

Table 2.5 Nutrients content in mango (raw nutritional value per 100 g)

Items	Unit	Amount	
Energy	KJ	250.00	(60 kcal)
Carbohydrates	g	15.00	
Sugars	g	13.70	
Dietary fiber	g	1.60	
Fat	g	0.38	
Protein	g	0.82	
Vitamin A equiv.	µg	54.00	(7%)
Beta-carotene	µg	640.00	(6%)
Thiamine (vit B_1)	mg	0.03	(3%)
Riboflavin (vit B_2)	mg	0.04	(3%)
Niacin (vit B_3)	mg	0.67	(4%)
Pantothenic acid (B_5)	mg	0.20	(4%)
Vitamin B_6	mg	0.12	(9%)
Folate (vit B_9)	µg	43.00	(11%)
Vitamin C	mg	36.00	(43%)
Calcium	mg	11.00	(1%)
Iron	mg	0.16	(1%)
Magnesium	mg	10.00	(3%)
Phosphorus	mg	14.00	(2%)
Potassium	mg	168.00	(4%)
Zinc	mg	0.09	(1%)

Source: USDA Nutrient Database 2010

Percentages are relative to US recommendations for adults.

2.7 Quality Criteria for Mango Fruit

According to Kader (2002), quality performance of mangoes depends largely on external and internal quality parameters. Consumers' acceptance is free from external damages including bruises, latex or sap injury and decay and the fruit should have uniform weight, color and shape which are external quality attributes. Internal quality attributes include uniform and intense flesh color, flesh firmness (juiciness, fiber content), freedom from damage and adequate acidity (or pH) and total soluble solids (Brix %), depending on cultivar and type of consumer preferences. There are large differences in flavor quality and fiber content of mango cultivars which can be grouped on the basic of fiber content into none to slight (Less than 1%), moderate (1-2%) and high (more than 2%) (Kader 2008).

Mango skin color is important for perception of overall quality and determining the appropriate maturity for harvesting, processing and consumption. The loss of green color is an obvious sign of fruit ripening in many mango cultivars. Some mango cultivars retain green color in ripe fruit. Depending on the cultivar, skin color can change from dark to olive-green, sometimes reddish, orange-yellow or yellowish hues appear from the base color. Some cultivars develop a reddish blush which has been attributed to anthocyanins (Jha et al. 2006). Skin color development is greatly influenced by the fruit position on the tree and fertilizer application practices, among other factors.

Flavor (taste and aroma) is an important quality trait that determines to a great extent in consumer acceptance. According to Baldwin (2010), flavor is combination of taste and odor and mainly composed of sweetness, sourness and aroma that correspond to sugars, acids and volatile compounds. Flavor is determined primarily by genetic factors and it can be affected due to pre-harvest conditions, stage of maturity at harvest, postharvest handling methods including the types of treatments and incidence of mechanical damages (Kader 2008).

Grading is compulsory for all mangoes marketed in Europe. The minimum weight of mangoes must not be less than 200 g. Mangoes are sized according to their weight into 3 categories in Europe and 5 categories in USA, respectively (Table 2.6 and 2.7).

Table 2.6 Grading of mango in Europe

Size code	Weight range (g)	Maximum variability within a package (g)
A	200-350	75
B	351-550	100
C	551-800	125

Source: Kader 2008

Table 2.7 Grading of mango in USA

Categories	Weight (g)
Small	< 200
Medium	201 – 400
Large	401 – 600
Extra-large	601- 800
Maximum large	>800

Source: Kader 2008

Another quality trait for mango is its shelf life which can vary with post-harvest conditions of storage temperature (Lechaudel and Joas 2007). The post-harvest life of mango fruit depends on the maturity stage at harvest. Therefore, the fruit has to be harvested at suitable stage of maturity in order to develop the optimum sensory quality attributes and extended the post-harvest life (Yahia 2006).

2.8 Factors Effecting Quality of Mango Fruit

Pre-harvest, harvest and post-harvest handling practices play a major role in ensuring that the fruit reach the consumers with the optimum organoleptic and nutritional quality attributes.

2.8.1 Pre-harvest factors

Pre-harvest factors may influence fruit quality by affecting the development and maturation processes of the fruit. Climatic condition is one of the important pre-harvest factors to ensure good growth and high quality fruit. Rainfall immediately before harvest of mango has been consistently related to increased skin browning following hot water dipping for disease control.

The greater the light interception by an individual fruit and surrounding leaves, the better the quality of that fruit. Better light penetration also assists fruit color development. Early pruning after harvest can also help to synchronized shoot growth to achieve more uniform flowering (Fivas and Grove 1998). To develop a strong trunk the trees should be allowed to grow to over 1 meter in height initially then cut back to a height of between 0.6 to 0.7 m. First pruning should be done immediately after harvest while the second follow the floral rather than a vegetative flush appearance.

The mango tree is considered to be drought-hardy. Too much water can lead to water logging and root rot and too little can stress the tree and stunt growth (Anonymous 2003). Vegetative growth should not be encouraged at the expense of flower and fruit production. Too much fertilizer at the wrong time can also affect fruit quality. Once trees are bearing, the time of fertilizer applications is as important as the quantity applied.

The time of nitrogen and potassium application is the most critical because high nitrogen is generally associated with maintenance of green color in mango and potassium has been shown to have a consistent effect on flavor through increased acidity. Most of the nitrogen and potassium needs are applied as soon as the harvesting is completed. Application of 1 kg Murate of potash or Sulphate of potash with 2 kg Urea and 6 kg Superphosphate was done during July-August. Calcium based nutrition is particularly important during early fruit growth and management practices should be targeted to maximize calcium available to fruit during this period. High calcium concentrations in mango fruit retard green color loss and softening during ripening (Burdon et al. 1991)

Fruit thinning produces the well known response of increasing fruit size. It also reduces total yield so a balance between yield and fruit size must be achieved. Generally maximum profit does not occur at maximum marketable yield since larger fruit bring a higher price in the market. A grower must rely on his own experience to determine the optimum thinning level. Leaving too many fruits on a tree not only reduces fruit size but also decreases the soluble solid content of each fruit. Therefore, fruit quality can be sacrificed in several ways if thinning is not performed correctly (Yeshitela et al. 2003). Davie et al. (1995) explained that an early reduction in the number of mango fruits on the tree can bear up to harvest greatly reduced fruit drop.

Proper management and early prevention are essential for successful insect pest control. Selection of pesticides and time of application are regularly monitored to control pest management with minimal adverse effects. Major mango pests are mango scale, fruit fly, mango hopper, spotting bugs, mango seed weevil, mango shoot caterpillar, mango tip borer and flower eating caterpillar. The major diseases are anthracnose, stem-end rot, mango scab, bacterial black spot (which damage fruit and shoot) and powdery mildew (which affects flowers) (Johnson et al. 1994).

Bagging of fruit for controlling the post-harvest diseases and bruises with newspaper or brown bags one month prior to harvest should be done to get maximum fruit quality. The bagged fruits will ripe uniformly without any disease and fruit fly infestation. The problem of blackening and over ripening is overcome (Johnson et al. 1994).

2.8.2 Harvest factors

Harvesting practices have probably the most dramatic effects on fruit quality and the post-harvest shelf life. As a fruit approaches to maturity, many quality parameters are changing rapidly. Generally, physical, physiological and chemicals parameters are used to define the maturity stage.

The mango fruit should be harvested in a green mature stage so that it can be packed and delivered to market before it ripens and becomes too soft. To achieve good flavor and appearance, mango must be fully mature before harvesting. The best way to observe maturity in mango is the color of the pulp which turns cream to yellow on maturity and hardening of the stone (Seymour et al. 1990).

Mango must be harvested and handled very carefully as the fruit easily damaged during handling. The harvesting of the fruit is done mostly by hand picking to avoid the falling of the fruits. The fruits should not be allowed to fall on the ground as the injured fruits cause spoilage to other fruits during packaging and storage. Low fruits are generally harvested with the help of clippers. At the time of harvesting, precaution is to be taken to leave a four-inch stem to avoid the spurt of resinous sap that exudes if the stem is cut close. Such fruits are less prone to stem-end rot and other storage diseases. Therefore, proper care should be taken to harvest the fruit cleanly and be kept as clean as possible (Bhushan 2012).

Mango should be harvested in the morning hours and collected in plastic crates under the shade. The best harvesting time of mango is the late morning because the oil glands which causing immediate discoloration of the peel are full in the early morning. Harvesting under wet conditions should also be avoided since wet fruits are more susceptible to microbial growth. The harvesting time of mango also varies with the distance to the market and local consumption. Moreover, the factors such as market price, market glut, etc. should also be considered while harvesting the mango fruits (Bhushan 2012).

It is a common practice to harvest fruits early in the season (premature stage) to capture early market. But fruits should be harvested when there is some yellow color on the fruits on the tree. If immature fruits are harvested, the fruits have white patches or air pockets are developed, the taste and flavor are poor whereas over-mature fruits lose their storage life. During handling, such kinds of fruit had numerous problems (Bhushan 2012).

Fruit should be harvested when firm and at the mature-green color stage for export market. Fruits harvested at the mature green stage ripe rapidly after harvest and begin to turn yellow within 3 to 5 days at ambient temperature. The harvested fruits should be kept in the shade and handled carefully at all times (Bhushan 2012).

After harvesting, fruits are generally heaped under the tree on the ground. Bruised and injure fruits should be removed from the heap as they might cause damage to adjacent fruits.

2.8.3 Post-harvest factors

Post-harvest management means the handling of an agricultural product after harvest to prolong storage life, freshness and an attractive appearance. Nearly 20-25 per cent of fruits are wasted due to unsystematic post-harvest practices during harvesting packaging, storage, grading etc. This wastage can be reduced to some extent through proper post-harvest management operations consisting of collection, curing, pre-treatment, washing, grading, packaging, pre-cooling, low temperature storage, pallet loading and transportation, processing and marketing depending upon various crops (Bhushan 2012). Improved post-harvest practices results in reduction in losses, improve overall quality, extend shelf life and higher profits for growers and marketers (Bhushan 2012).

On a commercial scale or for export purpose, hot water treatment (HWT) is an effective post-harvest treatment for mangoes. Dipping newly harvested fruits in hot water minimizes fruit fly damage, anthracnose and stem-end rot infections.

2.9 Impact of Fruit Fly on Mango Fruit Production

Fruit flies are one of the most serious pests on fruit crops throughout the tropical and subtropical regions (Hasyim 2006). The oriental fruit fly *Bactrocera dorsalis* is one of the five most important pests of mangoes in South-East Asia including Myanmar (Waterhouse 1993). Farmers undergo crop losses and export trade is inhibited due to fruit flies. Fruit flies cause enormous losses to horticultural crops throughout Asia and South-East Asia (Drew and Hancock 1994).

In Thailand, oriental fruit fly is considered to be the key pest of fruit production, causing yield loss and quality degradation. It causes losses of several million US$ annually of the fruit industry resulting from significant yield reduction and market restrictions. The damage caused by the oriental fruit fly decreased from over 82% in 1987 before the implementation of the area-wide integrated pest management program to 30, 26, 21, 18, 17 and 9 % respectively in the following six years (1988 to 1993) in Thailand (Orankanok et al. 2007).

The oriental fruit fly attacks a wide range of commercial fruits such as mango, papaya, avocado, guava, grapefruit, passion fruit, apple, star apple and grapes. It is a serious pest of a wide variety of fruits and vegetables throughout its range and damage levels were 5 to 100% in unprotected fruit (Kaplan 2007).

In Myanmar, oriental fruit fly is a very wide spread and important pest of mango, citrus, guava and cashew (Morris and Waterhouse 1998). The fruit fly plays an important role in fruit production for domestic consumption and export in Myanmar (IIE 1992). Allwood (1997) indicated that fruit flies caused losses of as high as 40–90% in guava, 20–25% in mango and 12–60% in papaya. Prevention of the impact of these pests would lead to enhanced food security and greater quantities of fruit and vegetables for international trade. Yin (2010) reported that the oriental fruit fly damaged 20-50% in Sein Ta Lone, Shwe Hin Thar, Yin Kwe and Ma Chit Su mango varieties in Yezin area in 2009.

Steiner et al. (1961) stated that damage symptoms of fruit flies consisted of (1) oviposition in fruit and soft tissue of vegetative parts of certain plants, (2) feeding by the larvae and (3) the decomposition of plant tissue by invading secondary microorganisms. Larvae feeding in fruit are the most damaging. The adults damage fruits and vegetables by laying eggs under the skin. The eggs hatch into larvae and they feed flesh of the fruits or vegetables. Infected fruits and vegetables quickly become rotten and inedible or drop to the ground prematurely, thus causing considerable losses in production (Hollingsworth et al. 1997).

Fruit fly damage usually occurs as breaking down of tissue and internal rotting associated with mango infestation. Water soaked appearance occurs in infested mature fruits and infested young fruits become distorted and usually drop. The larval tunnels are providing entry points for bacteria and fungi that cause rotting of the fruit (Steiner et al. 1961).

2.10 Bagging Practices in Quality Fruit Production

Fruit bagging has been applied early in the world and it was first introduced to China in the late of 1980's. In the early of 20^{th} century, pear and grape were bagged to protect the fruits from damaging of Peach Fruit Borer. A few years later, bagging was widely used in apple. Nowadays, bagging was not only used in apple, pear, peach, grape, but also used in tropical and sub-tropical fruits, such as mango, banana, longan, litchi, carambola, custard apple, dragon fruit, loquat, Indian jujube, guava and citrus (Huang Huixae 2010).

Indeed bagging has been shown to reduce winter stress under the optimal condition which resulted in early fruit maturation (Jia et al. 2005). This is due to enhanced physiological and metabolic activities provided by the microclimate created by bagging (Johns and Scott 1989).

There are many advantages in fruit bagging. They are (1) to prevent fruits from the infection and damage of pathogen, (2) to prevent fruits from the damage from birds and insects (especially fruit fly), (3) to prevent fruits from pollution of harmful matter in the air and acid rain, (4) to prevent fruits from ultraviolet radiation of strong sunlight burning the surface of the fruits, (5) to prevent fruits from scrubbing among fruits and between fruits and other matter, (6) to produce organic fruits by reducing the times and amount of chemicals spray and reduce the residue of the chemicals and (7) to improve the color and fruit appearance (Huang Huixae 2010). Bagging fruit during their development has been practiced for the control of insects and diseases (Johnson et al. 1994). Fruit bagging may also enhance fruit appearance by providing protection from temperature extremes and from abrasion (Kitagawa et al. 1992).

Bagging protects both fruit fly damage and physical damage to improve the appearance of fruits. Bagging, a physical protection technique, can not only protect fruit from diseases and pests but also change the microenvironment of fruit development which exerts multiple effects on the growth and quality of fruits (Li and Ye 2000). Bagging produced high quality fruits with attractive color (Kitagawa et al. 1992). However, different materials used to make bags have different physicochemical characteristics such as light transmittance, vapor permeability and heat conductance and consequently generate differential effects on microenvironment and quality of fruit (Lee et al. 1996).

Mango fruit may be bagged to reduce disease (anthracnose and stem end rot) and skin blemishes (Johnson et al. 1994). Bagging prevents fruit flies from laying eggs on the fruits. In addition, the bag provides physical protection from mechanical injuries (scars and scratches). Although laborious, it is cheap and safe and gives a more reliable estimate of the harvest. Almost all the fruits are significantly decreased in quality especially in mango, especially in developing countries. They are primarily due to pre-harvest practices, harvesting fruit at improper maturity, mechanical damage caused during harvesting or improper field handling, sap burn, spongy tissue, lenticels discoloration, fruit softening, decay, chilling injury pest-disease damage and others (Yahia 2006).

Bagging of mango is also a research focused in recent years. Mango bagging has following advantages: (1) to protect fruit surface to make it smooth and delicate, (2) to improve the internal quality of fruit, (3) to reduce the spraying frequency, (4) to decrease pesticide residues and production costs, (5) to improve fruit storability to extend the shelf-life, (6) to raise the price of fruit (Huang Huixae 2010).

In fruit bagging, there were various kinds of bagging materials such as transparent single layer paper bag, paper bag of yellow outside with black inside, double layers bags of yellow outside with black inside plus red paper inside, single layer bag of yellow paper, transparent plastic bag and blue plastic bag are often used (Huang Huixae 2010).

Pruning must be done before mango fruits are bagged. The disease infected branches, insect damaged branches and crossing branches are removed to improve sunlight penetration and the ventilation of the tree crown (Huang Huixae 2010).

Fruit thinning must be done before fruit bagging. Some of small fruits, malformed fruit, disease and insect damaged fruits and injured fruits are removed. Only one fruit is left for each cluster. The entire fruitless flower stalk is removed (Huang Huixae 2010).

Chemical spraying before bagging 1:1:1 of Bordeaux Mixture or 800 dilution times of Shibaoke or 600 dilution times of Carbendazim is needed. About 1-2 days before bagging, spraying of pesticide and germicide is needed. For some varieties of good prize, it is suggested that the fruit should be dipped in the chemical liquid individually before bagging (Huang Huixae 2010).

Bagging of mango with bags impregnated with insecticides has been shown to protect fruits from insect attack. The best time for bagging is determined based on the occurrence of diseases and pests, the growth and development of fruits, the nutrient situation of the trees, the characteristic of local climate, fruit species and varieties and the purposes of bagging. (Huang Huixae 2010).

If bagging is done too early when the stalk of fruit is still underdeveloped, the stalk is easily damaged and results more fruit drop and therefore mango fruits are bagged 35-45 days after the fruit setting. Fruits which are normally developed are selected and all the substances attached on the surface of the fruits are removed. Then, the bag is opened and expanded. After that, the stalk of the fruit is hold with two fingers of left hand with the bag in right hand and gently slid into the bag and opening of the bag is tied on the stalk (Huang Huixae 2010).

Bagging materials for mango are mainly paper bags. There are paper bags of single layer (white or yellow in color) and double layers (compound of double layers and mono-color layer bags). Different varieties of mango require different specialized paper bags with different size. For example, 36 cm × 22 cm of double layers bag (yellow outside and black inside) is suitable for Jinhuang mango and paper bags of single layer or double layer (yellow outside and black inside) with the size of 27 cm × 18 cm are suitable for Zihua mango. Paper bags of double layers (yellow outside and black inside) with the size of 27 cm × 18 cm and 26 cm × 18 cm (yellow outside and red inside) are suitable for Tainong No.1 mango (Huang Huixae 2010).

Success with mangoes can be high but bagging materials do not always resist the effect of rain or wind (Bondad 1985). Therefore, more research is needed to determine the type of bags to use for different mango varieties and the best time to bag fruit (Love et al. 2003).

In citrus, fruit thinning is done before bagging. 1 to 2 fruitlets are remained on each fruiting branch. All diseased fruits and malformed fruits are thinned out. Fruits to be bagged are dipped in a mixture liquid of pesticides (Chloropyrifos) and fungicide (Carbendazim or Thiophanate-methyl). Bagging practices will be done when the fruit is dry after dipping. Bagging time for citrus depends on the situation of disease occurrence. Bagging materials for pommelo are ordinary paper bag and yellow plastic film bags. For any types of bags, holes at the bottom of the bags should be made to let the water run away (Huang Huixae 2010).

In Guava, bagging of individual fruit with paper bag reduces insect damage and maintains visual quality (Pereira 1990). Before bagging, thinning is done leaving one fruit on one branch according to the tree age, the tree vigor and the density of the fruits on the tree. Spraying of fungicide is required before bagging to prevent the fruit from rotting in the bag. Bagging time for guava is 30 days after fruit set when the fruitlet is 1 to 2 cm in diameter. If bagging is done too early, it is hard to operate due to the fruit is too small. If fruit is bagged too late, bagging will not function properly to prevent the fruits from pests and diseases. Firstly, fruit is covered with the foam net bag (15 cm × 15 cm) and then the fruit with the foam net bag is covered with plastic film bag (25 cm × 20). The foam net bag is fixed in place by the plastic bag. The two corners at the bottom sides of the plastic bag are tied with string. Bagging materials for guava fruits are nontoxic plastic polyethylene bag which has vent holes at the bottom sides of the bag to avoid water accumulation and resulting in fruit rot (Huang Huixae 2010).

3. MATERIALS AND METHODS

3.1 Experimental Site and Period

The two experiments were conducted at the existing mango orchard in Department of Agricultural Research (DAR), Yezin, Nay Pyi Taw during mango season in respect of flowering, fruiting and fruit harvest from January to May 2011. Sample plants of Sein Ta Lone mango were randomly selected and tagged. The tested mango trees were 18-year-old for first experiment and 6-year-old for second experiment and the conventional cultural practices were used.

3.2 Experimental Design

These experiments were conducted with Randomized Complete Block design (RCBD) with ten replications. There were total of (20) trees and 10 trees in each experiment. Five fruits were randomly selected as sample fruits for each treatment and it consisted of total 30 fruits per tree. The six treatments were described in Plate (3.1).

T_1 = double-layer brown paper bag (made in Thailand) (TB)

T_2 = single-layer brown paper bag (made in China) (CB)

T_3 = single-layer Journal bag (JB)

T_4 = single-layer Journal bag coated with glue (JCB)

T_5 = single-layer Newspaper bag (NB)

T_6 = Control (Unbagged)

The weight and thickness and area of different bagging materials used in the experiments were shown in Table 3.1. All treatments were randomly assigned to one tree and each tree was regarded as one replication (Plate 3.2).

Thai bag

China bag

Journal paper bag

Journal paper bag coated with glue

Newspaper bag

Plate 3.1 Different bagging materials used in the experiments

Table 3.1 The weight, thickness and area of different bagging materials used in the experiments

Types of bag	Weight (g)	Thickness (cm)	Area (cm^2)
Double-layer brown paper bag (made in Thailand)	11.2	0.024	30 × 19
Single-layer brown paper bag (made in China)	5.8	0.013	23.7 × 20.2
Single-layer Journal bag	7.7	0.018	23.3 × 18.5
Single-layer Journal bag coated with glue	7.8	0.02	23.3 × 18.5
Single-layer Newspaper bag	4.7	0.013	24 × 18

Plate 3.2 A mango tree on which different bagging materials were randomly assigned

3.3 Experimental Procedure

3.3.1 Pruning

Pruning was done immediately after harvesting of the previous year fruits on May 2010 in order to get light and aeration by removing erect and disease infested branches. The aim of pruning is to cultivate and produce strong and proper fruit branches and to set dwarf trees. The overgrown, weak, bending, damaged and withered branches were cut to allow more sunlight interception.

3.3.2 Fertilization and irrigation

There were two purposes of fertilization. The first one is to refill the energy after fruiting and the second one is to enhance the capacity of fruit setting. There were three times of fertilization in a year. First fertilization was applied after pruning, June 2010, at the rate of 1 kg mixture of urea: super phosphate: potash (3:1:1) per plant.

Second fertilization was in late monsoon and fertilizers were mixed with the ratio of urea: super phosphate: potash (1:3:3). One month after flowering, multi N. P. K combined with extralaxyl (fungicide) and Carbryl (insecticide) were applied as foliar application on September 2010. The third fertilization was done at fruit setting stage on

January 2011 with the same ratio of second fertilization was used (Plate 3.3). Watering was done two-day intervals in both experiments.

Plate 3.3 Foliar application of mango tree by hand sprayer with bamboo pole

3.3.3 Tagging

Date of flowering and fruit setting were marked by label tagging to know the age of individual fruit exactly.

3.3.4 Preparation of bags

Thai bags and China bags were available in market. Other bags were done by using journals and newspapers which were cut and fold to make a rectangular bag. The sides and bottom of the sheets were glued. A hole was made about 10 mm in diameter at the edge of the bag. In preparation of journal bag coated with glue, all the outer surface of journal bags were glued and dried in the sun.

3.3.5 Time for bagging

Randomly selected 300 Sein Ta Lone mango fruits were measured and bagging was commenced when the fruit had reached the diameters of 6-7 cm in size (Plate 3.4) at about 70 to 75 days after flowering. Extra mango fruits were also bagged for each treatment to compensate for potential fruit drop.

The fruit is selected and individual fruit was inserted into the bag and closed the bag firmly with wire. The fruit is hanged in the bag to avoid contacting with the paper and causing bruise or sun burn.


Fruit length (7-9 cm)


Fruit width (5-6 cm)


Fruit diameter (6-7cm)

Plate 3.4 Measurements of fruit length, fruit width and fruit diameter at bagging time

3.3.6 Harvesting

All bagged mango fruits were manually harvested on 6^{th} May, 2011 and the bags were removed. The stalks were discarded and fruits were washed with tap water. They were placed upside down for air drying about 30 min in order to avoid latex burn. The fruits were placed at ambient condition of temperature (30 ± 1°C) and humidity (65 ± 5%).

3.4. Data Collection

All parameters of fruit drop %, fruit weight, fruit area (fruit diameter and fruit length), Brix %, peel color, defective fruit %, lenticels structure were measured at harvest time. The shelf life was also recorded till the end of the experiment.

3.4.1 Days to fruit maturity

The date of flower initiation was recorded on labels when the inflorescences were visible on tree to know the age of the fruit for bagging.

3.4.2 Fruit weight

After harvesting three hundred fruits were weighed by using electronic digital balance at harvest.

3.4.3 Fruit area

Three hundred fruits were measured for fruit diameter (cm), fruit length (cm) and fruit width (cm) by using Vernier caliper.

3.4.4 Peel color development

Peel color at harvest time was measured by using score system (Plate 3.5). Visual color assessment was carried out using the score of 1 to 5 where 1 = 100% green, 2 = 70-80% green with 20-30% yellow, 3 = 40-50% green with 50-60 % yellow, 4 = 20% green with 80 % yellow, 5 = 100% yellow (Table 3.2) (Joyee et al. 1997).

3.4.5 Total soluble solid (TSS) or Brix %

Mango juice was prepared by squeezing the fruit pulp and the total soluble solid (TSS) or Brix% was measured using a pocket refractometer Pal.1.

3.4.6 Defective fruits%

Fruit damages such as dirt, bruises (blemishes), fruit abrasion, sun burn, latex burn and fruit fly attack were counted as defective fruit. The data were expressed as % based on total fruits by visual inspection.

3.4.7 Structure of lenticels

The lenticels structure was investigated by using mango skin slice under the electronic microscope.

3.4.8 Shelf life

The shelf life was determined by means of the number of days that the fruits remained in a marketable condition. Five sample fruits for each treatment with 4 replications were stored at the ambient conditions of temperature (30 ±1°C) and humidity (65 ± 5%) in both experiments.

3.5. Statistical Analysis

All data were statistically analyzed by SAS program version 9.0. Treatment means were compared by Least Significant Difference (LSD) at 5% level.

Table 3.2 Description of color development by visual appearance at harvest time of Sein Ta Lone mango

Score	Color development
1	**Mature green** (100% green)
2	**Light yellow at cheek** (70-80% green with 20-30% yellow)
3	**Greenish yellow** (40-50% green with 50-60 % yellow)
4	**Yellowish green at stem end** (20% green with 80% yellow)
5	**Yellow with non green** (100% yellow)

Source: Joyee et al. 1997 with some modification

Score 1

Score 2

Score 3

Score 4

Score 5

Plate 3.5 Peel color system

4. RESULTS AND DISCUSSION

4.1. Days to Fruit Maturity

There were no significant differences in days to fruit maturity of Sein Ta Lone mango among the treatments in both experiments (Figure 4.1). The harvesting dates of Sein Ta Lone mango were the same at the average of 115-120 days after flowering. Most of the beginning of inflorescences was appeared on tree at the first week of January, 2011. The flower synchronization was occurred in both experiments at the first week of February. After that, small fruits were visible on the trees at the first week of March. The results from this study were similar to the following reports.

Lynch and Mustard (1955) reported that mango fruits are usually harvested at the physiological mature but unripe stage, 15 to 16 weeks after fruit setting. Moreover, harvest maturity in mango is reached about 12 to 16 weeks after fruit set and days from full bloom is most recommended. Physical methods to determine maturity in mango include softness of the cheek, peel color, development of shoulder and specific gravity (Yahia 1998).

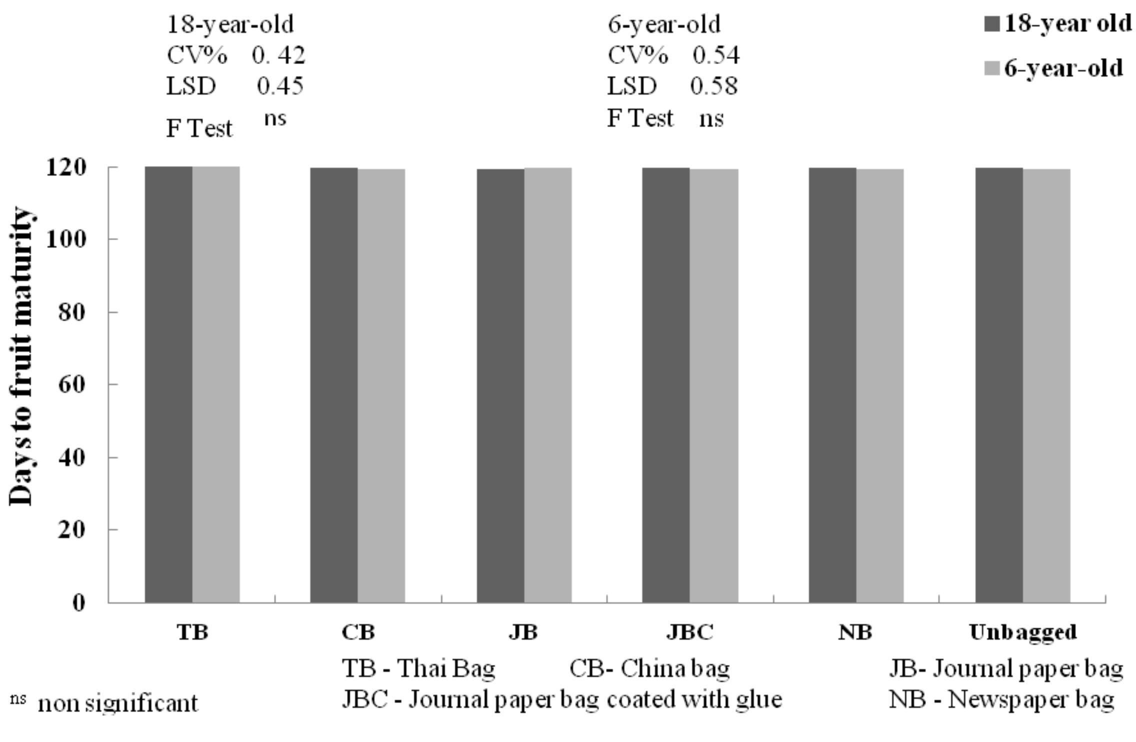


Figure 4.1 Days to fruit maturity of Sein Ta Lone mango in both experiments

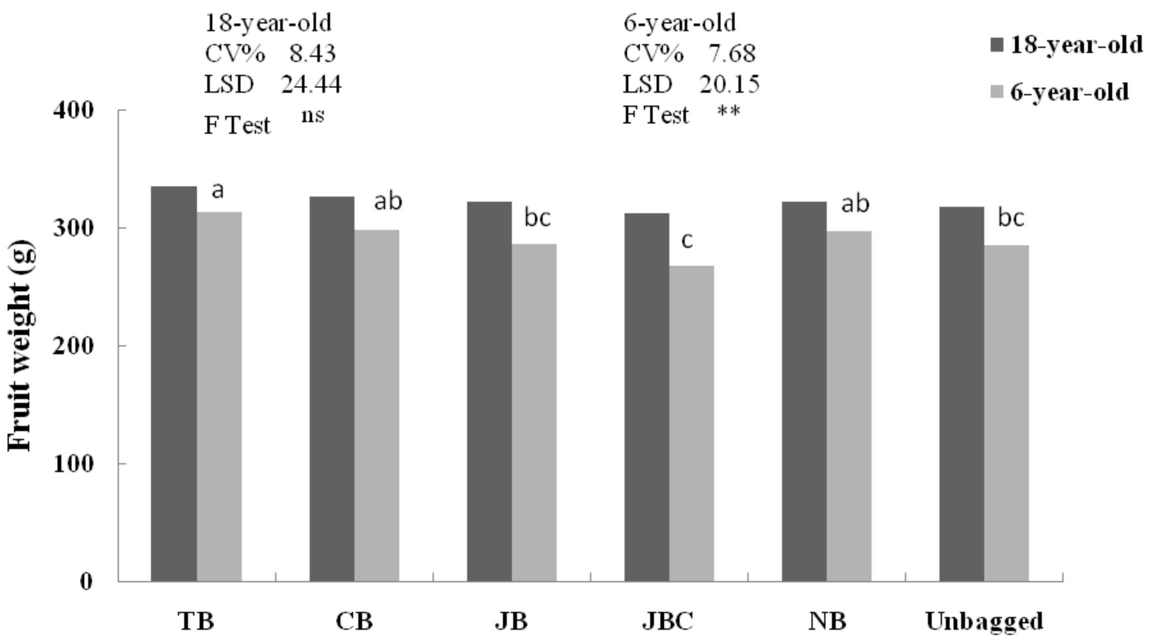
4.2. Fruit Weight

Different bagging materials had no significant effect on fruit weight in 18-year-old tree. However in terms of value Thai bag (TB) was higher fruit weight (335.1 g) than that of the other treatments and the lowest fruit weight (311.91g) was found in fruit treated with journal paper bag coated with glue (JBC). There were similar trend in both experiments (Figure 4.2). This statement was similar to the findings of Beaslay et al. (1999) who stated that bagging had no affect on fruit development and fruit weight in Kensington Pride mango and Sensation mango (Joyee et al. 1997).

In 6-year-old tree, there were significant differences in the fruit weight among the treatments. The highest fruit weight (313.6g) was found in fruit treated with Thai Bag (TB) among the treatments. The lowest fruit weight (267.41g) was found in fruit treated with journal bag coated with glue (JBC) (Figure 4.2). Similar observations had been reported by Johnson et al. (1994) that bagging on Keitt mango fruit at 91-112 days before harvest increased dry matter accumulation by 2% relative to unbagged. This may have been due to increased temperatures (0.5°C) inside the bag that favored fruit growth (Robinson 1996).

Han et al. (2002) noted that the temperature inside the bag was correlated with the physicochemical characteristics of the bag, i.e. light reflectance, absorbance and transmittance and air permeability.

In the present study, it can be assumed that fruit weight and fruit area was also affected by plant canopy, number of bearing fruits and fruit position on the tree. It was found that the different tree ages may respond different results by bagging in the present study. In current situation, bagging is a common approach for commercial fruit production.



** highly significant at 1 % level

ns non significant

TB – Thai bag CB- China bag JB- Journal paper bag
JBC- Journal paper bag coated with glue NB- Newspaper bag

Figure 4.2 Effect of different bagging materials on fruit weight of Sein Ta Lone mango in both experiments

4.3. Fruit Area

In 18-year-old tree, bagging had no significant effect on fruit area. However, the fruits bagged with Thai bag (TB) were the highest fruit area (81.9cm^2) while the lowest fruit area (78.3 cm^2) was found in fruits treated with journal paper bag coated with glue (JBC). The data on fruit area were similar trend in fruit weight (Figure 4.3). The result of this finding was in line with the findings of Kim et al. (2003) who found that type of bagging materials had little effect on fruit size.

In 6-year-old tree, there were significantly different in fruit area among the treatments. The fruits treated with Thai Bag (TB) were significantly the highest in fruit area (79.0cm^2) while fruits treated with journal bag coated with glue (JBC) were significantly the lowest in fruit area (70.8 cm^2) (Figure 4.3). The fruits treated with JBC were not significant with the unbagged fruit.

Bagging is a common approach to increase fruit size as a result of temperature increases inside the bag that creates a warmer microclimate for fruit development, although they did not alter the pattern of the diurnal temperature change (Wang et al. 2007). The result of this finding was supported to the above statement.

It was obvious that fruit area was positively correlated with fruit weight in 18-year-old Sein Ta Lone tree (R^2 = 0.89) and in 6-year-old (R^2 = 0.98). The larger the fruit area, the higher the fruit weight was observed in both experiments (Appendix Figure 1 and 2).

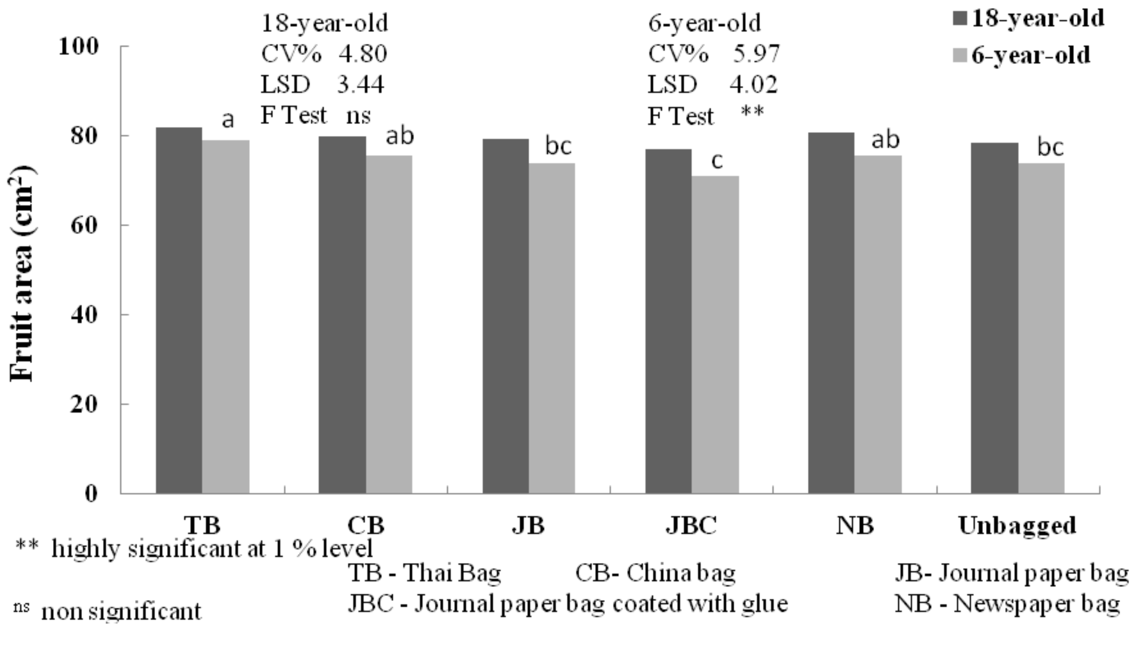


Figure 4.3 Effect of different bagging materials on fruit area of Sein Ta Lone mango in both experiments

4.4. Peel Color Development

Effect of different bagging materials on peel color development of Sein Ta Lone mango was described in Plate 4.1 and 4.2. There were highly significant differences in peel color development among the treatments in both experiments. Fruits treated with TB gave the highest peel color development and unbagged fruits showed the lowest peel color development. Among the bagging materials, there was no significant difference between TB and CB and also JB, JBC and NB.

The peel color changed from green to yellow as the chlorophyll was degraded to unmask the yellow carotenoids (Gray et al. 2004). When bagging affects fruit color development by visually due to the influence of the bag on radiation and temperature and consequently result the pigment production (Tyas et al. 1998). This may be due to the changing of chlorophyll to carotenoids because of lower light transmission to the bag.

Chloroplast changes into chromoplasts. Chromoplasts contain carotenoid, xnthophylls and anthocyanin. In yellow cultivar, catotenoid and xanthoplyll are predominant pigments and anthocyanin in red cultivars (Tharanthan et al. 2006).

The bags applied to the mango fruit in the current study were brown paper bags and it might be the modification of internal atmosphere inside the bag may reduce chlorophyll accumulation and enhance yellow color. Other factors may be ethylene synthesis in dark portion due to lack of light (Bassi and Spencer 1981).

The color development was due to disappearance of chlorophyll and appearance of other pigments especially carotenoid. In this study, it was found that 45 days bagging period increased peel color development about 100% in TB and CB and 20-40% in other paper bags (Appendix Plate 1). It can be assumed that bagged fruits would be harvested at 2-3 days earlier than normal harvest time due to earlier commence of yellow color. The earlier harvest would get the higher prices for the growers in the early market.

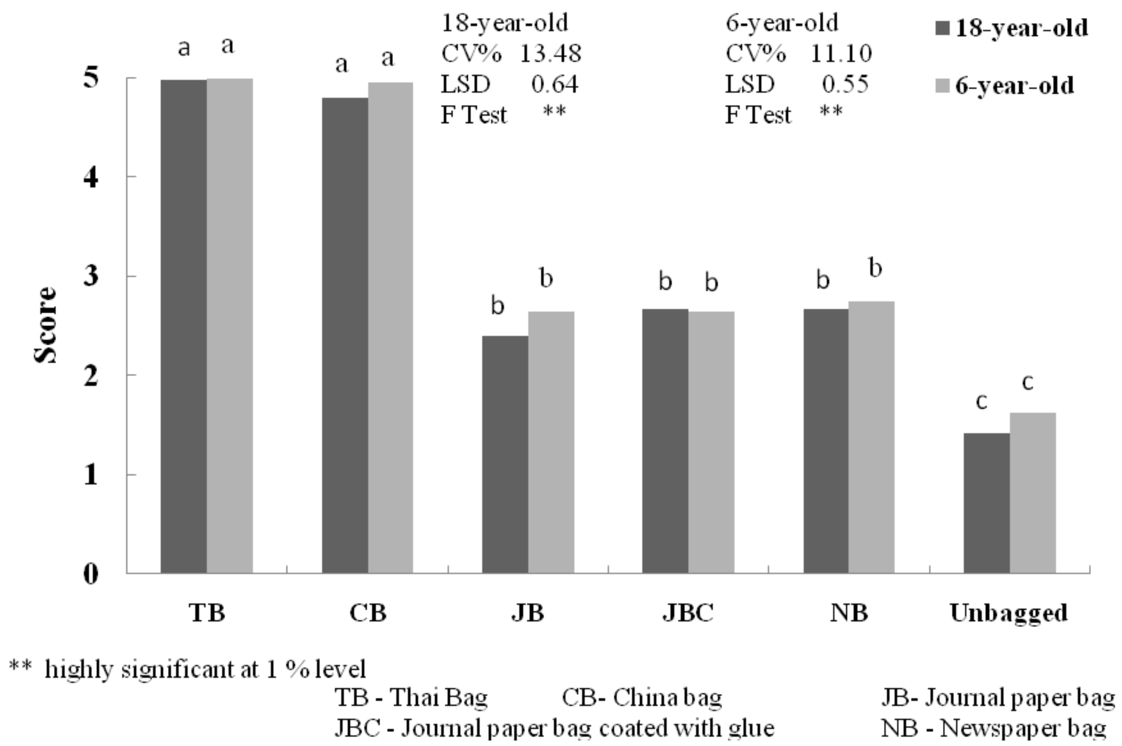


Figure 4.4 Effect of different bagging materials on peel color development of Sein Ta Lone mango in both experiments

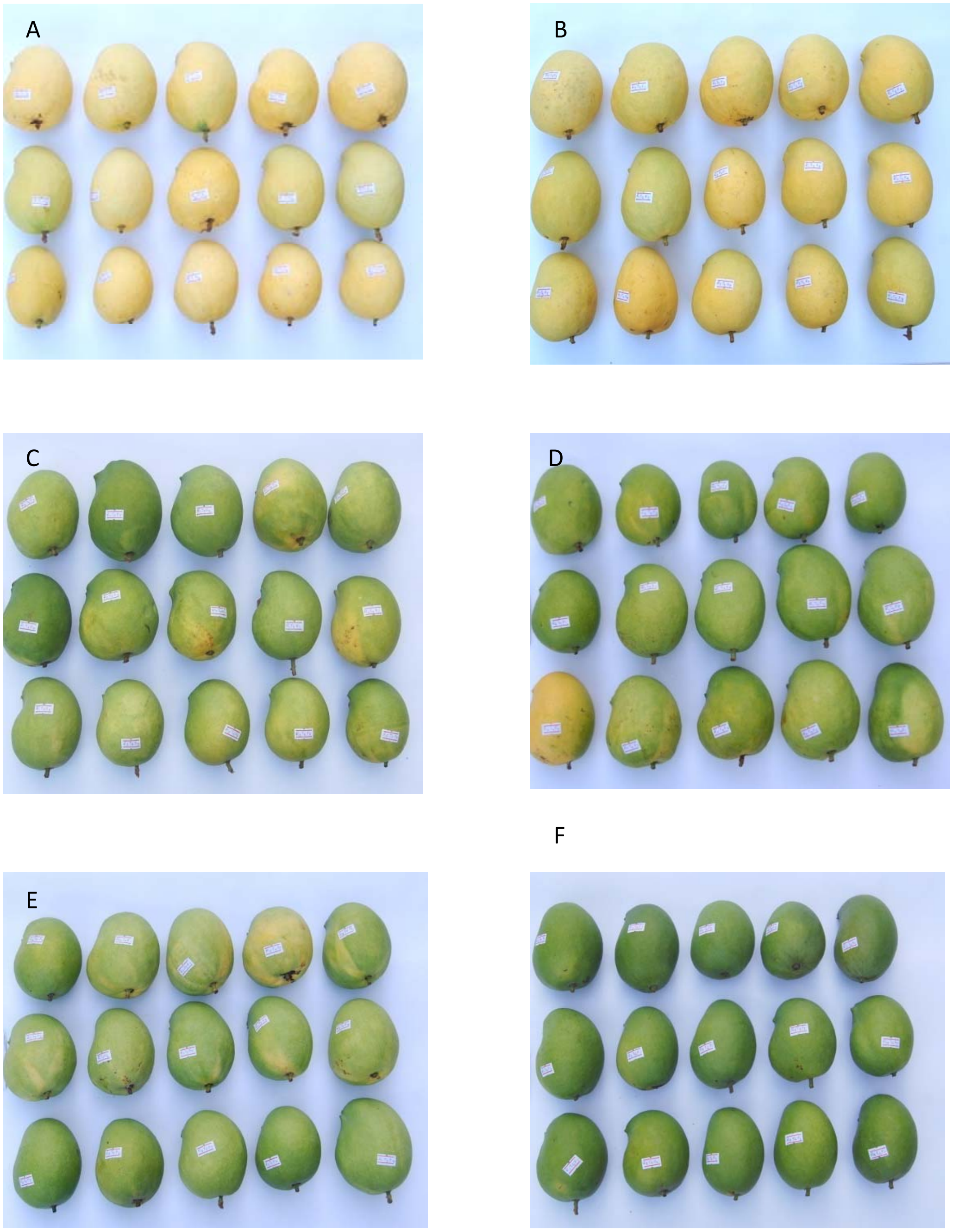


Plate 4.1 Effect of different bagging materials on peel color of Sein Ta Lone mango at harvest (18-year-old tree): (A) Thai bag, (B) China bag, (C) Journal paper bag, (D) Journal paper bag coated with glue, (E) Newspaper bag and (F) Unbagged fruit

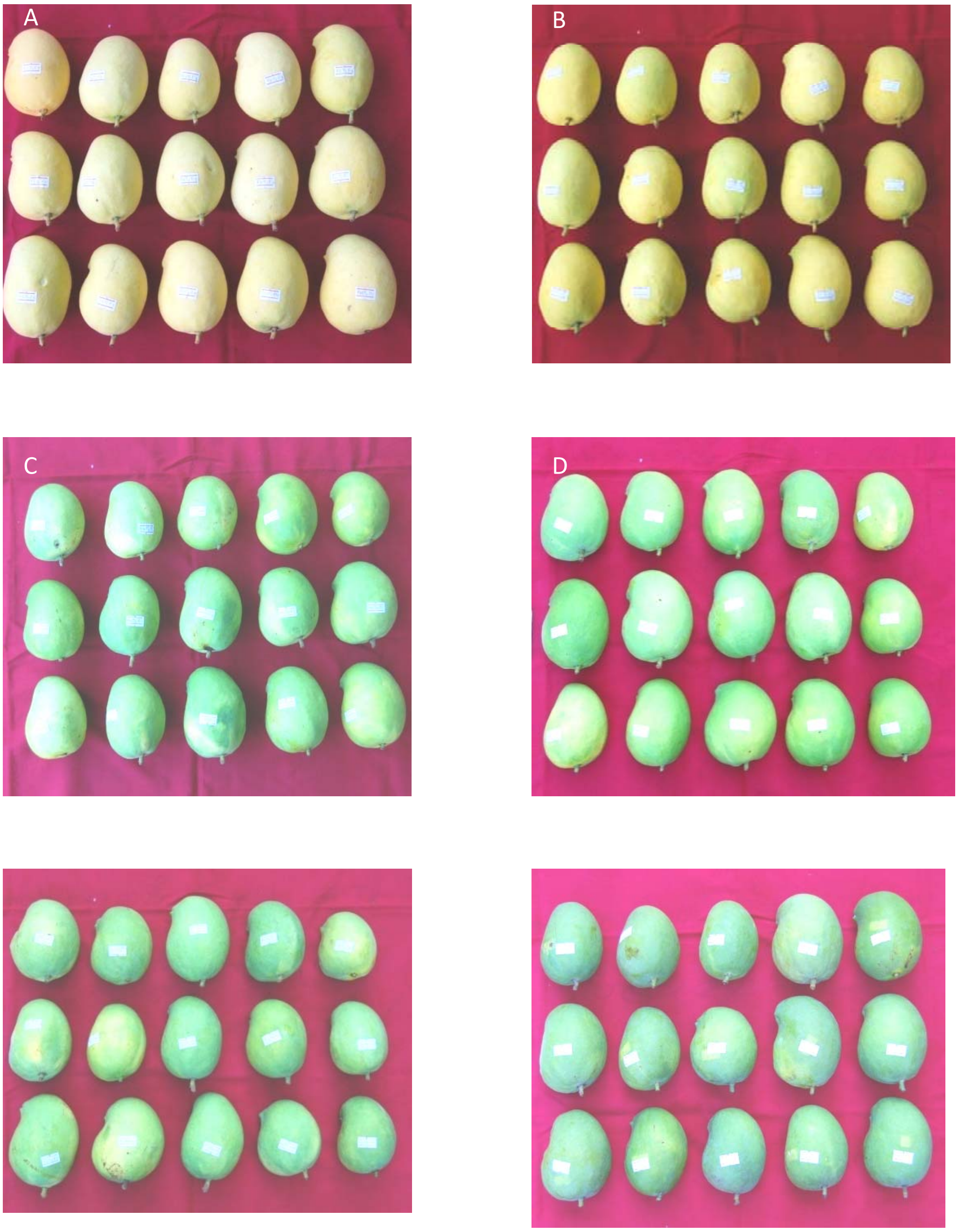


Plate 4.2 Effect of different bagging materials on peel color of Sein Ta Lone mango at harvest (6-year-old tree): (A) Thai bag, (B) China bag, (C) Journal paper bag, (D) Journal paper bag coated with glue, (E) Newspaper bag and (F) Unbagged fruit

4.5. Total Soluble Solid (TSS or Brix%)

Brix% at harvest was not significantly influenced by bagging. Although the fruits bagged with TB and CB had yellow color, the Brix % were not significantly different among the treatments in both experiments (Figure 4.5) .This finding was similar with the finding of Watanawan et al. (2009) who reported that fruit bagging of Nam Dok Mai mango did not significantly affect on the contents of SSC, TA, SS/TA ratio, vitamin C, total sugar, reducing sugar and sucrose. Hofman et al. (1997) also reported that total soluble solids were not affected by bagging in Keitt mango. Fruit ripening for mangoes was enhanced by pre-harvest bagging although there was no effect on Brix% and sensory quality at the post-harvest stage for the bagged and unbagged fruits (Hofman et al. 1997).

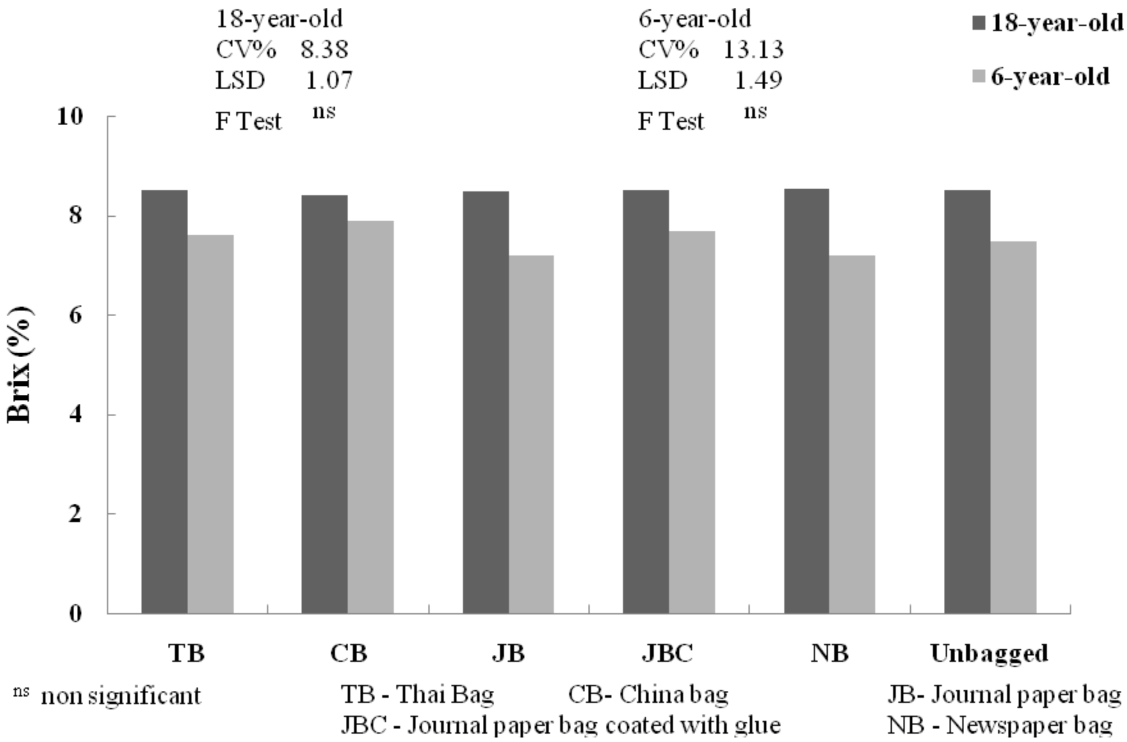


Figure 4.5 Effect of different bagging materials on Brix% of Sein Ta Lone mango in both experiments

4.6. Defective Fruit %

The criteria of defective fruits were damage symptoms caused by fruit flies, sun burn, latex burn and physical damage (Plate 4.4). In both experiments, the fruits treated with TB and CB significantly showed the lowest defective fruit (0.88% and 0.98%) in 18-year-old and (0.88% and 1.07%) in 6-year-old mango trees, respectively (Figure 4.6). This finding was in line with Estrada (2004) who reported that early cultivar such as Tommy Atkins can show 100% pest and disease control with bagging in Mexico. It can be assumed that bagging not only reduced defective fruit % by inhibiting the laying of fruit but also prevented fruit abrasion, sun light and latex staining. There was no significant difference among the treatments of JB, JBC, NB and unbagged fruits. In Asia, bagging of fruit is a conventional method that provides a physical barrier to pests, diseases, and mechanical damage.

In 6-year-old trees, fruits treated with TB and CB gave significantly the lowest in defective fruit % followed by the fruits treated with NB and JB. There was no significant difference between TB and CB and also NB and JB. There was significantly highest in defective fruit % in the unbagged fruits while JBC showed the second highest in defective fruit.

In this study, the 6-year-old mangoes trees were more infested by fruit flies than that of 18-year-old trees due to outbreak of fruit fly in that year and narrower plant spacing with more plant population. It seemed that the closer spacing was more seriously affected by fruit flies.

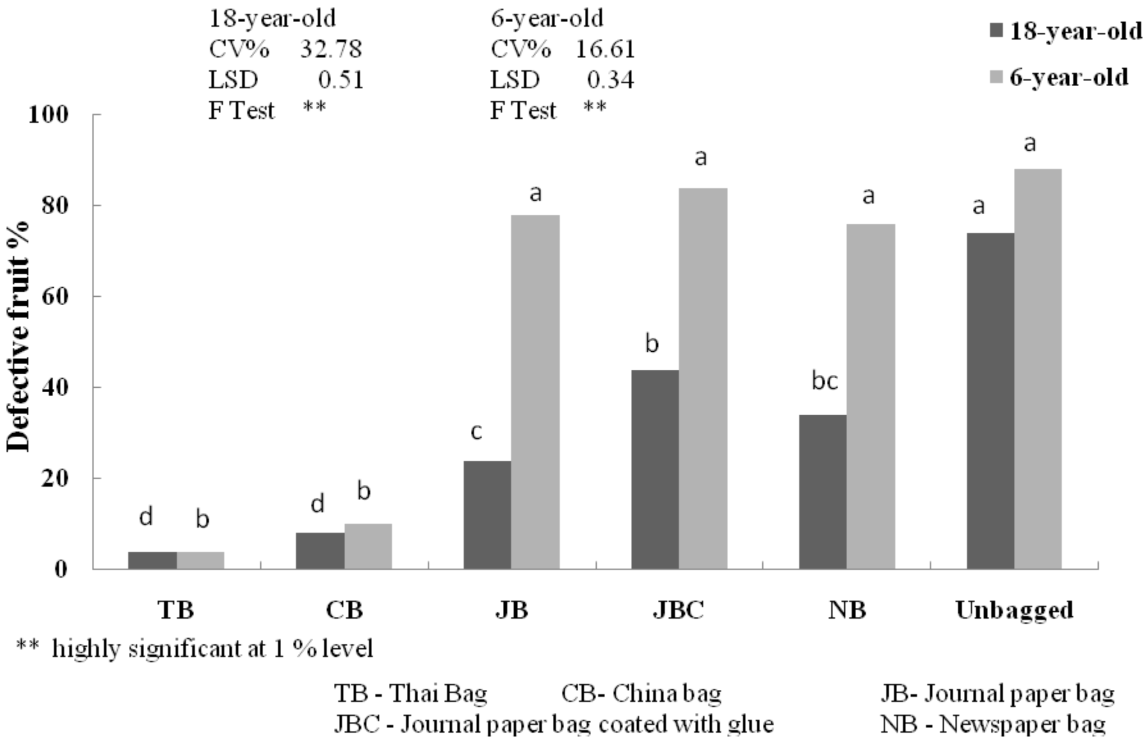


Figure 4.6 Effect of different bagging materials on defective fruit % of Sein Ta Lone mango in both experiments

Plate 4.3 Symptoms of defective fruits in this study: (A) and (B) fruit fly attack, (C) sun burn, (D) latex burn, (E) and (F) fruit abrasion

4.7. Structure of Lenticels

There were different lenticels structures under the electronic microscope in both experiments. In this study, structures of lenticels were not the same according to the different bagging materials. In both experiments, the structure of lenticels in TB and CB were uniform and narrow intercellular space. Moreover, it seemed that the cell structures of fruits treated with TB and CB were more compactly cell arrangement while JB and NB were compact cell arrangement. However, the fruits treated with JBC and unbagged fruits were loosely cell arrangement (Plate 4.4 and 4.5).

Tamjinda et al. (1992) found that lenticels are essential to the plant since they control gaseous exchange for photosynthesis, respiration and transpiration. Transpiration is the main cause in water loss of fruit through stomata, lenticels and other openings. Water loss is one of the most important factors that control quality (shriveling and softening due to water loss) and the shelf life of fruits (Vigneault et al. 2003). Light impacts and shading can reduce the number of lenticels in the apple epidermis (Eccher and Noe 1993).

Resin present in the skin of the fruit plays an important role in the discoloration of lenticels. Lenticels discoloration is a result of the stress that fruit underwent before harvest (especially by wind or cold) (Bally et al. 1996). The post-harvest practices such as suitable vapor heat or hot water treatment should be treated carefully when sap or latex is in contact with the skin. Inadequate handling treatments could induce lenticels spotting.

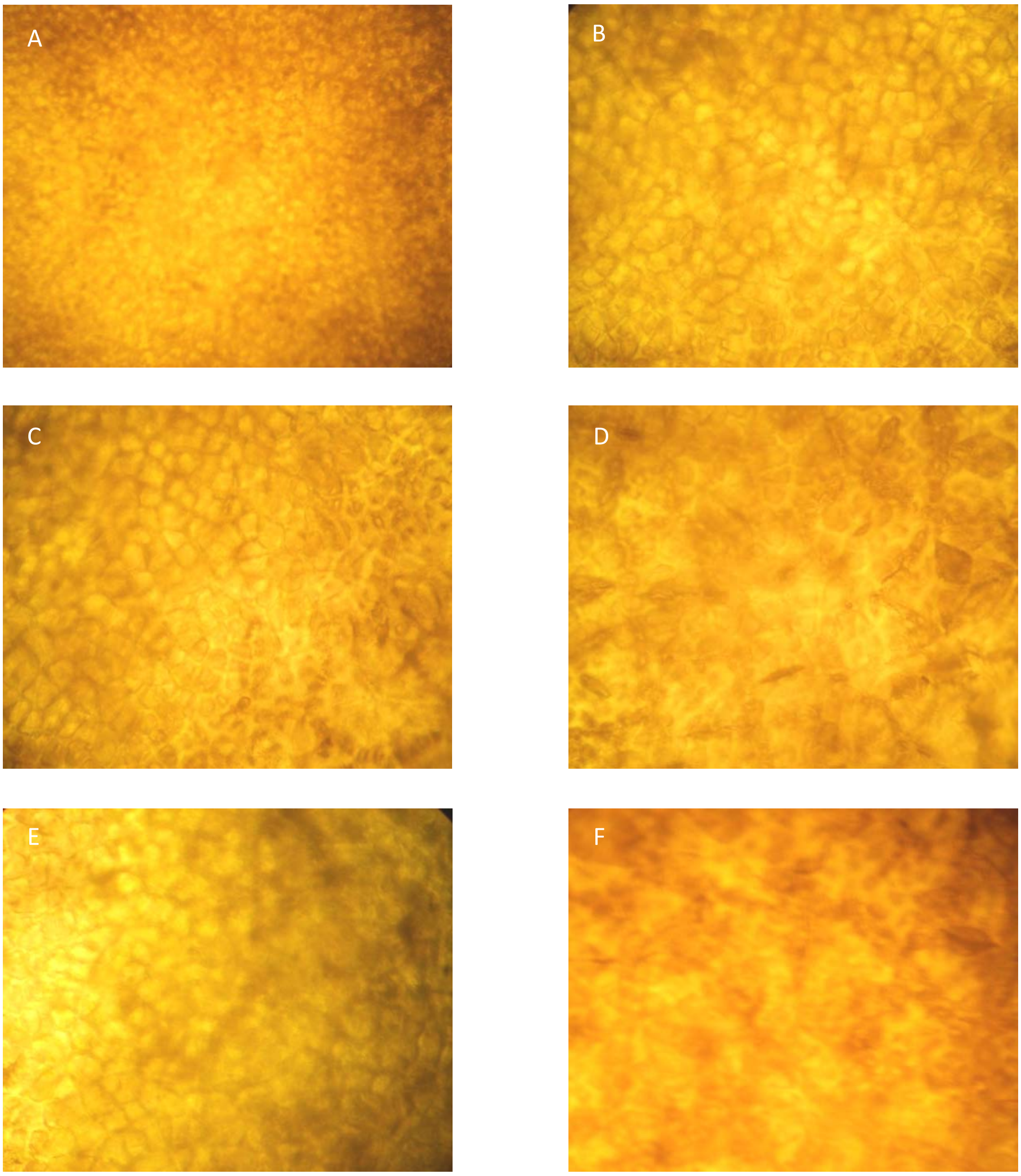


Plate 4.4 Observation on lenticels structure of Sein Ta Lone mango in 18-year-old tree affected by different bagging materials: (A) Thai bag, (B) China bag, (C) Journal paper bag, (D) Journal paper bag coated with glue, (E) Newspaper bag and (F) Unbagged fruit

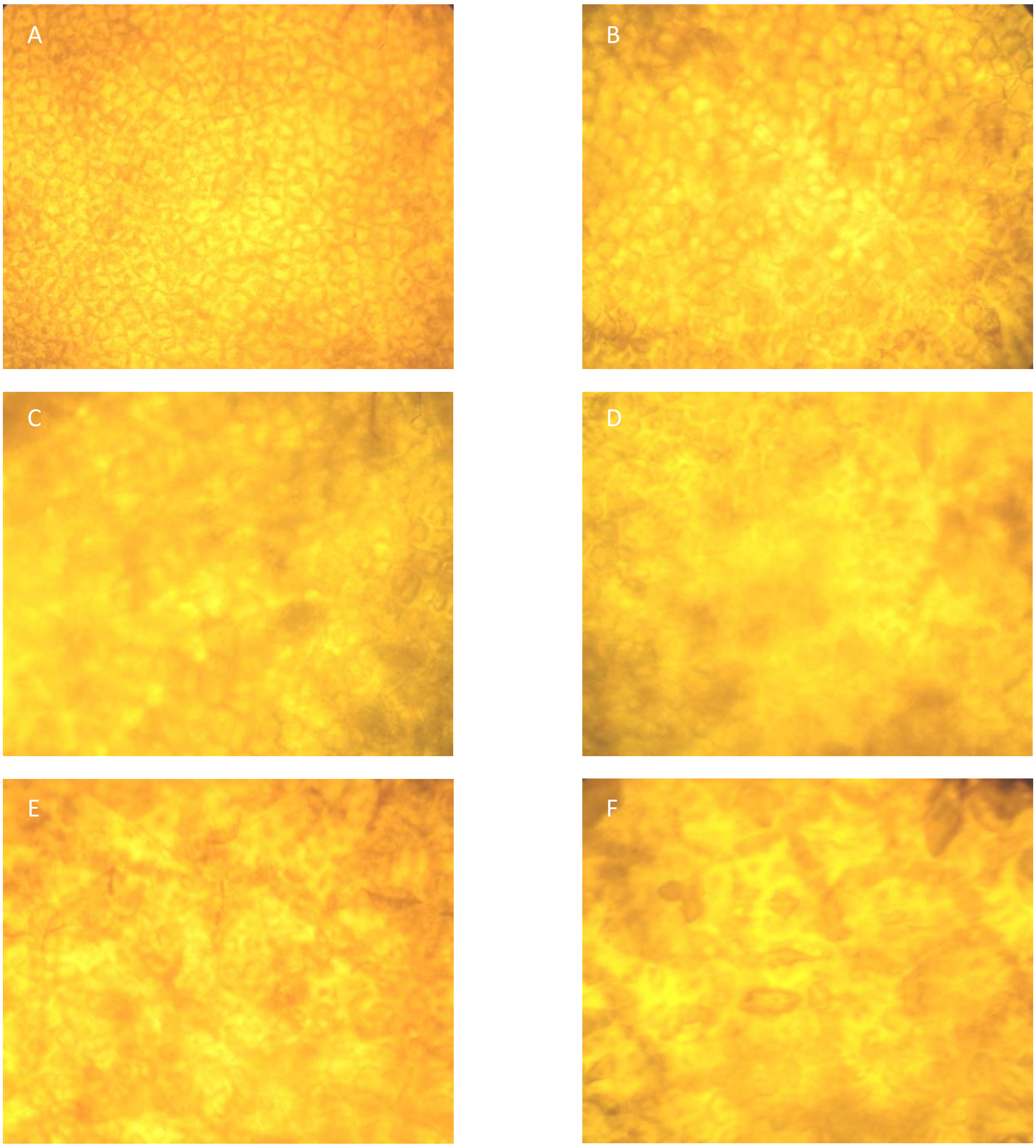


Plate 4.5 Observation on lenticel structure of Sein Ta Lone mango in 6-year-old tree affected by different bagging materials: (A) Thai bag, (B) China bag, (C) Journal paper bag, (D) Journal paper bag coated with glue, (E) Newspaper bag and (F) Unbagged fruit

4.8. Shelf Life

It was found that fruits treated with TB significantly showed the longest shelf life (8 days in 18-year-old and 7 days in 6-year-old) while unbagged fruits were significantly the shortest shelf life (5 days in 18-year-old and 4 days in 6-year-old) respectively (Figure 4.7). This finding was in line with Pathak (2009) who reported that brown paper bag increased shelf life about two to three days. Fruits treated with CB showed shelf life 7 days in 18-year-old and 6 days in 6-year-old, respectively. The fruits treated with JB, JBC and NB gave 6 days in 18-year-old and 5 days in 6-year-old in shelf life.

The shelf life of mango ranges from 4-8 days at room temperature and 14-21 days in cold storage at 13º C depending on cultivar (Carrillo et al. 2000). The shelf life of Sein Ta Lone mango is 7 days under ambient condition without any treatment (Soe 2008). Similar result was observed by Kyaw (2011) that non-wrapped fruits revealed the shortest shelf life 6-7 days at room temperature.

Shelf life was negatively correlated with defective fruit % in 18-year-old tree ($R^2 = 0.8631$) and in 6-year-old ($R^2 = 0.759$). It was found that the lesser the defective fruit%, the longer the shelf life was occurred in both experiments (Appendix Figure 4 and 5).

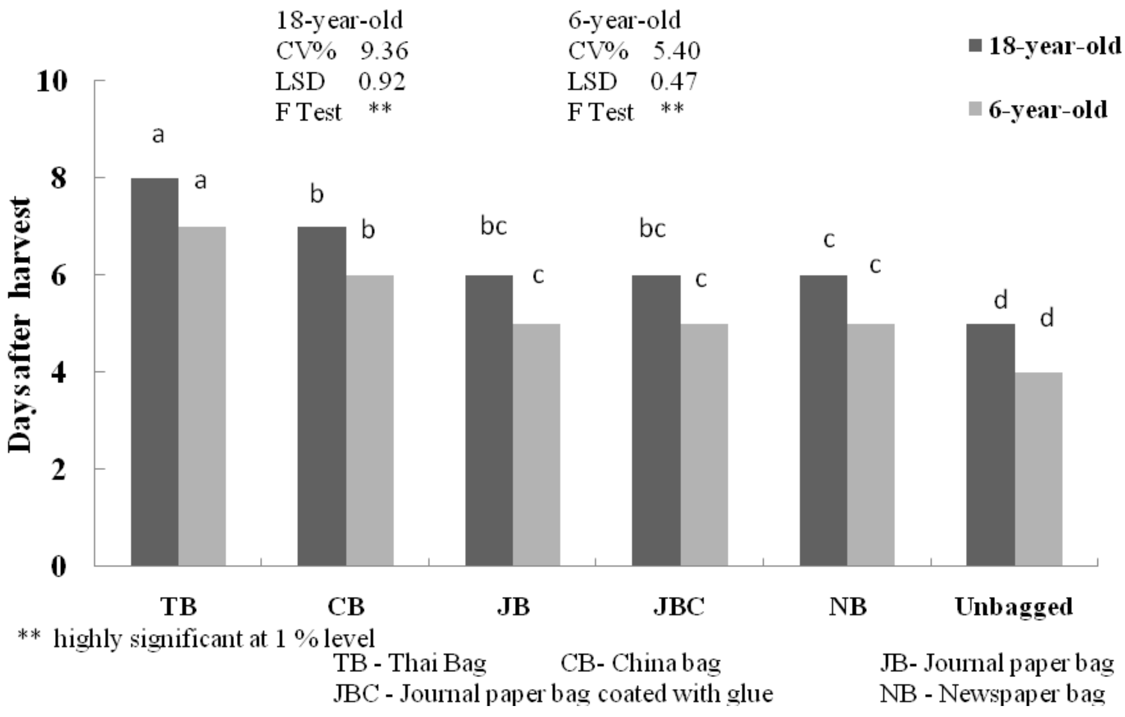


Figure 4.7 Effect of different bagging materials on shelf life of Sein Ta Lone in both experiments

5. CONCLUSION

Bagging materials had significantly affected on peel color, defective fruit % and shelf life of Sein Ta Lone mango in both experiments. Fruits treated with bagging of journal paper bag (JB), journal paper bag coated with glue (JBC) and newspaper bag (NB) showed significantly lower defective fruit % than that of unbagged fruits. Fruits treated with bagging of Thai bag (TB) and China bag (CB) not only improved peel color but also extended the shelf life for about 1-3 days.

The present study revealed that fruits bagged with TB and CB were significantly lowest in defective fruit % and the highest peel color development with the longer shelf life than those of other treatments. These bags were water proof, undamaged, reusable and they were suitable in mango fruit bagging for export market due to better quality (higher in peel color development, lower in defective fruit %).

The fruits treated with JB and NB gave lower in defective fruits % and better peel color than that of unbagged fruits. Therefore, these bags were suitable for local market due to cheaper price, easy availability and protective ability to fruit flies to some extent.

Bagging of Sein Ta Lone mango fruit within 45 days before harvest extended the shelf life 1-3 days longer than unbagged fruits by reducing any damage from insects, disease and others (sun burn and fruit abrasion). Bagging treatments increased fruit weight, area and enhanced peel color development.

The minimum external damage was found in the bagged fruits compared with the unbagged ones. These results indicated that bagging produced an unblemished and high quality fruit with preferable color leading to export market with higher prices for mango growers because it can mainly reduce damage from fruit fly.

6. SUGGESSION

Bagging should be used because it can prevent pest infestation especially fruit flies and mechanical damage such as fruit abrasion, latex burn and sun burn for export market. Growers can get higher price from early harvest (2-3 days earlier than normal harvest) from bagged fruits due to preferable color with damage-free fruits that prolonged shelf life. Further research is needed to conduct type of bagging materials and the optimum bagging time for specific crop.

7. REFERENCES

Allwood, A. J. 1997. Management of fruit flies in the Pacific: A regional Symposium, ACIAR Proceedings No. 76: pp 95-101.

Aluja, M. and R. L. Mangan. 2008. Host status determination for pestiferous fruit fly (Diptera: Tephritidae) species: conceptual, methodological and regulatory considerations. Ann. Review of Ento., 53: 473-502.

Anon, 2003. Bunch covers for improving plantain and banana peel quality. National Agricultural Research Institute, Technical Bulletin No. 4. www.agrinetguyana.org.gy/moa.mfcl

Anonymous, 2003. Optimization of irrigation management in mango trees by determination of water and carbon demands to improve water use efficiency and fruit quality. Report No. 1136/ 1/ 03.

Baldwin, E. A. 2010. Fruit and vegetable flavor. http://www.ne-postharvest.com

Bally, I. S. E., T. J. O'Hare and R. J. Holmes 1996. Detrimental effects of detergent in the development of mango skin browning. Acta Hort., 55: 612−621.

Bassi, P. K. and M. S. Spencer. 1981. Effect of carbon dioxide and light on ethylene production in intact sunflower plants. Plant Physiol. 69:1222-1225.

Beaslay, D. R., D. C. Joyee and P. J. Hofman. 1999. Effect of preharvest bagging and of embryo abortion on calcium levels in Kensington Pride mango fruit. Australian J. Exper. Agri. 39: 345-349.

Bezuidenhout, J. L. J., P. J. Robbertse and C. Kaiser. 2004. Anatomical investigation of lenticel development and subsequent discolouration of 'Tommy Atkins' and Keitt' mango (*Mangifera indica* L.) fruit. J. Hort. Sci. & Biotech, 80 (1): 18–22p.

Bhushan, N. 2012. Post Harvest Profile of Mango, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, Nagpur, 6: 142p.

Billah, M. K. 2009. Mango Production: http://www.allaboutmangoes.com/ mango/ mango production.html

Bompard, J. M. and R. J. Schnell. 1997. Taxonomy and Systematics, In: The Mango (ed. Litz R. E.), CABI Publishing, Wallingford, UK, pp. 21-47.

Bondad, N. D. 1985. Mango bagging: In: Animal Husbandry and Agriculture Journal, June Issue, 11-14.

Burdon, J. N., K. G. Moore and H. Wainwright. 1991. Mineral distribution in mango fruit susceptible to the physiological disorder soft-nose. Sci. Hort. 48: 329-366.

Carrillo, L. A., F. Ramirez-Bustamate, J. B. Valdez-Torres, R. Rojas-Villegas and E. M. Yahia. 2000. Ripening and quality changes in mango fruit as affected by coating with an edible film. J. Food Qlty. 2: 479-486.

DAP, 2013. Department of Agricultural Planning. Myanmar Agriculture at a Glance, Myanmar Agriculture in Brief. Ministry of Agriculture and Irrigation.

David and Dudandanrui, 2010. Myanmar exported 40 ,000 tons of Chinese majority: http://industry.fibiz.com/China-Food/Mango-2009.

Davie, S. J., M. Van Der Walt and P. J. C. Srassen. 1995. The energy demand of fruit production and its effect on fruit size in Sensation. South African Mango Growers' Association Yearbook, 15: 18-20.

De Candolle, A. P. 1886. Origin of cultivated plants (2nd ed.) Kegan Paul, Trench & Co., London, UK.

De Candolle, A. P. 1904. Origin of cultivated plants: In: The Mango (2nd ed.), Botany, Production and Uses, Tropical Research and Education Center and Center for Tropical Agriculture, University of Floridar, CAB International. pp 5-7.

Dietz, T. H., K. R. Thimma Raju and S. S. Joshi. 1988. Structure and development of cuticle and lenticels in fruits of certain cultivars of mango. Acta Hort. vol. 231: 457-460.

DOA, 2011. Department of Agriculture. Myanmar Horticultural Crops Production Report. Ministry of Agriculture and Irrigation.

Drew, R. A. I. and D. L. Hancock. 1994. The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia.

Eccher, T. and N. Noe. 1993. Influence of light on shape and quality of Golden Delicious apples. Acta Hort., 329:156-158.

Estrada, C. G. 2004. Effect of fruit bagging on sanitation and pigmentation of six mango cultivars. Acta Hort., vol. 645: 195-199.

FAO, 2010. The Statistical Division (FAOSTAT) of the Food and Agriculture Organization of the United Nations.
http://faostat.fao.org.

FAOSTAT, 2007. Food and Agriculture Organization of the United Nations database. http://faostat.fao.org.

FAOSTAT, 2012. http://faostat.fao.org/site/385/default.aspx accessed on 10th July.

Fivas, J. and H. Grove. 1998. Pruning of mango trees. In: de Villiers, E. A. (ed). The Cultivation of Mangoes. Institute of Tropical and Subtropical Crops, Nelspruit, pp.72-75.

Gray, J., E. Wardzala, M. Yang, S. Reinbothe, S. Haller and F. Paul. 2004. A small family of LLSI-related non-heme oxygenases in plants with an origin amongst oxygenic photosynthesizers. Plant Mol. Biol., 54: 39- 54.

Han, J. H., K. H. Jang, H. I. Cho, I. H. Choi and J. J. Lee. 2002. Effects of characteristics of the bags and microclimate in the bags on russet of pear fruit, Korea.

Hasyim, A. 2006. Trap types and trap height effectiveness on catching male fruit flies, *Bactrocera* spp. J. Hort. 16 (4): 314-320.

Hofman, P. J., L. G. Smith, D. C. Joyee, G. I. Johnson and G. F. Meiberg. 1997. Bagging of mango (*Mangifera indica* cv. Keitt) fruit influences fruit quality and mineral composition. Preharvest Bio. and Tech., 12: 83-91.

Hofman, P. J., D. R., Beasley and D. C., Joyee. 1999. Effect of preharvest bagging and embryo abortion on calcium levels in Kensington Pride mango fruit: http://www.publish.csrio.au/paper/EA98060.html.

Hollingsworth, R., M. Vagalo, and F. Tsatsia. 1997. Biology of melon flies, with special reference to the Solomon Islands. In: Allwood, A. J. and Drew, R. A. I. (eds.). Management of Fruit Flies in the Pacific. ACIAR Proceeding. 76: 140-144.

Htu, K. 2007. Growing mango for commercial purpose. Myanmar Agricultural Service, Ministry of Agriculture and Irrigation.

Huang Huixae, 2010. High-quality and high efficiency cultivation techniques of subtropical fruit trees. Textbook of International Training Workshop 6th edition, Baise, China.

IIE, 1992. International Institute of Entomology. Distribution Maps of Pests. No. 532.

Jain, N. L., G. V. Krishnamurthy and G. C. Lal. 1959. Non-volatile organic acids in unripe pickling mangoes and salted mango slices by paper chromatography. Food Science, 3: 115-118.

Jha, S. N., A. R. P. Kingsly and S. Chopra. 2006. Physical and mechanical properties of mango during growth and storage for determination of maturity. J. Food Eng. 72: 73-76.

Jia, H. J., A. Araki and G. Okamoto. 2005. Influence of fruit bagging on aroma volatiles and skin coloration of 'Hakuho' peach (*Prunus persica* Batsch). Postharvest Bio. Tech., 35: 61-68.

Joel, D. M. and A. Fahn. 1980. Ultrastructure of the resin ducts of *Mangifera indica* L. (Anacardiaceae). Resin secretion in the primary stem ducts. Annals of Botany, 46**:** 779–83.

Johns, G. G and K. J. Scott. 1989. Delaying harvesting of banana with 'sealed' covers on bunches. 1. Modified atmosphere and microclimate inside sealed covers. Austr. J. Expt. Agric., 29: 719-726.

Johns, G. G. 1996. Effect of bunch trimming and double bunch covering on yield of bananas during winter in New South Wales, Austr. J. Exp. Agric., 36: 229-235.

Johnson, G. I., T. P. Campbell, P. J. Holfman, and G. F. Meiburg. 1994. Effect of mango fruit bagging on fruit quality. In: Horticulture Postharvest Group Biennial Review, pp. 27-28.

Joyee, D. C., D. R. Beasley and A. J. Shorter. 1997. Effect of preharvest baggion on fruit calcium levels, and storage and ripening characteristics of Sensation mangoes. Australian J. Expt. Agri., 37: 383-389.

Kader, A. A. 2002. Modified atmospheres during transport and storage. In: Kader, A. A. (ed.) Postharvest Technology of. Horticultural Crops. Oakland: University of California, Division of Agriculture and Natural Resources Publication, 3311, pp. 535

Kader, A. A. 2008. Mango quality attributes and grade standards: A review of available information and identification of future research needs (Report to the National Mango Board). Davis, CA, USA. Kadar Consulting Servies. Bull., 152: 51p.

Kaplan, K. 2007. *Bactrocera dorsalis* complex Hendel. http://www.ars.usda. gov/is/pr/2007070601.htm.

Kim, Y. H., S. K. Kim, J. M. Park, S. C. Lim, C. K. Youn, B. A. Lee, T. Youn and T. S. Kim. 2003. Effects of physical properties of bagging papers and changes of microclimate in the bags on coloration and quality of peach fruits, Korea.

Kitagawa, H., K. Manabe and E. B. Esguerra. 1992. Bagging of fruit on the tree to control disease. Acta Hort., 321: 870–875.

Kitagawa, H., K. Manabe and E.B. Esguerra. 2009. Bagging of fruit on the tree to control disease: http://www.actahort.org/members/showpdf?booknrarnr= 321-110.

Kyaw, P. N. 2011. Effects of wrapping materials and potassium permanganate on postharvest characteristics of mango (*Mangifera indica* L.) cv. Sein Ta Lone, Master Thesis Dissertation, Department of Horticulture, Yezin Agricultural University, Myanmar.

Lakshimnarayana, S., N.V. Subhadra and H. Subramanyam. 1970. Some aspects of developmental physiology of mango fruit. J. Horti. Sci. 45: 133-142.

Lechaudel, M. and Jacques Joas. 2007. An overview of preharvest factors influencing mango fruit growth, quality and postharvest behavior, France.

Lee, W. Y., H. C. Chang and L.Y. Chen. 1996. A larval parasitoid wasp of the oriental fruit fly in Taiwan.

Li, H. X. and H. Ye. 2000. Infestation and distribution of oriental fruit fly (Diptera: Tephritidae) in Yunnan Province. J. Yunnan University.

Lizada, C. 1993. Mango. In: Seymour, G.B., Taylor, J.E. and Tucker, G.A. (eds) Biochemistry of Fruit Ripening. Chapman and Hill, London, pp. 255-271.

Love, K., R. Bowen and R. Paull. 2003. Increasing marketable production of exotic tropical fruit with protective covering. Western Region, In: Sustainable Agriculture Research and Education, Project Report, Farmer/Rancher, Utah State University, Captain Cook, Hawaii, USA.

Loveys, B. R., S. P., Robinson, J. J. Brophy and E. K. Chacko. 1992. Mango sapburn: components of fruit sap and their role in causing skin damage. Australian J. Plt. Physio., 19**:** 449–57.

Lynch, S. J. and M. J. Mustard. 1955. Mangoes in Florida: The Mango Forum, Homestead, Florida. p. 5-83.

Malundo, T. M. M., E.A. Baldwin, G.O. Ware, and R. L. Shewfelt. 1996. Volatile composition and interaction influence flavor properties of mango (*Mangifera indica* L.). Proc. Fla State Hort. Soc. 109: 264-268.

Malundo, T. M. M., R.L. Shewfelt, G. O. Ware and E. A. Baldwin. 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica* L.). J. Am. Soc. Horti. Sci. 126: 115-121.

MAS, 2005. Myanmar Agricultural Service. Mango Cultivation, Ministry of Agricultural and Irrigation, Myanmar.

Mauseth, J., D. 1988. Plant Anatomy. The Benjamin Cummings Publishing Company Inc. CA, USA.

Medlicott, A. P. and A. K. Thompson. 1985. Analysis of sugar and organic acids in ripening mango fruit (*Mangifera indica* var. Keitt) by high performance liquid chromatography. J. Sci. Food and Agri. 36: 561-566.

MFFVPEA, 2012. Myanmar Fruit, Flower and Vegetables Producers and Exporter Association, Postharvest handling, Food quality and Food Safety Activities.

Mon, C. T. 2003. Cultivars of mango thrived in Mandalay Area. Master Thesis Dissertation. Department of Botany, Mandalay University, Myanmar.

Morris, H. and D. F. Waterhouse. 1998. The distribution and importance of Arthropod pests and weeds of agriculture in Myanmar. ACIAR Monograph. No. 67: 73.

Mukherjee, S. K. 1997. Introduction: botany and importance. In: The mango: Botany, production and Uses. CAB International, Wallingford, UK.

Myat, K. 2012. Export Conditions of Myanmar Mango: Hindrances and Opportunities in the Supply Chain, Master Thesis Dissertation, University of Bologna, Italy.

Naing, W. 2003. Effects of modified atmosphere packing (MAP) with and without chemicals on postharvest characteristics of mango (*Mangifera indica* L.) cv. SeinTa Lone. Master Thesis Dissertation, Department of Horticulture, Yezin Agricultural University, Nyi Pyi Taw, Myanmar.

Nuevo, P. A., E. B. Pantastico and D. B. Mendoza. 1984. Gas diffusion factors in fruits. In. Anatomical studies in banana fruits. Postharvest Res. Notes. 1: 26-27.

O'Hare, T. J. and A. Prasad. 1992. The alleviation of sap-induced skin injury by calcium hydroxide. Acta Hort., 321: 372–81.

Opeke, L. K. 1982. Tropical tree crops, Jhon Wiley and Sons, Chichester, UK.

Orankanok, W., S. Chinvinijkul, S. Thannaphum, P. Sitilob and W. R. Enkerlin. 2007. Area-wide integrated control of oriental fruit fly *Bactrocera dorsalis* and guava fruit fly *Bactrocera correcta* in Thailand. Area-wide control of insect pests. Spribnger Netherlands. 789p.

http://www. Idfresearch.org.

Palozza, P. and N. I. Krinsky. 1992. Antioxidant effects of carotenoids in vivo and in vitro: an overview on Methods of Enzymology, 213: 403–420.

Pantostico, E. B., and Cosico V. B. 1975. Some Forms and Functions of the Fruits and Vegetable epidermis. Kalikasan, Pal. J. Biol. 4: 175:197.

Pathak, R.K. 2009. Protocol for pest harvest management of Mango:

Pereira, F. M. 1990. Factors affecting guava production and quality with special reference to Sao Paulo, Brazil. Acta Hort., 275:103-109.

Popenoe, W. 1920. Manual of Tropical and Subtropical Fruits, Macmillan, New York.

Proctor, J. T. and L. L. Creasy. 1969. The anthocyanin of the mango fruit. Phytochemistry, 8: 2108.

Purseglove, J. W. 1972. Mangoes west of India. Acta Hort. 24: 107-174.

Ram, S. 2002. Mango production and development, Union of Myanmar report. Food and Agriculture Organization of the United Nations, Regional Officer for Asia and the Pacific, Bangkok, Thailand.

Robinson, J. C. 1996. Bananas and plantains. In: Institute for Tropical and Subtropical Crops, University Press, Cambridge, pp.172-174.

Rodriguez-Amaya, D. B. 2001. A guide to Carotenoid Analysis in Foods. ILSI Press, Washington DC, USA.

Seymour, G. B., M. N'Diaya, H. Wainwright and G. A. Tucker. 1990. Effects of cultivar and harvest maturity on ripening of mangoes during storage. J. Hort. Sci. 65: 479-483.

Soe, T. T. 2008. Studies on improved methods of postharvest storage of mango fruits. Ph. D. Thesis Dissertation, Department of International Agricultural Development, Graduate School of Agriculture, Tokyo University of Agriculture, Japan.

Steiner, L. F., G.G. Rohwer, E. L. Ayers, and L. D. Christenson. 1961. The role of attractants in the recent Mediterranean fruit fly eradication program in Florida. J. Econ. Entomol. 54 (1): 30.35.

Tamjinda, B., J. Siriphanich and T. Nobuchi. 1992. Anatomy of lenticels and occurrence of their discoloration in mangoes. Kasetsart J. 26: 57-64.

Tharanthan, R. N., Yashoda, H. M. and Prabha, T. N. 2006. Mango (*Mangifera indica* L.), " The King of fruits " – An overview. Food Reviews International, 22: 95-123.

Tyas, J. A., P. J. Hoffman, S. J. R. Underhill and K. L. Bell. 1998. Fruit canopy position and panicle bagging affects yield and quality of 'Tai So' lychee. Sci. Horti., 72: 203-213.

Ueda, M., K. Sasaki, N. Utsumomiya, K. Inaba and Y. Shimabayashi. 2000. Changes in physical and chemical properties during maturation of mango fruit (*Mangifera indica* L. Irwin) cultured in a plastic greenhouse. Food Sci. Technol. Res. 6: 299-305.

UN FAOSTAT, 2011. Statistics from: Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division. UN Food and Agriculture Organization Corporate Statistical Database.

USDA Nutrient Database, 2010. Fruit Reports on Mango, USDA National Database for Standard Reference, SR-23: p 449

Vegneault, C., Raghavan, G. S. V., Markarian, N. R., De-Ell, J. R., Gariepy, Y. and 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. Science Publishers, Inc. Enfield (NH), USA. pp. 23-64.

Verheij, E. W. M. 1991. Edible fruits and nuts. Plant Resources of South-East Asia. pp. 211-216.

Wai, K. S. 2004. Review and analysis of the Competitiveness of Myanmar mango and chilli, Commodity Competitiveness Study for the Integration of Myanmar's

Agriculture nto the ASEAN. FAO, TCP/MYA/2902.Ministry of Agriculture and Irrigation, Yangon, Myanmar.

Wang, L., K. Xu, F. Bei and F. S. Gao. 2007. Effects of bagging on the microclimate, yield and quality of over-wintering tomato.

Watanawan, A., C. Watanawan, and J. Jarunate. 2009. Bagging on Nam Dok Mai Mango during development affects color and fruit quality: http://www.actahort.org.

Waterhouse, D. F. 1993. Biological control: Pacific Prospects. Supplement 2, Canberra, Australia.

Yahia, E. M. 1998. Postharvest handling of mangoes. Technical Report. Agricultural Technology Utilization and Transfer Project, Giza, Egypt. http://www.atut.gov.eg.

Yahia, E. M. 2006. Modified and controlled atmospheres for tropical fruits. Stewart Postharvest Review. 5: (6).

Yeshitela, T., P. J. Robbertse, P. J. C. Stassen, J. Grimbeek and M. Van der Linde. 2003. Fruit thinning intensities and their impact on the yield and quality of Sensation mango (*Mangifera indica* L.) fruits. Tropic. Agri. 8(2): 123-127.

Yin, N. N. 2010. Biology and Ecology of Oriental Fruit Fly, *Bactrocera dorsalis* HENDLE (Diptera: Tephritidae) in Mango and its Bioassay. Ph. D. Thesis Dissertation, Department of Zoology and Entomoloty, Yezin Agricultural University, Myanmar.

APPENDIX TABLES

Appendix Table 1. Effect of different bagging materials on days to fruit maturity, fruit weight and fruit area in 18-year-old Sein Ta Lone mango tree

Treatments	Days to fruit maturity (days)	Fruit weight (g)	Fruit area (cm^2)
Thai bag	119.90	335.06	81.88
China bag	119.80	323.38	79.71
Journal paper bag	119.49	322.06	79.28
Journal paper bag coated with glue	119.59	311.91	76.99
Newspaper bag	11958	322.42	80.49
Control	119.65	317.48	78.25
F Test	ns	ns	ns
CV%	0.42	8.43	4.80
$LSD_{0.05}$	0.46	24.44	3.44

ns = non significant

Appendix Table 2. Effect of different bagging materials on days to fruit maturity, fruit weight and fruit area in 6-year-old Sein Ta Lone mango tree

Treatments	Days to fruit maturity (days)	Fruit weight (g)	Fruit area (cm^2)
Thai bag	119.90	313.57 a	79.02 a
China bag	119.36	298.07 ab	75.37 ab
Journal paper bag	119.55	286.08 bc	73.83 bc
Journal paper bag coated with glue	119.44	267.41 c	70.80 c
Newspaper bag	119.49	297.08 ab	75.61 ab
Control	119.44	285.15 bc	73.81 bc
F Test	ns	**	**
CV%	0.54	7.68	5.97
$LSD_{0.05}$	0.58	20.15	4.02

Means followed by the same letters in each column are not significantly different at $P \leq 0.05$.

** highly significant at 1% level   ns = non significant

Appendix Table 3. Effect of different bagging materials on peel color, Brix%, defective fruit% and shelf life in 18-year-old Sein Ta Lone mango tree

Treatments	Peel color (score)	Brix%	Defective fruit (%)	Shelf life (days)
Thai bag	4.98 a	8.50	4 (0.88)[1] d	8.00 a
China bag	4.80 a	8.40	8 (0.98)[1] d	7.00 b
Journal paper bag	2.40 b	8.48	24 (1.59)[1] c	6.00 bc
Journal paper bag coated with glue	2.67 b	8.50	44 (2.14)[1] b	6.00 bc
Newspaper bag	2.67 b	8.55	34(1.9)[1] bc	6.00 c
Control	1.42 c	8.50	74 (2.79)[1] a	5.00 d
F Test	**	ns	**	**
CV%	13.74	8.38	32.78	9.36
$LSD_{0.05}$	0.6	1.07	0.51	0.92

Means followed by the same letters in each column are not significantly different at $P \leq 0.05$.

** highly significant at 1% level ns = non significant

([1] value of means in parenthesis are square root transformed data)

Appendix Table 4. Effect of different bagging materials on peel color, Brix%, defective fruit% and shelf life in 6-year-old Sein Ta Lone mango tree

Treatments	Peel color (score)	Brix%	Defective fruit (%)	Shelf life (days)
Thai bag	5.00 a	7.60	4 (0.88)[1] b	7.00 a
China bag	4.96 a	7.90	10 (1.07)[1] b	6.00 b
Journal paper bag	2.64 b	7.20	78 (2.89)[1] a	5.00 c
Journal paper bag coated with glue	2.64 b	7.70	84 (2.98)[1] a	5.00 c
Newspaper bag	2.75 b	7.20	76 (2.82)[1] a	5.00 c
Control	1.62 c	7.48	88 (3.04)[1]a	4.00 d
F Test	**	ns	**	**
CV%	11.10	13.13	16.61	5.4
$LSD_{0.05}$	0.55	1.49	0.34	0.47

Means followed by the same letters in each column are not significantly different at $P \leq 0.05$.

** highly significant at 1% level ns = non significant

([1] value of means in parenthesis are square root transformed data)

Appendix Table 5. Cost and Benefit for Sein Ta Lone mango by using different bagging materials (18-year-old tree)

Treatment	Materials cost/fruit	Labor cost /fruit	No. of fruit/ ton	Total cost/ fruit	Total weight (ton)	Export value (kyat /ton)	Return (kyat)	Benefit
TB	60/2years	5	50	1750	0.017	730,400	12,416.8	10,666.8
CB	30	5	50	1750	0.016	730,400	11,686.4	9,936.4
JB	5	5	50	500	0.016	650,400	10,406.4	9,906.4
JBC	7	5	50	600	0.014	323,700	4,531.8	3,931.8
NB	4	5	50	450	0.016	650,400	10,406.4	9,956.4
Unbagged	-	-	50	-	0.015	323,700	4,855.5	4,855.5

Cultural practices and management levels of all treatments were the same.

Bagged fruit - 880 $/ ton

Unbagged fruit - 390 $/ ton

Current price of $ - 830 Kyats [Source – Agri-business News (2011)]

Appendix Table 6. Cost and Benefit for Sein Ta Lone mango by using different bagging materials (6-year-old tree)

Treatment	Materials cost/fruit	Labor cost /fruit	No. of fruit/ ton	Total cost/ fruit	Total weight (ton)	Export value (kyat /ton)	Return (kyat)	Benefit
TB	60/2years	5	50	1750	0.016	730,400	11,686.4	9,936.4
CB	30	5	50	1750	0.015	730,400	10,956.0	9,206.0
JB	5	5	50	500	0.013	650,400	8,455.2	7955.2
JBC	7	5	50	600	0.014	323,700	4,531.8	3,931.8
NB	4	5	50	450	0.015	650,400	9,756.0	9,306.0
Unbagged	-	-	50	-	0.014	323,700	4,531.8	4,531.8

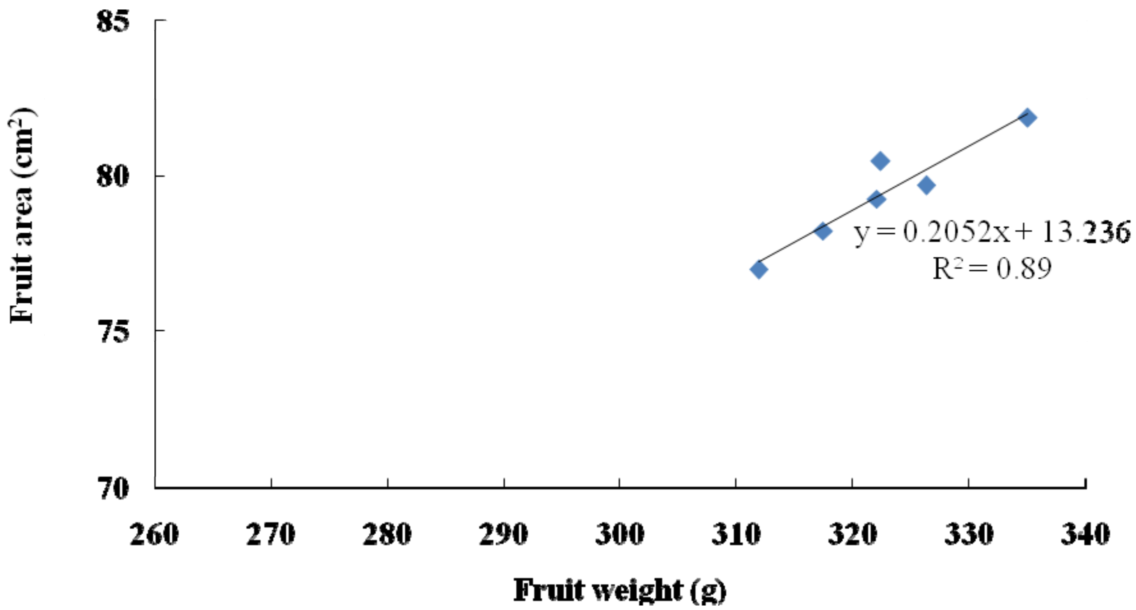
Cultural practices and management levels of all treatments were the same.

Bagged fruit - 880 $/ ton

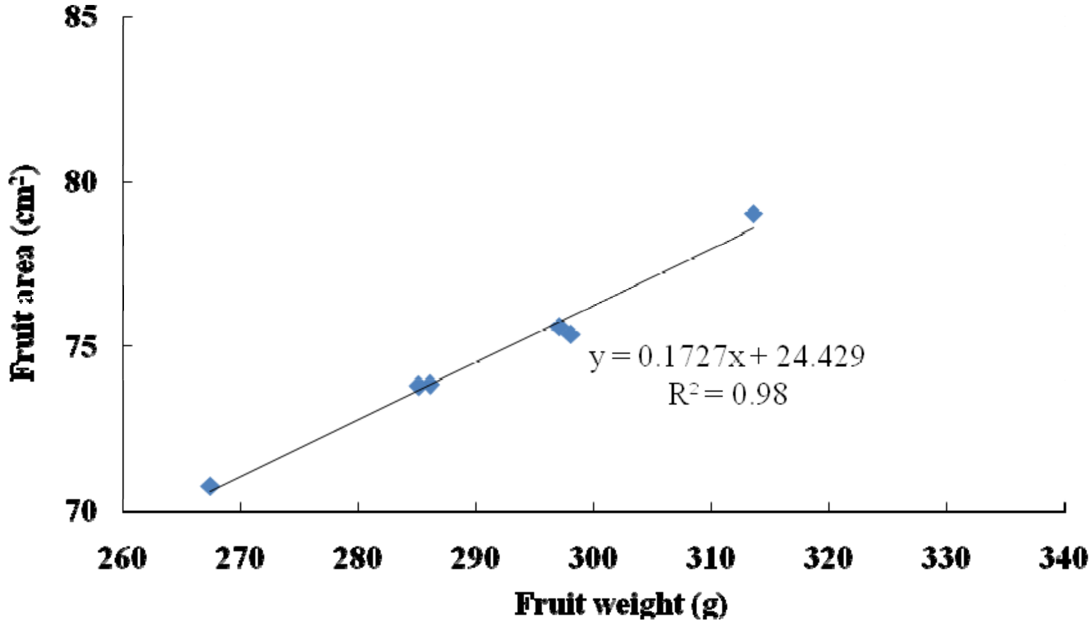
Unbagged fruit - 390 $/ ton

Current price of $ - 830 Kyats [Source – Agri-business News (2011)]

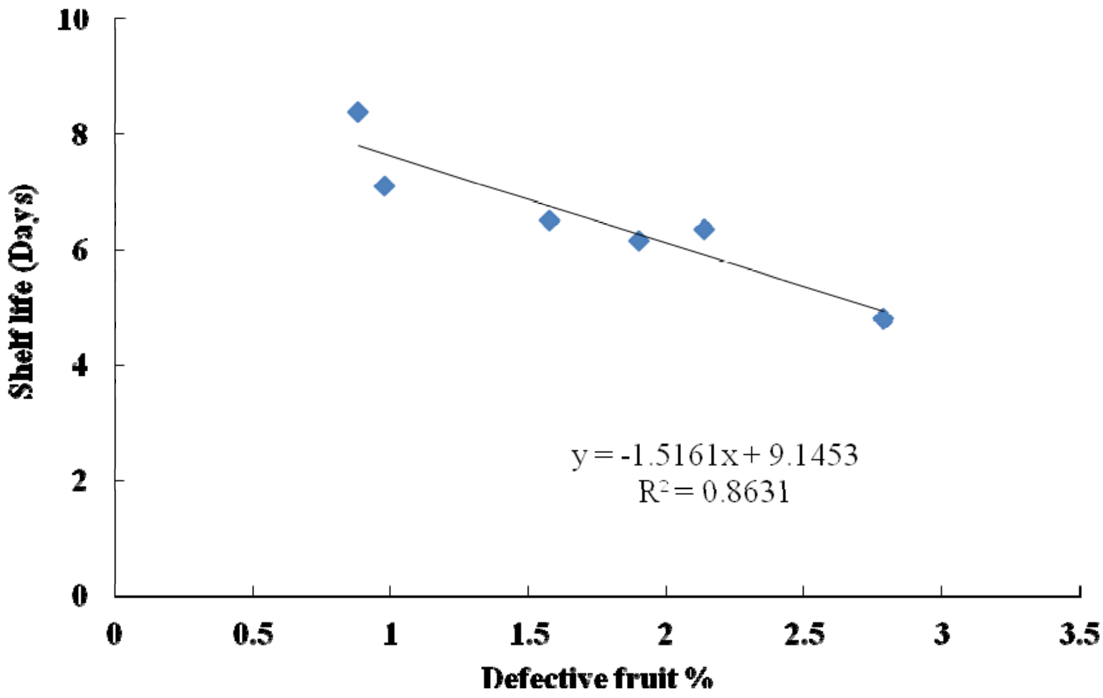
APPENDIX FIGURES



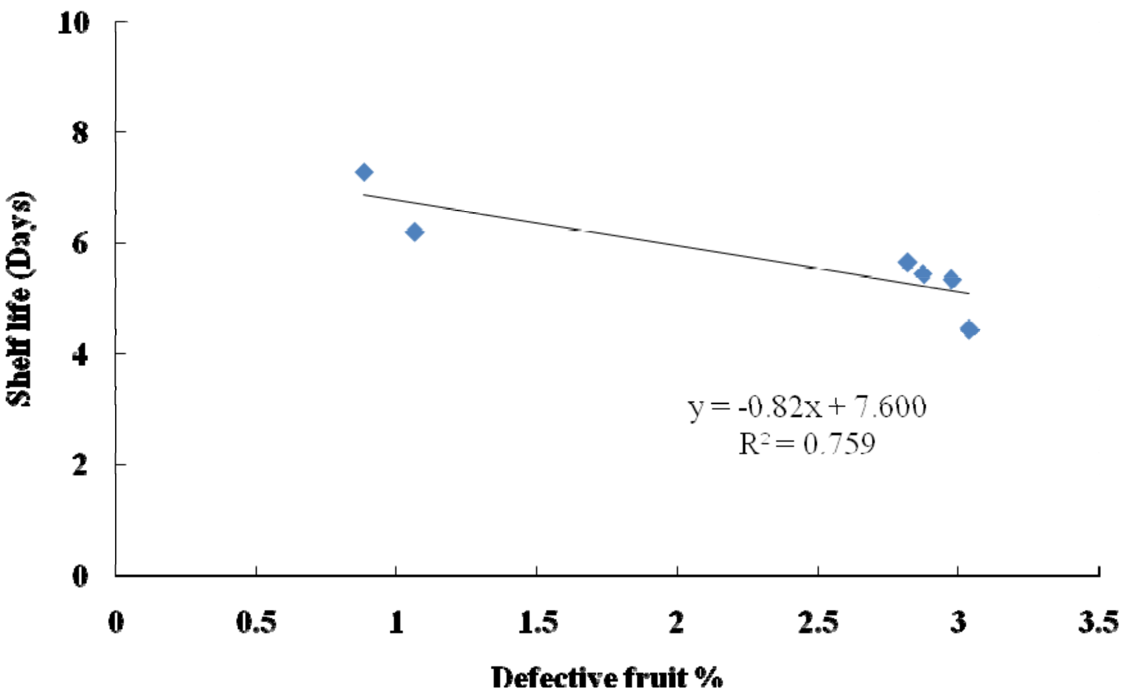
Appendix Figure 1. Relationship between fruit weight and fruit area in 18-year-old Sein Ta Lone trees



Appendix Figure 2. Relationship between fruit weight and fruit area in 6-year-old Sein Ta Lone trees



Appendix Figure 3. **Relationship between defective fruit % and shelf life in 18-year-old Sein Ta Lone trees**



Appendix Figure 4. **Relationship between defective fruit % and shelf in 6-year-old Sein Ta Lone trees**

APPENDIX PLATES

Appendix Plate 1. Effect of different bagging materials on peel color of Sein Ta Lone mango on tree: (A) Thai bags, (B) China bag and Journal bag, (C) China bag and Thai bag, (D) Thai bag and unbagged fruit, (E) China bag and Newspaper bag, (F) Newspaper bag and unbagged fruit, (G) Thai bag and unbagged fruit and (H) Thai bag and Newspaper bag