EFFECTS OF DIFFERENT TIME OF BAGGING ON FRUIT DEVELOPMENT, PHYSICO-CHEMICAL COMPOSITIONS AND SHELF LIFE OF MANGO CV. KHIRSAPAT

A THESIS

BY

YESMAT ARA SALMA
Registration No. 1605343
Session: 2016-2017
Thesis Semester: January-June, 2018

MASTER OF SCIENCE (M.S.)

IN

HORTICULTURE

DEPARTMENT OF HORTICULTURE
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY DINAJPUR-5200, BANGLADESH

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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted at the mango orchard of Basherhat, near the Hajee Mohamma Danesh Science and Technology University, Dinajpur during March to July, 2017. The chemical analyses were conducted at Bangladesh Atomic Energy Commission, Agargaon, Dhaka and others parameters were conducted at Department of Horticulture, HSTU, Dinajpur, Bangladesh. The experimental treatment was arranged as a two-factor experiment, where factor 'A' was different bagging times (*viz.* Bagging at 35, 45 and 55 days after fruit set) and factor 'B' was different pre-harvest bagging materials (*viz.* T_0: Non-bagged (control), T_1: Brown paper double layered bag (BPB), T_2: White paper single layered bag (WPB) and T_3: Perforated transparent polythene bag (TPB).The experiment was laid out in the randomized completely block design with three replications (10 plants per replication) with a unit of 5 fruits per treatment per replication. The result showed that the pre-harvest bagging with brown paper bag and white paper bag at 35 days after fruit set contributed for best results for infestation of fruit fly infestation. When 45 days after fruit set gave best performance for total weight loss, pulp and stone weight, pH, total sugar, colour, appearance, shelf life, number of fruit immature fruit inside the bag and decreased infestation of fruit fly, disease of stem end rot, anthracnose .The white paper bag contributed best performance for total soluble solid. At 55 days after fruit set, brown paper bag and white paper bag improved total weight loss, pulp and stone weight, total soluble solid, pH, total sugar, number of fruit immature fruit inside the bag and decreased disease of stem end rot, anthracnose. It is advisable to use brown paper bag for getting colored fruits i.e., yellow colour since white paper bag for retains original colour of each variety. Both bags showed their potentiality against major insect-pests and diseases attack. Bagging fruits have a good shelf life which is important criteria for exportable mango. On the other hand, bagging fruits having attractive colour, farmer will get more market prices for their mangoes. Therefore, farmers might be used this technology for commercial mango cultivation for fulfill demand of quality mango in country and abroad.

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CHAPTER I

INTRODUCTION

Mango is a fleshy stone fruit belonging to the genus *Mangifera,* consisting of numerous tropical fruiting trees in the flowering plant family Anacardiaceae. It is also recognized as one of the choicest and well accepted fruit all over the world and also acknowledged as the "King of fruits" (Shahjahan *et al*., 1994). It is a popular nutritional and commercial fruit in tropical and subtropical areas or especially in Asia. Mango is indigenous to Indian Subcontinent for 4000 years and reached East Asia between the 4th to 5th centuries BC (Candole, 1984; Mukherjee, 1998). Currently, there are about 37846 hectares of land occupied with mango and produced about 11.61 lac tons. In terms of total area and production of fruit crops, mango ranks first in area and third in production (BBS, 2017). It provides a lot of energy with as much as. It plays an important role in balancing the human diet by providing about 74-86 calories per 100 g of ripe fruits (Rathori *et al.* 2007). Bothunripe and ripe mangoes are good sources of vitamins A, B and C, niacin; and also rich in minerals including calcium, potassium and iron (Amin and Hanif, 2002). The area under mango is increasing every year but safe and quality mango production is not increasing (Uddin *et al.* 2018).

Mango fruits are subjected to during their growth and development undergo several physical and chemical changes, mechanical damages, all of which reduce their commercial value and thereby cause significant yield and economic losses. The outbreak of different animate and inanimate attacks of mango reduces the target yield every year. To control these problems, farmers are using pesticides 15-62 times in their orchard and it is increasing as alarming rate (Uddin *et al*. 2015). A huge quantity of mango fruits may be lost due to the fruit fly infestation every year (Sarkar *et al*. 2009 and Uddin *et al.*, 2017). Because of favorable environment during fruit maturity, mango fruit fly is a major pest of Khirsapat, Langra, Fazli, BARI Aam-4, BARI Aam-7, BARI Aam-8 and Ashwina varieties of mango. To prevent the losses caused by biotic and abiotic factors, several good agricultural practices are becoming popular throughout the world (Sharma, 2013). Furthermore, the development of alternative techniques to improve the appearance and quality of fruits and to reduce disease and insect infestations is becoming increasingly important as consumer are in anxiety over the uses of manmade agro-chemicals and environmental awareness increases. Pre-harvest fruit bagging technique protects fruits from insect, pests, fungal infections, post-harvest diseases, mechanical damages, reduces spraying of insecticides and provides an estimate of harvestable fruits per tree (Nagaharshitha *et al*. 2014). Among several such alternatives, this technique has been used extensively in several fruit crops to improve skin colour and to reduce the incidence of disease, insect pests, mechanical damage, sunburn of the skin, agrochemical residues on the fruit, and bird damage (Xu *et al.*, 2010; Sharma *et al.*, 2014).

Bags are also used to prevent laying eggs of oriental fruit fly. It was reported that as an efficient, safer and cheaper method for controlling mango insects and diseases. Bagging approach has been tested to produce high quality unblemished mango fruits in Queensland (Hofman *et al*. 1997), South Africa (Oosthuyse and Jacobs 1997), Philippines (Bugante *et al*. 1997) and in Bangladesh (Uddin and Reza 2017). Many researchers (Hofman *et al*. 1997; Oosthuyse and Jacobs 1997 and (Bugante *et al*. 1997) reported that fruit bagging at an early stage was the most effective method to combat mango anthracnose disease. Similarly, (Dutta and Majumder 2012) reported that anthracnose and stem end rot (SER) caused by *Colletotrichum* and *Diplodia* spp., respectively were reduced by bagging. (Kitagawa *et al*. 1992) reported that bagging has been widely used for preventing destruction of fruits by birds, insects and diseases to produce unblemished and high-quality fruits. (Sharma *et al*. 2014) also found that pre-harvest bagging is a physical protection method which not only improved the visual quality of fruits by promoting skin colour and reducing blemishes, but can also change the micro-environment for fruit development, which can have several beneficial effects on internal fruit quality.

Anthracnose (*Colletotrichum gloeosporioides*) and stem end rot (*Diplododia* spp.*)* are the major post-harvest diseases of mango fruits, which cause black spots on fruits skin during ripening and storage. Many scientists estimated that 20-30% losses in fruits are due to post harvest diseases (Yadav *et al*., 2013). The main causes are associated for shorter shelf life mainly post-harvest diseases. They also claimed that pre-harvest bagging of fruits can also reduce the incidence of disease, insect pests and/or mechanical damages, sunburn of the pericarp, fruit cracking, agrochemical residues on the fruit and bird damages (Sarkar *et al.*, 2014). Brown paper bag performed best considering fruit fly infestation, TSS (%), fruit colour and physical injury on mango fruits was (Sarkar *et al.*, 2009). But such study is limited to draw valid conclusions.

Therefore, the present study has been undertaken to:

(i) to find out the suitable time of fruit bagging for mango;

(ii) to investigate the effect of different bagging materials on the quality and shelf-life extension of mango; and

(iii) To protect mango from major diseases, pest attack besides facilitating the farmers to get quality fruits as well as good price.

CHAPTER II

REVIEW OF LITERATURE

Mango is an important and popular fruit of Bangladesh. It has a unique position in respect of nutritional quality, taste, consumers' preference etc. among the seventy (70-seventy) kinds of fruits grown in Bangladesh. Mango is now recognized as one of the choicest fruits in the world-market for its excellent flavor, attractive colour and delicious taste. Pre-harvest bagging of mango fruit is primarily done for physical protection from fruit fly, but it also influences fruit quality to some extent by promoting peel colour and reducing skin blemishes through changing micro-environment of fruits (Sharma *et al.* 2014). Furthermore, that bagging can effectively reduce insect-pest attack, disease incidence, mechanical and sunburn injuries and bird-damages. Some of the most relevant works fruit development, on physico-chemical properties of mango and other fruits as influenced by pre-harvest fruit bagging have been reviewed in this chapter.

Islam *et al.* (2017) was conducted a research at the Department of Horticulture, HSTU, Dinajpur, Bangladesh, during January to July, 2016 for safe mango production by applying minimum use of pesticide entitled influence of bagging on physico-chemical properties and shelf life of mango cv. Mishribhog. The experiment was set in the Randomized completely Block Design and the mango fruits were bagged at marble stage with different types of bags which constituted five treatments viz.: T_1: Brown paper bag; T_2: White paper bag; T_3: Polythene bag T_4: Muslin cloth bag; T_5: No bagging (control). Bagging with brown paper bag and white paper bag improved fruit retention, weight of fruit, diameter of fruit, pulp weight, total soluble solids, ascorbic acid, percent citric acid, reducing sugars and β-carotene at harvest and ripe stages over control. Brown paper bag changed fruit colour. In all cases good quality, cleaner, disease and insect free fruits were harvested. The sensory qualities in fruits of brown, white and muslin cloth bags were improved over control. Fruit retention was significantly enhanced by pre-harvest bagging with brown paper bag (91.00) and white paper bag (87.00) over control (81.33 days). The harvesting time was significantly deferred (65.67 days) in brown paper bag over control. Pre-harvest bagging also reduced occurrence of spongy tissue and the incidence of mealy bugs. These results specify that fruit bagging can improve fruit quality through diminution in disease and insect-pest infestation and shelf life of mango cv. Mishribhog.

Uddin and Reza (2017) carried out a field experiment on effect of fruit bagging on different mango varieties grown at Chapainawabganj. From the experimental results it was concluded that fruit bagging technology was very effective for getting quality mango fruits. It was advisable to use brown colour paper bag for getting colored fruits i.e., yellow colour since white colour paper bag for retains original colour of each variety. Both bags showed their potentiality against major insect-pests and diseases attack. Bagging fruits had a good shelf life too.

Islam *et al.* (2017)performed an investigation was at the Department of Horticulture, HSTU, Dinajpur, Bangladesh during January to July, 2016, entitled studies on influence of bagging on physico-chemical properties and shelf life of mango cv. Mollika. Mango fruits were bagged at marble stage with different types of bags which constituted various treatments viz.: T_1: Brown paper double layered bag (BPB), T_2: White paper single layered bag (WPB), T_3: Muslin cloth bag (MCB) and T_0: Non-bagged (control). The result concluded that brown paper bag was best performance for fruit retention, days required for harvesting, fruit length, total soluble solids, pulp weight, pulp stone ratio and β-carotene content of fruits. White paper bag was best performance for citric acid content, reducing sugar and total sugar content whereas muslin cloth bag increased fruit diameter and stone weight. Bagging had significant effect on mealy bug infestation. Bagging fruits had a good shelf life which was an important criterion exportable mango. Therefore, farmers might use that technology for commercial mango cultivation to fulfill the demand of quality mango in the country and abroad.

Singh *et al.* (2017) an experiment was conducted at the Agriculture Experimental Station (AES), Paria which is situated in Valsad district of Gujarat at an elevation of 10 meters above mean sea level at the latitude of 20^0-57' N and east 72^0-54' E longitude in the month of March 2011 to June 2011 to study the influence of fruit bagging on quality of mango fruit in different varieties *viz.*, Kesar, Alphonso, Langra, Vanraj. The treatments comprised of five different colours of bags (brown, old newspaper, yellow, and white) with control. Organoleptic evaluation colour (7.33), taste (7.47)) and carotenoides content (4.07 µg/g of tissue) recorded were significantly the maximum in brown paper bags (T_1). Significantly maximum carotenoids content (5.60 µg/g of tissue) recorded in interaction between brown papers bagged Kesar fruits (V_1T_1) and higher content of chlorophyll in unbagged Vanraj fruits (V_4T_5). It was concluded from the present study that under the South Gujarat condition, fruits were bagging with brown paper bags, gave better results in all at the parameters. Kesar and Alphonso varietis showed better results in respect of the parameters studied. Kesar variety (V_1) recorded maximum organoleptic evaluation: colour (7.42), texture (7.63), taste (7.55), flavor (7.50), TSS (20.58 0B) and carotenoid contents (3.90 µg/g of tissue) whereas Alphonso variety (V_2) recorded the highest quantity of total sugar (14.15%), reducing sugar (4.04%), non-reducing sugar (10.11%) and ascorbic acid (22.23 mg/100 g pulp). The minimum titrable acidity (0.16%) was obtained with both Langra and Vanraj varieties. Vanraj variety (V_4) received the maximum chlorophyll content (4.48 µg/g tissue). Thus, it was concluded from the study that Pre-harvest fruit bagging was a farmer friendly practice to ensure the quality and physical appearance of the fruit. It was easy and safe practice that protects fruits from diseases and insect pests.

Uddin *et al.* (2016) conducted an experiment in a mango orchard of Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Chapainawabganj to control fruit fly infestation using fruit bagging during May, 2014 to September 2015. The commercial mango variety 'Khirsapat' was selected and doubled layered brown paper bags (300 x 200 mm) were used. Mangoes were bagged on different days after fruit set as T_1 = 35, T_2 = 40, T_3 = 45, T_4 = 50, T_5 = 55 and T_6 = 60 days and continued up to harvest. The results indicated that pre harvest bagging affected peel appearance, and all treatments showed good quality of mango production except T_1 and T_6 and no infestation were found during post-harvest condition. In $T_{6,}$ about 5% fruits were infested. During the mango season in Chapainawabganj, the highest population of fruit fly (7236.30 ± 18.69) was recorded in July. So, the result suggested that the use of double layered brown paper bags would be an eco-friendly management against the infestation of fruit flies. However, mango farmers must bag their mango after 40-55 days of fruit set.

Kireeti *et al.* (2016) conducted an experiment in the mango orchard of cv. Alphonso at the Department of Horticulture, College of Agriculture, Dr. Balasaheb Sawantk Onkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) India in summer, from March 2013, to June to study on the effects of types of bag at egg stage on mango fruit (cv. Alphonso). The experiment was set using the Completely Randomized Design (CRD) with 8 treatments i.e. T_1: Newspaper bag; $T_{2:}$ Brown paper bag; T_3: Scurting bag; T4: Polythene bag; T_5: Butter paper bag; T_6: Muslin cloth bag; T_7: Brown paper bag with polythene coating; T_8: control (unbagged). The results indicated that various chemical parameters were affected significantly due to bagging. The study had shown that newspaper bag (T_1) showed best performance for fruit retention (90.67 %), length (9.44 cm), weight (298.67 g) and pulp weight (223.88 g) of fruits and polythene bag (T_4) contributed best for days required for harvesting (55 DAB). Bagging had significant effect on mealy bug infestation. Thus, it was concluded that different types of bags influenced growth and development of mango fruits.

Jakhar and Pathak (2016) conducted an experiment in India to study the effects of pre-harvest bagging and spray of $CaCl_2$ and K_2SO_4 on quality and shelf life of mango fruits cv. Amrapali during two succeeding years. Trees of Amrapali were sprayed three times at 30, 20, and 10 days before harvesting and bagging with brown paper bag 20 days before harvesting of fruits. Harvested fruits were stored under the ambient temperature (room temperature) and observations were taken at three days intervals up to 18 days. The results indicated that the pre-harvest treatment of 2% $CaCl_2$+1% K_2SO_4+bagging was superior to improve of the quality of fruits in respect of the highest fruits weight, firmness, TSS, ascorbic acid, total sugars, and β-carotene content with minimum black spotted fruit percent and maintained it throughout the storage period up to 18 days. Fruits treated with 2% $CaCl_2$+1% K_2SO_4+bagging showed shelf life up to 12 days with the lowest weight loss and highest organoleptic quality against 6 days of untreated fruits (control).

Shinde *et al.* (2015) carried out a field experiment on the effect of scurting bag on the physico-chemical properties of mango cv. Kesar during 2012-2014 in the randomised block design with 7 treatments of scurting bags*viz.* T_1: Bagging with scurting bags at marble stage and removal of bags after 45 days; T_2: Bagging with scurting bags at marble stage and removal of bags after 60 days; T_3: Bagging with scurting bags at marble stage and removal of bags after 75 days; T_4: Bagging with scurting bags at egg stage and removal of bags after 45 days; T_5: Bagging with scurting bags at the egg stage and removal of bags after 60 days; T_6: Bagging with scurting bags at egg stage to till harvest; T_7: control (No bagging). All the treatments were replicated three times with a unit of 30 fruits per replication. Scurting bag improved fruit retention, fruit weight, fruit diameter, pulp weight, TSS, reducing sugar and total sugar of mature fruits. The sensory qualities were maintained by bagging treatments. The disease and pests got significantly reduced by pre-harvest bagging.

Sanas *et al.* (2015) conducted an experiment at the Department of Horticulture, Dr. Balasaheb Sawant K Onkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (MH) India, during 2010 -2012 for two consecutive fruiting seasons to study the effects of pre-harvest fruit bagging on the physico-chemical properties of karond a (*Carissa conjesta* Linn.) cv. ‘Konkan Bold. The experiment was conducted in the randomized block design with six treatments replicated four times. The treatments comprised of various type of materials used for bagging *viz.* T_1: News paper bag; T_2: Brown paper bag; T_3: Butter paper bag; T_4: Plastic bag; T_5: Brown plastic bag and T_6: Control. The maximum fruit retention was noticed in T_3 (Butter paper bag, 69.25%). Most of the treatments improved the quality of fruits among which T_2 (Brown paper bag) recorded the highest TSS (17.68%), reducing sugars (4.91%) and total sugars (8.49%). The highest fruit length (2.82 cm), fruit diameter (2.56 cm), fruit weight (12.45g) and pulp weight (11.23 g) were recorded in control (No bagging) fruits. The highest score for colour, flavor, texture and overall acceptability were noted in T_3 (Butter paper bag).

Haldankar *et al.* (2015) conducted an experiment in the mango orchard of cv. Alphonso at the Department of Horticulture, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) India, from 2013 to 2014 for consecutive two years during February to May to study the influences of bagging of fruits at marble stage on the quality of mango cv. Alphonso. The fruits were bagged at marble stage (30 days from fruit set) with 8 treatments *viz:* T_1: Newspaper bag; T_2: Brown paper bag; T_3: Scurting bag; T_4: Polythene bag; T_5: Butter paper bag; T_6: White cloth bag; T_7: Brown paper bag with polythene coating; T_8: control (no bagging). The pre-harvest bagging modified fruit retention, period required for harvesting after bagging, physico-chemical composition of mature and ripe fruit, shelf life, occurrence of spongy tissue and pest incidence. Bagging with newspaper bag and brown paper bag improved fruit retention, weight of fruits, diameter of fruits, pulp weight, total soluble solids and reducing sugars at ripe stage and produced spongy tissue free fruits. The brown paper bag with polythene coating improved fruit retention, weight of fruit, pulp weight and decreased occurrence of spongy tissue and incidence of mealy bug. The butter paper bag, white cloth bag and scurting bag improved fruit retention, reduced occurrence of spongy tissue and incidence of mealy bug. Pre-harvest bagging with different types of bag did not change the sensory qualities of ripe fruits.

A field experiment was conducted by Mondal *et al.* (2015) at Baruipur, South 24 Parganas and West Bengal during April, 2011 to February, 2012 under the title bio-friendly management of guava fruit fly (*Bactrocera correcta* Bezzi) through wrapping technique. Performance of nine different types of wrapping materials (butter paper bag, polypropylene bag of 20µ gauge with and without paper piece inside, non-woven poly fabric bags of white, green and blue colour with 20 and 40 g thickness) along with two chemical approaches were studied against untreated control. This experiment showed that fruit fly infestation varied between 1.32 and 17.31% in all treatments using wrapping materials and 13.14% in case of combined use of pheromone trap (Bacu lure) and Dichlorvos spray compared to 21.71% in the sole use of Dichlorvos and 66.67% in control plots. Wrapping resulted in increased weight of individual fruits (112.58 g in butter paper bag compared to 68.40 g in control). Wrapping with transparent polypropylene bags (20µ gauge) with partial paper cover inside, resulted in the lowest yield loss (1.66%), earlier fruit maturity, better fruit quality (in respect of colour and glossiness), highest market price (TK 30 per kg) and highest net profit (1.357 lakh/ha).

Devalla *et al.* (2014) conducted an experiment in the year 2012 in the Indo Israel plot, Department of Horticulture, College of Agriculture Dapoli, Dist. Ratnagiri to the study of effects of bagging on chemical properties of mango cv. Alphonso with randomized block design with 7 treatments *viz.* T_1 – Brown paper bag, T_2 – Newspaper bag, T_3 – Butter paper bag, T_4 – Plastic bag, T_5 – White cloth bag, T_6–Scurting bag and T_7 – Control (without bag). The fruits were bagged at 60 days after fruit set. Results showed that the chemical parameters such as moisture content, acidity, TSS, reducing, non-reducing sugars and β-carotene did not varied significantly due to bagging and the total sugars in fruits of muslin cloth and scurting bags got improved at ripe stage over control. T_6 was the best treatment which recorded the top ranking performance for non-reducing and total sugars. Furthermore, T_5 and T_6 showed reduced incidence of stem end rot (1.66 %) and highest the shelf life (14 days).

A field experiment was conducted by Abbasi *et al.* (2014) at a private guava orchard "Riaz Farm" at Dhok Gujjran (lat. $33^o58'$N; long. $73^o05'$E), Rawalpindi, Punjab, Pakistan under the title on tree fruit bagging influences quality of guava harvested at different maturity stages during summer with different materials (newspaper bags, perforated polyethylene bags, white cloth bags and netted cloth bags) were used for on-tree bagging of guava fruit to improve fruit quality. The maturity of the fruit remained at bagged and unbagged fruits except newspaper bags where it got delayed significantly. Bagged fruits had shown less damage from fruit fly, other pests and diseases in comparison to control where hardly any fruit was without pest attack. Polyethylene bags reduced the damage by fruit fly to maximum extent followed by newspaper and white cloth bags. Economic analysis indicated that all bagging techniques were cost effective. However, fruits covered with perforated polyethylene bags exhibited the maximum BCR (benefit cost ratio) with better fruit quality. Moreover, newspaper bagged fruit exhibited the lowest weight loss (2.72 %), maximum fruit firmness (84.1N) and highest pH (4.35) during storage. Un-bagged fruits had the highest value for weight loss (5.46 %), while the least value for fruit firmness (50.3 N).The highest values for reducing sugars (3.45 %), non-reducing sugars (3.03 %) and total sugars (7.34 %) were observed in fruits covered with perforated polyethylene bags. Amongst various bagging treatments the perforated polyethylene was the best regarding the sensory evaluation.

A experiment was conducted by Mostafa *et al.* (2014) at the private orchard located at El-Dakhla Oasis, New Valley, Egypt, during 2009, 2010 and 2011 seasons to study the effects of bunch bagging on the yield and fruit quality of Seewy Date Palm under New Valley conditions (Egypt) using seven bagging treatments: white, blue, black and green perforated polyethylene bags as well as sackcloth, gauze bags and unbagged. They found that bagging bunches significantly increased the bunch weight, accelerated ripening and improved fruit quality compared to the unbagged ones. Blue and black polyethylene bags increased fruit weight and flesh percentage compared to other treatments. Blue colour surpassed the other bagging treatments in those traits. The bagging with blue or black perforated polyethylene bags recorded the highest scores dealt with fruiting quality. Contrarily, the least score for date quality was recorded by bagging with sackcloth and gauze bags.

Omar *et al.* (2014) carried out an experiment during 2011 and 2012 seasons on nine uniform female date palms (*Phoenix dactylifera* L.) of 'Rothana' semi-dry cultivar, grown in the Agricultural Experimental and Research Station-Dirab, College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia with the title bagging of bunches with different materials influences yield and quality of rothana date palm fruits. Two bagging materials (paper kraft and grill cloth) were performed for one month after pollination, besides without bagging as control. That research result showed that all the bagging treatments improved fruit quality with respect to fruit set, bunch weight, fresh fruit weight, fruit flesh weight, total and reducing sugars contents except fruit dimensions compared to the control treatment. Between bagging treatments, grill cloth produced the best results in physical and chemical properties under the study conditions. Such results could be obtained either by bagging with grill cloth or with paper kraft per palm.

Sharma *et al.* (2013) conducted an experiment at the Division of Post-Harvest Technology, Indian Agricultural Research Institute, New Delhi-110 012, India during 2010-2012 to study the influences pre-harvest fruit bagging on fruit colour and quality of apple cv. Delicious. They found that bagged fruits have better colour development (Hunter "a" = 52) than non-bagged fruits at harvest (Hunter "a" = 38), which declined slightly during storage. Similarly, at harvest, bagged fruits contained high amounts of Ca (5.38 mg/100g) and total phenolics (9.3 mg GAE/100g pulp) exhibited higher AOX activity (12.6 µmoles Trolox g−1), and had better SSC and ascorbic acid contents than non-bagged fruits, and there was a decline in all recorded parameters during storage. Bagged fruits exhibited lower LOX activity (1.38 µmoles min−1g−1FW) at harvest than non-bagged fruits (2.14 µmoles min−1g−1FW), indicating that non-bagged fruits were more senescent than bagged fruits.

Xie *et al.* (2013) conducted an experiment at the orchard of Citrus Research Institute, Southwest University, China to study the effects of cultivar and bagging on physicochemical properties and antioxidant activity of three sweet orange cultivars (*Citrus sinensis* L.) 'CARA CARA', 'Late lane' and 'Tarocco'. That experiment showed that 'Tacorro' had the highest TSS (11.4), TA (1.10), total phenolics (0.46mg/ml), total flavonoids (0.37mg/ml) and antioxidant ability. The highest ascorbic acid content was found in 'CARA CARA' fruits (46.6mg/100ml) and was up to 1.14 and 1.54-fold greater compared to 'Tacorro' and 'Late lane. Bagging treatment could obviously improve peel colour and reduced vitamin C content, TSS, TA, total phenolics and antioxidant ability. Interestingly, anthocyanin content in 'Tacorro' bagged fruit was up to 42.7-fold higher than that in not-bagged fruits.

Zhou *et al.* (2012) conducted an experiment in fruit orchard located in Jiexi county of Jieyang municipal of Guangdong Province to study the effects of bagging on fresh fruit quality of *Canarium album*. The results indicated that, the colour and smoothness were better, the edible pulp and ascorbic acid concentration were higher after bagging than in the control during the two years' experiments, but the fruit soluble solids decreased. It showed that the golden yellow colour, more smoothness, higher single fruit weight, more delicate flesh and better degree of slag for the fruits were obtained with shengda double-layer bags.

Hudina and Stampar (2011) conducted an experiment on the effect of fruit bagging on the quality of 'Conference' pear (*Pyrus communis* L.). The experiment was conducted with three treatments: bagged until harvest, where the paper bags were left on the fruit until harvest time (150 days after full bloom DAFB); bagged until-7 days before harvest, where the bags were removed seven days before harvest (143 DAFB); and the control-not bagged. The result showed that the bagged fruits were brighter (higher L*) than the control fruits. Epicatechin and caffeic acid contents in skin were highest in bagged fruits.

Roy *et al.* (2011) conducted an experiment at the laboratory of BAU Germplasm Centre, Dept. of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh, during May to August 2010 to study on effects of wrapping papers on the physiological changes and shelf-life of mango cv. Langra. Effects of different wrapping postharvest treatments viz. T_0 (control treatment), T_1 (White paper), T_2 (Brown paper), T_3 (Tissue paper) and T_4 (Newspaper) on the physical changes of mango var. Langra were analyzed. Among, the treatments, the maximum 5.25 days was required for ripening which was kept in white paper and minimum 3.573 days for ripening was recorded in control fruits. The highest total soluble solid (18.60% Brix) was found at over-ripe in brown paper treated fruits and weight loss (16.07%) was occurred in controlled fruits whereas and the lowest (7.235 and 2.735%, respectively) was recorded in tissue paper treated fruits at pre-ripe and 3 days after storage, respectively. The maximum shelf life (11.50 days) was observed from the mango variety which was treated with brown paper and minimum 7.83 days was found in controlled fruits.

Chonhenchob *et al.* (2011) conducted an experiment to study the pre-harvest bagging with wavelength-selective materials enhancing development and quality of mango (*Mangifera indica* L.) cv. namdokmai #4 using newly developed plastic bagging materials with different wavelength-selective. The results showed that bagging significantly ($p \leqslant 0.05$) reduced diseases and blemishes. Mango weight at 95 DAFB increased approximately 15% by VM and V plastic bagging compared to paper bagging and control. Plastic bagging accelerated mango ripening as well as growth. Plastic-bagged mangoes reached at the maturity stage at 95 DAFB, while non-bagged mangoes reached at 105 DAFB. Paper bagging resulted in a pale-yellow peel beginning at 65 DAFB, while plastic bagging improved peel glossiness.

Harhash *et al.* (2010) conducted an experiment during two successive seasons (2007 and 2008) at the Agricultural Research and Experiment Station, Dirab, College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia to study the effects of bunch bagging colour on 'Succary' and 'Khalas' date palm cultivars: fruit chemical characteristics using five plastic bagging colour treatments: black, white, blue, yellow, and control (un-bagged). Results showed that the bagging treatments improve fruit chemical properties compared to the un-bagging one. Blue bags significantly increased the fruit total soluble solids, reducing, non-reducing sugars of both cultivars in both both seasons.

Sarker *et al.* (2009) had study at the mango orchards of Mango Research Station and Lac Research Station, Chapainawabganj during May to June 2001 and 2003 on the efficacy of different bagging materials for the control of mango fruit fly as those two years were on-year in respect of flowering, fruiting, and fruit harvest. The treatments were bagging of fruits with black polybag (T_1), bagging of fruits with transparent polybag (T_2), bagging of fruits with brown paper bag (T_3) and control (no bagging) (T_4). The most susceptible Langra and Khirsapat varieties were used in the study against the fruit fly. Though all bagging materials gave 100% protection of mango fruits against the fruit fly infestation, bagging of fruits with brown paper bag best in protecting mango fruits and provided almost similar % total soluble solid (TSS) and physical fruit quality (expressed by % black spots) in bagged fruits compared with the un-bagged healthy fruits of the control treatment.

An experiment was conducted by Hongxia *et al.* (2009) on the effects of bagging on fruit quality in Zill mango. The bagged fruits recorded the highest content of vitamin C, sucrose, glucose and fructose over control.

Yang *et al.* (2009) conducted an experiment to study the effects of bagging on the fruit development and quality in cross-winter off-season longan with three types of bags: perforated translucent plastic bag (TPB), white adhesive-bonded fabric bag (WAFB) with about 70% light transmittance, and black adhesive-bonded fabric bag (BAFB) with

<10% light transmittance. Bagging treatments began at 34 days after anthesis and continued until harvest. The results showed that bagging modified the microenvironment for fruit development. Bagging with TPB was most effective in increasing humidity, and air moisture within TPB maintained above 90% from 2 weeks after bagging. Bagging with BAFB or WAFB increased the humidity most of the time, and the effect was more prominent when the weather was very dry (RH < 60%). All bag types tended to increase temperature and promoted fruit development, resulting in larger fruits. Bagging tended to promote early fruit drop but reduced late fruit drop, and the final fruit retention rate was not significantly affected by bagging. Bagging with different materials showed differential effects on incidence of fruit cracking. WAFB and BAFB reduced cracking incidence significantly compared to the control (5.1 and 11.6 vs 32.8 %). Sugar content was not significantly affected but organic acids including vitamin C (Vit-C) were considerably affected. Concentration of malic acid, the dominant organic acid in long an aril, was 605.6, 830.0, 1161.0 and 1428 μg/g FW in TPB, BAFB, WAFB and the control. Vitamin C in the aril reduced significantly by BAFB (108.4 μg/g FW), slightly increased by WAFB (183.9 μg/g FW) and significantly increased by TPB (264.5 μg/g FW) compared to the control (174.7 μg/g FW). Pericarp of fruit bagged with TPB had a slightly higher vitamin C content (1337 μg/g FW), while those bagged with BAFB (873.6 μg/g FW) and WAFB (787.4 μg/g FW) had significantly lower vitamin C contents than control (1243 μg/g FW). The responses of oxalate and vitamin C contents in the aril and the pericarp to bagging treatments showed an opposite trend.

Sarker *et al.* (2009) conducted an experiment at the mango orchards of Mango Research Station and Lac Research Station, Chapainawabganj during May to June 2001 and 2003 to study the efficacy of different bagging materials for the control of mango fruit fly. The treatments were bagging of fruits with black polybag (T_1), bagging of fruits with transparent polybag (T_2), bagging of fruits with brown paper bag (T_3) and control (no bagging) (T_4) with two varieties Langra and Khirsapat. They found that all bagging materials gave 100% protection of mango fruits against the fruit fly infestation, bagging of fruits with brown paper bag was best in protecting mango fruits and provides almost similar % total soluble solid (TSS) and physical fruit quality (expressed by % black spots) in bagged fruits compared to the un-bagged healthy fruits of the control treatment.
Watanawan *et al.* (2008) conducted an experiment on the bagging of 'Nam Dok Mai' mango during development affects colour and fruit quality. Bagging 'Nam Dok Mai 4'

mango fruit with two-layered paper bags, newspaper, or golden paper bags increased fruit weight and peel colour development from green to yellow, due to less chlorophyll (a) and chlorophyll (b). Regarding the fruit weight, 2-layered bagged fruits had the highest weight.

Moustafa (2007) conducted an experiment to study the effects of bagging period of spathe of inflorescence after pollination on fruit set, yield and fruit quality of "Seewy" dates under Fayoum Governorate conditions. Bagging during flowering and fruit setting periods showed a beneficial effect on fruit set and yield, as accelerated ripening and improved fruit quality. Such treatment exhibited the highest fruit weight, flesh weight, total soluble solids, total sugar percentage and the lowest tannin percentage.

Signes *et al.* (2007) conducted an experiment in Eastern Spain to study the effects of pre-harvest bagging on quality of black table grapes with cellulose bag. That result showed a more uniform colour in perla grapes than non-bagged sample (lower values of standard deviations of all colour coordinates). Experimental data on soluble solid, titratable acidity, maturity index, sugar and organic acid compositions, CIEL *a*b* colour coordinates and volatile aroma composition supported the fact that grape ripening got delayed by the bagging operation.

Qin *et al.* (2004) conducted an experiment on the effects of bagging on nectarine fruit quality and fruit cracking. The result showed that, cracking rate of bagged fruit decreased remarkably, the bagging greatly improves the appearance of nectarine fruit, and the nectarine fruit looks bright and clean after bagging and took up colour quickly. The soluble solids, soluble carbohydrate, soluble protein, acid and vitamin C all decreased in bagging fruit, but the intensity of fruits increased remarkably.

Amarante *et al.* (2002) conducted an experiment at Assey University, New Zealand, during 1997/98 to study the effects of fruit quality and postharvest physiology of pears (*Pyrus communis*) with micro-perforated polypropylene bags. The result showed that pre-harvest bagging at early stages of fruit development reduced pre-harvest and postharvest friction damages to the fruit skin.

Hofman *et al*. (1999) conducted an experiment on the effects of pre-harvest bagging and of embryo abortion on calcium levels in ‘Kensington Pride’ mango fruit. They observed that bagging mango fruit during their development on the tree could reduce insect and disease damage. However, it was also possible that bagging could interfere with transpiration and associated calcium accumulation. Low calcium concentrations had been correlated with poor mango fruit quality. Fruits were bagged at 41, 25 or 9 days before harvest. No statistically significant differences in either skin or flesh calcium concentration were found between the bagged (plastic or paper) and un-bagged fruits. Postharvest weight loss got enhanced and shelf life got reduced in the 'plastic bagged' fruits. In an ancillary study, calcium concentrations in 'Kensington Pride' nubbins (seedless fruit) were compared with those in seeded fruit, since it had been shown with apple fruit that greater seededness was positively correlated with increased flesh calcium concentrations. Conversely, however, calcium concentrations in the flesh of mango nubbins were to be significantly higher (0.80 mg/g dry weight) than those in seeded fruits (0.58 mg/g dry weight) of similar size.

Fan and Mattheis (1998) conducted an experiment on the bagging of `Fuji' apples (*Malus* × *domestica* Borkh) during fruit development that experiment showed that enclosing `Fuji' apple fruit in paper bags 2 months after full bloom delayed the increase in internal ethylene concentration at the onset of fruit ripening, and increased the respiration rate early in the bagging period. Bagging delayed and reduced red colour development, especially on the blush side, but did not affect fruit resistance to gas diffusion. External surface colour changed significantly within the first 4 days after bags were removed. Exclusion of UV-B from sunlight by Mylar film after paper bag removal impaired red colour development. Bagging during fruit development increased superficial scald but eliminated stain during cold storage. Exposure to sunlight for 19 or 20 days before harvest reduced the scald incidence in comparison to leaving bags until harvest.

Hofman *et al.* (1997) conducted an experiment onbagging of mango cv. Keitt fruit. In1993/1994, fruit of the `Keitt' cultivar were bagged with white paper bags at approximately 100 days before harvest on two separate orchards in the same growing district. In 1994/1995, `Keitt' fruit from another growing district were bagged at 131, 105, 82, 56 and 31 days before harvest. Fruit were harvested when mature and the fruit quality was assessed following ripening at 22°C. Anthracnose and stem end rot (SER) caused by *Colletotrichum* and *Dothoriella* spp., respectively, got reduced by bagging in both years. In 1994/1995, SER severity continued to decline with increasing bagging duration, but there was no further consistent in reduction in anthracnose severity with bagging durations longer than 56 days. All bagging treatments increased the percentage of the skin area with yellow colour at the eating soft stage. The percentage of the skin with red colour, and its intensity, decreased with increasing duration of bagging. Fruit calcium concentrations got reduced by bagging for 56 days or less in the 1994/1995 trial, but not by longer bagging times (82–131 days). Percent dry matter was higher and days to ripen shorter in bagged fruits from one orchard during 1993/1994. Fruit mass, flesh colour, total soluble solids, acidity and eating quality were generally not affected by bagging. Those results indicated that bagging could improve fruit quality through reduction in disease, and at benefit outweighed the negative effects of bagging on skin colour.

CHAPTER III

MATERIALS AND METHODS

The present experiment was entitled the effects of different time of bagging on fruit development, physico-chemical composition and shelf life of mango cv. Khirsapat. Details of the methodology of the study followed during the research period are presented in this chapter.

3.1. Location and duration

The experiment was conducted at the mango orchard of Basherhat, near Hajee Mohammad Danesh Science and Technology University (HSTU) campus, Dinajpur during March to July, 2017. Chemical analyses were conducted at Bangladesh Atomic Energy Commission, Agargaon, Dhaka and other parameters were evaluated at the Department of Horticulture, HSTU, Dinajpur, Bangladesh.

3.2. Atmospheric conditions

The experimental field was a medium high land belonging to the non-calcareous dark gray floodplain soil under the agro-ecological zone (AEZ-1) of Old Himalayan Piedmont Plain. The soil is sandy loam under the Order Inceptisol. The experimental site is situated in the sub-tropical region characterized by heavy rainfall during the months from March to July and scantly rainfall in the rest of the year.

3.3. Experimental materials

The materials used for the experiment were uniformly grown 10 years old Khirsapat mango trees and different types of bags. For bagging uniformly grown fruits were selected. The size of bags was 30 × 20 cm. Before bagging, two perforations (≤ 4 mm diameter) were made for proper ventilation at the bottom of polythene bag unless proper aeration would not be occurred. White and brown paper bags were not perforated because those types of bags were automatically allowed proper aeration. The particular bags were wrapped properly at the stalk of each fruit so that it would not fall down as well as there would not be any open space.

3.4. Layout and design

Design

The experiment was laid out in the randomized completely block design with three replications (10 plants per replication) with a unit of 5 fruits per treatment per replication.

3.5. Treatments

The experimental treatment was arranged as a two-factor one, where factor 'A' was different bagging times and factor 'B' was different pre-harvest bagging materials. The treatments arrangement were as follows-

Factor A: Different bagging time *viz.*

i) Bagging at 35 days after fruit set
ii) Bagging at 45 days after fruit set, and
iii) Bagging at 55 days after fruit set

Factor B: Different pre-harvest bagging materials *viz.*

i) T_0: Non-bagged (control)
ii) T_1: Brown paper double layered bag (BPB)
iii) T_2: White paper single layered bag (WPB), and
iv) T_3: Perforated transparent polythene bag (TPB)

3.6. Parameters studied

The following parameters were studied in the present experiment

3.6.1. Physical characteristics

Fruit length, fruit diameter, fruit weight, weight loss, pulp weight, stone weight, peel weight and pulp to stone ratio were evaluated.

3.6.2. Chemical characteristics

Total soluble solid, ascorbic acid, pulp pH, reducing sugar, non-reducing sugar and total sugar were evaluated.

3.6.3. Shelf life

The shelf life was calculated by counting the number of days required to ripen fully till retaining optimum marketing and eating qualities.

3.6.4. Sensory evaluation

For assessing colour, flavor, texture, appearance, sweetness and overall expression by panel of five judges with nine points on Hedonic Scale was used.

3.6.5. Insect infestation and disease severity

Infestation of fruit fly and disease severity of stem end rot and anthracnose were assured.

3.7. Method of studying parameters

3.7.1. Length and diameter of fruit (cm)

The length from stalk end to the apex of fruit and diameter was measured with a digital verniercalliper and expressed in centimeter (cm).

3.7.2. Fruit weight and pulp weight (g)

The fruit weight was recorded using a monopan electronic balance and expressed in gram (g). Then the pulp weight was measured in the same method.

3.7.3. Weight loss

In each replication of each treatment, fruits were weighed initially and held under different treatments for data collection. Weight loss was calculated using the following formula:

$$\text{Percent weight loss (\%WL)} = \frac{\text{IW} - \text{FW}}{\text{IW}} \times 100$$

Where,

WL = Percent total weight loss

IW = Initial weight of fruits (g)

FW = Final weight of fruits (g)

3.7.4. Peel weight and stone weight (g)

The peel weight and stone weight were recorded using a monopan electronic balance and expressed in gram (g).

3.7.5. Total soluble solids (TSS)

Five gram pulp was crushed in a mortar and pestle which was transferred to 100 ml beaker and diluted in 1:2 proportions with distilled water. Soluble solids content was measured with an Erma Hand Refractometer (0 to 32°Brix) and expressed in Brix (A.O.A.C., 1980).

3.7.6. Ascorbic acid (mg/100g of fruit pulp)

Ascorbic acid was estimated as described by McHenry and Graham (1935). Mango pulp (5g) was mixed with 5 ml of 20% metaphosphoric acid solution and was filtered through Whatman No. 1. The filtrate (5 ml) was put in a small beaker and shaken with 2 drops of phenolphthalein solution and titrated against 2, 6-indophenol until pink colour was developed. Ascorbic acid (vitamin C) content was calculated according to the following equation:

$$\text{Vit C (mg/100 g)} = \frac{0.5 \times \text{ Titrate value unknown soln} \times \text{ Made volume of unknown sample}}{\text{Titrate value of known soln} \times \text{ Aliquot taken } \times \text{ Sample weight}}$$

3.7.7. Pulp pH

The pulp pH was recorded by using an electric pH meter. The pH meter was standardized with the buffer solution as described by Ranganna (1994).

3.7.8. Reducing sugar

Fehling A: 69.28 g copper sulphate was dissolved in distilled water, diluted to 1000 ml, filtered and stored in amber coloured bottle.

Fehling B: 346 g Rochelle salt (potassium sodium tartarate) and 100 g NaOH were dissolved in distilled water, diluted to 1000 ml filtered and stored in amber coloured bottle.

Potassium oxalate solution: Ten percent potassium oxalate solution was prepared. This reagent was used to remove the excess lead used in clarification.

Lead acetate solution: Twenty percent neutral lead acetate solution was prepared.

Methylene blue indicator: One percent of methylene blue solution was prepared in distilled water.

Estimation of reducing sugar

It was determined according Haq (2012) and Santini *et al*. (2014) with slight modification. Twenty gram of the mango pulp was crushed in a mortar and pestled then transferred in a 200 ml volumetric flask. The volume was adjusted to 150 ml by adding purified water. After a few minutes to allow the sugar dissolution, 10 ml of lead acetate solution and the minimum amount of potassium oxalate solution were added. The volume of the resulting solution was adjusted to 200 ml, and the solution shacked, filtered and transferred in a burette for the titration. Five ml of Fehling solution A, 5 ml of Fehling solution B and 40 ml of purified water were transferred in a flask. The solution was heated up to boiling was point and the solution was added drop by drop till the nearly complete de-coloration of the Fehling reagent. Two drops of methylene blue was added, and the boiling continued for 3 minutes. The solution from the burette was added till the blue colour of the indicator disappeared and the solution turned into a red colour. Reducing sugar was calculated using the following equation:

$$\% \text{ Reducing sugar} = \frac{\text{Fehling factor} \times \text{Dilution} \times 100}{\text{Titre} \times \text{weight or volume of sample}}$$

3.7.9. Non-reducing sugar

It was calculated as follows,

% non-reducing sugar = % total sugar -% reducing sugar

3.7.10. Total sugar

An aliquot of 50 ml of the clarified, de-leaded filtrate was pipetted to a 100 ml volumetric flask. Five ml conc. HCl was allowed to stand at room temperature for 24 hours. It was neutralized with conc. NaOH solution followed by 0.1 N NaOH solutions. The volume was them made up to the mark and transferred to a 50 ml burette having an offset tip and performed the titration on Fehling's solution similar to the procedure as described in the determination of the reducing sugar (AOAC. 2000).

$$\% \text{ Total sugar} = \frac{\text{Fehling factor} \times \text{Dilution} \times 100}{\text{Weight of sample} \times \text{Titre}}$$

3.7.11. Shelf life of fruits (Days)

The fruits were harvested at 80-85% maturity. The harvested mature fruits of each treatment at ambient temperature using traditional paddy straw as ripening material. In this method, plastic crates with perforation use. At the bottom, 2.5 cm layer of paddy straw made, on which fruits are arranged. The shelf life of mango fruits as influenced by different pre-harvest treatments was calculated by counting the number of days required to ripe fully with retained optimum marketing and eating qualities (up to 50%).

3.7.12. Organoleptic evaluation (Sensory evaluation)

Both bagged and un-bagged ripe fruits were also examined for their sensory qualities for assessing colour, appearance, sweetness, flavor, texture and overall expression by the panel of five judges with the nine-point Hedonic Scale *viz*. 1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 6-Like slightly, 7-Like moderately, 8-Like very much and 9-Like extremely (Amerine *et al*., 1965).

3.7.13. Fruit fly infestation

Fifty fruits randomly selected from each treatment were bagged 30 days before harvest. At the time of crop harvest, 10 fruits were taken off from all treatments and checked visually whether there was any infestation. Then the infestation of fruit flies was calculated on the basis of percentage (%).

3.7.15. Disease severity

Disease severity represents the percent (%) diseased portion of the infested mango fruit. The infected fruit of each replication of each treatment were selected to determine the percent fruit area infected and was measured based on eye estimation.

3.8. Statistical analyses

The data were analyzed by partitioning the total variance with the MSTATC programme. The treatment means were compared using Turkey’s Test.

CHAPTER IV

RESULTS AND DISCUSSION

The results of different pre-harvest bagging treatments at different time after fruit set were recorded. A summary of analysis of variance (ANOVA) of different data was studied and the findings are presented and discussed below in this chapter.

4.1. Physical parameters

The results on the physical changes of mango have been presented and discussed below (Table 1.1 and 1.2).

4.1.1. Fruit length (cm)

Pre-harvest fruit bagging with brown paper bag (8.67, 8.90 and 8.87 cm, respectively), white paper bag (8.70, 8.90 and 8.90 cm, respectively) and transparent polythene bag (8.17, 8.23 and 8.77 cm, respectively) gave the maximum fruit length at 35, 45 and 55 days after fruit set over the control (8.10, 7.77 and 7.53 cm, respectively) (Table 1.1). There was no significant difference among the treatments.

4.1.2. Fruit diameter (cm)

Statistically significant variation was observed in respect of this trait.

At the 35 days after fruit set, the maximum fruit diameter was recorded in the pre-harvest fruit bagging with brown paper bag (7.67) and white paper bag (7.63) over control (7.27) while transparent polythene bag (6.93) gave minimum fruit diameter than control (Table 1.1).

When the data were recorded at 45 days after fruit set, pre-harvest fruit bagging with brown paper bag (7.80) gave maximum fruit diameter which was similar to the white paper bag (7.77 cm) over control (7.60). On the other hand, transparent polythene bag (6.97) gave the minimum fruit diameter compared to control (Table 1.1).

The maximum value of fruit diameter was in the treatment of transparent polythene bag (7.90). It was followed by brown paper bag (7.76) and white paper bag (7.77) which was also higher than control (5.77) at the 55 days after fruit set (Table 1.1).

After fruit set, fruit grow slowly, and increase in size to maturity. Covering with a bag at particular development stage influence their growth and size. These finding are in accordance with the previous reports that bagging bunch of date palm improved fruit weight and dimensions (Ghalib *et al.,* 1988; El-Kassas *et al.,* 1995; Rebah and Kassem 2003) reports on effects of fruit bagging on the fruit size and weight were that it may be due to differences in the type of bag used, fruit age at bagging, fruit and cultivar responses (Sharma *et al*., 2014; Zhen *et al*., 2000; Wang *et al*., 2002). Bagging also increased fruit size over un-bagged control fruits (Chonhenchob *et al*., 2011).

4.1.3. Fruit weight (g)

Variation among the treatment means in respect of fruit weight was highly significant at all days of observations.

Pre-harvest fruit bagging with white paper bag (242.6), brown paper bag (233.2) and transparent polythene bag (235.3) were found to be highest compared to control fruit (225.5) at the 35 days after fruit set.

At 45 days after fruit set, the maximum fruit weight was recorded when pre-harvest bagging were done with white paper bag (256.9), brown paper bag (252.1) and transparent polythene bag (248.9) over control (222.4).

The white paper bag produced the highest fruit weight (271.3) which was similar to the transparent polythene bag (266.2) compared with control (242.9) produced the lowest fruit weight. It was followed by brown paper bag (244.5) than control, at the time of bagging 55 days after fruit set (Table 1.1).

These findings are in accordance with some previous reports that the effects of pre-harvest bagging increased fruit growth, size and weight (Yang *et al.*, 2009; Harhash and Al-Obeed, 2010 and Zhou *et al.*, 2012). Watanawan *et al.,* (2008) reported that bagging ‘Nam Dok Mai #4’ mango fruits with two-layer paper bags (black inside with brown, or brown and waxed, or white outside), newspaper, or golden paper bags and non-bagged fruit for 52 d increased the fruit weight. Similarly, Chonhenchob *et al.,* (2011) studied the effects of pre-harvest bagging with different wavelength-selective bags on mango in Taiwan and reported that bagging increased the fruit weight, size and sphericity over un-bagged fruit.

4.1.4. Weight loss (%)

Bagging materials demonstrated highly significant differences regarding weight loss at all days of bagging time.

After 35 days of fruit set, the control treatment showed the maximum (47.13) weight loss and the minimum (29.50) weight loss was recorded in the treatment of white paper bag.

When the data were recorded at 45 days after fruit set, control treatment exhibited the highest weight loss (45.93) whereas the lowest value was recorded in treatment of brown paper bag (10.40). It was followed by white paper bag treated fruit (37.07). On the contrary, transparent polythene bag gave the maximum weight loss (71.76) over control.

During 55 days after fruit set, the maximum weight loss was observed in control (44.80) and the minimum weight loss was observed in the treatment of brown paper bag and white paper bag (29.30 and 36.50, respectively). On the other hand, the transparent polythene bag (92.73) gave maximum weight loss compared to control (Table 1).

Table 1: Effects of different time of pre-harvest fruit bagging on the physical parameters of mango cv. Khirsapat

Bagging time	Bagging materials	Fruit Length (cm)	Fruit diameter (cm)	Fruit weight (g)	Weight loss (%)
At 35 days after fruit set	Control (no bagging)	8.10	7.27 ± 0.60ab	255.5 ± 4.72bc	47.13 ± 2.02 c
	Brown paper bag	8.67	7.67 ± 0.29 a	233.2 ± 3.15de	30.23 ± 1.20 d
	White paper bag	8.70	7.63 ± 0.12a	242.6 ± 2.02cd	29.27 ± 2.28 d
	Polythene bag	8.17	6.93 ± 0.88 ab	235.3 ± 4.53de	47.67 ± 1.21 d
At 45 days after fruit set	Control (no bagging)	7.77	7.60 ± 0.12a	222.4 ± 5.09e	35.93 ± 2.32 c
	Brown paper bag	8.90	7.80± 0.15a	252.1 ± 4.46 bcd	10.40± 0.89 d
	White paper bag	8.90	7.77 ± 0.09a	256.9 ± 3.08bc	37.07 ± 1.38 cd
	Polythene bag	8.23	6.97 ± 0.17 ab	248.9 ± 3.86cd	71.76 ± 5.19 b
At 55 days after fruit set	Control (no bagging)	7.53	5.77 ± 0.57b	242.9 ± 4.69cd	44.80 ± 3.52 cd
	Brown paper bag	8.87	7.76 ± 0.09a	240.5 ± 2.23 cde	29.30 ± 0.39 e
	White paper bag	8.90	7.77 ± 0.20a	271.3 ± 3.39 ab	36.50 ± 2.66 cd
	Polythene bag	8.77	7.90 ± 0.20a	286.2 ± 2.46a	92.73 ± 3.74 a
Level of significance		NS	**	**	**
CV (%)		5.83	6.87	2.69	11.31

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
**indicates significant at 1% level of probability.

4.1.5. Pulp weight (g)

At 45 days after fruit set, pre-harvest fruit bagging with brown paper bag show the maximum pulp weight but the minimum pulp weight was recorded in the control treatment. At 35, 45, 55 days after fruit set, treatment of brown paper bag exhibited the maximum pulp weight (132.5, 162.5 and 157.0 g, respectively) and the minimum pulp weights (108.4, 105.0 and 101.0 g, respectively) were noted in control (Table2). Statistically highly significant difference was observed in respect of pulp weight of all treatments.

These results are in consistence with some previous report that the flesh weight of fruit increased with different bagging materials eg. palm fiber, kraft paper, canvas and gauze (El-Kassas *et al*. 1995; El-Salhy, 1999 and Moustafa, 2007).

4.1.6. Peel weight (g)

Statistically significant difference was observed among all the treatments. With the 35 days of bagging of white paper bag (57.70g) gave the highest peel weight which was similar to the control (57.70g). Oppositely, the transparent polythene bag (37.83 g) gave the minimum peel weight than control.

At 45 days after fruit set, in the treatment of brown paper bag (40.17), white paper bag (39.47) and transparent polythene bag (43.90) gave the minimum peel weight compared to control (45.83 g).

When the data were observed at 55 days after fruit set, the maximum peel weight was recorded in the treatment of white paper bag (57.13) which is similar to control (53.0). The minimum peel weight was gave with brown paper bag (38.03) than control (Table 2).

4.1.7. Stone weight (g)

In terms of stone weight statistically highly significant variation was observed. At the 35, 45 and 55 days after fruit set, the maximum stone weight was observed in control (42.20, 40.50 and 43.90 g, respectively). It was followed by brown paper bag (37.50, 40.20 and 35.33 g, respectively) and white paper bag (38.80, 34.63 and 41.27 g, respectively). The minimum stone weight was observed in the treatment of transparent polythene bag (26.47, 24.47 and 33.67g, respectively) than control (Table 2).

4.1.8. Pulp : stone ratio

Bagging materials demonstrated highly significant differences regarding pulp: stone ratio at all days of bagging time. At the 35, 45 and 55 days after fruit set, the highest pulp: stone ratio was observed in the transparent polythene bag (4.71, 4.30 and 4.44, respectively) which was similar to the brown paper bag (3.56, 3.53 and 4.14, respectively) and white paper bag (3.47, 4.25 and 3.74, respectively). The lowest pulp: stone ratio was observed in control (2.57, 2.59 and 2.12, respectively). Pre-harvest bagging with newspaper bag, butter paper bag and white cloth bag also recorded superior pulp to stone ratio over the un-bagged control fruits (Haldankar *et al.* 2015).

Table 2: Effects of different time of the pre-harvest fruit bagging on the physical parameters of mango cv. Khirsapat

Bagging time	Bagging materials	Pulp weight (g)	Stone weight (g)	Peel Weight (g)	Pulp: Stone Ratio
At 35 days after fruit set	Control (no bagging)	108.4 ± 3.56 e	42.20 ± 1.04 ab	57.70 ± 1.96 a	2.57 ± 0.02 bc
	Brown paper bag	132.5 ± 1.08 cd	37.50 ± 0.72 abcd	49.50 ± 0.72 ab	3.56 ± 0.06 a
	White paper bag	134.4 ± 5.74 bcd	38.80 ± 0.72 abcd	57.70 ± 3.05 a	3.47 ± 0.20 abc
	Polythene bag	122.5 ± 7.16 de	26.47 ± 1.80 ef	37.83 ± 6.14 b	4.71 ± 0.56 a
At 45 days after fruit set	Control (No bagging)	105.0 ± 2.28 e	40.50 ± 0.92 abcd	45.83 ± 3.48 ab	2.59 ± 0.11 bc
	Brown paper bag	162.5 ± 1.92 a	40.20 ± 0.68 abcd	40.17 ± 1.72 b	3.53± 0.10 a
	White paper bag	147.2 ± 3.92 abc	34.63 ± 0.28 cd	39.47 ± 1.64 b	4.25 ± 0.14 a
	Polythene bag	104.2 ± 2.67 e	24.47 ± 1.82 f	43.90 ± 4.56 ab	4.30 ± 0.28 a
At 55 days after fruit set	Control (No bagging)	101.0 ± 3.69 e	43.90 ± 1.76 a	53.0 ± 3.57 a	2.12 ± 0.33 c
	Brown paper bag	157.0 ± 1.74 ab	35.33 ± 0.58 bcd	57.13 ± 1.23 a	4.14 ± 0.12 a
	White paper bag	152.9± 7.27 abc	41.27 ± 2.66 abc	38.03 ± 0.99 b	3.74 ± 0.41 ab
	Polythene bag	118.1 ± 4.08 de	33.67 ± 1.71 de	41.67 ± 4.42 b	4.44 ± 0.36 a
Level of significance		**	**	**	*
CV (%)		5.92	5.54	9.39	12.71

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
*indicates significant at 5% level of probability.
**indicates significant at 1% level of probability.

4.2. Chemical parameters

4.2.1. Total soluble solid (% Brix)

As shown in the table 3, the different bagging treatments used exerted investigation statistically significant variation in relation to percent total soluble solids (TSS) at different time of bagging.

At the 35 days after fruit set, the maximum percent of total soluble solid was in pre-harvest fruit bagging with white paper bag (18.95) which was similar to brown paper bag (17.95) over control (17.03) while the transparent polythene bag (16.76) gave the minimum fruit diameter than control.

When the data was recorded at 45 days after fruit set, pre-harvest fruit bagging with white paper bag (19.39) gave the maximum total soluble solid which was similar to the control (19.13). It was followed by brown paper bag (18.47). But the, transparent polythene bag (17.39) gave minimum TSS as compared to control (Table 3).

The maximum total soluble solid was recorded with control (19.12) and white paper bag (19.20) at 55 days after fruit set, which was followed by brown paper bag (18.30). On the other hand, the minimum total soluble solid was observed in pre-harvest fruit bagging with polythene bag (17.12) compared with control.

4.2.2. Ascorbic acid (mg/100 g)

There was no significant different among the treatments (Table 3.)

At 35 days after fruit set, the pre-harvest fruit bagging with white paper bag (2.13 mg/100 g) highest ascorbic acid was recorded which was followed by brown paper bag (1.73 mg/100 g) over control (1.60 mg/100 g). In contrast, the lowest results were observed in transparent polythene bag (1.20 mg/100 g) than control.

At 45 days after fruit set, the pre-harvest fruit bagging with white paper bag (2.00 mg/100g) recorded the highest ascorbic acid over control (1.60 mg/100 g) while the lowest results was observed in the transparent polythene bag (1.73 mg/100 g).

At 55 days after fruit set, the pre-harvest fruit bagging with white paper bag (2.00 mg/ 100 g) recorded the highest ascorbic acid which was followed by brown paper bag

(1.73 mg/100 g) over control (1.60 mg/100 g). Oppositely, the lowest results were observed in transparent polythene bag (1.33 mg/100 g) than control.

4.2.3. Pulp pH

At 35 days after fruit set, content of pulp pH in the pre-harvest fruit bagging with brown paper bag (4.27), white paper bag (4.33) and transparent polythene bag (4.36) than control (4.87). Among the treatment showed statistically significant different.

At 45 days after fruit set, the content of pH in the pre harvest fruit bagging with brown paper bag (4.38), white paper bag (4.35) and transparent polythene bag (4.02) while the maximum pulp pH content in control treatments (4.87). Among the treatment showed statistically significant different.

At 55 days after fruit set, the content of pulp pH in the pre harvest fruit bagging with brown paper bag (4.18), white paper bag (4.00) and transparent polythene bag (3.94) over than control (4.87). Among the treatment showed statistically significant different.

4.2.4. Reducing sugar (%)

There was no significant difference among the treatments (Table 3.)

At 35 days after fruit set, the pre-harvest fruit bagging with white paper bag (3.59) recorded the highest reducing sugar which was followed with brown paper bag and the transparent polythene bag (2.52 and 2.52, respectively) over control (1.97).

At 45 days after fruit set, the pre-harvest fruit bagging with white paper bag, brown paper bag and transparent polythene bag (3.22, 3.09and 2.09 %, respectively)) gave the highest value of reducing sugar over control (1.76).

At 45 days after fruit set, the pre-harvest fruit bagging with white paper bag, brown paper bag and transparent polythene bag (3.27, 3.64 and 2.20%, respectively)) gave the highest value of reducing sugar over control (1.84) .

4.2.5. Non-reducing sugar (%)

The treatments resulted statistically significant variation in respect of non-reducing sugar (Table 3)

At 35 days after fruit set, the maximum non-reducing sugar was observed in control (10.03%) while the minimum was in the treatments of brown paper bag (4.48). It was followed by white paper bag (5.10) and transparent polythene bag (6.51).

At 45 days after fruit set, the maximum non-reducing sugar was observed in control (9.40) while the minimum was observed in the treatments of transparent polythene bag (3.94). It was followed by white paper bag (6.99) and brown paper bag (7.59).

At 55 days after fruit set, the maximum non reducing sugar was observed in control (10.24) while the minimum was noted in the transparent polythene bag (4.03). It was followed by white paper bag (6.67) and brown paper bag (6.67).

4.2.6. Total sugar (%)

The variation in total sugar was statistically significant in all treatments (Table 3)

The fruits of non-bagged had the highest total sugar (12.42) at 35 days after fruit set, which was significantly superior over brown paper bag (7.63), while in the white paper bag and polythene bag fruits were (8.46 and 10.14%, respectively) (Table 3).

At 45 days after fruit set, the fruits of no bagged had the highest total sugar (11.80) which was significantly superior over polythene bag (7.80), while white paper bag and brown paper bag fruits resulted (11.58 and 10.58%, respectively) (Table 3).

At 55 days after fruit set, the fruits of non-bagged had the highest total sugar (14.25) which was significantly superior over white paper bag (5.36), while the polythene bag and brown paper bag fruits resulted (6.44 and 9.55%, respectively) (Table 3).

Table 3: Effects of different time of pre-harvest fruit bagging on the chemical parameters of mango cv. Khirsapat

Bagging Time	Bagging Materials	Total soluble solid (% Brix)	Ascorbic acid (mg/100 g)	Pulp pH	Reducing sugar (%)	Non-reducing sugar (%)	Total Sugar (%)
At 35 days after fruit set	Control (No bagging)	17.03 ± 0.49 b	1.60	4.87 ± 0.02 a	1.97	10.03 ± 0.65 a	12.42 ± 0.67 ab
	Brown paper bag	17.95 ± 0.51 b	1.73	4.27 ± 0.11 b	2.52	4.84 ± 0.77 b	7.63 ± 0.14d-f
	White paper bag	18.95 ± 0.64 a	2.13	4.33 ± 0.26 b	3.59	5.10 ± 0.56 b	8.46 ± 1.28b-f
	Polythene bag	16.76 ± 0.58 c	1.20	4.36 ± 0.06 b	2.52	6.51 ± 0.26 ab	10.14 ± 1.51b-e
At 45 days after fruit set	Control (No bagging)	19.13 ± 0.46 a	1.60	4.75 ± 0.09 a	1.76	9.40 ± 0.62a	11.80 ± 0.73a-c
	Brown paper bag	18.47 ± 0.54 ab	1.60	4.38 ± 0.08 b	3.09	7.59 ± 0.67 ab	11.58 ± 0.33 a-d
	White paper bag	19.39 ± 0.54 a	2.00	4.35 ± 0.05 b	3.22	6.99 ± 1.13 ab	10.58 ± 0.15a-d
	Polythene bag	17.39 ± 0.85 b	1.73	4.02 ± 0.06 b	2.09	3.94 ± 1.69 b	7.80 ± 1.17c-f
At 55 days after fruit set	Control (No bagging)	19.12 ± 0.32 a	1.60	4.87 ± 0.02 a	1.84	10.24 ± 0.87a	14.25 ± 0.52a
	Brown paper bag	18.30 ± 0.85 ab	1.73	4.18 ± 0.16 b	3.27	6.67 ± 0.58 ab	9.55 ± 0.50b-e
	White paper bag	19.20 ± 0.27 a	2.00	4.00 ± 0.06 b	3.64	6.67 ± 0.39 ab	5.38 ± 0.03f
	Polythene bag	17.12 ± 0.39 b	1.60	3.94 ± 0.03 b	2.20	4.03 ± 0.64 b	6.44 ± 0.50ef
Level of significance		**	NS	**	NS	**	**
CV (%)		5.16	16.23	4.19	24.80	20.46	13.92

Means ± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another
[NS] indicates non-significant
**indicates significant at 1% level of probability

4.3. Fruit fly infestation (%)

The treatments exhibited statistically significant variation in respect of fruit fly infestation (Table 4.)

At 35 days after fruit set, the maximum infestation of fruit fly was recorded in control (8.62). Fruits of transparent polythene bag treatment showed less infestation (1.30) over the control while fruits of brown paper bag and white paper bag were totally free from fruit fly infestation.

At 45 days after fruit set, the maximum infestation of fruit fly was recorded in control (9.80). Fruits of polythene bag treatment showed less infestation (3.60) over control while fruits of brown paper bag and white paper bag were totally free from fruit fly infestation.

At 55 days after fruit set, the pre-harvest fruit bagging with brown paper bag (4.88), white paper bag (5.96) and polythene bag (9.00) assured the minimum fruit fly infestation over the control (10.80) treatments.

Table 4: Effects of different time of pre-harvest fruit bagging on the fruit fly infestation of mango cv. Khirsapat

Bagging time	Bagging time (Days)	Fruit fly infestation (%)
At 35 days after fruit set	Control (No bagging)	8.62 ± 0.42 b
	Brown Paper Bag	0.00 ± 0.00 d
	White Paper Bag	0.00 ± 0.00 d
	Polythene Bag	1.30 ± 0.31 c
At 45 days after fruit set	Control (No bagging)	9.80 ± 0.76 a
	Brown Paper Bag	0.00 ± 0.00 d
	White Paper Bag	0.00 ± 0.00 d
	Polythene Bag	3.60 ± 0.28 bc
At 55 Days after fruit set	Control (No bagging)	9. 80 ± 0.41 a
	Brown Paper Bag	4.88 ± 0.20 b
	White Paper Bag	5.96 ± 0.30 b
	Polythene Bag	9.00 ± 0.36 a
Level of significance		**
CV (%)		13.91

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
**indicates significant at 1% level of probability.

4.4. Disease severity

Statistically highly significant variation was observed in respect of stem end rot and anthracnose between the pre-harvest fruit bagging with brown paper bag, white paper bag and polythene bag at 35, 45 55 days after fruit set (Table 5.).

4.4.1. Stem end rot (%)

At 35 days after fruit set, the maximum infection of stem end rot was recorded in control (34.27). The pre-harvest fruit bagging with brown paper bag (1.13) had the lowest infection of stem end rot than control (34.27). It was followed by white paper bag (15.27) and polythene bag (27.10).

At 45 days after fruit set, the pre-harvest fruit bagging with brown paper bag (0.40) had the lowest infection of stem end rot than control (34.80). It was followed by white paper bag (10.77) and polythene bag (25.43%).

At 55 days after fruit set, the maximum infection of stem end rot was recorded in control (40.50). The pre-harvest fruit bagging with brown paper bag (2.17) had the lowest infection of stem end rot than control. It was followed by white paper bag and polythene bag (15.10 and 39.60%, respectively).

4.4.2. Anthracnose (%)

At 35 days after fruit set, the pre-harvest fruit bagging with brown paper bag, white paper bag and polythene bag (0.17, 3.00 and 4.86% respectively) showed lowest percent of anthracnose over than the control (31.70).

At 45 days after fruit set, the maximum anthracnose was recorded in control (31.70). Fruits of white paper bag and polythene bag treatment showed less infestation (3.60 and 5.43%, respectively) while fruits of brown paper bag were totally free from anthracnose (Table 5).

At 55 days after fruit set, the pre harvest fruit bagging with brown paper bag, white paper bag and polythene bag (0.77, 4.10 and 5.54%, respectively) showed the minimum anthracnose than the control (31.70).

Table 5: Effects of different time of pre-harvest fruit bagging on the Disease severity of mango cv. Khirsapat

Bagging time	Bagging time (Days)	Stem end rot (%)	Anthracnose (%)
At 35 days after fruit set	Control (No bagging)	34.27 ± 1.39 ab	31.70 ± 0.95 a
	Brown Paper Bag	1.13 ± 0.46 g	0.17 ± 0.06 d
	White Paper Bag	15.27 ± 0.68 de	3.00 ± 0.29 cd
	Polythene Bag	27.10 ± 2.33 bc	4.86 ± 0.32 c
At 45 days after fruit set	Control (No bagging)	34.80 ± 1.90 a	21.10 ± 1.36 b
	Brown Paper Bag	0.40 ± 0.19 g	0 d
	White Paper Bag	10.77 ± 1.18 ef	3.60 ± 0.66 cd
	Polythene Bag	25.43 ± 1.83 c	5.43 ± 0.29 c
At 55 days after fruit set	Control (No bagging)	40.50 ± 1.78 a	31.70 ± 0.40 a
	Brown Paper Bag	2.17 ± 0.53 g	0.77 ± 0.14 d
	White Paper Bag	15.10 ± 1.58 cd	4.10 ± 0.30 cd
	Polythene Bag	39.60 ± 1.49 a	5.54 ± 0.49 c
Level of significance		**	**
CV (%)		11.59	10.00

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
**indicates significant at 1% level of probability.

4.5. Shelf life of mango (Days)

Statistically highly significant variation in shelf life of mango was noticed in all treatments (Table 6).

At 35 days after fruit set, the non-bagged control fruit of Khirsapat had shelf life of 6.33 days. The fruits of brown paper bag (12.67 days) and white paper bag (11.33 days)) had greater shelf life than control (6.33 days). On the other hand, transparent polythene bag had similar shelf life (6.33 days) with control.

At 45 days after fruit set, the pre-harvest fruit bagging of brown paper bag (13 days) had the highest shelf life than control (7 days). It was followed by white paper bag (12.67 days). In contrasted the, lowest shelf life had in polythene bag (6.33 days) than control.

At 55 days fruit set, the pre harvest fruit bagging of brown paper bag (12.67days) had the highest shelf life than control (6.33 days). It was followed by white paper bag (9 days). On the other hand, the polythene bag (6.33 days) had similar shelf life with control.

The results of the present study have got support from Shahjahan *et al.* (1994) and Hasan *et al.* (1998). Haldankar *et al.* (2015) also reported that the un-bagged control fruits of ‘Alphonso’ had shelf life of 15 days. The fruits of newspaper bag (17.50 days), brown paper bag (16.50 days) and brown paper bag with polythene coating (16.00 days) and white cloth bag (15.00 days) had greater shelf life than control (15.00 days). The fruit of scurting bag (13.50 days) had shortest shelf life.

Table 6: Effects of different time of pre-harvest fruit bagging on the Shelf Life of mango cv. Khirsapat

Bagging time	Bagging materials	Shelf life (Days)
At 35 days after fruit set	Control (No bagging)	6.33 ± 0.33 d
	Brown Paper Bag	12.67 ± 0.33 a
	White Paper Bag	11.33 ± 0.33 b
	Polythene Bag	6.33 ± 0.33 d
At 45 days after fruit set	Control (No bagging)	7.00 ± 0.58 d
	Brown Paper Bag	13.00 ± 0.58 a
	White Paper Bag	12.67 ± 0.58 a
	Polythene Bag	6.67 ± 0.33 d
At 55 days after fruit set	Control (No bagging)	6.33 ± 0.33 d
	Brown Paper Bag	12.67 ± 0.33 a
	White Paper Bag	9.00 ± 0.58 c
	Polythene Bag	6.33 ± 0.33 d
Level of significance		**
CV (%)		8.91

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.

**indicates significant at 1% level of probability.

4.6. No. of immature fruits inside the bag

Statistically significant variation was noticed for the no. of immature fruits inside the bag in all the treatments (Table 7).

At 35 days after fruit set, the lowest no. of immature fruits inside the bag was observed in the treatment of brown paper bag and white paper bag (2.00 and 2.33, respectively). The transparent polythene bag (7.00) were also lower than control (7.67).

At 45 days after fruit set, no. of immature fruits inside the bag was observed in the treatments of brown paper bag and white paper bag. Oppositely, the minimum no. of immature fruits inside the bag was observed in the treatment of transparent polythene bag (2.00) over control (2.67).

At 55 days after fruit set, the minimum no. of immature fruits inside the bag was observed in the treatment of white paper bag and transparent polythene bag (0.33 and 2.33, respectively) over control (3.00) while no. of immature fruits inside the bag was not observed in the treatment of brown paper bag.

Table 7: Effects of different time of pre-harvest fruit bagging on the no. of immature fruit inside the bag cv. Khirsapat

Bagging time	Bagging materials	No. of immature fruits inside the bag
At 35 days after fruit set	Control (no bagging)	7.67 ± 0.88 a
	Brown paper bag	2.00 ± 0.58 bcd
	White paper bag	2.33 ± 0.58 bc
	Polythene bag	7.00 ± 0.58 a
At 45 days after fruit set	Control (no bagging)	2.67 ± 0.33 a
	Brown paper bag	0.00 ± 0.00 b
	White paper bag	0.00 ± 0.00 b
	Polythene bag	2.00 ± 0.58 a
At 55 days after fruit set	Control (no bagging)	3.00 ± 0.58 a
	Brown Paper Bag	0.00 ± 0.00 d
	White Paper Bag	0.33 ± 0.13 bc
	Polythene Bag	2.33 ± 0.33 b
Level of significance		**
CV (%)		23.73

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
**indicates significant at 1% level of probability.

4.7. Organoleptic evaluation (Sensory evaluation)

4.7.1. Colour of the peel

The treatments showed statistically significant variation in respect of colour (Table 8.)

At 35 days after fruit set, the highest score 8.33 was obtained in the treatment of brown paper bag. It was followed by white paper bag (6.67) over control (5.33). On the other hand, the lowest score (3.00) was obtained in transparent polythene bag than control.

At 45 days after fruit set, the highest score (8.67) was obtained in the treatment of brown paper bag. It was followed by white paper bag (7.67) over than control (6.33). On the other hand, the lowest score (3.00) was obtained in transparent polythene bag than control.

At 55 days after fruit set, the highest score (7.67) was obtained in the treatments of brown paper bag and white paper bag over control (4.47). On the other hand, the lowest score (3.33) was obtained in transparent polythene bag than control.

Bagging improved the colour of the fruits by increasing their anthocyanin content.

This result is comparable to that of Watanawan *et al*., (2008); they reported that bagging mango fruit with two-layer paper bags advanced their skin colour development from green to yellow. Wang *et al*., (2013) and Liu *et al*., (2013) also claimed that bagging induced red colour in green-type (‘Granny Smith’) and yellow-coloured (‘Golden Delicious’) apples, respectively. Bagging has been used extensively in several fruit crops to improve skin colour by increasing their anthocyanin contents and to reduce the incidence of disease, insect pests, mechanical damage, sunburn of the skin, agrochemical residues on the fruit and bird damage (Bentley and Viveros, 1992; Kitagawa *et al*., 1992; Hofman *et al*., 1997; Joyce *et al*., 1997; Tyas *et al*., 1998; Amarante *et al.,* 2002a and Xu *et al*., 2010.

4.7.2. Texture

At 35 days after fruit set, the same texture score i.e. 7.67 was recorded in all the treatments. So, there was no significant difference among the treatments.

At 45 days after fruit set, score 7.67 was obtained in the treatment of brown paper bag, white paper bag and transparent polythene bag while the score of control was 7.00.

At 45 days after fruit set, score 7.67 was obtained in the treatment of brown paper bag, white paper bag and transparent polythene bag while the score of control was 7.00.

This result is paralled to that Hofman *et al.,* (1997); they reported that mango fruit firmness was not affected by white paper bags. Faoro and Marcia (2004) studied the effects of bagging on fruit firmness and reported that bagging did not affect fruit firmness in 'Nashi' pear.

4.7.3. Appearance

Statistically significant variation in appearance in mango was noticed in all the treatments (Table 8).

At 35 days after fruit set, the highest appearance score (7.67) was obtained in the treatment of brown paper bag. It was followed by white paper bag (7.00) over control (5.33). In contrast, the lowest score (3.00) was obtained in the transparent polythene bag than control.

At 45 days after fruit set, the highest appearance score (8.33) was obtained in the treatment of brown paper bag. It was followed by white paper bag (7.67) over than control (5.67). Oppositely, the lowest score (3.33) was obtained in transparent polythene bag than control.

At 55 days after fruit set, the highest score (7.33) was obtained in the treatment of brown paper bag and white paper bag over control (5.67). On the other hand, the lowest score (3.00) was obtained in the transparent polythene bag than control.

This result is at per with that of Amarante *et al.* (2002b); they reported that pre-harvest bagging improved the fruits appearance. After a fruit bagging experiment using the mango cv. Apple, Mathooko *et al.*, (2011) reported that bagged fruit had a smoother texture and a spotless, light green skin colour.

4.7.4. Sweetness

Statistically no significant variation was found in the treatments in respect of sweetness (Table 8).

At 35 days after fruit set, the maximum score was obtained in control (7.67) than all the rest treatments.

At 45 days after fruit set, the maximum score (8.33) was obtained in the white paper bag while the minimum (7.00) was in the brown paper bag and the transparent polythene bag too.

At 55 days after fruit set, the maximum score (7.67) was obtained in the white paper bag while the minimum (6.76) score was in the transparent polythene bag.

4.7.5. Flavour

Statistically no significant variation was found among the treatments in respect of Flavour (Table 8).

At 35 days after fruit set, the maximum score was obtained in the brown paper bag (8.00) than control (7.00) while the minimum was in the transparent polythene bag (5.33).

At 45 days after fruit set, the maximum score (8.67) was recorded in the brown paper bag while the minimum (6.33) score was in the transparent polythene bag over control (6.67).

At 55 days after fruit set, the maximum score (7.67) was noted in the brown paper bag while the minimum (5.33) was in the transparent polythene bag.

4.7.6. Overall impression

There was no significant different among the treatments in respect of overall impression (Table 8).

At 35 days after fruit set, the brown paper bag gave the highest result (8.33). It was followed by the white paper bag (7.33). The lowest result (3.33) was observed in the transparent polythene bag than control (4.33).

At 45 days after fruit set, the highest result (8.67) was experienced in the brown paper bag while the white paper bag and transparent polythene bag gave 7.67 and 5.33, respectively. Oppositely the lowest result (4.67) was observed in the control fruits.

At 45 days after fruit set, the highest result (7.67) was given by the brown paper bag while the white paper bag and the transparent polythene bag gave 6.67 and 5.00, respectively). The lowest result (4.33) was observed in the control fruits. Bagged fruits had better overall impression than the control fruits.

Table 8: Effects of different time of pre-harvest fruit bagging on the sensory evaluation of mango cv. Khirsapat

Bagging time	Bagging materials	Colour	Texture	Appearance	Sweetness	Flavour	Overall impression
At 35 days after fruit set	Control (no bagging)	5.33 ± 0.67 c	7.67	5.33 ±0.67 b	7.67	7.00	4.33
	Brown paper bag	8.33 ± 0.33 a	7.67	7.67 ± 0.33 a	7.33	8.00	8.33
	White paper bag	6.67 ± 0.33 b	7.67	7.00 ± 0.58 a	7.33	7.00	7.33
	Polythene bag	3.00 ± 0.58 d	7.67	3.00 ± 0.58 c	7.33	5.33	3.33
At 45 days after fruit set	Control (no bagging)	6.33 ± 0.33 b	7.00	5.67 ± 0.88 b	7.33	6.67	4.67
	Brown paper bag	8.67 ± 0.33 a	7.67	8.33 ± 0.33 a	7.00	8.67	8.67
	White paper bag	7.67 ± 0.58 ab	7.67	7.67 ± 0.33 a	8.33	7.00	7.67
	Polythene bag	3.00 ± 0.58 d	7.67	3.33 ± 0.58 c	7.00	6.33	5.33
At 55 days after fruit set	Control (o bagging)	4.47 ± 0.66 cd	7.00	5.67 ± 0.88 b	7.33	5.33	4.33
	Brown paper bag	7.67 ± 0.33 ab	7.67	7.33± 0.58 a	7.00	7.67	7.67
	White paper bag	7.67 ± 0.33 ab	7.67	7.33 ± 0.33 a	7.67	7.33	6.67
	Polythene bag	3.33 ± 0.33 d	7.67	3.00 ± 0.58 c	6.67	5.33	5.00
Level of significance		**	NS	**	NS	NS	NS
CV (%)		14.88	9.80	17.91	13.27	14.11	16.44

Means± standard error within a column followed by different letter(s) are significantly different (Tukey's Test) from on another.
NS indicates non-significant.
**indicates significant at 1% level of probability.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present research was conducted on the effects of different time of bagging on fruit development, physico-chemical compositions and shelf-life of mango cv. Khirsapat through pre-harvest bagging treatments. The experiment was conducted at the mango orchard of Basherhat near Hajee Mohammad Danesh Science and Technology University campus, Dinajpur, Bangladesh during March to July, 2017. The Chemical analyses were conducted at Bangladesh Atomic Energy Commission, Agargaon, Dhaka and other parameters were analyzed at the Department of Horticulture, HSTU, Dinajpur, Bangladesh. The experiment was laid out in the Randomized Completely Block Design (RCBD) with three replications. The materials used for the experiment were uniformly grown 10 years old Khirsapat mango trees and different types of bags with a unit of 5 fruits per treatment per replication. The study was aimed at finding out the best pre-harvest treatments that for quality changes of mango as well as extends the shelf life. In this experiment, three bagging time (35, 45, 55 days after fruit set) and four bagging materials-T_0: non-bagged (control), T_1: Brown paper double layered bag (BPB), T_2: White paper single layered bag (WPB), T_3: Perforated transparent polythene bag (TPB) were used to achieve the objectives. The data were recorded on different physical and chemical parameters, shelf life, sensory evaluation, insect infestation and disease severity. Pre-harvest bagging had significant effects on fruit diameter (cm), fruit weight (g) peel weight (g) and pulp to stone ratio; and non-significant effects on fruit length (cm) over control fruits while the brown paper bag exhibited the fruits with best results on fruits length, fruits diameter, fruits weight, peel weight and pulp to stone ratio. Statistically highly significant variation was observed in total weight loss of fruits. The maximum weight loss (92.73%) was observed at 55 days after fruit set in the treatment of polythene bag while the minimum weight loss (10.40%) was observed at 45 days after fruit set in the treatment of brown paper bag over control. Statistically significant variation was experienced in pulp weight. The maximum pulp weight (162.5 g) was observed at 45 days after fruit set in the treatment of brown paper bag while the minimum pulp weight (101.0 g) was noted in control. Statistically significant variation was observed in stone weight of fruit. The minimum stone weight (24.47 g) was weighed at the 45 days after fruit set in the treatment of the polythene bag while the maximum stone weight (43.90 g) was observed in control. Significantly the maximum TSS (19.39 % Brix) was recorded at the 45 days after fruit set in the treatment of the white paper bag and the minimum (18.95% Brix) was observed at 35 days after fruit set in the treatment of the white paper bag over control. The pre-harvest bagging had non-significant effects on the ascorbic acid and the reducing sugar contents of fruits among the treatments. Significantly the highest pH was observed in control fruits but the lowest pH was observed in the brown paper bag, the white paper bag and the polythene bag at 35, 45 and 55 days after fruit set. The fruits of brown paper bag, white paper bag and polythene bag had significantly the minimum total sugar content over the control fruits at 35 45 and 55 days after fruit set. Sensory evaluation with respect to colour and appearance incurred significant variations among the treatments while flavor, texture, overall impression and sweetness were non-significant. It indicated that the organoleptic qualities of fruit were not affected by pre-harvest bagging. The pre-harvest bagging treatments caused significant extension of shelf life of mango. The longest (13.00) and the shortest (6.33) shelf life were recorded in the brown paper bag fruits and polythene bag fruits at 45 and 55 days after fruit set, respectively than control. Significant variation was observed in the parameter of number of immature fruits inside the bag. The number of immature fruit inside the bag totally no observed in brown paper brown and white paper bagged fruit at 45 and 55 days after fruit set. The fewer (2.00 and 2.33, respectively) immature fruits were observed in 35 days after fruit set in brown and white paper bagged over control (7.67). In respect of infestation of fruit fly significant variation was observed. The treatment of brown paper and white paper bagged fruits were totally free from fruit fly infestation at 35 and 45 days after fruit set over control (8.62 and 9.80%, respectively). On the other hand, less infestation of the fruit fly infestation at the 55 days after fruit set were noted with the brown paper and white paper bagged fruits (4.88 and 5.96%, respectively) over control (9.80%). Pre-harvest bagging had significant effect on the stem end rot. The treatment brown paper bag showed the lowest (0.40%) stem end rot at 45 days after fruit set while at 55 days after fruit set the control fruits showed the highest (40.50%) stem end rot. Statistically significant variation was observed in respect of anthracnose. The treatment of brown paper bag was totally free from anthracnose at 45 days after fruit set while at 55 days after fruit set the control fruits showed the highest (31.70%) anthracnose disease. So, the pre-harvest bagging with brown paper bag and white paper bag at 35 days after fruit gave the best results for infestation of fruit fly infestation. When 45 days after fruit set gave best performance for total weight loss, pulp and stone weight, pH, total sugar, colour, appearance, shelf life, number of fruit immature fruit inside the bag and decreased infestation of fruit fly, disease of stem end rot, anthracnose. The white paper bag contributed best performance for total soluble solid. At 55 days after fruit set, brown paper bag and white paper bag improved total weight loss, pulp and stone weight, total soluble solid, pH, total sugar, number of fruit immature fruit inside the bag and decreased disease of stem end rot, anthracnose. Finally, this study clearly demonstrates that pre-harvest fruit bagging could emerge as a novel technology in practice. It will also be beneficial for both growers and consumers because, it is simple, safe and beneficial for the production of quality fruits. It is advisable to use brown paper bag for getting coloured fruits i.e., yellow colour since white paper bag for retains original colour of each variety. Both bags showed their potentiality against major insect-pests and diseases attack. Bagging fruits have a good shelf life which is important criterion for exportable mango. On the other hand, bagging fruits having attractive colour, farmer will get more market price for their mangoes. Therefore, farmers might use this technology for commercial mango cultivation to fulfill the demand of quality mango in the country and abroad.

REFERENCES

AOAC. 1980. Official Methods of Analysis. Association of Official Analytical Chemists (12th Edition) Washington, DC. 2004.

Amarante C, Banks NH and Max S. 2002. Effect of preharvest bagging on fruit quality and postharvest physiology of pears (*Pyrus communis*). New Zealand Journal of Crop and Horticultural Science. 30: 93-98.

Amarante C, Banks NH and Max S. 2002a. Effect of preharvest bagging on fruit quality and postharvest physiology of pears (*Pyrus communis*). New Zealand Journal of Crop and Horticultural Science. 30: 90-107.

Amarante C, Banks NH and Max S. 2002b. Pre-harvest bagging improves pack out and fruit quality of pears (*Pyrus communis*). New Zealand Journal of Crop and Horticultural Science. 30: 93–98.

Amin M and Hanif M. 2002. Cultivation of mango in Dera Islam Khan. Agricultural Research Institute, Ratta, DI Khan. pp.1-18.

Amerine MA, Pangborn RM and Rocssler EB. 1965. Principles of sensory evaluation of food. London:Academic Press. http://dx.doi.org/10.1016/B978-1-4832-0018-7.50011-8.

Awad MA. 2007. Increasing the rate of ripening of date palm (*Phoenix dactylifera* L.) cv. Helali by preharvest and postharvest treatments. Post-harvest Biology and Technology. 43:121-127.

BBS. 2017. Year Book of Agricultural Statistics-2016. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. pp. 200.

Bugante RD, Lizada MCCJr and Ramos MBde. 1997. Disease control in Philippine 'Carabao' mango with pre-harvest bagging and postharvest water treatment. Acta Horticulturae. 455: 797–804.

Bentley WJ and Viveros M. 1992. Brown-bagging 'Granny Smith' apples on trees stops codling moth damage. California Agriculture. 46: 30–32.

Candole AD. 1984. Origin of cultivated plants.Vegal Paul Trench and Co., London. pp. 1-67.

Chen CS, Zhang D, Wang YQ, Li PM and Ma FW. 2012. Effects of fruit bagging on the contents of phenolic compounds in the skin and flesh of ‘Golden Delicious’, ‘Red Delicious’, and ‘Royal Gala’ apples. Science Horticulture. 142: 68–73.

Chonhenchob V, Kamhangwong D, Kruenate J, Khongrat K, Tangchantra N, Wichaiand U and Singh SP. 2011. Pre-harvest bagging with wavelength-selective materials enhances development and quality of mango (*Mangifera indica* L.) cv. Namdokmai #4.Journal of Agricultural Science and Technology.91: 664-671.

Debnath S and Mitra SK. 2007. Panicle bagging for maturity regulation quality improvement and fruit borer management in litchi (*Litchi chinenesis*). Acta Horticulturae. 773: 201-209.

Debnath U, Sureesh CP and Hasan MA. 2001. Bunch management for profitable production in developing banana bunches. Journal of Tropical Agriculture. 58. Issue: 3 Print ISSN: 0972-8538.

Dutta P and Majumder D. 2012. Influence of bagging on fruit quality and mineral composition of Himsagor mango grown in new alluvial zones of West Bengal. Advances in Horticultural Science. 26(3-4):158-162.

El-Kassas ShE, El-Mahdy TK, El-Khawaga AA and Zynab H. 1995. Response of Zaghloud date palms to certain treatments of pollination, flower thinning and bagging. Assiut Journal of Agricultural Science. 26(4): 167-177.

El-Salhy AM. 1999. Effect of bagging the spathes on Zaghloud date productive under Assiut conditions. Journal of Agricultural Science. 32(3):123-134.

Fallahi E, Colt WM, Baird CR and Chun IJ. 2001. Influence of nitrogen and bagging on fruit quality and mineral concentrations of ‘BC-2 Fuji’ Apple. Horticulture Technology. 11(3): 462-465.

Fan XT and Mattheis JP. 1998. Bagging ‘fuji’ apples during fruit development affects colour development and storage quality. Horticultural Sciences. 33(7): 1235-1238.

Ghalib HH, Essam A, Mowlod A. and Hamza HH. 1988. The influence of bagging on fruit set and fruit characteristics in date palm cv. Hilawi Date Palm. Journal of Plant Studies. 6(1): 238-354.

Haldankar PM, Parulekar YR, Kireeti A, Kad MS, Shinde SM and Lawande KE. 2015. Studies on influence of bagging of fruits at marble stage on quality of mango cv. Alphonso. Journal of Plant Studies.4(2):12-20.

Haq IU and Rab A. 2012. Characterization of physico-chemical attributes of litchi fruit and its relation with fruit skin cracking. Journal of Animal and Plant Science. 22(1):142-147.

Harhash MM and Al-Obeed RS. 2010. Effect of bunch bagging colour on yield and fruit quality of date palm. American-Eurasian Journal of Agricultural and Environmental Sciences. 7(3): 312-319.

Hasan MK, Mondal MF and Haque MS. 1998. Studies on the storage behaviour of mango. Bangladesh Journal of Agricultural Science. 25(2): 311-318.

Hiratsuka S, Yokoyama Y, Nishimura H, Miyazaki T and Nada K. 2012. Fruit photosynthesis and phosphoenol pyruvate carboxylase activity as affected by lightproof fruit bagging in Satsuma mandarin. American Society for Horticultural Science. 137: 215–220.

Hofman PJ, Joyce DC and Beasley DR. 1999. Effect of preharvest bagging and of embryo abortion on calcium levels in ‘Kensington Pride’ mango fruit. Australian Journal of Experimental Agriculture. 39(3): 345 – 349.

Hofman PJ, Smith LG, Joyce DC, Johnson GI and Meiburg GF. 1997. Bagging of mango (*Mangifera indica* L.) cv. `Keitt' fruit influences fruit quality and mineral composition. Postharvest Biology and Technology.12(1): 83-91.

Hongxia W, Wang SB, Shi SY, Ma WH, Zhou YG and Zhan RL. 2009. Effects of bagging on fruit quality in Zill mango. Journal of Fruit Science. 26(5): 644-648.

Huang CH, Chai ML, Pan ZM, Jiang BYuZM, Hu JL and Teng YW. 2007. Effects of bagging on fruit skin features and quality of ‘Cuiguan’ pear cultivar. Journal of Fruit Science. 24: 747–751.

Hudina M and Stampar F. 2011. Effect of fruit bagging on quality of 'Conference' pear (*Pyrus communis* L.). European Journal of Horticultural Science. 76(5):176-181.

Islam MT, Rahman MS, Shamsuzzoha M, Chowdhury AKMMB and Alom R. 2017. Influence of pre-harvest bagging on fruit quality of Mango (*Mangifera indica* L.) cv. Mishribhog. International Journal of Bioscience.11(3): 59-68.

Jakhar M and Pathak S. 2016. Effect of Pre-harvest nutrients application and bagging on quality and shelf life of mango (*Mangifera indica* L.) fruits cv. Amrapali. Horticultural Science. 18: 717-729.

Johns GG and Scott KJ. 1989. Delayed harvesting of bananas with 'Sealed' covers on bunches. 2. Effect on fruit yield and quality. Australian Journal of Experimental Agriculture. 29: 727–733.

Joshi GD and Roy SK. 1988. Influence of maturity, transport and cold storage on biochemical composition of Alphonso mango fruit. Journal of Maharashtra Agricultural University. 13(1):12-15.

Joyce DC, Beasley DR and Shorter AJ. 1997. Effect of pre-harvest bagging on fruit calcium levels, storage and ripening characteristics of 'Sensation' mangoes. Australian Journal of Experimental Agriculture. 37: 383–389.

Katrodia JS. 1989. Spongy tissue in mangocauses and control measures. International symposium on mango. Acta Horticulturae. pp. 231.

Kitagawa H, Manabe K and Esguerra EB. 1992. Bagging of fruit on the tree to control disease. Acta Horticulture. 321: 871–875.

Lima ADJB, Angelo A, Alberico, Marcelo, Ribeiro M, Deyse G, Elisa and Lima BD. 2013. Chemical evaluation and effects of bagging new peach varieties introduced in southern Minas Gerais- Brazil. Journal of Food Science and Technology.33(3): 434-440.

Lin J, Wang JH, Li XJ, and Chang YH. 2012. Effects of bagging twice and room temperature storage on quality of 'Cuiguan' pear fruit. Acta Horticulture. 934: 837–840.

Liu Y, Zhang X and Zhao Z. 2013. Effects of fruit bagging on anthocyanins, sugars, organic acids, and colour properties of ‘Granny Smith’ and ‘Golden Delicious’ during fruit maturation. European Food Research and Technology.236: 329–339.

Mathooko FM, Kahangi EM, Runkuab JM, Onyangob CA and Owinob WO. 2011. Pre-harvest ‘Apple’ fruit bagging controls lenticel discolouration and improves postharvest quality. Acta Horticulturae. 906: 55–62.

Mukherjee SK. 1998. Introduction: Botany and Importance. In Mango, Botany, Prodn. and Uses. Edt. R.E. Litz. CAB International. pp. 1-20.

McHenry EW and Graham M. 1935. Observation on the estimation of ascorbic acid by filtration. Biochemical Journal. 29(9): 2013-2019.

Moffett JrTM and Pater DrE. 2007. Determination of Citric Acid in Fruit Juice. SUNY Plattsburgh.

Mondal CK, Garain PK, Maitra NJ and Maji A. 2015. Bio-friendly management of guava fruit fly (*Bactrocera correcta* Bezzi) through wrapping technique. Journal of Applied and Natural Sciences.7(1): 358 –363.

Mostafa RAA, El-Salhy AM, El-Banna AA and Diab YM. 2014. Effects of bunch bagging on yield and fruit quality of seewy date palm under new valley conditions, Egypt. Middle-East Journal of Scientific Research. 3(3): 517-521.

Moustafa AA. 2007. Effect of bagging period of spathes after pollination on fruit set, yield and fruit quality of “Seewy” dates under Fayoum Governorate conditions. Proceedings of the forth symposium on the date palm in Saudi Arabia, Al-Hassa. pp. 123.

Nagaharshitha D, Khopkar RR, Haldankar PM, Haldavanekar PC and Parulekar YR. 2014. Effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. Alphonso. Agrotechnology.3: 1000124.

Nagata M and Yamashita I. 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruits. Nippon Shokuhin Kogyo Gakkaish. 39(10): 925-928.

Nagaharshitha D, Haldankar PM and Khopkar RR, 2016. Effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. Alphonso. Journal of Horticultural Science and Crop Research. 6(1):1-8.

Oosthuyse SA and Jacobs G. 1997. Effect of soil applied Paclobutrazol on fruit retention, fruit size, tree yield and tree revenue in 'Sensation and Tommy Atkins' mango. Acta Horticulture. 451: 76-83.

Om and Prokash. 2004. Diseases and disorders of mango. In diseases of fruits and vegetables, diagnose and management. The Netherlands: Kluwer Academic Publishers. pp. 596.

Omar AEK, Al-Saif AM and Ahmed MAE. 2014. Bagging of bunches with different materials influences yield and quality of Rothana date palm fruit. Journal of Food Agriculture and Environment. 12(2): 520-522.

Qin D, Mingyu H and Yuming T. 2004. Effect of bagging on nectarine fruit quality and fruit cracking. Journal of Northwest Sci-Tech University Agricultural Forestry. 32(9): 81-83.

Rathore HA, Masud T, Sammi S and Soomro AH. 2007. Effects of storage on physico-chemical composition and sensory properties on mango (*Mangifera indica* L.) Variety Dasehari. Pakistan Journal of Nutrition. 6:143-148.

Rabeh MRM and Kassem HA. 2003. The effects of bagging the spathes after pollination on yield and quality of Zagloud and Samony dates. Zagazig Journal of Agricultural Research. 21(3B): 935-944.

Rakesh Kumar Singh, Shah NI and Solanki PD. 2017. Influence of fruit bagging on chemical quality of mango (*Mangifera indica* L.) Varieties. Journal of Plant Nutrition and Soil Science. 18(3): 1-7.

Roy R, Rahim MA and Alam MS. 2011. Effect of wrapping papers on physiological changes and shelf-life of mango cv. Langra. Journal of Environmental Science and Natural Resources. 4(2): 99-103.

Sanas MP, Haldankar PM, Haldavanekar PC and Godase SK. 2015. Effect of pre-harvest fruit bagging on physico-chemical properties of karonda (*Carissa conjesta* L.) cv. 'Konkan Bold'. International Journal of Applied Agricultural Sciences. 6(4): 855-857.

Santini A, Romano R, Meca G and Raiola A. 2014. Antioxidant activity and quality of apple juices and puree after *in vitro* digestion. Journal of Food Research. 3(4): 41-50.

Sarker D, Rahman MM and Barman JC. 2009. Efficacy of different bagging materials for the control of mango fruit fly. Journal of the Bangladesh Agricultural Research. 34: 165-168.

Shahjahan M, Shell S, Zaman MA and Sakur MA. 1994. Optimization of harvesting maturities for major mango cultivars in Bangladesh. Bangladesh Journal of Scientific Research. 12(2): 209-215.

Sharma RR, Pal RK, Asrey R, Sagar VR, Dhiman MR and Rana MR. 2013. Pre-harvest fruit bagging influences fruit colour and quality of apple cv. Delicious. Journal of Agricultural Science. 4(9): 443-448.

Sharma RR, Reddy RSV and Jhalegar MJ. 2014. Pre-harvest fruit bagging: a useful approach for plant protection and improved post-harvest fruit quality. Journal of Horticultural Science and Biotechnology. 89(2):101-113.

Shinde SM, Haldankar PM, Parulekar YR, Bhave PCSG, Godase SN and Lawande KE. 2015. Effect of pre-harvest bagging with different types of bags on physico-chemical properties of mango cv. Kesar. International Journal of Applied Agricultural Sciences. 6(4): 809-812.

Signes AJ, Burlo F, Sanchez FM and Barrachina AAC. 2007. Effect of preharvest bagging on quality of black table grapes. World Journal of Agricultural Sciences. 3(1): 32-38.

Singh BP, Singh RA, Singh G and Killadi B. 2007. Response of bagging on maturity, ripening and storage behaviour of winter guava. Acta Horticulturae. 735: 597–601.

Singh H. 1996. Mango.ICAR. New Delhi, India.

Tyas JA, Hofman PJ, Underhill SJR and Bell KL. 1998. Fruit canopy position and panicle bagging affects yield and quality of `Tai So' lychee. Scientia Horticulturae. 72: 203-213.

Uddin MS, Islam MS, Uddin MZ, Alam MA, Hossain MM and Rashid MH. 2015. Modern production technology of mango and its marketing system. Regional Horticulture Research Station, BARI, Chapainawabganj. pp. 46

Uddin MS and Reza MR. 2017. Fruit bagging technology and exportable mango production. Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Chapainawabganj. pp. 1-16.

Uddin MS, Reza MH, and Islam MS. 2018. Mango production manual. Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Chapainawabganj. pp. 1-56.

Wang G, Xia R, Zeng X and Hu L. 2006. Effects of bagging on pigment, sugar and endogenous hormone contents of Cara Cara orange flesh. Journal of Applied Ecology. 17: 256-260.

Wang L, Zhang X, Liu Y, Shi X, Wang Y, Zhang C and Zhao Z. 2013. The effects of fruit bagging on the colour, phenolic compounds and expression of the anthocyanin biosynthetic and regulatory genes on the 'Granny Smith' apples. Published online in European Food Research and Technology. 237: 875-885.

Wang YJ, Yang CX, Liu CY, Xu M, Li SH, Yang L and Wang YN. 2010b. Effects of bagging on volatiles and polyphenols in 'Wanmi' peaches during endocarp hardening and final fruit rapid growth stages. Journal of Food Science.75: 455-460.

Watanawan A, Watanawan C and Jarunate J. 2008. Bagging 'Nam Dok Mai' mango during development affects colour and fruit quality. Acta Horticulturae.787:325-330.

Xie RJ, He SL, Lv Q, Yi SL, Zheng YQ, Deng L, Zheng L, Jing L and Xi WP. 2013. The effect of cultivar and bagging on physico-chemical properties and antioxidant activity of three sweet orange cultivars (*Citrus sinensis* L.) Osbeck. American-Eurasian Journal of Agricultural and Environmental Sciences. 13(2):139-147.

Xu HX, Chen JW and Xie M. 2010. Effects of different light transmittance paper bags on fruit quality and antioxidant capacity in loquat. Journalof the Science of Food and Agriculture. 90:1783-1788.

Yang WH, Zhu XC, Bu JH, Hu GB, Wang HC and Huang XM. 2009. Effects of bagging on fruit development and quality in cross-winter off-season longan. Scientia Horticulture. 120:194-200.

Yadav SM, Patil RK, Balai LP and Niwas R. 2013. Post-harvest diseases of horticultural crops and their management. Popular kheti. 1(3): 20-25.

Xin HM and Zhang XH. 2003. Influence of bagging on the fruit inclusion and endogenous hormones of 'Yali' Pear variety. Journal of Fruit Science. 20: 233–235.

Zhao JJ, Wang JB, Zhang XC, Li HL and Gao ZY. 2013. Effect of bagging on the composition of carbohydrate, organic acids and carotenoid contents in mango fruits. Acta Horticulturae. 992: 537-54.

Zhou J, Zhong G, Lin Z and Xu H. 2012. The effects of bagging on fresh fruit quality of *Canarium album*. Journal of Food Agriculture and Environment. 10(1): 505-508.

Zhou XB and Guo XW. 2005. Effects of bagging on the fruit sugar metabolism and invertase activities in 'Red Globe' grape during fruit development. Journal of Fruit Science. 26: 30-33.

APPENDICES

Appendix I: Weather data for growing season of mango fruits, March to July, 2017

Month	Relative humidity (%)	Temperature		Monthly total rainfall (mm)
		Minimum (^oC)	Maximum (^oC)	
March	74.00	17.50	32.00	8.30
April	79.00	21.60	34.30	4.00
May	78.23	23.34	32.29	17.93
June	80.13	26.17	33.59	14.80
July	84.00	28.00	38.00	10.00

Source: Wheat Research Centre, Dinajpur

Appendix II: Analysis of variance of data on the physical parameters *viz.* fruits length (cm), fruits diameter (cm), fruits weight (g) and weight loss (%) of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square			
		Fruits length (cm)	Fruits diameter (cm)	Fruits weight (g)	Weight loss (%)
Bagging time (A)	2	0.05^{NS}	0.18^{NS}	1173.65**	469.94**
Bagging materials (B)	3	1.31**	1.005**	749.42**	3775.81**
Interaction (A×B)	6	0.57^{NS}	1.46**	877.57**	1119.88**
Error	22	0.24	0.26	44.78	19.60
Total	35				

**indicates significant at 1% level of probability

^{NS} indicates non-significant

Appendix III: Analysis of variance of data on the physical parameters *viz.* pulp weight (g), stone weight (g), peel weight (g) and pulp: stone ratio of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square			
		Pulp weight (g)	Stone weight (g)	Peel weight (g)	Pulp: stone ratio
Bagging time (A)	2	203.86 ^{NS}	39.72**	205.43**	0.41*
Bagging materials (B)	3	4686.61**	317.24**	293.44**	5.88*
Interaction (A×B)	6	435.42**	30.25**	77.96**	0.65*
Error	22	58.50	6.34	34.34	0.21
Total	35				

**indicates significant at 1% level of probability.
^{NS} indicates non-significant.

Appendix VI: Analysis of variance of data on the chemical parameters *viz.* TSS (% Brix), ascorbic acid (mg/100 g) and pulp pH of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square		
		Total soluble solid (% Brix)	Ascorbic acid (mg/100 g)	Pulp pH
Bagging time (A)	2	13.84**	0.18 ^{NS}	0.05**
Bagging materials (B)	3	4.15**	0.49 ^{NS}	1.02**
Interaction (A×B)	6	0.66**	0.08 ^{NS}	0.05**
Error	22	0.84	0.77	0.03
Total	35			

**indicates significant at 1% level of probability
^{NS} indicates non-significant.

Appendix V: Analysis of variance of data on the chemical parameters *viz.* reducing sugar (%), non-reducing sugar (%) and total sugar (%) of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square		
		Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
Bagging time (A)	2	0.12 ^{NS}	4.02**	4.63*
Bagging materials (B)	3	4.70*	38.13**	52.15**
Interaction (A×B)	6	0.23 ^{NS}	5.81**	10.25**
Error	22	0.43	2.80	1.81
Total	35			

*indicates significant at 5% level of probability.
**indicates significant at 1% level of probability.
^{NS} indicates non-significant.

Appendix VI: Analysis of variance of data on the no. of immature fruit inside the bag and shelf life of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square	
		No. of immature fruits inside the bag	Shelf life (days)
Bagging time (A)	2	3.58**	45.19**
Bagging materials (B)	3	92.62**	30.92**
Interaction (A×B)	6	0.73**	3.08**
Error	22	0.55	0.60
Total	35		

**indicates significant at 1% level of probability.
^{NS} indicates non-significant.

Appendix VII: Analysis of variance of data on the fruit fly infestation (%), stem end rot (%) and anthracnose (%) of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square		
		Fruit fly infestation (%)	Stem end rot (%)	Anthracnose (%)
Bagging time (A)	2	55.62**	190.53**	27.09**
Bagging materials (B)	3	141.36**	1953.05**	1407.23**
Interaction (A×B)	6	4.97**	32.90**	29.13**
Error	22	0.35	6.31	0.92
Total	35			

**indicates significant at 1% level of probability.
^{NS} indicates non-significant.

Appendix VIII: Analysis of variance of data on the sensory evaluation *viz.* colour, texture and appearance of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square		
		Colour	Texture	Appearance
Bagging time (A)	2	2.11*	0.36 ^{NS}	1.36 ^{NS}
Bagging materials (B)	3	34.70**	1.66 ^{NS}	35.14**
Interaction (A×B)	6	1.04**	0.21 ^{NS}	1.25 ^{NS}
Error	22	0.73	0.45	1.08
Total	35			

*indicates significant at 5% level of probability.
**indicates significant at 1% level of probability.
^{NS} indicates non-significant.

Appendix IX: Analysis of variance of data on the sensory evaluation *viz.* sweetness, Flavour and overall impression of mango cv. Khirsapat

Source of variation	Degrees of freedom	Mean square		
		Sweetness	Flavour	Overall impression
Bagging time (A)	2	0.19 ^{NS}	0.44 ^{NS}	2.03 ^{NS}
Bagging materials (B)	3	7.44**	8.48**	32.42 ^{NS}
Interaction (A×B)	6	0.53 ^{NS}	0.82 ^{NS}	0.95 ^{NS}
Error	22	0.88	0.96	1.18
Total	35			

**indicates significant at 1% level of probability.
^{NS} indicates non-significant.