



SUSTAINABLE MANAGEMENT AGAINST FRUIT FLY AND BORER BY BAGGING SYSTEMS IN MANGO (*MANGIFERA INDICA* L.)

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Abstract

Mango is the leading seasonal cash crop in Rajshahi, Naogaon and Chapainawabganj and other regions of Bangladesh. But due to fruit fly and borer the important cash crop is prone to attacks of insect pests and diseases its developmental stages. The study has been conducted to find out the effect of pre-harvest fruit bagging against fruit fly and borer on post-harvest quality and shelf life of mango cv. Amrapali. Under this study five different bagging materials were used e.g (i) control (non-bag fruit), (ii) brown paper bag (T₁), (iii) white paper bag (T₂), (iv) black polythene bag (T₃) and (v) white polythene bag (T₄). In this case non-bagging fruits were considered as control (T₀). The experiment was laid out in randomized complete block design with three replications. Significant variations among the pre-harvest bagging materials in relation to physio-chemical quality attributes and shelf life of mango cv. Amrapali was found. The attributes such as weight, length and breadth of fruit, skin color, moisture content, dry matter content, Vitamin-C, sugar content (reducing, non-reducing and total sugar), total soluble solids content and shelf life were significantly influenced by the bagging materials. All parameters except Vitamin-C of the bagged fruits were higher than that of control fruits. Highly significant difference in respect of shelf life between bagged and non-bagged fruit was observed. The longer shelf life (15.06 days) was observed in brown paper bag whereas the shortest shelf life (7.92 days) was in control fruits. It was observed that all bagging materials were 100% effective against fruit fly and borer attack but all physical and chemical parameters were significantly affected due to apply different bagging materials. Considering all parameters, it was found that brown paper and white paper bagged fruits mangoes appeared to be the best in respect of skin color weight and size of fruit, moisture content, dry matter content, Vitamin-C content, total soluble solids content, and extending shelf life in mango cv. Amrapali.

Key words: Mango, Fruit fly borer, Bagging materials, Composition of bag.

Introduction

Mango (*Mangifera indica* L.) is one of the most popular and important fruit crops among all fruits grown in Bangladesh. In Bangladesh, mangoes are considered as the best of all local natural products because of their great taste, seductive aroma, stunning color, aromatic flavor and natural interaction. It is acknowledged as the king of fruits in Bangladesh. It is famous among all fruits because of its taste, variety and color, thus also known as King of Fruits (Karar et al. 2019). Currently, the mango ranch covers approximately 41,676 hectares with the total production of mango is about 1,288,315 metric tons and it ranks second in terms of

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production after banana in Bangladesh (BBS 2017). The area of the mango estate grew from year to year, but the production of protected and first-class mangoes did not develop. According to the BBS (2022) report, in general, mango is produced very well in the northern region of Bangladesh, especially in Rajshahi area.

As Bangladesh is geographically situated in the tropical and sub-tropical climatic zones, many insect pests and diseases attack mango and contribute to the low yield and poor quality of mango fruits. The mango fruit fly, *Bactrocera dorsalis* Hendel (Tephritidae: Diptera), is the most serious pest of mango in all production regions in Bangladesh (Karim 1989). A huge quantity of mango fruits is annually lost due to fruit fly infestations. In general, the yield loss due to fruit flies varies between 40 and 70%, depending on the mango variety and the availability of susceptible fruits during different parts of the season. Farmers mainly use chemical insecticides to control the mango fruit fly, and these pesticides are often used indiscriminately to the extent that mixtures of two or three insecticides are sprayed at very high frequencies (15-62 times in a season) (Uddin and Reza 2017). Integrated pest management (IPM) techniques, including the use of kairomones, protein baits, and fruit bagging, may prove effective in controlling the mango fruit fly, while reducing conventional pesticide use (Vargas et al. 2008, Sharma et al. 2014). The total average loss of mango in Bangladesh was found as much as 34% (Sarker et al. 2011).

Fruit bagging is one of the effective methods to protect the fruit from the attack of many pests and diseases (Matsumoto et al. 2018a, Rahman et al. 2018). It greatly reduced the number of chemical spraying times by farmers, limiting chemical residues on post-harvest products. In Japan, China, Korea, Australia and the USA fruit bagging is an integral part of fruits for domestic and export markets because it is a safe and eco-friendly technique to protect fruits from multiple stresses, preserving or improving the overall quality (Ali et al. 2021). Fruit bagging is considered an effective measure to control fruit borer *Nephopteryx* sp. Fruit bagging in mango not only protects fruits from pest and diseases but also improve the quality of fruit (Haldankar et al. 2015, Matsumoto et al. 2018b, Akter et al. 2020, Gethe et al. 2021). In addition, this technique increases the marketable yield, the size and weight of bagged fruit being higher than those that are unbagged (Chonhenchob et al. 2011). However, bagging fruits is a physical protection technique commonly applied to mango (Wu et al. 2009, Nagaharshitha et al. 2014, Haldankar et al. 2015, Jakhar and Pathak 2016, Islam et al. 2017a,b) to enhance the marketable value of the crop, explicitly, improving fruit coloration (Kim et al. 2010), internal quality of mango and reducing splitting (Ding et al. 2003), mechanical damage (Amarante et al. 2002) and skin sunburn (Muchui et al. 2010). It also decreases pesticide residues in the fruit (Amarante et al. 2002) and improves insect (Sarker et al. 2009), disease (Wang et al. 2011) and bird damage control (Amarante et al. 2002). Therefore, pre-harvest bagging has been an important technical measure in improving the commercial value and bringing down the postharvest losses (Okamoto et al. 1982). The reduced postharvest losses, attractive appearance and peel color may help to bring optimum production of high-quality exportable mango. Hence, this experiment was conducted to sustainable management against fruit fly and borer by bagging systems on the postharvest quality of mangoes in Bangladesh.

Materials and Methods

The present experiment investigated to sustainable management of mango production against fruit fly by the effects of pre-harvest bagging treatments on quality and shelf life of mango. The experiment was conducted in Kollayanpur Horticulture Centre, Chapainawabganj; postgraduate laboratory of the department of Biochemistry and Molecular Biology, Rajshahi University, Rajshahi. The experiment was laid out in a randomized complete block design with three replications having 100 fruits. The experiment was conducted in randomized complete block design with five treatments replicated three times with a unit of 20 fruits per treatment and 100 fruits per replication. Different types of bags constituted the treatments viz.: T₀: Control (no bagging), T₁: Brown paper bag, T₂: White paper bag, T₃: White polythene bag and T₄: Black polythene bag. Uniformly grown fruits at marble stage (30 days after fruit set) were selected for bagging. The size of bags was 25 × 20 cm. Before bagging perforations (≤4.0 mm diameter) were made at the bottom of all bags for proper ventilation. The particular bags were stapled properly at the stalk of each fruit of respective treatments so that it would not be fall down as well as there would not be open space. The white polythene bags and black polythene bags were tied with the help of thread. Five fruits were randomly selected per treatment per replication to record various physical and chemical observations.

Physical parameters: Skin color was measured for each fruit using a Minolta color difference meter. The weight of the fruit was taken by electrical balance and expressed in gram (g). The length and breadth of fruits at mature stage for each replication were measured by a scale and expressed in centimeter. Chemical parameters: Moisture content (%), Dry matter content (%), Total soluble solids (%), Total sugar (%), Reducing sugar (%), Non-reducing sugar (%) and Vitamin C content (mg/100 g).

Moisture and dry matter (%): A weighted fresh sample of mature mango of each germplasm was taken and cut into pieces. These samples were taken in porcelain crucible in triplicate and oven dried at 80°C till the weight become constant. Percent moisture content was calculated according to the following formula:

$$\% \text{ moisture} = \frac{IW - FW}{IW} \times 100$$

Where, IW= Initial weight of sample (mg), FW=Final weight of sample (g), Dry matter content was calculated according to the following formula: Dry matter content = 100- % moisture

Total soluble solids (%): Total soluble solid content was determined by a Refract meter. Three samples of each treatment were taken. A drop of juice squeezed from the sample was placed on the surface of the prism of the refractometer and percent total soluble solid was obtained from direct reading.

Determination of total sugar content of mango fruit (%): The amount of total sugar present in the extract was calculated from the standard curve of glucose (Fig. 1). Finally the percentage of total sugar was determined by using following formula:

$$\text{Percent total sugar} = \frac{\text{Amount of sugar obtained (ml)}}{\text{Weight of sample (gm)}} \times 100$$

Determination of reducing sugar (%): in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter. The amount of reducing sugar was calculated from the standard curve of glucose. The percentage of reducing sugar present in the mango pulp was determined by using the following formula: % reducing sugar (g/100 g of sample) = $\frac{\text{Amount of sugar obtained (ml)}}{\text{Weight of sample (gm)}} \times 100$

Vitamin C content (mg/100 g): The ascorbic acid content of the sample was calculated by following formula: Vitamin C content (mg/100 g) = $\frac{T \times D \times V1}{V2 \times W} \times 100$

Where, T = Titre, D = Dye factor, V1 = Volume made up (ml), V2 = Aliquot of extract taken for estimation and W = Weight of sample for estimation (gm).

Shelf life (days)

Shelf life of mango fruits as influenced by different postharvest treatments was calculated by counting the number of days required to ripen fully with retained optimum marketing and eating qualities.

Statistical analysis

The recorded data were compiled and analyzed by two factorial design to find out the statistical significance of experimental results by using the "Analysis of variance" (ANOVA) technique with the help of statistics 10 that was an analysis software.

Results and Discussion

Visual appearance of the fruit

Both bagged and no-bagging fruits were attained maturity at almost similar the time, and were harvested after 168 days after flowering. The peel of control fruits had attacked by fruit fly and borer with rust lesions, visible whitish colonies of fungal infection and spots of reddish blush. Bagged fruits had an unblemished peel with a light green color free from insect like fruit fly and borer and no reddish blush.



(a) Control fruit (no bagging)

(b) Bagged fruit (Brown paper bag)

Fig. 1 (a-b): Visual appearance of bagged and non- bagged mango fruit after 10 days of storage.

Skin color: Color is one of the most important criteria of quality of most fruits. Statistically highly significant variation was observed in respect of color between the fruits of with and without bagging before and after storage. The effects of pre-harvest bagging treatments were statistically significant on the change of skin color in storage. At harvesting time and after 12th day of storage, the most attractive color found in brown paper bagged fruits and worst color without bagging mango fruit (Table 1). Tyas et al. (1998) and Chen et al. (2012) reported that the brown paper bagged fruit became most attractive color after harvest and storage time. Also the recorded bagging improves the color of fruit by increasing their anthocyanin content. It is believed that bagging increases the light sensitivity of fruit and stimulates anthocyanin synthesis when the fruit are re-exposed to light after removal of bag.

Table 1: Effect of different type of bagging material on skin colour of mango fruit.

Treatment	After harvesting	After ripening
T ₀ (Control-non bag)	Green	Yellowish green
T ₁ (Brown paper bag)	Trace of yellow	Greenish yellow
T ₂ (White paper bag)	Trace of yellow	Yellowish green
T ₃ (Black polythene bag)	Green	Trace of yellow
T ₄ (White polythene bag)	Green	Trace of yellow

Fruit weight (g): Fruit weight of Amrapali fruit was significantly affected by different types of bagging materials. The maximum fruit weight was found in brown paper bag (175.71 g) and the lowest fruit weight was in control fruit (147.19 g) due to attacked by fruit fly and borer (Fig. 2). Reports on effects of fruit bagging on fruit size and weight opined that it may be due to differences in the type of bag used, fruit and cultivar responses (Sharma et al. 2014). Bagging 'Nam Dok Mai mango fruit with two-layer paper bags, newspaper, and golden paper bags increased fruit weight (Watanawan et al. 2008).

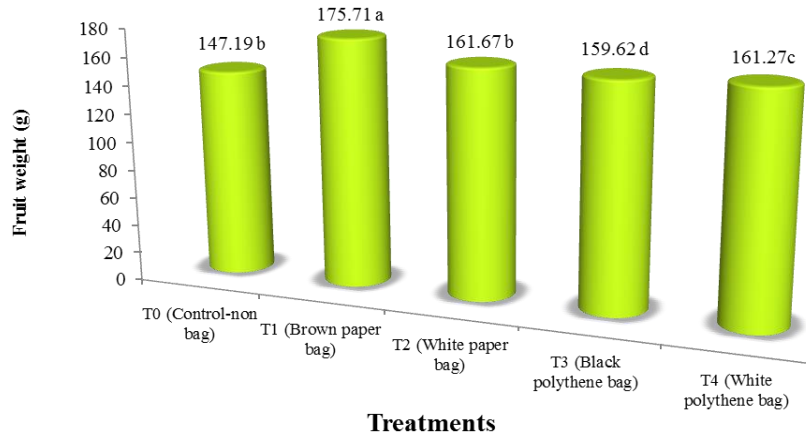


Fig. 2: Effect of different type of bagging material on fruit weight (g) of mango fruit.

Fruit length (cm): The length of fruit was showed significantly varied due to the application of different doses of poultry manure (Table 2). The fruit length varied from cm 8.24 to 8.77 cm. The highest statistically superior mango fruit was 8.77 cm measured in the treatment T₁ where applied Brown paper bag. On the other hand, the shortest mango fruit 8.24 cm was obtained in the treatment T₀ (control-non bag). Bagging promoted longan fruit development, resulting in larger-sized fruit (Yang et al. 2009).

Table 2: Effect of different type of bagging material on fruit length (cm) and fruit diameter (cm) of mango fruit.

Treatments	Fruit length (cm)	Fruit breadth (cm)
T ₀ (Control-non bag)	8.24e	5.87c
T ₁ (Brown paper bag)	8.77a	6.70a
T ₂ (White paper bag)	8.55c	6.33b
T ₃ (Black polythene bag)	8.43d	6.23b
T ₄ (White polythene bag)	8.66b	6.45ab
SE (%)	0.02	0.06
CV (%)	0.33	1.55

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test. Here, SE = standard error, and CV = co-efficient of variance.

Fruit breadth (cm): Due to the application of different types of bagging materials affect the breadth of fruit was observed significantly varied (Table 2). The fruit breadth varied from 5.78 cm to 6.70 cm. The highest statistically superior fruit breadth was 6.70 cm recorded in the treatment T₁ where used Brown paper bag as bagging materials. On the other hand, the lowest fruit breadth 5.78 cm was obtained in the treatment T₀ that

was control or no bagging. The results are in conformity with Mingire et al. (2017), Haldankar et al. (2015), Mohapatra (2016), Islam et al. (2017a) and Islam et al. (2017b) in mango.

Chemical characters of mango during storage

Moisture content (%): In general, the moisture content decreased with the increase of storage period under different treatments. It was observed that the statistically significant variations were found in moisture content after storage due to different treatments. The highest moisture content was recorded brown paper bag (82.40%) and the lowest moisture content black polythene bag (78.70%) (Table 3). White polythene bag was found to have higher moisture percent during storage period. The Moisture content higher (82.90%) in polythene bag than over control. The result of the present study is in support of the findings of Shahajahan et al. (1994).

Table 3: Effect of different type of bagging material on moisture content (%) and dry matter content (%) of mango pulp in ripening stage of mango.

Treatments	Moisture content (%)	Dry matter content (%)
T ₀ (Control-non bag)	82.17ab	18.80b
T ₁ (Brown paper bag)	82.40a	21.68a
T ₂ (White paper bag)	80.90c	18.67b
T ₃ (Black polythene bag)	78.70d	17.05c
T ₄ (White polythene bag)	81.47bc	16.58d
SE (%)	0.18	0.05
CV(%)	0.39	0.51

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test. Here, SE= standard error and CV= co-efficient of variance.

Dry matter content (%): Dry matter content of mango varied significantly due to the effect of different pre-harvest treatments (Table 4). The highest dry matter content was found in brown paper bagging fruit (21.68%) and the lowest dry matter content was in white polythene bag fruit (16.58%). The result of the present study is in support of the findings of Hofman (1997). He stated that due to pre-harvest bagging dry matter content in increased from 17.14 to 20.83% during storage.

Total soluble solids (TSS) content (%): Pre-harvest bagging treatments had significant effect on total soluble solids content of mango. The maximum TSS content (23.44 %) was found in control fruits while it was minimum TSS content (18.49 %) was found in black polythene bag at after ripening (Fig. 3).

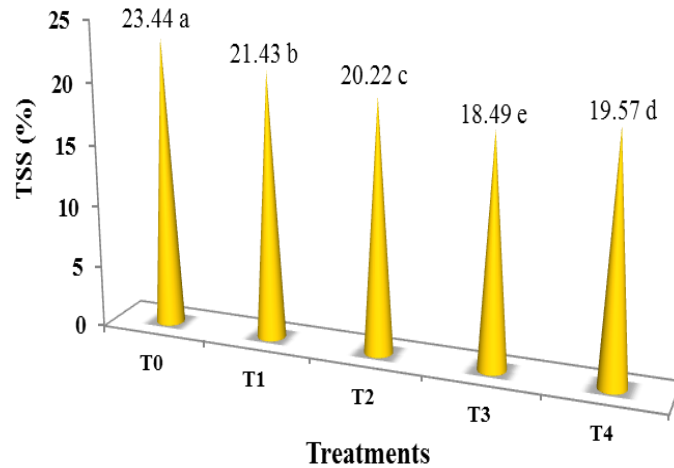


Fig. 3: Effect of different type of bagging material on Total soluble solids (%) content of mango pulp in ripening stage of mango. Here, T₀ (Control-non bag), T₁ (Brown paper bag), T₂ (White paper bag), T₃ (Black polythene bag), and T₄ (White polythene bag).

The findings revealed that percent total soluble solids increased sharply from harvest to ripe fruits have got support of who mentioned that TSS increase initially and declined later on. Similar finding was recorded in some previous studies (Haldankar et al. 2015, Awad 2007, Singh et al. 2007). The reason for higher total soluble solids in bagged fruits compared to control was due to heat built up in the micro environment which favors early maturity.

Reducing sugar content (%): The maximum reducing sugar content (9.92%) was recorded in white polythene bag at the 15th day of storage followed by control treatment while minimum reducing sugar content (8.99%) was found in black polythene bagged fruit at the same day of storage. Further, it was noticed that the reducing sugar content was increasing gradually in all the treatments during storage (Table 4). Similar findings were found in some previous research (Haldankar et al. 2015). They reported that fruits of newspaper bag exhibited the maximum reducing sugars at ripe stage in mango and soluble sugar was increased in grape due to pre-harvest bagging treatments.

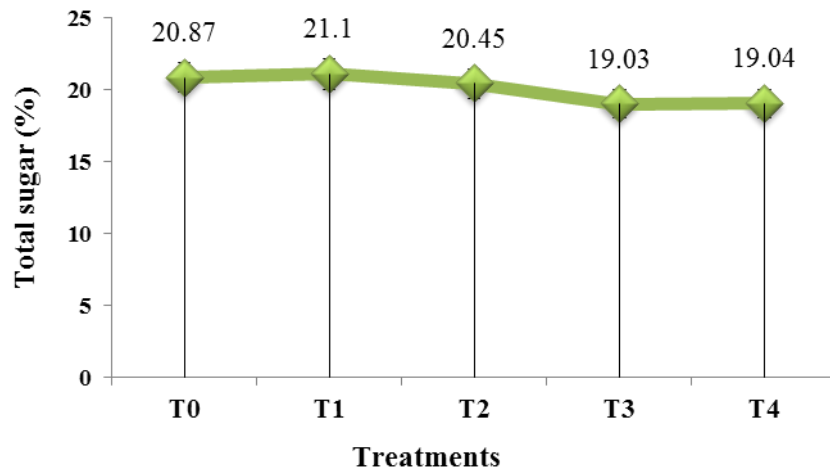
Non-reducing sugar content (%): The highest non-reducing sugar content (11.28%) was observed in control fruits while the lowest non-reducing sugar content (10.35%) was found in brown paper bag (Table 4).

Table 4: Effect of different type of bagging material on reducing sugar (%) and non-reducing sugar (%) of mango pulp of mango.

Treatments	Reducing sugar (%)	Non-reducing sugar (%)
T ₀ (Control-non bag)	9.90	11.28a
T ₁ (Brown paper bag)	9.17	10.35b
T ₂ (White paper bag)	9.69	10.63ab
T ₃ (Black polythene bag)	8.99	10.50b
T ₄ (White polythene bag)	9.92	10.60ab
SE (%)	0.45	0.15
CV(%)	8.12	2.42

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test. Here, SE= standard error and CV= co-efficient of variance.

Total sugar content (%): Results revealed that higher amount of total sugar content was present in control fruits than bagged fruits.

**Fig. 2:** Effect of different type of bagging material on Total sugar content (%) of mango pulp in ripening stage of mango. Here, T₀ (Control-non bag), T₁ (Brown paper bag), T₂ (White paper bag), T₃ (Black polythene bag) and T₄ (White polythene bag).

The treatments showed significant variation in respect of total sugar content during storage. The total sugar content (21.10%) was recorded in brown paper bagged followed by 20.87% in control fruit, 20.45% in white paper bagged fruit, 19.04% in white polythene bagged fruit and 19.03% in black polythene bagged treated

fruits. The highest (21.10%) and the lowest (19.03%) total sugar content were recorded at brown paper bagged and black paper bagged treated fruits of storage, respectively (Fig. 2). This result was confirmed with (Haldankar et al. 2015). They reported that brown paper bag with polythene coating (7.48%) recorded the maximum total sugars in mango which was significant. The fruits under polythene bag had significantly highest reducing sugars and beta carotene. The variation observed in chemical composition of mango fruits can be attributed to the changed microenvironment around fruit during its growth and development. The bagged fruits showed highest content of vitamin C, sucrose, glucose and fructose over control in Zill mango (Hongxia et al. 2009). The bagging of date palm fruits improved the total sugar content (Harhash and Al-Obeed 2010). Bagging enhanced carotenoid content in mango (Zhou et al. 2012).

Vitamin C content (mg/100 g): After ripening vitamin C content of mango pulp was significantly influenced of pre-harvest bagging treatment of mango. The higher vitamin C content (29.67 mg/100 g) was found in control fruit and lower vitamin C content (19.55 mg/100g) was in brown paper bag (Table 4). There was a decreasing trend in vitamin C content of fruit pulp in bagging fruit than control fruit (Table 4). The white paper bag, black polythene bag and white polythene bag showed 22.33, 24.61 and 23.36 mg/100 g respectively. The bagging led to lower content of chemical components such as vitamin-C, phenols and organic acids in most of peach varieties (Lima et al. 2013). The bagged fruits recorded highest content of vitamin C, sucrose, glucose and fructose over control in Zill mango (Hongxia et al. 2009). The above results are very close to the findings of (Haldankar et al. 2015) and (Sharma et al. 2014) in mango.

Table 4: Effect of different type of bagging material on Vitamin C content of mango pulp in ripening stage of mango.

Treatments	Vitamin C content (mg/100 g)
T ₀ (Control-non bag)	29.67a
T ₁ (Brown paper bag)	19.55e
T ₂ (White paper bag)	22.33d
T ₃ (Black polythene bag)	24.61b
T ₄ (White polythene bag)	23.36c
SE (%)	0.06
CV (%)	0.42

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test. Here, SE = standard error and CV= co-efficient of variance.

Shelf life (days): The effects of different pre-harvest fruit bagging treatments were statistically significant in respect of prolonging shelf life of mango cv. Amrapali. The shelf life of mango fruits ranged from 7.92 to 15.06 days. The shortest (7.92 days) and longest (15.06 days) shelf life was observed in control fruits and Brown paper bagged fruit respectively. The shelf lives were extended by 3.28, 4.79, 5.13, and 7.14 days in

black polythene bag, white polythene bag, white paper bag and brown paper bag treatments, respectively over control (Fig. 3). In contrast, untreated fruits were affected by diseases earlier giving the shortest shelf life was recorded. The greater storability of the bagged fruits that were bagging might be due to the reduced level of disease both in terms of incidence and severity. And this reduced disease may be due to the effects of antimicrobial components in sap that were not allowed to remove from the fruits. The antimicrobial properties of sap had been extensively investigated by Hassan (2010). Singh et al. (2007) reported that pre-harvest bagging delayed ripening resulting in extended shelf life of Perla, a black table-grape. All bagging treatments showed highly significant effect compared to control. The bagging modified the microenvironment near fruit especially in respect to temperature and humidity. The humidity as well as temperature in paper bag was greater than that in polythene bag. The longer shelf life of bagged fruits indicated that the effect of bagging persisted during ripening. Bagging provided physical barrier between fruit and pests. The spongy tissue disorder is associated with convective heat and exposure of fruit to sunlight (Prakash 2004). Bagging provided protection against both which helped in reducing the occurrence of spongy tissue in fruits. In mango cv. Keitt white paper bags at approximately 100 days before harvest reduced anthracnose and stem end rot (Hofman et al. 1999). Jakhar and Pathak (2016) also showed that the bagging fruits are harvested without any disease and fruit fly infestation. The shelf life of such fruits also increases by two to three days.

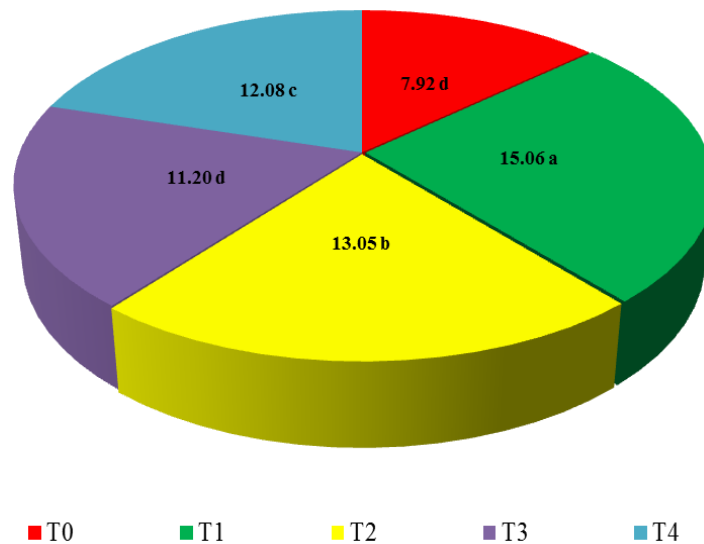


Fig. 3: Effect of different type of bagging material on self-life (days) after harvesting of Mango fruit. Here, T₀ (Control-non bag), T₁ (Brown paper bag), T₂ (White paper bag), T₃ (Black polythene bag) and T₄ (White polythene bag).

Conclusion

Considering the findings, it may be concluded that significant variation existed among the different pre-harvest fruit bagging treatments in respect of physical properties like weight, length and breadth of fruit, skin color and chemical properties like total soluble solids content, Vitamin-C content, sugar content (reducing, non-reducing and total) and shelf life. The shelf life of mango could be extended up to 15-16 days by using brown paper bag as a pre-harvest fruit bag. Treatment Brown paper bag might be slow down the changes of chemical components within mangoes which are 100% free from fruit fly and borer attack. It was found that the maximum physico-chemical changes occurred in control due to severe attacked by fruit fly and borer. Also, we clearly found that by bagging system it is possible to control mango fruit against fruit fly and borer attack to ensure the best quality mango production that was exportable and chemical free. Under this research some recommendations are- i) more research need to confirm bagging effect on Amropali mango and ii) we used only types of bagging materials but need to use more perforated and non-perforated bags as a bagging materials for sustainable research.

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