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Research Article

Effect of pre-harvest fruit bagging on yield, postharvest quality and shelf life of tomato (*Solanum lycopersicum* L.) cv. BARI Tomato-2

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Abstract
Fruit bagging protects fruits from pest infestation and multiple biotic and abiotic stresses during development without reducing yield. It also can potentially improve the quality and market value of fruits. Hence, the present study aimed to determine the effect of pre-harvest fruit bagging on the yield and quality of tomato (*Solanum lycopersicum*) cv. BARI Tomato-2. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications that constituted the various treatments- T_0: Control (no bagging), T_1: White paper bag (single layer), T_2: Brown paper bag (double layer), T_3: Non-woven fabric bag, and T_4: Jute bag from October 2021 to March 2022. The results showed that the non-woven fabric bag had the highest fruit length (57.79 mm), diameter (57.81 mm), number of fruits plant^{-1} (55.9), yield (4.06 kg plant^{-1}), vitamin C (24.63mg/ 100g^{-1}), and lycopene content (0.12 mg g^{-1}). The maximum insect incidence (18.41%) was recorded in control and the minimum was counted in T_3 (2.17%). The highest total soluble solid (6.73%^{0}Brix) and dry matter (8.63%) were observed in a white paper bag. The highest mean color score (6.08), firmness (26.81%), and shelf life (13 days) found in fabric bags outperformed non-bagged fruits. The fabric bag showed maximum net income (21.12 TK) and the highest benefit: cost ratio (2.36). Thus, the fabric bag was the best for improving the physical and chemical qualities of tomatoes (*Solanum lycopersicum*) among the various fruit-covering materials.

Keywords: Fruit covering, Harvesting, Quality, Shelf life, Tomato

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a member of the Solanaceae family, is one of Bangladesh's most significant and nutritionally rich vegetable crops (Hussain *et al.,* 2021). Fruit goes through various physical, chemical, and damage changes as they grow and develop. This crop is susceptible to a variety of arthropod pests, and pest infestations compromise the quality of the crop by reducing productivity and decreasing the value of the crops (Leite *et al.*, 2014; Pratissoli *et al.*, 2015). Insect infestations that significantly lower yield are the main issues farmers face when growing tomatoes. From the seedling stage through to the harvest stage, insects attack tomatoes. One of the main pests of tomatoes is the tomato fruit borer *Helicoverpa armigera* (Hub), whose damage to fruits can range up to 90% and reduce yield by 30-40% (Rijal and Dahal, 2019). The application of insecticides is the main technique used in Bangladesh to manage insect pests in tomato crops. However, the excessive, indiscriminate use of pesticides can have negative effects on human health and the environment and in some cases, the accumulation of toxic residues in fruits (Pathak *et al.,* 2022). This pattern suggests that it is time to consider brand-new pest management tactics.

Several Good Agricultural Practices (GAP) are gaining popularity globally to reduce losses caused by biotic and abiotic factors (Hoque *et al.*, 2022). Pre-harvest fruit bagging is one of these procedures; improving skin color and reducing flaws is a physical protection approach that modifies the fruit development microenvironment and fruit's visual quality. Pre-bagged fruit can help to lower the risk of diseases, pests, and/or mechanical harm. These methods have been shown to be successful in preventing fruit borer assaults (Mondal *et al.,* 2015). To improve skin color, and minimize disease, insect pests, mechanical injury, sunburn of the skin, and bird damage, bagging has been widely utilized in numerous fruit crops (Sharma *et al.,* 2014; Islam *et al.,* 2020; Ali *et al.,* 2021). Currently, fruit bagging is an environmentally favorable method for several types of fruits worldwide, including in Bangladesh. There is, however, very little information available on the impact of various bagging materials on the production of vegetables in Bangladesh, such as tomatoes. Therefore, the study aimed to investigate the effect of pre-harvest fruit bagging on yield with quality, insects-diseases infestation and to assess the benefit-cost ratio in the cultivation of tomatoes (*Solanum lycopersicum*) after using various fruit bags.

MATERIALS AND METHODS

Experimental material and design

The experiment was conducted from October 2021 to March 2022 on the Horticulture farm at Hajee Mohammad Danesh Science and Technology University in Dinajpur, Bangladesh. The experiment was designed by the Randomized Complete Block Design (RCBD) with three replications to assess the performance of different bagging materials. These baggings were T_0: Control (Non-bagging), T_1: White paper bag (Single layer), T_2: Brown paper bag (Double layer), T_3: Non-woven fabric bag, T_4: Jute bag (Decomposable). The BARI Tomato-2 variety was used as a planting material.

Application of fruit bagging

Two clusters of fruits on the chosen plant, each containing three to four fruits, were covered with studied fruit bags in the middle of December 2021, after the fruit set, when fruits had reached the marble stage. When fruits reached physiological maturity and developed a light pink color, all mature fruits of both bagged and un-bagged were progressively and properly collected.

Data collection

Data were collected on days to first harvest from bagging, length of fruit (mm), the diameter of fruit (mm), the weight of fruit (g), number of fruits per plant, yield per plant (kg), the incidence of insects (%), total sugar (%), reducing sugar (%), total soluble solids (% brix), fruit pH, vitamin-C content, lycopene content, dry matter (%), color, firmness (%), the shelf life of fruits (days) with cost-benefit ratio. The biochemical parameters of tomato pulp were estimated by the following methods:

Total soluble solid (˚Brix)

Using an ERMA hand refractometer, the total amount of soluble solids in the fruit juice (pericarp) was determined (0-32˚Brix).

pH

A digital pH meter (Delta 320 pH meter, Metller Toledo Instruments Co., Ltd., Shanghai, China) was used to measure pH.

Vitamin C (ascorbic acid)

Ascorbic acid (mg/100g) was measured by the method of Ranganna (1977).

Reducing sugar

Reducing sugar (%) was determined according to the method described by Haq and Rab (2012).

Total sugar

Total sugar (%) was estimated by the procedure described by Santini *et al.* (2014).

Lycopene content

The lycopene content (mg/g) in fresh tomato was determined according to a method described by AOAC (2000).

Dry matter

According to Sinha *et al.* (2019), the dry matter (%) of the tomato pulp is estimated from the data obtained during moisture estimation using the following formula: Dry matter (%) =100 - Moisture content (%).

Shelf life of fruits

Using perforated plastic crates, 20 collected mature fruits from each treatment were allowed to ripen at room temperature. Following ripening, a variety of observations, including shelf life (days), were noted. When the fruits began to rot, the fruits' shelf life was at an end.

Sensory evaluation

A panel of five judges used a nine-point hedonic scale to score the fruits' sensory attributes, determining their color by a panel of five judges with a 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 (AOAC, 2005). The firmness of fruits was determined by Force Gauge (HANDPI HP-200, China) and expressed in percentage (%)

Statistical analysis

All the collected data were statistically analyzed to determine the significance level using the Statistics 10 program. The mean differences were compared by LSD test at p<5% significance level and showed similar letters.

RESULTS AND DISCUSSION

Physical characteristics

Significant variation was recorded in the harvest (days) of fruits from bagging, size and weight of individual fruit, fruits plant^{-1}, yield, and incidence of insects due to the application of fruit bagging in tomato (Table 1). The maximum value for fruit length (57.79 mm), diameter (57.81 mm), number of fruits plant^{-1} (55.90), fruit weight plant^{-1} (63.29 g), and fruit yield plant^{-1} (4.06 kg) were recorded from the non-woven fabric bag treatment, while the control treatment gave the lowest performance for the characters mentioned above. Generally, bagging is used for microclimate (temperature, humidity, evaporation) regulation in fruit production. Previous studies showed that bagging improved fruit size and weight by increasing the temperature and humidity inside the bag (Yang *et al.*, 2009; Sharma *et al.*, 2014; Kireeti *et al.*, 2016). Pre-harvest fruit bagging dramatically improved the fruit's physical characteristics compared to control in mango (Islam *et al.*, 2020) and Guava (Sharma *et al.*, 2020). The non-woven fabric bag increased the temperature by the highest light absorption, which protected the fruit from extremely dry conditions and ultimately resulted in larger fruit sizes in longan (Yang *et al.*, 2009) and Carambola (Xu *et al.*, 2006). Fruit bagging increased numbers of fruits might be due to less infestation by insects and diseases under bagging conditions than non-bagged. The present results suggested that pre-harvest fruit bagging increased the fruit size and number of fruits, ultimately increasing productivity. The size and yield of tomatoes in this study were larger than those reported by Patel *et al.* (2020) in India.

Fruit bagging has been successfully used to control insects in mango (Islam *et al.*, 2020) and in Guava (Rahman *et al.*, 2018) in Bangladesh, but to the present knowledge, there have been no studies on the role of bagging in insect management of tomatoes. The results showed statistically significant differences in controlling insect incidence in bagged and non-bagged fruits but no significant difference was recorded among different bagged fruits. Therefore, the lowest insect infestation (2.17%) was found in non-woven fabric bags whereas the highest insect infestation (18.41%) occurred in control (Table 1). Non-bagged fruits were affected mostly due to insects coming directly in contact with fruits, whereas bagged fruits were under an artificial barrier that kept insects away (Sharma *et al.*, 2014).

Moreover, it was observed that the shortest period (34.33 days) from bagging to the harvest of the fruit was recorded from non-woven fabric bagged fruit compared to the control (38.0 days). The harvesting time (days) from bagging reported in this study was slightly higher than that reported by Patel *et al.* (2020) in India. It might be caused by an increase in the rate of transpiration and ethylene synthesis brought on by the conversion of chloroplasts into chromoplasts (Patel *et al.*, 2020).

Quality parameters

The pre-harvest fruit bagging had significant differences concerning quality parameters (Table 2). The

Table 1. Effects of pre-harvest fruit bagging on physical parameters of tomato

Treatment	1st harvest from bagging (days)	Fruit length (mm)	Fruit diameter (mm)	Fruit wt. (g)	No. of fruits per plant	Yield per plant (kg)	Incidence of insects (%)
T_0 (Control)	38.00 b	47.98 b	39.31c	45.30 c	34.33 b	2.87 d	18.41 a
T_1 (white paper bag)	37.33 bc	47.66 bc	46.60 bc	61.29 b	42.90 ab	3.55 bc	2.41 b
T_2 (Brown paper bag)	43.00 a	53.75 ab	48.91b	71.73 a	35.06 b	3.73 b	2.30 b
T_3 (Non-woven fabric bag)	34.33 d	57.79 a	57.81 a	63.29 ab	55.90 a	4.06 a	2.17 b
T_4 (Jute bag)	35. 00 cd	53.75 ab	47.32 b	55.52 b	45.70 ab	3.36 c	2.43b
CV (%)	2.60	5.28	5.64	5.98	5.41	6.32	6.25
LSD (0.05)	3.94	9.24	10.35	23.85	21.56	0.40	8.44

Mean with different letters in a column at 5% level of significance highest total sugar content was recorded from T_2 (6.67%), where the lowest was from T_0 (4.55%), which was statistically similar to T_4 (4.60%). During the ripening stage, the conversion of sugar percentage was increased by the influence of different bagging materials as these lead to the lower content of chemical components such as phenols and organic acids. Islam *et al.* (2017) reported that brown bag also influences the total fruit sugars in mango. T_1 had the utmost reducing sugar level (5.26%), total soluble solids (6.73%), and dry matter (8.63%) content, whereas T_0 had the lowest value for these characters (3.30%), (5.13%) and (5.58%) respectively. The degradation of pectin and cellulose during ripening was the reason for the accumulation of reducing sugar and the total soluble solids in fruit (Islam *et al.*, 2017). Bagging may have also decreased light intensity inside the bagging material, which influences dry matter increment. Chonhenchob *et al.* (2011) reported that bagging on fruit increased soluble solid, dry matter in mango. Improvement in the total soluble solids in bagged fruit has also been reported in guava (Sharma *et al.*, 2020) and banana (Rubel *et al.*, 2019). Pastori *et al.* (2017) reported that in the variety of valerin tomatoes in Brazil quality characters like total soluble solid and total carotenoid and lycopene content were not influenced by fruit bagging. Thus, variability among the bags, fruit, and the variety-specific response has played a significant role in the variability in the quality of tomato fruits (Sharma *et al.* 2014).

The fruit's pH (4.18), vitamin C content (24.63 mg/100g), and lycopene content (0.12 mg/g) was at the top in T_3 and the bottom in T_1 (4.01), T_4 (15.08 mg/100g) and in T_2 (0.04 mg/g) respectively. Vitamin C is temperature sensitive phytonutrient. The increased amount of vitamin C in the bagged fruit may be related to the selective permeability of bags to sunlight and microclimate (temperature, humidity, and moisture) around the fruit. Zhou *et al.* (2019) reported that spun-bonded light yellow fabric bagged significantly improved vitamin C content in apples and pears compared to the control. Moreover, higher lycopene content in the covered fruits may be due to the higher conversion of carotenoids like lycopene by lower light penetration in the covered fruits. According to Sharma *et al.* (2013), pre-harvest fruit bagging of apples increased anthocyanin synthesis and lycopene content, which ultimately improved fruit color and firmness.

Sensory evaluation

The sensory evaluation showed a statistically significant variation among the treatments, which affected the col-

Table 2. Effects of pre-harvest fruit bagging on chemical parameters of tomato

Treatment	Total Sugar (%)	Reducing Sugar (%)	TSS (% Brix)	Fruit pH	Vitamin-C (mg/100g)	Lycopene (mg/g)	Dry matter (%)
T_0 (Control)	4.55 c	3.30 e	5.13 d	4.03 c	23.38 ab	0.06 c	5.58 e
T_1 (white paper bag)	5.08 b	5.26 a	6.73 a	4.01 c	22.41 b	0.10 b	8.63 a
T_2 (Brown paper bag)	6.67 a	4.30 b	5.36 c	4.07 b	17.52 c	0.04 d	5.87 c
T_3 (Non-woven fabric bag)	4.97 b	4.11 c	5.93 b	4.18 a	24.63 a	0.12 a	6.48 b
T_4 (Jute bag)	4.60 c	3.82 d	5.30 c	4.02 c	15.08 d	0.09 bc	5.70 d
CV (%)	2.02	1.42	1.38	0.27	4.83	5.29	0.95
LSD (0.05)	0.19	0.11	0.14	0.02	1.87	9.09	0.11

Mean with different letters in a column at 5% level of significance

Table 3. Cost and profitability per plant of each treatment

Treatment	Cost per plant		Total cost per plant (tk)	Yield per plant (tk)	Price rate (tk kg^{-1})	Gross income $plant^{-1}$ (tk)	Net income $plant^{-1}$ (tk)	Benefit cost ratio (B:C)
	General cost (tk)	Price of bags (tk)						
T_0 (Control)	11.22	0.0	11.22	2.87	6.50	18.65	7.43	1.66
T_1 (White paper bag)	11.22	5.00	16.22	3.55	8.50	30.17	13.95	1.86
T_2 (Brown paper bag)	11.22	7.00	18.22	3.73	6.50	24.24	6.02	1.33
T_3 (Non-woven fabric bag)	11.22	4.20	15.42	4.06	9.00	36.54	21.12	2.36
T_4 (Jute bag)	11.22	3.50	14.72	3.46	8.50	29.41	14.69	2.00

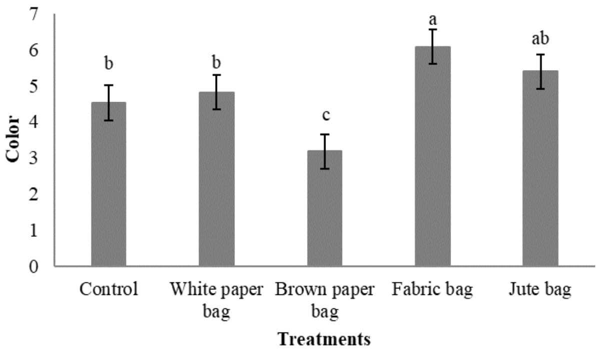

Fig. 1. *Effect of pre-harvest fruit bagging on color of tomato*

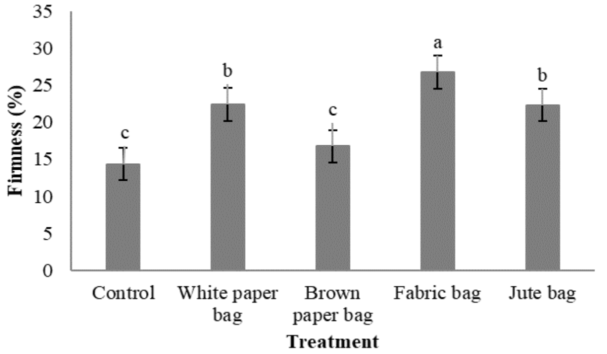

Fig. 2. *Effect of pre-harvest fruit bagging on firmness (%) of tomato.*

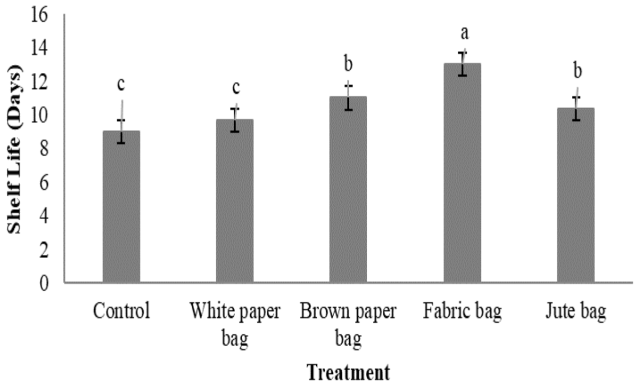

Fig. 3. *Effect of pre-harvest fruit bagging on shelf life (days) of tomato*

or and firmness of the tomato (Figs. 1 and 2). The score for fruit color was highest in non-woven fabric bag (6.08) and the lowest in a brown paper bag (3.18). The fabric bag (22.45) had the highest firmness score, whereas the control treatment had the lowest score (14.38). Various bagging techniques affected the appearance of apples based on their color, firmness, and other characteristics (Sharma *et al*., 2013). Different types of bagging influenced the visuals of apple fruits based on color, appearance, firmness, etc. (Wang *et al.,* 2013). Bagging treatments significantly affected the concentration of anthocyanin and the visual qualities of pear fruit (Huang *et al,* 2009).

Shelf life of fruits

The shelf life (days) of tomatoes was observed to differ statistically significantly depending on the fruit bags used (Fig. 3). The difference of 4 days was found between fabric bags and non-bagged in the present study. Previous studies focused on the quality of bagged fruit (Pastori *et al.,* 2017; Patel *et al.,* 2020), but little has been reported regarding the effect of bagging on the storability or shelf life of the tomato fruit. The fruit's microenvironment was altered by the bagging, particularly in terms of air, temperature and humidity (Yang *et al*., 2009). According to the theory, fruits that were not bagged, had higher rates of transpiration and respiration and had the shortest shelf life when stored.

Cost of production

The estimated cost of production of tomatoes is shown in Table 3. The maximum benefit-cost ratio (2.36) was recorded in the fabric bag, whereas the lowest B: C (1.33) was recorded in the brown paper bag. Due to bagging costs and variable yield per plant, net income and the B: C ratio was different. The yield of tomato fruit was higher in non-woven fabric bags as well as the cost of the bag was also lower, which resulted in the maximization of the benefit-cost ratio than other studied bags.

Conclusion

The present study concluded that non-woven fabric bags in tomato cv. BARI Tomato-2 showed the best performance for increasing fruit size and yield compared to the control. The bagging of tomato fruits with non-woven fabric bags was more effective in reducing damage by insects than the other bagging treatments and the control. Fruit bagging improved the fruit qualities like TSS, total sugar, pH, vitamin C content, and lycopene content over control. Non-woven fabric bags also improved the shelf life of tomato fruits. In this study, non-woven fabric bags gave the best result among the tested bag types for increasing fruit yield, improving quality, and significantly reducing insect incidence. Growers can apply this method for high-quality commercial tomato production to meet domestic and international demand.

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Conflict of interest

The authors declare that they have no conflict of interest.

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