Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 46 Issue 2 March 2025 pp. 299-307
DOI: http://doi.org/10.22438/jeb/46/2/MRN-5356

J. Environ. Biol., 2025
Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Effect of pre-harvest fruit bagging on post-harvest quality of rainy season guava cv. Allahabad Safeda

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Received: 02 May 2024 **Revised:** 10 July 2024 **Accepted:** 03 October 2024

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Abstract

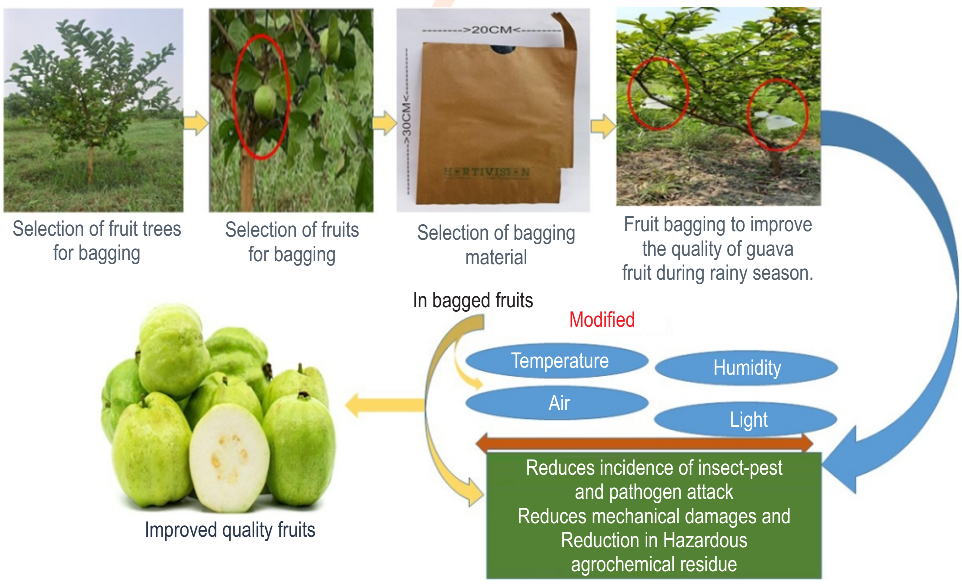
Aim: Guava crop is severely infested during rainy season by fruit fly that results in low quality fruits and lower yield. In view of this, a study was conducted to reduce the fruit fly infestation through bagging technique by using biodegradable bags.

Methodology: The present investigation was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Four-years-old plants of guava cv. Allahabad Safeda were selected for the experiment, and the fruits were bagged with different colour non-woven and perforated polyethylene bags.

Results: Pink colour non-woven bag reduced the time taken for maturity and improved the quality of fruits. Fruit fly infestation was eradicated by fruit bagging and also reduces bird damage. Total soluble solids, pectin content, ascorbic acid, titratable acidity and sugars were found maximum in pink non-woven bagged fruits. Principle Component Analysis (PCA) was also carried out for twelve quality parameters, out of which, component 1 and component 2 showed Eigen value 8.77 and 1.69, respectively. PC1 and PC2 collectively explained 87.237% of total variation. Correlation analysis indicated positive and negative correlation among various quality attributes.

Interpretation: This study provides a comprehensive information to reduce fruit fly infestation during rainy season through fruit bagging technique.

Key words: Bagging technique, Fruit fly, Guava fruits



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How to cite: Rawat, M., R. Kumar, V.P. Singh, S. Chand, S. Uniyal, N. Singh, O. Singh and M. Kumar: Effect of pre-harvest fruit bagging on post-harvest quality of rainy season guava cv. Allahabad Safeda. *J. Environ. Biol.*, **46,** 299-307 (2025).

Introduction

Guava (*Psidium guajava* L.), commonly known as the "Apple of the Tropics," is an important tropical or subtropical fruit crop a that belongs to Myrtaceae family (Patel *et al.,* 2015). It is primarily utilized as a fruit, however, due to considerable processing potential because of high pectin content (0.5–1.8%), it is used to make jam, jelly, nectar, cider and other processed products. Guava trees produce flower twice a year in North India: first during February and March a when the is crop cultivated during rainy season and second during in June and July for a crop cultivated during winter season. In comparison to winter crops, the fruit yield from rainy season crops is frequently higher, but the fruit quality and flavour are poor and there are higher chances of pest infestation, especially fruit flies and diseases (Maji, 2015). On the other hand, the quality and price of winter guava fruits are comparatively higher than the rainy season crop (Brar *et al.,* 2019). There is a great demand for high-quality guava fruits in order to fetch a reasonable return price. However, due to climate change, like as unusual rain, rapid temperature changes, fog, etc., have a detrimental impact on guava and severely influence the quality of fruits. Pre-harvest fruit bagging is a typical phyto-sanitary practice used to improve the quality of fruits and decrease the occurrence of pests and diseases.

This technique involves bagging of each fruit on the tree for a specific time in order to achieve the desired outcomes. Pre-harvest bagging affects the fruit size, maturity, peel colour, mineral content and fruit quality, which may be due to the usage of various types of bags. Pre-harvest bagging has been used extensively in a number of fruit crops to enhance skin colour and decrease the problem of splitting, mechanical damage and sunburn of fruit skin (Ram *et al.,* 2013). Fruit bagging is a technique where fruits still attached to trees are covered with protective bags or covers. This method enhances skin coloration and reduces blemishes in fruits. Additionally, the enclosed micro-environment created by bagging can lead to various positive effects on the internal quality of the fruits during various developmental phases (Son and Lee, 2008). These effects may include, improved sugar accumulation, enhanced flavour development and better texture of the fruit. Bagging also induces early ripening of fruits. Fruits are bagged prior to harvest to protect them from bruises, cuts, scars, infections, skin sunburn, pest attacks, pesticide residues on the fruit and to produce cleaner fruit skin with appealing colour (Bayogan *et al.,* 2006). Several researchers have worked on fruit bagging in fruit crops like mango (Hossain *et al.,* 2020), Pomegranate (Asrey *et al.,* 2020) and litchi (Purbey and Kumar, 2015) to improve the quality of rainy season guava. In view of the above, in order to a study was conducted to investigate the effect of different bagging materials in guava cv. Allahabad Safeda in Tarai region of Uttarakhand.

Materials and Methods

The present investigation was conducted at Horticulture Research Centre, Patharchatta, GovindBallabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experiment was carried out for two consecutive years 2021-22 and 2022-2023 during rainy season. Similar bagging material was used for bagging in both the seasons. Pooled data of both the seasons is presented in Tables and Figures. Biodegradable cellulosic bag and polyethylene bags, measuring 20 x 20 cm and 35 µm thick were used for bagging of individual fruit. Four-year-old uniform plants of guava cv. Allahabad Safeda were selected for bagging and marble size fruits (2-3 cm dia.) were bagged with non-woven bags and perforated polyethylene bags of different colours in the month of May (fortnight) as per treatment viz. T_1: White non-woven bag, T_2: Green non-woven bag, T_3: Pink non-woven bag, T_4: White perforated polyethylene bag, T_5: Green perforated polyethylene bag, T_6: Pink perforated polyethylene bag and T_7: Control. Fruit bagging continued till fruit harvest. The study was carried out using Randomized Block Design (RBD) with three replications. The fruits were bagged when they attained size of 2-3 cm diameter.

Physical quality assessment: Fruits were harvested at colour turning ripe stage. The fruits from different bags were harvested on different days when they were ready for harvest. The fruit maturity was calculated for each treatment by calculating the time period in days required for harvesting after bagging. The firmness was measured using a penetrometer and expressed in kg cm^{-2} by puncturing each fruit twice, once on the opposing cheeks, halfway between the stem-end and calyx-end. The fruits damaged by fruit flies, birds as well as physically damaged fruits were counted in each treatment.

Chemical quality assessment: The pectin content in guava fruit was determined by the method of Rangana (1986) as calcium pectate and expressed in percentage. Total soluble solids (TSS) were estimated using a hand refractometer (ERMA ehb-32). Titratable acidity of guava pulp extract was estimated by the method delineated by (AOAC, 1980). Filtered samples were titrated with alkali solution 0.1N NaOH using phenolphthalein as an indicator and expressed in percentage. Similarly, the ascorbic acid content in guava fruit was estimated by visual titration of 2, 6-dichlorophenol-indophenol proposed by (Rangana, 1986). Reducing sugars and total sugars were determined following of AOAC (1980). Non-reducing sugars were calculated by the formula (Total sugars – reducing sugars) x 0.95) (AOAC, 1980).

Statistical analyses: The experimental data was statistically analyzed in Randomized Block Design at 5% level of significance by Fisher method of ANOVA proposed by Cochran and Cox (1992). If the F-test was significant, CD values were calculated at the probability level of 0.05 ($p \leq 0.05$) and used to compare treatment means. Pearsons correlation and Principle component analysis was done using FactoMiner in R software (R-4.2.1). Significant differences among treatment means were calculated by Duncan's Multiple Range Test (DMRT) at significance level of $p \leq 0.05$ through SPSS 16 software. Figure of quality parameters was designed using Origin Pro-2021 software.

Results and Discussion

Fruit fly infestation, bird damages, fruit firmness, days taken to maturity and total damaged fruits were significantly influenced by different bagging materials in both the rainy season.Among the various treatments, the fruits bagged with non-woven bags did not report fruit fly infestation (0%) while, under control 49.15 ± 1.08% fruits were infested with fruit fly. Fruits bagged with white perforated polyethylene bags, green perforated polyethylene bags and pink perforated polyethylene bags reported 7.33 ± 0.11, 17.55 ± 0.31 and 20.40 ± 0.24 % fruit fly infestation, respectively. The lowest bird damage was observed in pink non-woven bagged fruits (6.10± 0.08) % which was at par with white perforated polyethylene bagged fruits (6.17± 0.04) % and green non-woven bagged fruits (6.84± 0.07) %, while maximum bird damage was observed in unbagged fruits (38.34± 0.57) %. Total damaged fruits were reported maximum under control (87.49 ± 1.13) % and minimum in pink non-woven bagged fruits (6.10 ± 0.08) %.Pink non-woven bagged fruits had taken minimum days (64.78 ± 1.10) for fruit maturity whereas, unbagged fruits taken maximum days (81.18 ± 0.88) for fruit maturity. Fruits bagged with white perforated polyethylene bags and pink perforated polyethylene bags took 73.35 ± 1.21 days and 73.68 ± 2.03 days for fruit maturity, respectively, which was statistically non-significant.

Fruit firmness was observed maximum in pink non-woven bagged fruits (7.83 ± 0.17 kg cm^{-2}), followed by green perforated polyethylene bagged fruits (7.45± 0.01 kg cm^{-2}), while, minimum (4.82± 0.15 kg cm^{-2}) was reported in control (Table 1). The present study revealed that the incidence of fruit fly was lower in bagged fruits because the direct damage by puncturing the fruit skin or to lay eggs inside the fruit was prevented. Bagging of fruits is an effective way for controlling the fruit flies in "star fruit" (Sierra *et al.,* 2001). Physical barriers created by enclosing the fruits in bags during fruit development reduces both physical and fruit fly damage (Muchui *et al.,* 2010). Previous studies on guava (Abbasi *et al.,* 2014; Mitra *et al.,* 2008; Mondal *et al.,* 2015; Morera-Montoya *et al.,* 2010; Sharma and Nagaraja, 2016) and mangoes (Buganic *et al.,* 1997; Hofman *et al.,* 1997; Sarker *et al.,* 2009), have reported that fruit bagging is an effective technique for controlling fruit fly infestation. Pre-harvest fruit bagging also reduces the bird damage by creating physical barrier against pests (Kumar *et al.,* 2021). Advancement in fruit maturity was observed in bagged fruits as compared to un-bagged fruits. Advancement in fruit maturity of bagged fruits might be due to alteration of micro-environment inside the bagged fruit because there was proper accumulation of temperature and humidity inside the bags as compared to the external surrounding environment. The results discussed above are in accordance with the findings of Hossain *et al.* (2020) in mango and Sharma *et al.* (2016) in 'Royal Delicious' apple. Improvement in fruit firmness of bagged fruits might be due to establishment of controlled atmosphere and providing better environment to the bagged fruit. Improvement in fruit firmness might be due to less transpiration, vapour pressure, water exchange and low calcium accumulation (Asrey *et al.,* 2020) in pomegranate.

The results showed that bagging of fruits with different types of bags significantly affected the total soluble solids, titratable acidity and total sugars content at ($p \leq 0.05$). total soluble solids increased in all bagged fruits, except control. The highest total soluble solids content was seen in pink non-woven bagged fruits (13.27± 0.11) ^{0}B, while, the lowest changes (10.15± 0.88) 0B was observed in unbagged fruits. Titratable acidity showed an increasing trend with bagged fruits as compared to control. The highest value for acidity (0.53 ± 0.04) % was found in pink non-woven bagged fruits and lowest (0.38± 0.03) 0B was seen in unbagged fruits. Data revealed that, the fruits bagged with pink non-woven bags showed the highest total sugars (9.91 ± 0.07%), whereas the lowest total sugar content (7.20 ± 0.12) % was recorded under pink perforated polyethylene bagged fruits. White perforated polyethylene bagged fruits and green perforated polyethylene bagged fruits had total sugars content of 8.42 ± 0.01 % and 8.55 ± 0.15 %, respectively, which were statistically non-significant (Table 2).

Increase in total soluble solids (TSS) content of bagged fruits might be due to differential sunlight intensity which affects the metabolic process of fruits inside the bags and other abiotic factors under bagging circumstances. Bagging has been found to increase TSS levels in fruits like date palm (Harhash and Al-

Table 1: Effect of bagging on fruit fly infestation, bird damages, firmness, days taken to maturity and total damaged fruits

Treatments	Fruit fly infestation (%)	Bird damages (%)	Firmness (kg cm^{-2})	Days taken to maturity	Total damaged fruits
White non-woven bag	0.00 (±0.00)^{e}	8.16 (± 0.11)^{d}	5.35 (± 0.17)^{d}	70.49 (± 1.01)^{c}	8.16 (± 0.11)^{e}
Green non-woven bag	0.00 (± 0.00)^{e}	6.84 (± 0.07)^{e}	6.55 (± 0.09)^{c}	68.42 (± 0.81)^{c}	6.84 (± 0.07)^{f}
Pink non-woven bag	0.00 (± 0.00)^{e}	6.10 (± 0.08)^{f}	7.83 (± 0.17)^{a}	64.78 (± 1.10)^{d}	6.10 (± 0.08)^{f}
White perforated polyethylene bag	7.33 (± 0.16)^{d}	6.17 (± 0.04)^{f}	5.35 (± 0.02)^{d}	73.35 (± 1.21)^{b}	13.50 (± 0.11)^{d}
Green perforated polyethylene bag	17.55 (± 0.31)^{c}	11.35 (± 0.21)^{c}	7.45 (± 0.01)^{b}	70.23 (± 1.13)^{c}	28.89 (± 0.52)^{c}
Pink perforated polyethylene bag	20.40 (± 0.24)^{b}	17.46 (± 0.19)^{b}	6.41 (± 0.08)^{c}	73.68 (± 2.03)^{b}	37.86 (± 0.39)^{b}
Control (unbagged)	49.15 (± 1.08)^{a}	38.34 (± 0.57)^{a}	4.82 (± 0.15)^{e}	81.18 (± 0.88)^{a}	87.49 (± 1.13)^{a}

Value represents mean ± SD. Different letters within same column indicate significant differences at $p \leq 0.05$ among the treatments as per DMRT Post-Hoc test

Table 2: Effect of bagging on TSS, titratable acidity and total sugars

Treatments	TSS (0B)	Titratable acidity (%)	Total sugars (%)
White non-woven bag	12.23 (± 0.09)^{c}	0.46 (± 0.08)^{d}	7.24 (± 0.01)^{e}
Green non-woven bag	12.53 (± 0.45)^{bc}	0.50 (± 0.06)^{b}	8.95 (± 0.12)^{b}
Pink non-woven bag	13.27 (± 0.11)^{a}	0.53 (± 0.04)^{a}	9.91 (± 0.07)^{a}
White perforated polyethylene bag	12.83 (± 0.10)^{b}	0.45 (± 0.01)^{e}	8.42 (± 0.01)^{c}
Green perforated polyethylene bag	11.83 (± 0.16)^{d}	0.44 (± 0.01)^{e}	8.55 (± 0.15)^{c}
Pink perforated polyethylene bag	11.58 (± 0.22)^{d}	0.48 (± 0.01)^{c}	7.20 (± 0.12)^{e}
Control (unbagged)	10.15 (± 0.88)^{e}	0.38 (± 0.03)^{f}	7.72 (± 0.09)^{d}

Value represents mean ± SD. Different letters within same column indicate significant differences at $p \leq 0.05$ among the treatments as per DMRT Post-Hoc test

Obeed, 2010), litchi (Pal *et al.,* 2022), guava (Srivastava *et al.,* 2023 and Meena *et al.,* 2016), peach (Kim *et al.,* 2023), pear (Lin *et al.,* 2012), mango (Singh *et al.,* 2017) and loquat (Ni *et al.,* 2011). Increase in acidity of bagged fruits might be due to high metabolic process and alteration in the microenvironment inside the bagged fruits. Improvement in acidity has been reported in loquat (Xu *et al.,* 2010), grape (Zhou and Guo, 2005), pear (Lin *et al.,* 2012) litchi. (Debnath and Mitra, 2008) and pomegranate (Sarkomi *et al.,* 2019) respectively. Increase in total sugars of bagged fruits might be due to alteration of metabolic activities inside the bagged fruits as they occupied ample sunlight intensity which may lead increase in metabolic process such as increase in respiration. Increased respiration causes rapid breakdown of carbohydrates and other organic acids, resulting in increased sugars level in bagged fruits. Meena *et al.* (2016) in guava and Pal *et al.* (2022) reported improved total sugars as a result of fruit bagging in litchi.

Pectin content, ascorbic acid, reducing sugars and non-reducing sugars were significantly affected by different bagging materials in the rainy season ($p \leq 0.05$). The highest pectin content was recorded in pink non-woven bagged fruits (1.06 ± 0.01 %) while, the lowest pectin content(0.85 ± 0.01) % was recorded in control, *i.e.,* unbagged fruits (Fig. 1a). The maximum ascorbic acid (237.90 ± 5.87 mg 100 g^{-1} pulp) was found in pink non-woven bagged fruits and the minimum (171.90 ± 2.72 mg 100 g^{-1} pulp) was recorded in control (Fig. 1b). Reducing sugars exhibited a significant difference with respect to various treatments. The maximum reducing sugars was recorded in fruits bagged with pink-non woven bags (5.46 ± 0.05%), while the minimum reducing sugars was noticed in control (3.84 ± 0.05%) (Fig. 1c). The effect of green non-woven bags, pink non-woven bags and white perforated polyethylene bags was non-significant for non-reducing sugars and it was recorded (4.51 ± 0.09) %, (4.46 ± 0.10) % and (4.41 ± 0.07) %, respectively. Minimum non-reducing sugars (Fig. 1d) was found in the white non-woven bagged fruits (3.08 ± 0.13%), which was statistically at par with pink perforated polyethylene bagged fruits (3.12 ± 0.19 per cent).

Increase in pectin content of bagged fruit might be due to alteration of microclimate inside the bagged fruit. Recently, Saxena *et al.* (2023) and Singh *et al.* (2023) reported higher pectin content in guava bagged fruits. Ascorbic acid content is influenced by temperature because Vitamin-C is heat-sensitive.The elevated ascorbic acid content in bagged fruit might be attributed to the selective sunlight permeability and alteration of microclimate such as relative humidity, moisture content and temperature inside the bagged fruits. All the bagging treatments proved significantly superior over control with respect to ascorbic acid. Meena *et al.* (2016) and Pal *et al.* (2022) found bagged fruits had the highest ascorbic acid content in guava and litchi. Increase in reducing sugar and non-reducing sugar of bagged fruits might be due to the alteration of metabolic activities. Bagged fruit occupied ample sunlight intensity which may increase the metabolic process such as respiration. Increased respiration leads breakdown of carbohydrates and other organic acids rapidly, resulting sugars level is increased in bagged fruits. Meena *et al.* (2016) in guava and Pal *et al.* (2022) in litchi found highest reducing sugars in bagged fruits. Highest non-reducing sugar content was recorded by Meena *et al.* (2016) in guava and Pal *et al.* (2022) in litchi as a result of fruit bagging.

Correlation analysis of physical and chemical traits in guava elucidated a concept that can be applied for a variety of beneficial aspects in the indigent breeding programme of guava. The positive correlation is advantageous for breeders because it enables for the simultaneous improvement of both the correlated attributes. A negative association will impede the corresponding expression of both of the abovementioned traits. The correlation analysis among various physical and biochemical characteristics of guava fruits are shown in Table 4. A significant strong positive correlation of TSS was observed with pectin content (0.936), acidity (0.841) and ascorbic acid (0.958), while it showed a significant negative correlation with days taken to maturity (-0.882), fruit fly infestation (-0.941), bird damage (-0.952) and total damaged fruits (-0.953). The pectin content was positively correlated with ascorbic acid content (0.957) whereas it showed a strong negative correlation with other physical and biochemical quality parameters such as days taken to maturity (-0.822), fruit fly infestation (-0.809) and bird damage (-0.871). Acidity (0.643), total sugars (0.617), reducing sugar (0.686), fruit firmness (0.542) and non-reducing sugar (0.390) had non-significant correlation with respect to pectin content.

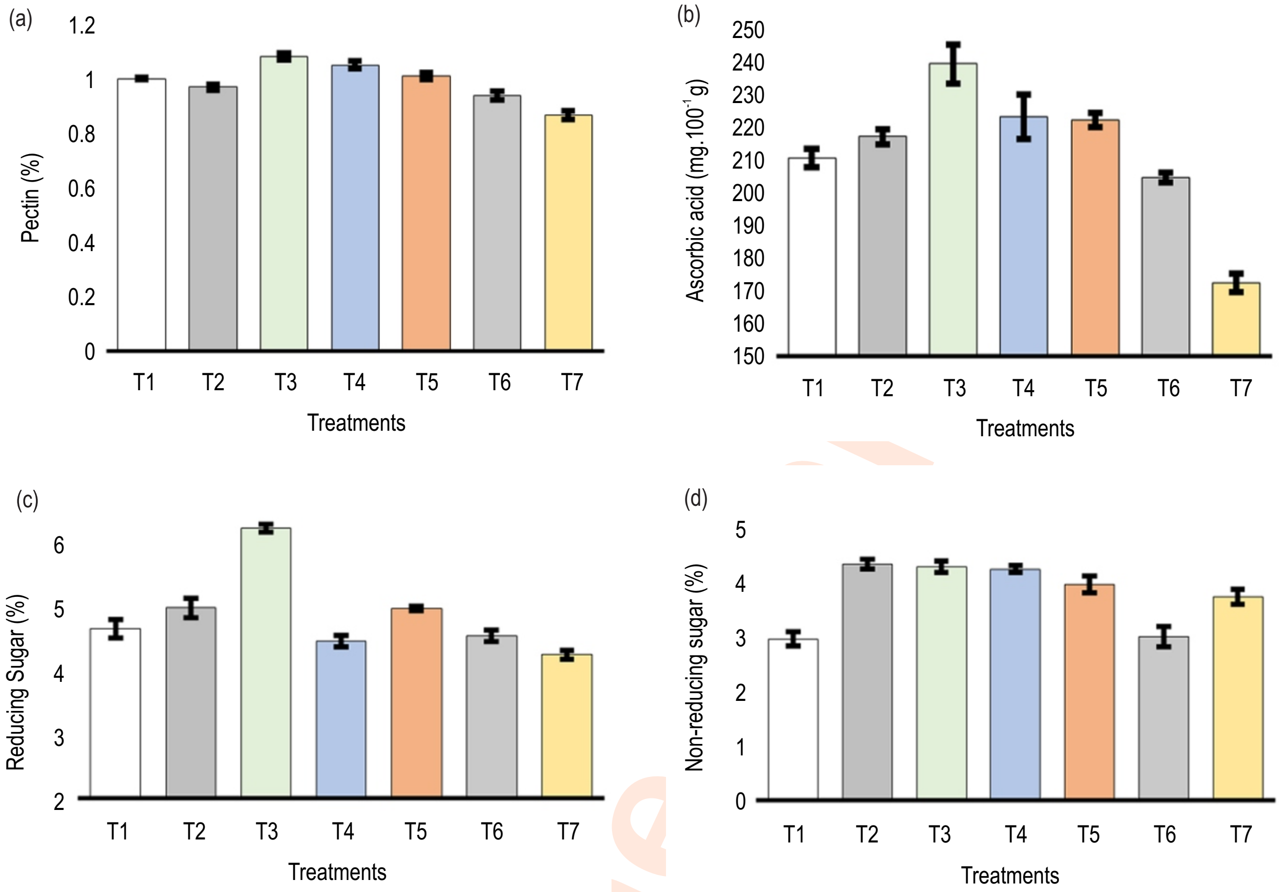

Fig. 1: Effect of different bagging materials on (a) pectin content, (b) ascorbic acid, (c) reducing sugar and (d) non-reducing sugar.

The significant positive correlation of acidity with ascorbic acid (0.793) and reducing sugar (0.773) was observed, while with fruit fly infestation (-0.835) and bird damage (-0.778), a highly negative significant correlation was reported. Ascorbic acid trait showed strong positive correlation with reducing sugar (0.760) whereas, its correlation with total sugars, non-reducing sugar and firmness was found to be non-significant. Total sugars had a significant positive correlation with reducing sugar (0.833) and non-reducing sugar (0.876). The reducing sugar had a highly significant positive correlation with fruit firmness (0.836), while, it showed a significant negative correlation with days taken to maturity (-0.845), fruit fly infestation (-0.546) and bird damage (-0.514). A strong negative correlation of total damaged fruits was found with ascorbic acid (-0.890) and acidity (-0.819). Days taken to maturity had a strong significant positive correlation with fruit fly infestation (0.895), bird damage (0.878) and total damaged fruits (0.895), while, a significant negative correlation was observed with fruit firmness (-0.786) and non-reducing sugar (-0.333). The strong positive correlation of fruit fly infestation was examined with bird damage (0.966) and total damaged fruits (0.994). Bird damage had a significant positive correlation with total damaged fruits (0.987). A significant negative correlation of non-reducing sugar was observed with fruit fly infestation (-0.201) and bird damage (-0.272). Fruit firmness had a non-significant negative correlation with fruit fly infestation (-0.433) and bird damage (-0.501).

PCA analysis was performed for data of 12 variables including fruit quality parameters and total 6 principal components were formed in 2 components having eigen value more than one (Jolliffie, 1986). The results showed that 87.23% of the data set's variation was accounted for the first two principle components. Fruit quality traits like total sugars, Reducing Sugar, Non-reducing sugar and TSS explained more variation with PC1 and days taken to maturity, bird damage and fruit fly infestation explained more variation for PC2 (Fig. 2). The variables DM, FF and BD performed relatively poor under PC1, whereas variables NR, TS, TSS and RS showed poor performance for PC2. PCA biplot depicted the noise of firmness in PC1, which was more and indicated by shorter arrow hand (Fig. 2). Ascorbic acid (C), pectin, acidity and TSS though showed less variation but were more stable. Table 3 displayed the Eigen values and the variance elucidated by primary component as a percentage. Perusal of Fig. 3, i.e., scree plot and Table 3 revealed that two of the fourteen

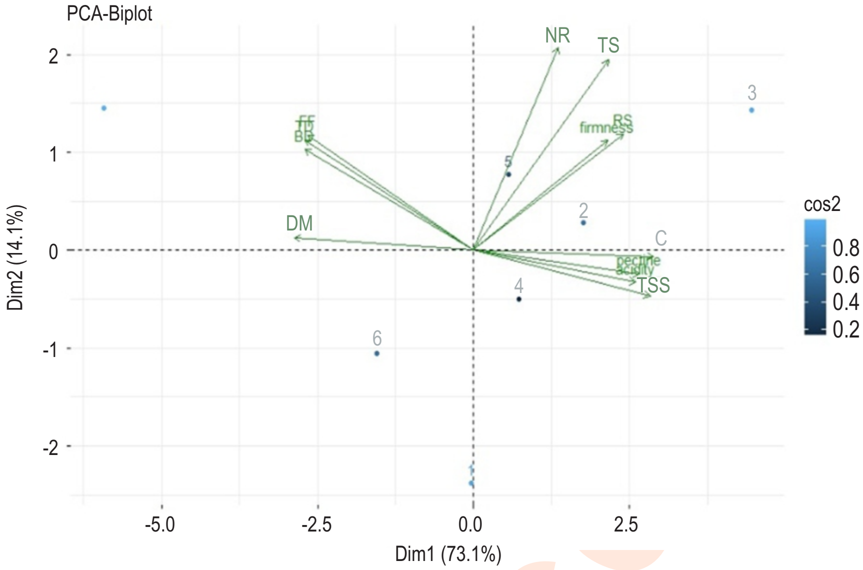

Fig. 2: Biplot of Principle Component Analysis.

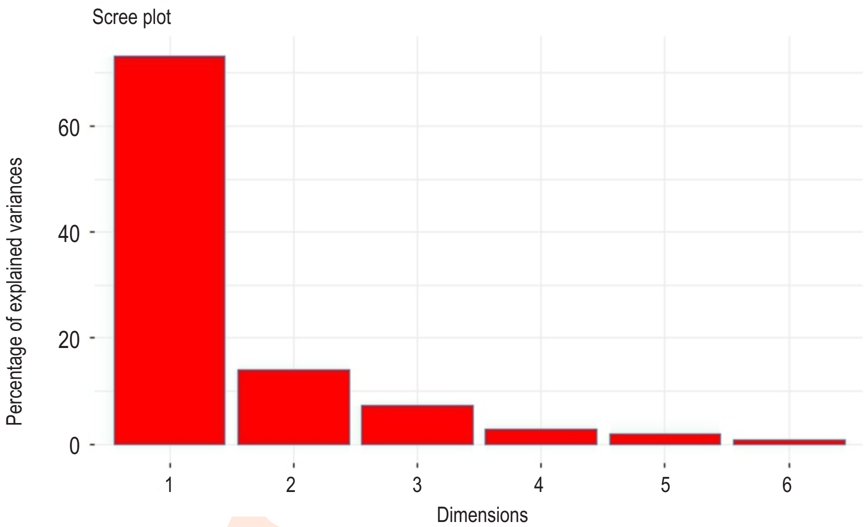

Fig. 3: Scree plot of Principle Components Analysis describing biochemical data in guava using first two Pcs.

Table 3: Eigen value, Percentage of variance and cumulative variance of Principle Components

Component No.	Eigen value	Percentage variance (%)	Cumulative variance (%)
PC_1	8.77254925	73.1045771	73.10458
PC_2	1.69593049	14.1327541	87.23733
Pc_3	0.88847367	7.4039473	94.64128
PC_4	0.33458871	2.7882392	97.42952
PC_5	0.22301960	1.8584966	99.28801
PC_6	0.08543828	0.7119856	100.00000

Table 4: Correlation between fruit quality characters in guava

	TSS	Pectin	Acidity	C	TS	RS	DM	Firmness	NR	FF	BD	TD
TSS	rg-1	0.9367**	0.8405*	0.9583**	0.6335NS	0.6709NS	-0.882**	0.5228NS	0.43NS	-0.9413**	-0.9527**	-0.9535**
	rp-1	0.8885**	0.785**	0.9147**	0.6174**	0.6484**	-0.8654**	0.5039*	0.4092NS	-0.9157**	-0.9266**	-0.9276**
Pectin	rg	1	0.6439NS	0.957**	0.6176NS	0.6862NS	-0.8221*	0.5421NS	0.3901 NS	-0.8096*	-0.8717*	-0.841*
	rp	1	0.6157**	0.9212**	0.609**	0.6573**	-0.7806**	0.533*	0.3888NS	-0.7915**	-0.8507**	-0.8217**
Acidity	rg		1	0.7938*	0.5498NS	0.7733*	-0.9154**	0.7001NS	0.207 NS	-0.8356*	-0.7788*	-0.8197*
	rp		1	0.7912**	0.5318*	0.7316**	-0.8827**	0.6881**	0.2045NS	-0.8202**	-0.7645**	-0.8048**
C	rg			1	0.6897NS	0.7608*	-0.9235**	0.7314NS	0.4415 NS	-0.8563*	-0.9243**	-0.8903**
	rp			1	0.6716**	0.7175**	-0.8999**	0.7189**	0.4361*	-0.8402**	-0.9063**	-0.8735**
TS	rg				1	0.8338*	-0.6677NS	0.6848NS	0.8761**	-0.4232 NS	-0.4502 NS	0.4375NS
	rp				1	0.8168**	-0.6388**	0.674**	0.8667**	-0.4209NS	-0.4487*	-0.4355*
RS	rg					1	-0.8458*	0.8361*	0.4644 NS	-0.5467 NS	-0.5146 NS	0.5384NS
	rp					1	-0.8103**	0.821**	0.4203NS	-0.5393*	-0.506*	-0.530*
DM	rg						1	-0.7868*	-0.333 NS	0.895**	0.8788**	0.8958**
	rp						1	-0.7665**	-0.3034NS	0.8706**	0.8553**	0.8717**
Firmness	rg							1	0.3693 NS	-0.4331 NS	-0.5014 NS	0.4638NS
	rp							1	0.3515NS	-0.4308NS	-0.4968*	-0.4606*
NR	rg								1	-0.201 NS	-0.2723 NS	0.2311NS
	rp								1	-0.1954NS	-0.2679NS	-0.226NS
FF	rg									1	0.9664**	0.9947**
	rp									1	0.9659**	0.9947**
BD	rg										1	0.9876**
	rp										1	0.9874**
TD	rg											1
	rp											1

Critical values for Pearson's correlation coefficient of two-tailed test: *and ** indicate the significance of values at $P \leq 0.05$ and $P \leq 0.01$, respectively.

TSS: Total Soluble Solids, C: Ascorbic acid, TS: Total sugars, RS: Reducing Sugar, DM: Days Taken to Maturity, NR: Non-reducing Sugar, FF: Fruit Fly Infestation, BD: Bird Damage, TD: Total Damaged Fruits, rg: genotypic correlation, rp: phenotypic correlation.

Principle Components (PCs) had Eigen value greater than unity, i.e., 8.77 (PC1) and 1.69 (PC2), which played a vital role in the analysis. These components explained 73.14% and 14.13% of the total variation and accounted 87.23% of total variation of the original variables. The highest percentage of variation was described by Principle Component 1, which was 73.14%. The variation among the principle components was distributed among PC1 and PC2 which is evident through the scree plot (Fig. 3).

Based on the overall findings, it can be concluded that On-tree fruit bagging has positive effects on fruit quality such as physical and biochemical attributes by modifying of internal microclimate inside the bagged fruits. Therefore, fruit bagging is cheapest and cost-effective technology to produce better quality fruits with high market returns in rainy season.

Acknowledgments

The author is are grateful to the Committee members and Officer-in-charge HRC, GBPUAT, Pantnagar, India, for providing necessary facilities for conducting this research work. Financial assistance as graduate teaching assistantship rendered by the university is also duly acknowledged.

Authors' contribution: M. Rawat: Conducted research work, data analysis, preparation of manuscript; **R. Kumar:** Superwised the research work, revision of manuscript; **V.P. Singh, S. Chand, S. Uniyal, N. Singh, O. Singh:** Revision of manuscript, helps during research work; **M. Kumar:** Revision of manuscript, data analysis, helped during research work.

Funding: Not applicable.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors state that they do not have any recognised competing interests (financial or personal) that might seem to have affected the work mentioned in this research paper.

Data availability: This manuscript and supplementary materials contain all of the data sets.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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