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Effect of pre-harvest fruit bagging on development and quality of mango cv Kesar under western Maharashtra conditions

SB JADHAV[1], VK GARANDE[1*] and VK BHALERAO[2]

[1]Regional Fruit Research Station, Ganeshkhind, Pune 411067 Maharashtra, India
[2]Regional Extension Centre, College of Agriculture, Pune 411005 Maharashtra, India
[*]Email for correspondence: vishnugarande@gmail.com

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ABSTRACT

The present investigations were carried out at the Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during 2019-2022 to study the effect of pre-harvest bagging on the quality of mango fruits (cv Kesar). The experiment was laid out in randomized block design with eight treatments and three replications, including different bag types viz newspaper bag, brown paper bag, brown paper bag with polythene coating, skirting bag, polythene bag, butter paper bag, muslin cloth bag and control (no bagging). The results revealed that bagging had a significant effect on the quality of mango fruits. Among all treatments, skirting bag recorded the highest fruit weight (226.86 g), TSS (20.49 °Brix), total sugars (13.93%) and reducing sugars (5.12%), along with the best overall acceptability (8.35). Brown paper bag and butter paper bag also performed better with higher fruit weight, improved biochemical parameters and extended shelf life. Bagging markedly reduced fruit fly infestation, which was highest in control (12.88%) and negligible in most other treatments. However, no significant effect of bagging was observed on stem-end rot incidence. Economically, the skirting bag treatment recorded the highest net return (Rs 161,384/ha) and benefit-cost ratio (2.70), followed by butter paper bag. The study concludes that pre-harvest fruit bagging, particularly with skirting and brown paper bags, enhances fruit quality, reduces pest infestation and improves profitability in mango cv Kesar under western Maharashtra conditions.

Keywords: Mango; pre-harvest bagging; fruit quality; benefit-cost ratio

INTRODUCTION

Mango (*Mangifera indica* L) is unarguably considered as 'King' of all fruits due to its nutritional richness, unique taste, pleasant aroma and its religious and medicinal importance. In India, the production of mango was 20,772.33 thousand MT from an area of 2,350.30 thousand hectares and in Maharashtra the production was 459.15 thousand MT from an area of 164.40 thousand hectares in 2021-22 (Anon 2023). The area under mango cultivation is increasing every year but safe and quality mango production is not increased (Islam et al 2019a).

The way we grow fruit is undergoing a vital transformation. There is a critical and growing need for new, alternative methods to produce high-quality, appealing fruit while still managing diseases and pests. This shift is driven by two main factors: increasing consumer anxiety over the use of synthetic agricultural chemicals and a greater focus on environmental awareness. Consequently, there is a much stronger emphasis on reducing the use of pesticides to safeguard the well-being of farm workers, protect consumer health and ensure environmental protection (Sharma et al 2009).

An attractive, spotless and pest free fruits fetch premium rate to the growers (Ravuri et al 2024). Mangoes are a beloved, seasonal treat, providing huge nutritional and economic value across tropical and subtropical nations. However, the systems that produce this vital crop are increasingly threatened by global challenges, especially a changing climate. To understand and manage this threat, scientists are heavily focused on phenology: the study of recurring natural events in a plant's life like flowering and fruiting and how those events relate to their environment.

Because of this, worldwide phenological monitoring has become an immensely valuable tool for assessing the true effects of climate change (Halder et al 2024).

Pre-harvest fruit bagging is a powerful yet simple technique that shields fruit directly on the tree (Fan and Mattheis 1998). This practice provides a crucial physical layer of protection for sensitive crops, creating an ideal micro-environment that ensures farmers can consistently produce high-quality, unblemished fruit with attractive colour (Yang et al 2009). This shield is vital because, during the growth phase, fruit is constantly under attack from biological and environmental stressors such as pests, diseases, sunscald and cracking, which would otherwise cause a drastic reduction in commercial value (Prasad et al 2016a, 2016b). Due to these substantial benefits, bagging has been used extensively around the world on many fruit crops, including mango, banana, guava, grape, apple and litchi (Kumar et al 2021). The technique successfully produces more attractive fruit with fewer blemishes and significantly reduces post-harvest losses, as documented in crops like mango (Sarker et al 2009, Ding and Syakirah 2010, Rahman et al 2019), guava (de Araújo Neto et al 2020, Sharma et al 2020) and banana (Lima et al 2020). Furthermore, pre-harvest bagging proves effective by reducing the incidence of diseases, insect-pest damage, mechanical injury, sunburn, fruit cracking and the presence of agrochemical residues on the fruit (Sharma et al 2014, Jakhar and Pathak 2016, Islam et al 2019b, Akter et al 2020).

The present research work was undertaken to study the effect of pre-harvest bagging on quality of mango fruit cv Kesar under western Maharashtra conditions.

MATERIAL and METHODS

The present research was conducted at the instructional-cum-research farm of the Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during 2019 to 2022. The experiment was conducted in randomized block design with eight treatments replicated thrice with a unit of 50 fruits per treatment per replication. The uniformly grown mango fruits from 10 years old mango trees were bagged (Plate 1) at egg stage ie 60 days from fruit set with different types of bags (25 cm × 20 cm) which constituted the various treatments viz T_1: Newspaper bag, T_2: Brown paper bag, T_3: Brown paper bag with polythene coating, T_4: Skirting bag, T_5: Polythene bag, T_6: Butter paper bag, T_7: Muslin cloth bag and T_8: Control (no bagging). Perforations of 2 per cent were made at the edges of all the bags for proper ventilation required during fruit development except for skirting and muslin cloth bags. In case of more than two fruits in a cluster, the smaller, underdeveloped, deformed and spotted fruits were removed and only one healthy fruit was bagged. While bagging, the brown paper, newspaper, butter paper and plastic bags were stapled properly, so that these do not fell down and to prevent the entry of insect pests. The skirting and muslin cloth bags were tied with the help of thread. Before bagging, two perforations ($\leq$4 mm diameter holes) were made for proper ventilation at the bottom of the polythene and brown paper bags with polythene coating. White and brown paper bags were not perforated as these bags automatically allowed

Plate 1. Mango fruits bagged with different types of bagging material

aeration. The observations on physical parameters of the fruits such as fruit length, fruit diameter, fruit weight, pulp to stone ratio, overall acceptability, shelf life of fruits; chemical parameters like, TSS, acidity, reducing sugars, non-reducing sugars and total sugars and incidence of fruit fly and stem-end rot were recorded. Four fruits were randomly selected per treatment per replication to record the various observations.

Growth parameters: The length from stalk end to the apex of fruit and diameter was measured with the help of a digital Vernier caliper. Weight of fruit, pulp and stone were recorded by using electronic weighing balance. The pulp to stone ratio was calculated from pulp weight and stone weight.

Chemical parameters: TSS content was determined by hand refractometer (ATAGO Company Ltd, Japan); titratable acidity by titrating a known volume of homogenized sample against 0.1 N NaOH using phenolphthalein as indicator. The results were expressed in per cent anhydrous citric acid (Anon 2005). The reducing, non-reducing and total sugars were estimated as per Lane and Eynon (1923) method with modification suggested by Ranganna (1977).

Sensory evaluation: The ripe fruits were examined for their sensory qualities for assessing colour, flavour and texture by panel of five judges with nine-point Hedonic scale (Amerine et al 1965).

Shelf life of fruits: Mature fruits were harvested at 80-85 per cent maturity. Twenty harvested mature fruits of each treatment were ripened at ambient temperature by using plastic crates with perforations and traditional paddy straw as ripening material. At the bottom, 2.5 cm layer of paddy straw was made on which fruits were arranged. Simultaneously, two more layers were kept on the first layer. The end of shelf life was noted when the fruits were spoiled.

Fruit fly infestation: The fruit infestation was determined by counting the total number of fruits and number of infested fruits and converted into per cent infestation as per below:

$$\text{Fruit fly infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

Stem-end rot incidence: Disease incidence was measured 10 days after harvest. Anthracnose lesions (caused by *Colletotrichum* spp) on the side of the fruit and stem-end rot lesions (caused by *Diplodia* spp) at the stem end of the fruit were rated for disease incidence.

Benefit-cost ratio: To assess the profitability level of mango based on bagging technology, simple tabular form and benefit-cost ratio (BCR) were checked. BCR was estimated by the ratio of gross return to variable cost and gross return to total cost.

Statistical analysis: The statistical analysis was performed as per the ANOVA suggested by Panse and Sukhatme (1985). The mean and standard deviations were computed using statistical software of OPSTAT programme.

RESULTS and DISCUSSION

Growth, yield and quality parameters: The data regarding growth parameters of fruits are presented in Table 1. The pooled data reveal that the average fruit weight was recorded higher in treatments T_4 (Skirting bag) (226.86 g), T_2 (Brown paper bag) (214.19 g) and T_6 (Butter paper bag) (212.40 g) which were at par as compared to lower weight observed in T_8 (Control) (180.44 g), T_5 (Polythene bag) (190.72 g), T_3: Brown paper bag with polythene coating (194.58 g), T_1 (Newspaper bag) (198.59 g) and T_7 (Muslin cloth bag) (199.94 g), all being at par. There was no effect of bagging on fruit length, fruit diameter and fruit yield per hectare.

Large number of physiological, biochemical and structural changes occur during the ripening of fruit which include the degradation of starch or other stored polysaccharides, production of sugars, synthesis of pigments and volatile compounds and the partial solubilization of cell wall (Jain et al 2003).

The pooled data regarding TSS content of the fruits presented in Table 2 show that higher TSS content was noticed in the treatment T_4 (20.49 °Brix), T_1 (19.95 °Brix), T_2 (19.61 °Brix) and T_5 (19.34 °Brix), which were at par, as compared to T_8 (17.84 °Brix), T_3 (18.41 °Brix), T_7 (18.89 °Brix) and T_6 (18.95 °Brix), which were also at par.

Total sugars were found to be higher in the fruits packed in T_4 (13.93%), T_2 (13.37%) and T_1 (13.30%), the three being at par, as compared to T_8 (12.11%), T_3 (12.56%), T_5 (12.61%) and T_7 (12.62%),

Table 1. Effect of bagging on growth and yield of mango fruits

Treatment	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Fruit yield (tonnes/ha)
T_1: Newspaper bag	10.94	6.98	198.59	6.76
T_2: Brown paper bag	11.08	6.86	214.19	7.29
T_3: Brown paper bag with polythene coating	10.39	6.70	194.58	7.04
T_4: Skirting bag	10.95	7.12	226.86	7.09
T_5: Polythene bag	10.47	6.76	190.72	6.56
T_6: Butter paper bag	10.47	6.85	212.40	7.18
T_7: Muslin cloth bag	10.47	6.85	199.94	6.48
T_8: Control (no bagging)	10.22	6.66	180.44	6.34
SEm($\pm$)	0.20	0.12	7.87	0.40
$CD_{0.05}$	NS	NS	24.09	NS

NS = Non-significant

Table 2. Effect of bagging on quality of mango fruits

Treatment	TSS (°Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Pulp (%)	Pulp to stone ratio	Shelf life of fruits (days)
T_1: Newspaper bag	19.95	0.41	13.30	4.91	8.61	61.72	3.72	14.41
T_2: Brown paper bag	19.61	0.42	13.37	4.92	8.27	61.56	3.72	12.80
T_3: Brown paper bag with polythene coating	18.41	0.42	12.56	5.05	7.53	61.53	3.66	14.13
T_4: Skirting bag	20.49	0.42	13.93	5.12	8.47	61.97	3.67	14.39
T_5: Polythene bag	19.34	0.47	12.61	4.73	7.21	60.17	3.62	13.21
T_6: Butter paper bag	18.95	0.46	13.08	4.85	7.64	60.95	3.69	14.20
T_7: Muslin cloth bag	18.89	0.44	12.62	4.69	7.80	59.51	3.60	13.01
T_8: Control (no bagging)	17.84	0.49	12.11	4.57	7.60	58.25	3.46	12.19
SEm($\pm$)	0.41	0.02	0.23	0.09	0.35	1.34	0.07	0.64
$CD_{0.05}$	1.26	NS	0.70	0.28	NS	NS	NS	NS

NS = Non-significant

whcich were also at par. Higher reducing sugars were observed in T_4 (5.12%), T_3 (5.05%), T_2 (4.92%), T_1 (4.91%) and T_6 (4.85%), all being at par and lower in T_8 (4.57%), T_7 (4.69%) and T_5 (4.73%) which were at par and also at par with T_6 (4.85%). There was no effect of bagging on the acidity, non-reducing sugars, pulp percentage, pulp to stone ratio and self life of fruits.

Bagging significantly influences the physical, biochemical and shelf life characteristics of mango fruits. Islam et al (2019b) reported that mango cv Langra fruits bagged with white and brown paper bags recorded the highest fruit length (97.93 and 103.5 mm), diameter (79.27 and 84.85 mm), weight (311.66 and 329.2 g) and pulp weight (278.9 and 289.8 g) respectively, while the lowest values were observed in polythene bag and control. Afsar and Sultana (2019) also found brown paper bags most effective for fruit weight, length and diameter. Haldankar et al (2015) observed that newspaper and brown paper bags improved fruit weight, diameter and pulp weight in Alphonso mango. Kumari (2023) reported that brown paper bagging in Mallika enhanced fruit weight (630.08 g), fruit length (16.34 cm), diameter (8.35 cm) and volume (591.83 ml) while in Pusa Shrestha, white paper bagging improved fruit weight (358.37 g), length (12.39 cm), diameter (6.65 cm) and volume (327.83 ml). Veeramanikandan et al (2024) found that Banganapalli mangoes bagged in brown/black double-layered bags showed the highest fruit weight (641.8 g) and improved peel colour and firmness. Ramez et al (2024) reported the highest fruit weight (256.00 g), volume (224.38 ml) and length (89.68 mm) in non-woven green bag treatment though chemical traits were not significantly affected.

Islam et al (2019b) and Haldankar et al (2015) observed higher total soluble solids (TSS), reducing and non-reducing sugars in paper-bagged fruits compared to control. Kireeti et al (2016) found that muslin cloth bags gave the highest TSS (17.61 °B), butter paper bags had maximum reducing (2.82%) and total sugars (9.65%) while polythene bags showed minimum values.

Sharma et al (2023) demonstrated that Dasheri fruits bagged in brown paper and treated with 0.05 per cent carbendazim had the highest TSS (21.16 °Brix) and sugar contents with the lowest acidity (0.11 per cent). Kumari (2023) reported higher TSS (22.67 °Brix), total sugars (14.64%) and non-reducing sugars (10.05%) in Mallika under brown paper bagging while white paper bagging improved biochemical traits in Pusa Shrestha. Veeramanikandan et al (2024) also recorded improved TSS (17.72 °Brix) and TSS-acid ratio (60.17) in double-layered bag treatments.

Bagging consistently extended fruit shelf life across studies. Islam et al (2019b) found that brown paper bags extended Langra mango shelf life to 11 days compared to 6 days in control. Hossain et al (2020) reported that brown paper bags prolonged Amrapali mango shelf life to 15 days while un-bagged fruits lasted only 8 days. Kumari (2023) observed shelf life of 11.67 days in Mallika and 14.67 days in Pusa Shrestha under paper bagging. Kireeti et al (2016) found that fruits bagged with newspaper and brown paper bags had the longest shelf life (17 days) and Veeramanikandan et al (2024) reported a 16-day shelf life in double-layered brown/black bagged Banganapalli mangoes.

Overall acceptability: The data presented in Fig 1 indicate that the mean organoleptic score for acceptability was the highest in T_4 (8.35) followed by T_3 (8.00) and T_2 (7.90) and the lowest in T_8 (6.50) followed by T_7 (6.70) and T_6 (7.20).

Pest and disease incidence: The data presented in Table 3 reveal that, significantly higher infestation of fruit fly was recorded in T_8 (12.88%) as compared to T_1 (3.89%). However, T_8 (12.88%) was also at par with T_2 (7.55%), which on the other hand was also at par with T_1 (3.89%). The fruit fly infestation was not noticed in rest of the treatments. There was no effect of bagging on stem-end rot disease of mango.

Economics of bagging: The data regarding the economics of mango fruits bagging have been presented in Table 4. Highest net return (Rs 161,384) and B-C ratio (2.70) were recorded in T_4 followed by T_6 (Rs

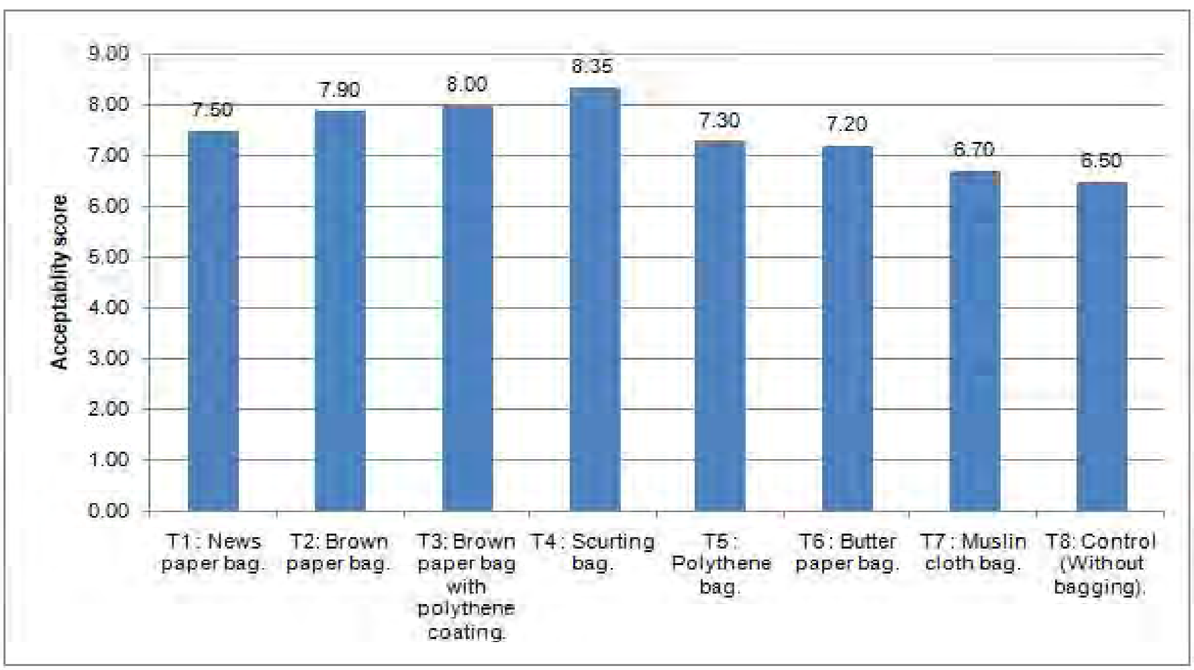

Fig 1. Effect of bagging on overall acceptability score of mango fruits

147,704 and 2.25 respectively), whereas, the lowest in T_7 (Rs 57,761 and 1.25 respectively).

Bagging of mango fruits significantly influences sensory quality, pest and disease incidence and economic returns. Islam et al (2019b) reported improved sensory qualities in mango fruits bagged with brown and white paper bags compared to control. However, Haldankar et al (2015) observed no major change in sensory qualities of Alphonso fruits, though brown paper bags with polythene coating and butter paper, muslin cloth and scurting bags reduced the incidence of mealy bag. Kireeti et al (2016) ranked muslin cloth bags highest for sensory evaluation, while newspaper and brown paper bags provided the best shelf life (17 days). Akhilesh et al (2024) found non-woven and brown paper bags most effective for sensory attributes in Banganapalli mango, with the highest scores for flavour (8.33), texture (8.67), taste (8.67) and overall acceptability (8.33).

Bagging also reduced pest and disease incidence in mango fruits. Hofman et al (1997) reported that bagging of cv Keitt decreased anthracnose and stem-end rot caused by *Colletotrichum* and *Dothoriella* spp. Veeramanikandan et al (2024) observed reduced fruit fly infestation and disease incidence (4.89%) in brown/black double-layered bags. del Pino et al (2021) found that yellow satin paper and white muslin cloth bags effectively minimized *Aulacaspis tubercularis* damage when applied before pest migration. Kumari (2023) reported that brown paper bagging in Mallika and white paper bagging in Pusa Shrestha minimized anthracnose, stem-end rot and sooty mould with lower incidence, severity and AUDPC values.

Table 3. Effect of fruit bagging on pest and disease incidence in mango

Treatment	Disease incidence (%)	
	Fruit fly	Stem-end rot
T_1: Newspaper bag	3.89 (6.66)	1.00 (3.32)
T_2: Brown paper bag	7.55 (13.06)	3.33 (6.14)
T_3: Brown paper bag with polythene coating	0.00	0.00
T_4: Skirting bag	0.00	0.00
T_5: Polythene bag	0.00	6.66 (12.23)
T_6: Butter paper bag	0.00	0.00
T_7: Muslin cloth bag	0.00	0.00
T_8: Control (no bagging)	12.88 (21.0)	10.11 (15.27)
SEm($\pm$)	3.56	4.35
$CD_{0.05}$	10.89	NS

NS = Non-significant; Figures in parentheses are angular transformations

Table 4. Economics of pre-harvest bagging materials

Treatment	Pooled yield	Gross return	Cost of cultivation	Additional cost (Rs)	Total cost (Rs)	Net return (Rs)	BCR
T_1: Newspaper bag	6.76	304,200	145,948	16,427	162,375	141,825	1.87
T_2: Brown paper bag	7.29	328,050	145,948	43,943	189,891	138,160	1.73
T_3: Brown paper bag with polythene coating	7.04	352,000	145,948	31,958	177,906	138,894	1.98
T_4: Skirting bag	7.09	425,400	145,948	11,718	157,666	161,384	2.70
T_5: Polythene bag	6.56	295,200	145,948	26,632	172,580	122,620	1.71
T_6: Butter paper bag	7.18	394,900	145,948	29,448	175,396	147,704	2.25
T_7: Muslin cloth bag	6.48	291,600	145,948	87,885	233,833	57,767	1.25
T_8: Control (no bagging)	6.34	285,300	145,948	-	145,948	139,352	1.95

Prices considered according to quality of fruits

Economically, bagging enhanced productivity and profitability. Afsar and Sultana (2019) recorded higher yield (10,850 kg/ha), gross return (Tk 596,750) and benefit-cost ratio (3.59) for adopters. Akhilesh et al (2024) observed increased yield (13,470 kg/ha) and the highest benefit-cost ratio (4.94) in reddish brown paper bag, while Kumari (2023) reported higher yield in Mallika (36.75 kg/tree, 14.70 t/ha) and Pusa Shrestha (21.14 kg/tree, 8.46 t/ha) with paper bagging.

CONCLUSION

Pre-harvest bagging significantly influenced the physical, biochemical and sensory quality of mango cv Kesar fruits. The use of skirting and brown paper bags resulted in superior fruit weight, higher TSS, sugars and overall acceptability, while effectively minimizing fruit fly infestation. Although no significant effect on stem-end rot was observed, bagging treatments enhanced fruit appearance and reduced blemishes. The skirting bag recorded the highest economic return and benefit-cost ratio, confirming its practical feasibility for commercial adoption. Thus pre-harvest fruit bagging, particularly with skirting or brown paper bags, can be recommended as a safe, eco-friendly and economically viable practice for improving marketable quality and profitability of mango production under western Maharashtra conditions.

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