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Impact of preharvest panicle bagging on fruit setting and quality of litchi (*Litchi chinensis* Sonn.) cultivar Dehradun

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ABSTRACT

The major problems associated with litchi production are poor fruit retention, pericarp sunburn and cracking. Fruits are also susceptible to insect pest infestations, bird attacks and various pathogens which reduces the commercial value of fruit and thus causing yield and economic losses. Preharvest bagging is one of the practice that is used to overcome these problems for the production of quality fruits. The present investigation was carried out at Punjab Agricultural University, Regional Research Station, Gurdaspur(Punjab) during the years 2023-24 and 2024-25. Twenty year-old fruit bearing litchi plants were selected for different fruit bagging treatments in the current study entitled "Impact of preharvest panicle bagging on fruit setting and quality of litchi (Litchi chinensis Sonn.) cultivar Dehradun". Litchi fruit panicles were covered with different colours i.e. white, pink and blue non-woven polypropylene bags on three different dates i.e. 10, 20 and 30 days after fruit set and a control(un-bagged). The study comprised of 10 treatment combinations i.e. T_1-Polypropylene non-woven white bagging at10 days after fruit set, T_2-Polypropylene non-woven white bagging at 20 days after fruit set, T_3 -Polypropylene non-woven white bagging at 30 days after fruit set, T_4-Polypropylene non-woven pink bagging at 10 days after fruit set, T_5-Polypropylene non-woven pink bagging at 20 days after fruit set, T_6-Polypropylene non-woven pink bagging at 30 days after fruit set, T_7-Polypropylene non-woven blue bagging at 10 days after fruit set, T_8- Polypropylene non-woven blue bagging at 20 days after fruit set, T_9-Polypropylene non-woven blue bagging at 30 days after fruit set and T_{10}- No bagging (control). It has been resulted that the highest fruit retention (95.56%), minimum fruit drop (1.0%), with no fruit cracking, pericarp sun-burn and nut borer infestation were recorded in fruits covered in polypropylene non-woven white bagging at 10 days after fruit set. It has been noted that maximum fruit weight (30.52g), fruit length (5.70cm), fruit breadth (5.25cm), yield (976.64g/panicle) and aril weight (26.86 g) were recorded in fruit panicles covered with polypropylene non-woven white bags at 30 days after fruit. Fruit total soluble solids (23.62°Brix), titratable acidity (0.36%), sugars (21.75%), ascorbic acid (45.36 mg/100g), colour (dark red), anthocyanin content (32.16 mg/100g) and sensory evaluation (8.70) were highest in polypropylene non-woven pink bagging at 30 days after fruit set. Highest benefit-cost ratio (4.25) was observed in polypropylene non-woven white bagging at 20 days after fruit set. Hence, the novel technique of fruit bagging significantly maintained the fruit appearance and improved the yield and quality.

Keywords: *Fruit setting, Litchi, Panicle bagging, Preharvest and Quality.*

Introduction

Litchi (*Litchi chinensis* Sonn.), popularly known as 'Queen of subtropical fruits' is native to Southern China and belongs to the family Sapindaceae and sub-family Nepheleae. Litchi is a non-climacteric fruit with attractive red peel colour, excellent physico-chemical fruit quality, juicy sweet, crispy flesh blended with acid and pleasant aroma. Generally, it flourishes in a moist atmosphere having abundant rainfall and frost-free environment. It has a strong commercial value in international market for its bright red skin and sweet, juicy and crisp aril [25].The litchi fruit has rich nutritive value, having good amount of sugar, total soluble solids (15.90 - 20.10 °Brix) and ascorbic acid (27.80 mg/100g) and vitamin C content, which can fulfil recommended daily allowance (RDA) of these nutrients by eating 14-17 fruits per day[33] . There is a need to make indian litchi globally competitive since it is highly export oriented in nature and has great potential to earn foreign exchange in international markets. The short span of availability of fruits, coupled with poor shelf-life limits the duration of the availability of fruits in national and international markets[38] . India ranks 2nd in litchi production after China [33]. The area and production of litchi in India are 100 thousand hectares and 743 thousand metric tonnes respectively [5] . It is grown in the states of Bihar, Tripura, West Bengal, Uttar Pradesh, Punjab and Haryana. In Punjab state, it can be grown successfully in the sub-montane parts comprising of Gurdaspur, Hoshiarpur, Pathankot, Roopnagar, SAS Nagar and Patiala districts. The climatic conditions of sub-montane tract of Punjab are suitable for the growth and fruiting of litchi. In these areas summers are quite hot to encourage vegetative growth of plants and winters are cool enough to provide 200-300 chilling hours to facilitate fruit bud differentiation in litchi.Flowering and fruit set in litchi are climate dependent and profoundly affected by temperature and humidity. Under Indian conditions, the fruits remains in the market for a very short period i.e. first week of May to the first week of July, hence farmers tried to fetch out more cost in comparison to other fruits being high-value fruit crops. The major problems responsible for low yield of litchi cultivation are poor fruit set and inferior fruit quality well as

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other factors like irregular flowering, heavy fruit drop, poor fruit retention, alternate bearing, fruit cracking, small fruit size and low yields are reported wherever litchi is grown, hampering its development as a major commercial crop. Fruit quality is considered to be the aspect of utmost importance which affects the profit of the litchi grower. Hence, to improve yield and quality, one of the good agricultural practices (GAP) is pre-harvest fruit bagging, which has emerged as one of the best techniques in different region of the world. In fruit bagging, single fruit or fruit bunches are covered with suitable bagging material for a some time on the tree to get excellent results. Bagging is not only save the fruits from the harmful effects of pesticide residues, insect and pest attacks including fruit sucking moth and fruit nut borer and also affecting various physiological disorders such as skin blemishes, improving fruit size, firmness, aroma volatiles, skin colour, fruit nutrient status, phenolic content and antioxidant activities [29, 33]. Bagging has been widely used to improve the commercial value by retaining the vitamin and mineral contents of the fruits [18]. Bagging, not only enhances fruit's visual quality by promoting peel colouration and decreasing the incidence of fruit cracking, sunburn burning but can also alter the micro-environment for fruit [16]. The date of bagging, bagging material and the duration of bagging have a profound influence on the fruit quality and other parameters [46].Thus, based on the above background, the study was carried out to explore the efficacy of different pre-harvest bagging techniques on fruit set, yield and quality traits of the litchi cultivar Dehradun.

2. Materials and Methods

The present investigation was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur (Punjab) in the years 2023-24 and 2024-25. Twenty year-old fruit bearing trees of litchi cultivar 'Dehradun' are selected for this study. White, pink and blue colour non-woven polypropylene bags were used to cover the litchi fruit panicles at different dates. Litchi fruit panicle bagging includes ten treatments i.e.T_1-Polypropylene non-woven white bagging at 10 days after fruit set, T_2-Polypropylene non-woven white bagging at 20 days after fruit set, T_3-Polypropylene non-woven white bagging at 30 days after fruit set, T_4-Polypropylene non-woven pink bagging at 10 days after fruit set, T_5- Polypropylene non-woven pink bagging at 20 days after fruit set, T_6-Polypropylene non-woven pink bagging at 30 days after fruit set, T_7- Polypropylene non-woven blue bagging at 10 days after fruit set, T_8 - Polypropylene non-woven blue bagging at 20 days after fruit set, T_9-Polypropylene non-woven blue bagging at 30 days after fruit set and T_{10} - No bagging (control). Bagging for each treatment was distributed equally in three directions and different height of the tree canopy to avoid possible influence on treatment effects. Bagged and non-bagged (control) fruits were harvested at the commercial maturity stage. Parameters like fruit drop, retention, cracking, sunburn and nut borer infestation were recorded. Fruit weight, length, breadth, yield, aril weight, total soluble solids(TSS), titratable acidity, sugars, ascorbic acid, anthocyanin content were estimated as per methods described by [39]. Sensory evaluation was done on a nine-point hedonic scale at fruit commercial maturity stage as per method given by [35]. The experiment was replicated with three times in randomized block design (RBD). The data obtained was subjected to SPSS software for the analysis. The level of significance for different variables was tested at 5% value of significance.

3. Results and Discussion

3.1 Fruit drop

The maximum (50.12%) fruit drop occurred in the control treatment whereas the minimum (1.0%) fruit drop was noticed in polypropylene non-woven white colour bagging at 10 days after fruit set (Table1). It means pre-harvest fruit bagging helps in the fruit retention of litchi. Similarly, [45] reported that bagging of 'Allahabad Safeda' guava at 15 days after fruit setting by yellow cloth bag was found best for maintaining yield attributes with minimum fruit drop . It might be due to perforations made in these bags allowing free circulation of air and preventing to build-up an excess temperature and relative humidity in bags. [22] Also noted that brown polypropylene bunch bagging in litchi was the best to reduce fruit dropping as compared to un-bagged fruits. Likewise, [23] noted the least number of fruit drops in 'Amrapali' mango in two-layer brown bagging.

3.2 Fruit retention

From Table 1, it has been observed that the highest (95.56%) fruit retention per panicle was recorded in bagging with polypropylene non-woven white colour bags at 10 days after fruit set. However, lowest (48.25%) fruit retention per panicle was recorded in un-bagged fruits. Similarly, [42] reported that bagging of the fruit panicle of litchi cultivar 'Rose Scented' showed maximum fruit retention in those bagged with white polypropylene bags with 10% perforation as compared to control. Likewise, [50] noted higher fruit retention in litchi cultivar 'Rose Scented' fruits bagged with white non-woven bags.

3.3 Fruit cracking and Fruit pericarp sunburn

It has been observed that no fruit cracking and pericarp sun burn were observed in litchi fruit panicles bagged with polypropylene non-woven white bags at 10 days after fruit set and maximum fruit cracking and pericarp sun burn were observed in control (Table1). Likewise, [7] reported that minimum sun-burn and fruit cracking were observed in fruits bagged with white non-woven bags and maximum were observed in the control. The declining trend in fruit cracking may have resulted from reduced moisture stress inside the bags [40]. Similar finding of fruit cracking in fruit bagging was reported in grapes [31,48], longan [55] and pomegranate[1] .The reduction in pericarp sunburn inside the bagged fruits might be due to protection of fruits from direct sunlight during the scorching summer. These results conform with the findings of [20], as they found bagging protected the navel orange from sunburn. [42] Also noted minimum fruit cracking in fruits bagged with white polypropylene (5% perforation) and it was highest in un-bagged fruits. The least pericarp sunburn was observed in fruits bagged with white polypropylene bags (no perforation), whereas maximum pericarp sun-burn was observed in un-bagged fruits. Similar trends in fruit cracking have been reported in litchi [26] and pomegranate [6,17] fruits . [50] Also noted minimum fruit cracking and pericarp sun burn in litchi cultivar 'Rose Scented' fruits bagged in white non-woven bags and maximum in un-bagged fruits.

3.4 Fruit nut borer infestation

Litchi cultivar Dehradun fruit panicles covered with polypropylene non-woven white bags at 10 days after fruit set reported no nut borer infestation as compared to the rest of treatments (Table1).

Similarly [30] noted that brown paper bags in combination with bagging time at 15 days after fruit set exhibited minimum nut borer infestation in litchi cultivar 'Shahi', while maximum infestation was recorded in un-bagged fruits. It may be due to bagging serving as a physical barrier and successfully protecting the fruits against borer infestation [14] . [23] Also noted that pre-harvest fruit bagging in 'Amrapali' mango reduced the insect- pest and disease infestation and bird attack , because they could not enter the bag as compared to control. [36] Also reported that litchi fruit bagging reduces pest incidence as compared to un-bagged fruits.

3.5 Fruit visual colour

Litchi fruit panicles covered with polypropylene non-woven pink colour bags at 30 days after fruit set significantly improved the fruit colour (dark red) as compared to the rest of treatments (Table1). Similarly, [22] reported that brown polypropylene bunch bagging in litchi was the best for improvement of fruit colour and [30] also reported that good colour of litchi cultivar 'Shahi' was noticed when fruits were bagged with brown paper bag and polypropylene pink bag at 30 days after fruit set i.e. deep purple red colour as compared to the un-bagged fruits with moderate purple red colour. Similarly, [9] reported that polypropylene bagged fruits showed the dark pinkish colour compared with un-bagged fruits, which showed light pinkish and un-even ripening. Increased relative humidity and temperature will create a better microclimate for colour improvement inside bags than outside un-bagged fruits.

3.6 Fruit weight

The data presented in Table 2, showed that litchi cultivar 'Dehradun' fruit panicles were covered at 30 days after fruit set with polypropylene non-woven white bags had highest (30.52g) fruit weight while it was found to be lowest (18.71g) in un-bagged fruits. Similarly [7] and [13] noted maximum fruit weight in litchi cultivar 'Piyaji' was recorded in fruits bagged with non-woven white bags, whereas the minimum fruit weight was noticed in un-bagged fruits. Likewise fruit weight in the litchi cultivar 'Rose Scented' was maximum in bagging at 25 days after fruit set with polypropylene bags[8] . This trend in fruit weight might be attributed to the favourable microclimate created inside the bags, which increased the accumulation of assimilates leading to maximum fruit weight. [12] Also revealed that mango cultivar 'Nam Dok Mai' bagged with different wavelength of selective bags relatively increased fruit weight, size and sphericity over un-bagged fruits. Earlier similar results were also reported by[19] who observed significant increment in finger and bunch weight with blue bags in datepalm cultivars 'Succary' and 'Khalas'. [50] Also noted that litchi cultivar 'Rose Scented' fruits bagged at 25 days before normal harvest in a pink non-woven bag had maximum fruit weight and minimum fruit weight noted in un-bagged fruits . Almost similar findings were observed in litchi[14,26], mango[4,44] and guava[45]. Similarly, [30] reported that litchi panicles covered with brown paper bags at 30 days after fruit set exhibited maximum fruit weight, followed by pink polypropylene bags in treatment combination with 15 days after fruit set, while minimum fruit weight was recorded in un-bagged fruits. Similarly, [37] reported maximum fruit weight in litchi fruits covered with a brown paper bag. [22] Also reported that brown polypropylene bunch bagging was the best to reduce fruit dropping, as well as increased the average fruit weight of litchi as compared to un-bagged fruits.

3.7 Fruit length and Fruit breadth

Highest fruit length(5.70cm) and breadth(5.25cm) were recorded in polypropylene non-woven white bagged fruits at 30 days after fruit set whereas, the lowest fruit length(3.51cm) and breadth (3.16cm) were observed in un-bagged fruits (Table2). Increased fruit length and breadth in bagged fruits might be due to rapid cell division and expansion under favourable micro climate. The results obtained are endorsed with the findings of [14] and [41] in litchi. Similar results were also noted by [7] and [13] that maximum fruit breadth and fruit length of the litchi cultivar 'Piyaji were recorded in non-woven white bagging. [45] Also noted that covering of guava (*Psidium guajava* L.) cultivar 'Allahabad Safeda' fruits at 15 days after fruit set by yellow cloth bag had maximum polar diameter of fruit as compared to un-bagged fruits. Similarly [15] observed that maximum fruit length, width and weight of mango cultivar 'Banganpalli' were recorded under reddish brown colour bagging. Likewise [22] also reported that larger fruits in 'Bombai' litchi were found in brown polypropylene bagging treatment.

3.8 Fruit yield

From Table 2 , it has been observed that litchi cultivar 'Dehradun' fruit panicles covered at 30 days after fruit set with polypropylene non-woven white bags resulted highest(976.64g) fruit yield, while it was found lowest (243.23g) in un-bagged fruits. Similarly [7] and [13] reported maximum fruit yield in litchi cultivar 'Piyaji' was found in non-woven white bagged fruits whereas minimum yield found in un-bagged fruits. Earlier studies made by several workers also have similar findings with fruit bagging treatments in date palm [19, 27], litchi [41], pomegranate[3] and mango [2] . [50] Also reported that maximum yield in litchi cultivar 'Rose Scented' was found in fruits covered at 25 days before normal harvest with pink non-woven bags.

3.9 Fruit aril weight

It was noted that the aril weight of litchi fruits was highest(26.86g) in polypropylene non-woven white bagged fruits at 30days after fruit set whereas, the lowest(14.62g) fruit aril weight was observed in un-bagged fruits (Table 2). Likewise maximum fruit aril weight of litchi was obtained when fruits were bagged with white non-woven white bags, while the minimum fruit aril weight was observed in un-bagged fruits [7,13]. Similar results were obtained by [56] in *Canarium album* fruit bagging. [50] Also reported that the maximum pulp weight of 'Rose Scented' litchi was observed in pink non-woven bagging and the minimum pulp weight was found in un-bagged fruits. This may be due to higher moisture levels and temperature inside the bags, which promotes better fruit development. Similar trends were found in different bagging treatments in litchi[41], mango [44] and pomegranate[6] .

3.10 Fruit total soluble solids (TSS) content

From Table 3, it has been observed that litchi cultivar Dehradun fruit panicles covered with polypropylene non-woven pink bagging at 30 days after fruit set had significantly maximum TSS content(23.62°Brix) and un-bagged fruits had minimum TSS content(17.05°Brix). Likewise, [7] noted that the highest TSS content was found in litchi fruits bagged with non-woven white bags and the lowest in un-bagged fruits . The difference observed in TSS content amongst all the treatments might be due to the high temperature inside the bags which helped in conservation of starch and other polysaccharides into sugar.

This result conforms with bagging in litchi [14], datepalm [19] , mango[4,24] and guava [45] . [42] Also noted maximum TSS in fruits bagged with white polypropylene bags (5% perforation) at 30 days before the harvest in litchi cultivar 'Rose Scented'. Likewise, [50] reported that litchi fruits bagged at 25 days before harvest in pink non-woven bags had maximum TSS content. However, minimum TSS was observed in un-bagged fruits in litchi cultivar 'Rose Scented'. Similarly, [30] noted maximum TSS content in litchi cultivar 'Shahi' fruits bagged with pink polypropylene bags at 15 days after fruit set and minimum was in un-bagged fruits. Mango cultivar 'Amrapali' covered with intact black polythene bagging has also significantly increased the fruit TSS as reported by [23]. Likewise [28] reported that bagging with white colour non-woven UV stabilized polypropylene bags was found to be significantly superior, to registered the highest total soluble solids. [22] Also reported that brown polypropylene bunch bagging improved the fruit TSS in litchi as compared to un-bagged fruits.

3.11 Fruit titratable acidity

The significantly lowest (0.36%) titratable acidity was recorded in fruit panicle bagged with polypropylene non-woven pink bagging at 30 days after fruit set and highest (0.48%) titratable acidity was observed in un-bagged fruits(Table3).Similarly, [7] noted the lowest titratable acidity percentage in fruits bagged with non-woven white bags, whereas, highest acidity was noted in un-bagged fruits. Reduced content of acidity in bagged fruits might be due to an improved microclimate created around the bagged fruits, which helped in increasing translocation of carbohydrates and metabolic conversion of acid into sugars, resulting in reduction of titratable acidity content as compared to un-bagged fruits. [42] Also noted minimum acidity in litchi fruits bagged with white polypropylene bags (no perforation) at 30 days before harvest. Fruit bagging treatments also retained the minimum acidity of mango fruits in accordance with the findings of [24]. [50] Also observed highest acidity in litchi was found in un-bagged fruits and the lowest acidity was found pink non-woven bags. A significant decrease in acidity was recorded in bagged fruits compared to un-bagged fruits which can be explained as harvesting of bagged and un-bagged fruits was taken on the same date and bagging resulted in early maturation of fruits due to favourable micro-climate. The findings are following fruit bagging in guava [47] and litchi[34] . [30] Also recorded minimum acidity in litchi fruits bagged with pink polypropylene at 15 days after fruit set and maximum in un-bagged fruits. Similarly [28] observed that grape berries bagging with white colour non-woven UV-stabilized polypropylene bag registered the lowest acidity as compared to un-bagged berries.

3.12 Fruit sugars content

Data on effect of different bagging time and bagging materials on total sugar in litchi was recorded and results showed that different bagging material and bagging time had a significant effect on total sugars of litchi fruit .Maximum (21.75%) value of total sugars noted in fruits bagged with polypropylene non-woven pink bags at 30 days after fruit set and minimum(12.21%) fruit sugars was observed in un-bagged fruits (Table3). These results are following the findings of [26, 34] in litchi and [52] in mango. Similarly, [7] and [13] reported that highest total sugar content was recorded in litchi fruits bagged with white non-woven bags and minimum in un-bagged fruits.

The increase in the level of total sugars inside the bagged fruits might be due to creation of modified atmospheric climate/micro climate around bagged fruit which help in increased enzymatic activity of sucrose synthase and sucrose-phosphate synthase. Sucrose synthase is an enzyme that plays an important role in sucrose decomposition, hence increased the sugars content . Likewise,[42] observed that maximum value of total sugars occurred in litchi cultivar 'Shahi' fruits bagged with white polypropylene bags (no perforation) at 30 days before the harvest. Similarly [50] noted that maximum total sugars were observed in litchi fruits bagged at 25 days before normal harvest in pink non-woven bags and minimum total sugars were observed in un-bagged fruits. [30] Also noted the maximum total sugars of litchi fruits in pink polypropylene bagging at 30 days after fruit set and minimum in control (un-bagged) fruits. The activity of sucrose synthase in bagged fruits increases during fruit development and found to be higher than un-bagged fruits. These results are in conformity with the results of bagging treatments in date palm [19] and mango [44].

3.13 Fruit ascorbic acid content

Highest ascorbic content (45.36 mg/100g) recorded in fruits bagged with polypropylene non-woven pink bags at 30 days after fruit set and the lowest (30.56mg/100g) ascorbic acid content was observed in un-bagged fruits(Table3). Likewise, [7] noted maximum ascorbic acid content in litchi fruits bagged with white non-woven bags followed by polypropylene bags whereas, minimum ascorbic acid was found in un bagged fruits. Similar findings were also observed by [10,11,54] in longan and [56] in *Canarium album*. [21] also reported that mango fruits bagged with single white layer type of bags had increased content of ascorbic acid over the control. Similarly [42] noted that litchi cultivar 'Rose Scented' fruits bagged at 30 days before harvest with white polypropylene bags showed highest ascorbic acid content . It might be since there is more temperature inside the bags which helps in more activation of phytochemicals and their synergistic effect therefore, increasing the levels of ascorbic acid inside the bags. [54] Also observed that maximum ascorbic acid content was found in fruits bagged in pink non-woven bags at 25 days prior to harvesting. Similar findings have been reported by [43] in apple.

3.14 Fruit peel anthocyanin content

From Table 3, It was noted that litchi cultivar 'Dehradun' fruit panicles covered with polypropylene non-woven pink bags at 30 days after fruit set retained highest (32.16 mg/100g) anthocyanin content and while the lowest (16.53 mg/100g) anthocyanin content was observed in un-bagged fruits. Likewise [7] reported maximum anthocyanin content in fruits bagged with polypropylene bags whereas, the minimum was recorded in un-bagged fruits. It is reported that bagging increases the light sensitivity of fruit which stimulates the anthocyanin synthesis and due to increase temperature inside the bags the anthocyanin synthesis was hastened at harvesting time when the fruits mature and hence accumulation of anthocyanin increases. The above results are following the findings of [14] in litchi, carambola [51] and mango[53]. [42] Also noted highest amount of anthocyanin content was noticed in the litchi cultivar 'Rose Scented' fruits bagged at 30 days before harvest with white polypropylene bags. The reason might be that due to increase in temperature inside the bags, the anthocyanin synthesis might have been hastened at maturity during harvesting. [30]

Also noted that anthocyanin content of fruit pericarp of the litchi cultivar 'Shahi' was significantly influenced by different bagging times and bagging materials. The maximum anthocyanin content was recorded in brown paper bag at 30 days after fruit set, whereas minimum was recorded in un-bagged fruits. [36] Also noted that bagging increases red colouration in the pericarp by upto 30%, reduces pest incidence and improves the overall quality of fruit in litchi.

3.15 Fruit sensory evaluation

Maximum (8.70) hedonic score was recorded in litchi fruits bagged with polypropylene non-woven pink bags at 30 days after fruit set and the minimum (6.65) hedonic score was observed in un-bagged fruits (Table3). Similarly [50] reported that maximum hedonic score was found in fruits bagged at 25 days before normal harvest in pink non-woven bags . However, lowest hedonic score was found in un-bagged fruits. The higher sensory hedonic score of bagged fruits may be due to improved quality parameters like colour, length, TSS, total sugars and reduced incidence of insect and diseases. The similar results were found by [32, 44, 49] in mango fruit bagging. [36] Also noted that bagging improved the overall quality of litchi fruits.

3.16 Benefit-cost ratio

The highest (4.25) benefit-cost ratio was noted in fruits bagged with polypropylene non- woven white bagging followed by pink and blue polypropylene non-woven bagging (Table4) Similarly [50] reported the highest benefit-cost ratio in the fruits bagged in white non-woven bags at 25 days before harvest which was equal to fruits bagged with pink non-woven bags at 25 days before normal harvest. However, lowest benefit cost ratio was found in fruits bagged with blue non-woven bags at 45 days before normal harvest and a low benefit cost ratio was observed in un-bagged fruits due to poor fruit retention with high sunburn, cracking and nut borer infestation percent that reduced the yield and affected other quality parameters of the fruits. Likewise, [47] noted that bagging technique was found to be highly economically viable for adoption in commercial cultivation with a highest benefit-cost ratio with pink polypropylene bagging.

Conclusion

From the present study, it can be concluded that both the qualitative and quantitative parameters of litchi fruits were enhanced at the time of harvest by pre-harvest fruit bagging using various bagging materials at different times of the fruit growth period which can fetch high remuneration to the litchi growers. Hence the novel technique of fruit bagging significantly maintained the fruit appearance and improved the yield and quality.

Future Thrust

The future scope and thrust of litchi fruit bagging techniques lie in enhancing fruit quality, improving marketability, and promoting sustainable agricultural practices. This includes developing more effective and environmentally friendly bagging materials, optimizing the timing and application of bagging, and integrating bagging with other pest and disease management strategies. Furthermore, research is needed to explore the economic viability and scalability of bagging on a commercial level.

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Conflict of Interest Statement

The author declare that they have no competing interests.

Table 1. Effect of various bagging materials on fruit drop, fruit retention, fruit cracking, sunburn, nut borer infestation of litchi cultivar Dehradun

Treatments	Fruit drop (%)	Fruit retention (%)	Fruit cracking (%)	Fruit Sunburn (%)	Fruit nut borer infestation (%)	Fruit visual colour
T_1- Polypropylene non-vowen white bagging at 10 days after fruit set	1.0	95.56	0	0	0	Red
T_2-Polypropylene non-vowen white bagging at 20 days after fruit set	10.52	85.25	0.50	0.75	0.50	Red
T_3-Polypropylene non-vowen white bagging at 30 days after fruit set	21.50	67.16	3.42	4.56	6.45	Red
T_4- Polypropylene non-vowen pink bagging at 10 days after fruit set	12.10	82.45	1.15	2.65	2.16	Red
T_5- Polypropylene non-vowen pink bagging at 20 days after fruit set	16.25	77.58	2.05	3.12	3.25	Red
T_6- Polypropylene non-vowen pink bagging at 30 days after fruit set	23.60	63.50	4.02	5.35	7.36	Dark red
T_7- Polypropylene non-vowen blue bagging at 10 days after fruit set	18.25	73.10	2.56	3.50	4.02	Red
T_8 -Polypropylene non-vowen blue bagging at 20 days after fruit set	20.32	70.18	3.05	4.12	4.51	Red
T_9 -Polypropylene non-vowen blue bagging at 30 days after fruit set	24.15	60.48	4.35	5.72	9.02	Red
T_{10} -No bagging (control)	50.12	48.25	30.14	30.56	56.12	Light red
SE(m)	**0.49**	**1.10**	**0.54**	**2.19**	**0.50**	-
CD(5%)	**1.45**	**3.31**	**1.61**	**6.55**	**1.49**	-

Table 2. Effect of various bagging materials on fruit weight, fruit length, fruit breadth, fruit yield and aril weight of litchi cultivar Dehradun

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit Breadth (cm)	Yield per fruit panicle (g)	Fruit aril weight (g)
T_1-Polypropylene non-vowen white bagging at 10 days after fruit set	27.10	5.02	4.76	650.40	23.56
T_2- Polypropylene non-vowen white bagging at 20 days after fruit set	27.65	5.36	5.05	746.55	24.02
T_3-Polypropylene non-vowen white bagging at 30 days after fruit set	30.52	5.70	5.25	976.64	26.86
T_4- Polypropylene non-vowen pink bagging at 10 days after fruit set	24.61	4.64	4.12	492.20	19.52
T_5-Polypropylene non-vowen pink bagging at 20 days after fruit set	25.12	4.81	4.21	527.52	20.38
T_6- Polypropylene non-vowen pink bagging at 30 days after fruit set	26.45	4.90	4.45	608.35	22.15
T_7-Polypropylene non-vowen blue bagging at 10 days after fruit set	20.65	4.15	3.52	351.05	16.73
T_8- Polypropylene non-vowen blue bagging at 20 days after fruit set	21.75	4.31	3.72	391.5	17.75
T_9-Polypropylene non-vowen blue bagging at 30 days after fruit set	23.52	4.45	3.90	446.88	18.25
T_{10} -No bagging (control)	18.71	3.51	3.16	243.23	14.62
SE(m)	**0.89**	**0.38**	**0.23**	**1.95**	**0.44**
CD(5%)	**2.67**	**1.13**	**0.69**	**5.83**	**1.32**

Table 3. Effect of various bagging materials on total soluble solids(TSS), acidity, ascorbic acid, anthocyanin and sensory evaluation of litchi cultivar Dehradun

Treatments	Fruit TSS (°Brix)	Fruit titratable acidity (%)	Fruit sugars (%)	Fruit ascorbic acid (mg/100g)	Fruit peel anthocyanins (mg/100g)	Fruit sensory evaluation
T_1-Polypropylene non-vowen white bagging at 10 days after fruit set	18.25	0.43	16.95	35.83	23.56	7.75
T_2-Polypropylene non-vowen white bagging at 20 days after fruit set	18.65	0.42	17.42	37.71	24.38	7.81
T_3-Polypropylene non-vowen white bagging at 30 days after fruit set	19.48	0.42	18.16	38.62	26.51	7.90
T_4- Polypropylene non-vowen pink bagging at 10 days after fruit set	20.15	0.41	18.52	40.08	27.45	8.06
T_5-Polypropylene non-vowen pink bagging at 20 days after fruit set	20.56	0.39	19.12	42.28	29.11	8.25
T_6- Polypropylene non-vowen pink bagging at 30 days after fruit set	23.62	0.36	21.75	45.36	32.16	8.70
T_7-Polypropylene non-vowen blue bagging at 10 days after fruit set	17.45	0.45	15.28	33.81	19.72	7.56
T_8 -Polypropylene non-vowen blue bagging at 20 days after fruit set	17.76	0.44	16.03	34.23	20.65	7.60
T_9-Polypropylene non-vowen blue bagging at 30 days after fruit set	18.02	0.44	16.56	34.61	22.72	7.65
T_{10} - No bagging (control)	17.05	0.48	12.21	30.56	16.53	6.65
SE(m)	**0.47**	**0.01**	**0.49**	**1.01**	**2.34**	**0.09**
CD(5%)	**1.39**	**0.03**	**1.49**	**3.02**	**0.78**	**0.26**

Table 4. Economic feasibility of bagging in litchi cultivar Dehradun for 100 kg fruits

Bagging materials	Benefit cost ratio
Polypropylene non-woven white	4.25
Polypropylene non-woven pink	2.85
Polypropylene non-woven blue	1.80
SE(m)	**1.56**
CD(5%)	**0.63**

References

1. Abd El-Rhaman, I E (2010) Physiological studies on cracking phenomena of pomegranates. J Appl Sci Res 6(6): 696-703.

2. Abdel Gawad-Nehad MA, Baiea MHM, Gioushy SF (2017) Impact of different bagging types on preventing sunburn injury and quality of 'keitt' mango fruits. Middle East J Agric Res 6(2): 484-494.

3. Abou El-Wafa M (2014) Effect of bagging type on reducing pomegranate fruit disorders and quality improvement. Egypt J Hortic 41(2):263-278.

4. Akter M, Islam Md, Akter N, Amin M, Bari Md, Uddin Md (2020) Pre-harvest fruit bagging enhanced quality and shelf-life of mango (*Mangifera indica* L.) cv. Amrapali. Asian J Agric Hortic Res 5(3):45-54.

5. Anonymous(2023), Agricultural Statistics at a Glance. Government of India, Department of Agriculture & Farmers Welfare, Economics , Statistics and Evaluation Division. Ministry of Agriculture & Farmers Welfare, New Delhi :179.

6. Asrey R, Kumar K, Sharma RR, Meena (2020) Fruit bagging and bag color affects physico-chemical, nutraceutical quality and consumer acceptability of pomegranate (*Punica granatum* L.) arils. J Food Sci Technol 57(4):1469-1476.

7. Barman D, Choudhury S, Chamuah S (2024) Studies on effect of pre-harvest fruit bagging on yield and quality of litchi (*Litchi chinensis*). Int J Sci Res 13(3):878-881.

8. Chand S, Sharma R, Srivastava R, Chandra A (2020) Impact of pre-harvest fruit bagging technology on growth and quality traits in litchi cv. Rose Scented under Indian prospective. Agric Food Sci: doi:10.20944/preprints 202008.0725.v1.

9. Chand S, Sharma R, Srivastava R, Chandra A K (2022) Impact of pre-harvest fruit bagging technology on growth and quality traits in litchi cv. Rose Scented under Indian prospective. J Fruit Sci 20: 233-235.

10. Changqing Y, Jianguang I, Dongmei H, Zhenxian W, Xuewen P, Rong L (2006) Effects of bagging on the quality and storage physiology of fruits of longan cv. 'Shixia'. J South China Agric Univ 27(4): 5-9.

11. Chen M, Lin H, Zhang S, Lin Y, Chen Y, Lin Y (2015) Effects of adenosine triphosphate (ATP) treatment on postharvest physiology, quality and storage behavior of longan fruit. Food Bioprocess Technol 8(5):971-982.

12. Chonhenchob V, Kamhangwong D, Kruenate J, Khongrat, K, Tangchantra, N, Wichai U, Singh SP(2011) Preharvest bagging with wavelength-selective materials enhances development and quality of mango (*Mangifera indica* L.) cv. Nam Dok Mai . J Sci Food Agric 91(4): 664-671.

13. Choudhury S, Barman D, Gogoi B, Pathak P(2024) Effect of pre-harvest fruit bagging on the physical qualities, shelf life and yield of litchi (*Litchi chinensis*). J Sci Res. Rep 30(8) : 114-118.

14. Debnath S, Mitra S K (2008) Panicle bagging for maturity regulation, quality improvement and fruit borer management in litchi (*Litchi chinensis* Sonn.). Acta Hort 773: 201-208.

15. Devi BL, Ramana KTV, Krishna VNPS, Sreedhar D, Sarada G and Reddy YSK(2023). Effect of different bagging materials on fruit physical parameters in mango cv. Banganpalli. The Phar Innov J 12(11): 1908-1913.

16. Fan X, Mattheis JP (1998) Bagging 'Fuji' apples during fruit development affects colour development and storage quality. Hort Sci 33(7):1235-1238.

17. Gethe AS, Hiray SA, Pujari CV, Patil RV, Lalge PM (2021) Effect of pre-harvest bagging on fruit yield, physiological disorders, pest and diseases in pomegranate. J Entomol Zool Stud 9(1):1543-1549.

18. Han J, Lee H, Jang H(1999) Comparison on skin characteristics between non-bagged and bagged 'Hosui' pear (*Pyrus pyrifolia* Nakai) fruits. J Korean Soc Hort Sci 40 (4):439 442.

19. Harhash MM, AL-Obeed R S (2010) Effect of bunch bagging colour on yield and fruit quality of date palm. Am Eurasian J Agric Environ Sci 7(3): 312-319.

20. Hong P, Zhengming L (2001) Effect of bagging on fruit quality of navel orange. South China Fruits 30(3): 27.

21. Hongxia X, Junwei C, Yuchao Z, Ming X, Liming Z, Jinlong Q, Qingming T, Chunming X (2009) Effect of bagging on fruit quality and antioxidant capacity in "Zill" mango. Acta Hortic Sin 35(8): 1193-1198.

22. Hossen MA, Ahmad M, Islam MA and Rokonuzzaman M (2024). Bunch bagging effect on fruit setting and quality of fruit in different litchi germplasm. Bangladesh J. Nuclear Agric 38(2): 81-88.

23. Islam M, Ratna M, Akter N, Yesmin MS, Rahman MM, Rahman MG, Ali ASMY, Haque ME(2023) Effect of different bagging materials on fruit quality of mango . East African Scholars J Agri Life Sci 6(11):189-196.

24. Jakhar MS, Pathak S(2014) Enhancing quality of mango (*Mangifera indica* L.) fruits cv. Amrapali with pre harvest foliar spray and fruit bagging. Ann Agri Bio Res, Faizabad 19(3):488-491.

25. Jiang YM, Wang Y, Song L, Liu H, Lichter A, Kerdchoechuen O , Joyce DC, Shi J (2006) Postharvest characteristics and handling of litchi fruit- an overview. Aust J Exp Agric 46(12):1541-1556.

26. Joshi K, Singh VP, Saxena D, Mishra DS, Kumar R (2016) Effect of pre-harvest bagging on fruit quality of litchi (*Litchi Chinensis* Sonn) cv. Rose Scented. Ann Hortic 9(1):41-44.

27. Kassem HA, Omar AKH, Ahmed MA (2011) Response of 'Zaghloul' date palm productivity, ripening and quality to different polyethylene bagging treatments. American Eurasian J Agric Environ Sci 11 (5): 616 621.

28. Kiran AS, Kavitha C, Soorianathasundaram K, Sritharan N (2019) Fruit bagging for improvement of quality attributes in grape. Int J Chem Stud 7(4): 500-502.

29. Kitagawa H, Manabe K, Esguerra EB(1992) Bagging of fruit on the tree to control disease. Acta Hort 321: 871-875.

30. Kumar KA , Maiti CS, Sarkar A, Alila P and Patil P (2023). Effect of bagging materials and time on fruit quality of litchi (*Litchi chinensis*) cv. Shahi in Nagaland. Indian J Agric Sci 93 (11): 1262-1265.

31. Li Juan S, Zhengen H, Jiyi W, Dingfeng I, Aijun C (2003) Bagging cultural techniques for grapes in high temperature and high wet conditions in Guangxi Autonomous region. S China Fruits, 32(6): 50-51.

32. Mathooko FM, Kahangi EM, Runkuab JM, Onyangob CA, Owinob WO (2011) Preharvest mango (*Mangifera indica* L.'Apple') fruit bagging controls lenticel discolouration and improves postharvest quality. Acta Hortic 906:55-62.

33. Nath V, Kumar G, Pandey SD, Gupta AK (2018) Status of litchi in India. Acta Hort 1211: 153-160.

34. Pal V, Kour K, Bakshi P, Thakur N, Jeelani MI, Kour S, Bhat DJ, Bhushan B (2022) Effect of pre-harvest panicle bagging on the physico-chemical characteristics of Litchi cv. Dehradun. The Pharm Innov 11(9):1701-1704.

35. Peryam DR and Pilgrim FJ (1957) Hedonic scale method of measuring food preferences. Food Technol 11: 9-14.

36. Pongener A, Purbey SK, Kumar V (2024) Bagging increases anthocyanins accumulation in pericarp and improves overall fruit quality in Litchi. Natl Acad Sci Lett. https://doi.org/10.1007/s40009-024-01526-w.

37. Purbey S K , Kumar A (2015) Effect of pre-harvest bagging on quality and yield of litchi (*Litchi chinensis* Sonn.) fruits. Bioscan 7: 197-201.

38. Raghavan M, Das S, Ramjan Md, Hazarika B, Langstieh L(2018) Integrated nutrient management in Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur for yield and fruit quality at foothills of Arunachal Pradesh. Int J Chem Stud 6(3):2809-2812.

39. Ranganna S (1995) Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw Hill Publishing Co. Ltd., New Delhi: 190-210.

40. Sanyal SJR, Hasan A, Ghosh B, Mitra SK (1990) Studies on sun-burning and skin cracking in some varieties of litchi. *Indian Agric* 34(1):19-23.

41. Senanan C, Khamsee Y, Manochai P, Somboonwong P , Wongnanta N (2011) Effect of fruit bagging on postharvest quality of litchi cv. 'HongHuay'. J Agric Ext Rural Dev 28 (2): 11-18.

42. Shah G, Chand S, Srivastava R, Kumar R, Sharma R (2020) Effect of pre harvest fruit bagging on the physico chemical properties of litchi (*Litchi chinensis* Sonn.) cv. rose scented. J Pharmacogn Phytochem 9(1): 1812-1819.

43. Sharma RR, Pal RK, Asrey R, Sagar VR, Dhiman MR, Rana MR (2013) Pre-harvest fruit bagging influences fruit color and quality of apple cv. Delicious. Agric Sci 4(09):443-448.

44. Shinde SM, Haladanker PM, Parulekar YR, Haldavanekaro PC, Bhave SG, Godase SN, Lawande KE(2015) Effect of pre-harvest bagging with different type of bags on physic-chemical properties of mango cv. Kesar. Green Farm 6(4):809-812.

45. Singh G, Vijay Bahadur and Saket Mishra (2024) Effect of different bagging materials on fruit growth, yield and quality attributes of guava (*Psidium guajava* L.) cv Allahabad Safeda. Int J Adv Biochem Res SP-8(5): 29-32

46. Singh J, Nath V, Lal N(2019) Bagging in litchi. Marumegh kisaan E-Patrika 4(3):55-57.

47. Singh VP, Kour K, Bakshi P, Bhat A, Kour S, Bhat D (2022) Economic analysis of bagging in Litchi fruit: A feasibility estimation from Jammu region. Economic Affairs 67(1):65-69.

48. Son IC, Kim (2010) Effect of bagging periods on pericarp characteristics and berry cracking in 'Kyoho'grape (*Vitis sp*.). Korean J Hortic Sci Technol 28(3):381-386.

49. Tendulkar SS, Haldanker PM, Bhuwad AV, Pawaskar SP, Parulekar YR, Salvi BR (2018) Effect of type of bags on chemical properties and sensory parameters of mango fruit cv. Alphonso. Int J Chem Stud 6(5):1931-1934.

50. Uniyal S, Chand S, Srivastava R , Shukla R , Singh R (2023) Response of colour of preharvest fruit bags on yield and quality of Litchi cv. Rose Scented. The Phar Innov J 12(9): 1663-1671

51. Wanichkul K, Subrungroeng P(2011) Effect of bagging materials on fruit quality of 'B17' carambola. In Proceedings of the 49th Kasetsart University Annual Conference, Kasetsart University, Thailand, 1-4 February, Subject: Plants 1:249-256.

52. Watanawan A, Watanawan C, Jarunate J (2008) Bagging "Namdokmai 4" mango during development affects color and fruit quality. Acta Hortic 787:325-328.

53. Wu HX, Wang SB, Ma XW, Ma WH, Zhan RL, Yao QS (2013) Effect of bagging on fruit quality in mango. Acta Hortic 992(73): 587-592.

54. Yang CQ, Li DM, Han ZX, Wu XW, Li R (2006) Effect on bagging on the quality and storage physiology of fruits of logan cv. 'Shixia'. J South China Agric Univ 27 (4): 5-9.

55. Yang W H, Zhu XC, Bu J H, Hu GB, Wang HC, Huang XM (2009) Effect of bagging on fruit development and quality in cross-winter off season longan. Sci Hortic 120(2): 194-200.

56. Zhou J, Zhong G, Lin Z, Xu HL (2012) The effects of bagging on fresh fruit quality of *Canarium album*. J Food Agric Environ 10(1):505-508.