Indian Journal of Agricultural Sciences **91** (1): 03–07, January 2021/Review Article
https://doi.org/10.56093/ijas.v91i1.110896

Research Review Articles

On-the-tree fruit bagging: A safe approach for production of quality fruits

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Received: 19 February 2020; Accepted: 16 September 2020

ABSTRACT

During production, fruits undergo several changes. Fruits are also infested by several insect-pests, diseases and birds which reduce their commercial value and thereby cause a significant reduction in yield, quality and returns. To prevent such losses, scientists have developed several good agricultural practices (GAP) which have become quite popular globally for the production of high quality fruits. Among such practices, on-the-tree fruit bagging has emerged as one of the most effective approaches world-wide recently. In this technique, individual fruit or fruit bunch is covered by a bag while attached to the tree. On-the-tree fruit bagging technique has been reported to have several beneficial effects on fruit colour, texture, incidence of several insect-pests, diseases and quality, as a result, it has become an integral part of production technology of apple, pear, peach, grape and loquat in several developed countries. The desirable benefits of fruit bagging may be due to the type of bag used, date and duration of bagging, the stage of fruit development, the duration of fruit exposure to natural light following bag removal, and/or fruit- and cultivar-specific responses. On-the-tree fruit bagging is a simple, grower and eco-friendly approach which has become an integral part of organic fruit production in some parts of the world yet it has to be popularized in India.

Key words: Bagging, Pre-harvest

Fruits undergo several physical and chemical changes during growth and development. During this period, fruits are usually infested by several pests, pathogens and birds, which reduce their commercial value, and thereby cause significant losses. To prevent these losses, several pesticides are applied by the growers but pesticidal residues is major concern among vigilant consumers nowadays (Sharma *et al*. 2009).With the rising awareness against harmful effects of pesticides, now several alternative techniques have been developed by the scientists, of which, on-the-tree fruit bagging has emerged as one of the best approaches for quality production of fruits. In this technique, individual fruit or fruit bunch is bagged on the tree for some period, which improves fruit colour, size and fruit quality (Sharma *et al*. 2014). The practice of pre-harvest bagging of fruits is being commercially used for growing of apple, pear, peach, grape and loquat in several countries of the world (Sharma *et al.* 2014) for reducing insect and bird damage and improvement in colour and quality of fruits (Amarante *et al*. 2002). Although, on-the-tree fruit bagging exhibit several beneficial effects on fruits yet contradictory results have also appeared in the literature which may be due to differences in the type of bag used, the stage of fruit development when it was bagged, duration of fruit exposure to natural light after bag removal, and/or fruit- and cultivar-specific responses (Kitagawa *et al*. 1992, Sharma *et al*. 2014a).

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Pre-harvest fruit bagging has been reported to influence several attributes in fruit crops. It includes, fruits size, fruit colour, insects, pests, diseases and fruit quality attributes which have been described in this review.

Size and weight

After setting, fruit grows slowly and reaches acceptable maturity. Pre-harvest bagging of the fruits is done during developmental stage which may increase the size and weight of some fruits and/or decrease in others. Such differences in effects of pre-harvest fruit bagging may be due to differences in the type of bag used, fruit age at bagging, and keeping conditions of fruit after harvest (Sharma *et al.* 2014b). The positive influence of fruit bagging on fruit growth, size and weight has been reported in mango, dates, apples and guava (Sharma and Nagaraja 2016, Sharma *et al*. 2014a,b, Sharma *et al.* 2020). Positive effects of fruit bagging may be due to creation of favourable environment for fruit growth inside the bag. However, reduction in fruit size following bagging has been reported in pear, plums and loquat (Xu *et al*. 2010) which may be due to accumulation of high RH and temperature in polyethylene-based bags.

Maturity and ripening

Several studies have reported that on-the-tree fruit bagging can have a significant influence on either delaying or hastening the fruit maturity. For example, polyethylene bags have enhanced the maturity in banana; whereas, newspaper bags did not have any effect in apple (Santosh

et al. 2017, Wang *et al*. 2010). Furthermore, Kim *et al*. (2008) had reported that maturity of peaches was enhanced by six days with white paper bags compared to fruits with newspaper bags or un-bagged fruits. However, in contrast, it was also reported that bagging did not affect fruit maturity of Delicious apples (Ju 1998).

Cosmetic appeal

During production, harvesting and postharvest handling, fruits get several injuries, and become unattractive to consumers. In the market, consumers like abrasions, injury, blemish or russet-free fruits having attractive colour. Several studies have reported that on-the-tree fruit bagging is very useful in improving cosmetic appeal of the fruits (Santosh *et al*. 2017, Sharma *et al*. 2014b, Sharma *et al*. 2020). Amarante *et al*. (2002) have reported that percentage of pear fruits accepted for export was significantly increased by on-the-tree bagging primarily by reducing peel blemishes. Similarly, pre-harvest fruit bagging resulted in the production of higher percentage of extra quality (grade) pear fruits by reducing blemishes, sun-burning and cracking in fruits (Lin *et al*. 2008). In old days, pre-harvest fruit bagging was reported to inhibit colour development in apple. However, now it has been established that fruit bagging is an effective way to promote anthocyanin synthesis and improve fruit coloration in apples black and brown doubled shaded bags (Ju 1998, Sharma *et al*. 2013, Wang *et al*. 2015). It has now been proved that pre-harvest fruit bagging increases light sensitivity of fruit and stimulates anthocyanin synthesis when fruits are re-exposed to light after bag removal. Santosh *et al*. (2017) have reported that covering banana bunches with blue polyethylene bags developed all fruits without

Table 1 Impact of on-the-tree fruit bagging on the incidence of insect-pests and diseases in different fruits

Fruit crop and cultivar	Bagging date/time	Bagging material	Insect-pest/disease controlled	Reference (s)
Incidence of insect-pests				
Apple cv. Imperial Gala	40 days after flowering	Transparent micro-perforated plastic or non-textured fabric bags	Reduction in fruit fly, Oriental fruit moth and woolly apple aphid	Rosangela *et al*. (2011)
Apple cv. Royal Delicious	30 days before harvesting	PP non-woven bags	Reduction in the incidence of San Jose Scale	Sharma *et al*. (2013, 2014a)
Guava cv. Allahabad Safeda	At marble stage	PP non-woven bags	100% reduction on the incidence of fruit fly	Sharma and Nagaraja (2016), Sharma *et al*. (2020)
Guava cv. Local	6-9 week before harvesting	Biodegradable films	Reduction in fruit fly and the guava weevil incidence	Bilck *et al*. (2011)
Pomegranate cv. Mridula	60-70 days before harvesting	Parchment paper bags	Nearly 90% reduction in the incidence of fruit borer	Bagle (2011)
Mango cv. Alphonso	30 days before harvesting	Different types of polybags	100% reduction in the incidence of fruit fly	Wu *et al*. (2013), Haldankar *et al*. (2015), Singh *et al*. (2017).
Mango cv. Langra and Khirshapat	30 days before harvesting	Black polybag, transparent polybag, brown paper bags	100% control of fruit fly	Sarker *et al*. (2009)
Litchi cv. Shahi	Bagging after 1 week of fruit set	Biodegradable cellophane paper bags, brown and news paper bags	Reduced incidence of stalk-end and stone borer	Debnath and Mitra (2008)
Incidence of diseases				
Apple cv. Royal Delicious	30 days before harvesting	PP non-woven bags	Reduction in scab, flyspeck and sooty blotch	Sharma *et al*. (2013,2014b)
Guava cv. Allahabad Safeda	Marble stage	PP non-woven bags	Reduction in anthracnose disease	Sharma and Nagaraja (2016), Sharma *et al*. (2020)
Mango cv. Nam Dok Mai #4	45 days after full bloom	Plastic bags with wavelength-selective characteristics	Reduction in the incidence of most of the postharvest diseases	Chonhenchob *et al*. (2011)
Loquat cv. California Advance	During fruit development	Plastic bags	Reduction in fruit rot	Ko *et al*. (2010).
Pear cv. Huangguan	During fruit development	3 layered bags	Increase in the incidence of browning spot	Wang *et al*. (2011)

blemishes, as a result, bagged bananas were attractive to consumers. Sharma and Nagaraja (2016) have reported that pre-harvest fruit bagging in Allahabad Safeda guava produced fruits of attractive colour, free from fruit fly and blemishes. Similarly, Mathooko *et al.* (2011) had reported that bagged mango fruits had developed spotless and light green coloured fruits, which were rated superior in all aspects than non-bagged ones. Similarly, colour in Lily mangoes was significantly improved by pre-harvest fruit bagging (Karanjalker *et al.* 2018). Recently, Zhou *et al.* (2019) observed that pre-harvest fruit bagging improved fruit peel colour in peach.

Incidence of insect-pests and diseases

Covering the fruits with different kinds of bags creates physical separation between environment and the produce. Hence, it produces most significant influence on protection of fruits from the damage caused by insect-pests (Table 1). Bagging of fruits has been effective in reducing incidence of fruit fly, fruit borer and several other pests in fruits (Sharma and Nagaraja 2016, Sharma *et al*. 2014a, Singh *et al*. 2017) (Table 1).

Pre-harvest fruit bagging has also been reported to reduce the incidence of diseases. It maintains physical separation between environment and the produce, as a result, pathogens are not capable of entering the developing fruits (Table 1). Pre-harvest fruit bagging has reduced the incidence of anthracnose and fruit rot in guava (Sharma and Nagaraja 2016), apple scab (Sharma *et al*. 2013) and several other fruits (Table 1). Thus, on-the-tree fruit bagging is a good practice for controlling insect-pests and diseases in fruits which thereby reduces dependency on pesticides.

Physiological disorders

Physiological disorders are anomalies which are not caused by pathogens or insect damage but are caused by the excess or deficiency of a nutrient or fluctuations in storage environment. Several disorders occur in fruits, which affect yield and quality, and for their management, several approaches are adopted by the growers. However, on-the-tree fruit bagging has also emerged as one of such approaches which reduce the incidence of such disorders in fruits (Sharma *et al*. 2014a,b). Studies have revealed that that pre-harvest fruit bagging can reduce the problem of sun burning and fruit cracking in apple, pomegranate fruits (Kitagawa *et al*. 1992). Similarly, it is helpful in reducing the incidence of russeting and bitter pit in apple, stone cells in pear, and lenticels discoloration in mango (Table 2). However, it may also increase the incidence of some disorders as well.

Fruit quality

The ultimate aim of a producer and consumer has to have fruits of better colour, appeal, and quality. On-the-tree bagging not only improves the physical appearance of the fruits but also influences fruit quality attributes (Table 3). It is helpful in increasing the sweetness in several fruits such as apple, loquat, peach, guava, pear, mango and litchi (Table 3). However, some studies have observed no significant effect of fruit bagging either on soluble solids and/or acidity in fruits.

Functional attributes

Fruits contain several functional attributes such phenolic compounds, flavonoids etc., which act as potential antioxidants and protect the consumers from several fatal diseases. The research reports have indicated pre-harvest fruit bagging influences the functional attributes of fruits significantly, yet contradictory information is also available, which may be due to differences in cultivar, type of bag used,

Table 2 Influence of pre-harvest fruit bagging on physiological disorders of different fruits

Fruit crop & cultivar	Bagging date/time	Bagging material	Disorder	Reference (s)
Apple cv. Royal Delicious	One month before harvesting	Non-woven PP bags	Reduction in the incidence of bitter pit, cork pit and brown core	Sharma *et al*. (2013, 2014b)
Carambola cv. Local	10-17 days after full bloom	Plastic bags	Reduction in fruit drop	Xu *et al.* (2008)
Date palm cv. Zaghloul	At pollination time	Transparent and blue polyethylene bags	Reduction in tip cracked fruit	Kassem *et al.* (2011)
Lonagn cv. Chuliang	34 days after anthesis	White adhesive-bonded fabric bag (WAFB) and BAFB	Reduction in fruit drop	Yang *et al.* (2009)
Mango cv. Apple	40-50 days before harvesting	White bags	Reduction in lenticel discoloration	Mathooko *et al*. (2011)
Pear cv. Doyenne du Comice	30 days after full bloom	Micro-perforated polyethylene bags	Reduction in russeting & sun burn	Amarante *et al*. (2002)
Pear cv. Bartlett	Paper bags once, or twice	35 days after full bloom or 20 days after full bloom	Reduction in stone cells	Lin *et al*. (2008)
Apple cv. Kurenainoyume	Biodegradable bags	40 DAFP	Reduction in New Cork Spot like disorder	Matsumoto *et al*. (2018)
Pomegranate cv. Kandhari	Paper bags	60 days after flowering	Reduction in sun burn and fruit cracking	Farzaneh *et al*. (2019)

Table 3 Effect of on-the-tree fruit bagging on fruit quality attributes

Fruit	Quality attribute	Reference (s)
Apple	Improvement in soluble solids and ascorbic acid contents	Sharma *et al.* (2013, 2014a)
Banana	Significant improvement in all quality attributes	Santosh *et al*. (2017)
Guava	Increase in soluble solids concentration, ascorbic acid (SSC)	Sharma and Nagaraja (2016), Sharma *et al.* (2020)
Litchi	Significant improvement in TSS/acid ratio	Debnath and Mitra (2008)
Loquat	Increase in soluble solids and decline in acidity	Xu *et al.* (2010)
Mango	Significant effects on SSC, TA, SS/TA ratio, vitamin C	Haldankar *et al.* (2015), Wu *et al.* (2013), Singh *et al.* (2017)
Grapes	Significant effect on sugar accumulation in the berries	Zha *et al.* (2019)

bagging date, period of bagging, and climatic conditions (Sharma *et al*. 2014b). Pre-harvest fruit bagging has improved total phenolic and flavonoid content in Delicious apple and Conference pears, but these content have been reduced in loquat (Sharma *et al.*2014b). Similarly, aroma volatiles were reported to increase by bagging in Hujingmilu peaches.

Pesticidal residues

Fruit production, several pesticides are used to control insect-pests, diseases and other problems. The residues of these pesticides are hazardous to human beings, and hence, now non-chemical approaches are gaining popularity for the control of insect-pests and diseases. Pre-harvest fruit bagging has emerged as one of the safest approaches for the production of residue-free fruits in litchi, apple and pears (Kitagawa *et al*. 1992, Debnath and Mitra 2008, Lin *et al*. 2008, Sharma *et al*. 2014b).

Although, on-the-tree fruit bagging has several advantages, but it is a laborious practice, because covering of individual fruits with bags requires a lot of labour and time. Further, there is difference of opinion among the researchers regarding kind of bag, date of bagging and date of bag removal before harvesting. Hence, we need to specify bag, date etc., for a specific crop and cultivar. Similarly, several researchers have recommended the use of plastic bags, but considering environmental issues, development and recommendations of biodegradable bags is the need of hour. Furthermore, some authors have shown profitable results with paper bags, but use of such bags in heavy rain fall areas may not be desirable. It has become an integral part of fruit culture of apple, pear, peach and loquat in countries like Japan, China and USA. Yet, its benefits have to be popularized in other countries as well and the cost-benefit analysis should be investigated for its successful adoption in the larger part of the world.

Conclusion

It can be concluded that on-the-tree fruit bagging is a simple, farmer and eco-friendly technology, which offers several beneficial effects on fruits. Further, it is a safest approach for protection of fruits from several biotic (insect-pests and diseases) stresses and has become an integral part of fruit production in several countries of the world, yet it needs popularization in several other countries, including India. By-and-large, it is a laborious process, and needs development of biodegradable bags, which can decompose after use. Moreover, we need to standardize specification in terms of kind of bag, bagging date and removal of bags etc. to harvest maximum benefits from this technology.

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