



## Influence of pre-harvest fruit bagging on Golden Delicious apple (*Malus × domestica*)

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### ABSTRACT

Studies were conducted to observe the effect of pre-harvest fruit bagging on Golden Delicious apples. For this, Golden Delicious apples were bagged on 60, 75 and 90 days after full bloom (DAFB), and bags were removed five days before harvesting. Our results revealed that apples bagged on 60, 75 and 90 DAFB matured 15, 10 and 3 days earlier than non-bagged apples. The incidence of Sanjose scale ( $2.6 \pm 0.2\%$ ), scab ( $6.3 \pm 0.4\%$ ), sooty mold ( $0 \pm 0\%$ ) and fly speck ( $2.8 \pm 0.2\%$ ) was the least in apples bagged on 60 DAFB than non-bagged apples. Apples bagged on 60 DAFB, developed appealing golden colour (Hunter 'b' value =  $58 \pm 2.2$ ) than those bagged on later dates or non-bagged ones (Hunter 'b' value =  $28 \pm 1.5$ ). Similarly, apples bagged on 60 DAFB were less firm ( $32.4 \pm 1.6$  N) but had higher levels of anthocyanins and exhibited high antioxidant activity ( $14.6 \pm 0.4$   $\mu\text{mol Trolox/g FW}$ ) than apples bagged on later dates or non-bagged apples with slight improvement in quality attributes. Thus, it can be concluded that pre-harvest fruit bagging in Golden Delicious apple on 60 days after full bloom is the best practice to get attractive golden coloured fruits with least incidence of insects and diseases and improved fruit quality.

**Key words:** Diseases, Fruit quality attributes, Golden Delicious apple, Pre-harvest bagging

Apple (*Malus × domestica* Borkh.) is the 5<sup>th</sup> most important fruit crop in India, where it is grown in hills ranging from 1200 – 3500 m above mean sea level. From hills, apples are transported to plains for marketing or storage (Chadha and Awasthi 2005). Usually, red coloured apples are preferred but golden or green coloured varieties equally fetch good price in the market. However, at lower elevations, colour development is not adequate, and hence, majority of the farmers spray ethrel for attractive colour development (Sharma *et al.* 2012, Sharma *et al.* 2016). Although, ethrel spray helps in developing attractive colour in apples but it also enhances fruit drop and pre-mature leaf-fall. In addition, ethrel-treated apples are of poor keeping-quality (Sharma *et al.* 2016). Furthermore, apple suffers badly from insect and diseases incidence, for which several pesticides are sprayed, which pose great health hazards to the consumers. Hence, efforts world over have been started to find out some alternative approaches for better colour development, and reduction in the incidence of insects, diseases and disorders in fruits including apple (Sharma *et al.* 2009).

In the recent years, pre-harvest fruit bagging has emerged as one of the best practices to improve physical

appearance of fruits by promoting fruit colouration (Sharma *et al.* 2014a,b). This approach also protects fruits from the damage caused by several insects and pathogens (Kitawaka *et al.* 1992). Hence, it is being commercially used for growing different fruits throughout the world (Sharma *et al.* 2014a,b). In our previous studies, we have reported the positive influence of pre-harvest bagging on Royal Delicious apple (Sharma *et al.* 2013, 2016). Hence, we attempted to investigate the effects of pre-harvest bagging on Golden Delicious variety of apple, which is considered as the best variety among non-red apple cultivars grown in India.

### MATERIALS AND METHODS

For this study, 20-year old, ten-trees of Golden Delicious apple cultivar were randomly selected in a private orchard, located at Katrain, Distt. Kullu, Himachal Pradesh (India) in the fruiting season of 2013-14. Twenty-fruits per tree were randomly bagged on the selected trees with non-woven bags on three different dates, i.e. 60, 75 and 90 days after full bloom (DAFB). Similarly, 20-randomly selected fruits were tagged in each selected trees at each date to be used as control. During the period of bagging, the trees were subjected to recommended cultural practices. The bags were uniformly removed 5 days before the expected date of harvest. After harvesting fruits at full maturity, fruits of different bagging dates and the non-bagged ones were kept separately by making 4-lots (each containing 200 fruits), were packed separately in corrugated fibre board (CFB)

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boxes and transported to the Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi, India, for further experimentation and observations.

After harvesting, observations on incidence of Sanjose scale, and diseases such as scab, sooty mold, and fly speck, and fruit colour, firmness, total anthocyanin content (TAC), lipoxygenase (LOX) activity, antioxidant (AOX) activity, and fruit quality attributes such as soluble solid content (SSC), total phenolic contents (TPC), and ascorbic acid contents (AAC) were recorded for bagged and non-bagged apples at harvest.

The incidence of Sanjose scale, scab, sooty mold and fly speck was expressed as the percentage of the fruit affected. Fruit colour in apple peel was measured by using Hunter colour lab system in which the parameter L\* indicates brightness or lightness (0 = black, 100 = white), a\* indicates chromaticity on a green (-) to red (+) axis, and b\* indicates chromaticity on a blue (-) to yellow axis (+). Fruit firmness was determined by using a texture analyzer and represented as N (Newton) (Sharma *et al.* 2013). The TAC of fruits was determined by the pH-differential method (Sharma *et al.* 2014a) and expressed in mg/kg FW. The TPC was determined by the method of Sharma *et al.* (2014a) and expressed in mg gallic acid equivalents (GAE)/100 g FW. The AOX capacity was determined following the CUPRAC method (Apak *et al.* 2004), and was expressed in  $\mu\text{mol Trolox/g FW}$ . The SSC values of fruits were estimated using a Fisher hand-held refractometer on a scale of 0 – 50, and expressed in  $^{\circ}\text{Brix}$  at 20°C. The AAC values were determined by standard procedures and expressed in mg ascorbic acid/100 g FW fruit pulp. The substrate and crude enzyme for the determination of LOX activity was prepared by the method of Sharma and Sharma (2016) with minor modifications, and the LOX activity was expressed in  $\mu\text{moles linolenic acid/g FW/min}$ .

The experiment was laid out in a completely randomized block design (CRBD). Analysis of variance using one-way ANOVA followed by Duncan's test was performed to test the significance of differences between means obtained among the treatments at the 5% level of significance.

## RESULTS AND DISCUSSION

The date of bagging has influenced the maturity of Golden Delicious apples. Apples bagged on 60, 75 and 90 DAFB matured 15, 10 and 3 days earlier than non-bagged apples (Table 1). Enhancement of maturity of Golden Delicious apples might be due to the fact that such apples

remained covered with bags for a substantial time which might have increased the inner temperature, triggering climacteric upsurge and thereby advanced the maturity of apples-bagged on an early date. Sharma *et al.* (2016) have also reported that the time of harvest of Royal Delicious apples can be hastened by pre-harvest fruit bagging. The incidence of Sanjose scale and diseases such as scab, sooty mold and fly speck was significantly influenced by bagging date. The incidence of Sanjose scale insect ( $2.6 \pm 0.2\%$ ), scab ( $6.3 \pm 0.4\%$ ), sooty mold ( $0 \pm 0\%$ ) and fly speck ( $2.8 \pm 0.2\%$ ) was the least in apples bagged on 60 DAFB than those bagged on 75 DAFB or 90 DAFB or non-bagged apples (Table 1). Pre-harvest fruit bagging is known for maintaining a physical separation between pathogens and the host, and fruits covered on different dates might have provided protection against insects and diseases for differential time (Sharma *et al.* 2014b). Further, differences in the incidence of insects and diseases among different bagging dates may be due to differences in the period for which apples remained covered with bags or remained uncovered as the case may be (Kitagawa *et al.* 1992, Sharma *et al.* 2013).

The date of bagging has significantly influenced colour development in Golden Delicious apples. Apples bagged on an early date (60 DAFB) developed excellent colour (Hunter 'b' value =  $58 \pm 2.2$ ) than those bagged on 75 DAFB (Hunter 'b' value =  $52 \pm 2.4$ ) or 90 DAFB (Hunter 'b' value =  $42 \pm 1.2$ ) or those which were not bagged (Hunter 'b' value =  $28 \pm 1.5$ ) (Table 2). Further, fruit bagging has pronounced effect on colour development of apple primarily because bagged apples become highly sensitive to anthocyanin accumulation once exposed to sunlight (Ju 1998). The differences in Hunter 'b' value in apples bagged on different dates may be due to differences in period for which they remained covered and the extent

Table 2 Fruit colour, fruit firmness and LOX activity of Golden Delicious apples as influenced by pre-harvest fruit bagging\*

Bagging date	Hunter 'b' value	Fruit firmness (N)	LOX activity ( $\blacktriangle$ OD/min/g FW)
60 DAFB	$58 \pm 2.2^a$	$32.4 \pm 1.5^a$	$0.430 \pm 0.02^a$
75 DAFB	$52 \pm 2.4^b$	$33.2 \pm 1.5^b$	$0.423 \pm 0.01^b$
90 DAFB	$42 \pm 1.2^b$	$35.6 \pm 0.4^c$	$0.412 \pm 0.01^c$
Non-bagged	$28 \pm 1.5^c$	$36.1 \pm 0.6^c$	$0.404 \pm 0.02^d$

\*Means within the column with the same alphabet are not significantly different by Duncan multiple range test at  $P \leq 0.05$ .

Table 1 Effect of pre-harvest fruit bagging on fruit maturity, and incidence of insects and diseases in Golden Delicious apple\*

Bagging date	Maturity date	Sanjose scale (%)	Scab (%)	Sooty mold (%)	Fly speck (%)
60 DAFB	30 <sup>th</sup> August	$2.6 \pm 0.3^a$	$6.2 \pm 0.2^a$	$0.0 \pm 0.0$	$2.2 \pm 0.3^a$
75 DAFB	5 <sup>th</sup> September	$7.4 \pm 0.2^b$	$8.4 \pm 0.2^b$	$0.0 \pm 0.0$	$2.8 \pm 0.1^a$
90 DAFB	12 <sup>th</sup> September	$9.5 \pm 0.4^c$	$10.5 \pm 0.3^c$	$0.0 \pm 0.0$	$3.6 \pm 0.2^a$
Non-bagged	15 <sup>th</sup> September	$19.8 \pm 0.2^d$	$22.4 \pm 0.3^d$	$12.4 \pm 0.2^a$	$10.2 \pm 0.3^b$

\*Means within the column with the same alphabet are not significantly different by Duncan multiple range test at  $P \leq 0.05$ .

Table 3 Effect of different dates of pre-harvest fruit bagging on fruit quality attributes of Golden Delicious apples\*

Bagging date	TAC (mg/kg FW)	TPC (mg/100 g GAE)	AOX activity ( $\mu$ mol Trolox/g FW)	AAC (mg/100g/ pulp)	SSC ( $^{\circ}$ B)
60 DAFB	292.6 $\pm$ 12.0 <sup>a</sup>	9.34 $\pm$ 0.1 <sup>a</sup>	14.6 $\pm$ 0.4 <sup>a</sup>	32.2 $\pm$ 0.7 <sup>a</sup>	14.5 $\pm$ 0.2 <sup>a</sup>
75 DAFB	278.5 $\pm$ 12.4 <sup>b</sup>	8.54 $\pm$ 0.1 <sup>b</sup>	12.2 $\pm$ 0.2 <sup>b</sup>	31.4 $\pm$ 0.9 <sup>a</sup>	13.4 $\pm$ 0.2 <sup>a</sup>
90 DAFB	268.4 $\pm$ 9.2 <sup>c</sup>	8.22 $\pm$ 0.1 <sup>c</sup>	11.6 $\pm$ 0.2 <sup>c</sup>	31.2 $\pm$ 0.7 <sup>a</sup>	13.5 $\pm$ 0.2 <sup>a</sup>
Non-bagged	222.8 $\pm$ 6.2 <sup>d</sup>	7.35 $\pm$ 0.2 <sup>d</sup>	11.4 $\pm$ 0.2 <sup>d</sup>	31.0 $\pm$ 0.9 <sup>a</sup>	13.0 $\pm$ 0.2 <sup>c</sup>

\*Means within the column with the same alphabet are not significantly different by Duncan multiple range test at  $P \leq 0.05$ .

of their sensitivity to anthocyanin accumulation caused by bagging time. Thus, apples covered on early date might have become more sensitive to anthocyanin accumulation than those bagged on later dates or those which were not bagged at all. Better colour development after pre-harvest fruit bagging has also been reported in Royal Delicious apple by Sharma *et al.* (2016) and in Golden Delicious and Granny Smith non-red apple cultivars by Liu *et al.* (2013).

Apples bagged on 60 DAFB were less firm (32.4  $\pm$  1.5 N) than those bagged on later dates or those which were not bagged at all (36.2  $\pm$  0.6 N) (Table 2). Reduced firmness in bagged apples over non-bagged ones may be due to senescence of these apples (Sharma *et al.* 2016). A significant effect of bagging date was observed on LOX activity of Golden Delicious apples. For instance, apples bagged on 60 DAFB exhibited high LOX activity (0.430  $\pm$  0.02  $\Delta$ OD/min/g FW) than those bagged on 75 or 90 DAFB or non-bagged apples (0.404  $\pm$  0.02  $\Delta$ OD/min/g FW). Higher LOX activity in apples bagged on early date may be due to low fruit firmness of fruits exhibited by increased senescence and maturity. Lower LOX activity in bagged Royal Delicious apples than non-bagged apples has also been reported by Sharma *et al.* (2013).

The TAC of Golden Delicious apples were significantly influenced by bagging date, being high in apples bagged on 60 DAFB (292.6  $\pm$  12.0 mg/kg FW) and significantly low in non-bagged apples (222.8  $\pm$  6.2 mg/kg FW) (Table 3). Such an increase in TAC by bagging is influenced by the time of re-exposure of fruits to sunlight (Ju 1998). High TAC in apples bagged on early dates than those bagged on later dates or non-bagged ones, may be because of increased ability of such apples for synthesizing total anthocyanins after re-exposure to sunlight. Like TAC, the date of bagging has significantly influenced the TPC of Golden Delicious apples, being low (9.34  $\pm$  0.1 mg/100 g GAE) in apples bagged on 60 DAFB and quite high in non-bagged apples (7.35  $\pm$  0.2 mg/100 g GAE) (Table 3) which may be because of the differences in the time period for which apples remained covered with bags. In a similar study, Sharma *et al.* (2016) have reported decline in the TPC of bagged Royal Delicious apples. In this study, the AOX activity of Golden Delicious apples was notably higher (14.6  $\pm$  0.4  $\mu$ mol Trolox/g FW) in apples bagged on 60 DAFB than those bagged on later dates or non-bagged apples (11.4  $\pm$  0.1  $\mu$ mol Trolox/g FW) (Table 3). This increase in the

AOX activity in spite of decline in the TPC may be due to accumulation of higher amount of the TAC, resulting in higher AOX activity.

There was a significant difference in the AAC among apples bagged on different dates, being higher in bagged apples than non-bagged ones (31.0  $\pm$  0.9 mg/100 g pulp) (Table 3). The AAC has been reported to be high in bagged Royal Delicious apples (Sharma *et al.* 2016) and Red Globe grapes (Zhou and Guo 2005). Similarly, the date of bagging has significant influence on the SSC of Golden Delicious apples, which was notably higher (14.5  $\pm$  0.2 %) in apples bagged on 60 DAFB than those bagged on 75 DAFB (13.4  $\pm$  0.2%) or non-bagged ones (13.0  $\pm$  0.2 %) (Table 3). Improvement in SSC due to bagging has also been reported in grapes (Zhou and Guo 2005), and Granny Smith and Golden Delicious apples (Liu *et al.* 2013).

Thus, it can be concluded that pre-harvest fruit bagging on different dates influences colour development, fruit firmness, shelf-life and different fruit quality attributes of Golden Delicious apple. However, bagging at 60 days after bloom (DAFB) is the best for getting intense golden coloured apples with least incidence of insect-pests, diseases and better quality attributes.

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