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Influence of bagging on fruit quality and mineral composition of Himsagar mango grown in new alluvial zones of West Bengal

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Abstract: The effect of polybagging of mango (*Mangifera indica* L.) fruits was evaluated at different stages of fruit development (35, 45, 55 and 65 days after fruit set). Fruits were harvested at different stages of maturity (75, 85 and 90 days after fruit set) and allowed to ripen at room temperature (34-36°C, RH 85-90%). The use of bagging at different stages of fruit development improved the appearance of fruit, fruit weight and size through other effects such as increased relative humidity and a consequently reduced fruit water loss. The maturity of fruits, at all stages of fruit harvest, was delayed with increasing bagging duration. Early bagging of fruit (35 days after fruit set) delayed the development of ripening characteristics in comparison to delayed bagging and unbagged control fruit, which ripened earliest. This was clearly evident from the carotene content in the mango flesh, at the different stages of harvest and of ripening fruit, which was the result of higher temperature inside the bags. In bagged fruits usually day/night temperature fluctuations were reduced and there was a cut off in the temperature curve inside the bag. The total soluble solids and sugar content were higher and titratable acid content was always less in unbagged fruit at all stages of fruit harvest and fruit ripening. Mineral elements were also affected by the number of days of bagging. The reduced Ca concentration in long-duration bagging (early bagging) might be due to increased RH around the fruits. Fruits bagged for 55 days recorded an increased content of N, P, Zn, Mn and Fe while fruit calcium concentration was reduced by bagging for 55 days. Anthracnose and stem-end-rot (SER) caused by *Colletotrichum* and *Diplodia* spp. respectively were reduced by bagging in both years through a reduction in contact between disease propagules and fruits. These results indicate that bagging can improve fruit quality by reducing disease, lead to a better appearance of fruit and increase fruit weight and size.

1. Introduction

In almost all fruits including mango, the stage of maturity at harvest is very important as it markedly influences not only ripening and storage but also taste and palatability of the fruit. Consumers seek a mango with a bright, fully developed skin colour without any blemishes, uniformly softened flesh and a fruit with small stone, more pulp and also good flavour and taste with appreciable storage life. Mango fruits when matured on the tree develop most of the above characteristics but such fruits have been associated with environmental hazards such as insect attack, sunburn, wind abrasion, sap spurt at harvest, damage due to hail and pre-harvest disease infection (Oosthuyse, 1997). Bagging may be useful as a means of preventing such problems in mango and can reduce disease and physical damage as well as improve colour at harvest in a number of fruits (Bentley and Viveros, 1992; Byers and Carbaugh, 1995). This approach has been tested to produce high quality unblemished mango fruits in Queensland (Hofman *et al.*, 1997), South Africa (Oosthuyse, 1997) and the Philippines (Bugante *et al.*, 1997).

However, different bagging materials behave in different ways, as has been reported by Ann *et al.* (1998). According to these authors fruit bagging at an early stage was the most effective method to control mango anthracnose disease. The use of different bagging materials did not affect disease controls, although it did affect fruit maturation, colour and °Brix. While some benefits (e.g. reduction in physical damage) could be expected, there may also be negative effects on quality as different days of bagging can delay the development of ripening characteristics of fruits.

The present paper describes the results of experiments on bagging in fruit quality and mineral element content of mango fruit cv. Himsagar, an important commercial cultivar of West Bengal, India.

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2. Materials and Methods

The experiment was conducted at the Mondouri Horticultural Research Station and the post harvest technology laboratory of the Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalay, Nadia, West Bengal, India during 2006-2008. Study trees of mango cv. Himsager were selected from the orchard at Mondouri (23.5° N latitude and 89° E longitude). The trees were healthy, uniform in size and more than 15 years old. About 250 developing mangoes were tagged and bagged with transparent polyethylene bags at different stages of fruit development: 35, 45, 55 and 65 days after fruit set and a control without any bagging. Then on each sampling date (75, 85, 90 days after fruit set), 10 mangoes were harvested at random from each bagging-date lot of polyethylene-bagged fruits. The fruits were washed and dried at ambient temperature (32°C±1°C), and kept in the laboratory for ripening. Ripe fruits were analyzed for physico-chemical characteristics; bagged fruits were analysed 55 days after fruit set for mineral elements and disease incidence.

Physico-chemical analysis

A. Physical characters. Weight, length and diameter. The weight of ripe fruit was determined using a digital balance and expressed in grams. Length of fruit was measured from the base to the apex and diameter at its widest part, near the shoulder of the fruit, with the help of a vernier caliper. Both were expressed in centimeters.

B. Bio-chemical constituents. Total soluble sugars, total soluble solids (TSS), titratable acidity. Total soluble sugar content was analysed using Fehlings' A and B solution, according to the methods of the AOAC (1996) and expressed as percentage. In this method, for inversion at room temperature an aliquot of clarified and diluted solution was transferred to a flask. 10 ml of HCl (1:1) was added and allowed to stand at room temperature for 24 h. The solution was then neutralized with concentrated NaOH solution and made to volume. An aliquot was taken and the total soluble sugars were determined as invert sugars using Fehling's A and B solution. In determining reducing sugar, acid hydrolysis was not done. Total soluble solids (TSS) content of juice was determined using a hand refractometer and expressed as °Brix at 20°C. Titratable acidity (% malic acid) was estimated by titrating fruit juice (5 ml) to pH 8 against 0.1 M NaOH using phenolphthale as an indicator.

Total carotenoids

Total carotenoids were estimated by the method of Ranganna (1977). Five grams of fresh sample were taken, a few crystals of anhydrous sodium sulphate were added, and then crushed in 10 ml acetone with the help of a pestle and mortar. The supernatant was decanted into a beaker. The process was repeated twice or thrice and the combined supernatant was transferred to a separating funnel out on standing. Petroleum ether (10 to 15 ml) was added in the separating funnel and rinsed; the pigment was then transferred to the petroleum ether phase by diluting the acetone with water or water containing 5% sodium sulphate. The extraction of the acetone phase with a small volume of petroleum ether was repeated, if necessary, until no more colour was extracted. The lower layer was discarded and the upper layer was collected in a 100 ml volumetric flask. The petroleum ether extract was filtered through anhydrous Na_2SO_4 and the volume was made up to 100 ml with petroleum ether. The optical density was recorded at 452 nm using petroleum ether as blank containing 3 ml acetone per 100 ml and expressed as µg 100 g^{-1} pulp. As carotenoids are light sensitive, all steps were performed under subdued light.

Flesh minerals

Dried flesh samples from the ripe fruit (unbagged and bagged 55 days after fruit set) were collected and ground with a mortar and pestle, further dried at 70°C for 2 days, then finely ground in a shatter box. A 0.3-0.5 g sub-sample was digested in 15 ml nitric acid/perchloric acid and analysed by atomic absorption spectroscopy against standards prepared in the same matrix. Nitrogen was determined using Kjeldahl digestion.

Disease 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 (SER : caused by *Diplodia* spp.) at the stem end of the fruit were rated for incidence (percentage of the fruit affected).

Statistical analyses

Data regarding observed characters were statistically analysed by complete Randomised Design and test of significance was carried out following the method described by Panse and Sukhatme (1967).

3. Results and Discussion

Fruit weight, length and diameter

Fruit bagging with polyethylene bags significantly increased the weight of fruit as compared with the control at all stages of fruit harvest (75, 85 and 90 days after fruit set). Early bagging (35 days after fruit set) proved most effective in increasing fruit weight compared to those bagged later (Table 1). It is evident from Table 2 that fruit length

Table 1 - Effect of bagging on fruit weight (g) at different stages of harvest

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	303.50	322.75	345.00
45	287.50	296.75	319.60
55	244.75	291.20	310.17
65	229.72	259.86	301.87
Control	205.25	229.50	276.02
SEm ±	21.22	28.52	24.12
LSD (P= 0.05)	63.62	85.11	72.42

Table 2 - Effect of fruit bagging with polyethylene on length (cm) of fruit at different stages of harvest

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	10.75	12.75	13.91
45	10.30	11.50	12.28
55	10.06	11.35	11.94
65	9.95	11.12	11.82
Control	9.40	10.92	11.32
SEm ±	0.425	0.414	0.380
LSD (P = 0.05)	1.241	NS	1.144

increased along with the increase in duration of bagging and also with delayed harvesting. Fruits bagged early (35 and 45 days after fruit set) were almost always longer than those bagged later (55 days after fruit set). However, the increase in fruit length due to polybagging was not significant for fruits sampled 85 days after fruit set. Like fruit length, the diameter of fruit also increased due to polybagging; the increase in diameter was significant at all stages of fruit harvest (Table 3).

Table 3 - Effect of fruit bagging with polyethylene on diameter (cm) of fruit at different stages of harvest

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	7.77	8.00	8.43
45	7.33	7.71	8.25
55	7.19	7.70	7.95
65	7.05	7.44	7.94
Control	6.91	7.25	7.68
SEm ±	0.172	0.210	0.211
LSD (P = 0.05)	0.521	0.591	0.610

Total Soluble Solids (TSS), total soluble sugar and titratable acidity (TA)

Total soluble solids and sugar contents of fruit were significantly affected by treatment with polybagging (Tables 4 and 5). TSS content of ripened fruit was always higher in those bagged later or not bagged at all. At fruit harvest 90 days after fruit set, TSS content was higher in fruits that were bagged later (at or after 55 days of fruit set)

Table 4 - Effect of fruit bagging on total soluble solids (°Brix) content of ripe mango fruit

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
45	9.90	12.20	15.40
55	10.05	13.50	17.30
65	10.40	14.30	17.85
Control	11.90	15.30	16.25
SEm ±	0.161	0.072	0.051
LSD (P = 0.05)	0.483	0.219	0.153

Table 5 - Effect of fruit bagging on total soluble sugar (% of fresh weight) content of ripe mango fruit

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	4.42	6.85	11.81
45	4.77	6.85	12.57
55	5.02	7.52	13.69
65	5.50	7.81	13.82
Control	6.20	7.97	12.83
SEm ±	0.129	0.061	0.051
LSD (P = 0.05)	0.391	0.180	0.158

than the rest of bagged or not bagged fruits, however TSS content was greatest in fruits bagged earliest (35 day after fruit set). As TSS, total sugar content of fruits was always greater than those that were bagged later (65 days after fruit set) or those that were not bagged at all (control). Fruit acidity decreased with a decrease in bagging period (Table 6). However titratable acid content of ripened fruits did not show any significant variations due to bagging at different stages of fruit development.

Table 6 - Effect of fruit bagging on titratable acid (% malic acid) content of ripe mango fruit

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	0.250	0.210	0.200
45	0.240	0.220	0.190
55	0.210	0.190	0.180
65	0.180	0.180	0.150
Control	0.170	0.160	0.140
SEm ±	0.012	0.014	0.015
LSD (P = 0.05)	NS	NS	NS

Carotenoid contents

Analysis at the eating ripe stage showed that the carotenoid content of fruit increased as harvesting was delayed from 75 to 90 days (Table 7). Early bagged fruits usually developed less carotenoid upon ripening as compared to those bagged later or to the control. The unbagged fruits

Table 7 - Effect of fruit bagging on carotene (µg/100 g pulp) content of ripe mango fruit

Bagging (days after fruit set)	Stages of fruit harvest (days after fruit set)		
	75	85	90
35	2247.50	4345.50	7782.50
45	2380.00	4773.50	8276.00
55	3565.00	6566.00	8958.50
65	3955.00	7318.50	9168.00
Control	4354.00	8485.50	9768.00
SEm ±	12.95	17.25	19.00
LSD (P = 0.05)	36.79	52.12	57.12

(control) at all stages of harvest developed maximum content of carotene while early bagged fruits (35 days after fruit set) contained minimum carotene upon ripening at all different stages.

Fruit minerals and disease incidence

Mineral element contents of fruits varied due to different days of bagging. Table 8 shows that N, P, Zn, Mn and Fe content of fruits were higher in bagged fruit (55 days bagged) while K and Ca contents were higher in control fruit (0 day bagged) as compared to 55 days of bagging. Bagging did not significantly reduce the incidence of anthracnose and stem-rot (SER) (Table 9) of ripe fruit. Reductions of only 5.5 and 6.0% of anthracnose and stem-end-rot, respectively, were noted in fruits bagged 55 days after fruit set.

Table 8 - Effect of fruit bagging on mineral elements contents of ripe mango fruit

Mineral elements	Days bagged		Significance
	0	55	
N (%) dry weight	0.57	0.74	*
P (%) dry weight	0.12	0.14	*
K (%) dry weight	0.71	0.64	*
Ca (%) dry weight	0.07	0.03	*
Zn (ppm)	22.50	23.33	NS
Mn (ppm)	11.75	12.18	NS
Fe (ppm)	49.00	49.75	NS

Assessment were made at eating soft stage.
NS indicates P>0.1.
* Represent effects significant at P<0.05.

Table 9 - Effect of bagging on fruit disease incidence (percent of fruit affected)

Parameter Incidence (%)	Days bagged	Anthracnose	Stem-end-rot
	0	82.5	77.0
	55	56.5	50.5
	Significance	NS	NS

All assessment were made at 10 days after harvest.
NS indicates P>0.1.

The results of the present investigation clearly demonstrate the benefits of polybagging on the development of mango fruit and fruit quality. Bagging of fruits improved fruit weight and size of litchi (Tyas *et al.,* 1998), banana (Johns and Scott, 1989) and pomegranate (Hussein *et al.* 1994). Bagging can affect fruit size through other effects such as increased relative humidity and therefore reduced fruit water loss (Tombesi *et al.,* 1993). According to Hofman *et al.* (1997), in the present study fruit mass and size may be due to the use of polybag instead of paper bag. The polybagging of fruits delayed the development of ripening characteristics of fruits. However, the extent of the fruit surface coloured yellow was greater with polybagged fruits, which was due to maintenance of a higher temperature inside the bags. In bagged fruits usually day/night temperature fluctuations were reduced, hence the range of minimum temperatures was between 18 and 27°C, which is very close to the optimal temperature range (24-30°C) for the development of Himsagar mango (Mukherjee, 1953; Whiley *et al*., 1989). The total soluble solids and total sugar content of ripe mango were almost always greater in control fruits and those with a shorter bagging period as compared to early-bagged fruits.

Titratable acid content of ripe fruits was greater in early-bagged fruits and acid content of ripe fruits declined as the period of bagging was reduced; minimum acid levels were noted in the control. This is only due to bagging which delayed the development of ripening characteristics of fruits. Similarly, the carotene content in the pulp of ripe mango fruit was at maximum in control and minimum in early-bagged fruits. This is mainly due to fact that polybagging of mango fruits delayed the development of ripening characteristics and therefore there was less development of carotene in fruits that were bagged early in comparison to control. These results are in close conformity with the previous findings of Singha (2002). However, Hofman (1997) opined that fruit quality of mango was not affected by bagging. Fruit mineral (N, P, K and Ca) contents were significantly influenced by bagging. Bagged fruit in the 55-day group had a amount of calcium in comparison to unbagged fruits. Calcium is transported mainly in the transpiration stream (Grange and Hand, 1987), thus tissues with greater transpiration generally have higher tissue Ca concentrations (Witney *et al.*, 1990 b). Increased RH around the fruit can reduce fruit Ca accumulation (Grange and Hand, 1987, Combrink *et al.*, 1995) and bagging of apple fruit has been associated with reducing fruit Ca concentrations and increasing bitter pit incidence (Witney *et al.,* 1991). Similar effects were observed in mangoes bagged for 55 days, although the higher fruit Ca concentration with longer bagging times may suggest a capacity of the fruit to import Ca by a mechanism other than transpiration. Longer bagging times may have caused changes in the surface of fruits that allowed higher transpiration rates and thereby the higher Ca accumulation noted with increased bagging times as described by Hofman *et al.* (1997).

Reduction in fruit disease as a consequence of bagging in a number of different fruits has been noted by Kitagawa *et al.* (1992). In mango, *colletotrichum* infection occurs during fruit development and remains quiescent until fruit ripening (Dodd and Jeffries, 1989). The reduction in anthracnose incidence with bagging (55 days) could be partly due to a reduction in contact between disease propagules and fruit as mentioned by Hofman *et al.* (1997).

In conclusion, bagging of mango can have important commercial benefits as a means to prevent problems like

insect attack, sunburn, sap spurt at harvest and damage due to small hail storms by reducing physical damage of fruit, as well as delaying the development of ripening characteristics of fruits.

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