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SAP BURN INJURY MANAGEMENT OF MANGOES (*MANGIFERA INDICA* L.) IN SRI LANKA

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Abstract

Sap burn injury is one of the major postharvest disorders that causes postharvest losses of mangoes. Popular dessert mango fruits from northern Sri Lanka were selected for this study. Mature mango fruits - 'Willard', 'Karuthakolumban', 'Chembaddan' and 'Ambalavi' - were harvested carefully with 5cm stalk for different treatments to minimize sap burn injury. Stalks were removed and fruits were dipped in GRAS compounds of 1 & 5% sodium chloride (Table salt) and 0.5 & 1% calcium hydroxide separately for 5 minutes. De-stemming and dipping fruits in 5% sodium chloride and 1% calcium hydroxide were effective in reducing sap burn injury in 'Karuthakolumban'. However, 1% table salt and 0.5% calcium hydroxide successfully reduced sap burn injury in 'Willard', 'Chembaddan' and 'Ambalavi' mangoes. Fruit quality was measured in terms of pH, Total Soluble Solids (TSS) and marketability. Quality parameters of treated fruits were not significantly different (P=0.05) from non chemical treated good quality mango fruits. Sap management dynamics was very useful in controlling sap burn in 'Chembaddan' and 'Ambalavi' mangoes. No latex exudation was observed in these mangoes when stalk was broken by next day after harvesting. These results suggest that low cost environmentally friendly methods could be used to reduce sap burn injury in mangoes.

Key words: Mango cultivars, Postharvest disorder, GRAS compounds, Sap management dynamics, Fruit quality.

Introduction

Mango is one of the most popular and delicious tropical fruits. 'Willard', 'Karuthakolumban', 'Chembaddan' and 'Ambalavi' are popular dessert mango cultivars grown in Jaffna district. Mango production in Jaffna is mostly at home garden level. Postharvest losses of mangoes are high in Jaffna due to lack of technology regarding harvesting, handling and storage and leads to the reduction of mango supply to mango industry in Sri Lanka. Sap burn injury is one of the major postharvest disorders that reduces storage life and market demand of the fruit. It will cause skin blemish and render the fruit susceptible to microbial infection.

The sap exudates that flows out on de-stemming is somewhat milky at first and causes brownish-black to black streaks or blotches on the mango skin due to its acidic nature (Campbell, 1992). It becomes pale yellow and transparent when dried. Sap injury is characterized as darkening or browning of the peel due to contact with the sap. Fruit sap is composed of lower and upper phase and components of lower aqueous phase do not cause sap burn (Loveys *et al*., 1992). Sap burn injury is mainly cultivar dependant and the most popular Australian CV Kensington is susceptible to sap burn injury (O'Hare & Prasad, 1994; Loveys *et al*., 1992; Brown *et al*., 1986).

De-sapping of mangoes and dipping in different solutions are the methods practised to control sap injury (O'Hare & Prasad, 1992; O'Hare & Prasad, 1994; Maqbool *et al.*, 2008; Amin *et al*., 2008). Various chemicals have also been tested to control sap burn injury including sodium hydroxide and alum (Barman *et al*., 2015) sodium carboximethyl cellulose, lauryl sulphate sodium, calcium hydroxide solutions, dabbing with vegetable oil, waxes and de-sapping in commercial detergent (Landrigan *et al*., 1991; Baker, 1991). Maximum sap burn control was observed in fruit harvested and de-sapped in the morning (Amin *et al*., 2008). Some investigations on composition of mango sap, sap burn injury and control of sap burn of Australian (Ledger, 1991; Holmes *et al*., 1993; Lim & Kuppelweiser, 1993) Indian (Saby John *et al*., 1999; Barman *et al*., 2015) Mexican (Sanchez *et al*., 2000) Brazilian (Menezes *et al*., 1995) and Pakistani (Maqbool *et al.*, 2008; Amin *et al*., 2008) mango cultivars have been reported in the literature. However, there is limited published information available regarding postharvest losses due to sap burn and sap management practices of mango cultivars in Sri Lanka. Thus the aims of this study were to assess sap burn in selected popular mango cultivars and recommend procedures to reduce sap burn injury.

Methods and Materials

Plant materials: 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mango cultivars were used in this study. Mango fruits were obtained from a home garden in Jaffna (Northern Province of Sri Lanka) where trees were grown under similar management practices. All four mango cultivars were collected and treated separately.

Harvesting of mangoes: Mature, firm green colour mangoes were harvested carefully with 4-5cm stalk. Fruit maturity was based on days after full bloom and external appearance. All four mango cultivars were carefully observed for external appearance of maturation such as size, shape, colour and appearance of white powdery material on the surface of the fruit after 90 days from full bloom stage. Harvested fruits were carefully packed in cardboard boxes as single layer packaging with stem end up and brought to the laboratory, Department of Botany, University of Jaffna.

Quantitative assessment of sap burn injury (controls): Fruits were randomly allocated according to a completely randomized design (CRD) consisting of 27 fruits with three replicates (27 fruits per replicate). Stalk was removed for 27 fruits and placed pedicel upwards to allow the sap to run down the surface of fruit to quantify sap burn injury (O'Hare, 1994**)**. These fruits were allowed normal ripening at ambient condition (28-34ºC & 65- 80% RH) and sap burn injury was assessed at eating ripe stage. Severity of sap burn injury was rated after 9 and 7 days of storage in 'Karuthakolumban' and 'Willard' mangoes and 8 days of storage in 'Ambalavi' and 'Chembaddan' mangoes by scoring such as 0 = No injury, 1 = 0 - 4% injury (slight), 2= 5-9% (Slight- moderate), 3 =10-14% (moderate), 4=15-25% (moderate – severe), 5 = Sap injury more than 25% of total area (severe).

Treatments of sap burn injury: Fruits in quantitative assessment of sap burn were used as controls for these treatments.

Dipping treatment: 27 mango fruits with 3 replicates from each cultivar were used for treatments.

Treatment 1: Dipping treatment in table salt (NaCl) and calcium hydroxide ($Ca(OH)_2$).

27 fruits with 4-5cm stalk were de-sapped and dipped immediately in 1% table salt for 5 minutes. Fruits were then washed in water. These treatments were repeated with 5% table salt, 0.5% and 1% $Ca(OH)_2$.

Treatment 2: Dipping and washing in water after sap collection.

27 fruits with 4-5cm stalk were harvested and sap was collected carefully in a glass ware. Then these fruits were throughly washed in water.

All treated fruits in treatment 1 and 2 were allowed for normal ripening under ambient conditions (28-34ºC & 65- 80% RH).

Sap management dynamic: Over 300 fruits with 4-5cm stalk were used for these treatments.

Stalks of 12 fruits (3 replicates) were removed carefully after harvest and placed stalk upwards in cardboard cartons to allow sap to run down the surface of fruit. These stalk removal procedures were repeated for first, second, third, fourth, fifth, sixth, seventh, eighth and ninth day of storage. These fruits were also allowed normal ripening under ambient conditions (28-34ºC & 65- 80% RH).

Measurement of quality parameters after ripening: Severity of sap burn injury of treatments was assessed using scoring method described in quantitative assessment of sap burn.The marketability of fruits was determined by the percentage of fruits which were suitable for the market with good external colour, appearance, minimum incidence of disease and eating quality ≤ 2. Eating quality was determined by a taste panel consists of 15 members with scores such as as 1-Excellent, 2- Very good, 3- Good, 4- Poor, 5- Bad (Krishnapillai, 1997). Selected treatments were repeated twice to determine marketability.

Penetrometer was used to measure firmness. Juice was prepared by squashing mesocarp of fruit and filtering through a muslin cloth. Total soluble solids of mango juice were measured directly by hand held refractometer (Krishnapillai,1997; AOAC,1990). pH meter was used to measure pH of pulp. Skin colour (For Karuthakoluman, 'Ambalavi' and 'Chembaddan' 1-Dark green, 7- orange and for 'Willard' 1- Dark green and 7- dark yellow with red) was assessed by scoring method (Krishnapillai, 2004). Internal flesh break down was judged on longtitudially cut section as 0= no break down, and 5=severe break down (Hofman *et al*., 1997).

Statistical analysis: The experimental design for treatments of four mango cultivars was Completely Randomized Design (CRD) since harvesting season of these mangoes was not similar. Data were subjected to descriptive statistics and analysis of variance using Minitab Release15.

Results

The marketability of mangoes is directly correlated with the postharvest quality of fruits. The popular 'Karuthakolumban' cultivar was the most seriously affected by sap burn and 'Chembaddan' and 'Ambalavi' mangoes were less susceptible to sap burn injury (Tables 1 & 2).

Sap burn control: Sap burn control treatments in Table 2 were selected from preliminary trials in the department of botany and these methods are suitable for home garden growers and small farm owners. Queensland department of primary industries in Australia has recommended several methods to reduce sap burn injury and successfully controlled sap burn injury at commercial level (Brown & Bagshaw, 1997).

Figure 1 clearly showed that no sap exudation was observed on first day of storage in 'Ambalavi' and 'Chembaddan' mangoes while it was 5th and 6th day in 'Karuthakolumban' and 'Willard' cultivars. Skin damage starts when exudates sap becomes in contact with fruit peel during harvest, producing browning and necrosis around lenticels (Holmes *et al*., 1993). Sap burn was the cause of skin damage and poor colour development. Soil particles were also observed to be attracted by sap due to its sticky nature.

The most popular dessert mango cultivars 'Karuthakolumban' and 'Willard' were found to be susceptible to sap injury (Table 1). Table 2 showed that 1% table salt and 0.5% $Ca(OH)_2$ treatment was effective in controlling sap burn in 'Willard', 'Chembaddan' and 'Ambalavi' mangoes whereas 5% table salt and 1% Calcium hydroxide treatments were efficient for 'Karuthakolumban' mangoes. No sap burn injury was observed on 6th, 5th,1st and 1st day of stalk removal in 'Karuthakolumban', 'Willard', 'Ambalavi' and 'Chembaddan' mangoes respectively. No internal disoders (flesh breakdown) was observed in all treatments.

Table 1. Fruit characteristics and sap burn injury of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes.

Fruit/sap burn	KK	Will	Amb	Che
Fruit weight (g) (Mean ± SE)	399.5 ± 2.63	267.9 ± 1.93	309.9 ± 1.19	209.4 ± 1.45
Storage life (days)	9	7	8	8
Colour after ripening	Dark yellow with green patches	Dark yellow with red	Orange	Dark yellow with green patches
Sap injury	Moderate –severe	Slight- Moderate	Slight	Slight
Sap injury score	4	2	1	1

[a]0 = No injury, 1 = 0 - 4% injury (slight), 2= 5-9% (Slight- moderate), 3 =10-14% injury (moderate), 4=15-25% injury (moderate – severe), 5 = Sap injury more than 25% of total area (severe)

Table 2. Effect of different treatments on sap burn injury score[a] (Median value) and appearance for marketing of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes after ripening.

Treatments	Sap burn score				Appearance
	KK	Will	Amb	Che	
Control	3	2	1	1	Not good
1% table salt	1	0	0	0	Good except KK
5% table salt	0	0	0	0	Good
0.5% $Ca(OH)_2$	1	0	0	0	Good except KK
1% $Ca(OH)_2$	0	0	0	0	Good
Sap collection and wash in water	0	0	0	0	Good
Sap management dynamics.	0	0	0	0	Good
Stalk removal on					
1st day	2	2	0	0	
2nd day	2	2			
3rd day	2	1			
4th day	1	1			
5th day	1	0			
6th day	0				

[a]0 = No injury, 1 = 0 - 4% injury (slight), 2= 5-9% (Slight- moderate), 3 =10-14% injury (moderate), 4=15-25% injury (moderate – severe), 5 = Sap injury more than 25% of total area (severe)

None of the control fruits was suitable for marketing since the skin was damaged by sap and showed poor external appearance (Table 2 & Fig. 2). There was no significant differences (P=0.05) observed in marketability of different sap control treatments. Marketability of all treated fruits were almost similar in each mango cultivars where Ambalvi mangoes showed higher % (90.53%) of marketability (Table 3).

Total soluble solid (TSS) and pH of of all 4 mango cultivars were in between 19.90 - 23.76 °Brix and 4.93 - 5.26 respectively. 'Willard' mangoes had highest TSS and KC mangoes showed lowest pH (Tables 4 & 5). Quality parameters in terms of Marketability, TSS and pH in Table 4, 5 & 6 were not showed significant relationshiop (P=0.05) between treatments. Similar colour development was observed in all treated and control mangoes. Green colour was gradually changed and finally reached dark yellow with red in 'Willard' and orange in 'Ambalavi' mangoes. 'Karuthakolumban' and 'Chembaddan' mangoes were dark yellow colour with green patches after ripening (Table 1). There was no significant difference (P=0.05) observed in firmness of treated and control fruits. 'Karuthakolumban' showed highest firmness while 'Willard' had lowest value.

Discussion

Sap injury was most severe in 'Karuthakolumban' mangoes and less in 'Chembaddan' and 'Ambalavi' mangoes (Table 1 & 2). The extent of sap burn injury vary from cultivar to cultivar, harvesting conditions, growing regions, age of trees, season of harvest and maturity of fruit (Lim & Kuppelweiser, 1993). In this study all four mango cultivars were sourced from a home garden where trees were grown under similar management practices.

When sap injured fruit came into contact with soil, it was easily infected with *Aspergillus* due to susceptibility of *Aspergillus* to the areas where sap injury has occurred (Johnson *et al*., 1997). *Aspergillus* rot on mangoes has been reported first time in Sri Lanka in 2013 (Krishnapillai & Wijeratnam, 2013). This clearly indicates the significance of sap burn control not only to minimize postharvest disorder but also postharvest rot of mangoes.

The appearance of skin around lenticels changed immediately after sap exudation and showed typical symptoms of early sap burn injury within 2 days in all four mango cultivars. Sap burn injury occurred when the oil fraction containing volatile components came in contact with the skin, resulting in tissue damage and subsequent enzymic browning (Loveys *et al*., 1992). 'Chembaddan' and 'Ambalavi' mangoes were harvested at proper physiological maturity stage with 5cm stalk and stalk removal was done the following day. No latex exudation was observed when stalk was broken. Thus sap management dynamics was very efficient method to control sap burn injury in 'Chembaddan' and 'Ambalavi' mangoes (Table 2). Stalk removal on fifth and sixth days after harvest was effective in 'Karuthakolumban' and 'Willard' mangoes respectively and no latex exudates was observed during stalk removal (Fig. 1). It was not possible to keep these mangoes for 5 - 6 days without marketing. Thus chemical treatments or careful removal of stalk and wash in water after sap collection were necessary for control of sap burn injury in 'Karuthakolumban' and 'Willard' mangoes.

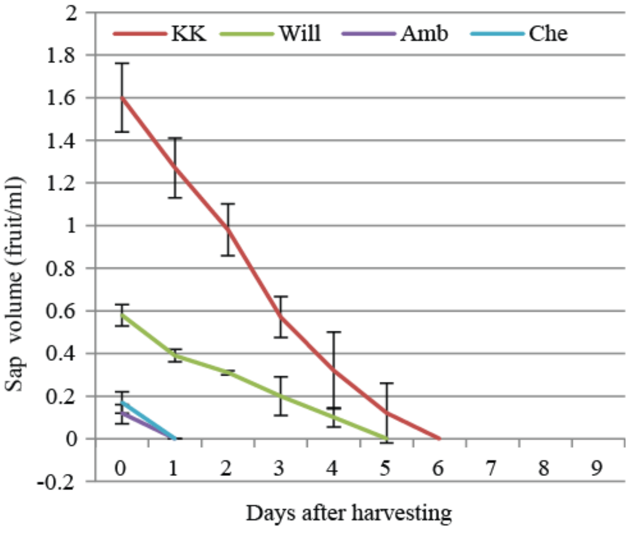

Fig. 1. Effect of stalk removal on sap volume of CV 'Karuthakolumban' (KK), 'Willard', 'Ambalavi' and 'Chembaddan' (Error Bars indicate standard errors of means).

De-stemming and dipping fruits in sodium chloride and calcium hydroxide were effective in reducing sap burn injury in all four mango cultivars used in this study (Table 2). These two compounds were generally considered as safe (GRAS) compounds with the recommendaion of US Food and Drug administration (www.fda.gov). Calcium compounds have shown quality retention of fruits through maintaining firmness, reducing respiratory rate, ethylene production (Poovaiah, 1986) and decreasing storage rots (Paliyath *et al*., 1984). However sodium chloride is superior to calcium hydroxide due to no milky appearance, cheap and freely available in all households compared to calcium hydroxide. De-stemming and dipping fruits in 5% Sodium Chloride (table salt) and 1% Calcium hydroxide were observed to be effective in reducing sap burn injury in 'Karuthakolumban' mangoes whereas 1% table salt and 0.5% Calcium hydroxide succeessfully reduce sap burn injury in other three mango cultivars without affecting quality (Tables 3, 4, 5 & 6). Maqbool *et al*. (2008) in Pakistan reported similar observations that mangoes de-stemmed under calcium hydroxide showed better results against sap burn injury in both 'Chausa' and 'Sindu' cultivars. O'Hare (1994) in Australia reported that several systems of de-sapping for reducing damage includes de-sapping in a 1% solution of calcium hydroxide. Barman *et al.* (2015) reported that 1% NaOH was highly effective in reducing sap burn in 'Chausa' mangoes compared to alum and $Ca(OH)_2$. Since the mango sap is acidic in nature, destalking the fruit in a basic solution will neutralize the exuded sap and reduce injury.

Mango fruit quality should be maintained for high economic returns. Internal and external quality parameters were determined to find treatment effect on fruit quality. Taste is a balance between total soluble solids and acidity (Shashirekha & Patwardhan, 1976). There was no significant difference (P=0.05) observed on Total soluble solids and pH of treated mangoes (Tables 4 & 5). External parameters skin colour, appearance and firmness were also not affected by treatments. Marketability of all treated mangoes were not shown significance difference among the treatments at P=0.05 (Table 3). Fruits used to quantify sap burn injury without any treatment were used as controls to compare sap burn injury.

Sap injured mangoes were not acceptable for consumers – particularly with respect to export market (Sap injury score = 0) and domestic super markets (Sap injury score < 2). Thus mangoes washed in water after sap collection were used as control for fruit quality comparison since wash in water after sap collecion and air drying were standard practice in postharvest laboratory experiments.

De-sapping machines are used in Australia to remove latex. Fruits are placed stem end down between the bars and a fine mist of water sprayed over the top of the fruit to help to remove any sap on the skin (Brown & Bagshaw, 1997). Applying polyethylene based wax surface coatings to mango fruit prior to de-sapping reduced sap burn without adversely affecting colour development (Shorter & Joyce, 1994). These high cost practices are not suitable for small scale mango production. Postharvest losses are high in Jaffna due to improper handling of mangoes. Thus this study recommends low cost environmentally friendly procedures to minimize losses and these recommendations have to be implemented to reduce postharvest losses of mangoes.

Fig. 2. External appearance of sap injured 'Karuthakolumban' and 'Willard' mangoes.

Table 3. Effect of treatments on fruit quality (% Marketability or acceptability, Mean±SE) of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes after ripening.

Treatments	KK	Will	Amb	Che
Table salt (5% for KK & 1% for other)	80.60 ± 0.40a	76.54 ± 0.72b	90.11 ± 0.71c	79.42 ± 0.41d
$Ca(OH)_2$ (1% for KK & 0.5% for others)	80.20 ± 0.69a	75.70 ± 1.12b	89.29 ± 1.09c	79.01 ± 0.71d
Sap collection and wash in water	81.83 ± 0.43a	76.54 ± 0.72b	90.53 ± 0.41c	79.83 ± 1.09d
Sap management dynamic	81.43 ± 0.72a	77.77 ± 0.70b	90.11 ± 0.71c	80.24 ± 0.71d

Means with the same letters along the raw are not significantly different at P=0.05

Table 4. Effect of treatments on Total soluble solids (ºBrix, Mean±SE) of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes after ripening.

Treatments	KK	Will	Amb	Che
Table salt (5% for KK & 1% for other)	22.17 ± 0.08a	23.26 ± 0.18b	23.17 ± 0.07c	19.90 ± 0.06d
$Ca(OH)_2$ (1% for KK & 0.5% for others)	22.20 ± 0.15a	23.54 ± 0.07b	22.30 ± 0.06c	19.97 ± 0.07d
Sap collection and wash in water	22.46 ± 0.14a	23.64 ± 0.08b	22.13 ± 0.03c	20.03 ± 0.09d
Sap management dynamic	22.30 ± 0.17a	23.76 ± 0.07b	22.23 ± 0.03c	20.03 ± 0.07d

Means with the same letters along the raw are not significantly different at P=0.05

Table 5. Effect of treatments on pH (Mean±SE) of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes after ripening.

Treatments	KK	Will	Amb	Che
Table salt (5% for KK & 1% for other)	5.13 ± 0.09a	4.93 ± 0.03b	5.00 ± 0.06c	5.10 ± 0.06d
$Ca(OH)_2$ (1% for KK & 0.5% for others)	5.23 ± 0.12a	5.06 ± 0.03b	4.97 ± 0.03c	4.93 ± 0.08d
Sap collection and wash in water	5.26 ± 0.12a	5.06 ± 0.06b	5.10 ± 0.03c	5.03 ± 0.06d
Sap management dynamic	5.20 ± 0.06a	5.06 ± 0.03b	5.10 ± 0.05c	5.03 ± 0.07d

Means with the same letters along the raw are not significantly different at P=0.05

Table 6. Effect of treatments on firmness (kPa, Mean±SE) of 'Karuthakolumban' (KK), 'Willard' (Will), 'Ambalavi' (Amb) and 'Chembaddan' (Che) mangoes after ripening.

Treatments	KK	Will	Amb	Che
Table salt (5% for KK & 1% for other)	1.96 ± 0.51a	0.98 ± 0.02b	1.30 ± 0.03c	1.40 ± 0.03d
$Ca(OH)_2$ (1% for KK & 0.5% for others)	1.90 ± 0.03a	0.92 ± 0.02b	1.26 ± 0.04c	1.42 ± 0.04d
Sap collection and wash in water	1.86 ± 0.03a	0.84 ± 0.03b	1.22 ± 0.04c	1.30 ± 0.03d
Sap management dynamic	1.86 ± 0.04a	0.88 ± 0.04b	1.30 ± 0.03c	1.32 ± 0.04d

Means with the same letters along the raw are not significantly different at P=0.05

Conclusions

This study recommends proper low cost sap management practices for reducing postharvest loss in terms of sap burn. Local popular mango cultivars should be harvested with 4-5cm stalk to minimize sap burn. Common method for all four cultivars was collection of latex carefully after stalk removal and washing fruits thoroughly in water. However it needs high labour cost and time. Control of sap burn in mango could be managed via the application of latex/sap dynamics in 'Ambalavi' and 'Chembaddan' mangoes. De-stemming and dipping fruits in 5% sodium Chloride (table salt) was observed to be effective in reducing sap burn injury in 'Karuthakolumban' mangoes whereas 1% table salt succeessfully reduce sap burn injury in 'Willard' mangoes without affecting quality. Thus the mango growers obtain better income from their crop and consumers will benefit from the availability of good quality mangoes in markets.

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