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Effect of time of harvesting and post-harvest treatments on physical characteristics of sap burn damage of mango (*Mangifera indica* L.) cv. Dashehari in Telangana state

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Abstract
The present investigation on the "Studies on the Effect of Time of Harvesting and Post-Harvest Treatments on Physical Characteristics of Sap Burn Damage of Mango (*Mangifera indica* L.) cv. Dashehari in Telangana State" was conducted at the Centre of Excellence in Mulugu, Siddipet district, during the *summer*- 2024. This experiment laid in a Factorial Completely Randomized Design with two main factors: Harvesting time (Morning, Afternoon and Evening) and Post-harvest treatments (Lime, Alum, Baking soda, Garlic and *Aloe vera* Extracts), resulting in eighteen treatment combinations, each replicated thrice. Results indicated that morning-harvested fruits recorded the highest sap content (1.65 ml). All treatments display zero sap burn injuries, except for the control (non-treated) afternoon harvest (H_2P_6), which exhibited a significant injury score of 3.71 showing the highest severity at 72 hours. Fruit firmness and shelf life, the combination of morning harvest with *Aloe vera* extract @ 1% (H_1P_5) showed the highest firmness (3.50 kg/cm²) and longest shelf life (13.67 days). H_1P_5 (*Aloe vera* extract @ 1%) consistently displayed the least spoilage on the 9th (33.33%), 12th DAH (73.33%) and exhibited the highest marketability (26.67%) by the 12th DAH across all harvesting times.

Keywords: Sap burn, harvesting times, post-harvest treatments, spoilage percentage, marketability percentage, *Aloe vera* extract and garlic extract

1. Introduction
Mango (*Mangifera indica* L.) is among the most significant fruit crops globally and in India, belonging to the family Anacardiaceae with a chromosome number of 2n = 40, cultivated across the tropics and subtropics. Mango is the most significant fruit crop in terms of production, marketing and consumption (Tharanathan *et al*., 2006) [20].

Mango, renowned for its exceptional taste, delightful fragrance and health benefits, is often referred to as the "King of Fruits." Its vibrant colours and sweetness have earned it a prominent place in the global market. Additionally, the mango tree is the national tree of Bangladesh and the official fruit of India, Pakistan and the Philippines (Bally, 2006) [4].

The area under mango cultivation in India is about 2.332 million hectares, with a production of approximately 20.927 million metric tonnes. Specifically, in Telangana, the area dedicated to mango cultivation spans about 0.122 million hectares, yielding a production of around 0.955 million metric tonnes (Anonymous, 2022) [3].

Mangoes are cherished for their delicious flavour, nutrient density and appealing texture, making them a healthy choice. A 100 g serving of ripe mango contains 83.46-86.70% moisture, along with essential nutrients such as 0.82 g protein, 16 g carbohydrates and significant vitamins like A and C. Remarkably, a single fruit can fulfil up to 40% of daily dietary fibre requirements (Chandra and Chandra, 1997) [8].

As a perishable fruit, mangoes are prone to various postharvest issues, including diseases and disorders, which diminish their value during storage (Reddy, 2022) [18]. Among different postharvest problems, sap burn or sap injury in mango is a major industry concern, as it results in poor fruit quality, lower prices and promotes microbial infection, due to the presence of

nutrient materials like carbohydrates, protein and vitamins (Bosquez *et al*., 2000) [6]. Mangoes are typically harvested at maturity before they reach full ripeness. During this process, a sticky sap exudes from the stem at the abscission zone, leading to sap injury (Negi *et al*., 2002) [14]. This damage diminishes the fruit's cosmetic appeal and quality, ultimately reducing consumer acceptance and shelf life, which can result in significant economic losses (Amin *et al*., 2008) [2].

The sap is highly acidic with a pH of 4.3. Sap is a colloidal suspension that can appear white-milky, yellow-brown, yellow-orange or colourless. It primarily flows after the peduncle is detached, leading to unsightly spots on the mango skin. (John *et al*., 2003) [10].

Sap burn intensity and quantity are influenced by factors such as cultivar, production location, tree nutrition, water relations, tree age, fruit maturity and harvesting conditions. Variations in sap exudation are affected by cultivar, maturity and production area (Saby John *et al*., 1999) [22]. One of the major quality concerns for mango producers and exporters is sap burn or sap injury. Presently, India loses about 30% of its total production due to this problem.

To effectively manage sap burn injury, it is crucial to understand the post-harvest losses associated with sap burn across various local varieties. This highlights the need for a standardized de-sapping technique to improve fruit quality and enhance market opportunities for farmers. Consequently, a study was conducted to investigate the effects of harvesting time and post-harvest treatments on the physical properties of sap burn damage in Dashehari mango (*Mangifera indica* L.) in Telangana state.

2. Material and Methods

2.1 Experimental material

Mango fruits cv. Dashehari were collected from the COE fruit orchard. The fruits were harvested based on maturity indices, specifically 84-90 days after fruit set and the opening of lenticels.

2.2 Selection of fruits for the experiment and method of treatment

The fruits were harvested at three different times of the day, morning (7 AM), afternoon (noon) and evening (5 PM) at full maturity. The fruits were hand-picked to avoid mechanical injuries, only firm, uniform and blemish-free fruits were selected. In the first step, fruits were randomly chosen from the experimental site at different harvesting times in a day. After harvesting, the fruits were immediately placed in an inverted position on the beaker to collect sap, which was measured using graduated syringes and measuring cylinders. In the second step, twenty fruits per treatment subjected to the post-harvest treatments for 5 to 10 minutes, were gently rubbed with a cloth and packed for ripening at room temperature. The control group used traditional harvesting methods.

2.3 Post-harvest treatments

The post-harvest treatments used in the experiment included Lime (*Calcium oxide*), Alum (*Potassium aluminium* sulfate), Baking soda (Sodium bicarbonate), Garlic extract and *Aloe vera* extract. The analytical-grade treatments (except for garlic and *Aloe vera* extracts) were purchased from standard Indian Chemical Companies. Garlic and *Aloe vera* extracts were prepared naturally.

2.4 Preparation of treatment solutions and extracts

1% lime solution was made by dissolving 1 gram of lime in 100 ml of water and then scaling it up to 15 litres by adding 150 grams of lime. Similarly, 1% alum solution was prepared by the same procedure. For the baking soda solution, 0.1% concentration was created by dissolving 1 gram in 1 litre of water, with 15 grams added to make a total of 15 litres. To prepare garlic extract, fresh, fully mature garlic cloves were peeled, sterilized in distilled water for 15 minutes and air-dried at 27 ± 2°C. Approximately 500 g of these cloves were blended with 500 ml of sterile distilled water, then filtered through sterile cheesecloth and Whatman filter paper (No. 1) to obtain the garlic extract, which was stored at 4 °C at a 100% concentration until further use. *Aloe vera* gel was prepared using the Fresh, disease-free leaves collected and the outer cortex was removed to access the parenchyma. This gel matrix was then blended to create a smooth, mucilaginous gel, filtered to remove fibrous material before use.

2.5 Experimental Design and Application of Post-Harvest Treatments

The experiment was carried out in a Factorial Controlled Randomized Design (FCRD) with two factors *viz.*, Time of harvesting (H_1: Morning; H_2: Afternoon; H_3: Evening) and Post-harvest treatments (P_1: Lime @ 1%; P_2: Alum @ 1%; P_3: Baking soda @ 0.1 %; P_4: Garlic extract @ 1 %; P_5: *Aloe vera* extract @ 1 %; P_6: Control, without any treatment) comprise eighteen (18) treatment combinations replicated thrice *i.e.* H_1P_1: (Morning harvest + Lime @ 1%, H_1P_2: (Morning harvest + Alum @ 1%), H_1P_3: (Morning harvest + Baking soda @ 0.1%), H_1P_4: (Morning harvest + Garlic extract @ 1%), H_1P_5 (Morning harvest + *Aloe vera* extract @ 1%), H_1P_6: (Control without any treatment), H_2P_1: (Afternoon harvest + Lime @ 1%, H_2P_2: (Afternoon harvest + Alum @ 1%), H_2P_3: (Afternoon harvest + Baking soda @ 0.1 %), H_2P_4: (Afternoon harvest + Garlic extract @ 1%), H_2P_5: (Afternoon harvest + *Aloe vera* extract @ 1%), H_2P_6: (Control without any treatment). H_3P_1: (Evening harvest + Lime @ 1%, H_3P_2: (Evening harvest + Alum @ 1%), H_3P_3: (Evening harvest + Baking soda @ 0.1%), H_3P_4: (Evening harvest + Garlic extract @ 1%), H_3P_5: (Evening harvest + *Aloe vera* extract @ 1%), H_2P_6: (Control without any treatment).

Physiological mature stage fruits of mango cv. Dashehari of uniform size were directly picked from the experimental site, allowing the sap to flow on the fruits. These sap-flown fruits were immersed in the solution for 5- 10 minutes, following which they were wiped with a cloth and transferred to corrugated boxes for ripening at room temperature.

2.6 Evaluation of Physical Characteristics

2.6.1 Estimation of Sap content (ml)

Fruits were harvested using traditional methods without pedicels in the morning, afternoon and evening. Immediately after harvesting, the fruits were placed upside down in measuring cylinders to collect and measure sap using graduated syringes.

2.6.2 Assessment of Sap burn injury score (0-4, No injury to severe)

The sap burn injury score was recorded during storage and damage was assessed from 0 to 4 depending on the injury level [0= no injury, 1= very mild (injury area < 1 cm^2), 2 = mild (injury area > 1 < 2 cm^2), 3= moderate (injury area > 2 < 4 cm^2), 4= severe (injury area > 4 cm^2)] (Brown *et al.*, 1986) [7].

2.6.3 Assessment of Shelf-life (Days)

The shelf life of the fruit was measured from harvesting until spoilage occurred, determined by counting the days it remained in good condition. The end of shelf life was recorded when spoilage exceeded 50%, marking the conclusion of the storage period (Padmalatha, 1995) [16].

2.6.4 Assessment of Marketability Percentage

The number of visibly sound and healthy fruits was counted and expressed as a percentage of the total harvest at 3-day intervals

starting from the 6th day after harvest (DAH). Marketability percentage indicates the proportion of the harvest that meets market standards and is calculated by determining the total fruit harvest, assessing the number of marketable fruits and then calculating the marketability percentage.

2.6.5 Assessment of Spoilage Percentage

The percentage of spoiled fruits in each replication was assessed through visual observations at 3-day intervals starting from the 6th day after harvest. Key indicators included shrivelling, fungal infections leading to rotting, over-ripening with splitting and browning or discolouration of the fruits.

2.6.6 Measurement/ Determination of Fruit Firmness (kg/cm^2)

The firmness of the fruits was recorded by measuring the penetration force using a penetrometer (Fruit pressure tester mod. FT 327).

2.7 Statistical analysis

The design adopted was completely randomized design with a factorial concept and the data were subjected to statistical analysis as per the procedure outlined by Panse and Sukhatme (1985) [17].

3. Results

3.1 Sap content (ml)

Significant differences were observed in sap content (ml) among the fruit harvested at different times of day summarized in Table 1 and graphically depicted in Figure 1. H_1- Morning harvested fruits (6:00 AM) exhibited a higher sap flow (1.65 ml) than those harvested at H_2- Afternoon harvested fruits (1.01 ml) and in the H_3- Evening (5:00 PM) (1.22 ml). This might be explained by increased turgor pressure in the fruits and pedicel resinous canal in the early morning). As the day progresses and temperatures rise, the fruit transpires more and releases less sap overall. The above results are under the findings of Maqbool *et al.* (2007) [11] and Barman *et al.* (2015) [5] in mango.

Table 1: Effect of time of harvesting on Sap content (ml) of mango cv. Dashehari.

Time of harvesting (H)	Sap content (ml)
Morning (H_1)	1.65
Afternoon (H_2)	1.01
Evening (H_3)	1.22
SE(m)	0.016
C.D at 5 %	0.066

3.2 Sap burn injury score

The results of the sap burn injury severity scores (ranging from 0 to 4, from no injury to severe) showed significant differences during different timing of harvesting and post-harvest treatments, presented in Table 2 and illustrated in Figure 2. The study evaluated the effectiveness of post-harvest treatments in minimizing fruit injury across H_1- Morning, H_2- Afternoon and H_3- Evening. Remarkably, all treatments in each harvest session, including P_1- (Lime @ 1 %), P_2- (Alum @ 1 %), P_3- (Baking Soda @ 0.1) %, P_4- (Garlic extract @ 1 %) and P_5- (*Aloe vera* extract @ 1 %) consistently displayed zero sap burn injury scores. In contrast, P_6- (Control- non-treated fruits) exhibited sap burn injury scores in H_1- Morning (1.53), H_2- Afternoon (3.71) and H_3- Evening (1.90), showing the maximum severity at 72 hours. This might be due to the higher daytime temperature increasing transpiration from mango fruit, reducing sap water concentration. This may have elevated terpinolene oil levels and deteriorating sap burn severity. Similar results were found by Maqbool *et al.* (2007) [11] in mango.

Table 2: Effect of time of harvesting and post-harvest treatments on Sap burn injury score (0-4, No injury to severe) of mango cv. Dashehari

Sap burn injury score							
Time of harvest	**Post-harvest treatment**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Mean H**
H_1	0.00	0.00	0.00	0.00	0.00	1.53^c	0.32^b
H_2	0.00	0.00	0.00	0.00	0.00	3.71^a	0.62^a
H_3	0.00	0.00	0.00	0.00	0.00	1.90^b	0.25^b
Mean P	0.00	0.00	0.00	0.00	0.00	2.38	
	Factor H			Factor P			H x P
S.Em ±	0.029			0.041			0.071
CD at (5%)	0.083			0.117			0.203

Factor 1: Time of harvesting (H)	**Factor 2: Post-harvest treatments (P)**
H_1 – Morning (6 AM)	P_1 – Lime @ 1 %
	P_2 – Alum @ 1 %
H_2 – Afternoon (12 PM)	P_3 – Baking Soda @ 0.1 %
	P_4 – Garlic Extract @ 1 %
H_3 – Evening (5 PM)	P_5 – *Aloe vera* Extract @ 1 %
	P_6 – Control (non-treated fruits)

3.3 Shelf life (Days)

The analysis of the recorded data reveals that significant differences were observed in shelf life across different times of harvesting and post-harvest treatments during the experiment. However, no significant differences were observed in the interaction effect, as presented in Table 3 and graphically represented in Figure 3. H_1- Morning harvested fruits showed the longest shelf life (11.28 days) which was on par with H_3- Evening harvested fruits (11.00 days). The shortest shelf life (10.44 days) was recorded in the H_2- Afternoon harvested fruits. Among the various post-harvest treatments, P_5- *Aloe vera* extract @ 1 % treatment recorded the longest shelf life of (12.56 days) followed by the P_4- Garlic extract @ 1 % (11.89 days) which is closely followed by P_1- Lime @ 1 % treatment (11.11 Days). P_6- Control (non-treated fruits) recorded the shortest shelf life (8.78 days).

Morning harvested fruits exhibited an extended fruit shelf life, likely due to cooler temperatures and reduced enzymatic activity that delayed ripening. In contrast, higher daytime temperatures increased transpiration, lowering water concentration and reducing shelf life.

Among the post-harvest treatments, *Aloe vera* extract @ 1% showed the longest shelf life. This might be a result of *Aloe vera* gel has been reported to modify the internal atmosphere of storage fruits and vegetables thereby prolonging their shelf life (Valverde *et al*., 2005) [21]. This study's findings align with Embuscado and Huber (2018) [9], who noted that *Aloe vera* extracts prevent moisture loss by regulating the gaseous exchange of oxygen, carbon dioxide and ethylene involved in respiration. The prevention of moisture loss by controlling respiration in this present study slowed down the mango fruit metabolism in coated fruits thereby delaying the ripening showing extended shelf life.

Table 3: Effect of time of harvesting and post-harvest treatments on Shelf-life (Days) of mango cv. Dashehari.

Shelf-life (Days)							
Time of harvesting	**Post-harvest treatments**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Mean H**
H_1	11.33	10.33	10.67	12.33	13.67	9.33	11.28^{a}
H_2	10.67	10.00	10.67	11.33	11.67	8.33	10.44^{b}
H_3	11.33	10.67	11.00	12.00	12.33	8.67	11.00^{a}
Mean P	11.11^{c}	10.33^{de}	10.78^{cd}	11.89^{b}	12.56^{a}	8.78^{e}	
	Factor H			Factor P			H x P
S.Em ±	0.124			0.176			0.304
CD at (5%)	0.356			0.504			NS

Note: Values with the same letters are not significantly different

Factor 1: Time of harvesting (H)	**Factor 2: Post-harvest treatments (P)**
H_1 – Morning (6 AM)	P_1 – Lime @ 1 %
	P_2 – Alum @ 1 %
H_2 – Afternoon (12 PM)	P_3 – Baking Soda @ 0.1 %
	P_4 – Garlic Extract @ 1 %
H_3 – Evening (5 PM)	P_5 – *Aloe vera* Extract @ 1 %
	P_6 – Control (non-treated fruits)

3.4 Marketability (%)

The data concerning the marketability percentage at three intervals *i.e.* 6th, 9th and 12th observed significant variations at different times of harvesting and post-harvest treatments during the experiment is presented in Table 4 and demonstrated in Figure 4.

On the 6th day of storage, morning-harvested fruits showed the highest marketability (87.78%), closely followed by evening fruits (86.67%), while afternoon fruits showed the lowest marketability (84.44%). Post-harvest treatments with *Aloe vera* extract, lime and garlic extracts displayed the highest marketability (93.33%, 93.33% and 91.11%, respectively), compared to the control (non-treated fruits) (68.89%). By the 9th day, morning fruits with *Aloe vera* extract exhibited the highest marketability at 51.11%, while the control (non-treated fruits) dropped to 11.11%. On the 12th day, morning fruits maintained the highest marketability (13.33%), with *Aloe vera* treatment showing 26.67%, while control (non-treated fruits) showed a complete loss of marketability.

The high marketability of fruits treated with aloe and garlic extracts is due to their effectiveness in reducing spoilage rates. *Aloe vera* extract, rich in polysaccharides, forms a protective barrier against moisture and oxygen, key factors in fruit deterioration (Misir et al., 2014) [12]. Similarly, garlic's ethanolic extract containing allicin acts as a potent natural fungicide, mitigating fungal diseases that commonly affect fruits (Mondal et al., 2011) [13]. These treatments extend shelf life by slowing respiration and maintaining cell integrity, also minimizing enzymatic degradation, reducing sap burn injuries and keeping fruits visually appealing and marketable for longer.

Table 4: Effect of time of harvesting and post-harvest treatments on Marketability (%) of mango cv. Dashehari.

Marketability (%)							
Marketability at 6th DAH							
Time of harvest	**Post-harvest treatment**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Mean H**
H_1	93.33^{a}	86.67^{b}	86.67^{b}	93.33^{a}	93.33^{a}	73.33^{d}	87.78^{a}
H_2	93.33^{a}	86.67^{b}	80.00^{c}	86.67^{b}	93.33^{a}	66.67^{e}	84.44^{b}
H_3	93.33^{a}	86.67^{b}	86.67^{b}	93.33^{a}	93.33^{a}	66.67^{e}	86.67^{a}
Mean P	93.33^{a}	86.67^{b}	84.44^{b}	91.11^{a}	93.33^{a}	68.89^{c}	
	Factor H			Factor P			H x P
S.Em ±	0.582			0.823			1.425
CD at (5%)	1.669			2.36			4.088
	Marketability at 9th DAH						
Time of harvest	Post-harvest treatment						
	P_1	P_2	P_3	P_4	P_5	P_6	Mean H
H_1	60.00^{b}	46.67^{d}	53.33^{c}	60.00^{b}	66.67^{a}	20.00^{g}	51.11^{a}
H_2	53.33^{c}	40.00^{e}	33.33^{f}	53.33^{c}	60.00^{b}	6.67^{h}	41.11^{c}
H_3	53.33^{c}	46.67^{d}	40.00^{e}	53.33^{c}	66.67^{a}	6.67^{h}	44.44^{b}
Mean P	55.56^{b}	44.44^{c}	42.22^{d}	55.56^{b}	64.44^{a}	11.11^{e}	
	Factor H			Factor P			H x P
S.Em ±	0.36			0.51			0.883
CD at (5%)	1.033			1.462			2.532
	Marketability at 12th DAH						
Time of harvest	Post-harvest treatment						
	P_1	P_2	P_3	P_4	P_5	P_6	Mean H
H_1	13.33^{c}	6.67^{d}	13.33^{c}	20.00^{b}	26.67^{a}	0	13.33^{a}
H_2	13.33^{c}	6.67^{d}	6.67^{d}	20.00^{b}	26.67^{a}	0	12.22^{b}

H_3	13.33^c	6.67^d	6.67^d	20.00^b	26.67^a	0	12.22^b
Mean P	13.33^c	6.67^e	8.89^d	20.00^b	26.67^a	0	
	Factor H			Factor P			H x P
S.Em ±	0.097			0.137			0.238
CD at (5%)	0.279			0.394			0.683

3.5 Spoilage (%)

The data concerning the spoilage percentage at three intervals *i.e.* 6th, 9th and 12th days after harvesting (DAH) noticed significant variations at different times of harvesting and post-harvest treatments during the experiment presented in Table 5 and illustrated in Fig 5. On the 6th day of storage, morning-harvested fruits showed the lowest spoilage (11.11%), while afternoon-harvested fruits had the highest (5.56%). *Aloe vera*, garlic, and lime treatments significantly reduced spoilage, with the control group experiencing the highest (24.44%). By the 9th day, morning fruits with *Aloe vera* had the lowest spoilage (33.33%), while afternoon and evening controls showed complete spoilage (100%). On the 12th day, morning and evening fruits with *Aloe vera* again recorded the least spoilage (73.33%), but all controls suffered total spoilage.

The reduced spoilage percentage observed in mangoes treated with Aloe extract @ 1 % followed by Garlic extract @ 1 % can be attributed to their ability to slow down the respiration rate, maintain cell integrity and decrease enzymatic degradation. *Aloe vera* extract primarily consists of polysaccharides that act as a natural barrier against moisture and oxygen, which are major agents responsible for the deterioration of fruits and vegetables (Misir *et al.*, 2014) [12]. While, the Garlic clove extracts contain biologically active fungicidal substances like allicin, which effectively control various fungal diseases affecting fruits (Mondal *et al.*, 2011) [13].

Table 5: Effect of time of harvesting and post-harvest treatments on spoilage (%) of mango cv. Dashehari.

Spoilage %							
Spoilage at 6th DAH							
Time of harvest	**Post-harvest treatment**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Mean H**
H_1	6.68^e	13.33^d	13.33^d	6.67^e	6.67^e	20.00^c	11.11^c
H_2	6.67^e	26.67^b	13.33^d	6.67^e	6.67^e	33.33^a	15.56^a
H_3	6.67^e	20.00^c	13.33^d	6.67^e	6.67^e	20.00^c	12.22^b
Mean P	6.67^d	20.00^b	13.33^c	6.67^d	6.67^d	24.44^a	
	Factor H			Factor P			H x P
S.Em ±	0.067			0.095			0.067
CD at (5%)	0.193			0.273			0.193
Spoilage at 9th DAH							
Time of harvest	Post-harvest treatment						
	P_1	P_2	P_3	P_4	P_5	P_6	Mean H
H_1	46.67^e	53.33^d	53.33^d	40.00^f	33.33^g	86.67^b	52.22^c
H_2	53.33^d	60.00^c	60.00^c	46.67^e	40.00^f	100.00^a	60.00^a
H_3	46.67^e	46.67^e	53.33^d	40.00^f	40.00^f	100.00^a	54.44^b
Mean P	48.89^d	53.33^c	55.56^b	42.22e	37.78^f	95.56^a	
	Factor H			Factor P			H x P
S.Em ±	0.405			0.573			0.992
CD at (5%)	1.162			1.643			2.845
Spoilage at 12th DAH							
Time of harvest	Post-harvest treatment						
	P_1	P_2	P_3	P_4	P_5	P_6	Mean H
H_1	80.00^d	86.67^c	86.67^c	80.00^d	73.33^e	100.00^a	84.44^c
H_2	86.67^c	100.00^a	93.33^b	86.67^c	80.00^d	100.00^a	91.11^a
H_3	80.00^d	93.33^b	93.33^b	80.00^d	73.33^e	100.00^a	86.67^b
Mean P	82.22^d	93.33^b	91.11^c	82.22^d	75.56^e	100.00^a	
	Factor H			Factor P			H x P
S.Em ±	0.484			0.685			1.186
CD at (5%)	1.388			1.963			3.4

3.6 Fruit Firmness (kg/cm^2)

Among the different times of harvesting and post-harvest treatments, significant differences were noted. However, no significant differences were observed in the interaction effect, presented in Table 6 and graphically depicted in Figure 6. H_1- Morning harvested fruits recorded the highest firmness (2.69 kg/cm^2) which was on par with H_3- Evening harvested fruits (2.67 kg/cm^2). The lowest firmness (2.60 kg/cm^2) was recorded in the H_2- Afternoon harvested fruits.

Among the post-harvest treatments (P), P_5- *Aloe vera* extract @ 1 % treatment recorded the highest firmness of (3.20 kg/cm^2) followed by P_4- Garlic extract @ 1 % treatment (2.85 kg/cm^2). P_6- Control (non-treated fruits) recorded the lowest firmness (2.15 kg/cm^2). Morning-harvested fruits exhibited the highest firmness, likely due to cooler temperatures that slow enzymatic activity related to cell wall degradation. Additionally, reduced metabolic activity in the morning limits the production of enzymes that contribute to fruit softening, helping to maintain firmness. These findings are consistent with Aguero *et al*. (2015) [1], reported that fruit firmness declines as daytime temperatures increase. *Aloe vera* extract is rich in polysaccharides, which may contribute to maintaining cell integrity, reducing enzymatic degradation of fruit tissues (Nicolau *et al.*, 2021) [15] *Aloe vera* gel extracts act as a physical barrier to water loss and respiration thus indicating effectiveness in maintaining fruit firmness.

Table 6: Effect of time of harvesting and post-harvest treatments on Fruit firmness (kg/cm^2) of mango cv. Dashehari.

Fruit firmness (kg/cm^2)							
Time of harvesting (H)	**Post-harvest treatments**						
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**Mean H**
H_1	2.70	2.50	2.60	2.90	3.26	2.20	2.69^a
H_2	2.58	2.45	2.50	2.80	3.15	2.10	2.60^b
H_3	2.64	2.54	2.55	2.85	3.20	2.15	2.67^a
Mean P	2.64^c	2.50^e	2.55^d	2.85^b	3.20^a	2.15^f	
	Factor H			Factor P			H x P
S.Em ±	0.014			0.019			0.033
CD at (5%)	0.039			0.055			NS

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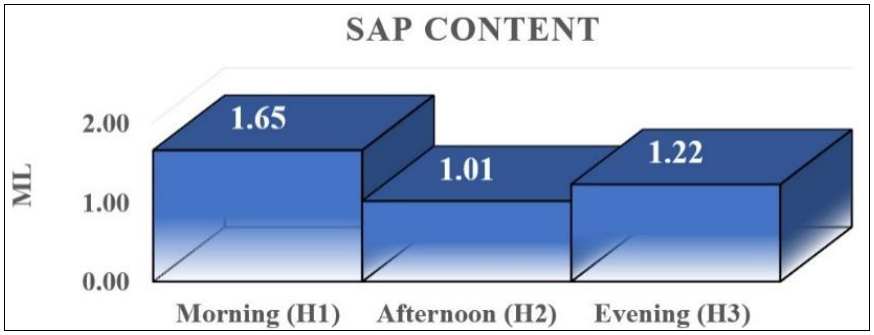

Fig 1: Effect of time of harvesting on Sap content (ml) mango cv. Dashehari

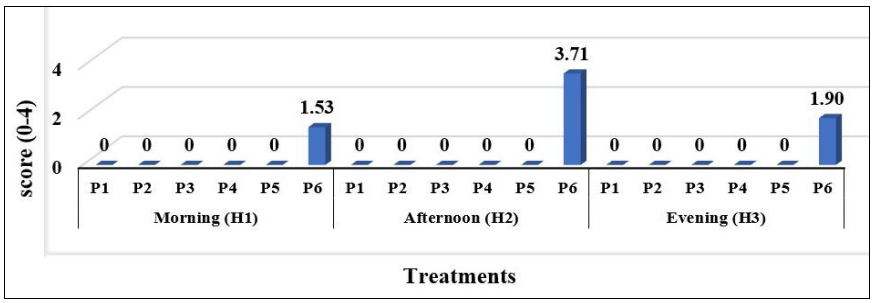

Fig 2: Effect of time of harvesting and post-harvest treatments on Sap burn injury score (0-4) of mango cv. Dashehari

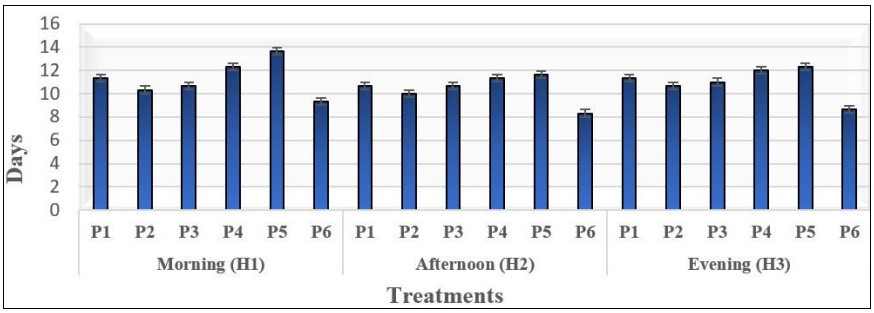

Fig 3: Effect of time of harvesting and post-harvest treatments on Shelf life (Days) of mango cv. Dashehari

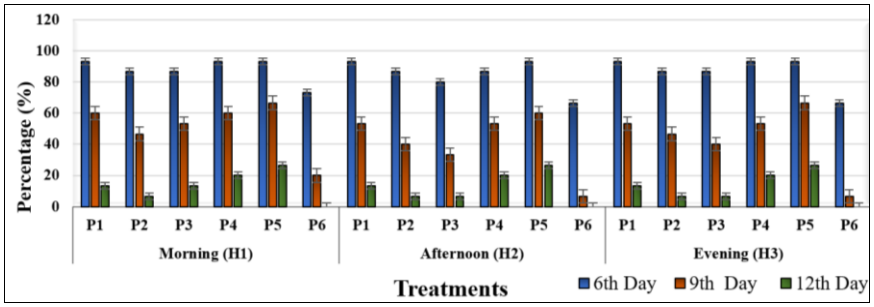

Fig 4: Effect of time of harvesting and post-harvest treatments on Marketability (%) of mango cv. Dashehari

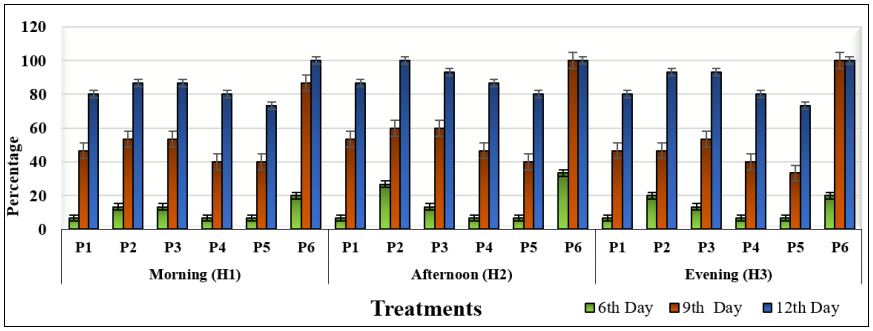

Fig 5: Effect of time of harvesting and post-harvest treatments on Spoilage (%) of mango cv. Dashehari

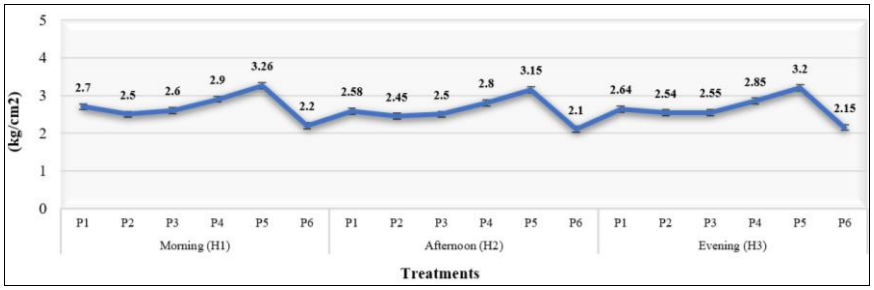

Fig 6: Effect of time of harvesting and post-harvest treatments on Firmness (kg/cm^2) of mango cv. Dashehari

4. Conclusions

Based on the results, it can be concluded that all the treatments, Lime @ 1 %, Alum @ 1%, Baking soda @ 0.1%, Garlic extract @ 1% and *Aloe vera* extract @ 1 %, consistently demonstrated the best results with zero sap burn injury scores. H_1P_5: (Morning harvested fruits treated with *Aloe vera* extract at 1%) exhibited better results in retaining the longest shelf life, the highest marketability percentage, the lowest spoilage percentage at different days of intervals and the maximum fruit firmness. Overall, H_1P_5: (Morning harvest + *Aloe vera* extract @ 1%) as post-harvest treatment is recommended to minimize the sap burn injuries thus enhancing fruit quality and extending shelf life and marketability.

5. Acknowledgements

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