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Can calcium sprays alleviate jelly seed in mango fruits?

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Abstract

Jelly seed is a major challenge in mango production leading to enormous losses in the value chain. This internal fruit disorder is characterised by disintegration of cells, consistency of jelly and broken cells. Calcium plays an important role in enhancing tissue stability and firmness thus reducing cell disintegration. A two-year field study was conducted in Embu County, Kenya using 'Van Dyke' cultivar trees of approximately 10 years old. The objective of the study was to investigate the effect of varied sources of calcium, applied at different rates and timing on jelly seed occurrence and tissue calcium distribution. Calcium in the form of calcium chloride, calcium nitrate and easygro® were applied at 1.0 %, 1.5 %, 2.0 % or 0 % (control) at three stages of fruit development (fruit set, 30 days after fruit set and 30 days to anticipated physiological maturity). The experiment was set up in a randomised complete block design with a split-split arrangement replicated three times. Fruits were harvested at physiological maturity and ripened at ambient conditions (28 ± 1 °C, 75–80 RH). Data collected included: jelly seed occurrence, calcium distribution (exocarp, mesocarp, endocarp and cotyledon) and fruit weight. Jelly seed occurrence and calcium distribution were determined at ripe stage. All the calcium sources invariably suppressed the occurrence of jelly seed. Calcium chloride (2.0 %) applied at fruit set had the lowest average jelly seed score of 1.2 and 2 in seasons I and II respectively. There was a significant negative relationship between fruit weight ($r = -0.55$, $r = -0.52$), calcium content in the exocarp ($r = -0.56$, $r = -0.49$), mesocarp ($r = -0.52$, $r = -0.76$), endocarp ($r = -0.76$, $r = -0.66$) and jelly seed incidence occurrence. This suggested that calcium has a role in alleviating jelly seed disorder. Application of calcium at fruit set was more effective in suppressing jelly seed occurrence than later applications. Calcium chloride (2.0 %) applied at fruit set was more effective in reducing jelly seed occurrence. There is need to study further on soil based calcium and other calcium formulations on the effects on jelly seed occurrence.

Keywords: calcium formulations, fruit disorder, losses, soil based

1 Introduction

Physiological disorders are among the many challenges mango (*Mangifera indica* L.) producers in Kenya and elsewhere in the world face. These disorders may cause enormous losses by reducing the quality of the fruits thereby affecting their consumer acceptability. They are characterised by flesh disintegration that is not necessarily pathogenic but can serve as entry point to pathogens (Kumar *et al*., 2016). These disorders can be caused by among other factors environmental conditions, imbalanced soil nutrients, minerals, soil pH and drainage.

Stem end cavity, jelly seed and soft nose are among the disorders that affect mango fruits and they have been described to affect different parts of the fruit (Raymond *et al*., 1998). According to Raymond *et al*. (1998) jelly seed affects the interior of the mesocarp while stem end cavity affect the proximal end of the fruit. Soft nose, on the other hand, affect the distal end of the fruit.

Jelly seed disorder manifests itself through the breakdown of tissues around the seed of the affected fruits. There appears a jelly like mass in the affected portion of pulp which is deeper yellow orange in colour and softer compared to the rest of the mesocarp. Raymond *et al*. (1998) further reported that the disorder occurs at the interface between the

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stone and the pulp of the fruit with no external symptoms except the appearance of a jelly like mass around the seed of the affected fruit. Therefore, fruits that have been affected by jelly seed can only be recognised so when cut. Additionally, the same authors reported that jelly seed affected fruits during early fruit development unlike other physiological disorders like soft nose which symptoms were detected only in fully developed fruit. This disorder affects the colour, taste, texture and appearance of the pulp and it intensifies with prolonged storage and maturity (Seshadri *et al*., 2019). The shelf life and fruit firmness are greatly affected by this condition in the long run. Jelly seed has been reported to be varietal and location specific and 'Van Dyke' variety is more prone to jelly seed than 'Tommy Atkins' (Njuguna *et al*., 2016).

Njuguna *et al*. (2016) proposed dolomitic lime application as a remedy to jelly seed disorder. However, application of dolomitic lime was not effective immediately due to its low mobility in the soil. Seshadri *et al*. (2019) reported that jelly seed is caused by germination of the seed of a developing fruit due to decreased level of very long chain fatty acids in the seed. A formulation V ($NaCl_2$, KCl, H_3BO_3, $CuSO_4$, $ZnSO_4$, $FeSO_4$, $MnSO_4$, and EDTA) by Seshadri *et al*. (2019) increased accumulation of calcium, among other compounds in the seed which delayed seed germination. A high level of calcium exerts osmotic stress (Torrecilla *et al*., 2001) which disturbs homeostasis (Liu *et al*., 2011). According to Weidner *et al*. (2009) osmotic stress induces accumulation of phenolic compounds and phenolic acids which inhibit seed germination (Colpas *et al*., 2003).

While some authors reported effective availability of calcium even after physiological maturity, there are reports that fruits accumulate calcium more effectively during the initial days (Bermadac *et al*., 1996; Bitange *et al*., 2019) than later periods of fruit development. Based on the above findings, the study aimed to evaluate the efficiency of different foliar calcium compounds in alleviating jelly seed therefore reducing mango losses. Effective strategies to address this challenge can contribute to reduced post-harvest losses.

2 Materials and methods

2.1 Experimental site

This study was conducted in two fruiting seasons (2017/2018/2019) at Karurumo orchard situated in the Eastern parts of Kenya, Embu County. The area has an elevation of 1174 m asl with coordinates of 0° 32' S 37° 41' E and it is classified as lower midland with an annual rainfall of 1206 mm of a bimodal pattern. Long rains start in March with peaks in April or May while short rains start in mid October with peaks in November. The soils in this area are loamy sand to clay (Ferralic Arenosol) that have been found to have low levels of calcium (Njuguna *et al*., 2016) and rich in nitrogen (0.12 %), organic carbon (1 %) and potassium (1.48 ppm) (Maloba, 2016).

2.2 Experimental material, treatments and design

Already established, uniformly sized in height and spread 'Van Dyke' cultivar trees of approximately 10 years old were used in this experiment. This cultivar is characterised by an attractive colour, bears regularly, has a poor to moderate productivity and is resistant to anthracnose and powdery mildew. 'Van Dyke' has a rich and pleasant flavour with an orange yellow flesh that is firm. This cultivar is however highly susceptible to jelly seed disorder. The plots were maintained in accordance with the cultural recommendations in Kenya as described by Griesbach (2003).

The experiment involved the application of three different calcium sources (calcium chloride, calcium nitrate and easygro®) at three different rates (1 %, 1.5 % and 2 % and 0 % (control)). These applications were done during different stages of fruit development (at fruit set, 30 days after fruit set and 30 days to anticipated physiological maturity).To obtain the spray volume per tree, the foliage diameter was calculated and the area covered by the foliage used to determine the amount of water per square meter. One square meter was equated to 0.5 litres of water. Application was done using a tractor drawn boom sprayer.

The treatments were laid out in a randomized complete block design with a split-split plot arrangement with three trees per replication, replicated three times. The calcium sources formed the main plots; the timing of application formed the subplots while the rates of application formed the sub-sub plots.

2.3 Data collection and analyses

Data collected included: calcium concentration (exocarp, mesocarp, endocarp and cotyledon), jelly seed occurrence, and weight of the fruit.

2.3.1 Jelly seed incidence, weight and calcium concentration determination

At physiological maturity 30 fruits were sampled randomly from each treatment. The collected samples were taken to *The Jomo Kenyatta University of Agriculture and Technology* (JKUAT) postharvest laboratory immediately after harvesting, pedicels were separated from the fruits which were washed under running water and the surface water was allowed to dry. The fruits were then ripened under

ambient conditions. Upon ripening, the fruits were weighed again, halved along the endocarp and the jelly seed incidence scored by use of a hedonic scale (Galan, 1984) and guided by figure 1.

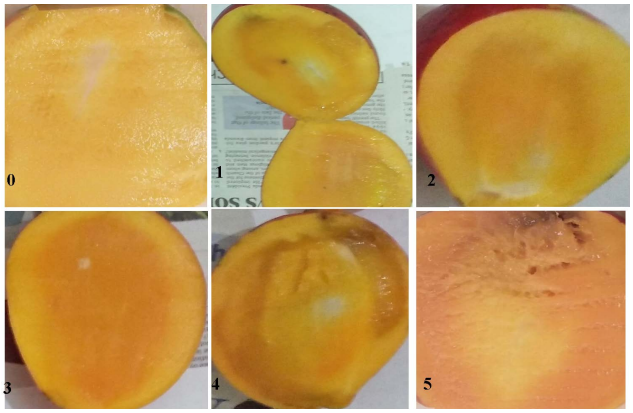

Fig. 1: *Personal classification of jelly seed incidence showing different levels of occurrence: (0) without symptoms. (1) decomposition of the petiole base without affecting the flesh. (2) slightly affected flesh near the seed. (3) 1/3 of the flesh affected. (4) 2/3 of the flesh affected. (5) almost all fruit decomposed.*

A sharp knife was used to separate the peel, mesocarp, seed coat and cotyledon of the fully ripened fruits for calcium analysis. The mesocarp samples for pulp mineral analysis were taken from the widest parts of the fruit sampled between the skin and the stone. This ensured reduced biasness of the concentration of calcium due to the gradient change caused by the variation of cell density with the outward movement to the skin from the seed (Bally, 2007). The samples were then dried at 68 °C until constant weight was obtained and ground to obtain a homogenous sample for calcium analysis. Calcium was determined using atomic absorption (AAS) spectrophotometer (AOAC, 1996) and expressed as μg mg^{-1}

2.3.2 *Data analysis*

Data collected was subjected to analysis of variance using Genstat software 14^{th} Edition (Payne *et al.*, 2011). The differences among the means of the treatments were compared using Fisher's Protected LSD test at 5 % probability level. A Pearson's product-moment was run to assess the relationship between weight of fruit, calcium concentration in the exocarp, mesocarp, endocarp and cotyledon, and jelly seed occurrence using Stata software 12^{th} edition. Data thereof was presented in tables.

3 Results

3.1 *Effect of varied calcium sources, rates and timing of application on mesocarp, exocarp, endocarp and cotyledon calcium concentration*

The souce of calcium, rate and timing of application and their interactions had significant effects on the calcium concentration in the mesocarp in seasons I and II except the source of application in season I and the interactions of the three variables in season II (table 1). As the rate of application increased from R1(1.0 %) to R3 (2.0 %) the mesocarp calcium content increased regardless of the source and timing of application. The calcium content in the fruit flesh exhibited a decreasing trend from timing 1 to timing 3 irrespective of the source of calcium and rate of application.

Application of calcium chloride (2.0 %) and easygro® (2.0 %) at fruit set led to the highest flesh calcium content (1.1 μg mg^{-1} in season I and 1.23 μg mg^{-1} for calcium chloride (2.0 %) in season II). The mesocarp calcium concentration ranged from 0.02 (control) to 1.23 μg mg^{-1}. Application of varied sources of calcium, rates and timing had significant effects on the exocarp calcium content in both seasons except the source of application in season I (table 2). The interactions of rate and source with time, on the other hand, did not have significant effects on the peel calcium content while the interaction of the three variables did not have significant effects on the peel calcium content in both seasons. The peel calcium content ranged from 0.1 to 1.2 μg mg^{-1}.

The application of varied sources of calcium, rates and timing of application on the fruits did not have significant effects on the on the cotyledon calcium content. However, the cotyledon calcium accumulation ranged from 0.01 to 0.07 μg mg^{-1} representing the lowest mean calcium accumulation relative to the exocarp, mesocarp and endocarp. Application of varied calcium sources, rates and timing of application and their interactions had significant effect on the seed endocarp calcium concentration in both season except in season I where the interactions between rate and source and that between rate, source and timing of application were not significantly different (Table 3). Application of calcium chloride (2.0 %) at fruit set registered the highest calcium concentration (1.73 μg mg^{-1}) followed by calcium nitrate (2.0 %) at fruit set (1.43 μg mg^{-1}) in season I. Similarly, in season II calcium chloride (2.0 %) applied at fruit set registered the highest calcium content (1.32 μg mg^{-1}) followed by calcium nitrate (2.0 %) applied at fruit set (1.1 μg mg^{-1}). The calcium concentration in the seed endocarp ranged from 0.13 to 1.7 μg mg^{-1}.

3.2 *Effect of varied calcium sources, rates and timing of application on jelly seed occurrence*

Application of calcium had significant ($p \leq 0.05$) effects on jelly seed incidence (table 4). Minimum jelly seed score was observed on fruits treated with 2.0 % calcium chloride applied at fruit set. Application of calcium nitrate and easygro® at 30 days to physiological maturity had non-significant effects on jelly seed occurrence. The rate source

Table 1: *Calcium concentration ($\mu g\, mg^{-1}$) in the fruit mesocarp as affected by varied calcium sources (S), rate (R) and timing (T) of application.*

		Season I				*Season II*			
Rate	*Source*	*T1*	*T2*	*T3*	*Mean*	*T1*	*T2*	*T3*	*Mean*
R0	CTRL	0.17	0.17	0.14	0.2	0.06	0.04	0.02	0.0
R1	S1	0.65	0.23	0.15	0.3	0.66	0.23	0.05	0.3
	S2	0.60	0.20	0.17	0.3	0.52	0.18	0.03	0.2
	S3	0.50	0.29	0.12	0.3	0.56	0.15	0.05	0.3
R2	S1	0.73	0.31	0.18	0.4	0.81	0.35	0.07	0.4
	S2	0.83	0.26	0.21	0.4	0.64	0.25	0.06	0.3
	S3	0.88	0.34	0.16	0.5	0.63	0.19	0.04	0.3
R3	S1	1.10	0.49	0.39	0.5	1.23	0.52	0.15	0.6
	S2	0.98	0.43	0.32	0.6	1.01	0.36	0.10	0.5
	S3	1.10	0.48	0.20	0.6	0.83	0.24	0.11	0.4
LSD		R 0.05 S ns T 0.03 RxS 0.05 RxT 0.06 SxT 0.08 RxSxT 0.01				R 0.07 S 0.05 T 0.05 RxS 0.09 RxT 0.15 SxT ns RxSxT ns			
CV (%)		14				26.9			

S-Source; T-Time; R-Rate. CTRL-Control; S1-Calcium chloride; S2-Calcium nitrate; S3-Easygro. R1-1.0 %; R2-1.5 %; R3-2.0 %; R0-0 %. T1-Fruit set; T2-30 days after fruit set; T3-30 days to physiological maturity. LSD-Least significant difference. ns-not significant. CV-Covariance.

Table 2: *Calcium concentration ($\mu g\, mg^{-1}$) in the fruit exocarp as affected by varied calcium sources (S), rate (R) and timing (T) of application.*

		Season I				*Season II*			
Rate	*Source*	*T1*	*T2*	*T3*	*Mean*	*T1*	*T2*	*T3*	*Mean*
R0	CTRL	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
R1	S1	1.0	0.4	0.5	0.6	0.8	0.4	0.3	0.5
	S2	1.0	0.5	0.5	0.7	1.0	0.5	0.5	0.7
	S3	1.1	0.7	0.7	0.8	1.1	0.7	0.6	0.8
R2	S1	1.3	0.7	0.6	0.9	1.3	0.7	0.6	0.9
	S2	1.1	0.8	0.8	0.9	1.1	0.9	0.9	0.9
	S3	1.3	1.0	0.9	1.0	1.4	1.0	1.0	1.1
R3	S1	1.6	1.0	0.8	1.1	1.5	1.0	0.8	1.1
	S2	1.3	1.0	0.9	1.1	1.4	1.1	1.0	1.2
	S3	1.5	1.1	1.1	1.2	1.5	1.2	0.8	1.1
LSD		R 0.07 S ns T 0.05 RXS ns RXT 0.13 SXT 0.16 RXSXT ns				R 0.15 S 0.12 T 0.08 RXS ns RXT 0.26 SXT ns RXSXT ns			
CV (%)		11.3				18.8			

S-Source; T-Time; R-Rate. CTRL-Control; SI-Calcium chloride; S2-Calcium nitrate; S3-Easygro. R1-1.0 %; R2-1.5 %; R3-2.0 %; R0-0 %. T1-Fruit set; T2-30 days after fruit set; T3-30 days to physiological maturity.LSD-Least significant difference. ns-not significant. CV-Covariance.

Table 3: *Calcium concentration ($\mu g\, mg^{-1}$) in the seed endocarp as affected by varied calcium sources (S), rate (R) and timing (T) of application.*

		Season I				*Season II*			
Rate	*Source*	*T1*	*T2*	*T3*	*Mean*	*T1*	*T2*	*T3*	*Mean*
R0	CTRL	0.12	0.16	0.11	0.13	0.13	0.18	0.18	0.16
R1	S1	1.23	0.85	0.48	0.85	0.65	0.63	0.58	0.62
	S2	0.90	0.63	0.62	0.72	0.69	0.68	0.53	0.63
	S3	0.90	0.62	0.30	0.61	0.59	0.63	0.58	0.60
R2	S1	1.23	0.92	0.64	0.93	0.92	0.71	0.64	0.76
	S2	1.13	0.67	0.68	0.83	0.80	0.73	0.65	0.73
	S3	1.03	0.78	0.43	0.75	0.72	0.69	0.65	0.68
R3	S1	1.70	1.28	0.72	1.23	1.32	0.81	0.69	0.94
	S2	1.43	0.81	0.69	0.98	1.11	0.80	0.73	0.88
	S3	1.10	0.89	0.52	0.84	0.83	0.76	0.67	0.76
LSD		R 0.16 S 0.13 T 0.09				R 0.07 S 0.06 T 0.04			
		RxS ns RxT 0.28				RxS 0.03 RxT 0.12			
		SxT 0.23 RxSxT ns				SxT 0.10 RxSxT 0.08			
CV (%)		21.9				10.7			

S-Source; T-Time; R-Rate. CTRL-Control; SI-Calcium chloride; S2-Calcium nitrate; S3-Easygro. R1-1.0 %; R2-1.5 %; R3-2.0 %; R0-0 %. T1-Fruit set; T2-30 days after fruit set; T3-30 days to physiological maturity. LSD-Least significant difference. ns-not significant. CV-Covariance.

and timing of application and their interactions had significant effects on the jelly seed occurrence in season II. The effect of the varied sources of calcium and timing of application is further shown in figures 2 and 3. Higher rates (2.0 %) of calcium chloride, calcium nitrate and easygro® applied at 30 days to physiological maturity had little or insignificant effect on jelly seed scores (figure 2). Further, calcium chloride sprayed at fruit set at a concentration of 2.0 % was more effective in suppressing jelly seed than application at 30 days after fruit set and 30 days to physiological maturity in that order (figure 3).

Fig. 2: *Mango fruits from control treatment (A) and from trees sprayed with easygro® 2.0 % (B), calcium nitrate 2.0 % (C), and calcium chloride 2.0 % (D) at 30 days to physiological maturity in season I.*

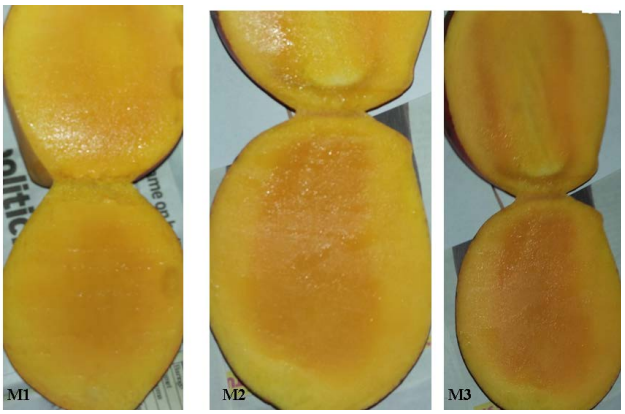

Fig. 3: *Mango fruits from trees treated with calcium chloride 2.0 % at fruit set (M1), at 30 days after fruit set (M2) and at 30 days to physiological maturity (M3).*

3.3 Correlation coefficient

There was a moderate negative correlation between jelly seed occurrence and weight of the fruit, in seasons I and II (table 5). Similarly, a negative correlation was reported between jelly seed occurrence calcium concentration in the exocarp, mesocarp and endocarp for both seasons.

Table 4: *Effect of varied sources of calcium applied at varied rates and timing on jelly seed occurrence in 'Van Dyke' fruits.*

		Season I				*Season II*			
Rate	*Source*	*T1*	*T2*	*T3*	*Mean*	*T1*	*T2*	*T3*	*Mean*
R0	CTRL	5.0	4.7	4.7	4.8	5.0	4.7	5.0	4.9
R1	S1	2.0	3.0	4.0	3.0	3.0	4.3	5.0	4.1
	S2	3.7	4.3	4.3	4.1	4.0	5.0	5.0	4.7
	S3	4.0	3.7	5.0	4.2	5.0	5.0	5.0	5.0
R2	S1	1.7	2.3	3.0	2.3	1.7	2.7	5.0	3.1
	S2	3.0	3.3	3.7	3.3	3.0	4.7	5.0	4.2
	S3	3.3	3.0	3.7	3.3	4.0	4.7	5.0	4.6
R3	S1	0.0	1.0	2.7	1.2	0.3	1.3	4.3	2.0
	S2	2.3	2.7	3.0	2.7	2.7	3.7	4.3	3.6
	S3	2.7	3.0	3.3	3.0	3.3	4.7	5.0	4.3
LSD		R 0.51 S 0.41 T 0.3 RxS ns RxT ns RxSxT ns				R 0.6 S 0.4 T 0.2 RxS 0.9 RxT 0.7 RxSxT 0.7			
CV (%)		16.8				10.7			

S-Source; T-Time; R-Rate. CTRL-Control; SI-Calcium chloride; S2-Calcium nitrate; S3-Easygro. R1-1.0 %; R2-1.5 %; R3-2.0 %; R0-0 %. T1-Fruit set; T2-30 days after fruit set; T3-30 days to physiological maturity. LSD-Least significant difference. ns-not significant. CV-Covariance.

Table 5: *Correlation (Pearson correlation r) between jelly seed occurrence, weight of fruits, calcium concentration in the seed, peel and mesocarp in seasons I and II*

	Season I		*Season II*	
	r	*p*	*r*	*p*
Weight	-0.5522	0.0000	-0.5228	0.0000
Calcium content				
Pericarp	-0.7604	0.0000	-0.6636	0.0000
Exocarp	-0.5596	0.0000	-0.4862	0.0000
Mesocarp	-0.5194	0.0000	-0.7631	0.0000

4 Discussion

Application of calcium led to an increased calcium accumulation in the fruits. The increase in fruit calcium content as reported in this experiment has also been reported by Cheour *et al.* (1990) and Garcia *et al.* (1996) who found that application of calcium chloride on strawberry led to an increased calcium content in the fruits. Similar results on an increase in flesh and peel calcium concentration have also been reported by Manganaris *et al.* (2007) after application of calcium salts on peach fruits.

Application of calcium salts at fruit set resulted in a higher calcium concentration in the exocarp, mesocarp and pericarp. This reinforces the fact that calcium is more available at early stages of fruit development. Similar findings on the availability of calcium at early stages have been reported by Amin *et al.* (2007), Karemera *et al.* (2013) and Bitange *et al.* (2019) in mango fruits and Penter *et al.* (2000) in avocado fruits.

The different fruit partitions showed varied calcium concentration with the endocarp and cotyledons registering the highest and lowest accumulation of calcium respectively. The maximum accumulation of calcium in the endocarp could be due to its role in ensuring the firmness and hardiness of the seed cover. Similar results in different accumulation of minerals in different parts of the fruit have been reported by Clark *et al.* (1989), Joyce *et al.* (1997), and Sinha *et al.* (2017) who suggested that the different concentrations in fruit tissues from similar treatments could be attributed to the positioning of vascular tissues and transpiration capability of the tissues in question.

There was a suppressed jelly seed incidence by the application of calcium which shows the role of calcium in enhancing tissue stability and firmness. Similar results on the suppressed internal breakdown by application of calcium have been reported in mango fruit by Burdon & Moore (1991), Kadiya (1995), Tarmizi *et al.* (1993), Singh *et al.* (2006), Amin *et al.* (2007), and Seshadri *et al.* (2019) and bitter pit in apples (Lotze *et al.*, 2008; Gago *et al.*, 2016).

Early application at fruit set was more effective in suppressing jelly seed probably because the fruits were actively taking up the nutrients. Similar results on the availability of calcium at early stages of fruit development have been reported by Bitange *et al*. (2019). Similarly, effective use of calcium at early stages in combating bitter pit in apples has been reported by Lotze *et al*. (2008). Amin *et al*. (2007) reported that pre-harvest application of calcium salts reduced soft nose incidence in mango fruits underscoring the role of calcium in enhancing tissue and cell wall firmness thus preventing disintegration and cell deterioration. The differences in the significance levels of the source, timing, rates and their interactions could be due to environmental factors or other factors that may affect the availability of calcium. Njuguna *et al*. (2016) reported that the occurrence of jelly seed is greatly affected by environmental factors. Additionally, Lotze *et al*. (2008) reported different effectiveness of calcium products absorption and suppression of bitter pit in apple fruit due to different stages of application.

Calcium content was higher in the fruit endocarp, mesocarp and exocarp of fruits with less on no jelly seed occurrence as indicated by the inverse relationship between calcium content and jelly seed score. This reinforces the role of calcium in alleviation of the disorder.

5 Conclusion

The reduction of jelly seed by application of calcium salts indicates that calcium salts can be used in its alleviation. Early application of calcium salts proved to be effective in reducing the occurrence of jelly seed underscoring the fact that calcium is more available to the fruit during early stages of development than later. Application of calcium chloride (2.0 %) at fruit set was more effective in jelly seed alleviation. However, there is need to study further on calcium compounds applied as soil based on the effects on jelly seed occurrence or different modern calcium formulations and agronomic practices that affect the availability of calcium.

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Conflict of interest

Authors have declared that no competing interests exist.

References

Amin, M., Aman, U. M., Nawab-U-Din, Abdul, J. & Ishtiaq, A. (2007). Mango soft nose disorder and fruit quality in relation to pre-and post harvest treatments. *Life Sciences International Journal*, 1 (4), 455–462.

AOAC (1996). *Official methods of analytical chemists*. Association of Official Agricultural Chemist, Washington, D.C., USA.

Bally, E. S. I. (2007). *The effect of pre-harvest nutrition and crop load on fruit quality and postharvest disease in mango* (*Mangifera indica* L.). Ph.D. Thesis; University of Queensland, Gatton, Australia.

Bermadac, A., Jean Baptise, I., Bertoni, G. & Morand, P. (1996). Changes in calcium content during melon (*Cucumis melo* L.) fruit development. *Science horticulture*, 66, 181–189.

Bitange, N., Chemining'wa, G. N., Ambuko, J. & Owino, W. O. (2019). Yield and tissue calcium concentration of mango (*Mangifera indica* L.) fruit as influenced by calcium source and time of application. *International Journal of Plant & Soil Sciences*, 28 (4), 1–12. doi: 10.9734/IJPSS/2019/v28i430112.

Burdon, J. N. & Moore, K. G. (1991). The 'soft-nose' disorder of mango fruit. *The Planter*, 67, 477–481.

Cheour, F., Willemot, C., Arul, J., Desjardins, Y., Makhlouf, J., Charest, P. M. & Gosselin, A. (1990). Foliar application of $CaCl_2$ delays postharvest strawberry ripening. *J. Amer. Soc. HortScience.*, 115, 789–792.

Clark, C. J., Smith, G. S. & Gravett, I. M. (1989). Seasonal accumulation of mineral nutrients by tamarillo fruit. *Scientia Horticulturae*, 40, 203–21.

Colpas, F. T., Ono, E. O., Rodrigues, J. D. & Passos, J. R. (2003). Effects of some phenolic compounds on soybean seed germination and on seed-borne fungi. *Brazilian Archives of Biology and Technology*, 46 (2), 155–161.

Gago, C. M. L., Guerreiro, A. C., Miguel, G., Panagopoulus, T., Da Silva. M. & Antunes, D. C. M. (2016). Effect of Calcium chloride and 1-MCP (Smartfresh™) postharvest treatment on 'Golden Delicious' apple cold storage physiological disorders. *Scientia Horticulturae*, 211, 440–448. doi:10.1016/j.scienta.2016.09.017.

Galan, S. V., Fernandez, G.D. & Calvo, R. (1984). Incidence of soft nose on mangoes in the Canary Islands. *Proceedings of the Florida State Horticultural Society*, 97, 358–360.

Garcia, J. M., Herrera, S. & Morilla, A. (1996). Effects of postharvest dips in calcium chloride on strawberry. *Journal of Agricultural and Food Chemistry*, 44, 30–33. doi:10.1021/jf950334l.

Griesbach, J. (2003). Mango growing in Kenya. ICRAF, Nairobi, Kenya.

Joyce, D. C., Beasley, D. R. & Shorter, A. J. (1997). Effect of preharvest bagging on fruit calcium levels, and storage and ripening characteristics of 'Sensation' mangoes. *Australian Journal of Experimental Agriculture*, 37, 383–389.

Kadiya, H. B. (1995). Composition and distribution of minerals in mango fruit during ripening and storage with reference to "internal breakdown" a postharvest disorder. In: *Proceedings of the International Symposium on Postharvest Science and Technology of Horticultural Crops*. 27 June - 1 July 1995, Beijing, China. pp. 10–17.

Karemera, U. N. J & Habimana, S. (2013). Performance of calcium chloride sprays on ripening, shelf life and physical chemical properties of mango fruits (*Mangifera indica* L.) cv. *Totapuri*. *International Invention Journal of Agricultural and Soil Science*, 2 (3), 33–38.

Kumar, R. & Kumar, V. (2016). Physiological disorders in perennial woody tropical and subtropical fruit crops. A review. *Indian Journal of Agricultural Sciences*, 86 (6), 703–17.

Liu, H. C., Jia, W. Q., Chen, Y., You, Y., Du, X. H. & Liu, H. Y. (2011). Effects of exogenous calcium on the seed germination and seedlings ions distribution of *Trifolium repens* under salt stress. International Conference on Remote Sensing, Environment and Transportation Engineering, Nanjing, China, 2011, pp. 6806-6809.

Lotze, E., Joubert, J. & Theron, K.I. (2008). Evaluating preharvest foliar calcium applications to increase fruit calcium and reduce bitter pit in 'Golden Delicious' apples. *Scientia Horticulturae*, 116, 299–304.

Maloba, S. E. (2016). *Application of ethephon and potassium nitrate to induce off-season flowering and fruit production in mangoes*. MSc. Thesis; University of Nairobi, Kenya.

Manganaris, G. A., Vasilakakis, M., Diamantidis, G. & Mignani, I. (2007). The effect of postharvest calcium application on tissue calcium concentration, quality attributes, incidence of flesh browning and cell wall physicochemical aspects of peach fruits. *Food chemistry*, 100 (4), 1385–1392. Njuguna, J., Ambuko, J., Hutchinson, M. & Owino W. (2016). Incidence of jelly seed disorder in 'Tommy Atkins' and 'Van Dyke' Mangoes as affected by agro-ecological conditions in Kenya. *International Journal of Plant and Soil Science*, 11 (5), 1–9. doi: 10.9734/IJPSS/2016/26447.

Payne, R. W., Murray, D. A., Harding, S. A., Baird, D. B. & Soutar, D. M. (2011). *An introduction to GENSTAT for Windows* (14th Edition). VSN International, Hemel Hempstead, UK.

Penter, M. G. & Stassen, P. J. C. (2000). The effect of pre- and postharvest calcium applications on the postharvest quality of Pinkerton avocados. *South African Avocado Growers' Association Yearbook*, 23, 1–7.

Raymond, L., Schaffer, B., Brecht, K. J, Jonathan, H. & Crane, J. H. (1998). Internal breakdown in mango fruit: Symptomology and histology of jelly seed, soft nose and stem-end cavity. *Postharvest Biology and Technology*, 13, 59–70.

Seshadri, S., Manoharan, S. & Singh, H. S. (2019). Preventive regulation of jelly seed disorder in Amrapali mango (*Mangifera indica* L) by pre harvest spray. *Horticultural Plant Journal*, 5 (2), 70–78.

Sihna, R., Ahmad, F. M., Jaiswal, U. S., Singh, G., Siddiqui, M. W & Prasad, K. (2017). Fractionate assessment of elemental composition in different mango cultivars to estimate nutrient losses through crop removal. *Asian Journal of Chemistry*, 29 (1), 9–12. doi: 10.14233/ajchem.2017.20016.

Singh, V. K., Singh, D. K. & Pathak, S. M. (2006). Relationship of leaf and fruit transpiration rates to the incidence of softening of tissue in mango (*Mangifera indica* L.) cultivars. *American Journal of Plant Physiology*, 1 (1), 28–33.

Tarmizi, A. S., Tengku, T. M., Pauziah, M. & Zahrah, T. (1993). Incidence of insidious fruit rot as related to mineral nutrients in Harumanis mangoes. *Journal of the Malaysian Agricultural Research and Development Institute*, 21, 43–49. doi:10.1016/J.HPJ.2018.08.002.

Torrecilla, F., Leganes, F., Bonilla, I. & Pinas, F. E. (2001). Calcium transients in response to salinity and osmotic stress in the nitrogen-fixing cyanobacterium *Anabaena* sp. PCC 7120, expressing cytosolic apoaequorin. *Plant Cell and Environment*, 24, 641–648.

Weidner, S., Karolak, M., Karamac, M., Kosinska, A. & Amarowicz, R. (2009). Phenolic compounds and properties of antioxidants in grapevine roots (*Vitisvinifera*) under drought stress followed by regeneration. *Acta Societatis Botanicorum Poloniae*, 78, 97–103.