Original Research Article

Yield and Tissue Calcium Concentration of Mango (*Mangifera indica* L.) Fruit as Influenced by Calcium Source and Time of Application

ABSTRACT

The effect of varied calcium sources, applied at different times and rates, on the yield and calcium concentration of mango fruit were investigated. "Van Dyke" mango cultivar tree of 10 years old was sprayed with calcium chloride, calcium nitrate, easy gro and water (control). The calcium sources were sprayed at the rates of 1%, 1.5% , 2% or 0% (control) during three different stages of fruit development i.e. fruit set, 30 days after fruit set and 30 days to physiological maturity. The experiment was carried out during 2017 and 2018 seasons at Karurumo, Embu County, Kenya. This orchard has been found to have low calcium levels. These experiments were laid in a completely randomized block designs with a split, split plot arrangement replicated three times. The results indicated that spraying with calcium significantly affected the weight, breadth, number and the total weight of fruits/tree. The concentration of calcium in the fruit flesh was also significantly increased by the application of calcium and a direct relationship between calcium concentration and yield attributes was reported. Calcium chloride (2.0%) sprayed at fruit set was the most effective in enhancing the fruit weight, breadth, number of fruits and the total weight of fruits. Application of calcium at fruit set was found to be the most effective in enhancing the yield. Further investigations need to be done to determine the effect of these calcium sources on the quality fruits and the optimal rate as there was an increase in the yield with an increase in the rates.

Key words: Mango; Calcium chloride; Calcium nitrate; Easy gro; Yield; uptake

1. INTRODUCTION

Mango (*Mangifera indica* L.) production supports an estimated 200,000 farmers directly and many more beneficiaries along the value chain in Kenya. However, its cultivation is faced with a number of challenges among them low yields. Previous studies indicate that cultivars grown in Kenya have a potential of producing 15-20 ton/ha but reported yields are less than 10 ton/ha (Kehlenbeck et al., 2012). 'Van Dyke' is a popular cultivar in Kenya because of its attractive color, bears regularly, mature earlier. However, it has poor productivity.

Fruit drop is one amongst many factors that affect yield in mango fruits. In spite of the high initial fruit set the ultimate fruit retention per panicle is very low due to fruit drop which happens at different fruit development stages. The intensity of fruit drop is highest during the first 15 days after pollination and pea stage (Sankar et al, 2013). At marble stage the percentage drop is 30% and it occurs between 28-35 days after fruit set while the third drop is at 3% and it occurs from 40 days to maturity (Singh et al., 2009). Fruit drop may lead to 90% loss of the fruit set in a given season (Bains et al., 1997).

Calcium enhances the yield of mangoes by increasing the initial fruit set per panicle and reduction of abscission therefore increasing the retention capacity per panicle. Calcium also influences the physical features of the fruits including: length, thickness, breadth, volume and weight. Calcium is an important component of the cell wall where, it plays an important role in the formation of individual cells and prevents cellular cells degeneration (Burdon et al., 1991; Burdon et al., 1992). Previous studies directly link an increase in yields with calcium application (Njuguna et al., 2016; Galan et al., 2004). Calcium chloride and calcium nitrate compounds have been reported to be applied in various fruits including papaya (Madani et al., 2016) and guavas. These salts are applied at varied rates and timing, mostly after physiological maturity. Stino et al. (2011) reported that spraying different mango cultivars with calcium nitrate at bud emergence, full bloom and pea stage increased the average fruit weight and pulp thickness. On the contrary some studies report calcium applications are not directly linked to increase in yield of some fruits (Lanauskas et al., 2006, Bonomelli et al., 2010). While there are studies that link increase in flesh calcium concentration with calcium spraying (Bonomelli et al., 2010) reports on the contrary. Previous studies indicate calcium deficiency in various mango growing sites in Kenya (Njuguna et al., 2016).

This study aimed to investigate the comparative effects of calcium nitrate, calcium chloride and easy gro applied at varied rates and timing on the yield and calcium uptake of Van Dyke mango cultivar.

2.0 MATERIALS AND METHODS

2.1 Experimental site description

This study was conducted in fruiting seasons 2017 and 2018 at Karurumo orchard Embu County, Kenya. The area has an elevation of 1174 m asl of coordinates 0° 32′ S 37° 41E (Njuguna et al., 2016) classified as lower midland 3 (LM3). This area receives an annual rainfall of 1206 mm, with a bimodal pattern and an average annual temperature of 22.7^{0}C. The soils in this area are loamy sand to clay ferralic arenosal that have been found to have low levels of calcium (Njuguna et al., 2016).

2.2 Soil and leaf sampling

Prior to experiment set up, soil samples from the experimental site and leaves from the cultivar tree used in the experiment were taken to establish the soil fertility and the plant nutritional status. Soil samples were taken from ten representative points of the entire plot using zig zag pattern at a depth of 0-20 cm. The soils from these points were thoroughly mixed to get a composite sample that was used for the analysis. The leaf samples were picked by selecting thirty (30) leaf samples randomly at physiological maturity from fruit bearing shoots per treatment for mineral composition analysis. Calcium was determined using flame photometer. The results indicated calcium deficiency in both soil and leaf samples.

2.3 Experimental material, design and treatments

The experiment involved use of "Van Dyke" cultivar of 10 years old. This cultivar is characterized by an attractive color, bears regularly, matures earlier, has a poor to moderate productivity and it is resistant to anthracnose and powdery mildew. Additionally, it has a rich and pleasant flavor with an orange yellow flesh that is firm. Three (3) calcium sources (Calcium chloride, calcium nitrate and Easygro) and one control (No calcium application) were used. The calcium compounds were applied at 1.0%, 1.5% and 2.0% or 0%. The treatments were separately applied at three (3) different developmental stages of the fruits (fruit set, 30 days after fruit set and 30 days to anticipated physiological maturity). The treatments were laid out in a completely randomized 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. Maturity was determined chronologically by counting 120 days after full bloom. At this stage, physiologically mature mangoes have their external color change from green to yellow, the stone becomes hard, pulp color changes from white to cream, to deep yellow starting from the endocarp progressing outward and the shoulders area swells then rises above the stem with swollen cheeks.

The plots were maintained in accordance with the cultural recommendations in Kenya as described by Griesbach (2003). Calcium chloride, calcium nitrate and Easygro were applied using a tractor drawn boom sprayer .Easygro® is a foliar based fertilizer recommended for mango production in Kenya with a chemical composition of: Nitrogen (14%), phosphorus (0%), magnesium (2.5%), potassium (2%) and calcium (13%).

2.4 Data collection and analysis

Data were collected on; average fruit length, breadth, number of fruit/tree, fruit retention percentage and calcium fruit concentration. The procedures taken for each parameter were as described below

2.4.1 Average length of the fruits (cm).

At physiological maturity 15 fruits were randomly picked for determination of length which was measured from the stalk end to the apex of the fruit using a vernier caliper (Model Mitutoyo, Japan) (Karemera et al., 2014).

2.4.2 Average breadth of the fruit (cm)

At physiological maturity 15 fruits were taken from each treatment for determination of the fruit breadth by use of a vernier caliper (Model Mitutoyo, Japan). This was measured by taking the maximum linear distance between the two shoulders of the fruit.

2.4.3 Average fruit weight

At physiological maturity 15 fruits were harvested from each treatment for the determination of fruit weight. The weight was determined using an electronic weighing balance (Model Libror AEG-220, Shimadzu Kyoto, Japan).

2.4.4 Total yield (kg/tree)

At physiological maturity, the number of fruits per tree was counted for each treatment. The average weight of the fruits from each treatment was determined immediately after harvesting of the fruit and the stalk of the fruit had been removed. An electronic weighing balance (Model Libror AEG-220, Shimadzu Kyoto, Japan) was used. Tree yield in (kg) was estimated by multiplying number of fruits per tree with the average fruit weight for each treatment.

2.4.5 Fruit retention percentage (%)

Twenty (20) panicles, randomly selected from all the four directions of the tree, in each treatment were tagged. Initial number of fruits per panicle was recorded before each treatment. At maturity, fruit retention per panicle was determined as shown below (Saraladevi et al., 2013).

$$\text{Retained fruit (\%)} = \frac{\text{Retained number of fruits at harvest}}{\text{Initial number of fruits set}} * 100$$

2.4.6 Fruit calcium concentration

At physiological maturity a sample of 3 fruits was taken from each treatment for the determination of calcium concentration in the flesh of the mango. The samples were dried and ground to fine powder and ashed in a furnace. The ash was then dissolved with hydrochloric acid. Total calcium was determined by atomic absorption spectrophotometer (AAS) and expressed as µgmg-1 dry weight.

All collected data were subjected to analysis of variance using Genstat software 14th Edition (Payne et al., 2011). Where ANOVA showed significant differences, the differences of the treatment means were compared using Fisher's protected Least Significant Difference (LSD) test at p≤ 0.05 probability level of significance (Steel et al., 1987). Correlations between calcium content in the flesh and yield parameters was carried out. The data thereof was presented in tables and graphs.

3.0 RESULTS

3.1 Fruit weight, length and breadth

Calcium source, rate, time of application and their interactions had a significant ($p<0.05$) effect on the fruit weight in both seasons (Table 1). Application of calcium chloride (2.0%) at fruit set gave a maximum fruit weight of 346.3 g and 316.0 g in season I and II respectively. This was followed by application of calcium nitrate (2.0%) and easygro (2.0%) at fruit set in that order in season I. The control (no calcium application) registered the lowest fruit mean weight.

Table 1 Mean weight (g) of fruits under different sources of calcium, rate of application and timing of application during season I and II

		SEASON 1			SEASON II		
Source	**Rate**	**T_1**	**T_2**	**T_3**	**T1**	**T2**	**T3**
S_1	R_1	282.0	268.4	101.2	271.4	251.8	129.6
	R_2	289.4	289.0	114.3	291.4	264.2	169.9
	R_3	346.3	291.6	254.8	316.4	299.1	260.4
S_2	R_1	295.6	283.1	244.7	281.3	277.3	230.2
	R_2	314.2	292.1	253.0	296.2	285.2	243.6
	R_3	342.7	312.1	259.6	313.5	294.9	257.2
S_3	R_1	267.8	248.7	107.9	295.7	250.2	127.6
	R_2	288.7	252.1	207.1	302.6	264.2	221.6
	R_3	299.9	266.5	259.3	312.1	272.1	258.3
CTRL	R_0	96.7	96.7	93.7	96.4	94.7	94.3
$LSD_{P=0.05}$							
	Source(S)	5.0			14.5		
	Rate (R)	10.7			6.1		
	Time (T)	6.2			6.0		
	SxR	8.7			9.5		
	SxT	10.6			14.5		
	RxT	8.7			13.2		
	SxTxR	10.6			16.8		
Cv (%)		2.7			3.9		

S_I-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance

The analysis showed that source, rate and time of application had a significant ($p<0.05$) effect on fruit length in season I and II (Table 2). The interaction between source and time had significant effect on the fruit length in both seasons but no significant effect was caused on the fruit length by the interaction between source, rate and time in both seasons.

Table 2: Mean length (mm) of fruits under different sources of calcium, rate of application and timing of application during season I and II

		SEASON I			SEASON II		
Source	**Rate**	**T_1**	**T_2**	**T_3**	**T_1**	**T_2**	**T_3**
S_1	R_1	106.4	103.8	92.8	105.8	95.4	81.5
	R_2	108.5	108.7	96.8	110.6	100.1	83.5
	R_3	117.3	115.4	103.9	115.6	109.4	90.5
S_2	R_1	109.3	104.9	101.0	99.9	93.1	83.4
	R_2	111.1	109.3	102.5	105.7	96.1	85.6
	R_3	111.7	110.6	103.0	113.4	106.2	90.8
S_3	R_1	98.7	102.7	87.7	100.1	95.8	85.0
	R_2	103.1	110.0	93.2	104.3	100.0	87.4
	R_3	112.2	113.7	109.7	114.4	109.1	91.5
CTRL	R_0	83.2	81.9	80.8	83.0	80.0	81.8
LSD $_{p\leq0.05}$							
	Source (S)	1.6			1.9		
	Rate(R)	3.2			1.6		
	Time (T)	0.9			1.6		
	SxR	1.6			NS		
	SxT	5.6			2.9		
	RxT	NS			NS		
	SxTxR	NS			NS		
Cv (%)		3.3			3.2		

S_I-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant

The source of calcium, rate, time of application and their interactions had significant effect on the fruit breadth in season II unlike in season I where only source, rate, time of application and the interaction between source and time had significant effect on the fruit length. Application of calcium at 30 days to physiological maturity had no significant effect on the fruit breadth in both seasons.

Table 3 : Mean breadth (mm) of fruits under different sources of calcium, rate of application and timing of application during season I and II

		Season I			Season II		
Source	Rate	T_1	T_2	T_3	**T_1**	**T_2**	T_3
S_1	R_1	63.5	58.9	50.9	66.0	57.7	52.1
	R_2	67.8	59.4	53.2	67.2	59.9	57.6
	R_3	68.6	63.6	55.6	69.5	63.3	58.1

S_2	R_1	64.5	56.1	50.6	60.8	59.8	52.4
	R_2	69.3	59.2	51.5	64.8	61.8	55.5
	R_3	71.8	63.9	55.5	71.4	65.1	57.4
S_3	R_1	61.4	55.3	52.2	54.0	51.7	53.8
	R_2	66.2	59.3	55.4	58.3	56.3	53.9
	R_3	71.9	62.6	56.6	61.6	59.1	54.4
CTRL	R_0	51.0	51.2	52.9	54.0	51.7	53.8
LSD $_{p\leq0.05}$							
	Source (S)	2.7			1.4		
	Rate(R)	1.6			1.1		
	Time (T)	1.5			0.8		
	SxR	NS			1.4		
	SxT	4.7			2.4		
	RxT	NS			2.0		
	SxTxR	NS			2.4		
Cv (%)		4.9			2.5		

S_l-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant

2.1 Number of fruits, total weight of fruits and fruit retention percentage

The source of calcium, rate, time of application and their interaction had significant ($p\leq0.05$) effect on the mean number of fruits in both seasons. Application of calcium chloride at fruit set (2.0% or 1.5%) had the highest number of fruits in season I at 184 and 156 respectively (Table 4).

Table 4: Mean number of fruits of fruits under different sources of calcium, rate of application and timing of application during season I and II

	Season I				**Season II**		
Source	Rate	T_1	T_2	T_3	T_1	T_2	T_3
S_1	R_1	114.0	105.0	68.3	84.7	68.7	61.7
	R_2	155.7	108.0	71.0	109.3	79.3	64.7
	R_3	184.0	114.7	74.7	123.7	112.0	68.3
S_2	R_1	115.7	93.3	81.0	104.7	67.7	59.7
	R_2	140.3	97.7	82.3	112.0	80.0	62.3
	R_3	152.3	108.3	86.0	119.3	100.7	67.7
S_3	R_1	106.0	94.0	77.3	110.7	94.3	65.3

	R_2	114.0	100.0	80.0	116.3	100.3	66.7
	R_3	124.0	103.3	87.3	124.7	111.0	68.7
CTRL	R_0	65.3	65.7	65.7	49.0	57.7	59.3
LSD							
	Source (S)	4.8				5.9	
	Rate (R)	5.9				4.8	
	Time (T)	3.4				3.2	
	SxR	8.4				5.9	
	SxT	3.4				5.9	
	RxT	3.0				8.3	
	SxTxR	10.3				10.2	
Cv (%)		6.2				7.3	

S_I-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant

The source, rate, time and their interactions had significant ($p \leq 0.05$) effect on the total weight of fruits (Table 5) in both seasons. Application of calcium chloride (2.0%) at fruit set recorded the highest total weight at 63723 kg followed by calcium nitrate (2.0%), and easy gro (2.0%) at 52172kg and 37183 kg respectively. The average total weight in season II was comparatively lower that the average total weight in season I with the highest recorded weight in season II being 39138 kg (calcium chloride, 2.0%). The total weight increased with an increase in the application rate from 1.0%, 1.5% and 2.0% in all the calcium sources in season I and II (Fig 1a &b).

Table 5: Mean number of fruits of fruits under different sources of calcium, rate of application and timing of application during season I and II

Source	Rate	T_1	T_2	T_3	T_1	T2	T3
S1	R1	32142	28184	6917	22912	17318	7984
	R2	45088	31221	8119	31866	20970	11006
	R3	63723	33438	19017	39138	33514	17798
S2	R1	34214	26422	19812	29435	18763	13729
	R2	44107	28538	20839	33163	22814	15179
	R3	52172	33797	22330	37400	29672	17408
S3	R1	28388	23372	8344	32704	23620	8338
	R2	32907	25216	16564	35198	26531	14811
	R3	37183	27552	22618	38913	30206	17732
CTRL	R0	6425	6217	6424	4504	5248	5626
LSD							
	Source (S)	1137				1378	
	Rate (R)	1607.9				1688	
	Time (T)	1078.6				462.4	
	SxR	1969.3				1688.5	
	SxT	2784				2924.6	
	RxT	2412				2388	
	SxTxR	3410.9				1462.1	

S1-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant.

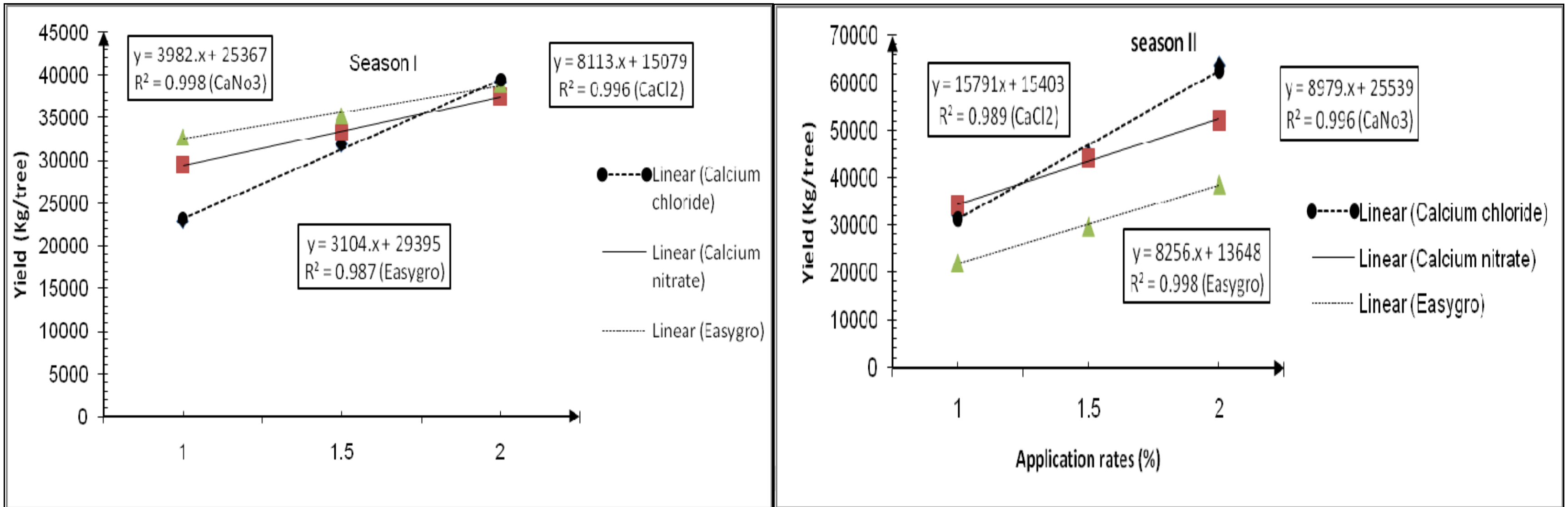

Figure 1a: Yield response curve (Application at fruit set) season 1 and II

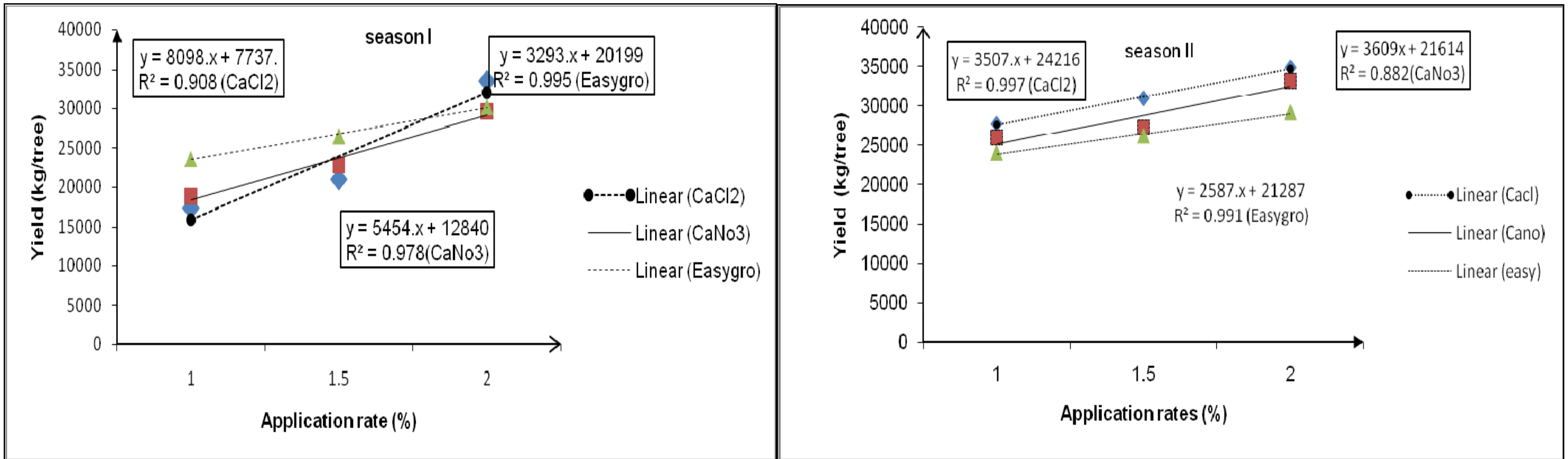

Figure 1b: Yield response curve (Application at 30 days after fruit set) season 1 and II

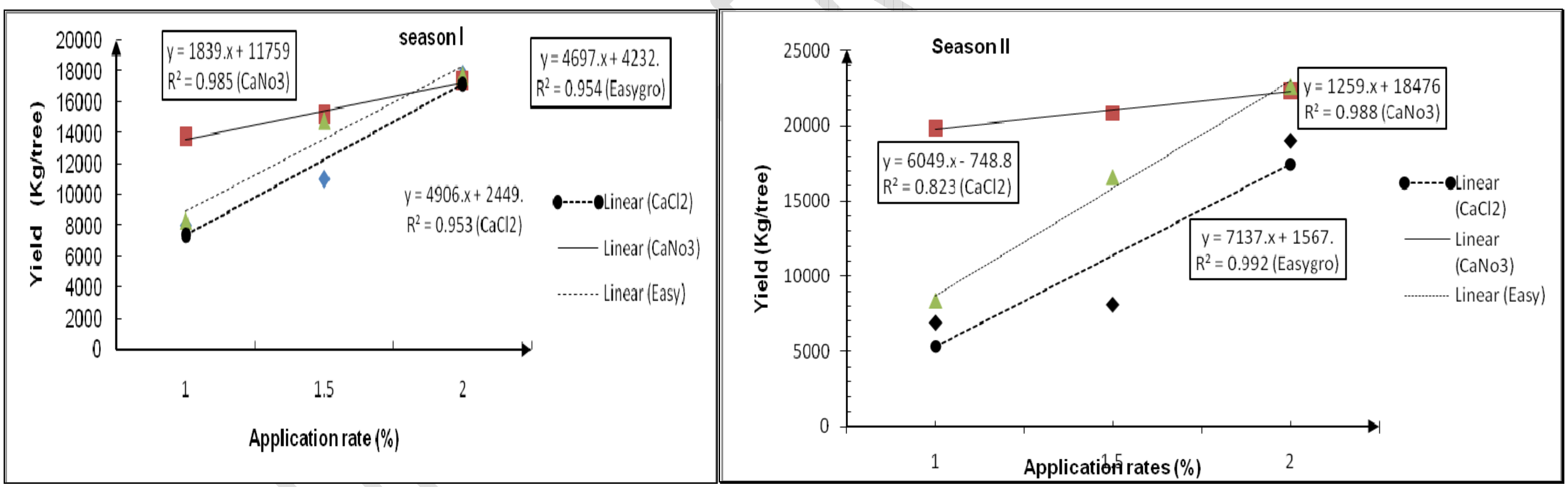

Figure 1c: Yield response curve (Applications at physiological maturity)

The source, rate and time of application had significant (p≤0.05) effect on the fruit retention (Table 6) in both seasons. The interaction between Source and time and rate and time had significant effects on the fruit retention in both seasons. The highest fruit retention was recorded with the application of calcium chloride (2.0%) at fruit set at 8.3 % followed by application of calcium chloride (1.5%) at fruit set in season I. In season II application of easy gro (2.0%) at fruit set had the highest fruit retention at 10.6% followed by calcium nitrate and calcium chloride applied at 2.0% during fruit set in that order.

Table 6: Mean fruit retention (%) of fruits under different sources of calcium, rate of application and timing of application during

			Season I			Season II	
Source	Rate	**T_1**	**T_2**	**T_3**	**T_1**	**T_2**	**T_3**
S_1	R1	7.2	5.4	3.1	7.0	3.8	2.8
	R2	7.8	5.6	3.1	7.9	5.7	3.1
	R3	8.3	6.2	2.5	9.6	8.0	5.0
S_2	R1	6.4	4.5	2.9	5.0	4.1	3.1
	R2	7.3	4.8	2.7	7.4	5.8	3.7
	R3	7.5	5.7	2.9	10.5	7.3	4.8
S_3	R1	6.1	4.5	2.5	5.2	4.0	3.0
	R2	6.6	4.8	2.6	8.2	5.2	4.0
	R3	7.4	5.1	2.7	10.6	7.5	5.2
CTRL	R0	2.3	2.2	2.5	1.7	2.5	2.8
LSD							
	Source (S)		0.25			0.31	
	Rate (R)		0.61			0.43	
	Time (T)		0.24			0.29	
	SxR		NS			NS	
	SxT		0.43			0.53	
	RxT		0.75			0.75	
	SxTxR		NS			0.92	
Cv(%)			9.60			10.20	

S1-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant

The source, rate, time of application and their interactions had significant (p≤0.05) effect on the fruit calcium content in season I (Table 7).The highest fruit calcium content was registered in fruits that were sprayed with easygro (2.0%) at fruit set at 1.13 µg/mg followed by calcium nitrate (2.0%) sprayed at fruit set. In season II calcium nitrate (2.0%) registered the highest fruit retention at 1.08%.Calcim source, the interaction between source and time and that between source, time and rate did not affect the calcium content in season II. Additionally, calcium content was higher in the high concentrations of all calcium sources.

Table 7: Effect of different sources of Ca applied at varied rates at different timings on the mango flesh calcium content (µg/mg) during the two seasons

		Season I			Season II		
Source	Rate	T_1	T_2	T_3	T_1	T_2	T_3
S1	R_1	0.55	0.49	0.38	0.85	0.58	0.52
	R_2	0.60	0.54	0.39	0.90	0.73	0.61
	R_3	0.81	0.66	0.43	1.03	0.90	0.69
S2	R_1	0.57	0.44	0.38	0.77	0.61	0.49
	R_2	0.62	0.52	0.40	0.95	0.76	0.60
	R_3	0.86	0.58	0.44	1.08	0.86	0.66
S3	R_1	0.61	0.50	0.37	0.76	0.70	0.59
	R_2	0.82	0.55	0.44	0.82	0.75	0.61
	R_3	1.13	0.68	0.49	1.00	0.87	0.67
CTRL	R_0	0.30	0.31	0.33	0.26	0.28	0.35
LSD							
	Source (S)	0.02			NS		
	Rate (R)	0.02			0.07		
	Time (T)	0.02			0.05		
	SxR	0.03			0.14		
	SxT	0.04			NS		
	RxT	0.03			0.08		
	SxTxR	0.05			NS		
	CV (%)	6.30			12.2		

S_I-Calcium chloride; S_2-Calcium nitrate;S_3-Easygro; CTRL-Control; R_1-1.0%;R_2-1.5%;R3-2.0%;R_0-0%; T_1-Fruit set; T_2-30 days after fruit set; T_3-30 days to physiological maturity S-Source;T-Time;R-Rate;LSD-Least significant difference;CV-Covariance;NS-Not significant

3.2 Correlation Analysis

Calcium content in the fruit flesh had a significant (p≤ 0.05) positive correlation with fruit length, weight, breadth, number of fruits and total weight of fruits in both seasons (Table 8.

Table 8: Correlation between Ca content in the mango flesh and yield parameter in the two seasons

	Season 1		Season II	
	Pearson correlation (r)	p-value	Pearson correlation (r)	P-value
Fruit length	0.5558	0.0000	0.809	0.0000
Fruit weight	0.3366	0.0003	0.7336	0.0000
Fruit breadth	0.7872	0.0000	0.8828	0.0000
No. of fruits	0.8645	0.0000	0.5880	0.0000
Fruit retention	0.5220	0.000	0.6235	0.000
Total weight of fruits	0.7524	0.0005	0.6845	0.0000

4.0 DISCUSSION

4.1 Yield parameters

Application of Ca significantly increased weight, fruit length, fruit retention percentage and the number of fruits per tree. Calcium chloride (2.0%), applied at fruit set, had the highest fruit weight, fruit length, number of fruits and the total number of fruits in season I and II. The increase in the yield by application of calcium could be attributed to the role of calcium in cell formation and its prevention of cellular degeneration (Burdon et al., 1991; Burdon et al., 1992). Calcium is an important mineral in the formation of cell membrane and development hence increases in the fruit physical attributes. This was in agreement with previous studies (Kumar et al., 2003; Hafle et al 2003; Karemera et al., 2013; Njuguna et al., 2016; Torres et al., 2004; Kumari et al., 2018). These results are contradictory to those reported by Lanauskas et al. (2006) and Bonomelli et al. (2010) who reported no increase in weight and yield of fruits by application of calcium.

The increase in fruit yield (total weight of fruits /tree) is as a result of the cumulative effect due to the increase in the number of fruits/tree due to reduced abscission and the increased growth caused by the calcium sources. Calcium increased the weight of the fruit and decreased fruit drop therefore increasing the yield.

A better performance in yield attributes was obtained with early application of calcium fruit set. Application of calcium at 30 days to anticipated physiological maturity gave poorer results than application at earlier stages perhaps due to poor availability of calcium at this stage. Pre- harvest calcium applications are more available during early stages of fruit development. Similar results have been reported by Karemera et al., (2013) and Penter et al., (2000) in mango and avocado fruits respectively. Higher concentration of the used calcium sources led to higher yields.

Fruit drop was high during initial stages of fruit growth with a decreased trend as maturity progressed. Consequently, fruit drop was highest at fruit set. Similar results have been reported by Sankar et al., 2013. Singh et al. (2013) reported a drop of between 3-5% from 40 days to maturity.

4.2 Calcium tissue concentration

This study showed an increase in the flesh calcium concentration due to the application of calcium. Similar results have been reported by Kader et al., (2004).Results from this study were not in agreement with those reported Bonomelli et al. (2010) and Val et al., (2008) who reported that calcium application did not have an effect on the fruit calcium content. The inconsistency in the results could be due to environmental conditions, rate or the frequencies of application.

4.3 Correlation analysis

Correlation analysis showed apparent association of yield parameters with calcium content. Additionally, the yield (total weight/tree) increased with an increase in calcium concentration. This suggests that application of calcium fertilizer at the right time could improve yields of mango fruits.

5.0 CONCLUSION

Increasing rates of applying calcium chloride, calcium nitrate and from 1.0% to 2.0% increased fruit yield components (fruit weight length, breadth and fruit percentage). It was established that there is a linear relationship between the yield (kg/tree) and the rate of application. The best application realized in this study was calcium chloride at 2.0% applied at fruit set.

Time of application also affected yield as well as yield components with early application giving best results relative to late application and the control. Therefore, it is apparent that calcium is needed during the early stages of fruit development for maximum yield. The established time of application from this study is at fruit set. Late application should be discouraged for better yields and efficient uptake of calcium by the fruit.

The source, rate and time of calcium application and the interaction amongst them had significant effect on the yield and calcium uptake by the fruit. However higher rates should be studied in order to determine the optimum rates.

Competing interests

Authors have declared that no competing interests exist

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