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Effect of various pre-harvest treatments on shelf life and morphological characteristics of fruits of mango (*Mangifera indica* L.) var. 'Amrapali'

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ABSTRACT

The mango is considered as 'king of fruits' in India due to its delicious taste and nutritional status. Extension of fruit shelf life is a prime importance for availability of fresh fruit in market for longer duration and distance transportation. India is the largest producer and a prominent exporter of mango in the world.In this context, the study was conducted to evaluate the effect of preharvest spray of different chemicals and plant growth regulators (PGRs) on mango var. 'Amrapali' for shelf life and its quality. As 'Amrapali' has regular bearer with very good flavor and taste with a late maturing character, selected for shelf life studies. The fruits of mango weresprayed with chemicals *viz.* $CaCl_2$ 1%, $CaCl_2$ 2%, $Ca(NO_3)_2$ 1%, $Ca(NO_3)_2$ 2%, KNO_3 1%, KNO_3 2%, GA_3 25 mg/l, GA_3 50 mg/l, Ethrel 0.1 ml/l and Ethrel 0.2 ml/l prior to harvest. After harvesting, fruits were stored under ambient storage condition. Among all the treatments, GA_3 25 mg/l treatment recorded significantly highest fruit length, fruit diameter, fruit volume and fruit weight at harvest and at fully ripe stage. Application of $CaCl_2$ 2% resulted in significantly minimum physiological loss in weight consistently from 2nd day to 16th day of storage besides significantly highest shelf life and quality. Hence, this intervention can contribute in preserving physical and chemical quality attributes for maximum acceptance by consumers.

Keywords: $CaCl_2$, GA_3, pre-harvest, PGRs and storage

INTRODUCTION

The mango is the national fruit of India and is a highly popular among the masses owing to its excellent flavour, delicious taste, delicate fragrance and attractive colour. Inadequate postharvest handling and management cause major losses in nutritional and quality attributes, pathogenic outbreaks, and economical losses all along the supply chain, from farm to fork. Fresh mangoes are perishable in nature that require coordinated activity by growers, storage operators, processors, and retailers to maintain quality and reduce wastage. In mango, major postharvest losses are due to the loss of quality in terms of firmness, high physiological weight loss and spoilage. In spite of the highest production, India contributes a small share of less than 5% in export market due to its postharvest losses. About 20–30% of the fruits grown in India are lost due to improper handling practices (NHB, 2018). However, It is a climacteric fruit, the upsurge in respiration rate after harvesting becomes faster which shortens the shelf life. The shelf life reduction due to rapid fruit ripening, senescence attack of biotic and abiotic stresses (Zhu *et al*. 2013). The researchers made attempts to extend the shelf life and to reduce spoilage of fruit *viz.* edible coating (Ali *et al.* 2011), modifed or controlled atmosphere storage (Martins and Resende 2015), low temperature storage (Aghdam and Bodbodak, 2013), application of fungicides (Sripong *et al*. 2015), and hot water treatment. Sometimes, due to reduced oxygen level in controlled atmospheric storage develops off-flavor in fruits. There is lacking in availability of storage facilities *viz.* controlled atmospheric storage and modified atmospheric storage at farmers in India and setting up infrastructures for advanced storage facilities is very costly. Also, a cold chain to

manage the time–temperature conditions is adequate for the preservation and transportation of perishables in the proper temperature range to slow down the biological decay processes and deliver safe and high-quality produce to consumers is a lacuna. Hence, preharvest spray of chemicals are very economical to extend the shelf life of fruits.

Potassium plays an important role in photosynthesis, synthesis of carbohydrates, oils, fats and proteins. It is also involved in the transportation of photosynthates towards the sink and enhances the production of protein (Lu *et al*., 2016). Potassium is an important nutrient for fruit weight and quality. Potassium is required for the production and transport of plant sugars that increase the weight of fruit (Jaiswal *et al*. 2021). Ethrel releases ethylene gas, influences the growth and development of fruits. Ethrel is responsible for early development of many fruits characterized by a high rate of ethylene evolution and hastens the ripening process with uniform colour development (Dhillon, 2013). Calcium is known to be essential plant nutrient involved in a number of physiological processes concerning membrane structure, function and enzyme activity (Jones and Lunt, 1967). It has received considerable attention in recent years due to its desirable effects in delaying ripening and senescence, increasing firmness, reduce respiration, extending storage life and reducing the incidence of physiological disorders and storage rots. Preharvest application of these compounds hinders the fruit ripening without affecting the edible quality. Preharvest application of $CaCl_2$ extends the shelf life and restrict the microbial infection without any detrimental effect and protects against post-harvest deterioration and extend shelf life (Saure, 2005). Gibberellic acid has been found to enhance the fruit size, increase the yield, and improve the physico-chemical characteristics of fruits through modification of various physiological and bio-chemical processes (Pandey and Sinha, 2013). Gibberellic acid in proper concentration and at appropriate time have been found to better results in fruits quality, yield, size, decrease fruit drop, increasing sugar content, improve the physico-chemical characteristics and extend the post-harvest life of fruits through modification of various physiological and bio-chemical processes of plant (Pandey and Sinha, 2013). Gibberellins have been useful in enhancing fruit retention and improving the size and quality of fruits. Further, gibberellic acid has anti-senescent property and help in maintaining cell wall integration and prevents growth of pathogen in the fruits and extend shelf life (Prasad, 2006).

Being a climacteric fruit, weight loss increases rapidly during storage period due to surge in respiration rate and transpiration process. However, it can be minimized by supplementary application of chemicals and plant growth regulators on fruits for maintaining fruit quality and extending their shelf life (Vishwakarma and Masu, 2018; Bisen and Thakur, 2012). Now a day, the mango variety 'Amrapali' grown commercially throughout the country because of its dwarf stature. It has very good flavor, taste and high in vitamins and carotenoids content as compared to other verities of mango with a late maturing character, selected for shelf life studies.Considering these points, the present study was designed to study the effect of preharvest spray of different chemicals and plant growth regulators on shelf life extension of mango fruits under ambient storage condition.

MATERIALS AND METHODS

The experiment was conducted at Horticultural Research Farm and Postgraduate Laboratory, Department of Horticulture, Bansilal Amrutlal College of Agriculture, Anand Agricultural University, Anand during summer season of the year 2016. The climate of Anand region is semi-arid and sub-tropical type. The temperature was in the range of 25 to 40 ^{o}C with 52 to 73 % relative humidity during experiment time in the month of June, 2016. There were eleven treatments embedded in Completely Randomized Design replicated thrice. Thirty-three uniform sizedfourteen-year old trees of mango var. 'Amrapali' were selected and preharvest sprayed with different chemicals ($CaCl_2$ 1 %, $CaCl_2$ 2 %, $Ca(NO_3)_2$ 1 %, $Ca(NO_3)_2$ 2 %, KNO_3 1 %, KNO_3 2 %), Ethrel 0.1 ml/l and Ethrel 0.2 ml/l) along with control at twenty days before anticipated date of harvest while, GA_3 25 mg/l and GA_3 50 mg/l were sprayed at marble stage. Mature and uniform sized ten fruits per replication were harvested from the representative trees and kept in ambient storage condition (32±1 ^{o}C). When the outer layer of fruits starts to spoil like discoloration, shriveling and visible sign of biotic spoilage

(anthracnose) considered as end of shelf life and noted as spoiled (Rahman *et al*., 2007).

RESULTS AND DISCUSSION

Effect of preharvest treatments on physical parameters of mango fruit

The fruit size is an important consideration for consumer preference. The effect of treatments on fruit size *viz*. length and diameter were found to be significant at harvest as well as at fully ripe stage (Table 1). The fruit length (10.20 cm) at harvest stage was found significantly maximum with GA_3 25 mg/l treatment followed by the treatments of $KNO_3$1 %, Ethrel 0.2 ml/l, GA_3 50 mg/l, $Ca(NO_3)_2$ 1% and 2% while at fully ripe stage significantly maximum fruit length l (10.16 cm) was recorded with GA_3 25 mg/ followed by treatments of Ethrel 0.2 ml/l, GA_3 50 mg/ l, $Ca(NO_3)_2$ 1% and 2%. The maximum fruit diameter (6.16 cm) at harvest stage was found significant in treatment of GA_3 25 mg/l and $Ca(NO_3)_2$ 1% followed by $Ca(NO_3)_2$ 2%, $CaCl_2$ 1%, GA_3 50 mg/l, Ethrel 0.1 ml/l, KNO_3 2% while, at fully ripe stage after storage under ambient condition the diameter of fruits (6.14 cm) was found significantly maximum in treatment of GA_3 25 mg/l followed by $Ca(NO_3)_2$ 1% and 2%, GA_3 50 mg/l, Ethrel 0.1 ml/l and KNO_3 2%. The significant effect of treatments was found on fruit volume at harvest as well as at fully ripe stage. Preharvest sprayed with GA_3 25 mg/l reported significantly highest fruit volume (150.54 cc) at harvest followed by KNO_3 1% and at fully ripe stage (fruit volume - 130.62 cc) also found maximum in treatments of GA_3 25 mg/l followed by KNO_3 1% and Ethrel 0.2 ml/l under ambient storage condition (Table 1). The fruit weight was significantly influenced by various chemicals and plant growth regulators at everyday up to last ripening stage. Application of GA_3 25 mg/l depicted significantly maximum fruit weight (170.50 g) at harvest and consistently up to 16th day of storage period under ambient condition as compared to rest of the treatments (Table 2). The lowest fruit weight, length, diameter and volume were recorded in the control at both the stages *i.e.* at harvest and fully ripe stage.

The fruit size of mango was greatly influenced by different treatments of chemicals. In comparison to all treatments gibberellic acid influenced significantly in terms of fruit weight, volume, length and diameter. It

Table 1. Effect of preharvest treatments on fruit length (cm.), fruit volume (cc.) and fruit diameter (cm.) in mango fruit var. 'Amrapali'.

Treatments	Fruit length (cm)		Fruit diameter (cm)		Fruit volume (cc)	
	At harvest	At fully ripening stage	At harvest	At fully ripening stage	At harvest	At fully ripening stage
T_1: $CaCl_2$ 1 %	9.45^{cde}	9.41^{cd}	6.05^{ab}	6.02^{ab}	126.33^{de}	101.58^{de}
T_2: $CaCl_2$ 2 %	9.27^{de}	9.25^{d}	5.53^{c}	5.50^{cd}	124.61^{e}	104.16^{cd}
T_3: $Ca(NO_3)_2$ 1%	9.83^{abc}	9.80^{abc}	6.13^{a}	6.08^{ab}	127.87^{cde}	104.12^{cd}
T_4: $Ca(NO_3)_2$ 2%	9.80^{abc}	9.77^{abc}	6.06^{ab}	6.04^{ab}	133.73^{c}	111.29^{b}
T_5: KNO_3 1 %	10.05^{ab}	10.01^{ab}	5.44^{cd}	5.41^{de}	148.88^{ab}	129.95^{a}
T_6: KNO_3 2 %	9.65^{bcd}	9.62^{bcd}	5.90^{ab}	5.87^{ab}	123.10^{e}	98.22^{e}
T_7: Ethrel 0.1 ml/l	9.25^{e}	9.21^{d}	5.95^{ab}	5.93^{ab}	115.43^{f}	101.43^{de}
T_8: Ethrel 0.2 ml/l	9.99^{ab}	9.96^{ab}	5.82^{b}	5.78^{bc}	142.23^{b}	126.33^{a}
T_9: GA_3 25 mg/l	10.20^{a}	10.16^{a}	6.16^{a}	6.14^{a}	150.54^{a}	130.62^{a}
T_{10}: GA_3 50 mg/l	9.85^{abc}	9.82^{abc}	5.96^{ab}	5.93^{ab}	131.88^{cd}	107.42^{bc}
T_{11}: Control	8.32^{f}	8.29^{e}	5.23^{d}	5.21^{e}	101.02^{g}	77.73^{f}
SEm±	0.123	0.126	0.089	0.089	2.112	1.612
C.D.	0.364	0.373	0.264	0.262	6.234	4.758
C. V. %	2.223	2.284	2.653	2.648	2.822	2.574

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5 % level of significance.

Table 2. Effect of preharvest treatments on fruit weight (g) of mango var. 'Amrapali'.

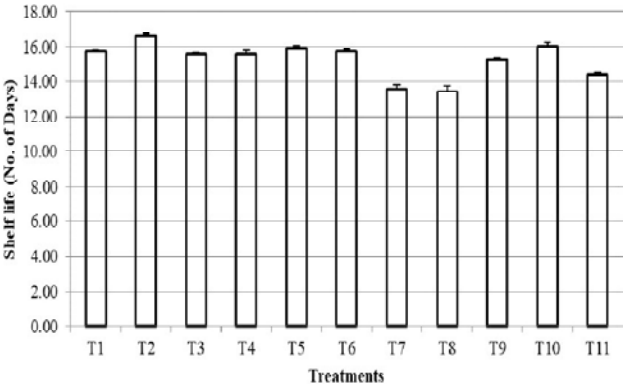
Treatments	Fruit weight (g) in storage at ambient condition (Days)															
	At harvest	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th
T_1: $CaCl_2$ 1 %	137.7^{e}	134.64^{de}	132.45^{fg}	129.93 ^{fg}	128.54^{ef}	126.57^{ef}	125.08^{ef}	122.32^{ef}	121.44^{ef}	120.03^{ef}	117.27 ^{fg}	115.05 ^{fg}	113.63^{cd}	112.01^{ef}	110.94^{cd}	108.30^{de}
T_2: $CaCl_2$ 2 %	138.1^{e}	136.28^{d}	134.32^{ef}	132.25^{efg}	130.23^{ef}	128.85^{def}	127.43^{def}	125.36^{def}	123.95^{def}	122.29^{de}	120.92 ^{def}	117.91^{ef}	115.11^{cd}	113.70^{def}	112.17^{cd}	109.83^{cd}
T_3: $Ca(NO_3)_2$ 1%	146.2^{d}	143.68^{c}	141.53^{de}	139.13^{de}	135.99^{de}	133.98^{cde}	131.92^{cde}	129.63^{cde}	127.69^{cde}	125.70^{cde}	124.03^{cdef}	122.52^{cdef}	121.60^{bc}	119.92^{cde}	117.66^{c}	113.82^{cd}
T_4: $Ca(NO_3)_2$ 2%	149.3^{d}	146.78^{c}	144.72^{cd}	142.15^{cd}	140.26^{cd}	137.51 ^{cd}	134.98^{cd}	133.18^{cd}	131.38^{cd}	129.61^{cd}	126.97 ^{cde}	125.35^{cde}	123.47^{bc}	121.87^{bcdee}	119.17^{bc}	117.53^{cd}
T_5: KNO_3 1 %	164.4^{b}	162.63^{a}	158.75^{ab}	156.05^{ab}	153.93^{ab}	151.87^{ab}	147.80^{ab}	145.14^{ab}	143.30^{ab}	141.33^{ab}	138.53 ^{ab}	137.22 ^{ab}	134.76 ^{a}	132.54 ^{ab}	130.53 ^{ab}	128.91^{ab}
T_6: KNO_3 2 %	138.6^{e}	135.89^{d}	134.52^{ef}	132.51^{ef}	131.11^{ef}	129.58^{def}	128.04^{def}	125.98^{de}	123.84^{de}	122.63^{de}	119.95^{ef}	118.77^{def}	116.95^{bc}	115.58^{cde}	113.06^{c}	111.06^{cd}
T_7: Ethrel 0.1ml/l	132.4^{f}	130.26^{e}	126.00^{gh}	124.25^{gh}	122.97^{fg}	120.95^{fg}	118.93^{fg}	116.65^{fg}	114.73^{fg}	112.40^{fg}	109.76^{gh}	107.87^{gh}	106.01^{de}	104.27^{fg}	101.73^{de}	99.36^{ef}
T_8: Ethrel 0.2ml/l	158.4^{c}	155.63^{b}	151.67^{bc}	147.57^{bcd}	145.62^{bc}	143.27^{bc}	140.60^{bc}	136.86^{bc}	134.51^{bc}	133.08^{bc}	130.74^{bc}	128.89^{bc}	125.73^{ab}	123.97^{bcd}	120.67^{bc}	118.65^{bcd}
T_9: GA_3 25 mg/l	170.5^{a}	167.18^{a}	164.14^{a}	160.34^{a}	158.99^{a}	156.38^{a}	153.79^{a}	150.46^{a}	147.31^{a}	145.02^{a}	143.41 ^{a}	142.22 ^{a}	135.37 ^{a}	135.29 ^{a}	132.86 ^{a}	130.92^{a}
T_{10}: GA_3 50 mg/l	155.8^{c}	153.23^{b}	150.06^{c}	148.13^{bc}	145.59^{bc}	142.74^{bc}	140.21^{bc}	137.18^{bc}	135.03 ^{bc}	133.08^{bc}	130.54 ^{bcd}	128.65^{bcd}	126.81^{ab}	124.70^{abc}	120.86^{bc}	119.42^{bc}
T_{11}: Control	124.9^{g}	123.29^{f}	121.83^{h}	119.5^{h}	116.9^{g}	115.8^{g}	113.36^{g}	111.93^{g}	109.60^{g}	107.42^{g}	105.0^{h}	103.9^{h}	102.1^{e}	100.4^{g}	96.65^{e}	96.00^{f}
SEm±	1.550	1.677	2.283	2.533	2.683	2.756	2.828	2.858	2.910	2.784	2.906	2.967	3.005	3.040	3.444	3.144
C.D.	4.575	4.950	6.739	7.478	7.918	8.137	8.347	8.435	8.591	8.217	8.579	8.757	8.869	8.973	10.168	9.280
C. V. %	1.826	2.010	2.788	3.151	3.384	3.530	3.685	3.795	3.925	3.808	4.050	4.192	4.331	4.449	5.142	4.777

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5 % level of significance.

might be due to the involvement of gibberellic acid in promoting cell elongation and cell enlargement of fruit (Jagtap *et al*. 2013; Lal *et al*. 2013). As, GA_3 level in developing cell is low, the exogenous application of GA_3 helps to increase its level in different parts of the fruits, which ultimately helps its growth. The cell elongation stimulated by exogenous gibberellins through altering the rheological properties of the cell wall; as a consequence, the water potential of the cell is lowered allowing for water uptake and greater accumulation of food materials and therefore an increase in cell volume (Derbyshire *et al*., 2007; Brahmachari and Rani, 2000). In the present study, results of GA_3 sprays are in line with those reported by El-Sese (2005) where Balady mandarin trees sprayed with GA_3 resulted in increased yield as of increased fruit weight, length and diameter. The results are also supported by Mostafa *et al.* (2001) on pear and ElSharkawy and Mehaisen (2005) on guava. Marschner (1986) indicated that application of GA_3 and/or IAA on higher plants caused elongation in the primary cells in the young tissues and growth centers. The bigger size and good quality fruits was also observed in plum by González-Rossia *et al.* (2006), Bhomick and Banik (2011) in mango and Singh *et al.* (2009) & Katiyar *et al.* (2008) in guava.

Effect of preharvest treatments on storage studies

There were significant differences observed in physiological loss in weight due to various preharvest treatments of fruits from harvest to everyday up to 16th day (Table 3). Among the treatments, $CaCl_2$ 2 % consistently recorded significantly minimum physiological loss in weight of fruits (1.12 % to 19.91%) from 2nd day to 16th day of storage period respectively, it was found on par with KNO_3 (2%). The significant effect of various treatments was observed on shelf life of mango fruit during storage periods and $CaCl_2$ 2 % was found most effective treatment for extending the shelf life. After storage at ambient temperature $CaCl_2$ 2 % was recorded significantly maximum shelf life (16.60 days) compared to rest of the treatments (Fig. 1) while Ethrel treated fruits were recorded lowest shelf life. There was a significant difference observed in the marketable fruit percentage and spoilage of the fruits during storage under ambient condition. The treatments were significantly influenced at harvest and everyday up to last ripening stage (Table 4). There were 100 % marketable fruits and no spoilage in fruits was recorded in all the treatments up to 12th day of storage



(T_1: $CaCl_2$ 1%, T_2: $CaCl_2$ 2 %, T_3: $Ca(NO_3)_2$ 1%, T_4: $Ca(NO_3)_2$ 2%, T_5: KNO_3 1 %, T_6: KNO_3 2 %, T_7: Ethrel 0.1 ml/l, T_8: Ethrel 0.2 ml/l, T_9: GA_3 25 mg/l, T_{10}: GA_3 50 mg/l and T_{11}: Control)

Fig. 1. Effect of preharvest treatments on shelf life (days) of mango var. 'Amrapali'.

periods. Significantly maximum marketable fruit percentage (90.93%) and minimum spoilage (9.07%) were found in treatment of $CaCl_2$ 2 % followed by $CaCl_2$1% at 13th and 14th day of storage. Significantly maximum marketable fruit percentage and minimum spoilage were found in treatment of $CaCl_2$ 2 %, $CaCl_2$1%, $GA_3$25 mg/l & 50 mg/l after 15th day of storage under ambient condition. Treatment with $CaCl_2$ 2 %, also recorded significantly highest marketable fruit percentage and minimum spoilage at 16th day of storage followed by treatment of $GA_3$25 mg/l and 50 mg/l.

Moisture content of the fruits is an important consideration for its freshness and stability to the storage for a longer duration. The physiological loss in weight in mango fruits was tended to increase during the storage irrespective of the treatments. This could be due to increased moisture loss and enhanced shriveling (Lata *et al.* 2017). Fruits sprayed with $CaCl_2$ 2 % retained the minimum physiological loss in weight and spoilage per cent and maximum shelf life & marketable fruit per cent as compared to rest of the treatments.

As calcium is known to increase fruit cell wall turgidity, serves as a semipermeable membrane, it is also supposed to reduce water diffusion over the fruit cuticle to reduce the differences in osmotic potential, which slows down the evapotranspiration and respiration rate in fruits due to reduced endogenous substrate catabolism and altered membrane permeability (Vercesi *et al*., 2018). Higher concentrations of $CaCl_2$ might be require for the driving force for water diffusion, and to

Table 3. Effect of preharvest treatments on physiological loss in weight (%)of fruit of mango var. 'Amrapali'

Treatments	Storage period (Days)														
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th
T_1: $CaCl_2$ 1 %	2.24^{a}	3.85^{c}	5.68^{c}	6.68^{de}	8.11^{bcd}	9.19^{b}	11.22^{bc}	11.85^{c}	12.85^{d}	14.87^{d}	16.48^{bc}	17.51^{cde}	18.68^{def}	19.47^{cd}	21.38^{cd}
T_2: $CaCl_2$ 2 %	1.12^{f}	2.13^{h}	4.33^{g}	5.43^{h}	6.53^{g}	7.66^{c}	9.15^{d}	10.26^{d}	11.47^{e}	12.44^{e}	14.35^{d}	15.66^{f}	16.66^{g}	18.48^{d}	19.91^{e}
T_3: $Ca(NO_3)_2$1%	1.76^{d}	3.23^{e}	4.87^{de}	7.02^{bc}	8.40^{bc}	9.80^{b}	11.37^{bc}	12.69^{bc}	14.05^{bc}	15.19^{cd}	16.22^{c}	16.85^{def}	18.00^{efg}	19.55^{cd}	22.18^{bc}
T_4: $Ca(NO_3)_2$2%	1.68^{d}	3.10^{e}	4.81^{ef}	6.07^{f}	7.90^{cd}	9.62^{b}	10.82^{bc}	12.01^{c}	13.19^{cd}	14.95^{cd}	16.04^{c}	17.30^{cde}	18.36^{ef}	20.18^{c}	21.29^{cd}
T_5: $KNO_3$1 %	1.97^{b}	3.48^{d}	5.12^{d}	6.41^{e}	7.66^{de}	10.13^{b}	11.74^{b}	12.87^{bc}	14.64^{b}	15.77^{bcd}	16.56^{bc}	18.06^{cde}	19.41^{cde}	20.63^{c}	21.62^{cd}
T_6: KNO_3 2 %	2.06^{c}	2.72^{f}	4.42^{g}	5.71^{g}	6.71^{fg}	7.74^{c}	9.24^{d}	10.68^{d}	11.56^{e}	13.50^{e}	14.62^{d}	16.65^{ef}	17.67^{fg}	18.78^{d}	20.47^{de}
T_7: Ethrel 0.1 ml/l	1.63^{ab}	4.83^{a}	6.16^{b}	7.13^{b}	8.66^{b}	10.18^{b}	11.90^{b}	13.35^{b}	15.12^{ab}	17.11^{ab}	18.53^{a}	19.95^{ab}	21.26^{ab}	23.18^{ab}	24.97^{a}
T_8: Ethrel 0.2 ml/l	1.81^{cd}	4.31^{b}	6.90^{a}	8.13^{a}	9.60^{a}	11.29^{a}	13.65^{a}	15.13^{a}	16.04^{a}	17.52^{a}	18.69^{a}	20.68^{a}	21.79^{a}	23.88^{a}	25.16^{a}
T_9: $GA_3$25 mg/l	2.00^{bc}	3.79^{c}	6.02^{b}	6.82^{cd}	8.35^{bc}	9.86^{b}	11.81^{b}	13.66^{b}	15.00^{ab}	15.94^{bcd}	16.64^{bc}	18.70^{bc}	20.70^{abc}	22.12^{b}	23.25^{b}
T_{10}: $GA_3$50 mg/l	1.70^{d}	3.74^{c}	4.98^{de}	6.60^{de}	8.43^{b}c	10.06^{b}	11.99^{b}	13.37^{b}	14.63^{b}	16.25^{abc}	17.47^{b}	18.65^{bc}	20.04^{bcd}	22.48^{b}	23.41^{b}
T_{11}: Control	1.30^{e}	2.35^{g}	4.57^{fg}	6.42^{e}	7.25^{ef}	9.25^{b}	10.40^{c}	12.26^{c}	13.99^{bc}	15.93^{bcd}	16.77^{bc}	18.20^{cd}	19.59^{bcde}	22.63^{ab}	23.14^{b}
SEm±	0.059	0.052	0.079	0.092	0.190	0.303	0.375	0.312	0.352	0.404	0.299	0.449	0.500	0.384	0.427
C.D.	0.175	0.155	0.232	0.273	0.562	0.893	1.106	0.920	1.038	1.191	0.882	1.325	1.475	1.134	1.260
C. V. %	5.86	2.659	2.585	2.433	4.137	5.502	5.791	4.301	4.391	4.538	3.122	4.315	4.486	3.163	3.295

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5 % level of significance.

Table 4. Effect of preharvest treatments on marketable fruit (%) and spoilage fruit (%) of mango var. 'Amrapali'

Treatments	Marketable fruit (%)					Spoilage fruit (%)				
	Storage period (Days)					Storage period (Days)				
	1 to 12th	13th	14th	15th	16th	1 to 12th	13th	14th	15th	16th
T_1: $CaCl_2$ 1 %	100	90.10^{ab}	76.67^{b}	54.41^{a}	42.40^{b}	00	9.90^{fg}	23.33^{d}	45.59^{c}	57.60^{e}
T_2: $CaCl_2$ 2 %	100	90.93^{a}	79.55^{a}	56.63^{a}	45.16^{a}	00	9.07^{g}	20.45^{e}	43.37^{c}	54.84^{f}
T_3: $Ca(NO_3)_2$ 1%	100	85.87^{f}	71.95^{e}	42.86^{bc}	36.43^{c}	00	14.13^{b}	28.05^{b}	57.14^{ab}	63.57^{d}
T_4: $Ca(NO_3)_2$ 2%	100	86.56^{ef}	73.99^{cd}	44.11^{bc}	34.40^{cd}	00	13.44^{bc}	26.0^{c}	55.89^{ab}	65.60^{cd}
T_5: KNO_3 1 %	100	87.04^{def}	73.44^{de}	42.48^{c}	32.34^{de}	00	12.96^{bcd}	26.56^{bc}	57.52^{a}	67.66^{bc}
T_6: KNO_3 2 %	100	86.84^{def}	73.81^{cd}	45.45^{b}	33.68^{d}	00	13.16^{bcd}	26.19^{c}	54.55^{b}	66.32^{c}
T_7: Ethrel 0.1 ml/l	100	86.18^{ef}	74.35^{cd}	43.15^{bc}	30.63^{ef}	00	13.82^{bc}	25.65^{c}	56.85^{ab}	69.37^{ab}
T_8: Ethrel 0.2 ml/l	100	88.22^{cd}	75.12^{bc}	43.05^{bc}	30.00^{f}	00	11.78^{de}	24.88^{cd}	56.95^{ab}	70.00^{a}
T_9: GA_3 25 mg/l	100	87.50^{de}	74.51^{cd}	56.26^{a}	43.10^{ab}	00	12.50^{cd}	25.49^{c}	43.74^{c}	56.91^{ef}
T_{10}: GA_3 50 mg/l	100	89.15^{bc}	76.66^{b}	56.55^{a}	43.59^{ab}	00	10.85^{ef}	23.34^{d}	43.45^{c}	56.41^{ef}
T_{11}: Control	100	80.14^{g}	68.03^{f}	43.42^{bc}	30.91^{ef}	00	19.86^{a}	31.97^{a}	56.58^{ab}	69.09^{ab}
SEm±		0.437	0.503	0.822	0.684		0.437	0.503	0.822	0.684
C.D.		1.290	1.484	2.426	2.020		1.290	1.484	2.426	2.020
C. V. %		**0.869**	**1.171**	**2.964**	**3.238**		**5.887**	**3.398**	**2.740**	**1.870**

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5 % level of significance.

strengthen the walls of epidermal cells that might had resulted in improved resistance to the fruit cell degradation, when the cells meet free flow of water (Sekse, 1997). Preharvest spray of $CaCl_2$ restricts the microbial infection without any detrimental effect, maintains cell turgor and delays lipid peroxidation, thereby extending shelf life of fruits (Saure, 2005). The calcium compounds significantly thickened the middle lamella of fruit cells owing to increased deposition of calcium pectate and thereby maintained the cell wall rigidity which inhibits the penetration and spread of pathogens in fruits (Gupta *et al.* 1987). This could be one of the reasons for reduction in physiological loss in weight and biotic and abiotic spoilage during storage under ambient condition for 2% calcium chloride treated mango fruits. The similar view of results was also reported in persimmon cv. Karaj (Bagheri *et al.* (2015), in pear cv. Leconte (Sajid *et al.*, 2014), in papaya (Lata *et al.*, 2018; Yadav and Varu, 2013; Ramkrishna *et al.*, 2001), in plum (Kirmani *et al.*, 2013), in mango(Bhusan *et al.*, 2015; Karemera *et al.,* 2014; Singh *et al.,* 2012) and ber (Jawandha*et al.,* 2009; Yadav *et al.,* 2009) for physiological loss in weight, shelf life and reduce spoilage during ambient storage after calcium treatments.

CONCLUSION

Quality evaluation and maintenance is must to be realized in all segments as consumers will not accept a product when it does not have the requirements or desired quality attributes that may cause major impact on the commercialization chain, especially exportation.The results obtained from present investigation concluded that, GA_3 25 mg/l treatment found better in response to improve the physical charactertics of fruit like fruit length, fruit diameter, fruit volume and fruit weight during storage period. Whereas, application of $CaCl_2$ 2% effectively improved the shelf life of fruits and marketable fruit percentage while, minimizing the physiological loss in weight and spoilage percentage of fruits under ambient storage condition. The study

shows that preharvest spray of calcium chloride is eco-safe and could be done for improving shelf life of mango fruits for better marketability.

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