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ORIGINAL PAPER

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YIELD AND FRUIT QUALITY OF *Ziziphus jujuba* L. TREES AS AFFECTED BY PREHARVEST FOLIAR APPLICATION OF CALCIUM AND ASCORBIC ACID

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ABSTRACT

The present study was carried out during the seasons of 2014 and 2015 at the Research and Agricultural Experimental Station, King Saud University, Saudi Arabia, to investigate the effects of foliar application of $CaCl_2$ at 1 or 2%, $Ca(NO_3)_2$ at 0.5 or 1% and ascorbic acid at 50 or 100 ppm on yield and fruit quality of *Ziziphus jujuba* trees. All treatments were repeated twice (December 15 and January 15) before harvest date in both seasons. Treatments significantly improved yield and fruit physical characteristics (fruit weight, flesh weight, fruit volume, fruit length, fruit diameter and fruit firmness) in comparison to untreated control in both seasons. Fruit chemical characteristics (TSS, Acidity, total sugar contents, ascorbic acid, and total chlorophyll) were mostly improved by most tested treatments in both seasons over the control (water only). It can be concluded that foliar application with $Ca(NO_3)_2$ at 1% would be the best treatment to obtain highest yield, fruit physical and chemical composition of *Z. jujuba*.

Key words: *Ziziphus jujuba*, $CaCl_2$, $Ca(NO_3)_2$, ascorbic acid, yield, fruit quality

INTRODUCTION

Ber (*Ziziphus* spp.), which belongs to the family *Rhamnaceae* that consists of 45 genera and 550 species, is widely distributed in tropical and subtropical climates in the world; i.e. Northern Africa, Southern Europe, and Western Asia [Mukhtar et al. 2004]. Ber fruits are a rich nutritional source for energy, protein and minerals. It refreshes, restores and improves memory and is a remedy for high blood pressure [De Bairacli 1991]. Jujube fruits help to eliminate oxidative stress in the liver [Xiangchun et al. 2009] and inhibit tumor cells [Fatemeh et al. 2008]. There is a great need to decrease fruit deterioration after harvest and to enhance fruit quality in order to prolong the handling season with acceptable yield. To reach this goal, different agrochemicals can be used such as ascorbic acid, calcium chloride and calcium nitrate. Ascorbic acid is considered as having auxinic action, as well as having synergistic effect on growth and productivity of most fruit trees [Ragab 2002]. In addition, the positive action of antioxidants in catching or chelating the free radicals could result in stimulating plant growth aspects and enhancing fruit storability [Rao et al. 2000]. In the meantime, ascorbic acid is considered a regulator of plant growth. Calcium is a nutrient that plays an important role in improving fruit quality [Rizk-Alla et al. 2006]. Low fruit calcium levels have been

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associated with reduced postharvest life and physiological disorders [Wills et al. 1998]. Calcium is one of the nutrients which are multifunctional in plant physiology and vital for vegetative growth and development [Assmann 1995], also important as intracellular messenger mediating response to hormones, biotic and abiotic stress signals and a variety of developmental processes [Reddy and Reddy 2004]. Calcium foliar application is widely used as fruit tree treatment which is shown to increase calcium contents of apple fruits, prevent or alleviates physiological fruit disorders and reduces cherry creaking [Centkowski and Tomala 2000]. Calcium compounds (nitrate and calcium chloride) can reduce the appearance of brown spots and also increase calcium levels in flesh of the fruits [Shamili and Hajiani 2012], and keep the quantity and the quality of *Ziziphus mauritiana* fruit [Shahi et al. 2015]. In addition, calcium has long been known to confer rigidity of cell walls, which in turn reflected on increasing the tissue firmness. The present investigation aimed at studying the effect of preharvest foliar spray of calcium and ascorbic acid (antioxidants) on yield and fruit quality of *Ziziphus jujuba* L. trees.

MATHERIALS AND METHODS

Experimental setting

The present study was carried out during the seasons of 2014 and 2015 at the Research and Agricultural Experimental Station, King Saud University, Saudi Arabia to study the effect of calcium chloride, calcium nitrate and ascorbic acid on yield and fruit quality at harvest date of jujube fruits. Twenty-one years old of Ber trees grown in a calcareous soil under flooding irrigation system, planted at 4 × 5 m spacing (500 trees/ha) and pruned severely in April. Trees were subjected to the same cultural practices usually done in the orchard. The trees were fertilized with organic manure and calcium super phosphate (15% P_2O_2) at a rate of 20 kg and 1.5 kg per tree respectively in May in both seasons. In addition to 3 kg ammonium sulphate (20.6% N) and 1.5 kg potassium sulphate (48% K_2O) per tree were added in 3 equal doses at the beginning of May, June and August.

All treatments were foliar applied twice (December 15 – January 15) in both seasons. The experiment was designed as randomized complete design (RCD) and the following 5 foliar spray treatments were applied with 3 replicates for each treatment: water only (control), $CaCl_2$ at 1%, $CaCl_2$ at 2%, $Ca(NO_3)_2$ at 0.5%, $Ca(NO_3)_2$ at 1%, ascorbic acid at 50 ppm, ascorbic acid at 100 ppm.

All trees were foliar spraying was carried out early in the morning by used 5 L/tree (total 2500 L/ha). The surfactant Nourfilm (produced by Alam Chemica) was added at the rate of 40 cm^3/100 L water (v/v), to all sprayed chemical sand applied when fruitlet diameter was at 3.0–4.0 mm (15–20 days after fruit set), in order to obtain the best penetration results.

Measurements and determination

Yield. At harvest date, fruits from each replicate tree were harvested when the fruit color turned to light green (ovary green) and weighed to record the total yield (kg/tree) in both seasons.

Fruit physical characteristics: a sample of 3 kg fruits for each replicate was randomly collected in both seasons and the following fruit characteristics were determined: fruit weight (g), flesh weight (g), seed weight (g), fruit volume (cm^3), fruit length and diameter (cm), fruit shape index (fruit length/ diameter) and fruit firmness (was recorded by using Fruit Hardness Tester, No. 510-1).

Fruit chemical characteristics: at maturity stage, a representative sample of 2 kg fruits were taken from each tree (replicate) in both seasons and the following characteristics were determined: total soluble solids by using hand refractometer, total acidity (%), fruit pH by using pH meter, sugar content (reducing, non-reducing and total sugar), ascorbic acid content (mg/100 ml juice), moisture content, were determined according to AOAC [1995].

Pigments (total chlorophyll): fresh mature fruit samples from skin (0.03 gm) were extracted with 5 mL N dimethyl formamide then chlorophyll a, b and total chlorophyll were determined calorimetrically at wave length of 663.8 and 646.8 nm respectively, then concentrations of each component was calculated by Porra et al. [1989] as follows:

Chlorophyll a = 13.43 × A 663.8 – 3.47 × A 646.8 (nm/mL)

Chlorophyll b = 22.9 × A 646.8 – 5.38 × A 663.8 (nm/mL)

Total chlorophyll = 19.43 × A 646.8 + 8.05 × A 663.8 (nm/mL)

Statistical analysis

Data obtained throughout this study were statistically analyzed using the analysis of variance method as reported by Snedecor and Cochran [1980]. Least significant difference (LSD) at 5% was used to compare between means.

RESULTS AND DISCUSION

Yield. Yield (kg⁄tree) was changed significantly in response to different treatments in comparison to untreated control trees in both seasons of investigation (Tab. 1). The highest average of yield per tree was achieved using $Ca(NO_3)_2$ at 1% and/or $Ca(NO_3)_2$ at 0.5% followed by $CaCl_2$ at 1% and 2% respectively in both seasons. The lowest average of fruit yield per tree resulted from untreated control trees in both seasons. Results of our work are in line with those of Husein et al. [2015] and Zheng et al. [2017] who found that foliar application of calcium could increase yield and quality components of treated fruits. On the other hand, foliar application of calcium nitrate had no positive effect on strawberry yield [Lanauskas et al. 2006].

Fruit physical characteristics. Fruit weight-correlation factors: the average of fruit weight, flesh weight, fruit volume, fruit length and fruit diameter of *Zizyphus jujube* have changed significantly in both seasons in response to all treatments compared to untreated control trees (Tab. 1). The highest average of fruit weight, flesh weight, fruit volume, fruit length and fruit diameter was achieved by $Ca(NO_3)_2$ at 1%. The lowest ones were given by the untreated control trees in both studied seasons.

Table 1. Yield and fruit physical characteristics of *Ziziphus jujuba* as affected by foliar spray of $CaCl_2$, $Ca(NO_3)_2$ and ascorbic acid during 2014 and 2015 seasons

Treatments	Yield (kg⁄tree)	Fruit weight (g)	Fresh weight (g)	Seed weight (g)	Fruit volume (cm^3)	Fruit length (cm)	Fruit diameter (cm)	Fruit shape index	Firmness (kg⁄cm^2)
2014 season									
Control	74.33_e	32.58_e	29.81_e	2.77_a	38.33_e	4.57_b	4.07_c	1.12_a	5.50_f
$CaCl_2$ 1%	88.33_{cd}	35.77_c	33.43_c	2.34b	40.33_d	4.70_{ab}	3.90_e	1.21_a	9.07_b
$CaCl_2$ 2%	95.00_{bc}	39.10_b	36.26_b	2.84_a	43.67_c	4.77_{ab}	4.20_b	1.13_a	9.73_a
$Ca(NO_3)_2$ 0.5%	101.00_a	39.74_b	36.80_b	2.94_a	45.00_b	4.83_a	4.20_b	1.15_a	8.70_c
$Ca(NO_3)_2$ 1%	106.67_a	43.74_a	40.35_a	3.39_a	50.00_a	4.87_a	4.37_a	1.12_a	9.47_a
Ascorbic acid 50 ppm	83.67_d	34.02_{de}	32.76_{cd}	2.55_b	39.00_e	4.67_{ab}	3.97_d	1.18_a	6.33_e
Ascorbic acid 100 ppm	82.33_d	35.31_{cd}	31.50_d	2.52_b	39.00_e	4.70_{ab}	4.00_d	1.18_a	7.47_d
2015 season									
Control	62.00_f	26.78_g	24.81_g	1.97_a	31.67_g	4.33_d	3.57_e	1.21_a	6.83_e
$CaCl_2$ 1%	76.67_c	32.83_d	30.54_d	2.29_a	36.67_d	4.57_c	3.83_c	1.19_a	9.17_d
$CaCl_2$ 2%	81.67_b	35.62_c	33.27_c	2.35_a	38.33_c	4.67_c	4.03_b	1.16_a	10.20_c
$Ca(NO_3)_2$ 0.5%	90.00_a	38.56_b	36.18_b	2.38_a	41.00_b	4.90_b	4.20_a	1.17_a	11.00_b
$Ca(NO_3)_2$ 1%	92.33_a	41.62_a	39.24_a	2.38_a	45.33_a	5.17_a	4.20_a	1.23_a	12.10_a
Ascorbic acid 50 ppm	65.67_e	27.89_f	25.73_f	2.16_a	33.00_f	4.43_d	3.70_d	1.20_a	7.40_e
Ascorbic acid 100 ppm	70.00_d	31.19_e	29.02_e	2.17_a	34.67_e	4.43_d	3.83_c	1.16_a	8.57_d

* Means within each column with the same letter are not significantly different at 5% level

Our results are in line with other studies reporting that $Ca(NO_3)_2$ recorded the highest significant values of fruit weight and tree yield [Zheng et al. 2017]. On the other hand, foliar application of all Ca products plus boron did not affect fruit weight as compared to the control [Koutinas et al. 2010]. It is also found that foliar spray of calcium compounds had no positive effect on *Pyrus pyrifolia* pear fruit weight [Moon et al. 2000, Lanauskas et al. 2006].

Fruit firmness. The results in Table 1 revealed that both of $CaCl_2$ and $Ca(NO_3)_2$ at different concentration increased the average of fruit firmness significantly in comparison to other treatments in both seasons. The lowest average of fruit firmness was given by the untreated control fruits in the both seasons of study. The results are conformity with those reported that calcium foliar application increased fruit firmness of strawberry [Moon et al. 2000, Cicco et al. 2007], tomato [Husein et al. 2015] and of *Pyrus pyrifolia* pear fruit [Moon et al. 2000]. On the other hand, foliar applied calcium nitrate had no positive effect on berry firmness. In addition, calcium nitrate applied to the soil decreased berry firmness [Lanauskas et al. 2006].

Calcium is known to act as an anti-senescent agent as it provides cellular disintegration by maintaining protein and nucleic acid synthesis [Faust and Klein 1973]. It is also reported to be effective in decreasing the respiration rates of several commodities [Faust 1978]. Low Ca concentrations in fruits have generally been found to accelerate the ripening process by stimulating the production of ethylene and by increasing the enzymes activity, which are responsible for softening of the tissues [Poovaiah 1979].

Meanwhile, postharvest treatment of fruits using ascorbic acid resulted in the highest value of firmness in comparison with untreated fruits [Gill et al. 2014]. Ascorbic acid as an antioxidant can reduce the biosynthesis of ethylene, by neutralizing and scavenging the free radicals, causing delay of pear ripening and compositional changes associated with ethylene production [Ling et al. 2007].

Fruit chemical characteristics

Total soluble solids (TSS%). The results in Table 2 showed that the ascorbic acid at both concentrations increased the average of TSS% significantly compared to other treatments in both seasons. The lowest average of given by the $Ca(NO_3)_2$ at 1% in both seasons of study. Our results are conformity with Lin et al. [2008] who found that application of chitosan combined with ascorbic acid was more effective than chitosan alone in improved total soluble solids in pear fruits. Furthermore, guava fruits treated with ascorbic acid as a postharvest treatment recorded the highest values of TSS% in comparison with untreated fruits [Gill et al. 2014]. In addition, Shamili and Hajiani [2012] reported that nitrate and calcium chloride could inhibit the increase of total soluble sugar content compared with the control of fruit of *Ziziphus mauritiana*. Cicco et al. [2007] found that soluble solids of kiwifruit decreased after Ca sprays. Furthermore, foliar spray of liquid calcium (oyster) and calcium nitrate did not affect or had no positive effect on soluble solids [Moon et al. 2000, Lanauskas et al. 2006]. On the other hand, foliar application of chelated calcium increased TSS% of tomato fruits [Husein et al. 2015, Zheng et al. 2017]. Also foliar application of $Ca(NO_3)_2$ increased total soluble solids of pomegranate fruits which may be due to lesser utilization of sugars in metabolic process as a result of respiration (calcium is known to retard respiration rate) and increase of rate of photosynthesis which might have resulted more accumulation of sugars [Zheng et al. 2017].

Acidity %

The data in Table 2 revealed that the ascorbic acid at 50 ppm decreased the average of acidity significantly compared to other treatments in both seasons. The highest average of acidity (%) was given by the $Ca(NO_3)_2$ at 1% in the both seasons. Our results are in line with those of Wójcik and Lewandowski [2003] who reported that spraying plum with waxal Ca enhanced fruit acidity over the control. Also fruit acidity was increased after Ca sprays [Cicco et al. 2007]. On the other hand, foliar application of calcium nitrate did not influence concentration of titratable acids [Lanauskas et al. 2006]. Moreover, foliar application of chelated calcium decreased the acidity of tomato [Husein et al. 2015, Zheng et al. 2017]. However, immersion of fruits in a solution of ascorbic acid reduced the rate of ripening with no change in the total amount of acid [El-Shazly et al. 2013]. On the other hand, fruit treated with ascorbic acid maintained a higher acidity value during the storage possibly due to delayed rip-

Table 2. Fruit chemical characteristics of *Ziziphus Jujuba* as affected by foliar spray of $CaCl_2$, $Ca(NO_3)_2$ and ascorbic acid during 2014 and 2015 seasons

Treatments	TSS (%)	Acidity (%)	Total sugars (%)	Vitamin C (mg/100 ml juice)	Moisture content (%)	Total chlorophyll (nm/mL)
2014 season						
Control	15.33_e	0.61_b	13.10_d	70.86_{bc}	68.39_a	1.74_f
$CaCl_2$ 1%	16.40_c	0.54_d	14.14_b	62.99_d	79.15_a	1.92_d
$CaCl_2$ 2%	16.00_d	0.57_c	13.56_c	67.94_c	79.46_a	2.15_c
$Ca(NO_3)_2$ 0.5%	14.73_f	0.64_b	12.64_e	72.73_b	80.33_a	2.37_b
$Ca(NO_3)_2$ 1%	13.47_g	0.70_a	11.57_f	78.18_a	80.35_a	2.61_a
Ascorbic acid 50 ppm	17.40_a	0.47_e	14.67_a	52.67_f	78.06_a	1.76_{ef}
Ascorbic acid 100 ppm	17.00_b	0.51_d	14.62_a	58.66_e	79.06_a	1.91_{de}
2015 season						
Control	13.87_c	0.41_d	11.75_c	54.56_c	78.23_a	1.53_e
$CaCl_2$ 1%	14.60_b	0.52_c	12.69_b	48.88_c	78.53_a	1.76_d
$CaCl_2$ 2%	14.07_c	0.58_b	12.26_b	51.66_c	78.56_a	2.00_c
$Ca(NO_3)_2$ 0.5%	13.55_d	0.61_{ab}	11.31_c	61.29_b	78.57_a	2.17_b
$Ca(NO_3)_2$ 1%	13.27_e	0.64_a	11.27_c	68.00_a	79.46_a	2.33_a
Ascorbic acid 50 ppm	15.33_a	0.45_d	13.76_a	48.92_c	77.12_a	1.56_e
Ascorbic acid 100 ppm	15.27_a	0.50_c	13.39_a	48.41_c	77.64_a	1.71_d

* Means within each column with the same letter are not significantly different at 5% level

ening [Jayachandran et al. 2007]. Furthermore, guava fruits treated with ascorbic acid as a postharvest treatment recorded the highest values of acidity in comparison with untreated fruits [Gill et al. 2014].

Fruit total sugar content

The results in Table 2 showed that the ascorbic acid at both concentrations increased the average of total sugar content significantly in comparison to other treatments in both seasons. The lowest average of total sugar content was observed in the $Ca(NO_3)_2$ treatment at 1% in the both seasons of study. Foliar application of calcium nitrate increased berry sucrose content but it did not influence concentration of total sugars [Lanauskas et al. 2006]. Ascorbic acid caused the highest increase in total sugars, non-reducing sugars content of 'Swelling' Peach as compared with all other different agrochemicals such as gibberellic acid and salicylic acid [El-Shazly et al. 2013].

Vitamin C (mg/100 ml juice)

The presented results in Table 2 revealed that $Ca(NO_3)_2$ at 1% increased the average of vitamin C mg/100 ml juice significantly in comparison to the other treatments in both seasons. The lowest average of vitamin C resulted from ascorbic acid treatments at both concentrations in both seasons. Results of our study are in line with those of Husein et al. [2015] who reported that foliar application of chelated calcium increased vitamin C of tomato. On the other hand, foliar application of calcium nitrate did not influence concentration of ascorbic acid [Lanauskas et al. 2006]. Moreover, Ghurbat [2013] showed that vitamin C in pepper cv. 'Habanero' fruits was increased by spraying ascorbic acid.

Conversely, guava fruits treated with ascorbic acid as a postharvest treatment recorded the highest values of vitamin C in comparison with untreated fruits [Gill et al. 2014].

Average of total chlorophyll content (nm/mL). The presented results in Table 2 revealed that $Ca(NO_3)_2$ at 1% increased the average of total chlorophyll content (nm/mL) significantly in comparison to the other treatments in both seasons. The lowest average of total chlorophyll content (nm/mL) was observed under the untreated control one in both seasons of investigation. Foliar spray of $Ca(NO_3)_2$, compared with the untreated control, increased leaf magnesium content in addition to Ca and K. Meanwhile it increased the photosynthetic capacity [Zheng et al. 2017]. This may attributed to the increasing of leaf chlorophyll contents in response to the increase of leaf magnesium content which in turn increased the fruit weight and quality, as well as vegetative growth and root development which was restricted with the lower Ca leaf content [Zheng et al. 2017].

Finally, it seems that the form and the composition of Ca (organic, inorganic, etc.) of these products have a significant role on the absorption and transportation of Ca within the plants. The efficiency of the foliar sprays on some of the tested parameters varied from year to year indicating that the climatic conditions (temperature, relative humidity) affecting the calcium delivered to leaves by means of spraying [Rosen et al. 2006]. Therefore, the best results are observed when a solution of calcium preparation is applied directly onto the fruit surface. Young fruits are characterized by the highest calcium absorption [Schonherr 2001] as the permeability of the cuticle is at its highest level at that time [Petit-Jmenez et al. 2009] and properly functioning stomata are an easy route for Ca^{2+} absorption. The rate of $Ca(NO_3)_2$ absorption through the cuticle layer was increased a twice with increasing in humidity from 50% to 90% [Schonherr 2001]. It is clear that Ca formulations, their rate, and timing of application affect the efficacy of Ca on several fruit quality attributes and not all impacts of Ca on fruit quality appear to be positive [Sotiropoulos et al. 2010].

CONCLUSION

It can be concluded that Ca treatments especially $Ca(NO_3)_2$ recommended to use under Riyadh condition to increase the yield and fruit weight of Ber and improve fruit quality. More studies on the effect of combinations of Ca and ascorbic acid in different stages need to be done.

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