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Full Length Research Paper

Jujube post-harvest fruit quality and storagability in response to agro-chemicals preharvest application

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The present study was conducted on Peyuan jujube cultivar (*Ziziphus Mauritania* Lamk) during the two successive seasons, 2010 and 2011 at Research and Agricultural Experimental Station, King Saud University, Saudi Arabia in order to investigate the effects of preharvest application of putrescine (Put), gibberellic acid (GA_3), salicylic acid (SA), naphthalene acetic acid (NAA), cytofex (CPPU) and calcium chloride ($CaCl_2$) on fruit yield, ripening date and quality at harvest and after cold storage at 5℃ and 85 to 90% relative humidity (RH). Fruits were sprayed once three weeks before harvest (at the beginning of fruit color break) when they reached a diameter of 6 to 7 mm. Data showed that, the latest harvest was obtained with NAA followed by GA_3 and CPPU treatments and then SA and $CaCl_2$. The $CaCl_2$ and NAA gave the shortest harvest spread (period). All agro-chemical substances gave the lowest yield percentage at the first harvest date, while at the second harvest date, GA_3, putrescine (Put) and SA sprays resulted in the highest yield followed by CPPU and then NAA applications. At the third harvest date the NAA, GA_3, Put and CPPU gave the highest yield percent followed by SA and then $CaCl_2$. Fruit vitamin C, total soluble solids (TSS), acidity, firmness and quality grade increased significantly by all treatments as compared with the control either at harvest time or after cold storage. The percentage of fruit weight loss, commercially unacceptable peel as well as, fruit browning index tended to decrease with all sprayed substances.

Key words: Jujube, fruit quality, storagability, agro-chemicals, pre-harvest application.

INTRODUCTION

Jujube fruit is the major fruit crop of arid and semi-arid regions in the tropical and subtropical areas (Liu et al., 2008). Jujube fruit is one of the world most nutritious plants rich in vitamin C, minerals and amino acids (Li et al., 2007; Boora and Bal, 2008). It contains various types of bio-active substances such as, triterpenic acid, volatile oil, glycosides, saponins and flavonoids that have wide pharmacological effects on humans (Al Zhao et al., 2008). Jujube fruit is non-climacteric, and it is highly perishable and encounters several problems during storage and marketing such as, rapid senescence at room temperature and during cold storage (Kader et al., 1989). Jujube fruit has a short post-harvest life characterized by softness and decrease in soluble solids content due to senescence, peel browning and quality deterioration (Jiang et al., 2004) as well as, fungal diseases (Tian et al., 2005). Therefore, any efforts that could be done to produce fruits with high quality parameters such as, firmness, color intensity and fruit uniformity, at harvest and during marketing, would be very important for the jujube growers in order to obtain higher monetary return.

Accordingly, some efforts have been made by employing certain agro-chemical substances to hasten or delay ripening, reduce losses and to improve and maintain fruit quality by slowing down the metabolic activities of the strawberry fruit at harvest or during storage (Shafiee et al., 2010). Some chemicals are reported to arrest the growth and spread of micro organisms which ultimately leads to increase sapota fruit shelf life and maintain its marketability for a longer period (Sudha et al., 2007). According to John (1987) calcium improves rigidity of cell walls and obstructs enzymes such as polygalcturonase from reaching their active sites, thereby, retarding tissue

softening and delaying ripening. Calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus, extending storage life of fresh fruits (Rizk-Alla and Meshreki, 2006). Moreover, calcium existing in fruit tissues usually prevents post-harvest disorders, retards fruit ripening and decreases post-harvest fruit weight loss and decay (Lara et al., 2004; Hernandez-Munoz et al., 2006).

In addition, gibberellic acid (GA_3) is reported to delay the loss in fruit firmness and vitamin C content, delay fruit ripening and senescence and retard peel chlorophyll degradation in jujube (Jiang et al., 2004). It is also proven being effective in retarding fruit quality disorders by controlling transpiration and respiration rates (Tumminelli et al., 2005) and thus, reducing fruit weight loss during storage (Rizk-Alla and Meshreki, 2006). Tecchio et al. (2009) recorded similar influences of naphthalene acetic acid (NAA). Furthermore, putrescine is another important compound that plays a role in delaying fruit ripening, senescence and prolonging fruit storage by reducing softening, increasing firmness, delaying color change and reducing weight loss during storage (Valero et al., 2002). Also, salicylic acid (SA) is an endogenous growth regulator with phenolic nature, which participates in regulation of several physiological processes in plants, such as stomata closure, ion uptake, inhibition of ethylene biosynthesis and transpiration (Khan et al., 2003). It is used in handling harvested fruits as a food additive to delay some fruit ripening processes as well as in enhancing the resistance of fruits against pathogens, especially at the earlier maturity stage (Cao et al., 2006). SA reduces fruit weight loss and softening (Shafiee et al., 2010). Moreover, the cytofex (CPPU) a plant growth regulator with high physiological activities and its effect on fruit quality is recently studied (Yuan et al., 2004). It is reported to improve the synthesis of chlorophyll, increase fruit setting rate, accelerate fruit cell division and the growth, prolong fruit developing stage and induce the parthenocarpy (Zai-xin and Yong-ling, 2005).

In view of the aforementioned, the present study has been undertaken to evaluate the effect of preharvest applications of putrescine (Put), GA_3, SA, NAA, CPPU and calcium chloride ($CaCl_2$) to jujube fruits once when their color started to change from green to yellowish (three weeks before harvest) on fruit physico-chemical quality at harvest and during cold storage at 5°C and 85 to 90% relative humidity during 2010 and 2011 seasons.

MATERIALS AND METHODS

Plant materials, treatments and experimental design

The present study was conducted on jujube (*Ziziphus mauritiana* Lamk) cv. Peyuan during the two successive seasons, 2010 and 2011 at the Research and Agricultural Experimental Station, King Saud University, Saudi Arabia in order to study the formic test of Put, GA_3, SA, NAA, CPPU and $CaCl_2$ preharvest application on fruit quality at harvest as well as, fruit quality and storagability after storing at 5°C and 85 to 90% relative humidity (RH). Fifteen-year-old Jujube trees were grown in a calcareous soil under flooding irrigation system, planted at 4 × 5 m spacing and pruned in April by removing all primary branches leaving branches 60cm length from the trunk base. Trees were subjected to the same cultural practices usually done in the orchard. During month of May in both seasons, trees were fertilized with organic manure and calcium superphosphate (16% P_2O_2) at a rate of 12 and 1.5 kg per tree, respectively. Also, 4 kg ammonium sulphate (21% N) and 1.5 kg potassium sulphate (48% K_2O) per tree were added in three equal doses at the beginning of May, June and August of both seasons. The experiment was designed as a randomized complete block design (RCBD). Twenty-one trees were selected as uniform as possible and subjected to the following seven preharvest sprays treatments with three replicates for each treatment (1 replicate = 1 tree):

T1- Water only (control)
T2 - 2 g/L calcium chloride ($CaCl_2$)
T3 - 100 mg/L gibberellic acid (GA_3)
T4 - 5 mg/L cytofex (N-(2-chloro-4-pyridyl)-N-phenyl urea, CPPU)
T5 - 150 mg/L salicylic acid (SA)
T6 - 75 mg/L naphthalene acetic (NAA)
T7 - 8 mM putrescine (Put)

The surfactant Nourfilm (Alam Chemica, Egypt) was added at the rate of 40 cm^3/100 L water to all sprayed chemicals for better penetration. The chemicals were applied directly to tree canopy with a handheld sprayer until runoff in the early morning. Fruits were sprayed three weeks before harvest when they reached at approximately 6 to 7 mm diameter and at the beginning of fruit color break.

Initial harvest date and harvest spread

In both seasons, fruits from each tree (replicate) were harvested when the fruit color was turning to light green (ovary green). Commercially, acceptable fruits were harvested on any date and each treatment was harvested three times during the harvest period (spread). The initial and final harvest date and the harvest period (spread) for each treatment were recorded. In addition, fruits weight (kg/tree) at each harvest date was recorded for each treatment to estimate fruit yield percentage at the first, second and third harvest dates according to the following equation:

% Yield = weight of fruit at each harvest / total fruit weight of the three harvests.

The initial harvest date of the control was considered zero time and all other treatments were compared with the control (- = before, + = after the control harvest date).

Fruit physico-chemical quality

A sample of 4 kg fruits was taken at each harvest date from each replicate and packed in plastic boxes that included liners and transported immediately to the laboratory to determine the fruit physico-chemical quality. The fruits quality grade (overall visual appearance) was rated according to the following scale: (1) excellent, (2) acceptable, or (3) commercially unacceptable (unmarketable) according to the scale of marketing specifications that is, excellent= fruits more than 2.5 cm in length, acceptable = fruits from 1.5 to 2 cm, while unmarketable = fruits less than 1.5 cm in length with discoloration (browning or incomplete in yellow color)

Table 1. Effect of agro-chemicals substances on jujube initial harvest date, yield, harvest spread with quality grade.

Treatments	Initial harvest date	Yield (%)			Harvest spread (days)	Fruit quality grade (%)		
		First harvest	Second harvest	Third harvest		Excellent	Acceptable	Commercially unacceptable
Control	Zero	43^{a}	36^{b}	21^{c}	25^{a}	35^{c}	40^{a}	25^{a}
$CaCl_2$	+8	11^{b}	53^{a}	36^{bc}	9^{e}	62^{b}	22^{b}	16^{b}
GA_3	+22	7^{bc}	25^{c}	68^{a}	13^{cd}	84^{a}	10^{cde}	6^{de}
Put	+14	8^{bc}	47^{a}	45^{a}	19^{b}	74^{ab}	16^{bcd}	10^{cd}
CPPU	+21	6^{bc}	31^{bc}	63^{a}	18^{b}	77^{ab}	18^{bc}	5^{e}
SA	+16	9^{bc}	50^{a}	41^{b}	14^{c}	80^{ab}	8^{de}	12^{bc}
NAA	+26	3^{c}	27^{c}	70^{a}	10^{de}	90^{a}	6^{e}	4^{e}
H.S.D	-	7	9	17	4.0	21	11	5

Means within each column with the same letter are not significant at 5% level.

as well as, decayed or wilted fruits.

% Fruit quality grade = (Fruits weight at each grade / Total fruits weight) × 100

Moreover, a fruit total soluble solid (TSS) was measured by a hand refractometer (Brix readings, 0-32 ranges, A.S.T., Japan). Ascorbic acid content (vitamin C) as mg/100 ml juice was determined by using 2 - 6 dichlorophenol indophenol blue dye, while the titrable acidity (expressed as citric acid %) was determined by titrating 5 ml of fruit juice with 0.1 N sodium hydroxide, using phenolphthalein as an indicator (AOAC, 2000). In addition, six individual fruits were used to measure fruit firmness expressed in Newton (g/cm^2) by using a fruit texture analyzer instrument (Fruit Hardness Tester, No. 510-1). Measurements were made on two sides of each fruit after removing a small piece of fruit peel with a penetration depth of 4 mm, and rate of 1 mms^{-1} and data were expressed in g/cm^2.

Post-harvest fruit quality evaluation

Another sample of 10 kg fruits for each replicate was taken, packed in boxes that included liners and transported immediately to the laboratory. The fruit samples were then stored at 5℃ and 85 to 90 % relative humidity in polyethylene bags for five weeks to investigate fruit TSS, acidity, vitamin C, firmness, weight loss, browning index, commercially unacceptable and storage life (storagability). The percentage of fruit weight loss, browning index and commercially unacceptable fruits was recorded at 7 days intervals during five weeks of cold storage. Whereas, fruit TSS, acidity and vitamin C were recorded at the end of the cold storage period (five weeks). Commercially, unacceptable fruits were measured based on the extent of browning and injury. Fruit storage life was calculated by counting the number of days required for attaining the last stage of ripening, until the stage that they remained acceptable for marketing, or when the percentage of commercially unacceptable fruits reached 30 for any treatment using the formula:

% Commercially, unacceptable fruits = (number of brown stained and injured fruits / total number of fruits) ×100.

In another separate sample for each replicate, fruits were weighed at weekly intervals until the end of the experiment and weight loss was estimated as follows:

% Weight loss = [(initial weight − fruit weight after storage intervals)/ initial weight] × 100

Browning index was assessed weekly by measuring the extent of browning area as described by Wang et al. (2005) using the following scale:

0=no browning, 1=less than ¼ browning, 2=¼ to ½ browning, 3= ½ to ¾ browning, 4=more than ¾ browning. The browning index was calculated using the following equation:

Browning Index= $[(1 \times N_1 + 2 \times N_2 + 3 \times N_3 + 4 \times N_4) / (4 \times N)] \times 100$

Where N=total number of fruits and N_1, N_2, N_3 and N_4=the number of fruits showing the different degrees of browning.

Statistical analysis

The data at harvest time or after cold storage were tested for the effect of the different agro-chemical treatments on analyzed parameters by the general linear model (GLM) and analysis of variance (ANOVA) technique as a combined analysis. Meanwhile, data during cold storage were tested for the effects of storage period, agro-chemical treatments and their interaction on the analyzed parameters by the two-way analysis of variance technique as a combined analysis. Means over the two years were separated and compared using the Honest Significant Differences (H.S.D) at 0.05 level of significance according to Snedecor and Cochran (1989). The statistical analysis was performed using Statistical Analysis System (SAS, 1988).

RESULTS AND DISCUSSION

Initial harvest date, harvest spread, yield and fruit quality

The obtained data of both seasons in Table 1 shows that the $CaCl_2$, CPPU, GA_3, SA, NAA and Put sprays delayed initial harvest date of jujube fruits as compared to the control. The latest harvest date was obtained with NAA followed by GA_3 and CPPU treatments then, SA and finally, $CaCl_2$. In addition, jujube fruits reached harvest quality between 10^{th} March and 15^{th} April, depending on

Table 2. Effect of agro-chemicals substances on jujube fruit chemical quality at harvest and after cold storage at 5℃ with 85 to 90% RH.

Treatment	TSS (%)		Acidity (%)		V.C mg/100 ml juice		Firmness	
	At harvest	After storage	At harvest	After storage	At harvest	After storage	At harvest	After storage
Control	13.5^{c}	10.2^{c}	0.41^{e}	0.30^{e}	38.6^{d}	27.8_{d}	6.9^{d}	6.2^{c}
$CaCl_2$	15.3^{ab}	14.7^{b}	0.47^{d}	0.42^{d}	47.4^{c}	43.5_{c}	11.0^{a}	10.0^{a}
GA_3	15.9^{ab}	14.8^{b}	0.63^{a}	0.56^{a}	53.7^{ab}	49.9_{ab}	11.3^{a}	9.6^{a}
CPPU	15.7^{ab}	14.8^{b}	0.52^{c}	0.48^{bc}	52.2^{b}	47.8_{bc}	10.6^{a}	9.8^{a}
SA	16.2^{ab}	15.9^{ab}	0.49^{cd}	0.45^{cd}	48.3^{c}	45.7_{bc}	9.5^{b}	8.0^{b}
NAA	15.4^{ab}	14.7^{b}	0.56^{b}	0.54^{a}	55.1^{a}	52.3_{a}	8.1^{c}	7.8^{b}
Put	15.2^{b}	15.0^{ab}	0.48^{d}	0.44^{cd}	56.6^{a}	53.8_{a}	9.4^{b}	8.4^{b}
H.S.D	1.3	1.7	0.04	0.06	3.2	4.7	1.0	0.8

Means within each column with the same letter are not significant at 5% level.

the treatment they received. In the meantime, all foliar sprays shortened fruit harvest spread (days) than control. Fruits treated with $CaCl_2$ and NAA resulted in the shortest harvest period (spread) as compared with the control and all other sprayed substances.

Furthermore, substances resulted in lower tree yield percentage at the first harvest date than the control. While, at the second harvest date, GA_3, Put and SA sprays resulted in the highest yield followed by the control and CPPU, and then, NAA applications. As for the third harvest date, the NAA, GA_3, Put and CPPU applications resulted in the highest yield percent followed by SA, then, the Ca and control treatments. In general, quality grade of fruits harvested at the different dates in treated fruits were shown to be higher (excellent) than that of the control.

With regard to the fruit quality characteristics at harvest or after cold storage, the data of Table 2 shows that fruit vitamin C, TSS and acidity contents and fruit firmness increased significantly by all treatments as compared with the control, with no significant differences among all treatments in their TSS content. The application of GA_3 or NAA gave higher fruit acidity content than all other treatments at harvest time, whereas, after cold storage, GA_3 resulted in the highest fruit acidity content compared to all other treatments. Furthermore, the application of GA_3, NAA and Put had similar and greater influence on fruit V.C content than $CaCl_2$ (at harvest or after cold storage) and SA (at harvest). Fruit firmness at harvest and after cold storage was similarly increased by the $CaCl_2$, GA_3 and CPPU sprays and they resulted in higher firmness than SA, Put and NAA sprays, with no significant difference obtained among the SA, Put and NAA treatments after cold storage only.

The mentioned results indicated that the sprayed agro-chemicals maintained fruit physico-chemical quality (V.C, TSS, acidity and firmness) without any deterioration at harvest or during cold storage. Also, in general, the sprayed agro-chemicals had a positive influence in delaying fruit initial harvest date and increasing yield percentage at the second and third harvest dates whereas, they decreased the harvest spread. The application of plant growth regulators plays a role in re-enforce cell hormonal balance. For example, GA_3, CPPU and NAA may maintain fruit firmness by reducing the various physiological activities related to the softening of fruits preventing the synthesis of hydrolytic enzymes such as cellulase which decomposes the cell wall (Davies, 1995). This might explain their influence in improving quality and in delaying fruit initial harvest date obtained in the present study. The improvement in fruit quality grade obtained by the different sprayed growth regulators might be due to the increase in cell enlargement and the carbohydrate sink strength (Dokoozlain, 2000), resulting in increasing fruit size and weight. In this respect, Valero et al. (2002) reported that polyamines are essential for cell growth and differentiation and their intracellular concentrations increase during periods of rapid cell proliferation. Similar increment in fruit quality grade by GA_3, CPPU or NAA was also reported by Tumminelli et al. (2005). In addition, the increase in fruit quality obtained by putrescine application in the present study might be due to its influence in increasing fruit firmness as reported by Martinez-Romero et al. (2000). Additionally, Perez-Vicente et al. (2002) explained the mechanism of increasing firmness by polyamines application. They reported that polyamines block the access of degrading enzymes such as polygalacturonase and pectin methyl-esterase involved in softening and are able to cross-link pectic substances in the cell wall, thus resulting in its rigidification. Also, the role of putrescine in delaying fruit color break was reported by Martinez-Romero et al. (2000). Similarly, CPPU sprays were found to delay chlorophyll breakdown and fruit aging (Yuan et al., 2004). In addition, Martinez-Romero et al. (2000) reported that putrescine and GA_3 are reported to have a great effect on ethylene content in the cell tissues. They also found that putrescine and GA_3 treatments inhibited ethylene production during peach storage with putrescine being the most effective, and this correlated to the inhibition of ripening process and the

Table 3. Effect of agro-chemicals substances on jujube fruit weight loss percent during five weeks of cold storage at 5℃ with 85 to 90% RH.

Treatments	Storage periods (weeks)					
	1	2	3	4	5	Average
Control	1.6	3.8	7.5	9.8	13.6	7.26^{a}
$CaCl_2$	1.1	2.3	3.1	6.0	7.4	3.98^{bc}
GA_3	0.7	1.6	3.5	5.2	7.6	3.72^{bc}
CPPU	1.3	2.5	3.8	6.1	7.3	4.20^{bc}
SA	0.9	1.4	2.8	4.6	6.9	3.32^{c}
NAA	1.5	2.7	4.3	5.7	8.3	4.50^{b}
Put	1.1	2.1	3.8	5.2	7.1	3.86^{bc}
Average	1.17^{e}	2.34^{d}	4.11^{c}	6.09^{b}	8.31^{a}	-

H.S.D: Agro-chemicals, 1.07; Storage periods, 0.98; Interaction, 1.89.

increase of peach firmness during storage.

It is well known that calcium (Ca^{2+}) has been extensively reviewed for its necessity as an essential nutrient, and its potential role in maintaining post-harvest quality of fruit and vegetable crops (Kirkby and Pilbeaam, 1984). Calcium is utilized for harvested fruits to maintain qualities, prevent softening and reduce rottenness rate (Chen et al., 2011). Calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus, it extends the storage life of fresh fruits (Rizk-Alla and Meshreki, 2006). According to John (1987), calcium improves rigidity of cell wall and obstructs enzymes such as polygalacturonase from reaching their active sites, thereby retarding tissue softening and delaying ripening. Furthermore, calcium is reported to delay the rapid oxidation of ascorbic acid (Veltman et al., 2000). This might explain the significant increase in fruit ascorbic acid content as a result of calcium application in the present study. Ruoyi et al. (2005) stated that ascorbic acid content of peaches was stable for fifty days storage period with the application of 0.5% $CaCl_2$. Aaddition of calcium improves rigidity of cell wall and prevents enzymes such as polygalacturonase from reaching their active sites (John, 1987), thereby, increasing firmness, retarding tissue softening and prolonging harvest season (Cheour et al., 1991; Marzouk and Kassem, 2011). This effect can be explained by the formation of cross links between the carboxyl groups of polyuronide chains found in the middle lamella of the cell wall. It reduces the rate of senescence during commercial and retail storage of fruit, with no detrimental effect on consumer acceptance (Lester and Grusak, 2004). Similar increase in ascorbic acid content as a result of calcium application was found by Singh et al. (2007). Likewise, Chopra et al. (1981) working on apricot reported that GA_3 was found the most effective in reducing respiration rate and increasing fruit TSS. At low respiration rates, the oxidation of ascorbic acid was minimum (Kumar et al., 2011). The reduction in water content of fruit and conversion of cell wall components such as starch, protein, pectin and hemicelluloses into simple soluble sugars during storage is responsible for increasing TSS content.

SA has been shown to interfere with the biosynthesis and/or action of ethylene, abscisic acid and cytokines in plants (Srivastava and Dwivedi, 2000). Recently, SA has been proposed to be a new kind of plant hormone that significantly maintained fruits with higher firmness and lower fruit chilling injury and decay incidences (Rao et al., 2011). Wang et al. (2006) found that SA alleviated chilling injury by influencing the antioxidant system in order to prevent fruit softening as well as, it affects cell swelling which leads to higher fruits firmness. Wang et al. (2006) also indicated that SA application at 6 to 10 mM positively increased the average fruit weight, fruit yield, vitamin C and carotenoids contents, cuticle thickness of fruit pericarp and the translocation of sugars from leaves to fruits. According to these results, it is expected that SA treatment may regulate sugars translocation from source to sink. Also, SA works as antioxidant, as it activates ascorbate peroxidase, which increases antioxidant ability and ascorbic acid amount in fruits (Dat et al., 1998; Wang et al., 2006). In addition, salicylic acid has been shown to affect the biosynthesis and action of ethylene (Srivastava and Dwivedi, 2000), to prevent vitamin C destruction (Wisniewska and Chelcowski, 1999) and recently, as anti stress power (Elwana and El-Hamahmy, 2009).

Fruit weight loss, peel browning index and commercially unacceptable fruits

Data of Tables 3, 4 and 5 show that, regardless of the agro-chemical treatments, fruit weight loss, peel browning and the number of commercially unacceptable fruits increased with time during cold storage. Meanwhile, regardless of cold storage, the percentages of fruit weight loss, peel browning and commercially, unacceptable fruits tended to decrease with all sprayed substances compared to the control.

Table 4. Effect of agro-chemicals substances on jujube fruit peel browning index during five weeks of cold storage at 5℃ with 85 to 90% RH.

Treatments	Storage periods (weeks)					
	1	2	3	4	5	Average
Control	32	54	81	129	184	96[a]
$CaCl_2$	11	21	37	56	79	41[d]
GA_3	16	29	43	75	98	52[cd]
CPPU	14	30	48	82	107	56[c]
SA	9	25	42	70	89	47[cd]
NAA	20	36	65	98	138	71[b]
Put	17	24	41	64	80	45[cd]
Average	17[e]	31[d]	51[c]	82[b]	111[a]	-

H. S. D: Agro-chemicals, 14; Storage periods, 11; Interaction, 23.

Table 5. Effect of agro-chemicals substances on jujube fruit commercially unacceptable percent during five weeks of cold storage at 5℃ with 85 to 90% RH.

Treatments	Storage periods (weeks)					
	1	2	3	4	5	Average
Control	5.8	17.2	38.5	56.7	78.6	39.36[a]
$CaCl_2$	0.8	3.9	7.6	11.3	24.8	9.68[c]
GA_3	1.0	2.5	5.4	9.2	21.3	7.88[c]
CPPU	0.8	4.9	6.8	11.1	25.3	9.78[c]
SA	0.5	1.2	4.7	8.3	19.7	6.88[c]
NAA	2.1	5.4	15.4	24.6	33.4	16.18[b]
Put	1.3	2.1	4.8	10.3	17.7	7.24[c]
Average	1. 76[e]	5.31[d]	11.89[c]	18.79[b]	31.54[a]	-

H.S.D: Agro-chemicals, 6.02; Storage periods, 5.31, Interaction, 11.46.

The application of SA decreased fruit weight loss percent compared to NAA treatment. No significant differences fruit weight loss were obtained between SA, Put, CPPU, GA_3 and $CaCl_2$ treatments on one hand, and between NAA, Put, CPPU and GA_3 on the other hand. In the mean time, the application of GA_3, SA, $CaCl_2$ and Put decreased the fruit peel browning as compared with the NAA treatment. No significant differences in fruit browning index were obtained between SA, Put, CPPU and GA_3 treatments on one hand, and between $CaCl_2$, Put, SA and GA_3 on the other hand. Similarly, the application of GA_3, SA, $CaCl_2$, CPPU and Put had similar and lower percent of commercially unacceptable fruits than NAA treatment. In addition, a significant interaction effect was recorded between the agro-chemicals spray treatments and the cold storage on fruit weight loss, peel browning and the percentage of commercially unacceptable fruits.

Weight loss is an important factor that limits post-harvest fruit storage life (Adato and Gazit, 1974). Fruits going into ripening and senescence are mainly characterized by disintegration of organelle structures, intensive loss of chlorophyll and proteins, membrane leakage and breakdown of cell wall components leading to loss of tissue structure (Buchanan-Wollaston, 1997). Fruit weight loss is reported to be due to metabolic activity, respiration and transpiration (Shafiee et al., 2010). Thus, presservation of a constant water status prior to and during post-harvest handling may have an important role in maintaining peel quality (Alferez and Burns, 2004). Also, alteration in water potential or its components (osmotic and turgor potentials) in fruit plays a major role in the development of rind staining (Alferez and Burns, 2004). Additionally, the increase in electrolyte leakage and phospholipase A_2 activity induces cellular membrane breakdown leading to peel pitting (Alferez et al., 2008). Oxidative membrane injury allows the mixing of the normally separated enzyme (PPO) and oxidizable substrates (polyphenols), which lead to browning (Hodges, 2003).

The decrease in fruit weight loss, commercially, unacceptable fruits percent and peel browning index obtained in the present study might be due to the effect of the sprayed substances on regulating the above discussed

Table 6. Effect of agro-chemicals substances on jujube fruit storage life (storagability; days) during cold storage at 5°C with 85-90% RH.

Control	Treatments					
	$CaCl_2$	GA_3	CPPU	SA	NAA	Put
15.2[e]	44.8[b]	42.7[b]	35.3[c]	49.8[a]	24.4[d]	50.6[a]

Means within each row with the same letter are not significant at 5% level.

metabolic activities and physiological processes as well as, reducing fungal attack (Lara et al., 2004). In addition, putrescine is known to compete directly with ethylene for their common precursor S-adenosylmethionine, thus, reduce or even nullify ethylene emission in the final days of fruit growth (Bagni and Torrigiani, 1992). It was also found to reduce the activities of fruit softening enzymes in the skin and pulp tissues (Khan et al., 2007) and maintaining membrane integrity (Valero et al., 2002). It has been reported that putrescine delayed the removal of epicuticular waxes which play an important role in water exchange through the skin of mandarin fruits (Schirra and D'Hallewin, 1997).

Furthermore, the presence of Ca_2^+ ions increases the cohesion of cell-walls and reduces the rate of senescence and fruit ripening (Ferguson, 1984). Studies have shown that the rate of senescence often depends on the calcium status of the tissue and by increasing calcium levels, various parameters of senescence such as respiration, protein, chlorophyll content and membrane fluidity are altered (Poovaiah, 1986). Moreover, flesh browning symptoms were found to be directly associated with calcium content in the fruits (Hewajulige et al., 2003). Therefore, calcium treatments may raise the possibility of producing fruits with less susceptible to flesh browning. Rosen and Kader (1989) reported that $CaCl_2$ treatments reduced softening and browning rates of pear. Calcium ions are involved in the cross linking of pectic polysaccharides present in the cell wall and middle lamella, which is involved in cell-cell adhesion and it is expected to strengthen the cell wall and middle lamella of fruits, thus, enhancing tissue resistance to fungal activity (Hernandez-Munoz et al., 2006).

Salicylic acid as an electron donor that produces free radicals prevents normal respiration and decreases fruit weight loss by closing the stomata (Shafiee et al., 2010). Application of exogenous methyl salicylate on kiwifruits led to prevent the softening process, kept ascorbic acid content and firmness during 5 months of cold storage (Solaimani et al., 2009). Moreover, salicylic acid and calcium preharvest applications are other choices to reduce moisture losses, restrict oxygen uptake, reduce respiration, and retard ethylene production, which all lead to retardant of discoloration and microbial growth inhibit (Montanaro et al., 2006). Similar to the results obtained, exogenous applied SA has been reported to delay the ripening of apple (Yan et al., 1998) and banana (Srivastava and Dwivedi, 2000). In a recent study, it was reported that six antioxidants and three pathogenesis-related) PR proteins induced by SA were involved in the defense response of peach fruit against fungal pathogens (Chan et al., 2007). Similar results have been obtained on tangerine, cherry and peach (Wang et al., 2006). Cao et al. (2006) recorded an increase in some defensive enzymes activity such as chitinase, peroxidase and phenylalanine ammonia-lyase in young pear fruits after spraying with SA.

Similar effects of GA_3 in minimizing weight loss have been observed in banana (Parmar and Chundwat, 1984). Sudha et al. (2007) postulated the reduction of weight loss in the fruits treated with GA_3 that it might be due to its anti-senescent action, as well as, its role in the chemical changes of fruit components, which may retain more water against the force of evaporation (Kumar et al., 2011). Further, GA_3 has anti-respiring and anti senescence effect, which slow down all physiological activities, as it is also known to counteract ethylene biosynthesis.

Storagability

Data of Table 6 shows that the fruits storage life has been extended significantly with all the currently tested preharvest treatments compared to the control fruits. During storage at 5℃, the fruits treated with SA and Put had similar and longer storage life than all other sprayed substances, while least of it was recorded for the control fruits. Fruits treated with SA, and Put were found to extend their storage life to the maximum duration of almost 50 days followed by GA_3 and $CaCl_2$, 42 days then CPPU, 35 days while, least of it was seen in the NAA treatment. In addition, no significant difference was found between the GA_3 and $CaCl_2$ treatments. These results also supports the findings of Cheour et al. (1991) who reported that the application of calcium prolonged the storage life of strawberries and tomato fruits, as measured by a delay in accumulation of sugars, decrease in organic acids, increase of color saturation index and mold development. Furthermore, Lam et al. (1987) stated that SA as an anti-transpiring chemical can retard moisture loss associated with pericarp browning of fruits. It may also inhibit senescent changes, which will consequently prolong fruit storage life. Similar findings were reported by

Parmar and Chundawat (1984) for GA_3 application in banana, Singh et al. (1981) in guava. Moreover, softening was delayed and storage life was increased by 10–12 weeks in Kiwi fruits stored at 0℃ by application o f $CaCl_2$ (Dimitrios and Pavlina, 2005).

Conclusion

In general, the results showed the positive influence of all sprayed agro-chemicals on the quality of jujube fruit. SA and Ca spray had better effect than NAA application. GA_3, SA sprays were more effective than Put and CPPU. Application of Ca and SA improved characteristics such as firmness and vitamin C content and reduced fruit decay and weight loss. Finally, the application of SA can be easily used to improve the quality of jujube fruits.

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