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Productivity, Fruit Quality and Profitability of Jujube Trees Improvement by Preharvest Application of Agro-Chemicals

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Abstract: The present study was conducted during the two successive seasons, 2010 and 2011 at the Research and Agricultural Experimental Station, King Saud University, Saudi Arabia in order to investigate the effects of preharvest foliar sprays on pu-yun jujube trees cultivar, after fruit set, when fruitlet diameter was ca. 3.0 -4. 0 mm, of putrescine (Put) gibberellic acid (GA_3), salicylic acid (SA), naphthalene acetic acid (NAA), cytofex (CPPU) and Calcium nitrate ($CaNO_3$) on the fruit retention, productivity, physico-chemical quality at harvest day. The output of the analyses showed that the CPPU, GA_3, SA, NAA and Put sprays delayed initial harvest date compared to the control and $CaNO_3$. The early harvest date was obtained by spraying $CaNO_3$ as compared to the control. Jujube fruits treated with $CaNO_3$ and NAA resulted in the shortest harvest spread (period) as compared with the control and all other sprayed substances. A significant increase in yield, fruit retention, flesh and seed weight, volume, length, diameter, shape index, TSS, maturity index, V.C, reducing, non-reducing and total sugars, moisture content and the percentage of fruit grade one (largest fruit) by most chemical sprays. The highest yield and fruit retention obtained by GA_3 and CPPU sprays compared to the control and other treatments. Fruit chlorophyll a, b and total content were increased by all chemical substances treatment. Whereas, the fruit carotenoids content was decreased.

Key words: Jujube · Growth regulators · Calcium nitrate · Fruit quality

INTRODUCTION

Chinese jujube (*Ziziphus jujuba* Mill.) is the most important genus of family Rhamnaceae, followed by *Z. mauritiana* Lam. (ber or Indian jujube) and *Z. acidojujuba* [1]. The *Ziziphus* name is related to an Arabic word used along the North African coast, Zizoufo used for *Z. lotus* (L.) Desf. but also related to the ancient Persian words Zizfum or Zizafun and ancient Greeks used the word Ziziphon for the jujube [2]. Jujube tree is called in the Arab countries as Sider, Nabk or ber [2, 3]. The jujube fruit is one of the ancient fruit crops, which is popular due to its wider adaptability under adverse soil and climatic conditions. As one of the true native species of Arabia, *Zizyphus spina*-christi and *Z. numularia* are growing in Arab States as native plants along with the exotic plants [3]. Jujube fruit is one of the world's most nutritious plants rich in P, K and Fe [4], vitamin C and amino acids [5]. Jujube fruit helps to eliminate oxidative stress in the liver [6], inhibit tumor cells [7] and it contain various types of bio-active substances, such as triterpenic acid and flavonoids that have a wide pharmacological effect on humans [8]. Arabs used it to maintain a healthy lifestyle and used for soothing properties [9]. *Zizyphus* species are commonly used in folklore medicine for the treatment of various diseases such as digestive disorders, weakness, liver complaints, obesity, urinary troubles, diabetes, skin infections, loss of appetite, fever, pharyngitis, bronchitis, anemia, diarrhea and insomnia [10].

Appearance fruit quality factors are very important from the marketing point of view to fetch higher price. It includes size, shape, color, gloss and freedom from defects and decay [11]. The curve of jujube fruit growth, was a double sigmoid. The first rapid growth phase was very important to determine the fruit yield [12]. Jujube tree produces good crop during January-February. However,

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one of the main constraints in jujube fruit production is producing small fruit size and high natural fruit drop (about 70%), which adversely affects fruit productivity and quality which, affects the profit growers [13]. The discovery of plant hormones and their ability to regulate all aspects of plant growth and development were defining moments in horticulture crops [13]. NAA use to enhance the fruit set, growth, retention, yield and marketable of some fruit species [14], delayed fruit ripening [15] as well as its effect on fruit formation through cell division and elongation [16]. The discovery of gibberellins and cytokinins led to commercial uses of products in these hormone categories that include improving shape of fruit, enhancing market value by reducing blemishes, improving tree architecture that may be accomplished the by overcoming apical dominance [17]. Gibberellins are used to increase fruit set, size, retention and yield [18, 19], improve fruit physico-chemical characteristics and ripening [20]. Similarly, found that cytofex (CPPU, a new plant growth regulator) with high physiologic activity, is widely studied recently. It affects on improving chlorophyll synthesis, increase rate of setting, accelerate the cell division and growth, prolong the fruit develop stage, induce the parthenocarpy fruits as well as contributed to the establishment of systemic resistance [19].

Another compound which was reported to play an important role in improving fruit set, growth and productivity is the putrescine [21] reported to be involved in stress tolerance, cell division and morphogenesis [22]. Their functions in delaying ripening have been demonstrated in fruit [23] by reducing softening [24]. Moreover, salicylic acid (SA), a common plant-produced phenolic compound, is an endogenous growth regulator, which participates in the regulation of physiological processes in plants [25]. Exogenous application of salicylic acid may influence ion uptake and transport [26], inhibition of ethylene biosynthesis, transpiration and stress tolerance [27]. It plays an essential role in determining fruit quality such as color, flavour, astringency and bitterness [28]. In addition, SA shows some benefits for human health for example, in prevention of cardiovascular disease [27]. Several studies have recorded the important role of pre and postharvest applications of calcium in improving fruit quality parameters especially size, firmness and fruit ripening in many fruit species [29]. Therefore keeping the above points of view, the present study was undertaken during 2010 and 2011 growing seasons in order to investigate the effects of preharvest foliar sprays after fruit set, when fruitlet diameter was ca. 3.0 -4. 0 mm, of putrescine (Put) gibberellic acid (GA_3), salicylic acid (SA), naphthalene acetic acid (NAA), cytofex (CPPU) and calcium nitrate (Ca) on the fruit retention, productivity, physico-chemical quality at harvest day and ripening time of jujube fruits.

MATERIALS AND METHODS

Plant Materials, Treatments and Experimental Design: The present study was conducted 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 effect of putrescine (Put) gibberellic acid (GA_3), salicylic acid (SA), naphthalene acetic acid (NAA), cytofex (CPPU) and calcium nitrate (Ca) on the fruit retention, productivity, physico-chemical quality at harvest date and ripening time of pu-yun jujube trees cultivar grown in a calcareous soil under flooding irrigation system. The trees were planted at 4 × 5 m spacing and pruned in April by removal of all primary branches leaving 60 cm from base of the trunk. Trees were subjected to the same cultural practices usually done in the orchard. In May of both years trees were fertilized with organic manure and calcium super phosphate (15% $P2O_2$) at a rate of 12 and 1.5 kg per tree, respectively. Also, 3 kg ammonium sulphate (20.6% 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. Twenty one trees were selected as uniform as possible and were subjected to foliar spray during two seasons. The experiment was designed as randomized complete design (RCD) and the following seven foliar spray treatments were obtained with three replicates for each treatment (1 replicate = 1 tree):

- Water only (control).
- 3 g/l calcium nitrate ($Ca NO_3$)
- 75 mg/l gibberellic acid (GA_3)
- 10 mM putrescine (Put)
- 10 mg/l cytofex (N-(2-chloro-4-pyridyl)-N-phenylurea, CPPU)
- 100 mg/l salicylic acid (SA)
- 75 mg/l naphthalene acetic (NAA)

All chemicals were sprayed when fruitlet diameter was ca. 3.0-4.0 mm, ~ 15-20 days after fruit set. The surfactant Nourfilm (produced by Alam Chemica) was added at the rate of 40 cm^3/100 L water to all sprayed chemicals in order to obtain best penetration results. The chemicals were applied directly to tree canopy with a handheld sprayer until runoff in the early morning.

Yield, Initial Harvest Date, Harvest Spread and Fruit Retention and Grades: In both seasons, fruits from each tree (replicate) were harvested when the fruit color turning to light green (ovary green). Only commercially acceptable fruits were harvested on any date and each treatment was harvested two or more times during the harvest season. At harvest, all the harvested fruits were weighed to record the total yield (kg/tree) and the average fruit weight (g/fruit). At harvest, a sample of 4 kg fruits for each replicate was randomly collected in both seasons. Each fruit was inspected individually to facilitate assessment of fruit size distribution. The fruit distributed inside the grades as following: grade one (fruit length 3.5 cm or more), grade two (fruits from 2.5 to less than 3.5 cm) and grade three (fruits from 1.5 to less than 2.5 cm in length), then calculate the percentage of fruits grade at each grate. In addition, the percentage of the unmarketable fruits was estimated by weigh the small (less than 1.5 cm in length), fruit deformation and the defected fruits (decayed or wilted):

- Unmarketable fruits % = Small and defected fruits weight / Total fruits weight x 100

The initial harvest date for control considered zero time and other treatments was compared to the control (- before control and + after control).

- Fruit retention % = Fruits number at harvest / Fruits number at spray days x100

After that fruits of each replicate were packed in boxes that included liners and transported immediately to the laboratory to determine the fruits physico-chemical quality characteristics. In addition, harvest spread (the number of days from the first to the final harvest dates) and initial harvest date were recorded for each treatment.

Fruits Physical Characteristics at Harvest: At harvest, a sample of 3 kg fruits for each replicate was randomly collected in both seasons and the following fruit characteristics were determined:

- Average fruit length and width (cm).
- Average fruit shape index (fruit length/fruit width).
- Average seed weight (g)
- Average flesh weight (g)
- Average fruit volume (ml)
- Average fruit firmness was recorded by using a fruit texture analyzer instrument (Fruit Hardness Tester, No. 510-1) as a small cylinder (5 mm in diameter) penetrates into a distance of 3 mm inside the fruit, then the resistance of fruit to this penetration force was recorded and taken as an expression of fruit firmness (g/cm^2).

Fruits Chemical Characteristics at Harvest: Another sample of 2 kg was randomly collected at harvest from each replicate in both seasons. In the fruit juice, the pH of the fruit samples was determined according the method described by AOAC [30], while the titrable acidity (expressed as citric acid %) was determined by titrating 5-ml of juice with 0.1 N sodium hydroxide, using phenolphthalein as an indicator[30]. The fruit TSS content was determined by using refractometer (Atago Co. Tokyo, Japan) and maturity index (MI) defined as the TSS/TA ratio was estimated.

The reducing and non-reducing sugar contents were determined by following the dinitrosalicylic acid method, while the anthrone method was followed for the total soluble sugars [31]. The percentage of fruit moisture content was also determined. The quantitative analysis of pigments such as total chlorophylls and total carotenoids was carried out according the methods described by Wang *et al.* [32]. Vitamin C (ascorbic acid) content was determined by using titrimetric method with the titration of filtrate against 2, 6- dichlorophenol indophenol and the results of vitamin C content were expressed as mg/100 g [30].

Statistical Analysis: All data were tested for treatments effects on analyzed parameters by the general linear model (GLM) and analysis of variance (ANOVA) technique as a combined analysis. Means of treatments over the two years were separated and compared using the Honest Significant Differences (HSD) at 0.05 level of significance according to Snedecor and Cochran [33]. The statistical analysis was performed using Statistical Analysis System [34].

RESULTS

Initial Harvest Date and Harvest Spread: Regardless of the experimental years, the obtained data in Table 1 showed that the CPPU, GA_3, SA, NAA and Put sprays delayed initial harvest date of jujube fruits compared to the control and $CaNO_3$. The latest harvest date obtained by CPPU and GA_3 treatments followed by NAA then Put and SA. On the other hand, early harvest date was obtained by spraying $CaNO_3$ as compared to the control. $CaNO_3$ enhanced berries colour change, thus, initial harvest date was 8 days earlier than the control. In addition, jujube fruits attained harvest ability quality between 24 February and 18 March, depending on the treatment types they received. Jujube fruits treated with $CaNO_3$ and NAA resulted in the shortest harvest spread (period) as compared with the control and all other sprayed substances followed by Put, SA then CPPU and GA_3.

Yield and Fruit Retention: Yield and fruit retention are a horticultural trait of immense importance. Regardless of the experimental years, data presented a significant increase in jujube tree yield and fruit retention by all sprayed chemicals compared to the control (Table 1). The highest yield and fruit retention of jujube trees obtained by GA_3 and CPPU sprays compared to the control and other treatments followed by NAA and Put then $CaNO_3$ and SA, no significant differences between GA_3 and CPPU, NAA and Put or between $CaNO_3$ and SA.

Fruit Physical Characteristics: The effect of the different treatments on fruit physical characteristics at harvest date is presented in Tables 1and 2. Regardless of the experimental years, a significant increase in fruit flesh and seed weight as well as fruit volume was obtained by all sprayed substances except $CaNO_3$ when compared to the control. Maximum values for fruit, flesh and seed weight as well as fruit volume were found in case of CPPU closely followed by NAA then GA_3. Whereas, the maximum values were found in SA treatment. No significant differences were found between SA and $CaNO_3$ in their flesh and seed weight.

Fruit diameter is of commercial importance for fruits marketing and trade/business. Generally it is considered that in fruit trees with excessive increase in size the quality is impaired, while on the other side small sized fruits are of low quality [14]. Data in Table 2 showed that longer and wider fruit than the control were obtained by all sprayed substances except $CaNO_3$. The longest fruits were obtained by spraying CPPU followed by NAA then Put and GA_3 and finally SA treatment. Whereas, the wider fruits were obtained by CPPU closely followed by NAA, Put and GA_3 then SA treatment. Also, an increase in shape index was recorded by all sprayed substances as compared with the control and Put. Moreover, data showed a significant increase in the percentage of fruit grade one (excellent) by all sprayed substances compared with the control. GA_3, NAA and CPPU had similar and significantly higher fruit grade one percent Put then SA and finally $CaNO_3$ (Table 2). Furthermore, the SA and $CaNO_3$, had similar and significantly higher fruit grade two percent than all sprayed substances treatments except the Put treatments, with no significant difference were obtained between control, Put, CPPU and NAA. Whereas, all substances treatments decreased the percentage of fruits grade three and the unmarketable as compared with control. Maximum values were found in control closely followed by $CaNO_3$ then Put, SA and finally CPPU and NAA. Furthermore, the presented data showed that firmer fruits were obtained by all $CaNO_3$ spraying. The GA3, CPPU and $CaNO_3$ had similar and significantly higher fruit firmness followed by Put, NAA then SA treatment (Table 2).

Fruit Chemical Characteristics

Fruit Acidity, Vitamin C, Maturity Index and Sugars Content: The effect of the different sprayed substances treatment on fruit chemical characteristics of jujube fruit at harvest is presented in Table 3. A significant increase in total soluble solids (TSS) content in comparison with the control was obtained by all sprayed compounds except NAA. SA spray resulted in higher TSS content than GA_3 and CPPU, Put and $CaNO_3$. Meanwhile, GA_3 spray had higher fruit TSS than CPPU followed by Put and $CaNO_3$ then NAA. Fruit acidity content was increased

Table 1: Effect of the sprayed substances on fruits yield, initial harvest date, harvest spread and fruit retention and grade of jujube trees over the two seasons (combined analysis)

Treatments	Initial harvest date	Harvest spread (days)	Yield (kg/tree)	*Fruit retention	Fruit weight (g/tree)	Fruit volume (ml)	Flesh weight (g)	Seed weight (g)
Control	Zero	21a	43e	28f	18.03f	18.33f	16.56f	1.47f
$CaNO_3$	-8	7e	52d	40e	18.53f	19.00f	16.93ef	1.60ef
GA_3	+15	10cd	84a	56ab	31.77c	33.67c	29.04c	2.73c
Put	+8	12c	64bc	51bd	28.97d	29.33d	26.67d	2.30d
CPPU	+14	10cd	77a	62a	44.37a	46.33a	41.17a	3.80a
SA	+7	12c	58cd	36ef	19.50e	19.93e	17.83e	1.87e
NAA	+12	8de	69b	42de	35.30b	36.00b	31.50b	3.20b
H.S.D	-	3.0	8.0	10.0	0.97	0.85	1.05	0.34

*= (%), Means within each column with the same letter are not significant at 5% level

Table 2: Effect of the sprayed substances on fruit physical characteristics of jujube trees over the two seasons (combined analysis)

Treatments	Fruit length (cm)	Fruit width (cm)	Fruit shape	*Fruit grade one	*Fruit grade two	*Fruit grated three	*Unmarketable fruits	Firmness g/cm^2
Control	3.70e	3.27cd	1.13d	12e	28cd	37a	24a	5.89d
$CaNO_3$	3.85e	3.17d	1.21ab	23d	35ab	27b	17b	9.55a
GA_3	4.33c	3.63b	1.19bc	58a	21e	14d	9cd	9.33a
Put	4.37c	3.87b	1.13d	42b	30bc	18c	11cd	8.21b
CPPU	4.90a	4.23a	1.16cd	61a	23de	11d	7d	9.16a
SA	3.90d	3.20cd	1.22ab	32c	36a	21c	13bc	7.33c
NAA	4.70b	3.83b	1.23a	54a	24de	13d	10cd	8.20b
H.S.D	0.16	0.35	0.04	9.0	6.0	4.0	6.0	0.87

(*=5)Means within each column with the same letter are not significant at 5% level

Table 3: Effect of the sprayed substances on fruit chemical characteristics of jujube trees over the two seasons (combined analysis)

Treatments	*TSS	**Acidity	MI	**Vitamin C	*Reducing sugars	*Non- reducing sugars	*Total sugars
Control	14.5e	0.44c	35.2cd	32.1d	4.98b	3.14d	8.12e
$CaNO_3$	15.3d	0.43cd	35.6c	39.5c	5.56a	3.90c	9.46d
GA_3	16.7b	0.47b	35.5c	56.8a	6.03a	5.19a	10.17c
Put	15.1d	0.41e	36.8b	39.4c	5.98a	4.59b	10.57b
CPPU	15.7c	0.50a	31.4e	52.2b	5.92a	4.09bc	10.01c
SA	18.2a	0.48b	37.9a	58.0a	5.77a	5.54a	11.31a
NAA	14.4e	0.42de	34.3d	40.1c	5.53a	4.08bc	9.61d
H.S.D	0.31	0.02	1.1	2.2	0.64	0.54	0.29

(*%** mg/100ml juice), Means within each column with the same letter are not significant at 5% level

Table 4: Effect of the sprayed substances on fruit chemical characteristics of jujube trees over the two seasons (combined analysis)

			Chlorophyll mg/100g fw.			
Treatments	pH	Moisture content (%)	a	B	Total	Carotenoids mg/100g fw.
control	3.59 a	78.1d	0.57e	0.15d	0.72d	6.2a
$CaNO_3$	3.61a	79.0cd	0.86d	0.38 bcd	1.24c	3.6d
GA_3	3.62a	79.6c	1.12bc	0.56ab	1.68b	4.0cd
Put	3.78a	80.0bc	0.92cd	0.24cd	1.16c	4.3bc
CPPU	3.68a	79.2c	1.61a	0.77a	2.38a	4.7b
SA	3.72a	80.7b	0.86d	0.49abc	1.35c	4.3bc
NAA	3.71a	82.9a	1.28b	0.38bcd	1.66b	3.4d
H.S.D	NS	1.2	0.24	0.31	0.28	0.7

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

by CPPU, GA_3 and SA only. The highest values were with CPPU followed by GA_3 and SA then control, with no significant difference between control, Put and NAA, control and $CaNO_3$ and NAA and $CaNO_3$. A significant enhancement in fruit maturity index (MI) was obtained by spaying SA and Put. Maximum maturity index (37.9) was observed in case of SA followed by Put (36.8) then CPPU (31.4). No significant difference was obtained between control, $CaNO_3$ and GA_3 and between NAA and control. Fruit vitamin C content was increased with the all treatments as compared with the control, with the highest value recorded by SA and GA_3 followed by CPPU then $CaNO_3$, Put and NAA. Fruit total sugars content was increased by all sprayed compound to the control, with the highest value recorded by SA spray followed by Put then GA_3 and CPPU and finally NAA and $CaNO_3$. Whereas, the fruit reducing and non-reducing sugars content were increased by all different sprayed substances treatment when compared to the control (Table 3). No significant difference was obtained between SA and GA_3, Put, NAA and CPPU or between $CaNO_3$, CPPU and NAA in their fruit non-reducing sugars.

Fruit Ph, Moisture, Chlorophyll and Carotenoids Content: Regardless of the experimental years, data in Table 4 showed that the all different sprayed substances treatment did not affect the fruit pH as compared with the control. A significant increase in fruit moisture content was recorded by all sprayed substances treatment except $CaNO_3$ treatment, with the highest value in NAA treatment followed by Put and SA then GA_3 and CPPU. Likewise, the fruit chlorophyll a, b and total content were increased by all chemical substances treatments. The highest value was recorded with CPPU followed by NAA, GA_3 then $CaNO_3$, Put and SA treatments. Fruit carotenoids content was decreased by all chemical substances treatment as compared with control, no significant difference were obtained between CPPU, SA and Put and between the SA, GA_3 and Put as well as between NAA, GA_3 and $CaNO_3$ treatments.

DISCUSSION

Most applied compound delayed initial harvest dates of jujube fruits. This might be attributed to their inhibiting effect on ethylene production [27]. Ethylene is the key ripening hormone of climacteric fruits and can influence ripening in many non-climacteric fruits [35]. Jujube fruits are classified as non-climacteric fruit, however, they respond to exogenous ethylene inhibitors preharvest treatments [36]. Therefore, spraying ethylene inhibitors would decrease fruit ethylene content, delay maturing and ripening processes and thus, delays the harvest date. The delay maturity observed in this study as a result of ethylene inhibitors application is in agreement with Amiri *et al.* [37] on grape. On the other hand, the early harvest date by $CaNO_3$ spray might be due to that the Ca enhanced fruit colour change, thus, advanced initial harvest date [38]. In the meantime, NAA delayed fruit ripening [15]. Salicylic acid is a phenolic compound that regulates a number of processes in plants. It inhibits ethylene biosynthesis [39] and regulates expression of pathogenesis related protein genes and provides resistance against pathogen attack. Therefore, exogenous applied salicylic acid has been reported to reduce decay, delay ripening and extend postharvest life of various fruits [39] on Kiwi and [40]on cherries.

Furthermore, all sprayed chemicals increased jujube fruit retention and yield. Similar results were recorded by Rizk-Alla and Meshrake [29] on deferent fruit trees. Also, Nawaz *et al.* [14] found that the auxin (2, 4-D and NAA) exceeded the GA_3 and proved their superiority to increase fruit yield. Davies and Zalman [41] reported that preharvest application of 2,4-D and GA_3 significantly increased yield and fruit retention by reducing the preharvest fruit drop in citrus species. Likewise, Rizk-Alla *et al.* [42] reported an increase in Thompson seedless grape vine by spraying CPPU. The role of exogenous applied polyamines in increasing tree yield is previously stated [21, 23]. The plant growth regulators are known to enhance the source sink relationship and stimulate the translocation of photoassimilates and accumulation of sugars thereby helping in better retention of flowers and fruits [43]. The increase in yield obtained by the mentioned substances might be due to that they also increased fruit retention and weight in the present study. Likewise, the synthetic auxins such as NAA use to enhance the fruit set, retention and yield of some fruit species [14]. Calcium reduced fruit drops [44]. The obtained enhancement in fruit physical characteristics goes on line with those reported by Gholami *et al.* [40] and Rizk-Alla and Meshrake [41] on fruit trees. Fruit growth of most, if not all, species appears to depend on a triple interaction between auxins, gibberellins and cytokinins, although the limiting hormone may vary between species or cultivars. In addition, the response of fruit to the synthetic NAA and the cytokinin-like compound CPPU depended on time of application and concentration [45]. Zhang and Whiting [19] reported that the GA_3 improved fruit size, but NAA showed less effect in increasing fruit size than SA or Ca treatments. The direct effect of gibberellic acid and putrescine on stimulating cell division and cell enlargement and increasing fruit size was previously indicated [14,18,19, 22]. Generally, gibberellins are involved in cell division and cell elongation. They are known to influence fruit size [19]. Gibberellic acid is also reported to promote growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation [46]. Auxins like NAA are known to stimulate cell division, cell elongation, photosynthesis, RNA synthesis and membrane permeability to water uptake [47]. Also use to enhance the fruit growth and cell size of some fruit species [14] as well as its effect on fruit formation through cell division and elongation [16], through an enhancement of cell enlargement rather than cell division [48]. Anatomical studies revealed that the main effect of NAA was via direct stimulation of fruit cell enlargement [49]. In addition, the auxin (phenothiol) plus gibberellic acid increased marketable yield and fruit size [50]. The physiological activity of auxin within plant cells depends on the concentration of auxin and external concentration of Ca^{2+}, thus the higher concentrations of Ca^{2+} (1 mM) in the medium not only intensified the hormonal induced reaction, but also increased cell sensitivity to auxin. This illustrates that external Ca_2^+ would directly affect the cytoplasmic pH [51]. Likewise, CPPU has been reported to stimulate both cell division and cell elongation resulting in berry size increase when applied shortly after fruit set to grape berries [52]. SA plays an essential role in determining fruit quality as well as characteristics such as size, colour, flavour, astringency and bitterness [28]. Calcium reduced fruit drops and regulates fruit ripening and stimulates their coloring, ethylene production and flesh firmness [44].

The increase in fruit firmness by GA_3, Put, NAA, CPPU, $CaNO_3$ and SA application could be attributed to their influence on inhibiting ethylene biosynthesis and thus producing firmer fruits [22]. In the meantime, application of putrescine leads to changes in cell wall stability [53] by inhibiting of the action of polygalacturonase and pectin methyl esterase involved in softening and also cross-links pectic substances in the cell wall, producing rigidification and increasing fruit firmness [54]. Additionally, as a constituent of the cell wall, calcium plays an important role in forming cross-bridges which influence cell wall strength [55]. Exogenous applied calcium therefore stabilizes the plant cell wall and protects it from cell wall degrading enzymes which have major influences on firmness [56]. According to Wang *et al.* [32] and Zhang, *et al.* [39], SA prevents fruit softening. They found that rapid softening of fruits during ripening was simultaneous with rapid decrease in endogenous SA of fruits. SA affects cell swelling which lead to higher firmness of fruits [39]. Cheour *et al.* [57] earned similar results in preharvest application of Ca on strawberry cultivars. This effect can be explained by the formation of cross links between the carboxyl groups of polyuronide chains found in the middle lamella of cell wall. Ca also increases cell turgor pressure [58] and stabilizes the cell membrane [59]. In this experiment the preharvest application of Ca and SA was promising in increasing the fruit firmness. Fruits that were sprayed with putrescine showed significantly higher firmness levels than control fruits. GA_3-treated fruits did not show significant differences when compared with putrescine-treated or control fruits [54]. The GA_3 and putrescine reduced the ethylene production [54].

From the mentioned results an overall enhancement in the fruit chemical quality characteristics and maturity index was obtained by the different sprayed substances. These results agreed with those obtained by Liu *et al.* [22], Marzouk and Kassem [38] and Gholami *et al.* [40]. Otmani *et al.* [60] reported that the application of GA_3 and NAA reduced acidity percentage. Vitamin C is a powerful antioxidant and is an important part of human feed. It helps to save the human from many serious diseases and scavenges the reactive oxygen species (ROS) produced in the body [14]. Vitamin C is being affected by the environmental factors, harvesting time, plant vigour, age of plant and by application of growth regulators [14]. So the vitamin C was measured as quality parameter for the plants sprayed with various growth regulators. Observations revealed the significant results for treatments. Singh and Bal [61] found that the GA_3 and NAA significantly increased the vitamin C contents of jujube fruit. They added that the NAA treatments proved better compared to GA_3 treatments. Fruit ascorbic acid content was significantly increased with the application of GA_3 [47]. The augmentation of ascorbic acid content with GA_3 might be due to either increased ascorbic acid biosynthesis or to protection of synthesized ascorbic acid from oxidation through ascorbic acid oxidase [43]. Calcium absorption and accumulation in fruit is an important technique to manage and to improve the calcium status of fruit trees in order to achieve the best nutrient balance and to reach a better quality product [44]. Wang *et al.* [62] find that GA_3 application increased the fruit sugar contents of mandarin and sweet orange. However, Amiri *et al.* [37] found that the juice pH, SSC and titratable acidity were not significantly affected by preharvest calcium sprays, whereas fruit firmness, color and appearance improved at harvest time. Asghari [63] reported that the SA retarded TSS decrease in strawberry. Also found that SA and Ca Preharvest treatments could not change fruit acidity content. Dat *et al.* [64] found that the highest ascorbic acid content was observed in fruits sprayed with SA and Ca treatments. They added the salicylic acid activates ascorbate peroxidase, which increases antioxidant ability and ascorbic acid amount in fruits [65]. Increased antioxidant ability and anti stress power of plants and fruits induced by SA, prevents vitamin C destruction [66]. Calcium spray was effective on ascorbic acid content. Higher ascorbic acid content in such fruits may be due to positive effects of Ca on vitamin C content [67].

CONCLUSION

It might be concluded that the preharvest application of plant growth regulators such as GA_3, Put, NAA, SA and CPPU at the early stages of fruit growth of jujube fruit had a positive influence in increasing the yield and fruit retention and enhancing the fruit physico-chemical characteristics, increased the amount of large and marketable fruits, as well as extending harvest season. The same substances could be used when a delay in harvest date and marketability are required, on the contrary the $CaNO_3$ sprays which could be used for an early harvest date and for direct consumption, as it resulted in the shortest marketability compared to other sprayed substances.

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