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Full Length Research Paper

Effect of bioregulators preharvest application on date palm fruit productivity, ripening and quality

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This study was conducted during 2010 and 2011 to investigate the effect of preharvest sprays on yield, harvest date, harvest period and fruit physico-chemical quality characteristics at commercial harvest date of Sokary date palm growing in Riyadh area, Saudi Arabia. These palms were sprayed at hababouk and khalal stages with naphthalene acetic acid (NAA), gibberellic acid (GA_3), cytofex (CPPU), putrescine (Put), salicylic acid (SA) or ethyphon (Eth). The results showed that the yield components and fruit physical characteristics (except ground color) were improved by all sprayed bioregulators, especially NAA, GA_3 and CPPU. The applications of bioregulators delayed harvest date in comparison with the control and Eth treatments. The latest harvest date was obtained with NAA followed by GA_3 and CPPU treatments. On the other hand, Eth advanced fruit ripening date in comparison with the control. All the bioregulator treatments decreased the harvest period and the percentage of unmarketable fruits. It also delayed fruit carotenoids pigment formation, but increased fruit acidity and chlorophyll content as compared with control and Eth treatments. Fruit TSS and sugar content at rutab stage were higher compared to the control. However, at tamar stage, fruit acidity was decreased by all treatments.

Key words: Date palm, bioregulators, preharvest, yield, ripening fruit quality.

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is one of the ancient domestic fruit trees in the Middle East countries. According to FAO (2011), Saudi Arabia is considered the third country of the top ten date producers (982,546 tonnes). Generally, all dates are harvested and marketed at three stages of fruit development; mature firm (bisir or khalal), full ripe (rutab) and dry (tamar). The decision for harvesting at one or these stages depends on cultivar characteristics, especially soluble tannins levels, climatic conditions and market demand. Fruits of the Sokary cultivar are harvested and consumed at the tamar stage, because it contains high levels of soluble tannins, thus removal of tannins are necessary for the fruit to be edible. At the bisir stage, Sokary fruit is considered physiologically mature and firm with maximum weight and size and at this stage the colour has changed from green to yellow. At the rutab stage, fruits start to ripen from the apex, change to brown or black in colour and become soft. Additionally, even fruits of the same bunch do not ripen evenly and therefore they need consequently several harvest dates are needed.

Marketing of date fruits depends mainly upon its desirable appearance, homogeneity in fruit size, shape and ripening. The small fruit size of Sokary dates growing in the Riyadh region is one of the limiting factors for its marketing. Therefore, any efforts that could be done to enhance its quality characteristics, especially fruit size, weight, colour intensity and bunch uniformity at harvest date and during marketing, would be very important for the Sokary dates growers in order to obtain higher monetary return.

The discovery of plant hormones and their ability to regulate all aspects of growth and development were defining moments in horticulture (Greene, 2010).

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Accordingly, the exogenous application of various plant bioregulators to different stages of developing fruits, as well as their endogenous levels, have highlighted their importance for fruit development and quality characteristics (Srivastava and Handa, 2005). Most of these substances are used to control ripening date, improve fruit quality and increase productivity, thereby increasing the income and the revenues of farmers (Shafat and Shabana, 1980; Amorós et al., 2004). Naphthalene acetic acid (NAA) was found to increase fruit size, weight and delay ripening of dates (Aboutalebi and Beharoznam, 2006). Similar effects were reported for gibberellic acid (GA_3) (Moustafa and Seif, 1996; Moustafa et al., 1996). In addition, cytofex (CPPU) is reported to increase fruit size and delay chlorophyll breakdown and fruit aging (Stern et al., 2006). Furthermore, the promotive role of ethylene in increasing the fruit quality and yield and delaying senescence is evident (Kassem et al, 2011). Salicylic acid (SA) is a hormone with an impact on several areas of plant biology such as determining fruit characteristics, for example, colour, flavour, size, astringency and bitterness (Vlot et al., 2009). Putrescine (Put) is a polyamine that is purported to be involved in stress tolerance, cell division and morphogenesis (Liu et al., 2006). It is also found to retard fruit color change, decrease firmness loss, delay ethylene production, decrease respiration rate and induce mechanical resistance (Valero et al., 1999), which all result in reducing senescence rate after harvest (Martınez-Romero et al., 2002). Growers and researchers should be aware that plant growth regulators applied in the field may have beneficial carry-over effects on postharvest quality (Lurie, 2010).

This present study was undertaken during the 2010 and 2011 growing seasons in order to investigate the effect of preharvest sprays of Sokary dates at hababouk and khalal stages naphthalene acetic acid (NAA), gibberellic acid (GA_3), cytofex (CPPU), putrescine (Put), salicylic acid (SA) or ethyphon (Eth) on the yield, harvesting date and spread (period), as well as fruit quality characters at commercial harvest date.

MATERIAL AND METHOD

Plant material, design and treatments

This present study was conducted during 2010 and 2011 seasons at the Research and Agricultural Experimental Station at Dirab, King Saud University, Saudi Arabia on Sokary date palm (*Phoenix dactylifera* L.). The palms were planted 10 × 10 m apart and subjected to the same cultural practices usually done in the orchard. Organic manure, calcium super phosphate and potassium sulfate were applied in January of each season at the rate of 15, 1.5 and 2.0 kg per palm, respectively. Also, ammonium sulphate at the rate of 4.0 kg/palm was applied at three equal doses; mid-February, mid-April and mid-May of each season. After the completion of fruit set, the number of bunches was adjusted to 9 to 10 bunches per palm as a normal level of fruit load. The experiment was designed as a randomized complete block design (RCBD). Twenty one palms were selected as uniform as possible and bunches were pollinated from the same male palm tree and subjected to the following seven preharvest spray treatments with three replicates for each treatment (each replicate = one tree). Treatments were as follows:

1. Water only (control)
2. 75 mg/L naphthalene acetic acid (NAA)
3. 75 mg/L gibberellic acid (GA_3)
4. 10 mg/L cytofex (N-(2-chloro-4-pyridyl)-N-phenylurea, CPPU)
5. 8 mM putrescine (Put)
6. 75 mg/L salicylic acid (SA)
7. 200 mg/L ethyphon (Eth)

All chemicals were sprayed twice, that is, at hababouk (first stage of fruit development) and at the end of kamar stage (beginning of the mature stage). The surfactant Nourfilm (Alam Chemica, Egypt) 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 the bunches with a handheld sprayer in the early morning.

Fruit physico-chemical characteristics at rutab stage

In order to determine the effect of the different treatments on fruit physico-chemical characteristics at rutab stage, a sample of ten strands were randomly collected from each bunch/replicate during both seasons for each treatment. Fruit physical characteristics were determined at rutab stage; fruit and pulp weight (g), fruit diameter and length (cm), fruit volume (cm^3). Ground fruit color was estimated by giving five degrees of color stages as follows; (1) = 100% green, (2) = 25% yellow (3) = 50% yellow, (4) = 75% yellow and (5) = 100% yellow. Fruit chemical properties were also determined. The percentage of total soluble solids was measured by a hand refractometer, acidity (%) was determined by titration according to AOAC (2000), carotenoids and total chlorophyll contents (mg/100 g peel fresh weight) were achieved by the method of Moran and Porath (1980), as 80% acetone extract was colorimetrically assayed at 440 nm for caroteneand 650 nm for total chlorophyll using a Spectrophotometer. Reducing, non-reducing and total sugar percentage were determined according to the method of Malik and Singh (1980).

Fruit chemical characteristics, yield, and harvest date and spread at tamar stage

In both seasons, bunches from each date palm were harvested at tamar stage after most (80%) of the fruits were considered to have exceeded the minimum marketability and full fruit colour. At harvest, all the harvested bunches were counted and weighed, and the total yield was recorded (kg/bunch and kg/date). Bunches were inspected and fruits that had quality defects (decayed or wilted) were removed with a shear and discarded, then bunches were re-weighed in order to estimate the percentage of unmarketable fruits:

$$\text{\% unmarketable fruits} = \frac{\text{Average total weight of bunch} - \text{Average bunch weight after removing defected fruits}}{\text{Average total weight of bunch}} \times 100$$

Table 1. Effect of bioregulators on the physical characteristics of Sokary fruits at rutab stage in 2010 and 2011 seasons.

Treatments	Fruit weight (g)	Fruit volume (cm^3)	Fruit length (cm)	Fruit diameter (cm)	Fruit shape	Pulp weight (g)	Ground fruit color
2010 season							
Control	10.43^{c}	9.81^{c}	3.14^{d}	2.41^{d}	1.30^{a}	9.72^{d}	4.8^{a}
NAA	14.52^{a}	13.86^{a}	3.97^{a}	3.19^{a}	1.24^{b}	13.45^{a}	4.0^{d}
GA_3	14.18^{a}	13.67^{a}	3.63^{bc}	3.03^{ab}	1.25^{ab}	12.83^{ab}	4.4^{bc}
CPPU	14.30^{a}	13.73^{a}	3.92^{ab}	3.17^{a}	1.24^{b}	13.17^{a}	4.0^{d}
Put	13.47^{ab}	12.87^{ab}	3.78^{abc}	2.95^{c}	1.23^{b}	12.07^{bc}	4.4^{bc}
SA	12.80^{b}	12.15^{b}	3.49^{c}	2.75^{c}	1.27^{ab}	11.67^{c}	4.3^{c}
Eth	12.92^{b}	12.27^{b}	3.58^{c}	2.91^{bc}	1.23^{b}	11.82^{bc}	5.0^{a}
L.S.D 0.05	1.28	1.40	0.31	0.21	0.06	1.16	0.3
2011 season							
Control	10.28^{d}	9.72^{c}	3.09^{c}	2.39^{d}	1.29^{a}	9.64^{c}	4.8^{a}
NAA	14.63^{a}	13.97^{a}	3.91^{a}	3.36^{a}	1.16^{b}	13.61^{a}	4.0^{b}
GA_3	13.81^{ab}	13.09^{ab}	3.83^{ab}	3.22^{ab}	1.22^{ab}	13.47^{a}	4.1^{b}
CPPU	14.49^{a}	13.88^{a}	3.92^{a}	3.35^{a}	1.14^{b}	12.78^{ab}	4.2^{b}
Put	13.37^{bc}	12.83^{ab}	3.70^{ab}	3.13^{bc}	1.18^{b}	12.53^{ab}	4.2^{b}
SA	12.73^{c}	12.15^{b}	3.54^{b}	2.98^{c}	1.19^{b}	11.89^{b}	4.0^{b}
Eth	12.94^{c}	12.22^{b}	3.59^{b}	3.07^{bc}	1.17^{b}	12.23^{ab}	4.9^{a}
L.S.D 0.05	1.07	2.08	0.37	0.13	0.11	1.51	0.2

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

After that a sample of ten strands were randomly collected from each replicate during both seasons for each treatment and packed in boxes that included liners and transported immediately to the laboratory to determine the fruit chemical quality characteristics at tamar stage (fruit acidity, TSS and sugar content). In addition, harvest spread (the number of days from the first to the final harvest date) and initial harvest date were recorded for each treatment.

Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) to detect treatment effect. Mean separation were performed by using least significant difference (L.S.D) at the $p \leq 0.05$ level. The data were analyzed using the statistical analysis system SAS (SAS, 2000) version 8.02.

RESULTS

Fruit physical characteristics

Data of both seasons presented in Table 1 indicated a significant increase in fruit weight, volume, length, diameter and pulp weight by all sprayed chemicals compared to the control. NAA, GA_3 and CPPU had similar and significantly higher fruit weight, volume and pulp weight than SA and Eth, with no significant difference between Put, SA and Eth obtained in both seasons. In addition, GA_3 had CPPU similar and significant higher fruit length than SA and Eth, with no significant differences between GA_3, Put, SA and Eth in both seasons. Spraying NAA and CPPU indicated similar result and had significant higher effect in increasing fruit diameter than Put, SA and Eth. In addition, data of both seasons showed a remarked delay in the fruit green color break by all sprayed compounds as compared with the control and Eth treatments. Fruit green color break was significantly lower by NAA and CPPU than GA_3, Put, SA, and Eth sprays in the first season. Moreover, in both seasons no significant differences were found between Eth and control on one hand and between GA_3, Put and SA treatments on other hand. In the second season (2011), no significant differences were obtained between NAA, GA_3, CPPU, Put and SA treatments. However, fruit shape decreased by all treatments except GA_3 (in both seasons) and SA (in the first season) as compared with the control (Table 1).

Fruit chemical characteristics

The effect of the various spray treatments on fruit chemical characteristics of Sokary date at rutab and tamar stages are presented in Tables 2 are 3. The data obtained showed that at the rutab stage, fruit acidity was significantly increased by spraying NAA, GA_3, CPPU and SA as compared with the control and Eth treatment in both seasons. No significant differences between NAA and CPPU and between GA_3, Put and SA were obtained. At the tamar stage, all substances (except CPPU) decreased the fruit acidity significantly as compared with the control, with no significant difference between NAA, GA_3, Put and SA in both seasons. In addition, data of

Table 2. Effect of bioregulators on the chemical characteristics of Sokary fruits at rutab stage during 2010 and 2011 seasons.

Treatment	Chlorophyll mg/100 g	Carotene mg/100 g	Acidity (%)	TSS (%)	Sugars (%)		
					Reducing	Non-reducing	Total
2010 season							
Control	4.1^{d}	4.0^{b}	0.34^{d}	27.6^{d}	16. 4^{c}	8. 8^{d}	25.2^{d}
NAA	6.2^{ab}	2.1^{c}	0.59^{a}	33.9^{b}	19.4^{b}	11.3^{ab}	30.7^{b}
GA$_3$	6.1^{ab}	2.5^{c}	0.47^{bc}	30.6^{c}	18.3^{b}	10.4^{c}	28.7^{c}
CPPU	6.7^{a}	2.6^{c}	0.53^{a}	32.2^{c}	18.4^{b}	11.9^{a}	30.3^{bc}
Put	5.7^{bc}	2.9^{c}	0.42^{cd}	31.4^{c}	19. 0^{b}	10. 9^{bc}	29.9^{bc}
SA	5.0^{c}	2.7^{c}	0.43^{c}	32.1^{c}	18.1^{b}	10.7^{bc}	28.8^{c}
Eth	3.0^{e}	5.2^{a}	0.23^{e}	35.8^{a}	21.2^{a}	9.4^{d}	30.6^{a}
L.S.D 0.05	0.9	0.8	0.09	1.7	1.6	0.9	1.9
2011 season							
Control	4.3^{d}	4.2^{b}	0.35^{c}	28.7^{d}	15. 9^{d}	9.0^{d}	24.9^{c}
NAA	7.2^{ab}	1.8^{d}	0.51^{ab}	34.8^{b}	20.0^{bc}	10.6^{b}	30.6^{b}
GA$_3$	6. 8^{ab}	3.1^{c}	0.48^{b}	32.4^{c}	20.1^{b}	10.5^{b}	30.6^{b}
CPPU	7.8^{a}	2.5^{cd}	0.58^{a}	32.7^{c}	19. 6^{bc}	10.8^{a}	30.4^{b}
Put	6.2^{bc}	2.4^{cd}	0.42^{bc}	32.1^{c}	18.1^{c}	11.7^{a}	29.8^{b}
SA	5. 4^{c}	2.6^{cd}	0.46^{b}	32.3^{c}	20.6^{b}	9.2^{c}	29.8^{b}
Eth	3.2^{e}	5.5^{a}	0.20^{d}	37.1^{a}	22.8^{a}	9. 9^{bc}	32.7^{a}
L.S.D 0.05	1.0	1.0	0.10	2.1	2.0	1.1	2.1

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

Table 3. Effect of bioregulators on the chemical characteristics of Sokary fruits at tamar stage during 2010 and 2011 seasons.

Treatment	Acidity (%)	TSS (%)	Sugars (%)		
			Reducing	Non-reducing	Total
2010 season					
Control	0.64^{a}	70.8^{d}	25.7^{d}	23.8^{d}	49.5^{d}
NAA	0.49^{bc}	76.7^{ab}	28.0^{bc}	27.7^{b}	55.7^{b}
GA$_3$	0.40^{cd}	77.2^{a}	28.9^{ab}	28.2^{ab}	57.1^{ab}
CPPU	0.53^{ab}	74.7^{bc}	29.8^{a}	26.9^{bc}	56.7^{ab}
Put	0.38^{cd}	75.7^{abc}	29.3^{ab}	30.5^{a}	59.8^{a}
SA	0.40^{cd}	76.3^{abc}	28.2^{abc}	26.6^{bc}	54.8^{bc}
Eth	0.31^{d}	74.4^{c}	27.1^{cd}	24.8^{cd}	51.9^{cd}
L.S.D 0.05	0.13	2.2	1.8	2.7	3.3
2011 season					
Control	0.58^{a}	73.2^{b}	28.7^{e}	22.6^{c}	51.3^{c}
NAA	0.41^{bc}	77.4^{a}	33.8^{bc}	27.4^{b}	61.2^{b}
GA$_3$	0.30^{cd}	77.9^{a}	33.9^{abc}	26.8^{b}	60.7^{b}
CPPU	0.48^{ab}	76.9^{a}	36.1^{a}	30.2^{a}	66.3^{a}
Put	0.32^{cd}	77.7^{a}	34.2^{ab}	25.9^{b}	60.1^{b}
SA	0.32^{cd}	78.4^{a}	31.9^{cd}	27.7^{b}	59.6^{b}
Eth	0.24^{d}	76.7^{a}	29.7^{de}	23.7^{c}	54.4^{c}
L.S.D 0.05	0.15	3.2	2.3	2.0	4.2

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

both seasons indicated an increase in fruit total soluble solids percentage by all sprayed chemicals as compared with the control at rutab stage.

At the rutab stage, spraying Eth resulted in the lowest fruit acidity content compared to all other treatments and the control in both seasons. It also gave the highest TSS

Table 4. Effect of bioregulators on yield components, harvest date and spread and the unmarketable at tamar stage of Sokary fruits during 2010 and 2011 seasons.

Treatment	Initial harvest date		Harvest spread (days)		Yield components				Unmarketable fruits (%)	
					kg/bunch		kg/date			
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Control	21/8	24/8	30[a]	36[a]	8.7[d]	7.9[d]	90[d]	81[d]	28.7[a]	23.5[a]
NAA	25/9	30/9	19[b]	21[b]	13.1[abc]	11.4[abc]	136[ab]	116[b]	15.9[bc]	16.7[bc]
GA_3	15/9	17/9	16[b]	15[c]	14.2[a]	13.2[a]	144[a]	135[a]	13.8[bcd]	17.5[b]
CPPU	10/9	15/9	21[b]	18[bc]	13.7[ab]	12.4[ab]	140[ab]	127[a]	11.5[cde]	14.1[cd]
Put	2/9	6/9	18[b]	20[b]	13.2[abc]	10.1[c]	135[ab]	106[c]	10.5[de]	8.7[ef]
SA	30/8	4/9	10[c]	8[d]	12.5[bc]	11.2[abc]	129[bc]	114[bc]	8.2[e]	6.9[f]
Eth	6/8	8/8	9[c]	6[d]	11.7[c]	10.7[bc]	120[c]	112[bc]	17.4[b]	12.7[de]
L.S.D 0.05	-	-	6	4	1.6	2.1	13	11	5.1	3.3

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

value followed by NAA. However, no significant differences were obtained among GA_3, CPPU, Put and SA sprays in fruit TSS content. Similarly, the fruit TSS percentage at tamar stage was increased by all sprayed chemicals as compared with the control in both seasons, with no significant differences between NAA, CPPU, Put, SA and Eth. Moreover, the fruit reducing and total sugars content at rutab stage was also increased by all treatments as compared with the control during both seasons. No significant differences were found between NAA and CPPU. The results also showed that the Eth treatment gave the highest fruit reducing and total sugar content as compared to other chemicals at rutab stage. In addition, the fruit non-reducing sugars were increased with all treatments as compared to the control and Eth in the first season. Likewise, all sprayed bioregulators except Eth increased fruit total, reducing and non-reducing sugars at tamar stage in both seasons as compared with the control. Additionally, data of both seasons showed that, spraying NAA, GA_3 and Put did not differ significantly in affecting total and reducing sugars. Whereas, NAA, GA_3 and SA did not differ significantly in affecting fruit non-reducing sugar content. In the first season, no significant differences were obtained between the control and Eth and between Eth and SA in their fruit total, reducing and non-reducing sugars at tamar stage. However, in the second season the SA resulted in higher fruit reducing and non-reducing sugars content than Eth. Also, spraying CPPU indicated the highest fruit reducing and non-reducing sugars compared to all other treatments.

As for the fruit chlorophyll and carotene content, the data in Table 2 also showed that all the sprayed substances decreased the fruit carotene content at rutab stage in both seasons as compared with the water sprayed control and Eth. No significant differences were obtained between NAA, CPPU, Put and SA during both seasons. In addition, the fruit peel chlorophyll was increased significantly with all treatments (except Eth) during both seasons. Spraying CPPU had a significant higher effect in increasing the fruit chlorophyll content than Put and SA, with no significant difference found between Put and SA and between NAA, GA_3 and Put during both seasons. The value obtained by spraying with NAA, GA_3 and CPPU were similar and had the highest values of chlorophyll content followed by Put, SA and Eth. In addition, spraying of Eth gave the lowest value of chlorophyll content as compared with all other treatments and the control in both seasons.

Harvest date, spread, yield and unmarketable fruits

The effect of different foliar sprays on fruit harvest date (ripening time), harvest spread (period), yield and unmarketable fruits in both seasons is presented in Table 4. Data showed that the ripening time was prolonged by 36, 26, 21, 13 and 10 days for NAA, GA_3, CPPU, Put and SA sprays respectively as compared with the water sprayed control. The latest harvest date was obtained with NAA followed by GA_3 and CPPU treatments then Put and finally SA, whereas Eth advanced fruit ripening by 15 days in comparison with the control. All foliar sprays had a higher effect in decreasing fruit harvest spread (days) and percentage of unmarketable fruits than the control. Fruits treated with Eth resulted in the shortest harvest spread (period) followed by SA as compared with the control and all other sprayed substances. Furthermore, all the substances resulted in higher tree yield components (kg/bunch or kg/tree) than the control during both seasons.

DISCUSSION

Fruit physical characteristics

In general, the data of this present study showed that the preharvest application of all bioregulators had positive influences in increasing fruit weight, diameter, length, volume and pulp weight. It also retarded fruit green color break of Sokary dates. This increment in fruit physical characteristics was also reported by numerous researchers working on different fruit species (Aljuburi et al., 2000; Stern et al., 2006; Aboutalebi and Beharoznam, 2006; Kassem et al., 2011). The improvement in fruit physical properties as a result of the different sprayed growth regulators might be due to their influence in enlarging cell size and enhancing the strength of carbohydrate sink, thus increasing fruit size and weight. Kuiper (1993) suggested that sink strength is established and regulated by plant growth regulators which stimulate transport of nutrients through the phloem, modify the strength of the sink by stimulating fruit growth and increase the ability for sugar unloading from the phloem. They may also act on metabolism and compartmentalization of sugar and its metabolites (Brenner and Cheikh, 1995).

Certain plant hormones can increase mobilization of assimilates to fruit and modulate many of the rate-limiting components in carbon partitioning (Ozga and Dennis, 2003). Furthermore, the direct effect of GA_3 and Put on stimulating cell division and cell enlargement, and increasing fruit size was previously indicated (Liu et al., 2006; Valero, 2010). The increase in fruit size as a result of exogenously applied GA_3 was found to be associated with an increase in the cells size of the mesocarp and the increase in sink demand (Zhang et al., 2007). The application of GA_3 increased sink demand by the enhancement of phloem unloading or/and metabolism of carbon assimilates in fruit. Larger fruits with an increased sink demand were closely correlated with changes in activities of sugar metabolizing enzymes induced by GA application. Also, Zhang et al. (2007) expressed that the increase of sink demand by GA application is closely related to the activation of invertase cell wall-bound in the core and invertase neutral and NAD-dependent sorbitol dehydrogenase in the pulp during rapid period of fruit growth. Moreover, GA_3 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 (Richard, 2006).

CPPU has been reported to stimulate both cell division and cell elongation resulting in fruit size increase when applied shortly after fruit set (Dokoozlain, 2000). Similar increase in fruit weight and size by preharvest Eth spray was previously mentioned by Amiri et al. (2010) working on grapes. It is suggested that early application of Eth regulates fruit transmission from cell division to cell enlargement leading to an increase in size and weight of fruits (Atta-Aly et al., 1999). Also the foliar application of ethephon has been observed to increase photosynthetic rate in some crops (Pua and Chi, 1993). Similarly, Valero et al. (2002) reported that polyamines are essential for cell growth and differentiation and their intracellular concentration increases during periods of rapid cell proliferation. The role of Put in delaying fruit color break was reported by Kassem et al. (2011). Inaddition, CPPU sprays were found to delay chlorophyll breakdown and fruit aging (Stern et al., 2006).

Fruit chemical characteristics

The increase in fruit total chlorophyll, TSS and total, reducing and non-reducing sugars at rutab or tamar stage and the decrease in acidity at rutab stage, as well as the decrease in fruit carotene content at rutab stage and in fruit acidity at tamar stage obtained in this present study by NAA, GA_3 and CPPU applications might translate their influence in retarding fruit ripening process as mentioned before (Moustafa and Seif, 1996; Aljuburi et al., 2000) working on date palm. Sucrose synthase and invertase may be important in determining sink activity and could play critical roles in both phloem transport and in photosynthetic partitioning in sucrose-translocating plants (Ramezani and Shekafandeh, 2009).

Additionally, the role of Put and SA in delaying fruit ripening was previously indicated (Kassem et al., 2011). The main effect of Put is lowering ethylene production and respiration rate as well as inducing mechanical resistance (Valero et al., 1999; Martinez-Romero et al., 2002). SA was reported to activate the metabolic consumption of soluble sugars to form new cell constituents as a mechanism for stimulating plant growth, and might also be assumed to inhibit polysaccharide-hydrolyzing enzyme system and/or accelerate the incorporation of soluble sugars into polysaccharides (Akhodary, 2004). The previous mentioned might be leading factors to the role of SA in retarding fruit ripening. Date palm fruits are classified as non-climacteric fruit, however, they respond to exogenous Eth preharvest treatments (Becatti et al., 2010). Therefore, spraying ethyphon in this present study would increase ethylene content in the fruit, accelerate fruit maturing and ripening processes.

Harvest date, spread, yield and unmarketable fruits

The increase in yield obtained by the mentioned substances might be due to the fact that they also increased fruit and bunch weight in this present study. A similar increase in the yield by different GA_3 and CPPU sprays was recorded (Rizk-Alla and Meshrake, 2006). The role of exogenous applied polyamines in increasing tree yield was previously stated (Melouk, 2007). Moreover, Roy et al. (1980) working on pineapples reported an increase in the yield by Eth application. Also, Wang et al. (2006) indicated that SA application positively increased the average fruit weight and yield. The application of plant growth regulators plays an role in re-enforcing cell hormonal balance. GA_3, CPPU and NAA for example 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 delaying fruit initial harvest date obtained in this present study. Similarly, CPPU sprays were found to delay chlorophyll breakdown and fruit aging (Yuan et al., 2004). CPPU treatments also noticeably delayed maturity (Zai-xin and Yong-ling, 2005). Also, Martinez-Romero et al. (2002) found that Put and GA_3 treatments inhibited ethylene production during peach ripening with Put being the most effective and this correlated to the inhibition of the ripening process and delaying fruit color break. Furthermore, SA has been shown to affect the biosynthesis and action of ethylene (Srivastava and Dwivedi, 2000).

Most applied compounds extended the harvest date.This might be attributed to their inhibiting effect on ethylene production (Davies, 1995; Malik and Singh, 2006). Ethylene is known as the ripening hormone. Date palms are classified as non-climacteric fruit, however, they respond to exogenous ethylene preharvest treatments (Kassem et al., 2011).

Therefore, spraying Eth would increase ethylene content in the fruit, accelerate fruit maturing and ripening processes and thus, advances the harvest date. In addition, ethephon also affects several cellular, developmental and stress-response processes related to photosynthesis (Balota et al., 2004). The ripening response observed in this study as a result of Eth application is in agreement with literature to date (Amiri et al., 2010). GA_3 is reported to decrease ethylene production and reduce flesh softening, thus delaying fruit ripening and fruit senescence (Gholami et al., 2010). SA was found to be more effective in decreasing ethylene production and prolonging fruit green color compared with the GA_3 treatments (Gholami et al., 2010).

Conclusion

From the above results it might be concluded that, the application of bioregulators delayed harvest date (normally ripen) as compared to the control and Eth treatments. The latest harvest date was obtained with NAA followed by GA_3 and CPPU treatments. Eth advanced fruit ripening date in comparison with the control. All bioregulator treatments decreased harvest period, fruit carotenoids content and the percentage of unmarketable fruits, and increased fruit acidity and chlorophyll content compared to the control and Eth treatments and fruit TSS, sugars contents at rutab stage as compared with control only. Also, yield components and fruit physico-chemical characteristics at tamar or rutab stage were improved by all sprayed bioregulators, especially GA_3, NAA and CPPU.

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