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Full Length Research Paper

Pre-harvest fruit drop, bunch weight and fruit quality of 'Rothana' and 'Ghur' date palm cultivars as affected by some plant growth regulators

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Pre-harvest fruit drop is a serious problem of some date palm cultivars. During 2010 and 2011 seasons, the effect of plant growth regulators 2,4-dichlorophenoxyacetic acid (2,4-D) (50 and 100 ppm), naphthalene acetic acid (NAA) (100 and 150 ppm), gibberellic acid (GA_3) (100 and 150 ppm) and benzyladenine (BA) (100 and 150 ppm) applications, at 40 and 70 days after pollination, on pre-harvest fruit drop and quality of 'Rothana' and 'Ghur' dates were studied. In both cultivars, the application of growth regulators at both rates significantly decreased fruit drop. In this respect, 2,4-D and GA_3 were the most effective treatments followed by BA, while NAA was the least effective. The reduction in fruit drop resulted in a higher bunch weight in the treated fruit than the control. The high rate of BA was more effective than the low rate in decreasing fruit drop of 'Ghur' cultivar. In 'Rothana' cultivar, bunch weight was higher than the control with both 2,4-D rates; whereas, with GA_3 and BA, only the high rate was effective; while in 'Ghur' cultivar, bunch weight of all growth regulators treatments was higher than the control. The rutab percentage was lower in NAA treatments than for all the other treatments, except for control in 'Ghur' cultivar. Fruit and flesh weight of 'Rothana' cultivar were higher at the high rate of 2,4-D, the low rate of GA_3 and BA treatments than in the control. There were no consistent effects for growth regulators on the physical and chemical quality characteristics of fruit, possibly due to the large variations of the fruit load among the treatments. It was concluded that under hot arid conditions, the application of growth regulators of especially 2,4-D (50 ppm) and GA_3 (150 ppm) at both 40 and 70 days from pollination is recommended to reduce pre-harvest drop, and improve fruit quality of both 'Rothana' and 'Ghur' date palm cultivars.

Key words: Date palm, plant growth regulators, yield, quality, fruit drop, *Phoenix dactylifera* L.

INTRODUCTION

Date palm is the most successful and particularly important subsistence crop in most of the hot arid regions (Botes and Zaid, 1999). However, under such conditions, date palms are challenged by environmental stress such as heat, drought, and salinity which limit tree growth and productivity (Youssef and Awad, 2008). One of the major problems that face some date palm cultivars production in the Hada Al-Shame valley at the western region of the Kingdom of Saudi Arabia is the low fruit set and/or abnormal flowering accompanied by subsequent high fruit drop percentage (Al-Qurashi and Awad, 2011). Date palms, as most other fruit trees, have two waves of fruit drop. The first occurs few weeks following pollination. This drop is usually caused by lack of or incomplete pollination or fertilization. The second drop is usually serious and more dramatic and occurs 5 to 6 weeks later, at the end of the kimri and beginning of bisir stage, around mid May (Ben Salah, 2001). However, this second drop is called 'June drop' in many other fruit

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species because it usually occurs in early June (Racsk´et al., 2007; Robinson et al., 2006, 2010). Under the Hada Al-Shame valley conditions, both 'Ghur' and 'Rothana' date palm cultivars show normal flowering, fertilization and fruit setting. However, close to the maturation stage (bisir stage, color break around mid May) a severe fruit drop percentage (50 to 80%) occurs specifically in these two cultivars, in contrast to others, causing a serious economic loss. This drop occurs very rapidly, often within a few days.

Fruit drop is genetically, physiologically and environmentally regulated but plant stress and premature ethylene production is at the basis of true physiological drop (Robinson et al., 2006, 2010; Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li and Yuan, 2008; Zhu et al., 2008, 2010). Stress factors such as heat, drought, nutrient imbalance or deficiency, and heavy crop load can contribute to fruit drop (Racsk´et al., 2007; Robinson et al., 2006, 2010). It is well known that plant hormones such as auxins, cytokinins and gibberellins have critical role in fruit set and subsequent growth, maturation and ripening (Dennis, 1986; Racsk´et al., 2007). After bloom, seeds formation positively contributes to fruit set, growth and retention; primarily because they are the sites of hormones biosynthesis, especially the auxin indole acetic acid (IAA).

It is believed that fruit drop is mainly due to an imbalance between the level of IAA and ethylene within fruit tissues and abscission zone (Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li and Yuan, 2008; Zhu et al., 2008, 2010). In this context, some growth regulators such as 2,4-dichlorophenoxyacetic acid (2,4-D), naphthalene acetic acid (NAA), benzyladenine (BA) and gibberellic acid (GA_3) showed positive effects on fruit retention in many plant species when applied at proper time (Anthony and Coggins, 1998; Robinson et al., 2006, 2010; Stover, 1998; Byers et al., 2000; Nawaz et al., 2008; Trueman, 2010; Villalobos-Acuå et al., 2010; Wood, 2011).

In date palm, Al-Juburi et al. (2001) reported that the application of GA_3, ethephon or mixture of both growth regulators and NAA did not affect fruit set, and subsequent fruit drop of 'Khaniezy' cultivar. They also found that NAA alone showed no effect on fruit set (measured at 45 days following pollination) but decreased fruit drop after 90 and 135 days from pollination compared to the control. They observed that fruit drop progressively increased with fruit development. However, the application of 50 or 100 ppm GA_3, about 60 days from pollination, had no effect on the number of fruits per bunch at commercial harvest of 'Sewy' dates (Abou Aziz et al., 1982). The growth regulators namely 2,4-D; 2,4-5TP 2,4-5T; NAA and GA_3 which were sprayed at concentrations of 25 to 100 ppm repeated three times at 4 weeks interval starting at flowering, successfully produced normal seedless dates of identical quality to the seeded dates (Abd-Alaal et al., 1982). The objective of this study was to evaluate the effect of some growth regulators spray on pre-harvest fruit drop in 'Rothana' and 'Ghur' date palm cultivars.

MATERIALS AND METHODS

During 2010 and 2011 growing seasons, 'Rothana' and 'Ghur' cultivars which show sever pre-mature fruit drop were selected for this study. At the pollination period, four uniform trees of each cultivar were selected and for each tree, nine spadices were nominated for classical pollination with pollen strands collected from one male tree. All spadices were bagged with craft paper perforated bags directly following pollination. These bags were removed after three weeks from pollination. After both 40 and 70 days from pollination (the kimri and the early beginning of bisir stage, respectively), one spadix on each female tree was sprayed with one concentration of the following growth regulators: 2,4-D at 50 and 100 ppm, NAA at 100 and 150 ppm, GA_3 at 100 and 150 ppm and BA at 100 and 150 ppm. On each palm, one spadix was sprayed only with water to serve as the control. A non ionic wetting agent (Tween 20 surfactant) at 0.01% was added to all treatments including the control. All the selected palm trees received the normal cultural practices and normal fertilization and irrigation program. After 40 days from pollination, directly before the first application of growth regulators, 10 strands per bunch were selected, marked and total number of fruits were recorded. At the end of the bisir stage, the retained fruit on the selected strands were recorded, and drop percentage was then calculated. At the beginning of the rutab stage for 'Ghur' and at the tamer stage for 'Rothana' (about mid June and late July for 'Ghur' and 'Rothana', respectively), bunch weight was recorded and fruit samples of 20 fruit for each bunch (replicate) were collected and kept at -20°C for physical and chemical analysis.

Physical characteristics, total soluble solids, acidity and vitamin C determinations

Fruit, flesh and seed weight, flesh/seed ratio, fruit length and diameter were recorded independently in each of the 20 fruit per replicate, at the bisir and the rutab stage. Homogeneous samples were prepared from these 20 fruit per replicate for measuring total soluble solids (TSS), acidity, vitamin C, total phenols and soluble tannins. Total soluble solids (TSS) were measured as Brix (%) in fruit juice with a digital refractometer (DR 6000, A. Kruss Optronic GmbH, Hamburg, Germany). Titratable acidity was determined in juice by titrating with 0.1 N sodium hydroxide in the presence of phenolphtalene as indicator, and the results were expressed as a percentage of malic acid. Ascorbic acid (vitamin C) was measured by the oxidation of ascorbic acid with 2,6-dichlorophenol endophenol dye, and the results were expressed as mg/100 ml juice (Ranganna, 1979).

Total phenols determination

Total phenols were measured according to Velioglu et al. (1998) using Folin-Ciocalteu reagent. 200 mgof fruit tissue (including skin and flesh) were extracted with 2 ml of 50% methanol for 2 h at ambient temperature. The mixture was centrifuged for 10 min and the supernatant was decanted into 4 ml vials. A 200 □l of the extract was mixed with 1.5 ml Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water) and allowed to stand for 5 min before the addition of 1.5 ml of 20% sodium carbonate. After 90 min, absorbance was measured at 750 nm using a UV-Vis Spectrophotometer. The blank contains only water and the reagents. Total phenols were quantified from a calibration curve obtained by measuring the absorbance of known concentrations of gallic acid.

Soluble tannins determination

Soluble tannins were measured according to Taira (1996). 5 g of fruit tissue (including skin and flesh) was homogenized with 25 ml of 80% methanol in a blender and then centrifuged. The supernatant was collected and the precipitant was re-extracted with 80% methanol and centrifuged. The combined supernatant was brought to 100 ml with distilled water. 1 ml of sample solution was mixed with 6 ml distilled water and 0.5 ml Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water). After 3 min, 1 ml of saturated sodium carbonate and 1.5 ml of distilled water was added and kept for 1 h at ambient temperature before measuring absorbance at 750 nm using a UV-Vis Spectrophotometer. The blank contained only water and the reagents. Soluble tannins were quantified from a calibration curve obtained by measuring the absorbance of known concentrations of gallic acid.

Statistical analysis of data

The obtained data were statistically analyzed as a randomized complete block design with four replicates by analysis of variance (ANOVA) using the statistical package software SAS (SAS Institute Inc., 2000, Cary, NC., USA). Comparisons between means were made by *F*-test and the least significant differences (LSD) at $P = 5\%$.

RESULTS

Fruit drop percentage, bunch weight and rutab percentage

The application of growth regulators 2,4-D, NAA, GA_3 and BA at both the low and high rates significantly decreased fruit drop percentage in both 'Rothana' and 'Ghur' cultivars (Table 1). In this respect, 2,4-D and GA_3 were the most effective treatments, followed by BA while NAA was the least effective especially in 'Ghur' cultivar (Table 1). The high rate of BA was more effective than the low rate in decreasing fruit drop only in 'Ghur' cultivar. In 'Rothana' cultivar, the bunch weight was significantly higher with 2,4-D at both rates, and with GA_3 and BA only at the high rate treatments than the control; while in 'Ghur' cultivar, the bunch weight was higher with all of the growth regulators treatments than control. NAA application decreased the rutab percentage compared with all other treatments, except the control in 'Ghur' cultivar (Table 1).

Physical quality characteristics of fruit

Fruit and flesh weight of 'Rothana' cultivar, were higher at the high rate of 2,4-D, the low rate of GA_3 and BA treatments than the control (Table 2). However, the flesh/seed ratio, diameter and length of the fruit were not affected by any of the treatments; while in 'Ghur' cultivar, at the bisir stage, both fruit and flesh weight were lower at low rate of 2,4-D and at low and high rates of BA treatments than the control (Table 2). The flesh/seed ratio and fruit diameter were higher at the high rate of 2,4-D than all other treatments. The BA application at both rates significantly decreased the flesh/seed ratio compared to the control. Fruit length was lower at the high rate of BA treatment than the control (Table 2). At the rutab stage, fruit and flesh weight in 'Ghur' cultivar were higher at the high rate of 2,4-D and NAA than the control (Table 2). The flesh/seed ratio was higher at the high and low rates of 2,4-D than the control. Fruit length was higher in most of the growth regulator treatments than the control. The 2,4-D application at the high rate produced longer fruit than all other treatments (Table 2).

Chemical quality characteristics of fruit

In 'Rothana' cultivar, the TSS concentration was higher than in all other treatments (Table 3). The application of 2,4-D at high and low rate, NAA at low rate and BA at high rate significantly increased the TSS concentration compared to the control, while the NAA at high rate and GA_3 at both high and low rate significantly decreased the TSS concentration. All the growth regulators treatments significantly increased acidity compared to control. The highest acidity was obtained at the high rate of NAA followed by the BA at the low rate treatments (Table 3). Vitamin C concentration was higher at the low rate of NAA than for all other treatments except for the high rate of NAA and the BA at both studied rates. Total phenols concentration was higher at the high rate of 2,4-D and at the BA at both rates than the control. However, soluble tannins concentration was not affected by any of the treatments. In 'Ghur' cultivar, at the bisir stage, the TSS concentration was higher at the high rate of 2,4-D than for all other treatments (Table 3). Also, the 2,4-D at the low rate, GA_3 and BA at the high rate significantly increased the TSS concentration compared to the control; while, the NAA at both rates and the GA_3 at the low rate significantly decreased the TSS concentration compared to all other treatments. Acidity concentration was not affected by the applied growth regulators compared to the control except for the high rate of 2,4-D and the low rate of GA_3 that decreased acidity concentration. Also, vitamin C concentration was not affected by the applied treatments compared to control except for the high rate of BA that lowered vitamin C than the control (Table 3). The total phenols concentration was not affected by any of the treatments. However, the soluble tannins concentration was higher at the low rate of 2,4-D, the high rate of NAA, and the low and the high rates of GA_3 and BA compared to the control.

At the rutab stage, the TSS concentration was higher in all treatments than the control, except for the high rate of NAA (Table 3). The high rate of 2,4-D and NAA showed the highest TSS concentration which was higher than all other treatments. Acidity concentration was higher at the high rate of 2,4-D than for all other treatments. The application of BA at both rates and 2,4-D at low rate significantly increased acidity concentration compared to

Table 1. Fruit drop percentage and bunch weight of 'Rothana' (at the tamer stage) and 'Ghur' (at the bisir and rutab stage) dates as affected by growth regulators application.

Treatment	Fruit drop (%)	Bunch weight (kg)	Rutab (%)
'Rothana'			
Tamer stage			
Control	51.5[a]	5.1[c]	-
2,4-D 50 ppm	16.6[cd]	7.4[a]	-
2,4-D 100 ppm	19.2[bcd]	7.1[a]	-
NAA 100 ppm	22.7[bcd]	5.1[c]	-
NAA 150 ppm	28.2[b]	5.6[c]	-
GA_3 100 ppm	18.2[bcd]	5.6[c]	-
GA_3 150 ppm	12.9[d]	7.3[a]	-
BA 100 ppm	23.8[bc]	5.9[bc]	-
BA 150 ppm	28.4[b]	6.9[ba]	-
F-test	***	**	-
LSD 0.05	10.5	1.2	-
'Ghur'			
Bisir stage			
Control	83.2[a]	2.9[e]	17.8[abc]
2,4-D 50 ppm	3.5[e]	11.0[a]	19.7[a]
2,4-D 100 ppm	4.9[e]	8.3[cd]	18.7[a]
NAA 100 ppm	23.7[c]	9.1[bc]	11.6[c]
NAA 150 ppm	32.7[b]	7.4[d]	12.1[c]
GA_3 100 ppm	8.1d[e]	8.2[cd]	23.2[a]
GA_3 150 ppm	8.1d[e]	10.5[ab]	21.3[a]
BA 100 ppm	21.8[c]	7.1[d]	22.2[a]
BA 150 ppm	12.4[d]	8.6[cd]	22.6[a]
F-test	***	***	**
LSD 0.05	6.5	1.6	7

Data are the mean of 2010 and 2011 seasons. For each cultivar, means within each column followed by the same letter are not significantly different at level $P \leq 0.05$. *, **, ***Significant at $P \leq 0.05$, 0.01 and 0.001, respectively; NS, not significant; -, not calculated.

the control. Vitamin C concentration was lower with 2,4-D at both rates and BA at low rate treatments than the control. Total phenols concentration was higher at the GA_3 at both high and low rates than all other treatments. Soluble tannins concentration was lower with 2,4-D at both rates, the high rate of NAA, and the low rate of GA_3 and BA treatments than for the control (Table 3). Generally, during ripening (changing from bisir to rutab stage) of 'Ghur' dates, the concentration of TSS and acidity greatly increased, while soluble tannins, total phenols and vitamin C concentration greatly decreased (Table 3). Also, the physical quality characteristics decreased due to lose of moisture (Table 3).

DISCUSSION

In contrast to other date palm cultivars growing in the Hada Al-Shame valley, both 'Rothana' and 'Ghur' have heavy fruit drop percentage (about 50 to 80%) close to the maturation stage (around mid May). This phenomenon occurs very rapidly, often within a few days. In the current experiment, the application of growth regulators 2,4-D, NAA, GA_3 and BA at both low and high rates significantly decreased, but not completely for control and fruit drop in both cultivars (Table 1). In this respect, 2,4-D and GA_3 were the most effective treatments followed by BA, while NAA was the least effective. The reduction in fruit drop resulted in a significantly higher bunch weight in the treated fruit than in the control (Table 1). However, in other date palm cultivars that normally shows a slight fruit drop close to maturation, GA_3 and ethephon sprayed alone or in combination with NAA, had no effect on fruit set percentage or on subsequent fruit drop of 'Khenazy' cultivar (Al-Juburi et al., 2001). They found, however that the NAA application alone decreased fruit drop after 90 and 135 days from pollination compared to control. Also, the application of GA_3 on 'Sewy' dates at 50 or 100 ppm

Table 2. Physical quality characteristics of 'Rothana' (at the tamer stage) and 'Ghur' (at the bisir and rutab stage) dates as affected by growth regulators application.

Treatment	Fruit weight (g)	Flesh weight (g)	Flesh/Seed (ratio)	Diameter (cm)	Length (cm)
'Rothana'					
Tamer stage					
Control	6.4^{c}	5.5^{c}	6.8	2.2	2.6
2,4-D 50 ppm	6.9^{abc}	6.1^{abc}	7.2	2.2	2.7
2,4-D 100 ppm	7.3^{a}	6.5^{a}	7.8	2.2	2.6
NAA 100 ppm	6.8^{abc}	5.9^{abc}	7	2.3	2.6
NAA 150 ppm	6.6^{bc}	5.7^{bc}	6.9	2.2	2.6
GA_3 100 ppm	7.2^{a}	6.4^{a}	7.4	2.3	2.9
GA_3 150 ppm	6.7^{abc}	6.0^{abc}	8.1	2.2	2.7
BA 100 ppm	7.1^{ab}	6.3^{ab}	7.6	2.2	2.6
BA 150 ppm	6.6^{bc}	5.8^{bc}	7.1	2.2	2.7
F-test	*	*	NS	NS	NS
LSD 0.05	0.59	0.55	-	-	-
'Ghur'					
Bisir stage					
Control	7.3^{ab}	6.5^{ab}	8.2^{bc}	1.7^{b}	2.9^{ab}
2,4-D 50 ppm	6.2^{dc}	5.5^{de}	8.2^{bc}	1.7^{b}	2.8^{ab}
2,4-D 100 ppm	7.5^{a}	6.8^{a}	10.3^{a}	1.9^{a}	3.0^{a}
NAA 100 ppm	6.4^{bc}	5.6^{cde}	6.9^{cde}	1.6^{cd}	2.7^{bc}
NAA 150 ppm	6.6^{bc}	5.9^{cde}	8.5^{b}	1.6^{cd}	2.8^{abc}
GA_3 100 ppm	7.1^{ab}	6.3^{abc}	8.3^{bc}	1.7^{bc}	3.0^{a}
GA_3 150 ppm	6.8^{abc}	6.1^{abcd}	7.9^{bcd}	1.6^{bcd}	2.8^{ab}
BA 100 ppm	5.5^{d}	4.6^{f}	5.9^{e}	1.7^{bcd}	2.7^{bc}
BA 150 ppm	6.0^{cd}	5.2^{ef}	6.7^{de}	1.6^{d}	2.6^{c}
F-test	**	***	***	**	**
LSD 0.05	0.88	0.81	1.38	0.11	0.18
'Ghur'					
Rutab stage					
Control	4.3^{b}	3.6^{b}	5.5^{b}	1.3^{b}	2.2^{d}
2,4-D 50 ppm	4.9^{ab}	4.4^{ab}	8.7^{a}	1.4^{b}	2.5^{bc}
2,4-D 100 ppm	6.2^{a}	5.6^{a}	8.9^{a}	1.7^{a}	2.9^{a}
NAA 100 ppm	5.4^{ab}	4.7^{ab}	6.5^{ab}	1.3^{b}	2.4^{cd}
NAA 150 ppm	6.0^{a}	5.3^{a}	7.5^{ab}	1.4^{b}	2.6^{b}
GA_3 100 ppm	5.2^{ab}	4.5^{ab}	6.8^{ab}	1.4^{b}	2.5^{cb}
GA_3 150 ppm	5.2^{ab}	4.5^{ab}	6.8^{ab}	1.4^{b}	2.4^{cb}
BA 100 ppm	4.3^{b}	3.7^{b}	6.6^{ab}	1.4^{b}	2.5^{cb}
BA 150 ppm	4.3^{b}	3.6^{b}	5.2^{b}	1.4^{b}	2.4^{cd}
F-test	*	*	*	*	***
LSD 0.05	1.3	1.3	2.5	0.22	0.19

Data are the mean of 2010 and 2011 seasons. For each cultivar, means within each column followed by the same letter are not significantly different at level $P \leq 0.05$. * and **, Significant at $P \leq 0.05$ and 0.01, respectively; NS, not significant; -, not calculated.

about 60 days from pollination had no effect on the number of fruits per bunch at commercial harvest (Abou Aziz et al., 1982). The growth regulators, namely 2,4-D; 2,4-5TP 2,4-5T; NAA and GA_3 sprayed at concentrations

Table 3. Chemical quality characteristics of 'Rothana' (at the tamer stage) and 'Ghur' (at the bisir and rutab stage) dates as affected by growth regulators application.

Treatment	TSS (Brix %)	Acidity (%)	Vitamin C (mg/100 g fw)	Total phenol (mg/g fw)	Soluble tannin (mg/g fw)
'Rothana'					
Tamer stage					
Control	44.2^{c}	0.41^{d}	3.2^{bdc}	0.25^{c}	2.23
2,4-D 50 ppm	47.6^{b}	0.55^{bc}	3.5^{bc}	0.28^{bc}	1.95
2,4-D 100 ppm	52.9^{a}	5.55^{bc}	2.7^{d}	0.33^{ab}	2.2
NAA 100 ppm	47.1^{b}	0.51^{c}	4.2^{a}	0.32^{abc}	2.28
NAA 150 ppm	42.5^{d}	0.61^{a}	3.7^{ab}	0.30^{abc}	2.2
GA_3 100 ppm	42.5^{d}	0.49^{c}	3.0^{cd}	0.25^{c}	2.05
GA_3 150 ppm	37.0^{e}	0.41^{d}	3.0^{cd}	0.26^{c}	2.02
BA 100 ppm	45.6^{c}	0.57^{ab}	3.7^{ab}	0.36^{a}	2.1
BA 150 ppm	47.0^{b}	0.49^{c}	3.6^{abc}	0.35^{a}	2.05
F-test	***	***	**	*	NS
LSD 0.05	1.4	0.06	0.7	0.06	-
'Ghur'					
Bisir stage					
Control	30.0^{d}	0.29^{a}	6.2^{ab}	0.59	10.3^{e}
2,4-D 50 ppm	33.0^{b}	0.28^{ab}	6.2^{ab}	0.7	13.2^{bc}
2,4-D 100 ppm	36.0^{a}	0.24^{bc}	5.0^{bc}	0.7	11.1^{de}
NAA 100 ppm	28.0^{e}	0.25^{abc}	7.0^{a}	0.69	11.9^{cd}
NAA 150 ppm	24.0^{f}	0.28^{ab}	7.0^{a}	0.78	10.1^{e}
GA_3 100 ppm	27.0^{e}	0.23^{c}	6.7^{a}	0.96	12.8^{c}
GA_3 150 ppm	32.0^{bc}	0.27^{abc}	7.0^{a}	1.02	14.5^{ab}
BA 100 ppm	31.0^{cd}	0.28^{ab}	5.7^{abc}	0.94	14.8^{a}
BA 150 ppm	33.0^{b}	0.25^{abc}	4.5^{c}	0.76	13.1^{bc}
F-test	***	**	**	NS	***
LSD 0.05	1.5	0.05	1.3	-	1.4
'Ghur'					
Rutab stage					
Control	50.0^{g}	0.32^{e}	5.7^{ab}	0.49^{b}	5.8^{ab}
2,4-D 50 ppm	58.5^{d}	0.43^{cb}	3.2^{d}	0.51^{b}	4.7^{d}
2,4-D 100 ppm	64.5^{a}	0.55^{a}	4.0^{cd}	0.54^{b}	5.0^{cd}
NAA 100 ppm	49.0^{g}	0.36^{de}	3.2^{b}	0.49^{b}	5.5^{abc}
NAA 150 ppm	61.2^{b}	0.37^{cde}	5.2^{b}	0.48^{b}	4.7^{d}
GA_3 100 ppm	58.3^{d}	0.35^{de}	6.2^{a}	0.66^{a}	5.0^{cd}
GA_3 150 ppm	56.5^{e}	0.36^{de}	6.2^{a}	0.68^{a}	5.5^{abcd}
BA 100 ppm	55.0^{f}	0.40^{cd}	4.2^{c}	0.49^{b}	6.1^{a}
BA 150 ppm	60.0^{c}	0.47^{b}	5.7^{ab}	0.51^{b}	5.2^{bcd}
F-test	***	***	***	***	**
LSD 0.05	0.96	0.07	0.85	0.09	0.75

Data are the mean of 2010 and 2011 seasons. For each cultivar, means within each column followed by the same letter are not significantly different at level P ≤ 0.05. *, **, ***, Significant at *P* ≤ 0.05, 0.01 and 0.001, respectively; NS, not significant; -, not calculated.

of 25 to 100 ppm and repeated three times, started at flowering and successfully produced normal seedless dates of identical quality to the seeded dates (Abd-Alaal et al., 1982).

During the last few decades, the use of plant growth regulators, especially 2,4-D and NAA has become a wide-spread practice to control fruit drop of different species (Anthony and Coggins, 1998; Robinson et al.,

2010). It is believed that fruit drop is mainly due to an imbalance between the level of auxin and ethylene within fruit tissues. Ethylene trigger the system for abscission layer formation and the hydrolytic enzymes (cellulase and polyglacturonase) that break down the cell walls leading to fruit drop (Stover et al., 1998; Wood, 2011). Accordingly, the combination of retain and napthaleneacetic acid (NAA) controlled preharvest drop of several apple cultivars better than either chemical alone (Robinson et al., 2010; Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li and Yuan, 2008). NAA alone controls the genes associated with abscission zone formation (MdPG2 and MdEG1) but stimulates ethylene production in the fruit which advances ripening caused by polyglacturonase (controlled by MdPG1 gene). In contrast, retain acts by controlling ethylene biosynthesis and thus, the genes associated with fruit abscission (MdPG2) and fruit softening (MdPG1) (Robinson et al., 2010; Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li and Yuan, 2008; Zhu et al., 2008 and 2010).

At the time of severe and fast fruit drop (around mid May) in both 'Rothana' and 'Ghur' date palm cultivars, the seed was almost developed and the endocarp lignified. The recorded air temperature in the orchard was generally higher by about 5.5° than that in April. According to Racsk´et al. (2007), in one-seeded fruits for example, stone fruits, June drop increases when the growth of embryo is intense. At this stage, the embryo consumes most of the endosperm which is coincident with a lag phase of fruit growth often associated with fruit drop. When the embryo completes its growth, the secondary endosperm appears and starts to produce auxin that is required for inhibiting abscission. In the current experiment, none of the used growth regulators completely controlled fruit drop (Table 1). It has also been reported that in warm seasons (over 95°F in August), retain suppressed ethylene production but did not adequately control pre-harvest drop of McIntosh apples (Robinson et al., 2006). The physiological responses of date palm fruit to environmental stress such as high temperature and drought might induce such a high degree of fruit drop. These climatic factors might induce specific changes within the abscission zone (for example, lack of carbohydrate supply, reduced export of indole-3-acetic acid (IAA) out of the fruit; increased fruit ethylene synthesis) which subsequently leads to fruit drop.

Initial results reported on mango fruit by Roemer et al. (2009) showed a correlation between a reduced IAA export and fruit drop. The higher the temperatures at the time in which McIntosh apples began to ripen and to produce ethylene, the more severe and earlier is pre-harvest fruit drop (Walsh, 1977). In apricot, fruit drop ensued most clearly close, after the initial lignification of the stone (endocarp) at the mid of May. About 34% of the fruits of the tree were dropped. Under conditions of drought, the water absorption of the leaf is stronger than that of the fruit; therefore the fruits are more exposed to be dropped than leaves (Racsk´et al., 2007). Our data showed that bunch weight was significantly higher with 2,4-D at both rates, and GA_3 and BA treatments at the high rates than all the other treatments including the control (Table 1). In confirmation, the application of GA_3 on 'Sewy' dates at 50 or 100 ppm at 60 days from pollination increased bunch weight, fruit and flesh weight, fruit diameter and length, and slightly increased total tannins concentration compared to the control (Abou Aziz, 1982). The rutab percentage in 'Ghur' cultivar was lower with NAA treatments than all the other treatments, except for the control (Table 1). Also, at the bisir stage, NAA decreased the TSS concentration than all other treatments, indicating delay in fruit ripening (Table 3). Delay in fruit ripening of 'Zahdi' date palm up to one month by NAA application at 40 and 60 ppm has been previously reported (Mohammed and Shabana, 1980).

In our study, there were no consistent effects for the applied growth regulators on the physical and the chemical quality characteristics of fruit (Tables 2 and 3). This might be due to the large variations in fruit load among the treatments in comparison with the control (Table 1). Despite the relatively high fruit load in growth regulators treated bunches in both cultivars (Table 1), most of the treatments gave even higher or similar fruit and flesh weight compared with the control, except for the low rate of 2,4-D and BA at both rates in 'Ghur' cultivar at the bisir stage (Table 2). The positive effect of growth regulators on fruit quality might be through influencing cell size and numbers and/or the movement of assimilates into the fruit. Cell size and numbers was increased in 'Sayer' date palm cultivar by the NAA application (Al-Ani et al., 1976). Also, GA_3 application has been found to increase both the rate, and amount of assimilates moved into the grape berries which resulted in higher berry weight and size (Weaver and Pool, 1971). BA may have affected the sink strength of individual fruit directly by increasing sink activity or indirectly by stimulating fruit growth and increasing sink size in apples and other fruit (Wismer et al., 1995; BubJn, 2000; Stern and Flaisman, 2003). Thus, the competition among the fruit within a bunch and among bunches on the same tree on assimilates might also influence fruit growth and retention.

Ben Salah (2001) reported that the minimum fruit drop percentage was obtained when 1/3 of strands were thinned out from the inside of the bunch of 'Khenazy' cultivar. It was concluded that, under the Hada Al-Shame valley conditions, the application of growth regulators, especially 2,4-D at 50 ppm and GA_3 at 150 ppm at both 40 and 70 days from pollination is recommended to reduce, but not completely control fruit drop and improve quality of both 'Rothana' and 'Ghur' date palm cultivars. The possibility of re-applying the growth regulators alone or in combinations, with especially ethylene inhibitors and/or manipulating crop load, that may control fruit drop is worthy of further investigation.

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