



Journal Homepage: - www.journalijar.com
**INTERNATIONAL JOURNAL OF
 ADVANCED RESEARCH (IJAR)**

Article DOI: 10.21474/IJAR01/11711
 DOI URL: <http://dx.doi.org/10.21474/IJAR01/11711>



RESEARCH ARTICLE

BENZYLADENINE FOLIAR APPLICATION AS A MEANS TO ENHANCE BRANCH PRODUCTION FROM THE YOUNG PLANTS OF THREE JOJOBA CLONES GROWN IN MIDDLE SINAI

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Manuscript Info

Manuscript History

Received: 15 July 2020

Final Accepted: 18 August 2020

Published: September 2020

Key words:-

Simmondsia chinensis, Benzyladenine, Branch Production, Flower Density, Seed Yield, Wax Content

Abstract

Foliar applications of benzyladenine (0, 100 and 150 mg L⁻¹) are studied as a potential way to increase production of branches for young plants of three jojoba clones (S-700, S-1300 and S-118) grown in sandy soil under drip irrigation system from well at El- Maghara Research Station, Desert Research Center, North Sinai Governorate, Egypt. Benzyladenine (BA) was applied four times a year starting on 1st May, (2015 and 2016) with one-month intervals in both seasons. Vegetative growth parameters, flower buds production and seed yield were statistically different between clones. The total number of branches, the flower number and seed yield in three clones were significantly increased by treatment with BA. In general, a higher BA concentration resulted in highest number of branches. The increase in the production of flower buds and the yield of seed was correlated with the increase in the production of branches. Moreover, clone S-700 showed the highest positive response to foliar applications of BA.

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Introduction:-

Jojoba (*Simmondsia chinensis* (Link) Schneider), commonly called jojoba, is the only species in the *Simmondsiaceae* family native to Southwest USA and Northern Mexico's Sonoran Desert. It is a wild, evergreen species and also known as "ho-ho-ba" (Yermanos, 1982). Moreover, it is cultivated in Argentina, Egypt, Israel, Peru and Morocco. Jojoba has a deep root system, resistant to drought and can tolerate extreme temperatures, and therefore grows in marginal soils not used for conventional crops (Bhardwaj et al., 2010).

The primary product of this evergreen shrub is the unique liquid wax found in the seed. This wax has heat-resistant lubricating characteristics, it is potential to be used in the chemical sector and used for a wide range of cosmetic products as a natural basis (Nelson et al., 1993). In recent years there have been about 300 jojoba products on the market, and the use of jojoba is expected to rise in future (Benzioni and Vaknin, 2002; Benzioni et al., 2005).

Jojoba is growing slowly and has low seed yield in early growing years (Agrawal et al., 2007; Benzioni and Vaknin, 2002; Sharma et al., 2008). The reproductive cycle in jojoba is highly complex because it begins with primordial cell formation a year and a half before the fruit is full matured and harvested (Dunstone, 1988).

Jojoba clones showed variations in vegetative growth traits i.e. (tree height, tree canopy volume, and branching and node traits), differences in fruiting traits i.e. (fruit set, seed yield, seed weight and seed wax content) (Al-

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Soqeer, 2014; Bakeer et al., 2017; Genaidy et al., 2016; Osman and Hassan, 2013). The number of flowers, solitary flowers and the number of seeds in each branch varies depending on clone (Prat et al., 2008). Extreme genetic variations, including growth habit, branches production, flowers number, flowering date, and seed yield, refers to differences between clone (Purcell et al., 2000).

In jojoba, floral buds (and later fruit) only develop on new growth close to shoot tips (Gentry, 1958). As a result, the number of branches produced places an upper limit of the number of flowers and seed produced by a plant (Ravetta, 1990). Apical dominance controls the plant's branching rate and thus prevents lateral buds from releasing and growing (Martin, 1983). There are several methods for enhancing branches production. Hedging pruning orchards are active ways to gain a large number of branches for some jojoba clones (Bakeer, 2019). But this type may be appropriate for older plants. Lateral branches can also be induced by foliar application of exogenous cytokinines. The most widely used cytokinins as a plant growth regulator in induction of lateral branches is 6-benzyladenine (Forshey, 1982; Fooshee and Henny, 1986; Nauer and Boswel, 1981). Several researchers have reported the ability of exogenous cytokinines to reduce apical dominance.

Ravetta and Palzkill (1992), observed a marked increase in the production of branches, and floral buds with some differences in jojoba clones responses, after using growth regulators during the early years of growth. Apple cultivars have shown similar differential responses (Elfving, 1984). BA has been used to overcome apical dominance and stimulate the development of lateral shoots (Jaumien et al., 2002), BA stimulated vegetative growth (Dal Cin et al., 2007; Elfving and Cline, 1993), BA appear to be the most efficient in inducing branching (Elfving, 1985; Keever, 1995; Keever and Morrison, 2003). Neri et al.(2004), reported that a more pronounced branching effect in young sweet cherry trees could be achieved by applying BA. 100 mg L⁻¹ BA foliar application on jojoba plants resulted in a stimulation of the branching and increased floral buds production (Prat et al., 2008). BA at 80 or 100 mg L⁻¹ improving yield and fruit quality of Manzanillo olive trees (AbouRayya et al., 2015). Cytokinines should be considered as one of the multifactorial components of the floral stimulus (Bernier et al., 1993).

Plant growth regulators may be helpful to increase branching and thus reduce the growth delay of young plants. Repeated applications should also be tested to reach a higher rate of bud break (Ravetta, 1990).

The objective of present study was to determine the effect of BA treatments on the branches production of young plants of three jojoba clones (S-700, S-1300 and S-118). It is advantageous to maximize the development of branches in order to increase the production of flower buds and seed yield for young jojoba plants.

Materials And Methods:-

Plant material and experimental design

The trial was conducted on two-month - old plants of clones S-700, S-1300 and S-118, and propagated using stem cuttings prior to field establishment at the Middle Sinai Experimental Station (El-Maghara), Desert Research Center, North Sinai Governorate, Egypt. By the time of treatments were applied, all plants had new growth.

The plants were established in rows 2 m apart, with a spacing of 4 m in the row. Male plants were propagated from stem cuttings and planted every third plant in every third row. This arrangement produced an 8 female: 1 male ratio, with every female plant adjacent to a male. The soil is sandy and poor in organic matter (0.87%), has a pH of 7.4 and is well drained. A drip irrigation system was used to supply the water from an artesian well with a salinity of 2548.4 ppm. For the experimental area, the agro-techniques used were similar to those of the whole plantation. A completely randomized experimental design was used, with a 3×3 factorial design, with BA treatments (0, 100, 150 mg L⁻¹) being the first factor and clones (S-700, S-1300 and S-118) the second, with three replicates for each treatment and each replicate was represented by two plants.

Foliar spraying of BA treatments was performed four times a year starting on 1 May (2015 and 2016) with one-month interval.

A stock solution (1 mg/ml) of BA was prepared by dissolving 1 g BA in 8 ml 1 M NaOH and bringing the final volume to 1 L with distilled water. Tween-20[®] was added to BA working solutions at a final concentration of 0.05% (v/v) as a wetting agent. Working solutions of both concentrations of BA (100 and 150 mg L⁻¹) were

sprayed onto entire plants with a hand sprayer, wetting the plant to the point of run-off (approximately 500 ml BA working solution per plant). Control plants were sprayed with 500 ml distilled water containing 0.05% (v/v) Tween-20®.

Response of three jojoba clones to foliar applications of BA was evaluated through the following determinations.

Vegetative growth parameters

Observations of plant height, plant circumference, diameter of the plant, and volume of canopy were reported under growth parameters, during January 2016 and 2017. Plant height was vertically measured and expressed in centimeters from the ground to the tip of the plant. The plant circumference was measured and expressed in meters. The diameter of the plant's ground area was measured in the 'North-South' and 'East-West' directions and expressed in centimeters. The canopy volume was calculated and expressed in cubic meters by applying measurements of height and 2 diameter to a derivative of the basic ellipsoid volume formula:

$$\text{Canopy volume} = \frac{2}{3} \times \pi \times H \times \left(\frac{A}{2} \times \frac{B}{2} \right)$$

Where H is the height of the tree, and (A and B) the diameter readings are taken at 50% of tree height with B perpendicular to A (Thorne et al., 2002).

The number of branches per plant was described as branching. For five branches per plant, branch length and number of nodes were determined.

Flowering parameters

During the first of January 2016 and 2017, five branches per plant were labeled and the number of flowers per branch was recorded. Flower density has been defined as a ratio of the number of flower buds on previous year's growth to the number of nodes, and fruit set percentage was recorded.

Yield and seed dry weight

The seed yield (in g) was calculated by weighing the total seeds harvested from each plant. Seed weight was determined by recording the weight of 10 seeds from each plant and unit was g. The seeds were harvested at proper maturity, cleaned and corrected to dry weight.

Seed wax content

Seed wax was extracted using petroleum ether as solvent for 24 h in a Soxhlet apparatus. Wax content was quantified according to AOCS method Ci 1-91 (American Oil Chemists' Society, 1992), using 5 g of crushed dry seeds for each tree.

Statistical analyses

Data were tabulated and statistically analyzed according to Snedecor and Cochran (1980) using MSTAT. Duncan multiple rang tests at level of 5% were used to differentiate means (Duncan 1955).

Results And Discussion:-

Vegetative growth characteristics

Plant height (cm)

The findings obtained from the analysis of the average plant height of jojoba clones are shown in Table 1. There was a significant difference in the average of the plant height of three jojoba clones. Clone S-700 had the tallest plant (34.86 and 50.33 cm), followed by clone S-1300 (23.04 and 34.43 cm) whereas, clone S-118 proved the shortest plant (17.23 and 26.09 cm) in both seasons, respectively.

With respect to the effect of BA, it is clear that the BA, a cytokinin, appears to inhibit plant growth. As the BA

concentration of applications increased, there was a corresponding reduction in plant height. Maximal plant height was observed with control plants and lowest level of BA application, while minimal plant height resulted from highest level of BA application.

The combined effects of three jojoba clones with BA foliar spray treatments showed that clone S-700 without applied BA treatments gave the highest values of plant height in both seasons.

Table 1:- Effect of benzyladenine (BA) foliar spray on plant height and plant diameter of three jojoba clones during 2016 and 2017 seasons.

Benzyladenine treatments	2016				2017			
	Clones							
	S-700	S-118	S-1300	Mean	S-700	S-118	S-1300	Mean
Plant height (cm)								
Control	38.86 a	20.50 ef	26.70 d	28.69 A	55.52 a	30.20 d	38.13 c	41.28 A
100 mg L ⁻¹	31.18 b	18.60 f	23.40 e	24.39 B	46.20 b	28.23 d	35.90 c	36.78 B
150 mg L ⁻¹	34.53 c	12.60 g	19.03 f	22.05 C	49.27 b	19.83 e	29.27 d	32.79 C
Mean	34.86 A	17.23 C	23.04 B		50.33 A	26.09 C	34.43 B	
Plant diameter (cm)								
Control	25.48 d	23.57 d	27.07 cd	25.37 C	29.94 ef	35.03 e	30.25 ef	31.74 C
100 mg L ⁻¹	30.25 b	30.89 b	30.57 b	30.57 B	44.90 bc	38.54 de	40.76 cd	41.40 B
150 mg L ⁻¹	34.71 a	34.71 a	36.62 a	35.35 A	51.59 a	42.36bcd	45.54 b	46.50 A
Mean	30.15 A	29.72 A	31.42 A		42.14 A	38.64 B	38.85 B	

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Plant diameter (cm)

The diameter of the plant has no significantly differed among the studied clones in the first season (Table 1). In the second season, clone S-700 showed to be the widest plant diameter (42.42 cm), whereas the smallest plant diameter (38.64 cm) was noticed in clone S-118.

The results show that plant diameter was significantly increased by BA treatments in both seasons compared to the control treatment. The highest significant plant diameter was obtained from trees sprayed with 150 mg L⁻¹ BA treatment (35.35 cm) in season 2016 and (46.50 cm) in season 2017. While, the lowest values of plant diameter (25.37 and 31.74 cm) resulted from control treatment in the 1 and 2 seasons, respectively.

The interaction between clones and BA treatments reveals that the highest plant diameter value was recorded with clone S-700 treated with 150 mg L⁻¹ BA. On the contrary, the combination of clone S-118 and control treatment gave the least positive effect on plant diameter.

Table 2:- Effect of benzyladenine (BA) foliar spray on plant circumference and plant canopy volume of three jojoba clones during 2016 and 2017 seasons.

Benzyladenine treatments	2016				2017			
	Clones							
	S-700	S-118	S-1300	Mean	S-700	S-118	S-1300	Mean
Plant circumference (m)								
Control	0.80 d	0.74 d	0.85 cd	0.80 C	0.94 f	1.10 e	0.95 f	1.00 C
100 mg L ⁻¹	0.95 bc	0.97 b	0.96 b	0.96 B	1.41 bc	1.21 de	1.28 cd	1.30 B
150 mg L ⁻¹	1.09 a	1.09 a	1.15 a	1.11 A	1.62 a	1.33 bcd	1.43 b	1.46 A
Mean	0.95 A	0.93 A	0.99 A		1.32 A	1.21 B	1.22 B	
Plant canopy volume (m ³)								
Control	0.017 cde	0.006 f	0.012 e	0.012 C	0.037def	0.021 f	0.029 ef	0.029 C
100 mg L ⁻¹	0.032 b	0.015de	0.018 d	0.022 B	0.119 b	0.035def	0.050 cd	0.068 B
150 mg L ⁻¹	0.048 a	0.020cd	0.025 c	0.031 A	0.168 a	0.045 de	0.057 c	0.090 A
Mean	0.032 A	0.014 C	0.018 B		0.108 A	0.034 C	0.045 B	

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Plant circumference (m)

It is clear from Table 2 that average plant circumference was not significantly affected by various clones in the first season. While in the second season, clone S-700 possessed the largest plant circumference (1.32 m) while, the smallest one (1.21 m) was observed for clone S-118.

The effect of BA as growth regulator treatments on plant circumference was significant in both seasons. The broadest circumference was a result of treating plants with 150 mg L⁻¹ BA. On the other hand, the narrowest circumference was detected on plants treated with distilled water.

The combined effects of jojoba clones with foliar spray treatments showed that clone S-700 with 150 mg L⁻¹ BA treatment gave the largest plant circumference in second season.

Plant canopy volume (m³)

The average of plant canopy volume was significantly differed according to clones (Table 2). Clone S-700 had the highest plant volume (0.032 and 0.108 m³) in both seasons, respectively. Whereas, the lowest plant volume (0.014 and 0.034 m³) was obtained from clone S-118.

The effect of BA treatments on plant volume was significant in both seasons. Despite this fact, it could be noticed that 150 mg L⁻¹ BA gave the highest plant volume (0.031 and 0.090 m³) in both seasons, respectively. The lowest plant volume (0.012 and 0.029 m³) was produced by control treatment in both seasons, respectively.

The interaction between jojoba clones and BA treatments illustrates that the highest plant volume was recorded when clone S-700 sprayed with 150 mg L⁻¹ BA. The lowest plant volume was recorded when the clone S-118 had untreated plants with BA.

Number of branches per plant

Results shown in Table 3 revealed that there were differences among clones in the number of branches per plant. Clone S-700 produced the highest number of branches per plant (23.64 and 53.61) in both seasons, respectively. Meanwhile, clone S-1300 produced the lowest number of branches per plant (14.40 and 29.07).

The effect of BA treatments on number of branches per plant was significant in both seasons. The highest number of branches per plant (23.56 and 53.37) was obtained when 150 mg L⁻¹ BA applied in the first and second seasons, respectively. The lowest values (15.59 and 27.76) in the same regard were noticed by spraying distilled water in the first and second seasons, respectively.

The interaction effect of three jojoba clones and foliar spraying treatments showed that the highest number of branches per plant was scored from BA foliar application at 150 mg L⁻¹ with clone S-700. Meanwhile, the lowest values were recorded when clone S-1300 was sprayed by distilled water.

Branch length (cm)

Table 3, represents the length of branches during the growing seasons in three jojoba clones. Generally, the length of branches was significantly higher in clone S-700, significantly lower in clone S-118 and clone S-1300 was intermediate in this regard.

There is no significant effect of BA treatments on the length of branches in both seasons. BA may inhibit branch elongation. As the concentration of BA treatments increased, there was a corresponding decrease in the length of the branch. Maximal branch length was observed in control treatment and low level of BA applications.

Moreover, the interaction between jojoba clones and BA foliar spraying treatments showed that clone S-700 treated with distilled water treatment gave the highest length of branches, while the lowest length of branches obtained from S-118 clone combined with 150 mg L⁻¹ BA treatment in the 1 and 2 seasons.

Table 3:- Effect of benzyladenine (BA) foliar spray on number of branches per plant, branch length and number of nodes per branch of three jojoba clones during 2016 and 2017 seasons.

Benzyladenine treatments	2016				2017			
	Clones							
	S-700	S-118	S-1300	Mean	S-700	S-118	S-1300	Mean
Number of branches/plant								
Control	17.97 b	17.40 b	11.40 c	15.59 B	33.17 ef	27.93 g	22.17 h	27.76 C
100 mg L ⁻¹	25.97 a	24.73 a	15.17 b	21.96 A	58.60 b	48.97 d	30.40 fg	45.99 B
150 mg L ⁻¹	26.97 a	27.07 a	16.63 b	23.56 A	69.07 a	56.40 c	34.63 e	53.37 A
Mean	23.64 A	23.07 A	14.40 B		53.61 A	44.43 B	29.07 C	
Branch length (cm)								
Control	13.34 a	8.27 f	11.67 c	11.09 A	14.18 a	9.40 f	12.03 d	11.87 A
100 mg L ⁻¹	12.50 b	7.73 g	10.60 d	10.28 B	13.24 b	8.53 g	11.37 e	11.05 B
150 mg L ⁻¹	12.24 b	7.67 g	9.53 e	9.81 B	12.92 c	8.33 g	11.60 e	10.95 B
Mean	12.69 A	7.89 C	10.60 B		13.45 A	8.75 C	11.67 B	
Number of nodes/branch								
Control	5.50 a	4.33 c	4.46 c	4.76 A	5.61 a	4.57 c	4.70 c	4.96 A
100 mg L ⁻¹	5.09 b	4.02 de	4.37 c	4.49 B	5.46 b	4.53 c	4.60 c	4.86 A
150 mg L ⁻¹	5.05 b	3.90 e	4.27 cd	4.41 B	5.38 b	4.15 e	4.40 d	4.64 B
Mean	5.21 A	4.08 C	4.37 B		5.48 A	4.42 B	4.57 B	

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Number of nodes per branch

From the data presented in Table 3 it is evident that the number of nodes per branch varied significantly according to clones. Clone S-700 produced the highest number of nodes per branch. While, the lowest number of nodes per branch was obtained by clone S-118.

The effect of the plant growth regulator on the number of nodes per branch was insignificant. The highest number of nodes per branch (4.76 and 4.96) emerged on untreated plants. The lowest number of nodes per branch (4.41 and 4.64) resulted from the plants treated with 150 mg L⁻¹ BA in both seasons, respectively.

In addition, S-700 jojoba clone combined with distilled water proved to be the most effective treatment in increasing the number of nodes per branch. On the contrary, clone S-118 combined with 150 mg L⁻¹ BA gave comparatively the lowest values in this respect.

The current study has shown that cytokinin BA is useful for releasing lateral branches of jojoba plants younger than two years old. The increasing number of branches resulting from treatments with BA appears to offer an effective way to improve seed production. The results are agreement with those obtained by (Abd El-aziz, 2007; Dal Cin et al., 2007; Elfving and Cline, 1993), those found that BA is stimulated vegetative growth. Ravetta and Palzkill (1992) reported that the most significant increases in the number of branches compared with control have occurred in BA-treated plants of both jojoba clones (AT-1310 and AT-1487). Significant differences in branching were caused by the different concentrations used. BA is used as a branching agent in nurseries and young orchards (Cline and Dong, 2002). Zhalnerchuk et al. (2015) suggested that the increase in branches number as a result of BA application could be attributable to its impact on counteraction or elimination of apical dominance and stimulate the lateral branching development. The apical dominance and branching, as reported by Sachs and Thimann (1967), depend on the concentration of auxine commonly secreted by the apex, and cytokinin provided by the inhibited organ. Auxin produced through a growing apex prevents the lateral buds development. Lateral branches may develop as a result of any weakening of the dominant apex that will reduce its inhibitory effects.

The differences in vegetative growth characteristics i.e. (plant height, plant diameter, plant volume, number of branches per plant, branch length and number of nodes per branch) of three mentioned clones are due to variable differences based on genotype variations. Such variations were reported to occur in different jojoba clones by (Al-Soqeer, 2014; Bakeer et al., 2017; Osman and Hassan, 2013), and confirm the observation of (Purcell et al., 2000), whose mentioned that growth habit and branching refers to differences in genotypes. Normally, branching frequency of clone AT-1487 is lower than AT-1310, possibly due to a high apical dominance. In addition, the greatest response was shown by clone AT-1310, which has the highest natural branching frequency. Therefore, the

effectiveness of the response directly depends on factors such as applied hormone concentration, various growth habits and branching frequency, and developmental stage of clones used (Ravetta and Palzkill, 1992). Similar differential responses have been found among apple cultivars (Elfving and Visser, 2007). Moreover, there were significant differences among clones, with clone 4.8 showing a larger length of branches than clone 4.11.32. The natural growth habits and branching of clones may explain this disparity (Prat et al., 2008).

The BA, a cytokinin, appears to prevent shoot elongation. The corresponding decrease in shoot length occurred when the BA concentration and the number of applications increased. Maximum elongation was observed in untreated plants and low levels of BA applications (Inglis, 1984).

Flower parameters

Flowers number

Data in Table 4 also indicate that the flowers number varied from clone to another. Clone S-1300 had the highest flowers number (5.21 and 5.52), while clone S-700 gave the lowest flowers number (3.39 and 3.44) in both seasons, respectively.

The effect of BA treatments on the number of flowers per branch was significant in both seasons. The highest branches in flowers number (4.94 and 5.18) were those treated with BA at 150 mg L⁻¹ in the first and second seasons, respectively. The lowest number of flowers (3.72 and 4.19) was recorded when plants untreated as control ones in the first and second seasons, respectively.

The combined effects of jojoba clones with BA foliar spraying treatments showed that clone S-1300 sprayed with 150 mg L⁻¹ BA was the most effective treatment in increasing the number of flowers per branch.

Flower density

Data on the flower density of jojoba clones presented in Table 4 indicated that the highest rate of flower density was found in clone S-1300 followed by clone S-118, while the lowest flower density appeared in clone S-700.

The effect of BA treatments on flower density was significant in both seasons. However, it could be observed that the highest flower density belonged to plants treated with BA at 150 mg L⁻¹. The lowest flower density resulted when plants were left untreated as control in the first and second seasons.

Table 4:- Effect of benzyladenine (BA) foliar spray on flower number, flower density and fruit set percentage of three jojoba clones during 2016 and 2017 seasons.

Benzyladenine treatments	2016				2017			
	Clones							
	S-700	S-118	S-1300	Mean	S-700	S-118	S-1300	Mean
Flowers number								
Control	2.69 g	4.20 d	4.27 d	3.72 B	2.76 f	4.67 d	5.13 cd	4.19 C
100 mg L ⁻¹	3.70 ef	5.00 c	5.67 ab	4.79 A	3.73 e	5.17 bc	5.77 a	4.89 B
150 mg L ⁻¹	3.79 e	5.33 bc	5.70 a	4.94 A	3.84 e	6.03 a	5.67 ab	5.18 A
Mean	3.39 C	4.84 B	5.21 A		3.44 C	5.29 B	5.52 A	
Flower density								
Control	0.49 e	0.97 c	0.96 c	0.81 B	0.49 g	1.02 de	1.09 cd	0.87 B
100 mg L ⁻¹	0.73 d	1.24 bc	1.30 ab	1.09 AB	0.68 f	1.14 c	1.25 bc	1.02 AB
150 mg L ⁻¹	0.75 d	1.37 a	1.33 ab	1.15 A	0.71 f	1.45 a	1.29 b	1.15 A
Mean	0.66 B	1.19 A	1.20 A		0.63 B	1.20 A	1.21 A	
Fruit set %								
Control	81.90 a	30.31 c	25.12 d	45.78 A	84.15 a	35.02 c	30.12 d	49.76 A
100 mg L ⁻¹	59.46 b	21.97 de	21.50 de	34.31 B	63.20 b	22.31 ef	20.33 ef	35.28 B
150 mg L ⁻¹	58.91 bc	20.64 de	19.70 e	33.08 B	61.17 b	23.61 ef	18.94 f	34.57 B
Mean	66.76 A	24.31 B	22.11 C		69.51 A	26.98 B	23.13 C	

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Concerning the interaction between the tested clones and foliar spraying of BA treatments, clone S-1300 sprayed with 150 mg L^{-1} BA proved to be the best interaction in this regard.

Fruit set percentage

Data on fruit set percentage of three jojoba clones are presented in Table 4. Fruit set percentage varied greatly among clones, the highest fruit set percentage was found in clone S-700, while the lowest appeared in clone S-118 in both seasons.

BA treatments failed to induce any positive effect on fruit set percentage of three jojoba clones as compared to control treatment in 2016 and 2017 seasons.

The interaction effect of jojoba clones and BA treatments foliar spraying demonstrated that fruit set percentage gave the highest values when clone S-700 treated with distilled water in both seasons. While the lowest values obtained from clone S-1300 when received the highest concentration of BA.

The obtained results of foliar application of BA regarding its positive effect on flower characters are in harmony with the findings of (Prat et al., 2008; Ravetta and Palzkill, 1992) who found that jojoba clones had a significant response in enhancing flower number after BA application. The increase of flower buds has been related to an increase in the number of branches and production of nodes (Ravetta, 1990). Accumulated information reveals that the increase in flowers number caused by BA could result from cytokinin's positive role in inflorescence meristem activity and size regulation (Kiba and Sakakibara, 2010; Werner and Schmulling, 2009). On contrary, the reduction in fruit set percentage has been associated with an increase in the number of flowers (Prat et al., 2008).

The differences among the clones in flower parameters i.e. flower number per branch, flower density and fruit set percentage of three mentioned clones are evidently due to genetic variations. These results are agreement with those of (Al-Soqeer, 2014; Bakeer et al., 2017; Osman and Hassan, 2013; Purcell et al., 2000). In addition, Prat et al. (2008) found that significant variations were observed between jojoba clones in the number of flowers and flower density. However, Benzioni et al. (1999) detected that some of the jojoba clones are usually low in fruit setting and have a high percentage of abortion.

Yield parameters and seed wax content

Yield

It is clear from Table 5 that the yield per plant was varied among clones. In two seasons clone S-700 had the highest seed yield per plant (27.51 and 76.15 g), while no significant differences appeared in seed yield among clones S-1300 and S-118.

The effect of spraying BA on yield (g/plant) is considered a reflection of the studied treatments on seed productivity of the examined clones. During the two seasons of study, 150 mg L^{-1} BA application resulted in the highest significant yield (25.62 and 74.08 g/plant) compared to the lowest significant yield produced from control treatment (16.75 and 40.08 g/plant).

In addition, clone S-700 combined with 150 mg L^{-1} BA treatment proved to be the most effective treatment in improving yield. On the contrary, clone S-1300 or clone S-118 combined with control treatment gave comparatively the lowest values in this respect.

Seed weight

Data disclosed in Table 5 show that the highest values of seed weight (0.97 and 1.05 gm) were recorded by clone S-1300 followed by clone S-118 while the lowest ones (0.62 and 0.67 gm) come from clone S-700 in the two seasons, respectively.

On the other hand, the seed weight of three jojoba clones was not affected significantly by BA treatments in both seasons.

The combined effects of jojoba clones with foliar spraying treatments showed that clone S-1300 combined with 150 mg L⁻¹ BA was the most effective treatment in increasing seed weight meanwhile the lowest values were recorded with clone S-700 treated with distilled water.

Table 5:- Effect of benzyladenine (BA) foliar spray on seed yield, seed weight and seed wax content of three jojoba clones during 2016 and 2017 seasons.

Benzyladenine treatments	2016				2017			
	Clones							
	S-700	S-118	S-1300	Mean	S-700	S-118	S-1300	Mean
Yield (g)								
Control	24.11 bc	13.68 d	12.45 d	16.75 C	51.98 f	31.42 g	36.83 g	40.08 C
100 mg L ⁻¹	28.37 a	19.87 c	21.15 bc	23.13 B	83.91 b	55.53 e	61.05 de	66.83 B
150 mg L ⁻¹	30.06 a	22.79 bc	24.02 b	25.62 A	92.56 a	63.55 cd	66.13 c	74.08 A
Mean	27.51 A	18.78 B	19.21 B		76.15 A	50.17 C	54.67 B	
Seed weight (g)								
Control	0.63 f	0.74 d	0.94 c	0.77 B	0.69 f	0.82 d	1.01 c	0.84 B
100 mg L ⁻¹	0.62 f	0.72 e	0.97 b	0.77 B	0.68 f	0.81 d	1.05 b	0.85 A
150 mg L ⁻¹	0.61 g	0.72 e	1.01 a	0.78 A	0.65 g	0.78 e	1.10 a	0.84 B
Mean	0.62 c	0.73 b	0.97 a		0.67 C	0.80 B	1.05 A	
Seed wax content %								
Control	49.54 a	46.54 c	46.43 c	47.50 A	52.59 a	52.11 bc	52.09 bcd	52.26 A
100 mg L ⁻¹	48.25 b	45.99 c	45.80 c	46.68 B	52.48 ab	51.34 e	51.80 cde	51.87 B
150 mg L ⁻¹	48.60 b	46.08 c	46.20 c	46.96 B	51.91 cde	51.61 de	51.49 e	51.67 B
Mean	48.80 A	46.20 B	46.14 B		52.33 A	51.69 B	51.79 B	

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Seed wax percentage

The results obtained from studying seed wax content are presented in Table 5. Clone S-700 had the highest values, while no significant differences have appeared in seed wax content among clones S-1300 and S-118 in both seasons.

In both seasons, the highest seed wax content of three jojoba clones was found in untreated plants with BA.

The interaction effect of jojoba clones and BA foliar applications showed that untreated plants of clone S-700 gave the highest values in this respect.

The purpose of using BA foliar application as a plant growth regulator is to optimize plant production by modifying growth, increasing branches production and the quantitative and qualitative yield of jojoba plants. The improvement in the yield of jojoba seed can be attributed to an increase in the number of branches, as flower buds only develop on new growth (Benzioni, 1995). The release of lateral branches has been shown to increase crop production of young fruit trees (Erez, 1987). Foliar spray of BA to cotton at the early stage of growth has the potential to increase yield (Burke, 2011). Foliar application of BA on Manzanillo olive trees resulted in improving yield and fruit quality. In addition, the higher concentration of BA was used (from 100 to 150 mg L⁻¹) was recorded the higher fruit weight (Abou-Rayya et al., 2015).

The observations in this study are in accordance with those obtained by (Al-Soqeer, 2014; Bakeer et al., 2017; Genaidy et al., 2016), they reported that there were many differences among jojoba genotypes in fruiting traits i.e. seed yield, seed weight and seed wax content. Differences in seed yield due to genetic variations between clones (Ravetta, 1990).

Conclusion:-

In this study, the increase in the branches production in the early years of growth induced by BA treatments seems to be an effective way to improve the yields of jojoba clones. This could shorten the period from planting to the beginning of economic yield. BA, a cytokinin, appears to inhibit branch elongation, plant height, and fruit set, and

additional studies are needed to stimulate increased elongation or prevent growth inhibition and improve fruit set in combination with BA applications.

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