Benzyladenine foliar application as a means to enhance branches production from the young plants of three jojoba clones grown in Middle Sinai

**A.S.M. Salama\***

Pomology Unit, Plant Production Department, Desert Research Center, Cairo, Egypt.

Abstract

Foliar applications of benzyladenine (0, 100 and 150 mg L−1) were investigated as a potential means for enhancing development of branches production 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 Experimental Station, Desert Research Center, North Sinai Governorate, Egypt. Benzyladenine was applied four times a year started 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 benzyladenine (BA). A higher concentration of benzyladenine generally resulted in greater numbers of branches. The increase in flower buds production and seed yield were associated with the increase in branches production. Moreover, clone S-700 showed the highest positive response to foliar applications of benzyladenine.

**Keywords: *Simmondsia chinensis*; Benzyladenine; Branches production; Flower density; Seed yield; Wax content**

1. Introduction

Jojoba (*Simmondsia chinensis* (Link) Schneider) is an evergreen, commonly known as jojoba (pronounced as ‘‘ho-ho-ba’’), is the sole species in the family *Simmondsiaceae* and is native to the Sonoran desert of southwestern USA and northern Mexico (Yermanos, 1982). It is cultivated in other countries including Argentina, Egypt, Israel, Peru, and Morocco. Jojoba has a deep root system, drought-resistant, can tolerate extreme temperatures and hence can be grown on marginal lands that are not used for conventional crops (Bhardwaj et al., 2010).

The primary product of this evergreen shrub is a unique liquid wax contained in the seed. This wax is used as a natural base for a wide range of cosmetic products, has heat-resistant lubricating properties, and is potentially useful in the chemical industry (Nelson et al., 1993). As many as 300 products containing jojoba have appeared in markets in recent years and the use of jojoba products will increase in future (Benzioni and Vaknin, 2002; Benzioni et al., 2005).

Jojoba has slow-growing habit, and low seed yield in the early years of growth (Benzioni and Vaknin, 2002; Agrawal et al., 2007; Sharma et al., 2008), and the reproductive cycle in jojoba is very complex as it begins with formation of the primordial cell a year and a half before the complete maturity and harvest of the fruits (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-Soqeer, 2014; Bakeer et al., 2017; Genaidy et al., 2016; Osman and Hassan, 2013).

The total number of flowers, solitary flowers per branch and the number of seeds in the plant vary according to the clone (Prat et al., 2008). The extreme genetic variation that exists in morphological and physiological characteristics such as growth habit, branching, seed yield, frequency of floral buds and flowering date refers to differences in clones (Purcell et al., 2000).

 In jojoba, flower buds (and later fruit) develop exclusively on new growth near branch tips (Gentry, 1958). Because of this, the number of branches produced puts an upper limit on the number of flowers, fruit and seed that a plant can produce (Ravetta, 1990). The branching frequency of a plant is governed by apical dominance, thus keeping lateral buds dormant and preventing their growth (Martin, 1983). Several methods exist to increase the branching of a plant. For some jojoba clones, hedging pruning orchards are an effective means of obtaining large numbers of branches (Bakeer, 2019). But this type may be appropriate with older plants. Induction of lateral branches can also be achieved through foliar application of exogenous cytokinins. The most commonly used plant growth regulator in induction of lateral branches is 6-benzyladenine (BA, a cytokinin) (Nauer and Boswel, 1981; Forshey, 1982; Fooshee and Henny, 1986). The ability of exogenous cytokinins in reducing apical dominance has been observed by many workers.

Ravetta and Palzkill (1992), after using growth regulators on jojoba plants during the early years of growth, observe a significant increase in branching and flower bud production with some differences in clone responses. Similar cultivars differential responses have been found in apple (Elfving, 1984). Benzyladenine (BA) has been used to overcome apical dominance and stimulate the development of lateral shoots (Jaumien et al., 2002), BA stimulated vegetative growth (Elfving and Cline, 1993; Dal Cin et al., 2007), BA appear to be the most efficient in inducing branching (Elfving, 1985; Keever, 1995; Keever and Morrison, 2003), that a more pronounced branching effect in young sweet cherry trees might be accomplished (Neri et al., 2004). Foliar application of 100 mg L−1 6-benzyladenine on jojoba plants resulted in branching stimulation and increased flower number (Prat et al., 2008). Benzyladenine at 80 or 100 mg L-1 improving yield and fruit quality of Manzanillo olive trees (AbouRayya et al., 2015). Cytokinins are suggested to act as one of the multifactorial components that function as the floral stimulus (Bernier et. al., 1993).

Plant growth regulators might be useful to increase branching and thereby causing an economically valuable reduction in the growth lag period of jojoba young plants. Also repeated applications to maintain a higher level of bud break should be tested (Ravetta, 1990).

The objective of present study was to determine the effect of BA treatments on branches production from the young plants of three jojoba clones (S-700, S-1300 and S-118). Maximizing branches development would be advantageous in increasing the flower buds and seed yield production for young jojoba plants.

2. Materials and methods

2.1. Plant material and experimental design

 The trial was conducted on plants of clones S-700, S-1300 and S-118, 2 months of age (Bakeer et al., 2017), and propagated using stem cuttings before establishment in the field at 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 type is sandy with low organic matter (0.87 %), a pH of 7.4, and is well drained. Water from an artesian well with a salinity of (2548.4 ppm) was supplied via a drip system.

The agro techniques used for the experimental area were the same as those for the whole plantation. A completely randomized experimental design was used, with a 3×3 factorial design, with benzyladenine 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 sprays of benzyladenine (BA) treatments were carried out four times a year started at 1st May, (2015 and 2016) with one-month intervals in both seasons.Tween-20 was added at 0.05% (v/v) as a surfactant to spray solution including the control " distilled water ". Spraying was carried out using a hand sprayer at the previously mentioned times.

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

2.2. Vegetative growth parameters

Plant height (cm) above the surface ground and plant diameter (cm) were measured; plant circumference (m), and plant canopy volume (m3) were recorded for all plants in January 2016 and 2017 seasons. Branching was defined as the number of branches per plant. The branch length and number of nodes were determined for five branches per plant.

2.3. Flowering parameters

Branches (five per plant for six plants), were tagged in the first January 2016 and 2017, and the number of floral buds was recorded. Flower density was defined as the ratio of the number of flower buds to the number of nodes in the shoots of the previous year’s growth. The number of flowers that set fruit was recorded.

2.4. Yield and seed dry weight

The yield of plant (g) and seed weight (g) were determined after manual harvesting every year in mid of July. Seeds were cleaned and corrected to dry weight.

2.5. Seed wax content

To evaluate the liquid wax ester levels, the jojoba seeds were manually harvested at full maturity. They were cleaned, dried and weighed, and seed wax was extracted using petroleum ether as a solvent for 24 h in a Soxhlet apparatus. Wax content was quantified according to (American Oil Chemist Society 1992), using a sample of 100 randomly picked seeds.

2.6. 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).

3. Results and discussion

3.1. Vegetative growth characteristics

3.1.1. Plant height (cm)

The results obtained from studying the average plant height of jojoba clones are presented 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 benzyladenine, it is clear that the BA, a cytokinin, appears to inhibit plant growth. As BA concentration of applications increased, there was a corresponding decrease 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 sprays treatments showed that clone S-700 without applied BA treatments gave the highest values of plant height in both seasons.

3.1.2. 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.

3.1.3. Plant circumference (m)

It is clear from Table 2 that average plant circumference was not significantly affected by various clones in the first season. Wherever 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 sprays treatments showed that clone S-700 with 150 mg L−1 BA treatment gave the largest plant circumference in second season.

**3.1.4. 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 benzyladenine 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 benzyladenine.

3.1.5. Number of branches/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 using 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.

3.1.6. 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. Benzyladenine may inhibit branch elongation. As BA concentration of treatments increased, there was a corresponding decrease in branch length. Maximal branch length was observed in control treatment and low level of benzyladenine 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.

3.1.7. Number of nodes/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 plant growth regulator treatments 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 present study has shown that there are advantages in using the cytokynin BA to release lateral branches for jojoba plants less than two years old. The increased numbers of branches induced from benzyladenine treatments appear to offer an effective means to improve seed yield. The results are agreement with those obtained by (Elfving and Cline, 1993; Abd El-aziz, 2007; Dal Cin et al., 2007), those found that benzyladenine is stimulated vegetative growth. BA treated plants of both jojoba clones (AT-1310 and AT-1487) had the greatest increase in the number of branches compared to control plants. 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). Jaumien et al., (2002), postulated that the increment in branch number as a result of BA application may be attributed to its influence on counteracting or eliminating the apical dominance and stimulate the development of lateral shoots. As stated by Sachs and Thimann (1967), apical dominance and branching depend on the levels of auxin-commonly secreted by the growing apex, and cytokinin produced by the inhibited organ. Auxin produced by a growing apex prevents lateral buds from developing. 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 (Osman and Hassan, 2013; Al-Soqeer, 2014; Bakeer et al., 2017), and confirm the observation of (Purcell et al., 2000), whose mentioned that growth habit and branching refers to differences in genotypes. Clone AT-1487 normally has a lower branching frequency than AT-1310, presumably due to a higher apical dominance. Also, clone AT-1310, which has the highest natural branching frequency, showed the greatest response. Consequently, the efficiency of the response depends directly on factors such as concentration of the applied hormone, different growth habits and branching, and developmental stages of the clones used (Ravetta and Palzkill, 1992). Similar cultivar differential responses have been found in apple (Elfving, 1984). However, significant differences appeared between the clones, with clone 4.8 showing more branches lengthening than clone 4.11.32. This difference could be explained by the natural growth habits and branching of clones (Prat et al., 2008).

The BA, a cytokinin, appears to inhibit shoot elongation. As BA concentration and number of applications increased, there was a corresponding decrease in shoot length. Maximal elongation was observed in control plants and low levels of BA applications (Inglis, 1984).

3.2. Flower parameters

3.2.1. Flowers number

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

The effect of benzyladenine 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 benzyladenine 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.

3.2.2. 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 benzyladenine 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 ones in the first and second seasons.

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.

3.2.3. 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 benzyladenine.

The obtained results of foliar application of benzyladenine regarding its positive effect on flower characters are in harmony with the findings of (Ravetta and Palzkill1992; Prat et al., 2008) who found that jojoba clones had a significant response in increasing flower number after growth regulator application. Moreover, benzyladenine increased the number of flowers compared to control (Ravetta, (1990). The increase in flower buds was associated with an increase in the number of growing tips and node production. Accumulating evidence suggests that the BA-induced increase in the number of flowers may result from the positive role of cytokinin in the regulation of inflorescence meristem activity and size (Werner and Schmulling, 2009; Kiba and Sakakibara, 2010). On contrary, an increase in the number of flowers per branch caused in a reduction in fruit set percentage (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 (Purcell et al., 2000 Osman and Hassan, 2013; Al-Soqeer, 2014; Bakeer et al., 2017). In addition, Prat et al. (2008) found that the total number of flowers and flower density were different between jojoba clones. However, Benzioni et al. (1999) noticed that some jojoba clones tend to have a low fruit set and a high abortion percentage.

3.3. Yield parameters and seed wax content

3.3.1. 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.

3.3.2. 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.

3.3.3. Seed wax content (%)

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 values of seed wax content of three jojoba clones were found in untreated plants.

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 increase in the number of growing tips was assumed to be related to jojoba seed yield, since flower buds develop exclusively on new growth near branch tips (Benzioni, 1995). In cereals and young fruit trees, the release of lateral branches has been shown to enhance crop production (Erez, 1987). Foliar spray of 6-benzyladenine 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. Also, 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; Genaidy et al., 2016; Bakeer et al., 2017), 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 increased branches production induced from BA treatments appears to offer an effective means to improve seed yield of jojoba clones in the early years of growth. This could shorten the period from planting to the beginning of economic yield. The BA, a cytokinin, seems to inhibit branch elongation, plant height and reduce fruit set, and additional studies are needed to stimulate greater elongation or prevent inhibition of growth and improve fruit set, in combination with BA applications.

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**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 | 42.36 bcd | 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.

**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 (m3) |
| **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 | 0.015 de | 0.018 d | **0.022 B** | 0.119 b | 0.035def | 0.050 cd | **0.068 B** |
| **150 mg L-1** | 0.048 a | 0.020 cd | 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.

**Table 3.** Effect of benzyladenine (BA) foliar spray on number of branches/plant, branch length and number of nodes/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.

**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.

**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.