



RESEARCH ARTICLE

REDUCING GROWTH LAG OF S-700 JOJOBA CLONE GROWN IN A NEWLY ESTABLISHED ORCHARD IN MIDDLE SINAI BY NPK AND BENZYLADENIN FOLIAR SPRAY

S.M. Bakeer, O.H.M. El-Gammal and A.S.M. Salama

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

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Abstract

A two-year trial was conducted during 2015/2016 and 2016/2017 seasons on young plants of S-700 jojoba clone grown in sandy soil under drip irrigation system from well at El-Maghara Experimental Station, Desert Research Center, North Sinai Governorate, Egypt. The experiment was laid out in randomized complete block design with split plot arrangement using three replications. The effect of foliar application of NPK (0, 3 and 5 g L⁻¹) and benzyladenine (0, 100 and 150 mg L⁻¹) on vegetative growth, flowering, seed yield and wax content of S-700 jojoba clone was studied. The results showed that foliar sprays of NPK treatments in combination with benzyladenine treatments enhanced vegetative growth parameters, flower bud production and seed yield. Particularly, NPK at 5 g L⁻¹ combined with 150 mg L⁻¹ benzyladenine proved to be most effective treatment in these respects.

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Introduction:-

Jojoba (*Simmondsia chinensis* (Link) Schneider) is a slow-growing, dioecious, evergreen, woody perennial shrub with a life span of around 100 years. The roots of the plant can penetrate to a depth of 9 meters. This widespread root structure enables the plant to subsist the arid conditions of its native Sonora Desert in Arizona and California and northwestern Mexico (Gentry, 1958; Benzioni et al., 2007).

Jojoba tolerates high temperature, drought and salinity, and it has aptitude to thrive in marginal soils with little nutrient requirements and low care (Hogan, 1985). Moreover, it is a potential alternative crop in Egyptian desert because its seed contains a liquid wax, which is marketed extensively in several industrial uses (Bakeer et al., 2017). Jojoba requirements little water for survival (a third or less of the moisture required by crops like citrus or cotton), while economic consideration demands that irrigation is important for a healthy, profitable crop in several dry areas (Ayerza, 1993).

Jojoba seeds contain 45-60 % of its weight as oil, which has exactly the same properties as the oil achieved from the sperm whale (Hogan and Bemis, 1983). The produced oil contains only a very small quantity of saturated wax, steroids, and tocopherol, and it has no resins and tars. The liquid wax and its derivatives have potential in extensive range of uses in cosmetics (lipsticks, skin fresheners, face creams, shampoos, winter care lotions, moisturizers, soaps), lubricants, electrical insulators, anti-foaming agents, and plastic industries (Reddy and Chikara, 2010; Radwan et al., 2007). It has pharmaceutical (tablets coating, antibiotic production) and medicinal uses (sores, wound, skin disorders treatment, burnt skin and to eliminate stretch marks). However, the wax looks like human sebum and can improve dry and oily skin. It has no triglycerides or cholesterol (Benzioni and Vaknin, 2002; Benzioni et al., 2005) and therefore it can be used as low calorie edible oil.

Jojoba can be propagated directly by seeds or either by asexual propagation methods. Commercial orchards of jojoba are fundamentally established using cuttings from high-yielding clones have produced up to five times the average yield of orchards planted with seed (Hogan and Bemis, 1983; Dunstone et al., 1985). Jojoba grown from seed takes about 3 years to flower and up to 4-5 years to bear seed in the tropical climate (Muthana, 1981). Differing from of the most cultivated crop species, jojoba has long juvenility stage, slow-growing habit and low seed yield in the early years of growth (Benzioni and Vaknin, 2002). Currently, there is low production in the existing jojoba plantations in Egypt partly due to inappropriate agricultural practices, hence the need for this study. Horticultural practises that favour the production of new vegetative growth can lead to an increase in the production of flower buds that will eventually develop into seeds.

Jojoba tree is a dioecious species, with male and female flowers existent in independent plants, and is wind pollinated (Gentry, 1958; Benzioni et al., 2007). Usually, female jojoba plant carries flowers at alternate nodes of branch and focuses its flower production on new vegetative growth (Dunstone, 1980, 1986). Increase the number of shoots by weakening apical dominance and stimulate the growth of lateral shoots led to increase in the number of flowers per plant (Ravetta, 1990). Therefore, increasing the number of branches per plant seems critical for the improvement of jojoba seed yield.

Canopy formation is very important in jojoba trees because the preconditions of early productivity in young plants are (1) increasing the number of branches per plant (2) increasing the number of nodes per branch which have high flowering potential. These can be achieved using chemicals such as BA and NPK on young plants. Benzyladenine (BA) as plant growth regular is used to increase the number of growing points by weakening apical dominance, and NPK promoting growth of buds already released.

Plant growth regulators are applied to enhance the growth rate of plants, eliminating apical dominance and stimulate lateral buds to release (Baskaran et al., 2009). One of the most plant growth regulators commonly used to disrupt apical dominance is synthetic cytokinin benzyladenine (Ravetta and Palzkill, 1992). Exogenous application of the 6-benzyladenine raises the ratio of cytokinin to auxin in the plants and break apical dominance. This results in more lateral branching and fuller plants (Carey, 2008). Ravetta and Palzkill (1992) observed during the first 3 years of growth on jojoba plants that branching and flower bud production increase significantly after using growth regulators.

Furthermore, N, P and K fertilization play a vital role in growth and development of all plants. Fertilization of plants causes them to develop more rapidly and strongly, just such as ensuring a manufacturing plant has all the raw materials it necessitates for a production line. For natural plants to grow and thrive they require a number of chemical elements, but the most crucial are nitrogen, phosphorus and potassium. Most packaged fertilizers comprise these three macro elements with microelements, which also play a crucial function in most vital processes of plants (Marschner, 1995). Benzioni and Nerd (1985) noticed that the increase in growth of jojoba plants and seed yield due to NPK fertilization through irrigation water. Foliar spray of nutrient did not only increase the growth and crop yields but also reduce the quantities of fertilizer applied through soil. Foliar application can also reduce the lag time between application and uptake by the plant. Mallarino et al. (2001) reported that foliar fertilization at early growth stages could be improved P and K uptake at the time when root system is not well developed.

The objective of this work was to study the effect of foliar application of NPK (19:19:19) and benzyladenine (BA) on branching, flower buds production and seed yield of S-700 jojoba clone grown in a newly established orchard.

Materials and methods:-

Plant material and experimental design:

S-700 jojoba clone plants produced from stem cuttings by El-Maghara Experimental Station nursery were planted in March 2015 at Middle Sinai Experimental Station (El-Maghara), Desert Research Center, North Sinai Governorate, Egypt, (30° 43" N latitude, 33° 19" E longitude, at an elevation of 200 m above sea level). The selection clone was chosen from the collection of about 40 clones based on its high seed yield and waxes content (Bakeer et al., 2017). The experiment was carried out from May 2015 (when the plants were two months old) to June 2017.

Fifty- four plants of S-700 jojoba clone planted in sandy soil under drip irrigation system from well and received the same horticulture practices were selected as test plants. 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 (Fig 1).

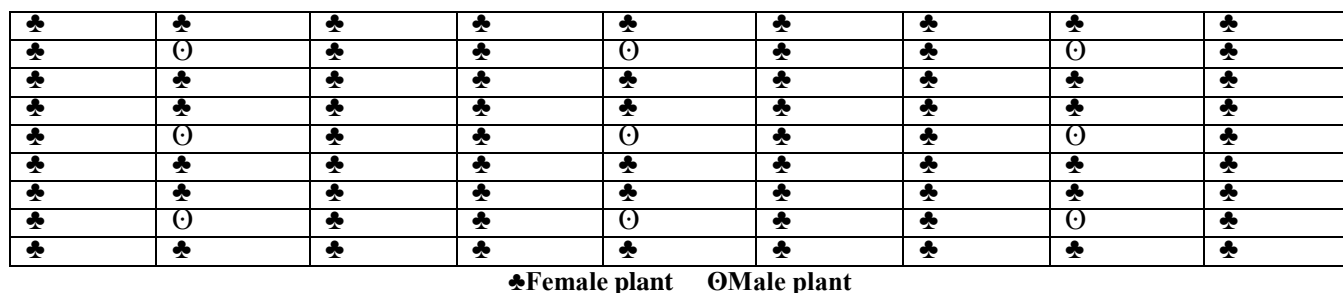


Fig. 1:- Distribution of male and female plants grown in a newly established orchard in Middle Sinai.

Soil samples from the experimental site before jojoba planting were taken for physical and chemical analysis. Physical and chemical analysis of the experimental soil was shown in Table 1, meanwhile the chemical analysis of used water for irrigation was recorded in Table 2.

Table 1:- Analysis of the tested soil of El-Maghara Experimental Station.

Physical analysis of El-Maghara soil											
Soil depth (cm)	Particle size distribution			Texture class	Moisture content (%)						
	Total sand	Silt + clay	Field capacity		Wilting point						
0-30	95.5	4.5	Sand	11.4	4.2						
30-60	97	3	Sand	11.2	4.1						
Chemical analysis of El-Maghara soil											
Soil depth (cm)	CaCO ₃	pH soil past	E.Ce (dSm ⁻¹)	Soluble cations (mequiv./L)				Soluble anions (mequiv./L)			
				Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	CO ₃ ²⁻	HCO ₃	Cl ⁻	SO ₄ ²⁻
0-30	11.6	7.4	0.8	3.29	0.14	3.9	1.4	-	1.7	5.1	1.94
30-60	9.59	7.5	1.1	4.79	0.28	4.4	1.9	-	1.2	5.4	4.62

Table 2:- Chemical analysis of water used for irrigation at El-Maghara Experimental Station.

pH	E.C. (dSm ⁻¹)	O.M (%)	Soluble cations (mequiv./L)				Soluble anions (mequiv./L)			
			Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃	Cl ⁻	SO ₄ ²⁻
8.36	4.06	1.40	11.40	3.48	24.60	0.69	-	4.40	32.20	3.57

The experimental design was factorial between foliar sprays of NPK (three concentrations) and benzyladenine (BA) (three concentrations) in completely randomized block design with three replicates for each treatment and each replicate was represented by two trees. The three NPK concentrations were 0, 3 g L⁻¹ and 5 g L⁻¹ while the three benzyladenine (BA) concentrations were 0, 100 mg L⁻¹ and 150 mg L⁻¹.

Foliar sprays of benzyladenine (BA) and NPK treatments were carried out at four times a year started at 1st May, (2015 and 2016) with one-month intervals in both seasons. Spraying of benzyladenine and NPK was conducted at dusk with one-week interval between them.

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[®]. Kristalon is the commercial preparation of NPK 19:19:19 with macro and microelements.

Vegetative growth parameters:

Plant height (cm) above the surface ground was measured for all plants in January 2016 and 2017 seasons and plant circumference (m) was calculated from canopy diameters. Plant canopy volume was estimated by applying the height and 2 diameter measurements 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 represents plant height, and A and B are the diameter readings taken at 50% of plant height with B perpendicular to A (Thorne et al., 2002).

Branching parameters were measured in January of both seasons. Branching was defined as the number of branches per plant. Branch length and number of nodes were determined for five branches per plant.

Flowering parameters:

Five branches per plant were tagged in the first of January 2016 and 2017, and then 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 in April of both seasons.

Yield and seed dry weight:

The yield per plant (g) and seed weight (g) were determined after manual harvesting at full maturity every year in mid of July. Seeds were cleaned, dried and weighed.

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:

The measured data were statistically analyzed by MSTAT-C software and means were differentiated using multiple range test at the 0.05 level (Duncan, 1955).

Results:-

Vegetative growth parameters:-

Plant height (cm):

It is observed, by Table 3 that foliar applications of benzyladenine (BA) in combination with NPK succeeded to induce a remarkable positive effect on plant height of jojoba plants as compared with those produced by control treatment in both seasons. In addition, 150 mg L⁻¹ BA in combination with 5 g L⁻¹ NPK treatment resulted in highest increase of plant height (83.87 % and 149.08 %) more than control treatment in 2016 and 2017 seasons, respectively. While, BA treatments without the use of NPK resulted in the shortest plant in the first and second seasons.

Table 3:-Effect of benzyladenine and NPK foliar sprays and their interactions on plant height, plant circumference and plant canopy volume of S-700 jojoba clone in 2016 and 2017 seasons.

NPK treatments	2016				2017			
	Benzyladenine treatments							
	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean
Plant height (cm)								
Control	38.86 f	31.18 h	34.53 g	34.86 C	55.52 g	46.20 i	49.27 h	50.33 C
3 g L ⁻¹	55.68 e	58.46 d	62.70 c	58.95 B	81.52 f	104.00 d	110.70 c	98.74 B
5 g L ⁻¹	56.18 e	66.36 b	71.45 a	64.66 A	89.04 e	120.70 b	140.80 a	116.85 A
Mean	50.24 C	52.00 B	56.23 A		75.36 C	90.30 B	100.26 A	
Plant circumference (m)								
Control	0.80 i	0.95 h	1.09 f	0.94 C	0.94 i	1.41 h	1.62 g	1.32 C
3 g L ⁻¹	1.03 g	1.27 d	1.39 c	1.23 B	1.83 f	2.22 d	2.58 c	2.21 B
5 g L ⁻¹	1.15 e	1.51 b	1.77 a	1.48 A	1.96 e	2.67 b	2.83 a	2.49 A
Mean	0.99 C	1.24 B	1.42 A		1.58 C	2.10 B	2.34 A	
Plant canopy volume (m3)								
Control	0.020 g	0.020 g	0.033 f	0.024 C	0.038 i	0.071 h	0.099 g	0.069 C
3 g L ⁻¹	0.047 e	0.077 d	0.097 c	0.074 B	0.212 f	0.392 d	0.575 c	0.393 B
5 g L ⁻¹	0.057 e	0.120 b	0.180 a	0.119 A	0.266 e	0.660 b	0.874 a	0.600 A
Mean	0.041 C	0.072 B	0.103 A		0.172 C	0.374 B	0.516 A	

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

Plant circumfluence (m):

Table 3, illustrates that BA and NPK foliar applications, alone or combined, had the highest values of plant circumference of jojoba plants as compared with control treatment in both seasons. Furthermore, 150 mg L⁻¹ BA combined with 5 g L⁻¹ NPK treatment increased plant circumference about (121.25 % and 201.06 %) when compared to control plants in both seasons, respectively. Besides, other treatments had intermediate values in this respect.

Plant canopy volume (m³):

It can be seen in Table 3 that foliar applications of BA and/or in combination with NPK induced the highest positive effect on plant canopy volume of jojoba plants in both seasons. In addition, 150 mg L⁻¹ BA supported with 5 g L⁻¹ NPK treatment record (0.180 and 0.874 m³) against (0.020 and 0.038 m³) for control treatment in both seasons, respectively. However, other treatments had intermediate values in this respect.

Number of branches per plant:

The data in Table 4 indicates that BA alone or in combination with NPK treatments significantly improved number of branches per plant as compared with control in 2016 and 2017 seasons. However, 150 mg L⁻¹ BA combined with 5 g L⁻¹ NPK treatment record (38.83 and 107.10) against (17.97 and 33.17) for control treatment in 2016 and 2017 seasons, respectively. Moreover, other treatments induced intermediate values in this respect.

Branch length (cm):

It is clear from Table 4 that NPK alone or combined with BA foliar applications exerted the highest stimulative effect on branch length as compared with control treatment in both seasons. Furthermore, 5 g L⁻¹ NPK treatment exerted the highest positive effect on branch length in both seasons. While, plants that were just sprayed with benzyladenine treatments had branches shorter than control in both seasons.

Table 4:- Effect of benzyladenine and NPK foliar sprays and their interactions on number of branches per plant, branch length and number of nodes per branch of S-700 jojoba clone in 2016 and 2017 seasons.

NPK treatments	2016				2017			
	Benzyladenine treatments							
	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean
Number of branches/plant								
Control	17.97 h	25.97 f	26.97 e	23.64 C	33.17 i	58.60 g	69.07 e	53.61 C
3 g L ⁻¹	22.36 g	29.20 d	31.30 c	27.62 B	51.97 h	76.97 d	85.63 c	71.52 B
5 g L ⁻¹	23.30 g	34.63 b	38.70 a	32.21 A	62.30 f	92.97 b	107.10 a	87.46 A
Mean	21.21 C	29.93 B	32.32 A		49.15 C	76.18 B	87.27 A	
Branch length (cm)								
Control	13.34 f	12.50 g	12.24 g	12.69 C	14.18 e	13.24 f	12.92 f	13.44 C
3 g L ⁻¹	17.30 c	15.57 e	17.46 c	16.78 B	18.30 c	17.46 d	19.12 b	18.29 B
5 g L ⁻¹	19.17 a	16.69 d	18.51 b	18.12 A	20.50 a	17.57 d	20.08 a	19.38 A
Mean	16.60 A	14.92 C	16.07 B		17.66 A	16.09 B	17.37 A	
Number of nodes/branch								
Control	5.50 d	5.09 e	5.05 e	5.21 C	5.61 f	5.46 fg	5.38 g	5.48 C
3 g L ⁻¹	6.26 b	5.91 c	6.69 a	6.29 B	7.30 d	6.92 e	7.55 c	7.26 B
5 g L ⁻¹	6.82 a	6.25 b	6.76 a	6.61 A	7.98 a	7.01 e	7.77 b	7.59 A
Mean	6.20 A	5.75 B	6.17 A		6.97 A	6.46 B	6.90 A	

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

Number of nodes per branch:

It can be seen in Table 4 that NPK alone or in combination with BA treatments succeeded in improving number of nodes per branch of jojoba plants in both seasons as compared with the control treatment. Generally, 5 g L⁻¹ NPK treatment gave the highest number of nodes per branch (6.61 and 7.59) against (5.21 and 5.48) for the control treatment in both seasons respectively. Whereas, the lowest number of nodes per branch obtained from plants treated with benzyladenine treatments in both seasons.

Flower parameters:**Flowers number:**

The data in Table 5 indicates that foliar applications of NPK alone or combined with BA treatments exerted the highest stimulative effect on number of flowers per branch as compared with control treatment in both seasons, but with 5 g L⁻¹ NPK treatment the effect was more intense. In addition, control treatment resulted in the lowest number of flowers per branch in both seasons.

Table 5:-Effect of benzyladenine and NPK foliar sprays and their interactions on flowers number, flower density and fruit set of S-700 jojoba clone in 2016 and 2017 seasons.

NPK treatments	2016				2017			
	Benzyladenine treatments							
	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean
No. flowers/branch								
Control	2.69 f	3.70 d	3.79 d	3.40 C	2.76 g	3.73 d	3.84 d	3.44 C
3 g L ⁻¹	3.05 e	3.92 c	4.21 b	3.73 B	3.11 f	4.46 c	4.51 c	4.03 B
5 g L ⁻¹	3.16 e	4.44 a	4.51 a	4.04 A	3.24 e	4.75 b	5.05 a	4.35 A
Mean	2.97 C	4.02 B	4.17 A		3.04 C	4.31 B	4.46 A	
Flower density								
Control	0.49 f	0.73 b	0.75 a	0.66 A	0.49 e	0.68 b	0.71 a	0.63 A
3 g L ⁻¹	0.49 e	0.66 c	0.63 d	0.59 B	0.43 f	0.65 c	0.60 d	0.56 B
5 g L ⁻¹	0.46 f	0.71 b	0.66 c	0.61 B	0.41 f	0.68 b	0.65 c	0.58 B
Mean	0.48 B	0.70 A	0.68A		0.44 B	0.67 A	0.65 A	
Fruit set %								
Control	81.90 a	59.46 g	58.91 g	66.76 B	84.15 a	63.20 g	62.17 g	69.84 B
3 g L ⁻¹	72.55 c	63.04 f	66.66 d	67.42 B	78.34 c	67.64 e	70.18 d	72.05 A
5 g L ⁻¹	78.10 b	64.86 e	66.49 de	69.82 A	81.78 b	65.37 f	68.88 de	72.01 A
Mean	77.52 A	62.45 C	64.02 B		81.42 A	65.40 C	67.08 B	

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

Flower density:

It is observed by Table 5 that foliar applications of BA treatments had the highest values of flower density as compared with the control treatment in the first and second seasons of study. Generally, 150 mg L⁻¹ BA treatment gave the highest flower density in both seasons. Whereas, the lowest flower density obtained from plants treated with NPK treatments in both seasons.

Fruit set percentage:

It is clear from Table 5 that foliar application of NPK treatments significantly improved fruit set percentage as compared with control in 2016 and 2017 seasons. Whereas, the highest values of fruit set percentage obtained from untreated plants in both seasons. While, the lowest fruit set percentage resulted from plants treated with BA treatments in both seasons.

Yield parameters and seed wax content:**Seed weight:**

It can be seen in Table 6 that NPK treatments succeeded in improving seeds weight of jojoba plants in both seasons. Generally, 5 g L⁻¹ NPK application without the use of BA gave the highest seeds weight in both seasons. On the other hand, BA treatments showed to be the lowest efficient in this respect.

Yield:

It is observed by Table 6 that foliar spraying of BA and NPK, alone or combined, improved significantly plant yield as compared with control in 2016 and 2017 seasons. However, 150 mg L⁻¹ BA in combination with 5 g L⁻¹ NPK treatment record (72.23 and 260.49 g/plant) against (24.11 and 51.98 g/plant) for control treatment in 2016 and 2017 seasons, respectively. Moreover, other treatments induced an intermediate values in this respect.

Yield (kg per hectare) was estimated based on seed yield per plant and 1111 female plants per hectare (Fig 2). The presented data demonstrates that all tested treatments succeeded in increasing seed yield per hectare of S-700 jojoba clone as compared with the control treatment. Particularly, 150 mg L⁻¹ BA in combination with 5 g L⁻¹ NPK treatment attained the highest seed yield per hectare (80.25 and 289.40 kg/hectare) against (26.79 and 57.75 kg/hectare) for the control treatment in both seasons respectively .

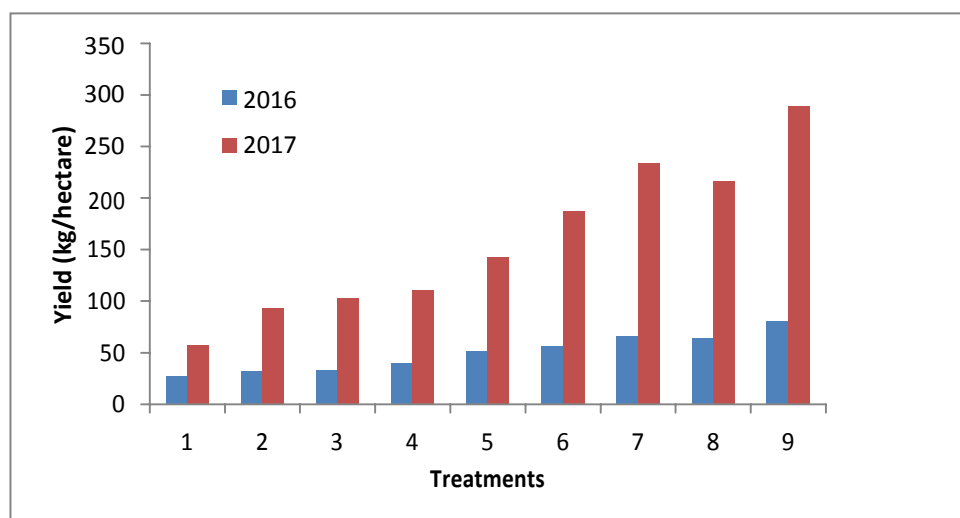
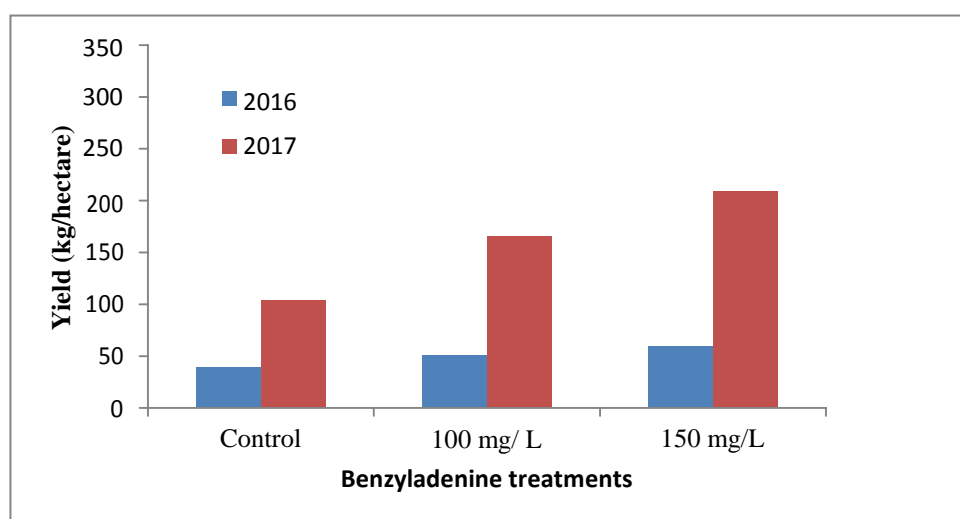
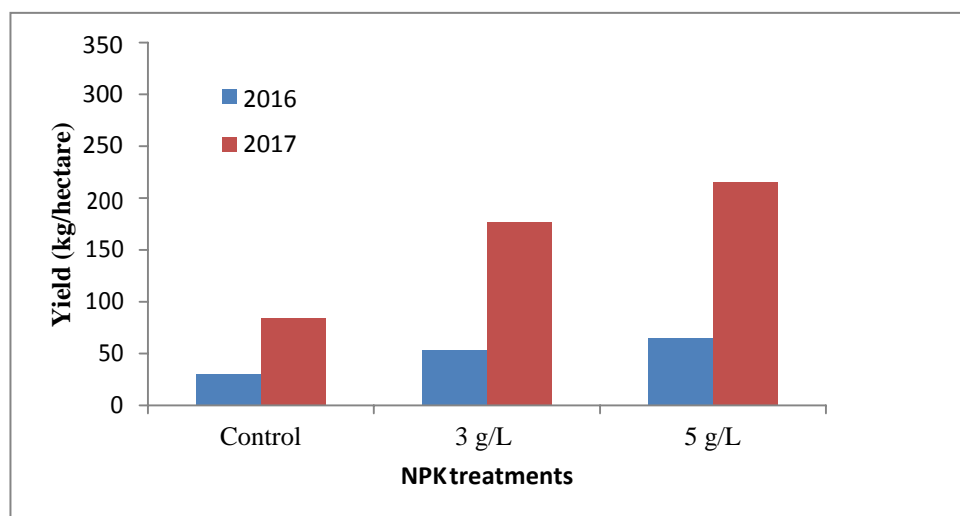


Fig. 2. Effect of benzyladenine and NPK foliar sprays and their interactions on hectare productivity of S-700 jojoba clone seed in 2016 and 2017 seasons.

Table 6:-Effect of benzyladenine and NPK foliar sprays and their interactions on yield, seed weight and seed wax content of S-700 jojoba clone in 2016 and 2017 seasons.

NPK treatments	2016				2017			
	Benzyladenine treatments							
	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean	Control	100 mg L ⁻¹	150 mg L ⁻¹	Mean
Yield (g)								
Control	24.11 g	28.37 f	30.06 f	27.51 C	51.98 i	83.91 h	92.56 g	76.15 C
3 g L ⁻¹	35.67 e	50.56 c	59.07 b	48.43 B	99.83 f	168.81 d	210.32 b	159.66 B
5 g L ⁻¹	46.31 d	57.67 b	72.23 a	58.74 A	128.00 e	194.21 c	260.49 a	194.23 A
Mean	35.36 C	45.53 B	53.79 A		93.27 C	148.98 B	187.79 A	
Seed weight (g)								
Control	0.630 de	0.620 ef	0.614 f	0.621 B	0.695 d	0.677 e	0.658 f	0.677 B
3 g L ⁻¹	0.651 c	0.642 cd	0.669 b	0.654 A	0.729 c	0.730 c	0.751 ab	0.737 A
5 g L ⁻¹	0.706 a	0.638 cd	0.640 cd	0.661 A	0.763 a	0.699 de	0.734bc	0.732 A
Mean	0.662 A	0.633 C	0.641 B		0.729 A	0.702 C	0.714 B	
Seed wax content (%)								
Control	49.54 a	48.25 b	48.60 b	48.80 A	52.59 a	52.48 a	51.91 ab	52.33 A
3 g L ⁻¹	48.48 b	46.92 c	46.95 c	47.45 B	52.59 a	50.77 b	52.80 a	52.05 A
5 g L ⁻¹	49.47 a	46.53 c	45.64 d	47.21 B	52.46 a	51.84 ab	50.85 b	51.72 A
Mean	49.16 A	47.23 B	47.06 B		52.55 A	51.70 B	51.85 B	

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

Seed wax content:

It is clear from Table 6 that foliar spraying of BA and NPK, alone or combined, had no positive effect on seed wax content of S-700 jojoba clone as compared with control treatment in both seasons of study. Generally, untreated plants produced the highest seed wax percentage in both seasons. On the contrary, 150 mg L⁻¹ BA supported with 5 g L⁻¹ NPK treatment showed to be the lowest efficient in this respect.

Discussion:-

Vegetative growth parameters :

S-700 jojoba clone plants can be influenced to grow with a more compact habit. This habit is a result of changes in the frequency of branching by using benzyladenine and NPK foliar sprays. The enhancement effect of benzyladenine foliar spray to stimulate vegetative growth may be attributed to its effect on counteracting or disrupting the apical dominance. Apical dominance is the dynamic mechanism of inhibition of lateral buds exerted by the rising terminal bud (Elfving and Cline, 1993; Dal Cin et al., 2007).

These observations are in accordance with those obtained by Elfving (1985), Jaumien et al. (2002) and Elfving and Visser (2006) they found that benzyladenine applications had more significant effect on the number of lateral vegetative growth of sweet cherry plants in nursery and used to break apical dominance and promote the growth of lateral shoots on apple trees. Also, benzyladenine has been used to stimulate branching in young fruit trees (Carswell et al., 1996). Moreover, 6-benzyladenine a synthetic cytokinin, can induce lateral branches in a vary of ornamental plant species (Keever and Foster, 1990).

In young plantations, the treatments should be applied in the spring (perfectly after erupting of terminal buds of elongated shoots) producing proleptic shoot formation and disrupt acrotony. Generally, 100 to 200 mg L⁻¹ (in young plantations) of benzyladenine is applied by consecutive spraying 3 to 4 times (Elfving 1985). On the other hand, application of benzyladenine induced bud break, increasing the number of growing shoots but inhibited their elongation. In addition, jojoba plants treated with benzyladenine were short, compact and dense (Ravetta, 1990).

Fertilization had a major effect on jojoba shrubs growth. Such large effect of foliar Kristalon may be due to its content of N, P, K and microelements. But since we sprayed fertilizer as a mixture of NPK, it is not possible to identify their separate results. S-700 jojoba clone showed the most clearly and immediate positive response to fertilization and this is consistent with that reported by Soad (2005). Chapin and Shaver (1985) indicated that NPK fertilization promoted significantly the growth of evergreen dwarf shrubs and produced greater basal area increment than untreated shrubs. Moreover, Khattab (2016) on Gladioli corms showed that NPK resulted in a significant increase in plant height, number of shoots per plant and shoot length, similar results were achieved by Abd El-Latif (1984) on coriander plants, Bishr and Makarim (1988) on guar plants.

Flower parameters:

The obtained results regarding the effect of benzyladenine (BA) and/or NPK fertilizer foliar sprays on flowering go in line with the finding of Ohkawa (1979), Ravetta and Palzkill (1992) and Prat et al. (2008) on jojoba plants. S-700 clone bears one flower bud on every second node, the flower density being 0.5 (Bakeer et al., 2017). Benzyladenine foliar application on clone S-700 led to a significant increase in flowers per branch. The significant increase in the number of flowers per branch resulted by benzyladenine application may be attributed to the cytokinin action on the axillary meristems, reverberated in magnification of the axillary meristematic area, producing an increase in total number of flowers and individual flowers per branch (Prat et al., 2008). Such great effect of BA on *Nicotiana tabacum* meristems was reported by Werner et al. (2001), who observed that cytokinins had a significant regulative effect on flower meristem morphogenesis, expanding the meristem, which resulted in a greater probability for the growth of flower meristems. Furthermore, the increase in flower buds production was correlated with an increase in the number of branches and nodes per branch. Also, flowers on long branches were larger than those on short ones (Ravetta, 1990). On the other hand, an increase in the flowers number per plant resulted in reduction in fruit set percentage. This fact can be explained in terms of competition, thus when flowering intensity is greater, metabolite demand and weight gaining is increase by the flowers (Prat et al., 2008).

Furthermore, improved mineral nutrition by using foliar spray is often considered a flower-inducing treatment. Fertilization of tuberose with NPK (20:20:20) advanced flowering and improved growth (Bankar and Mukhopadhyay, 1990). Qasim et al. (2008) reported that NPK application enhanced various growth indices and increased the number of flowers per plant and per square meter of *Rosa hybrida* L.

Yield parameters and seed wax content:

The results of this study indicate that benzyladenine and NPK foliar sprays can be used to significantly increase yield of S-700 jojoba clone in the early years of growth. These observations are consistent with those findings by Panayotov et al. (2005) on yield of pepper, Burke (2011) on cotton and AbouRayya et al. (2015) on Manzanillo olive. The increase in seed yield production was appeared to be associated to increase in the number of growing shoots (Benzioni, 1995). Thus, it is considered one of the major factor limiting yields in jojoba plants. In young fruit trees, ornamental plants and cereals, increase of lateral branches has been shown to enhance yield production (Erez, 1987).

Various kinds of research reported a positive effect of macronutrient use in the increase of plants yield (Tavassoli et al., 2010). In addition, several methods had been conducted in order to increase persimmon fruit yield by spray the trees with nutrients (Eliwa et al., 2003). Nitrogen, phosphorous, potassium and calcium are the major nutrients necessary for fruit growth and quality (Rizzi and Abruzzese, 1990). Benzioni et al. (1982) found that fertilization jojoba plants with NPK (20-20-20) three times a year resulted in an increment of 65% higher seed yield than those of untreated plants.

Conclusion:-

Benzyladenine and NPK (19:19:19) foliar sprays significantly increased branching, flower bud production and seed yield on S-700 jojoba clone. This could mean an important reduction in the lag period of growth of young plants. Clones treated with 150 mg L⁻¹ BA plus 5 g L⁻¹ NPK showed the greatest increases in these respects, this being the recommended treatment.

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