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Planting of jojoba for oil production under salt and water stress in Taif region

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Abstract: This study was conducted at Biology Department, Faculty of Science, Taif University, Saudi Arabia to investigate the effect of irrigation intervals (15, 21, 30 or 45 days) and different salinity concentrations (0 control tap water), 8.6, 12.9, 17.2, 25.9, 34.5, 51.7, 86.2, 103.4 and 120.7 mM NaCl) on shoot growth, root parameters, leaf measurements and leaf chemical constituents of jojoba (*Simmondsia chinensis* (Link) Schneider). A pot experiment was conducted and arranged in a complete randomized block design (split-plot) with three replicates. The results indicated that irrigation treatment every fifteen days, in general, was more effective on increasing plant height, number of both leaves and branches on the stem, as well as, the number of nodes on the stem, followed by irrigation every three weeks compared to other irrigation intervals. Similar trend has been observed for the leaf measurements (length, width, area and stomatal density). The root parameters followed the same trend of shoot growth. Leaf chlorophyll content, carbohydrates, protein and elements measured were increased with frequent irrigation. On the other hand, salinity treatments significantly decreased the most of the previous characteristics. Meanwhile, sodium, chloride and carbohydrates were gradually increased with increasing the concentration of salinity especially, with higher levels. Regarding the interaction between irrigation intervals and salinity concentrations, higher values were recorded with irrigation every two or three weeks interacted without or with lower salinity levels (8.6 or 12.9 or 17.2 mM).

Key words: Irrigation - Salinity - Jojoba – Chlorophyll – Stomata - Carbohydrates.

INTRODUCTION

Jojoba (*Simmondsia chinensis* (Link) Schneider) is a relatively new crop that is adapted to hot, dry climates. It is a new industrial crop being grown commercially in hot arid and semiarid regions. *Simmondsia chinensis* (Link) Schneider is a perennial evergreen shrub. It is dioeciously, with male and female flowers present in separate plants. Jojoba has become an attractive alternative crop because of the promising commercial applications for its seed oil in cosmetics. Many countries are looking toward developing jojoba culture to solve overproduction and low price for their food and other traditional crops (Ayerza, 1996). Ceron and Delatorre (1984) and Botti *et al*. (1998) indicated that jojoba plantations now have a better chance for economic and agricultural success. Jojoba is an extremely drought resistant species and is gaining world wide attention, for extraction of oil which is used in pharmaceuticals and lubricant industries as a replacement of sperm whale oil. In recent years, renewed interest in commercial cultivation of jojoba has begun as the useful properties of the liquid wax obtained from the seed have been confirmed (Wisniak,1987 and Brown *et al.*, 1996).

Irrigation is very important factor affecting the growth and yield of medicinal and aromatic plants. Irrigation also may affect the volatile oil composition. From the other point of view, water scarcity is a growing global problem that challenges sustainable development and expansion of cultivated area to meet increasing food requirements. Water is characterized as such no alternative source can substitute it and it is not a commercial resource or commodity. Based on this fact, the great challenge for the coming decades will be the task of increasing the productivity of water unit (Abdin and Salem, 2009). Oster *et al*. (2007) reported that different amounts of applied water had little or no impact on the average root zone salinity; also, they did not result in Cl levels in the leaves that are associated with leaf injury. They added that differences in yields were the result of the differences in applied water because the soil-water salinity was also limiting yields. Yields increased with increasing applied water because trees evapotranspired more water before the EC reached a level that restricted water uptake.

Salinization threatens the productivity of agricultural land (Mckee *et al.*, 2004) and agricultural sustainability (Waisel, 2001). Salinity is a major problem that negatively affects agricultural activities in many regions in the world, especially the Near East and North Africa region. Generally, salinity problems increase with increasing salt concentration in irrigation water. Crop growth reduction due to salinity is generally related to the osmotic potential of the root zone soil solution (Abou-Hadid, 2003).Water used for irrigation can vary greatly in quality depending on type and quantity of dissolved salts. Almost 50% of the irrigated land is affected

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by high salinity (Zhu, 2001), often resulting in secondary salinization due to inappropriate use of saline irrigation water. Despite the essentiality of chloride as a micronutrient for all higher plants and of sodium as mineral nutrient for many halophytes and some species, salt accumulation may convert agricultural areas in unfavorable environments, reduce local biodiversity, limit growth and reproduction of plants, and may lead to toxicity in non salt-tolerant plants, known as glycophytes (Ashraf and Harris, 2004, and Parida and Das, 2005). The effects of salinity are generally summarized as water stress, salt stress and stress due to ionic imbalance (Greenway and Munns, 1980). Therefore at least one part of salt stress is associated with water stress, which is a general condition, and it can be expected that plant adaptation to salinity may show features similar to those characteristic of adaptation to water stress.

It believed to be future arid plant, in general, jojoba developed reasonably well under salinities of 8 dSm^{-1} (Benzioni *et al*., 1990). Thomson (1982) investigated that jojoba tolerated 4 dSm^{-1} salts in the irrigation water. Salinity and drought are considered to be the most serious growth-limiting factors for crop plants (Boyer, 1982, and Vinocur and Altman, 2005). Increasing salinity of irrigation water has contributed to progressive salinization of agricultural soils inhibiting agricultural productivity in many semi-arid and arid regions of the world (Qadir *et al*., 2000). Sodium chloride (NaCl) is the most commonly encountered source of salinity (Li *et al*., 2006). Exposure of plants to extreme conditions such as high salinity causes a diverse set of physiological, morphological and developmental changes (Jensen *et al*., 1996). Much of the strain in salinity stress is related to water stress arising from excessive uptake of salts by the plants and the resulting reduction in water potential.

For this crop to be an economically profitable alternative for arid and semi-arid zones, it is necessary to first select plants of high productivity that also possess sufficient resistance to abiotic stresses (water deficit and salinity). Salinity and drought are considered to be the most serious growth-limiting factors for crop plants (Boyer, 1982 and Vinocur and Altman, 2005). In spite of information showing that jojoba tolerates fairly high levels of salinity (Benzioni *et al.*,1996) and water stress (Foster and Wright, 1980), the selections to date have not been intended for use in regions with extremely high levels of salinity and water stress (Botti *et al*., 1998b). Therefore, the aim of this study was to paper evaluate the effect of irrigation intervals and salinity concentrations and their combinations on shoot and root growth, leaf measurements and chemical constituents of jojoba leaves.

MATERIALS AND METHODS

This study was carried out at Biology Department - Faculty of Science - Taif University - Saudi Arabia at the seasons of 1433 and 1434. The experimental design was arranged in a complete randomized block (split-plot) with three replicates. The main plot comprehends the irrigation frequency (15, 21, 30 or 45 days). Each main plot was divided into ten sub-plots represented salinity treatments (500, 750, 1000, 1500, 2000, 3000, 5000, 6000, 7000 ppm NaCl), besides control (tap water). These salinity concentrations 8.6, 12.9, 17.2, 25.9, 34.5, 51.7, 86.2, 103.4 and 120.7 mM NaCl. Each plot comprised four pots. To balance the evaporative losses, and also to maintain plants at the required levels of salts, they were watered every alternative day (Rawat and Banerjee, 1998). The measurements of shoot and roots were taken.

The study was conducted in order to study the effect of irrigation intervals and different salinity treatments on vegetative growth (plant height, number of branches, number of leaves, number of nodes on the stem of each plant, stem diameter, fresh and dry weight of the branches, fresh and dry weight of roots, root length, leaf measurements; its length, with, area and stomatal density) as well as the leaf chemical constituents (leaf chlorophyll, total carbohydrates, protein and elemental content i.e. nitrogen, phosphorus, potassium, sodium, chloride and calcium) of jojoba leaves. Seeds of jojoba were sown directly into plastic pots (30 x 20 cm). Each pot included four seeds. The physical and chemical characteristics of the soil used in this study were shown in **Table (A).**

The shoot characters taken in this experiment were plant height (cm), number of main branches/plant, stem diameter (cm), shoot weight (fresh & dry) and number of nodes/stem. The root measurements were root weight (fresh & dry) and root diameter (cm). Data recorded concerning leaf were number of leaves/plant, leaf width, length (cm) and its area (cm^2) and stomatal density (number/mm^2).

Leaf area:

Blade area was measured using digital image analysis according to the method of Matthew *et al*. (2002). Digital image of the leaf blade was created in digital format using a Hewlett- Packard scanner (Hewlett Packard, Cupertino, ca), image was scanned at dot per inch (100 dpi), the blade area was measured using public domain software (scion image version 4.02).

Stomatal Density Measurement:

Stomatal density (number/mm^2) was measured according to the method as described by (Botti *et al*., 1998 a).

Table A: Physical and chemical properties of used soil

Particle size distribution (%)				pH	E.C. dSm^{-1}
Sand	Silt	Clay	Texture grade		
82.40	7.10	10.50	Sandy	8.37	3.68

Total $CaCO_3$ (%)	Organic matter (%)	Soluble ions (meq/l.) [soil paste]						Total N (%)	Total P (%)	Total K (%)
		Anions				Cations				
		Cl^-	$CO_3^=$	HCO_3^-	$SO_4^=$	Ca^{++}	Na^+			
0.98	0.11	0.67	-	2.33	47.55	44.75	3.67	0.17	0.036	0.043

Chemical Constituents:

Chlorophyll Content:

Randomly samples of fresh leaves were taken by the end of October from the middle part of stem for chlorophyll determination. Chlorophyll content was determined according to Sadasivam and Manickam (1992) by using spectrophotometer (Pharmacia, LKB-Novaspec II) at wave length of 663 nm for chlorophyll (a), 644 nm for chlorophyll (b). Total chlorophyll fractions calculated as mg/gm fresh weight of leaves.

Total Carbohydrates:

Total carbohydrates percentages were determined in leaf samples taken by the same way and in the meantime of chlorophyll samples. The leaf samples were dried in an electric oven at 70 °C for 24 hours according to A.O.A.C. (1995). Then, the fine powder used to determine total carbohydrates percentage in leaves. Total carbohydrates including polysaccharides in leaves of jojoba were calorimetrically determined with the anthrone sulphuric acid method according to El-Enany (1986).

Leaf Mineral Content:

Nitrogen, phosphorus, potassium, calcium, sodium and chloride were determined in dried leaf samples, digested using sulphuric and perchloric acids method as mentioned by Piper (1967), according to the methods described by Black *et al.* (1965), (Chapman and Pratt, 1961), Jackson (1973) and Johnson and Ulrich (1959). Protein percentage in leaves calculated by using the conversion factor of 6.25 based on the assumption that the protein contains 16 % nitrogen according to Ranganna (1978). Data were subjected to statistical analysis using "F" test according to Snedecor and Cochran (1973) and least significant difference (L.S.D.) values at 0.05 and 0.01 were used for comparison between means according to Gomez and Gomez (1984).

Results:

3.1. Shoot Growth Characteristics:

Data presented in **Tables (1, 2 and 3)** clearly show that jojoba shoot growth was affected by different salinity and irrigation treatments. The plant height, branch number/plant, shoot weight (fresh & dry), number of nodes/plant and stem diameter were gradually decreased with increasing irrigation intervals and reached its minimum values by applying irrigation every 45 days. In the same direction increasing salinity concentration led to decrease the previously mentioned characters since the lowest values in this respect were obtained by the maximum dose (120.7 mM) of salinity. However, the control plants recorded the highest values of shoot growth in comparison with any salinity level. The statistical analysis of results indicated that the differences between the treatments were significant, in most cases.

Concerning the interaction between salinity and irrigation treatments, it could be noticed that the control plants which irrigated every 15 days resulted in the maximum growth of jojoba plants while applying the highest dose of salinity combined with irrigation at 45 days resulted in the lowest values in this concern. Otherwise, in some cases, in the control treatment which receive no salt, there were no significant differences between irrigation every 15 or 21 days treatment.

Tabl 1: Plant height and branch number of jojoba plants as affected by salinity and irrigation frequency treatments.

Treatments	Plant height (cm)					Branch number/plant				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	40.32	37.34	36.67	36.00	37.58	3.00	3.31	2.35	2.33	2.75
8.6 mM	37.34	36.31	35.00	34.33	35.75	3.00	2.33	2.33	2.67	2.58
12.9 mM	37.67	35.34	35.68	32.67	35.34	2.67	2.67	2.33	2.33	2.50
17.2 mM	36.00	34.32	33.34	33.67	34.33	2.33	2.00	1.67	2.33	2.08
25.9 mM	33.67	33.00	33.00	32.00	32.92	2.00	2.00	1.67	1.67	1.84
34.5 mM	32.33	32.33	31.00	30.67	31.58	2.00	1.33	1.33	2.00	1.67
51.7 mM	30.67	26.33	26.00	24.00	26.75	1.67	2.00	1.67	1.00	1.59
86.2 mM	25.67	23.67	24.00	23.31	24.17	2.00	1.67	1.33	1.00	1.50
103.4 mM	26.67	23.00	21.31	19.67	22.67	1.33	1.33	1.00	1.00	1.17
120.7 mM	22.33	19.67	20.68	18.66	20.34	1.00	1.00	1.00	1.00	1.00
Mean	32.27	30.13	29.67	28.50		2.10	1.96	1.67	1.73	
LSD	0.05		0.01			0.05		0.01		
Irrigation	1.30		1.73			0.38		0.57		
salinity	0.87		1.32			0.36		0.48		
Interaction	NS		NS			NS		NS		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Table 2: Number of nodes/plant and stem diameter of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Number of nodes/plant					Stem diameter (cm)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	15.33	14.00	14.33	13.67	14.33	0.63	0.63	0.57	0.60	0.61
8.6 mM	14.33	13.67	13.67	13.00	13.67	0.63	0.57	0.57	0.50	0.57
12.9 mM	13.67	12.67	12.33	11.67	12.59	0.57	0.50	0.57	0.47	0.53
17.2 mM	12.67	11.33	11.33	10.33	11.42	0.53	0.50	0.43	0.43	0.47
25.9 mM	11.67	11.00	10.00	10.00	10.67	0.53	0.47	0.47	0.47	0.49
34.5 mM	10.67	9.67	9.67	8.67	9.67	0.50	0.43	0.43	0.40	0.44
51.7 mM	8.33	7.67	7.33	7.33	7.67	0.47	0.40	0.37	0.37	0.40
86.2 mM	6.67	6.00	5.67	5.33	5.92	0.37	0.33	0.37	0.40	0.37
103.4 mM	5.33	4.67	4.67	4.67	4.84	0.40	0.33	0.33	0.27	0.33
120.7 mM	3.33	4.00	3.67	3.00	3.50	0.37	0.30	0.27	0.33	0.32
Mean	10.89	10.02	9.83	9.34		0.50	0.45	0.44	0.42	
LSD	0.05		0.01			0.05		0.01		
Irrigation	0.38		0.51			0.04		0.05		
salinity	0.29		0.44			0.03		0.05		
Interaction	0.76		1.01			NS		NS		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Table 3: Shoot weight (fresh &dry) of jojoba as affected by salinity and irrigation frequency treatment

Treatments	Shoot fresh weight (g)					Shoot dry weight (g)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	14.81	13.95	13.95	13.59	14.08	3.72	3.51	3.50	3.42	3.54
8.6 mM	14.59	13.85	13.48	13.40	13.83	3.65	3.47	3.39	3.38	3.47
12.9 mM	14.00	12.99	12.95	13.06	13.25	3.52	3.26	3.21	3.24	3.31
17.2 mM	13.70	12.97	12.35	12.33	12.84	3.43	3.25	3.11	3.10	3.22
25.9 mM	13.26	12.19	11.80	11.59	12.21	3.32	3.05	2.98	2.90	3.06
34.5 mM	13.07	11.78	11.22	10.65	11.68	3.28	2.96	2.82	2.72	2.95
51.7 mM	11.11	9.81	9.28	8.93	9.78	2.77	2.48	2.32	2.24	2.45
86.2 mM	9.92	8.07	7.47	6.81	8.07	2.50	2.07	1.86	1.70	2.03
103.4 mM	7.73	6.47	6.40	5.80	6.60	1.94	1.64	1.58	1.44	1.65
120.7 mM	5.92	5.18	4.48	4.65	5.06	1.49	1.31	1.11	1.13	1.26
Mean	11.81	10.73	10.34	10.08		2.96	2.70	2.59	2.53	
LSD	0.05		0.01			0.05		0.01		
Irrigation	0.30		0.45			0.08		0.12		
salinity	0.24		0.32			0.06		0.08		
Interaction	0.48		0.64			0.12		0.16		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.2. Root Growth Parameters:

The averages of jojoba root growth parameters as influenced by irrigation frequency and salinity levels are listed in **Tables (4, 5 and 6)**. The obtained data revealed that the highest weights (fresh & dry) of root/plant and root diameter were obtained from plants grown under 15 days followed by 21 days. Mostly, those grown under 30 or 45 days produced the lightest weights and thinnest roots.

Table 4: Root weight (fresh &dry) of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Root fresh weight (g)					Root dry weight (g)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	3.28	3.24	3.36	3.21	3.27	0.93	0.91	0.94	0.90	0.92
8.6 mM	3.22	3.25	3.27	3.11	3.21	0.92	0.93	0.92	0.90	0.92
12.9 mM	3.17	3.09	3.15	3.03	3.11	0.90	0.87	0.89	0.85	0.88
17.2 mM	3.04	3.02	2.94	2.87	2.97	0.86	0.86	0.82	0.79	0.83
25.9 mM	3.00	2.98	2.93	2.81	2.93	0.86	0.84	0.83	0.77	0.83
34.5 mM	2.95	2.84	2.89	2.63	2.83	0.81	0.78	0.78	0.72	0.77
51.7 mM	2.74	2.63	2.62	2.35	2.59	0.77	0.74	0.73	0.64	0.72
86.2 mM	2.82	2.73	2.74	2.59	2.72	0.79	0.78	0.76	0.72	0.76
103.4 mM	2.33	2.03	2.02	1.87	2.06	0.62	0.69	0.56	0.48	0.59
120.7 mM	2.07	1.93	1.82	1.80	1.91	0.56	0.53	0.48	0.44	0.50
Mean	2.43	2.27	2.42	2.20		0.67	0.64	0.66	0.70	
LSD	0.05		0.01			0.05		0.01		
Irrigation	0.07		0.10			0.04		0.05		
salinity	0.05		0.08			0.03		0.05		
Interaction	0.14		0.19			0.08		0.11		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

The differences between the effects of irrigation every 15 days and 45 days on fresh and dry weights of roots and root diameter were highly significant. It is also clear from the obtained data that applying salinity levels resulted in a highly significant reduction in fresh and dry weight of roots as well as root diameter compared to the control. The interaction effect between irrigation intervals and the salinity levels on root weight (fresh & dry)/plant was significant.

Table 5: Shoot/root ratio (fresh & dry) of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Shoot/root ratio (fresh)					Shoot/root ratio (dry)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	4.52	4.30	4.15	4.23	4.30	4.01	3.84	3.72	3.79	3.84
control	4.54	4.25	4.12	4.31	4.31	3.98	3.74	3.68	3.76	3.79
8.6 mM	4.41	4.20	4.11	4.31	4.26	3.90	3.73	3.62	3.80	3.76
12.9 mM	4.51	4.29	4.20	4.30	4.33	3.99	3.79	3.79	3.93	3.88
17.2 mM	4.42	4.07	4.01	4.12	4.16	3.85	3.63	3.57	3.77	3.71
25.9 mM	4.43	4.15	3.85	4.09	4.13	4.07	3.82	3.64	3.78	3.83
34.5 mM	4.11	3.70	3.49	3.80	3.78	3.65	3.32	3.14	3.49	3.40
51.7 mM	4.12	3.48	2.99	3.07	3.42	3.81	3.17	2.75	2.57	3.08
86.2 mM	3.33	3.10	3.07	3.05	3.14	3.15	2.33	2.76	2.93	2.79
103.4 mM	2.89	2.62	2.46	2.56	2.63	2.73	2.42	2.33	2.55	2.51
Mean	4.13	3.82	3.65	3.78		3.71	3.38	3.30	3.44	
LSD	0.05		0.01			0.05		0.01		
Irrigation	0.17		0.23			0.14		0.19		
salinity	0.15		0.23			0.11		0.16		
Interaction	0.34		0.46			0.28		0.37		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

The heaviest roots were obtained by plants irrigated every 30 days combined with control treatment. However, there were no significant differences between the interactions treatments concerning root diameter. The shoot/root ratio (fresh & dry) was significantly increased as a result of applying irrigation every 15 days in comparison with the other irrigation treatments. However, the differences among irrigation every 21, 30 and 45 days were insignificant. The shoot/root ratio (fresh & dry) were (4.13 and 3.71), (3.82 and 3.38), (3.65 and 3.30) and (3.78 and 3.44) for the treatments of 15, 21, 30 and 45 days, respectively (Table, 5).

Increasing salinity concentration caused a significant decreased in shoot/root ratio (fresh & dry) and this reduction was gradually with increasing the salt levels. Shoot/root ratio (fresh & dry) was 4.30 and 3.84 with control, while it was 2.63 and 2.51 for salinity at 120.7 mM, respectively. The highest salinity level combined with irrigation every 30 or 45 days resulted in the lowest values of shoot/root ratio (fresh & dry). On the other hand, frequent irrigation without salinity or with the lowest salinity level recorded the highest in this respect (**Table, 5**).

3.3. Leaf Measurement:

3.3.1. Leaf Length, Width And Area:

The leaf length, width and its area were significantly promoted by using different irrigation intervals. The previous parameters were decreased with increasing irrigation intervals. The largest leaf area (3.58 cm^2) was obtained by irrigation every 15 days and there were no significant differences between this treatment and irrigation every 21 days one in this concern **(Tables, 7 and 8)**. The increase of the salinity concentration, the decrease of leaf measurements was occurred. The shortest leaf length (2.43 cm) was recorded by 120.7 mM treatment, also the previous treatment recorded the narrowest leaves (0.68 cm) and the smallest leaf area (1.54 cm^2) compared to the untreated control. The interaction effect of salinity and irrigation treatments was not significant in this respect, the plants which received no water salinity and irrigated every 15 or 21 days resulted in the highest values of leaf characteristics.

Table 6: Root diameter of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Root diameter (cm)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	0.60	0.43	0.57	0.43	0.51
8.6 mM	0.50	0.43	0.43	0.40	0.44
12.9 mM	0.53	0.40	0.47	0.43	0.46
17.2 mM	0.47	0.37	0.43	0.33	0.40
25.9 mM	0.43	0.33	0.37	0.33	0.37
34.5 mM	0.37	0.27	0.37	0.33	0.34
51.7 mM	0.37	0.23	0.33	0.23	0.29
86.2 mM	0.33	0.23	0.27	0.27	0.28
103.4 mM	0.23	0.17	0.13	0.20	0.18
120.7 mM	0.17	0.10	0.13	0.13	0.13
Mean	0.40	0.30	0.35	0.31	
LSD	0.05		0.01		
Irrigation	NS		NS		
salinity	0.05		0.06		
Interaction	NS		NS		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.3.2. Stomata Density (no/mm^2):

It was observed from data in **Table (8)** that, there was insignificant effect of irrigation intervals on stomatal density of jojoba leaves. On the other hand, salinity concentration showed reversed trend. Mostly, salinity levels significantly decreased stomatal density of jojoba leaves compared with control. Stomatal density decreased gradually with increasing salinity concentrations, the lowest stomatal density (72.08 and 71.67 mm^2) were obtained by 103.4 and 120.7 mM. Whereas, the control plants recorded (81.25 mm^2). Otherwise, there were no significant differences regarding the interaction effects between irrigation intervals and salinity concentrations in this respect (Table, 8).

Table 7: Leaf length and width of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Leaf length (cm)					Leaf width (cm)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	3.54	3.64	3.53	3.51	3.56	1.32	1.28	1.26	1.26	1.28
8.6 mM	3.55	3.52	3.52	3.50	3.52	1.29	1.25	1.25	1.22	1.25
12.9 mM	3.48	3.55	3.47	3.45	3.49	1.26	1.22	1.21	1.18	1.22
17.2 mM	3.40	3.53	3.35	3.33	3.40	1.25	1.21	1.15	1.14	1.19
25.9 mM	3.40	3.44	3.28	2.94	3.27	1.23	1.16	1.13	1.11	1.16
34.5 mM	3.33	3.37	3.17	3.11	3.24	1.20	1.11	1.08	1.04	1.11
51.7 mM	3.24	3.21	2.96	3.04	3.11	1.11	1.03	0.97	0.95	1.02
86.2 mM	3.06	2.96	2.70	2.77	2.87	0.94	0.89	0.82	0.81	0.87
103.4 mM	2.83	2.75	2.46	2.51	2.64	0.82	0.79	0.71	0.75	0.77
120.7 mM	2.53	2.45	2.39	2.36	2.43	0.71	0.68	0.67	0.66	0.68
Mean	3.23	3.24	3.08	3.05		1.11	1.06	1.03	1.01	
LSD	0.05		0.01			0.05		0.01		
Irrigation	0.09		0.12			0.09		0.12		
salinity	0.07		0.11			0.06		0.08		
Interaction	0.19		0.25			NS		NS		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.3.3. Leaf number/plant:

Data concerning the leaf number as affected by different salinity and irrigation treatments were tabulated in **Table (9)**. The results clearly indicate that the leaf number was significantly decreased with increasing irrigation intervals from 15 to 45 days. The same trend was recorded with increasing the salinity concentrations from 8.6 to 120.7 mM since the control plants resulted in the highest leaf number (28.42) compared to (6.50) for 120.7 mM treatment. The statistical analysis of results showed a highly significant difference among the interaction values of salinity and irrigation treatments. The interaction treatment of irrigation every 15 days without salinity recorded the highest leaf number (30.33)/plant. However, the lowest leaf number (6.00) was obtained by interaction treatment of irrigation at 45 days and 120.7 mM salinity **(Table, 9)**

Table 8: Leaf area and stomata density of jojoba plants as affected by salinity and irrigation frequency treatments

Treatments	Leaf area (cm^2)					Stomatal density (no./mm^2)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	4.52	4.58	4.36	4.30	4.44	81.33	81.00	81.67	81.00	81.25
8.6 mM	4.52	4.24	4.30	4.14	4.30	79.33	81.33	80.67	80.67	80.50
12.9 mM	4.31	4.23	4.13	3.91	4.15	79.00	79.67	80.00	80.67	79.83
17.2 mM	4.12	4.17	3.84	3.73	3.97	76.67	79.00	78.67	79.67	78.50
25.9 mM	4.14	3.98	3.61	3.19	3.73	75.67	77.67	77.67	79.33	77.58
34.5 mM	3.94	3.61	3.37	3.17	3.52	74.00	75.67	76.33	76.33	75.58
51.7 mM	3.49	3.26	3.24	2.80	3.20	73.00	74.33	75.00	74.33	74.17
86.2 mM	2.83	2.52	2.19	2.11	2.41	72.67	71.33	73.67	73.00	72.67
103.4 mM	2.26	2.13	1.69	1.70	1.95	71.67	71.33	73.33	72.00	72.08
120.7 mM	1.64	1.58	1.51	1.45	1.54	71.67	71.00	72.33	71.67	71.67
Mean	3.58	3.43	3.22	3.05		75.50	76.23	76.93	76.87	
LSD		0.05		0.01			0.05		0.01	
Irrigation		1.14		1.51			NS	NS		
salinity		0.92		1.40			0.66	0.89		
Interaction		NS		NS			1.33	1.33		

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Table 9: Leaf number/plant of jojoba as affected by salinity and irrigation frequency treatments

Treatments	Leaf number/plant				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	30.33	28.00	27.63	27.61	28.42
8.6 mM	28.67	26.71	26.62	25.68	26.92
12.9 mM	27.00	24.67	24.31	23.35	24.83
17.2 mM	24.58	21.76	22.00	20.33	22.17
25.9 mM	23.00	21.67	20.00	19.67	21.09
34.5 mM	21.00	19.00	18.33	17.00	18.83
51.7 mM	16.33	15.00	14.33	14.00	14.92
86.2 mM	12.67	11.67	10.67	10.67	11.42
103.4 mM	10.00	9.00	8.33	8.33	8.92
120.7 mM	6.33	7.00	6.67	6.00	6.50
Mean	19.99	18.45	17.89	17.26	
LSD		0.05		0.01	
Irrigation		0.59		0.79	
salinity		0.31		0.46	
Interaction		1.18		1.57	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.4. Chemical Constituents:

3.4.1. Elements Content:

The chemical analysis based on dry weight of jojoba leaves as affected by irrigation frequency and salinity concentrations are tabulated in **Tables (10 and 11)**. The obtained results indicated that N, P and K^{+1} percentages were influenced by using different salinity concentrations, irrigation frequency and their combinations. The highest N, P and K^{+1} percentages were obtained by irrigation every 15 or 21 days followed by 30 or 45 days. In addition, increasing irrigation interval led to a gradual increase in N, P and K^{+1} percentages. Significant increases were observed in N, P and K^{+1} percentages as a result of irrigation every 15 days and either 30 or 45 days. Regarding salinity concentrations, the obtained data revealed that, insignificant differences were observed among control, 8.6, 12.9 or 17.2 mM, in most cases. Increasing the concentrations over 17.2 significantly decreased these elements compared to lower ones. The interaction between salinity treatments and irrigation frequency showed that the treatment of irrigation every 21 or 15 days combined with control treatments resulted in the maximum values in this respect. Unlike the previous three cations, Ca^{+2} content was gradually increased with increasing irrigation level and reached its maximum value by applying 30 or 45 days irrigation treatments, while Ca^{+2} level was higher in untreated leaves and salinity treatments led to a gradual decrease in its concentrations. There were no significant differences concerning the interaction between irrigation and salinity treatments in this respect **(Table, 12).**

Irrigation every 15 days significantly decreased Na^{+1} and Cl^{-1} content compared to the other irrigation treatments. Meanwhile, the treatment of 45 days irrigation intervals resulted in the highest values in this concern. Increasing salinity concentration gradually increased Na^{+1} and Cl^{-1} content from 0.41 and 6.38 mg g^{-1} for control to 1.61 and 22.10 mg g^{-1} by 120.7 mM treatment, respectively (**Table, 11 and 12).** The differences among salinity treatments were significant for both anions. However, the interaction effects between irrigation frequency and salinity levels on Na^{+1} and Cl^{-1} content in dry leaves of jojoba were not significant.

Table 10: Nutrients content (N &P) of jojoba leaves as affected by salinity and irrigation frequency treatments

Treatments	N (%)					P (%)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	2.91	2.96	2.91	2.82	2.90	0.38	0.37	0.36	0.36	0.37
8.6 mM	2.90	2.89	2.86	2.82	2.87	0.37	0.36	0.35	0.36	0.36
12.9 mM	2.88	2.87	2.83	2.80	2.85	0.36	0.35	0.34	0.33	0.35
17.2 mM	2.86	2.84	2.80	2.75	2.81	0.35	0.34	0.33	0.33	0.34
25.9 mM	2.82	2.81	2.77	2.71	2.78	0.33	0.33	0.31	0.31	0.32
34.5 mM	2.78	2.75	2.72	2.64	2.72	0.32	0.31	0.29	0.29	0.30
51.7 mM	2.70	2.56	2.51	2.43	2.55	0.31	0.29	0.28	0.26	0.29
86.2 mM	2.46	2.34	2.27	2.24	2.33	0.29	0.26	0.25	0.24	0.26
103.4 mM	2.21	2.08	2.07	2.00	2.09	0.28	0.25	0.23	0.22	0.25
120.7 mM	2.03	1.92	1.88	1.79	1.91	0.25	0.23	0.22	0.19	0.22
Mean	2.66	2.59	2.55	2.49		0.32	0.31	0.30	0.29	
LSD		0.05		0.01			0.05		0.01	
Irrigation		0.02		0.03			0.02		0.04	
salinity		0.04		0.05			0.02		0.03	
Interaction		0.04		0.06			0.04		0.05	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Table 11: Nutrients content (K^{+1} & Na^{+1}) of jojoba leaves as affected by salinity and irrigation frequency treatments

Treatments	K (%)					Na (mg g^{-1})				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	2.73	2.73	2.72	2.68	2.72	0.40	0.41	0.43	0.41	0.41
8.6 mM	2.71	2.70	2.68	2.66	2.69	0.42	0.44	0.44	0.46	0.44
12.9 mM	2.66	2.65	2.62	2.58	2.63	0.45	0.48	0.49	0.51	0.48
17.2 mM	2.61	2.56	2.55	2.50	2.56	0.50	0.54	0.57	0.59	0.55
25.9 mM	2.53	2.49	2.46	2.38	2.47	0.57	0.61	0.65	0.70	0.63
34.5 mM	2.47	2.42	2.38	2.30	2.39	0.66	0.70	0.71	0.78	0.71
51.7 mM	2.22	2.12	2.11	2.08	2.13	0.80	0.81	0.85	0.91	0.84
86.2 mM	2.02	1.93	1.83	1.79	1.89	0.93	0.97	1.07	1.13	1.03
103.4 mM	1.84	1.75	1.60	1.56	1.69	1.17	1.30	1.50	1.43	1.35
120.7 mM	1.52	1.52	1.39	1.37	1.45	1.47	1.57	1.70	1.70	1.61
Mean	2.33	2.29	2.23	2.19		0.74	0.78	0.84	0.86	
LSD		0.05		0.01			0.05		0.01	
Irrigation		0.06		0.08			0.10		0.15	
salinity		0.05		0.06			0.06		0.09	
Interaction		0.07		0.11			NS		NS	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Table 12: Nutrients content (Cl^{-1} & Ca^{+2}) of jojoba leaves as affected by salinity and irrigation frequency treatment

Treatments	Cl^{-1} (mg g^{-1})					Ca^{+2} (mg g^{-1})				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	6.27	6.41	6.31	6.53	6.38	17.00	17.20	17.22	17.30	17.18
8.6 mM	6.77	6.84	7.41	7.39	7.10	16.48	16.45	16.85	16.92	16.68
12.9 mM	7.53	7.64	7.99	8.39	7.89	15.69	15.75	16.10	16.25	15.95
17.2 mM	8.17	8.23	8.58	9.06	8.51	14.90	15.09	15.45	15.26	15.18
25.9 mM	8.80	9.60	9.54	10.01	9.49	14.40	14.50	14.79	14.62	14.58
34.5 mM	10.97	11.50	11.55	13.10	11.78	13.80	13.86	14.26	13.95	13.97
51.7 mM	13.27	14.07	14.23	14.41	14.00	13.21	13.12	13.40	13.35	13.27
86.2 mM	14.60	16.33	16.31	16.02	15.82	12.70	12.74	12.82	12.74	12.75
103.4 mM	18.07	19.23	19.09	19.47	18.97	12.06	12.20	12.41	12.21	12.22
120.7 mM	22.01	21.70	22.32	22.35	22.10	11.77	11.82	11.98	11.89	11.87
Mean	11.65	12.16	12.33	12.67		14.20	14.27	14.53	14.45	
LSD		0.05		0.01			0.05		0.01	
Irrigation		0.29		0.38			0.12		0.17	
salinity		0.23		0.35			0.11		0.15	
Interaction		NS		NS			NS		NS	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.4.2. Leaf Chlorophyll Content:

Data concerning the effect of irrigation intervals and salinity concentrations on the chlorophyll content of jojoba leaves revealed that chlorophyll “a” was decreased with increasing irrigation intervals; however the differences were significant only with 45 days compared to the other irrigation intervals. Irrigation treatments did not affect the chlorophyll “b” content. The total chlorophyll content of leaves followed the same trend of chlorophyll “a”. Increasing salinity concentrations significantly decreased chlorophyll

“a”, “b” and total chlorophyll. The treatment of salinity at 120.7 mM combined with irrigation every 30 days resulted in the lowest total chlorophyll content (0.13 mgg^{-1}) however, the highest value in this respect (1.26

mg g^{-1}) was obtained when the treatment of irrigation every 21 or 30 days without salinity was applied (**Table, 13 and 14**).

Table 13: Chlorophyll content (a & b) of jojoba plants as affected by salinity and irrigation frequency treatments.

Treatments	Chlorophyll (a) (mg/g f.w)					Chlorophyll (b) (mg/g f.w)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	0.81	0.81	0.79	0.75	0.79	0.44	0.41	0.43	0.40	0.42
8.6 mM	0.76	0.77	0.70	0.71	0.74	0.36	0.34	0.36	0.35	0.35
12.9 mM	0.75	0.70	0.71	0.67	0.71	0.28	0.28	0.29	0.29	0.29
17.2 mM	0.69	0.66	0.68	0.61	0.66	0.25	0.26	0.28	0.25	0.26
25.9 mM	0.63	0.62	0.58	0.52	0.59	0.20	0.23	0.24	0.21	0.22
34.5 mM	0.51	0.49	0.52	0.48	0.50	0.19	0.22	0.22	0.20	0.21
51.7 mM	0.43	0.52	0.45	0.41	0.45	0.15	0.18	0.18	0.14	0.16
86.2 mM	0.37	0.39	0.34	0.32	0.35	0.11	0.12	0.12	0.08	0.11
103.4 mM	0.24	0.24	0.24	0.22	0.24	0.08	0.08	0.07	0.03	0.06
120.7 mM	0.14	0.14	0.09	0.11	0.12	0.03	0.05	0.04	0.11	0.06
Mean	0.53	0.53	0.51	0.48		0.21	0.22	0.22	0.21	
LSD		0.05		0.01			0.05		0.01	
Irrigation		0.04		0.06			0.02		0.03	
salinity		0.03		0.04			0.01		0.02	
Interaction		0.06		0.09			0.05		0.06	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.4.3. Protein Percentages:

Data concerning protein percentages of jojoba leaves as affected by salinity treatment and irrigation frequency were shown in **Table (14)**. The obtained data indicated that, increasing irrigation interval from 15 to 45 days gradually increased protein percentages. In the same time, irrigation frequency every 15 recorded the highest protein percentage compared to either 30 or 45 days. The same trend was observed between irrigation every 21 days in comparison with 45 days. Salinity treatments showed significant differences among control, 8.6, 12.9, 17.2, 25.9 or 34.5 mM treatments and the other salinity ones. Also, the treatment of 34.5 mM significantly increased protein percentage in comparison with 86.2, 103.4 or 120.7 mM treatments. The interaction treatments between salinity and irrigation intervals resulted in the maximum values in this respect. The treatments of irrigation every 15 or 21 days without salinity resulted in the highest protein values of jojoba leaves.

Table 14: Total chlorophyll and protein contents of jojoba plants as affected by salinity and irrigation frequency treatment

Treatments	Total chlorophyll (mg g^{-1})					Protein (%)				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	1.26	1.22	1.22	1.15	1.21	18.19	18.50	18.19	17.63	18.13
8.6 mM	1.12	1.11	1.06	1.06	1.09	18.13	18.06	17.88	17.63	17.94
12.9 mM	1.03	0.98	1.00	0.96	0.99	18.00	17.94	17.69	17.50	17.81
17.2 mM	0.94	0.92	0.96	0.86	0.92	17.88	17.75	17.50	17.19	17.56
25.9 mM	0.84	0.85	0.82	0.73	0.81	17.63	17.56	17.31	16.94	17.38
34.5 mM	0.70	0.72	0.74	0.68	0.71	17.38	17.19	17.00	16.50	17.00
51.7 mM	0.58	0.70	0.64	0.55	0.62	16.88	16.00	15.69	15.19	15.94
86.2 mM	0.47	0.52	0.45	0.40	0.46	15.38	14.63	14.19	14.00	14.56
103.4 mM	0.32	0.32	0.31	0.25	0.30	13.81	13.00	12.94	12.50	13.06
120.7 mM	0.17	0.19	0.13	0.22	0.18	12.69	12.00	11.75	11.19	11.94
Mean	0.74	0.75	0.73	0.69		16.63	16.19	15.94	15.56	
LSD		0.05		0.01			0.05		0.01	
Irrigation		0.04		0.07			0.15		0.21	
salinity		0.04		0.05			0.09		0.14	
Interaction		0.08		0.11			0.31		0.41	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

3.4.4. Total Carbohydrates Percentage:

Data in **Table (15)** postulated that irrigation every 15 days significantly improved carbohydrate percentage of jojoba leaves compared to the other irrigation treatments. Increasing irrigation interval from 15 to 45 days reduced carbohydrate percentage. However, there were no significant differences observed among 21, 30 and 45 days treatments.

Regarding salinity concentrations, total carbohydrate percentages were increased with increasing salinity concentration from 8.6 to 120.7 mM, the maximum carbohydrate percentages (24.45 and 23.40 %) were observed with salinity treatment of 103.4 and 120.7 mM. In the meantime, the interaction effects between irrigation frequency and salinity levels on total carbohydrates percentages of jojoba leaves were significant, salinity at 120.7 mM combined with irrigation every 30 or 45 days treatments recorded the highest values in this regard.

Table 15: Total carbohydrates (%) of jojoba plants as affected by salinity and irrigation frequency treatment

Treatments	Total carbohydrates %				
	Irrig. 1	Irrig. 2	Irrig. 3	Irrig. 4	Mean
control	14.48	14.65	14.69	14.80	14.65
8.6 mM	14.88	15.10	15.27	15.41	15.17
12.9 mM	15.23	15.67	16.14	16.14	15.80
17.2 mM	16.26	17.08	17.57	17.22	17.03
25.9 mM	17.81	18.49	18.55	18.68	18.38
34.5 mM	19.07	19.80	19.91	19.87	19.66
51.7 mM	20.32	20.74	21.04	21.12	20.81
86.2 mM	21.85	22.08	22.33	22.98	22.31
103.4 mM	23.08	23.16	23.37	24.00	23.40
120.7 mM	24.25	24.21	24.52	24.81	24.45
Mean	18.72	19.10	19.34	19.50	
LSD		0.05		0.01	
Irrigation		0.13		0.18	
salinity		0.19		0.28	
Interaction		0.27		0.36	

Irrig.1, Irrig.2, Irrig.3 and Irrig.4 means irrigation every 15, 21, 30 and 45 days, respectively.

Discussion:

Water is very important factor affecting the plant growth. The obtained results from this experiment proved that the previous sentence is completely true for jojoba plant. Mostly, the growth characteristics i.e. plant height, branch number, node number, shoot weight (fresh & dry), root weight (fresh & dry), root length, leaf measurements (its length, width and area) were significantly decreased with increasing the irrigation interval from 15 to 45 days. Increasing the growth of jojoba plant by decreasing irrigation intervals could be explained through the effect of frequent irrigation on stimulating the vegetative growth. This stimulation may reflect in increasing plant height, branch number and shoot weight (fresh & dry), root weight (fresh & dry), leaf measurements (length, width, area and stomatal density), root length, leaf and nodes number (Tables,1,2,3,4,5,6,7,8 and 9). These results support other results obtained by Ayerza (1993) on jojoba and Zwach and Graves (1999) on *Acer rubrum,* L.

As the water content of the plant decreases, its cells shrink and the cell walls relax which results in lower turgor pressure and the subsequent concentration of solutes in the cells, as well as, cell expansion. Because leaf expansion depends mostly on cell expansion, the principals that underlie the two processes are similar. The smaller leaf area transpires less water, effectively conserving a limited water supply from the soil over a longer period (Taiz and Zeiger, 2002). Shortening irrigation interval had a positive effect on chemical constituents of jojoba plant. As a result of vegetative growth promotion, the absorption of nutrient elements could be increased. However, water stress reduced photosynthesis rate (Pascale *et al.,* 2001). In addition, water stress led to more loss in photosynthesis area in the plant (Taiz and Zeiger, 2002). The reduced growth obtained at low frequency resulted from deficiency of nutrients, as our results shown, rather than of water, and that high irrigation frequency could compensate for nutrient deficiency (Silber *et al.,* 2003).

The obtained results clearly indicated that, elemental contents i.e. N, P, K, Ca^{+2} in jojoba leaves were increased with decreasing irrigation intervals **(Tables, 10, 11 and 12)**. On the other hand, an opposite trend was found concerning Na^{+1} and Cl^{-1} since it increased with increasing irrigation intervals **(Tables, 11 and 12)**. Decreasing nutrients content of jojoba leaves with increasing irrigation interval may be due to the water stress in lower rates, which reduces the rate of metabolic process for secondary products which lead to increasing leaf nutrients content; however, in the presence of frequent irrigation water the accumulation of products may be increased. In addition, the increment in these nutrients could be explained through the increment in growth as a result of using higher irrigation levels. The promotion effect of shorting the irrigation period was reflected in chlorophyll contents in jojoba leaves, hence their contents were increased **(Tables, 13 and 14)**. However, water stress led to an increase in carbohydrates in leaves **(Table, 15)**. The highest chemical constituents' percentages obtained by irrigation may be due to the effect of water which produces growth promoting substances resulting in more efficient absorption of nutrients, which main components of carbohydrates was increased as our data indicated. These results were in accordance with the findings of Edris *et al.* (2003) and El-Hady (2005).

The effective regulation of water is central to resistance of many stresses, including salt stress. A common indicator of salt stress is the reduction of growth due to inadequate water uptake (Munns, 2002 and Borsani *et al*., 2003). In our results, the plant growth was negatively correlated with increasing salinity concentrations. The values of plant height, branch number, number of leaves and nodes, shoot weight (fresh & dry), shoot/root ratio and leaf measurements were decreased with salinity levels increased, especially with higher salinity concentrations (Tables,1,2,3,4,5,6,7,8 and 9). Inhibition of shoot growth has been considered a whole plant adaptation to salt stress or water stress (Meloni *et al*., 2001; Akhtar *et al*., 2003; Mulholland *et al.*, 2003 and Qaderi *et al*., 2006). The suppression of shoot and root growth under salt-stress may either be due to osmotic reduction in water availability or to excessive accumulation of ions, known as specific ion effect (Marschner, 1995). These results confirm the others obtained by (Katerji *et al*., 2004 and Mansour *et al*., 2005).

It is very important here to refer to salt stress on leaf measurements and stomatal density as our data revealed that there is a reduction in these characters were recorded by salt stress **(Table, 9)**. Some researchers indicated that the most salt-resistant plants had the lowest stomata, stomatal density and leaf area tended to lower with higher salinity (Botti *et al*,. 1998a). This reduction may be occurred to make an adaptation to salt and inhabitation of its uptake. Further studies are needed to supply information concerning the previous relationship. Regarding nutrients contents of jojoba leaves as affected by salinity levels, it was, mostly, noticed that N, P, K and Ca contents were higher with control or lower salinity levels **(Tables, 10, 11 and 12).** On the contrary of the above results Na^{+1} and Cl^{-1} showed opposite trend, whereas, they increased gradually with increasing salinity concentrations **(Tables, 11 and 12).** When salinity results from the excess of NaCl, which is by far the most common type of salt stress, the increased intercellular concentration of Na^{+1} and Cl^{-1} is deleterious to cellular systems (Serrano *et al.*, 1999). In addition, the homeostasis of not only Na^{+1} and Cl^{-1} but also of essential cations such as K^{+1} and Ca^{2+} is disturbed (Serrano *et al*., 1999; Tattini *et al*., 2002, Roussos *et al*., 2007). Plant survival and growth under salt stress depend on adaptations that re-establish ionic homeostasis, thereby reducing the cellular exposure to ionic imbalances. High concentrations of salt impose a hyperosmotic shock by decreasing the chemical activity of water, thereby causing loss of turgor.

Our data showed that increasing levels of NaCl induced a progressive absorption of Na^{+2} and Cl^{-1} in jojoba leaves, agreeing with Chavan and Karadge (1986), Taban *et al*. (1999) and Turan *et al*. (2007). Accumulation of Cl^{-1} in the root tissue is disruptive to membrane uptake mechanisms, and hence may increase translocation of Cl^{-1} to the shoots. When NaCl was applied to the soil, the levels of K in plant were reduced in accordance with the antagonism between Na and K (Alberico and Cramer, 1993 and Azevedo and Tabosa, 2000). Salinity levels considerably decreased leaf content of chlorophyll "a", chlorophyll "b" and total chlorophyll compared to the control **(Tables, 13 and14).** Apparently, the lowest leaf content of chlorophyll was obtained from 120.7 mM. These results may be due to salt-induced water stress reduction of chloroplast stoma volume and regeneration of reactive oxygen species in playing an important role in the inhibition of photosynthesis seen in salt-stressed plants (Price and Hendry, 1991 and Allen, 1995). Our results are in agreement with many authors who revealed that, the total chlorophyll content of leaves was reduced by increasing NaCl level (Cha-Um and Kirdmanee, 2009). The salinity could seriously change the photosynthetic carbon metabolize, leaf chlorophyll content as well as photosynthetic efficiency. It was observed that the high levels of salinization induced a significant decrease in the contents of pigment fractions (chlorophyll a and b) and consequently of the total chlorophyll content as compared with control plants (Seeman and Critchley, 1985 and Sharkey *et al*. 1985). The decreased levels in chlorophyll content under saline stress is commonly reported phenomenon and established that it may be due to different reasons; one of them is related to membrane deterioration (Ashraf and Bhatti, 2000).

Concerning carbohydrates percentage, our results concluded that carbohydrate content of jojoba leaves significantly increased with increasing salinity levels **(Table, 15)**. This increment may be occurred in order to regulate the osmotic potential under salt stress (Sasiakala and Prasad, 1993 and Teixeira and Pereira, 2007). These results are in agreement with Dhanapackiam and Muhammad (2010). Many plants, which are stressed by NaCl salinity, accumulated starch and soluble carbohydrates (Greenway and Munns, 1980 and Rathert, 1984). This accumulation has been attributed to impaired carbohydrate utilization (Munns and Jermaat, 1986). It has been generally recorded that salinity adversely affects seedlings growth and some relevant metabolic processes of glycophytic plants (Hampson and Simpson, 1990 and Zidan and Al-Zahran 1994). Interestingly, our data indicated that the protein content of jojoba leaves was decreased with increasing salinity concentrations in the same direction of nitrogen content in leaves. These data were in the opposite trend of Pruvot *et al*. (1996) who mentioned that salt stress increased protein content since they found the salt stress increased the proline amino acids. The negative effect of water and salt stresses were clearly appeared when the combination between them was occurred, consequently, shoot and root growth and chemical constituents of jojoba plant were inhibited. Even thought, the irrigation intervals was decreased the limitation of water absorption and biochemical processes were happened. These results were in accordance with the findings of Cusido *et al*. (1987) and Parida and Das (2005).

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