

**EFFECT OF DIFFERENT LEVELS OF IRRIGATION ON GROWTH,
FLOWERING AND CHEMICAL CONSTITUENTS OF *Jatropha curcas*
PLANTS GROWN IN SANDY SOIL**

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ABSTRACT

This investigation was carried out during 2012, 2013 and 2014 seasons on *Jatropha curcas* grown in plastic pots of 40 cm diameter at Antoniadès Research Branch, Horticulture Research Institute, A.R.C., Ministry of Agriculture, Alexandria, Egypt. The study was a trial to investigate the effect of different levels of irrigation (20, 30, 40, 50, 60, 70, 80, 90 and 100 % of the field capacity) on the vegetative growth, yield production and some chemical constituents of *Jatropha curcas* plants grown in sandy soil. The results revealed that the highest level of available moisture (100 % of field capacity) gave the highest significant values of plant height, leaf number, leaf dry weight, leaf area, stem diameter, stem dry weight, branch number per plant, root length, root dry weight, fruit yield per plant, seed yield per plant, total chlorophyll content, carbohydrate content, proline content and relative water content. In general, the results recommended that irrigating the cultivated *Jatropha curcas* in the sandy soil daily using irrigation level not less than 80 % of field capacity gave the best vegetative growth, yield production and chemical analysis of *Jatropha curcas* plants, compared with the lower irrigation levels used in this study.

Key words: *Jatropha curcas*, drought tolerance, vegetative growth, yield production, chemical analysis.

1. INTRODUCTION

Jatropha curcas (purge nut/physic nut) is a major succulent crop plant, shrub and tree (same are deciduous, like resistant *Jatropha curcas* L.), belongs to the family Euphorbiaceae. It is a drought tolerant perennial plant, grows well in marginal/poor soil and is widely distributed throughout many tropical and sub-tropical regions throughout America, Africa and Asia (Takeda, 1982).

While this plant grows well in low-rainfall conditions, requiring only about 200 mm, it can also respond to higher rainfall up to 1200 mm, particularly in hot climatic conditions. This plant can withstand extremely low air humidity and can tolerate long-term water stress by shielding most of its leaves to reduce transpiration. Due to the above mentioned characteristics, it has received special attention in many countries and is one of the main crops to be promoted for growing in marginal lands for biodiesel production (Kumar *et al.*, 2011). *Jatropha*, the wonder plant, produces seeds with an oil content

of 37%. *Jatropha* is gaining importance commercially as a green fuel source and is being advocated for development of wastelands and dry lands. Currently the oil from *Jatropha* seeds is used as biodiesel fuel in many developing and developed countries (Dong, 2004).

This plant is characterized by its high drought and salinity tolerance (Maes *et al.*, 2009 and Silva *et al.*, 2010), high oil content, rapid growth and adaptability to widely different agro-climatic conditions (Divakara *et al.*, 2010). *Jatropha* seeds have received much attention because their oil can be converted into biodiesel (Openshaw, 2000) and because *Jatropha* plants can improve soil resistance to wind and water erosion under flooded conditions (Ogunwole *et al.*, 2008).

Water is essential for various metabolic activities. Its deficiency induces water stress on vegetation in combination with soil, plant and climate. All these factors interact to determine the water absorption and loss by the plants (Baquedano and Castillo, 2006). In arid and semi-arid regions, plants are often exposed to

water deficit stress, also known as moisture stress which negatively influence plant growth and biomass productivity (Wu *et al.*, 2008, Efeoglu *et al.*, 2009 and Zhang *et al.*, 2011). The plants can avoid moisture stress by maximizing water uptake i.e., absorbing ground water by deep roots or minimizing water loss through stomatal closure, small thick leaves, etc. (Kozłowski and Pallardy, 2002). The morphological and physiological nature may lead to some adaptation to moisture stress which varies considerably among species (Souza *et al.*, 2004). The apparent consequences of moisture stress are the progressive decline in photosynthetic capacity though photosynthetic system found to be resistant to irrigation levels linked with stomatal closure (Cornic, 2000). The reduced leaf water reserve in relation to the limiting transpiration rate (Baquedano and Castillo, 2006) eventually impairs biomass accumulation (Osipova *et al.*, 2011).

Water is a major constituent of tissues, a reagent in chemical reaction, a solvent and mode of translocation for metabolites and minerals within plant and is essential for cell enlargement through increasing turgor pressure. With the occurrence of water deficits many of the physiological processes associated with growth are affected and under severe deficits, death of plants may result.

The objective of this investigation was to study the effects of using different levels of field capacities (irrigation levels) on the vegetative growth, seed yield characteristics and some chemical analyses of *Jatropha* grown in sandy soil under the conditions of Alexandria, Egypt.

2. MATERIALS AND METHODS

The present study was carried-out at Antoniadis Research Branch, Horticultural Research Institute, A.R.C. Alexandria, Egypt during the three successive seasons of 2012, 2013 and 2014. The aim of this study was to evaluate the effects of stress irrigation water on *Jatropha curcas* plants grown in sandy soil

under the circumstances of Alexandria.

On the 15th of February, 2012, 2013 and 2014 (in the first, second and third seasons, respectively) homogeneous seedlings of *Jatropha curcas* (70-80 cm height and 20-25 leaves per plant in average) were planted individually in plastic pots (40 cm diameter) filled with 20 kg of sandy soil. The chemical constituents of the soil were measured as described by Jackson (1958) in Table (1). On the 1st of March (in all seasons), the irrigation water treatments were initiated. On the 30th of October (in all seasons), data were calculated on *Jatropha curcas* seedlings from March 2012 until October 2014 (in the three seasons). On the 30th of October in the three seasons, the plants were harvested.

Tap water was used as a source of irrigation water. After that the regime of irrigation levels was started. Nine irrigation levels were used to keep the soil moisture at the field capacity of the sandy soil at 100, 90, 80, 70, 60, 50, 40, 30 and 20%. The reduction in the moisture level of each treatment was determined daily by using Moisture Tester Model KS-DI (Gypsum Block "Fig. 1") during the growing seasons. The amounts of water of different treatments were added daily to each pot to keep the soil moisture of each treatment at the corresponding percentage. At the end of the experiment the total amount of irrigation water for each treatment was calculated and presented in Tables (2a, b and c). The field capacity of the sandy soil was determined by the pressure Cooker method at 1/3 atm., as described by Israelsen and Hansen (1962). Table (3) shows meteorological data during 2012, 2013 and 2014 seasons under the circumstances of Alexandria.

In the third season, all plants received NPK chemical fertilization using soluble fertilizer (Milagro Aminoleaf 20-20-20) at the rate of 3 g/ pot. Fertilization was repeated every 30 days throughout the growing season (from the 1th of March till the 30th of October). In addition, weeds were removed manually upon emergence.

Table (1): Some chemical analyses of the used sandy soil for the three successive seasons 2012, 2013 and 2014.

Season	pH	EC (dSm ⁻¹)	Soluble cations (mg/l)				Soluble anions (mg/l)		
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃ ⁻	Cl ⁻	SO ₂ ⁻
2012	7.87	1.43	3.1	2.8	6.1	0.8	3.0	6.1	2.0
2013	7.92	1.51	3.4	3.4	6.4	1.1	3.5	6.5	2.4
2014	7.89	1.47	3.2	3.0	6.2	0.9	3.2	6.3	2.2



Fig.(1): Gypsum Block (Model KS-DI).

Table (2a): Total amount of the water used for each plant (l/pot) in each treatment during the growing season of 2012.

Field Capacity(%)	First season (2012)								
	March	April	May	June	July	August	September	October	Mean
100 %	31.00	33.00	37.20	39.00	43.40	49.60	42.00	40.30	315.50
90 %	27.90	29.70	33.50	35.10	39.10	44.70	37.80	36.30	284.10
80 %	24.80	26.40	29.80	31.20	34.80	39.70	33.60	32.30	252.60
70 %	21.70	23.10	26.10	27.30	30.40	34.80	29.40	28.30	221.10
60 %	18.60	19.80	22.40	23.40	26.10	29.80	25.20	24.20	189.50
50 %	15.50	16.50	18.60	19.50	21.70	24.80	21.00	20.20	157.80
40 %	12.40	13.20	14.90	15.60	17.40	19.90	16.80	16.20	126.40
30 %	9.30	9.90	11.20	11.70	13.10	14.90	12.60	12.10	94.80
20 %	6.20	6.60	7.50	7.80	8.70	9.90	8.40	8.10	63.20

Table (2b): Total amount of the water used for each plant (l/pot) in each treatment during the growing season of 2013.

Field Capacity(%)	Second season (2013)								
	March	April	May	June	July	August	September	October	Mean
100 %	34.10	36.00	40.30	45.00	52.70	58.90	51.00	43.40	361.40
90 %	30.70	32.40	36.30	40.50	47.50	53.10	45.90	39.10	325.50
80 %	27.30	28.80	32.30	36.00	42.20	47.20	40.80	34.80	289.40
70 %	23.90	25.20	28.30	31.50	36.90	41.30	35.70	30.40	253.20
60 %	20.50	21.60	24.20	27.00	31.70	35.40	30.60	26.10	217.10
50 %	17.10	18.00	20.20	22.50	26.40	29.50	25.50	21.70	180.90
40 %	13.70	14.40	16.20	18.00	21.10	23.60	20.40	17.40	144.80
30 %	10.30	10.80	12.10	13.50	15.90	17.70	15.30	13.10	108.70
20 %	6.90	7.20	8.10	9.00	10.60	11.80	10.20	8.70	72.50

Table (2c): Total amount of the water used for each plant (l/pot) in each treatment during the growing season of 2014.

Field Capacity(%)	Third season (2014)								
	March	April	May	June	July	August	September	October	Mean
100 %	37.20	39.00	43.40	48.00	55.80	62.00	54.00	46.50	385.90
90 %	33.50	35.10	39.10	43.20	50.30	55.80	48.60	41.90	347.50
80 %	29.80	31.20	34.80	38.40	44.70	49.60	43.20	37.20	308.90
70 %	26.10	27.30	30.40	33.60	39.10	43.40	37.80	32.60	270.30
60 %	22.40	23.40	26.10	28.80	33.50	37.20	32.40	27.90	231.70
50 %	18.60	19.50	21.70	24.00	27.90	31.00	27.00	23.30	193.00
40 %	14.90	15.60	17.40	19.20	22.40	24.80	21.60	18.60	154.50
30 %	11.20	11.70	13.10	14.40	16.80	18.60	16.20	14.00	116.00
20 %	7.50	7.80	8.70	9.60	11.20	12.40	10.80	9.30	77.30

Table (3): Meteorological data at Central Laboratory of Agricultural Climate (CLAC) during 2012, 2013 and 2014 under the circumstances of Alexandria.

	Maximum temperature (°C)			Minimum temperature (°C)			Mean Humidity (%)			Maximum sustained wind speed (Km/h)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
January	16.7	18.7	19.8	8.7	8.8	9.5	73.8	74.9	79.3	25.6	22.7	16.4
February	17.8	20.4	20.3	8.4	9.7	10.8	70.9	71.8	74.0	23.3	22.2	20.6
March	20.1	23.4	22.7	11.0	12.4	12.3	68.2	64.2	68.6	23.9	24.5	22.9
April	25.2	24.6	25.6	13.6	14.8	14.2	65.7	62.9	68.3	20.5	25.5	20.5
May	28.2	28.7	28.5	17.4	18.8	17.6	67.2	68.0	64.8	20.9	24.6	22.8
June	29.8	30.3	30.1	21.3	21.7	21.3	70.7	68.4	68.0	20.4	24.0	22.0
July	32.0	30.2	30.8	24.6	23.4	23.5	72.0	71.4	71.4	21.4	23.8	22.1
August	32.2	31.7	32.0	24.7	23.9	24.7	70.2	72.1	70.6	20.1	22.0	22.2
September	30.2	30.5	31.1	21.7	21.8	22.2	69.4	67.4	66.6	19.3	21.9	20.5
October	28.8	26.8	28.2	18.6	18.7	18.6	72.5	66.5	63.2	19.2	24.4	18.8
November	25.4	25.2	24.2	16.1	15.4	15.4	74.5	73.4	63.3	17.8	19.3	20.0
December	20.5	19.9	21.8	11.3	10.2	11.5	72.3	72.9	68.4	20.8	21.0	18.2

Data recorded

(1) **Vegetative growth parameters:** Plant height (cm), leaf number per plant, leaf area (cm²), leaf dry weight per plant (g), stem diameter (cm), stem dry weight (g), root length (cm) and root dry weight (g).

(2) **Chemical analyses**

- Chlorophyll contents were determined as SPAD unit in the fresh leaves of plants for the different treatments under the experiment at the end of the season using Minolta (chlorophyll meter) SPAD 502 according to Yadava (1986).
- Carbohydrate contents of the leaves were determined according to Dubios *et al.* (1956).
- Relative water content of the leaves (%) in the fresh leaves were determined according to Barrs (1968) and Ritchie (1974).
- Proline content (% of dry matter) in the

leaves was determined according to Bates *et al.* (1973).

The layout of the experiment was a randomized complete blocks design (RCBD), with 9 treatments and 3 replicates, each replicate conceived (3 plants). The data of the three seasons were statistically analyzed as described by Snedecor and Cochran (1980). Means of all characters were compared by L.S.D. test at 0.05 level of significance.

3. RESULTS

3.1. Plant height (cm)

Data presented in Table (4) show that, in both three seasons, irrigation levels reduced the height of *Jatropha curcas* plants, compared to plants irrigated with 100% field capacity (control). Plants irrigated with 100% field capacity had the highest mean values of plant height 109.25, 119.00 and 134.83 cm in the first,

second and third seasons, respectively. Moreover, reducing the irrigation level caused steady significantly reduction in plant height, with the lowest irrigation level (20% field capacity) giving significantly the shortest plants (with mean height of 84.75, 90.75 and 101.25 cm in the three seasons, respectively) than those receiving any other irrigation level.

3.2. Number of leaves per plant

The data presented in Table (4) show the effect of irrigation levels on the number of leaves formed on *Jatropha curcas* plants. Plants irrigated with 100% field capacity had the highest number of leaves (23.33, 29.83 and 36.00) per plant in the first, second and third seasons, respectively. Accordingly, the lowest number of leaves 15.83, 21.83 and 29.50 per plant in the first, second and third seasons, respectively, was formed by plants irrigated using the lowest level.

3.3. Leaf dry weight per plant (g)

The results recorded in the three seasons in Table (4) show that the heaviest dry weights of leaves per plant (31.09, 38.43 and 46.44 g in the first, second and third seasons, respectively), were obtained from plants irrigated with 100% field capacity. Irrigation with 20% field capacity decreased the dry weight of leaves significantly. Moreover, the recorded values were decreased steadily with reducing irrigation level. Accordingly, the lowest values (22.88, 31.45 and 37.88 g per plant in the first, second and third seasons, respectively), were obtained from plants irrigated with 20% field capacity.

3.4. Leaf area (cm²)

The results recorded in the three seasons presented in Table (4) show that irrigation with 20% field capacity decreased the leaf area of *Jatropha curcas* plants, compared to plants irrigated with 100% field capacity (control). In the three seasons, plants irrigated with 100% field capacity (control) had the largest leaves area with means of 1082.90, 2050.64 and 3042.80 cm² in the first, second and third seasons, respectively. The leaf area was decreased steadily with reducing irrigation to 20% field capacity. Accordingly, the smallest leaves with mean areas of 523.56, 700.92 and 1069.78 cm² in the first, second and third seasons, respectively, were formed on plants irrigated with 20% field capacity.

3.5. Stem diameter (cm)

The data recorded on the stem diameter of *Jatropha curcas* plants in the three seasons in Table (5) show that reducing irrigation levels

decreased stem thickness, compared to that of plants irrigated with 100% field capacity (control). In the third season, plants irrigated with 100% field capacity had the thickest stems, with a mean diameter of (3.08, 3.62 and 4.37 cm) in the first, second and third seasons, respectively. Reducing irrigation levels caused a steady reduction in stem diameter. This reduction in stem diameter was significant (compared to the control), which gave stem diameters of (2.35, 3.33 and 3.74 cm) in the first, second and third seasons, respectively.

3.6. Stem dry weight (g)

Data presented in Table (5) show that, in the third season, irrigation levels significantly decreased dry weight of stem of *Jatropha curcas* plants, compared to plants irrigated with 100% field capacity (control). Plants irrigated with 100% field capacity had the heaviest mean dry weight of stem 39.98, 43.47 and 52.52 g per plant in the first, second and third seasons, respectively. The dry weight of the stem showed a gradual reduction as irrigation level was gradually reduced. Accordingly, the lowest dry weight of stem (32.16, 40.14 and 44.98 g per plant in the first, second and third seasons, respectively), was recorded in plants receiving the lowest irrigation level.

3.7. Branch number per plant

The data presented in Table (5) show the effect of irrigation levels on branch number per plant formed on *Jatropha curcas* plants. In the third season, plants irrigated with 100% field capacity had the highest branch number per plant (2.33, 4.66 and 8.00) branches per plant in the first, second and third seasons, respectively. Accordingly, the lowest branch number (1.00, 2.00 and 3.00 branches per plant in the first, second and third seasons, respectively), was formed by plants irrigated using the lowest irrigation level.

3.8. Root length (cm)

Data presented in Table (6) show that all the tested irrigation level treatments significantly decreased the root length (cm) of *Jatropha curcas*, compared to plants irrigated with 100% field capacity (control). In the third season, plants irrigated with 100% field capacity had the highest mean root length (81.83, 89.25 and 101.25 cm) in the first, second and third seasons, respectively. Reducing the irrigation levels caused a steady reduction in the root length, which reached its lowest values (63.83, 68.08 and 76.00 cm) in the first, second and

Table (4): Means of vegetative growth characteristics of *Jatropha curcas* plants as influenced by irrigation levels (field capacity (F.C.) percentage) in the three seasons of 2012, 2013 and 2014.

Treatments F.C (%)	Plant height (cm)			Number of leaves per plant			Leaves dry weight per plant (g)			Leaves area (cm ²)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
100 %	109.25	119.00	134.83	23.33	29.83	36.00	31.09	38.43	46.44	1082.90	2050.64	3042.80
90 %	105.00	114.50	130.16	22.16	28.33	35.00	30.00	37.60	45.43	1001.25	2018.00	3089.66
80 %	102.00	111.33	125.41	21.83	27.66	33.33	29.65	35.92	44.12	979.76	1710.40	2606.29
70 %	99.75	108.91	122.33	20.66	26.83	33.00	29.44	35.22	42.59	912.25	1681.94	2552.83
60 %	98.25	106.75	119.41	19.66	25.33	31.66	28.19	35.09	41.38	829.36	1366.20	2069.33
50 %	93.00	101.50	114.16	18.83	24.16	31.50	27.01	33.47	40.80	739.86	1104.93	1613.20
40 %	92.25	98.41	109.66	18.00	23.66	31.16	26.76	32.79	39.79	648.55	991.01	1482.40
30 %	88.50	94.50	105.75	18.00	22.50	30.00	25.23	32.24	38.39	597.70	766.64	1248.90
20 %	84.75	90.75	101.25	15.83	21.83	29.50	22.88	31.45	37.88	523.56	700.92	1069.78
L.S.D. 0.05%	6.23	4.49	3.46	1.54	0.99	0.84	2.62	2.25	1.64	52.07	53.43	78.67

Table (5): Means of stem growth characteristics of *Jatropha curcas* plants as influenced by irrigation levels (field capacity (F.C.) percentage) in the three seasons of 2012, 2013 and 2014.

Treatments F.C (%)	Stem diameter (cm)			Stem dry weight (g)			Branch number per plant		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
100 %	3.08	3.62	4.37	39.98	43.47	52.52	2.33	4.66	8.00
90 %	3.05	3.60	4.27	39.10	43.34	51.36	2.16	4.50	7.33
80 %	3.04	3.58	4.26	37.42	43.08	51.18	1.83	3.66	6.50
70 %	2.91	3.51	4.01	36.64	42.20	48.20	1.66	3.33	6.33
60 %	2.83	3.49	3.88	36.61	41.88	46.60	1.50	3.33	6.16
50 %	2.70	3.48	3.88	35.07	41.88	46.58	1.50	3.16	5.83
40 %	2.67	3.38	3.84	32.50	40.66	46.07	1.33	3.00	5.00
30 %	2.67	3.35	3.79	32.35	40.26	45.45	1.00	2.33	3.50
20 %	2.35	3.33	3.74	32.16	40.14	44.98	1.00	2.00	3.00
L.S.D. 0.05%	0.19	0.11	0.16	3.15	2.31	2.24	0.36	0.76	1.33

third seasons, respectively, in plants irrigated using the 20% field capacity.

3.9. Root dry weight (g)

Data presented in Table (6) show that irrigation of *Jatropha curcas* plants with irrigation levels significantly decreased the dry weight of roots, compared to plants irrigated

with 100% field capacity (control). In the third season, plants irrigated with 100% field capacity had the heaviest dry weight of roots (36.00, 42.88 and 48.34 g per plant) in the first, second and third seasons, respectively. Steady significant reductions in the dry weight of roots was recorded as the lowest irrigation level was

Table (6): Means of root growth characteristics of *Jatropha curcas* plants as influenced by irrigation levels (field capacity (F.C.) percentage) in the three seasons of 2012, 2013 and 2014.

Treatments F.C. (%)	Root length (cm)			Root dry weight (g)		
	2012	2013	2014	2012	2013	2014
100 %	81.83	89.25	101.25	36.00	42.88	48.34
90 %	78.83	85.83	97.75	34.32	40.13	46.76
80 %	76.50	83.50	94.08	33.86	39.97	46.56
70 %	74.75	81.83	91.66	32.66	38.52	45.10
60 %	73.50	80.16	89.33	31.59	38.22	44.10
50 %	69.83	76.16	85.50	29.99	37.82	43.28
40 %	69.00	73.83	82.25	29.92	37.46	42.99
30 %	66.16	70.91	79.33	29.71	37.27	41.16
20 %	63.83	68.08	76.00	25.95	36.94	40.89
L.S.D. 0.05%	4.65	3.36	2.66	2.15	1.11	1.44

reduced. The 20% field capacity gave the lowest mean values in the third season (25.95, 36.94 and 40.89 g per plant) in the first, second and third seasons, respectively.

3.10. Fruit yield per plant (g)

Data presented in Table (7) show that all the tested irrigation level treatments significantly decreased the fruits yield per plant (g) of *Jatropha curcas*, compared to that of plants irrigated with 100% field capacity (control). In the third season, plants irrigated with 100% field capacity had the highest mean fruit yield per plant (124.88, 547.00 and 1168.76 g) in the first, second and third seasons, respectively. Reducing the irrigation levels caused a steady reduction in the fruit yield per plant, which reached its lowest value (20.88, 91.47 and 196.08 g) in the first, second and third season, respectively, in plants irrigated using the 20% field capacity.

3.11. Seed yield per plant (g)

Data presented in Table (7) show that irrigation of *Jatropha curcas* plants with irrigation levels significantly decreased the seed yield per plant, compared to plants irrigated with 100% field capacity (control). In third seasons, plants irrigated with 100% field capacity had the heaviest seed yield per plant (92.26, 406.10 and 834.17 g per plant) in the first, second and third seasons, respectively. Steady significant reductions in the seed yield per plant were recorded as the lowest irrigation level was used. The 20% field capacity gave the lowest mean values in the third season (14.00, 62.12 and 127.21 g per plant) in the first, second and third seasons, respectively.

3.12. Seed yield per faddan (Kg)

Data presented in Table (7) show that irrigation of *Jatropha curcas* plants with irrigation levels significantly decreased the seed yield per faddan, compared to plants irrigated with 100% field capacity (control). In third season, plants irrigated with 100% field capacity had the heaviest seed yield per feddan (64.58, 284.27 and 583.91 Kg per feddan) in the first, second and third seasons, respectively. Steady significant reductions in the seed yield per faddan were recorded as the lowest irrigation level was reduced, which the 20% field capacity gave the lowest mean values in third season (9.80, 43.48 and 89.04 Kg per feddan) in the first, second and third seasons, respectively.

3.13. Total chlorophyll content (SPAD unit)

The results presented in Table (8) show that

the highest content of total chlorophylls were obtained in plant irrigation with 100% field capacity (56.99, 57.42 and 57.32 SPAD) in the first, second and third seasons, respectively. Reducing irrigation levels resulted in gradual significant reductions in the total chlorophyll content, which reached its lowest values (49.13, 50.03 and 50.12 SPAD) in the first, second and third seasons, respectively.

3.14. Total carbohydrate content (%)

The data resulting from leaf chemical analysis in Table (8) show that, the total carbohydrates % in the dried leaves of *Jatropha curcas* plants was decreased steadily with reduce in the irrigation levels. The highest mean carbohydrate content (21.46, 21.86 and 21.90 %) in the first, second and third seasons, respectively, was found in the leaves of the control plants, whereas the lowest mean values (18.70, 17.33 and 17.74 %) in the first, second and third seasons, respectively, were found in plants irrigated with 20% field capacity.

3.15. Proline content (mg/g)

Results of leaf samples taken from plants receiving different irrigation levels Table (8) show that, with reducing the irrigation levels, the proline % in the dry leaves was generally increased. Accordingly, plants irrigated with 20% field capacity had the highest mean proline values (2.40, 2.50 and 2.48 mg/g) in the first, second and third seasons, respectively. On the other hand, plants irrigated with 100% field capacity had the lowest mean proline values (1.29, 1.15 and 1.20 mg/g) in the first, second and third seasons, respectively.

3.16. Relative water content of leaves (%)

Results of leaf samples taken from plants receiving different irrigation levels (Table 8) show that, with reducing irrigation level, the relative water content % in fresh leaves was generally decreased. Accordingly, plants irrigated with 20% field capacity had the lowest mean relative water content values (56.25, 56.39 and 53.79 %) in the first, second and third seasons, respectively. On the other hand, plants irrigated with 100% field capacity had the highest mean relative water content values (78.96, 78.64 and 76.50 %) in the first, second and third seasons, respectively. The considerable enhancement of relative water content accumulation in plants irrigated may lead to the conclusion that relative water content plays a role in plant drought tolerance.

Table (7): Means of fruit growth characteristics of *Jatropha curcas* plants as influenced by irrigation levels (field capacity (F.C.) percentage) in the three seasons of 2012, 2013 and 2014.

Treatments F.C (%)	Fruits yield per plant (g)			Seed yield per plant (g)			Seed yield per faddan (Kg)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
100 %	124.88	547.00	1168.76	92.26	406.10	834.17	64.58	284.27	583.91
90 %	118.79	515.34	1103.99	83.06	363.85	748.27	58.14	254.69	523.79
80 %	98.70	427.49	919.39	72.39	314.28	647.77	50.67	219.99	453.43
70 %	80.59	353.97	756.26	60.61	264.93	547.59	42.43	185.45	383.31
60 %	74.65	323.37	693.66	51.23	223.95	459.32	35.86	156.76	321.52
50 %	54.16	234.10	499.35	46.29	198.30	411.44	32.40	138.81	288.01
40 %	37.95	164.54	355.60	29.72	129.61	269.45	20.80	90.72	188.61
30 %	23.20	102.71	218.95	19.73	86.99	179.79	13.81	60.89	125.85
20 %	20.88	91.47	196.08	14.00	62.12	127.21	9.80	43.48	89.04
L.S.D. 0.05%	15.35	53.38	121.13	9.41	31.45	62.01	6.59	24.12	43.41

Table (8): Means of chemical constituents of *Jatropha curcas* plants as influenced by irrigation levels (field capacity (F.C.) percentage) in the three seasons 2012, 2013 and 2014.

Treatments F.C (%)	Total chlorophyll content (SPAD unites)			Total carbohydrates content of leaves(%)			Proline content of leaves (mg/g dry weight)			Relative water content of leaves (%)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
100 %	56.99	57.42	57.32	21.46	21.86	21.90	1.29	1.15	1.20	78.96	78.64	76.50
90 %	56.89	55.62	55.71	21.20	21.21	21.25	1.32	1.25	1.29	78.15	77.32	74.96
80 %	54.36	55.09	55.51	20.43	20.72	21.15	1.34	1.71	1.74	77.05	76.34	74.13
70 %	53.94	54.43	54.53	20.21	20.74	20.84	1.37	1.87	1.88	74.73	72.54	70.58
60 %	50.57	53.49	53.59	19.92	19.61	19.72	2.12	2.17	2.18	74.43	71.53	69.05
50 %	50.47	52.55	52.99	19.50	19.25	19.28	2.16	2.24	2.28	67.81	65.82	63.73
40 %	50.14	52.21	52.31	19.11	18.45	18.73	2.22	2.39	2.36	64.64	62.10	61.20
30 %	49.72	50.62	51.04	18.81	18.04	18.33	2.35	2.40	2.39	58.26	58.12	55.97
20 %	49.13	50.03	50.12	18.70	17.33	17.74	2.40	2.50	2.48	56.25	56.39	53.79
L.S.D. 0.05%	1.19	1.68	1.73	1.34	0.99	0.95	0.066	0.063	0.042	2.11	1.39	1.42

4. DISCUSSION

The results obtained in Tables (4 to 7) showed that the above-ground vegetative growth including plant height, leaf number per plant, leaf dry weight, leaf area, stem diameter, stem dry weight and branch number per plant were gradually increased as the level of irrigation water was upward. The highest values for all these parameters were obtained due to the use of the high irrigation level (100% field capacity). Similar results were reported on *Jatropha curcas* by Mazher *et al.* (2010) Kesava *et al.* (2012) and Hussein *et al.* (2012).

The reductions in these growth parameters due to low irrigation level (20% field capacity) conditions may be attributed to losses of tissue water which inhibited cell division and enlargement. El -Monayeri *et al.* (1985) reported that the vital roles of water supply at adequate amounts for different physiological processes such as photosynthesis respiration, transpiration translocation, enzyme reaction and cells

turgidity occurs simultaneously. Such reduction could be attributed to a decrease in the activity of meristemic tissues responsible for elongation, as well as the inhibition in photosynthetic efficiency under insufficient conditions (Siddique *et al.*, 1999). Ali *et al.* (1999) indicated that soil drying decreased leaf growth thereby reducing leaf water status in addition to accumulation of organic solutes to osmotic adjustment which in turn inhibit the incorporation of small substrate molecules into the polymers needed to grow new cell. On the contrary, all water aforementioned vegetative growth parameters root length and dry weight of roots took on similar trend as they were gradually decreased when the irrigation levels were sloping down. These results are on line with those reported by Burman *et al.* (1991) on *Simmondsia chinensis*, Uday *et al.* (2001) and Mazher *et al.* (2006b) on *Taxodium distichum* and Achton *et al.* (2004) on *Jatropha curcas*. Farahat (1990) on *Schinus molle*, *Schinus*

terbinthifolius and *Myoporum ocminatum*, Metwally *et al.* (2002) on roselle and Mazher *et al.* (2007) on *Bauhinia variegata* seedlings, found that plant height, stem diameter and fresh and dry weights of leaves, stem and root decreased with prolonging water intervals. The same was true with Shehata (1992) working on *Cupressus sempervirens* and *Eucalyptus camaldulensis*, El-Tantawy *et al.* (1993) on *Eucalyptus camaldulensis*, Mazher *et al.* (2006a) on *Melia azedarach* seedlings and Mazher *et al.* (2006b) on *Taxodium distichum*, and Mazher *et al.* (2010), Kesava *et al.* (2012) and Hussein *et al.* (2012) on *Jatropha curcas*.

Also, Uday *et al.* (2001) studied the effect of irrigation at (field capacity 10.4% w/w) 0.2 F.C., 0.5 F.C. and 10 F.C. levels on the growth of *Simmondsia chinensis* and found that growth was increased with increasing irrigation levels. Sayed (2001) on *Khaya senegalensis* and Ibrahim (2005) on *Simmondsia chinensis*, Mazher *et al.* (2006b) on *Taxodium distichum*, supplied seedling with three soil moisture content (40, 60 and 80% of water holding capacity). They observed that plant height, stem diameter, fresh and dry weight of leaves, stem and roots were increased by increasing soil moisture, but root length and fresh and dry weight of roots were decreased. Also, Uday *et al.* (2001) studied the effect of irrigation at (field capacity 10.4% w/w) 0.2 F.C., 0.5 F.C. and 10 F.C. levels) on the growth of *Simmondsia chinensis* and found that growth was increased with increasing irrigation levels. Sayed (2001) on *Khaya senegalensis* and Ibrahim (2005) on *Simmondsia chinensis*, Mazher *et al.* (2006a) irrigated seedlings of *Melia azedarach* and Mazher *et al.* (2007) seedlings of *Bouhinia variegata*, with different water regimes. They found that chlorophyll (a, b and carotenoid) contents were increased as soil moisture content decreased. In addition to that total sugars, N, P and K concentration in the leaves were also stimulated gradually by decreasing water supply. While, leaf content of nitrogen, phosphorus and potassium were increased by increasing water supply. Mazher *et al.* (2006b) on *Taxodium distichum* found that increasing water supply gradually increased N, P and k uptake in shoot. Data also revealed that proline tended to increase by decreasing water level. Similar results were reported by Mazher *et al.* (2010) on *Jatropha curcas*.

As regards the effect of irrigation levels the previous results indicated that 100% field

capacity of different irrigation levels significantly enhanced yield of fruits and seeds of *jatropha curcas* followed by 20% field capacity gave the lowest yield. These results are parallel with the findings of El-Shafie *et al.* (1994) on Roselle plants who cleared that the more frequent irrigation 100% field capacity was very necessary for producing higher number of fruits, heavier fruits and sepals yield per plant compared with those irrigated 90% field capacity, while the lowest values in this respect were obtained from 20% field capacity. Similar results were reported by El-Makawy (1999) on *Peganum harmala*. Reddy *et al.* (1996) on castor bean (*Ricinus communis*) showed that seed yield was markedly decreased when water stress occurred during either the vegetative phase or during the early stages of flowering and on castor varieties, including seed yield Dinesh *et al.* (2001) on castor plants and Salem (2002) on *Simmonds chinensis*. The role of water in increasing yield of flowers may be explained by its role in photosynthesis that will be reflected on the relative growth rate and flowering.

From the given data in Table (8) it can be concluded that, increasing irrigation rates caused an increase in the content of total chlorophylls. Accordingly it can be stated that irrigation with 100% field capacity was the most effective irrigation treatment for promoting the synthesis and accumulation of the pigments. In harmony with these results were those obtained by Ibrahim (2005) on jojoba seedlings, Mazher *et al.* (2006b) on *Taxodium distichum*, Kashiwagi *et al.* (2004) on *Cicer arietinum* and Mazher *et al.* (2010) on *Jatropha curcas*.

From the data given in Table (8) it can be concluded that decreasing irrigation level caused an increase of proline content. This may be due to the proline metabolism which is a typical mechanism of biochemical adaptation subjected to stress condition. The catabolism of proline involves its conversion to glutamic acids. Pyrroline-carboxylate reduction and subsequent metabolism of glutamate by Krebs cycle reaction that release CO₂ as the end product Armstrong (1993) obtained results were in harmony with the findings of Mazher *et al.* (2006b) on *Taxodium distichum*, Mazher *et al.* (2010) and Gabriela *et al.* (2011) on *Jatropha curcas*.

Conclusion

Water stress decreased the growth and development of *Jatropha* plants but the plants continued to grow even when irrigated with as low as 40% daily water use. Growth and yield of

Jatropha would be reduced at suboptimal moisture conditions and its reduction depends on the degree of water stress.

The results indicate that the effect of water stress on plant growth parameters (leaf number, stem diameter, plant height and root length) was significant, but the effect of water stress on chlorophyll levels was not significant. It seems insufficient increase in the activity of antioxidant enzymes in the plant will reduce the plant's ability to tolerate stress and will cause induction of injury to plant lives. Therefore, Jatropha plant with drought avoidance mechanisms, such as: maintaining higher RWC, reduced leaf area and increase in the number of chlorophyll meter, has to confront drought stress. Since variations in growth and parameter values were large, further experiments may be needed to reach more solid conclusions.

Chlorophyll is more sensitive to drought and consequently the ratio of total chlorophylls decreases with increasing drought severity. Results found that there was a significant difference in early growth, dry matter accumulation and pigments. The root length, shoot length, total leaf area, fresh and dry weights and total chlorophylls were significantly reduced under water stress treatments.

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تأثير مستويات مختلفة من الري على النمو والإزهار والمكونات الكيميائية لنباتات *Jatropha curcas* النامية في الأراضي الرملية

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ملخص

أجريت هذه الدراسة خلال المواسم 2012, 2013, 2014 على نبات الجاتروفا النامي في أصص بلاستيكية ذات قطر 40 سم. في فرع بحوث أنطونيداس - معهد بحوث البساتين - مركز البحوث الزراعية - الإسكندرية - مصر. كانت الدراسة محاكاة لدراسة تأثير مستويات مختلفة من الري عبارة عن (20, 30, 40, 50, 60, 70, 80, 90, 100% من السعة الحقلية للتربة) على النمو الخضري وإنتاج المحصول وبعض التحليلات الكيميائية لنبات الجاتروفا النامي في تربة رملية.

كشفت النتائج أن أعلى مستوى من الرطوبة المتاحة (100% من السعة الحقلية للتربة) أعطى أعلى قيم من حيث ارتفاع النبات وعدد الأوراق ووزن الأوراق الجاف والمساحة الورقية وقطر الساق والوزن الجاف للساق وعدد الأفرع على النبات وطول الجذور ووزن الجذور الجاف ومحصول الثمار للنبات و محصول البذور للنبات ومحتوى الكلوروفيل الكلي ومحتوى الكربوهيدرات ومحتوى البرولين , المحتوى المائي النسبي للأوراق.

عموماً ينصح برى نبات الجاتروفا النامي في تربة رملية يومياً مع استخدام مستوى رطوبي لا يقل عن 80% من السعة الحقلية حيث أعطت أفضل نتائج من حيث النمو الخضري وإنتاج المحصول والتحليلات الكيميائية لنبات الجاتروفا النامي في التربة الرملية , مقارنة مع باقي مستويات الرطوبة المنخفضة.

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