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Effect of water stress on vegetative growth and some physiological aspects of Jojoba [*Simmondsia chinensis* (Link) Schneider] in newly reclaimed sandy soil

Hussein, M. M[1], M. M. Tawfik[2], M. K. A. Ahmed[2] and M. F. El Karamany[2]

[1]Water Relation and Field Irrigation Department National Research Centre, Dokki ,Giza Egypt.

[2]Field Crops Research Department National Research Centre, Dokki ,Giza Egypt.

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ABSTRACT

Developing countries face increasing local demand for energy in rural areas, they also have both economic and environmental pressure on agricultural lands. The possibility of growing energy crops such as [*Simmondsia chinensis* (Link) Schneider] has the potential to enable some smallholder farmers, producers and processors to cope with these pressures. In this concern, A field experiment was carried out at a private farm in Manshyet El Gammal, Tamiah district, Fayum Governorate to study the effect of foliar application with tap water (control), zinc (300 ppm Zn-EDTA), potassium (2.0% KNO_3) or ascorbic acid (200 ppm) on vegetative growth and some physiological aspects of Jojoba [*Simmondsia chinensis* (Link) Schneider] under three drip irrigation treatments (irrigation every 3,5 and 7 days (represent optimum, moderate and severe water stress. Increasing irrigation interval significantly decreased all the studied growth characters, as well as the content of potassium and zinc. While it increased the content of chlorophyll a+b , proline, soluble carbohydrates as well as the value of succulence and osmotic potential. Foliar application with potassium, zinc or ascorbic acid positively affected all the growth and physiological criteria of the tested plants compared with (control treatment). Foliar application with potassium surpasses the other foliar application treatments especially by prolonging the irrigation interval period.

Introduction

Jojoba (*Simmondsia chinensis* (Link) Schn.) is a nontraditional crop in arid and semi-arid areas. Jojoba is becoming more and more popular and widely known as a new crop for semi-arid regions. (Azocar and Covarrubias, 1990). The jojoba, is an arid xerophytic shrub native to the Sonoran Desert of Arizona, Northern Mexico. Jojoba is now grown commercially in Australia, Argentina, Chile, Peru, Egypt and Israel. Plantations in South Africa and India are also reported. Jojoba is covering a surface of about 8500 hectares (Canoira, 2006). Jojoba is a dioeciously species, i.e. having separate male and female plants. Only the females, however, give the valuable seeds. When raised through seeds about 50% or more seedlings are males. The sex can be recognized only when plants start bearing after 3 - 4 years of planting. While, for commercial yield only 10% male population is required. As jojoba is a cross pollinated crop, the progeny is highly heterozygous having tendency to generate seedlings of widely varying size, shape and yield, which has raised doubts about the economic feasibility of cultivating jojoba. The success of jojoba growers and indeed of the entire jojoba industry depends upon selection of high yielding genotypes and their multiplication through vegetative means. Jojoba is a difficult to root plant, however, semi-green shoots can be rooted and permit rapid multiplication of superior clones (Agrawal *et al*., 2007).

Under limited water supply conditions the farmer tends to increase the irrigation interval, which creates water stress (Jain *et al*., 2000). Drought stress are considered to be the major environmental factor limiting plant growth and yield. It induces many biochemical, molecular, and physiological changes and responses that influence various cellular and whole plant processes that affect crop growth and quality (Aown *et al*., 2012). Drought stress induces several changes in various physiological, biochemical and molecular components of photosynthesis either through pathway regulation by stomatal closure and decreasing flow of CO_2 into mesophyll tissue (Flexas *et al*., 2004). They added that it affect carbon assimilation and cell growth.

Currently, foliar-applied nutrients have limited direct use for enhancement of stress resistance mechanisms in crops. Nevertheless, the interactions between plant nutrient levels and stress repair mechanisms are now being studied (Lavon *et al*., 1999). Foliar application of potassium during vegetative growth is one of these precautions. Potassium is essential in maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increase tolerance to water stress (Epstein, 1972). Moreover, it is involved in activating a wide range of enzyme systems which regulate photosynthesis, water use efficiency and movement, nitrogen uptake and protein building (Nguyen *et al*., 2002). While, zinc is an component of a number of dehydrogenases, proteinases and peptidases, thus Zn influences electron transfer reactions including those of the Krebs cycle and hence affecting the plant's energy production, also, zinc binding tightly to Zn-containing essential metabolites in vegetative tissues, such as in Zn-activated enzymes, e.g., carbonic anhydrase, which plays a role in photosynthesis, is localized in the cytoplasm and chloroplasts and may facilitate the transfer of CO /HCO G for photosynthetic CO fixation (Srivastava,2006).

Tele:
E-mail addresses: medhatnrc@hotmail.com

Applying growth regulators especially ascorbic acid can modify morphological and physiological characteristic of plant and may also induce better adaptation of plant to environment which improve the growth and yield. It plays a major role in cell division and cell differentiation and affects many other physiological and developmental processes in plants including apical dominance, nutrient mobilization, chloroplast development, senescence and improves yield and chemical constituents of many crops and increasing the photosynthetic pigments content (Pignocchi and Foyer, 2003).

Therefore, this investigation was undertaken to evaluate the efficiency of foliar application of zinc, potassium or ascorbic acid to reduce the harmful effect of water stress on growth and some physiological aspects of Jojoba plants in new reclaimed sandy soil, and develop a management technique for productive use of jojoba in arid lands.

Material and methods

A field experiment was carried out at a private farm in Manshyet El Gammal, Tamiah district, Fayum Governorate to study the effect of foliar application with tap water (control), zinc (300 ppm Zn-EDTA), potassium (2.0% KNO_3) or ascorbic acid (200 ppm) on vegetative growth and some physiological aspects of Jojoba [*Simmondsia chinensis* (Link) Schneider] under three drip irrigation treatments (irrigation every 3,5 and 7 days (represent optimum, moderate and severe water stress. Drip irrigation system was applied in the experiment using drippers (6 L/h) for one hour every time. Experiment was laid out in split plot design with three replicate (4x3 m distance between trees) i.e. 350 trees /fed., irrigation treatments were in the main plots and foliar treatments were in the sub-plots. Seeds of jojoba plants were sown on 24 May 2011. The initial physical and chemical characteristics of the soil were determined according to Klute (1986) are shown in Tables (1). Nitrogen was applied in the form of urea (46% N) at the rate of 200 g / tree. Phosphorus fertilizers in the form of super phosphate (15.5% P_2O_5) 150 g / tree and potassium as potassium sulphate (48% K_2O), 100 g / tree for 100% mineral fertilization treatment (all mineral fertilizer were added in 4 doses , at sowing and every 50 days later. All agronomic practices were followed as recommended for jojoba production in this district. A representative vegetative plant sample was taken after 240 days from sowing for each treatment from four replicates for measuring plant height (cm.), number of branches/plant, number of nodes/branch, shoot and root dry weight (g) as well as shoot/root ratio. Drought Susceptibility Index (DSI) was calculated as total plant dry weight obtained from different irrigation treatments compared to total plant dry weight obtained from water stressed plants, DSI = [(TDW at Sx / TDW at S1) x 100], whereas DSI = Drought Susceptibility Index, TDW = total dry weight, S1 = control treatment, Sx = x treatment (Fischer and Maurer,1978). The following physiochemical measurements were determined in the fresh harvested shoot: chlorophyll a+b (mg/g fresh weight) according to von Wettstein (1957) and proline (µg/g) according to Bates *et al.,* (1973). Osmotic potential were then obtained from the corresponding values of cell sap concentration tables given by Gusev (1960). Then the harvested shoots were dried to constant weight at 70° and the values of succulence (ratio of fresh weight/dry weight) were calculated according to Tiku (1975). The dried plants were then thoroughly ground to fine powder and the content of potassium was determined in the digested material using Jenway flame photometer as described by Eppendrof and Hing (1970). Soluble carbohydrates content was also determined by the method described by Dubois *et al.,* (1956). Zinc was determined by the method described by A.O.A.C. (1980). The obtained results were subjected to statistical analysis of variance according to method described by Snedecor and Cochran (1982).

Results and discussion

Effect of irrigation intervals and foliar treatments on vegetative growth of Jojoba

Negative relationship was obtained between prolonging irrigation interval and growth criteria. Prolonging the intervals between irrigations to 7 days decreased plant height, number of branches, number of nodes/branch, shoot dry weight and shoot/root ratio by 18.73, 26.50, 27.36, 27.38 and 25.17 % compare to irrigation every 3 days, respectively. In spite of that jojoba considered drought resistant plants, the prolonging irrigation intervals had significant effects on growth of plants (Table 2). This may be due to the negative effect on soil moisture conditions mainly in depression of water availability and absorption of nutrients (Hussein and El-Diweny, 2011 and Michelazzo *et al*., 2011), photosynthesis and protein building (Sinniah *et al*., 1998; Pettigrew and Dowd, 2011; Hussein *et al*., 2012 and khalil *et al.,* 2012), enzymes and hormonal imbalances and /or disturbance in oxidative defense system (Sade *et al.,* 2011, Abogadallah, 2011 and Beis and Patakas, 2012). In this regard, El-Tomi (1982) studies the effect of three levels of irrigation (namely irrigation after the depletion of 40%, 70% and 100% available water) on the growth of jojoba plant. The results indicate that the vigorous vegetative growth expressed as: plant height, diameter of plant crown, number of main branches, number of leaves and number of internodes, were achieved under the first and second irrigation levels, where the differences in most cases were not significant. Nelson, *et al.* (1993) noticed that withholding irrigations for part of the jojoba growing season can improve flower and bud survival. On the other hand, prolonging irrigation intervals insignificantly affected root dry weight, this could be due to lower water supply causes the root system to penetrate deeper and extending wider in the soil with higher root system researching for moisture in lower. These results were in agreement with those obtained by Soad (2005).

Application of ascorbic acid (antioxidant) or zinc and potassium nitrate (foliar fertilizers) enhancing the growth characters but application of potassium nitrate was the superior followed by ascorbic acid treatment (Table 3). Beltagi (2008) mentioned that the biochemical functions of ascorbate have been divided into four categories, (1) antioxidant, regenerates the lipophilic antioxidant-tocopherol, vitamin E; (2) enzyme cofactor for hydroxylase enzymes involved in the synthesis of hydroxyproline-rich glycolproteins, cell wall structural proteins;; (3) electron transport, acts as an in vitro electron donor and acceptor in transmembrane electron transport; and (4) oxalate and tartarate synthesis. Hussein *et al.,* (2012) demonstrated that proline increased the growth parameters of jatropha plants grown under stress conditions.

Exogenous application of ascorbic acid (vitamin C) induces anabolic changes for salt tolerance in chick pea (*Cicer arietinum* L.) plants Roosta and Hamidpour (2011) concluded that foliar application of K, Mg and Zn increased fruit number, growth and yield of plants compared to control. These results indicated that foliar application of some elements can enhance growth and effectively alleviate nutrient deficiencies in tomatoes. This may be due to its roles in enzymes activities and adjusting of water status in plant tissues. Potassium has the major role in osmoregulation, photosynthesis, transpiration, stomatal opening and closing and synthesis of protein etc. (Milford and Johnston, 2007 and Ali and Mohamed, 2013). Hussein and Orabi (2008) on onion and Hussein *et al.,* (2009) on cotton found that antioxidants application via leaves had positive effect on growth of plants.

The interactive effect of foliar treatments and irrigation intervals on growth characters were illustrated in Table (4). Application of ascorbic acid as well as zinc and potassium nitrate led to improve these growth parameters. Moreover, KNO_3 was the superior among over the other treatments. Furthermore, shoot to root ratio lowered by widening of irrigation intervals but foliar treatments improved it and diminished the adverse effects of drought. Bybordi (2012) stated that in general, ascorbic acid and silicium were involved in the defensive mechanisms against stress and it can be suggested that, ascorbic acid and silicium application had positive effect on canola growth under stress conditions. El-Ashry *et al*., (2005) reported that the negative effect of drought on growth of wheat can be decreased by spraying K, plants translocate this K to all its parts, in turn yield per plant increased. Aown *et al.*, (2012) emphasized that foliar application of K at critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive.

Effect of irrigation intervals and foliar treatments on some physiological aspects of Jojoba

Widening of periods between irrigations from 3 to 7 days induced decrements in zinc and potassium concentrations as well as the values of succulence and drought susceptibility index (DSI). On the contrarily, total chlorophyll, soluble carbohydrate, osmotic potential and proline was increased with these treatments (Table 5). This may be due to the vital roles of water supply at adequate amounts for different physiological processes such as photosynthesis, respiration, transpiration, translocation, enzyme reaction and cell turgidity occurs simultaneously. Moreover, this may be due to proline metabolism which is a typical mechanism of biochemical adaptation of plants subjected to stress condition. Proline is considered as a cell stabilizer for osmotic potential and some enzymes synthesis. Greenway and Munns (1980). Khalil *et al.*, (2012) found that increasing water stress significantly retarded growth attributes and RWC%. On the contrary, increasing severity of drought caused a significant increase in osmotic pressure and soluble carbohydrates%. Foliar treatments markedly increased the content of chlorophyll a+b, potassium and zinc as well as succulence value and DSI, while osmotic potential, proline content and percentage of soluble carbohydrates significantly decreased compared with control plants. Sankar *et al.*, (2007) indicated that proline content and g-glutamyl kinase were significantly enhanced and proline oxidase activities were reduced. Mohammadkhani and Heida (2008) showed a higher amount of soluble sugars and a lower amount of starch were found under stress. Soluble sugars concentration increased (from 1.18 to 1.90 times) in roots and shoots of both varieties when the studied varieties were subjected to drought stress, but starch content were significantly decreased (from 61.6 to 84%) in both varieties. This suggests that sugars play an important role in osmotic adjustment in maize. The free proline level also increased (from 1.56 to 3.13 times) in response to drought stress. Hussein and El-Dwieny (2011) demonstrated that the uptake of N, P, K, Fe, Mn and Cu decreased as a result of missing of irrigation and on the contrary the uptake of Zn was increased in fenugreek plants. Wang *et al.*, (2012) showed that foliar Zn application significantly improved the grain Zn concentration of maize by 27% and 37% and of wheat by 28% and 89% during the first and second growing seasons, respectively. They added that, grain Fe concentrations during both growing seasons were also enhanced by foliar Zn application. The foliar application of Zn realized higher grain Zn recoveries of 35.2% and 42.9% in maize as well as 26.4% and 32.3% in wheat during the first and second growing seasons respectively. Cakmak (2008) stated that zinc is an essential component of a large number of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients and plays an important role in the production of biomass. Arjenaki *et al.*, (2012) showed that chlorophyll content, relative water content (RWC), ions concentration of K and Na made difference between resistance and susceptible genotypes. Bybordi (2012) pointed out that ascorbic acid application improved photosynthesis and seed yield and mitigated antioxidant enzyme activity. In addition, nitrate reductase activity and chlorophyll *a* and *b* were positively affected by ascorbic acid.

Shahri *et al.*, (2012) mentioned that regarding the limitation of water resources, application of Zn could be used as a good strategy for yield sustainability of sunflower under drought stress. From the results obtained by Amin *et al.*, (2009) it seems that ascorbic acid can considerably alleviate oxidative damage that occurred under drought stress condition. Therefore, we concluded that ascorbic acid in the concentration 1 mM can mitigate drought stress. Majlesy *et al.*, (2012) concluded that in drought stress, using potassium with micronutrients leads to improvement of growth index, therefore under these conditions using these nutrients is recommended in Urmia.

Table (6) illustrated the data of the effect of different foliar treatments i.e. ascorbic acid, zinc and potassium on jojoba plants. The differences in chemical constituents measured herein i.e chlorophyll content, soluble carbohydrates, proline and zinc and potassium concentrations and moisture status parameters as osmotic potentials, succulence and drought susceptibility as a result of these treatments were significant. In fact, potassium content increased by spraying KNO_3 and zinc content by spraying Zinc EDTA while chlorophyll concentration, succulence and drought susceptibility index showed its higher values by KNO_3 , while control treatment (tap water) recorded the highest content of soluble carbohydrates and proline as well as osmotic potential values, In this concern, Cakmak (2008) stated that zinc is an essential component of a large number of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients and plays an important role in the production of biomass. Ayad *et al.*, (2010) reported that all criteria of vegetative growth expressed as plant height, fresh and dry weight of plants were significantly affected by application of the two factor used in this study. They added that, foliar application of putrescine and zinc as $ZnSo_4$ promoted all the above mentioned criteria, especially at 20 mg/L putrescine and 200 mg/L zinc sulphate. Chemical constituents i.e. chlorophyll (a). chlorophyll (b) and protein content were increased at all concentrations of the two factors especially at 40 mg/L zinc. Treatment 200/L mg/L zinc followed by that of 40mg/L putrescine were more effective for decreasing lipid peroxidation.

Table (1) Soil mechanical and chemical analysis

Sand %	89.13
Silt %	3.51
Clay %	7.36
Textural class	Sandy soil
Na^+ (mg/100 g)	35.25
pH	8.01
EC (mmohs/cm)	0.78
Organic matter %	0.82
Available N ppm	13.25
Available K ppm	26.54
Available P ppm	10.23

Table (2) Effect of irrigation interval treatments on vegetative growth of Jojoba

Irrigation interval	Plant height (cm)	Number of branches/plant	Number of nodes/branch	Shoot dry weight (g)	Root dry weight (g)	Shoot / root ratio
Every 3 days (control)	53.28	13.13	11.51	24.8	5.47	4.53
Every 5 days moderate water stress	47.95	10.82	9.34	20.12	5.21	3.86
Every 7 days moderate water stress	43.3	9.65	8.36	18.01	5.32	3.39
LSD 5%	3.69	0.87	0.74	1.62	N.S	0.31

Table (3) Effect of foliar treatments on vegetative growth of Jojoba

Foliar treatments	Plant height (cm)	Number of branches/plant	Number of nodes/branch	Shoot dry weight (g)	Root dry weight (g)	Shoot / root ratio
Tap water (control)	46.73	10.86	9.43	20.33	5.22	3.90
200 ppm Ascorbic acid	48.63	11.33	9.81	21.13	5.39	3.91
300 ppm Zn-EDTA	47.60	11.08	9.66	20.82	5.36	3.88
2.0% KNO_3	49.73	11.52	10.04	21.63	5.37	4.02
LSD 5%	3.91	0.92	0.80	1.69	N.S	0.32

Table (4) Effect of interaction between irrigation intervals and foliar treatments on vegetative growth of Jojoba

Irrigation interval	Foliar treatments	Plant height (cm)	Number of branches/plant	Number of nodes/branch	Shoot dry weight (g)	Root dry weight (g)	Shoot / root ratio
Every 3 days (control)	Tap water (control)	52.30	12.92	11.36	24.48	5.25	4.66
	200 ppm Ascorbic acid	53.60	13.22	11.50	24.78	5.57	4.45
	300 ppm Zn-EDTA	52.60	13.02	11.51	24.80	5.56	4.46
	2.0% KNO_3	54.60	13.34	11.68	25.16	5.51	4.57
Every 5 days moderate water stress	Tap water (control)	46.60	10.47	9.02	19.44	5.02	3.87
	200 ppm Ascorbic acid	48.30	10.89	9.41	20.28	5.33	3.80
	300 ppm Zn-EDTA	47.60	10.71	9.25	19.93	5.15	3.87
	2.0% KNO_3	49.30	11.19	9.67	20.84	5.33	3.91
Every 7 days severe water stress	Tap water (control)	41.30	9.19	7.92	17.07	5.38	3.17
	200 ppm Ascorbic acid	44.00	9.87	8.51	18.34	5.26	3.49
	300 ppm Zn-EDTA	42.60	9.51	8.23	17.73	5.36	3.31
	2.0% KNO_3	45.30	10.02	8.77	18.90	5.28	3.58
LSD 5%		5.78	1.34	1.17	2.52	N.S	0.47

Table (5) Effect of irrigation interval treatments on some physiological aspects of Jojoba

Irrigation interval	Chlorophyll a+b mg/g fresh wt.	Soluble carbohydrates %	Proline content (ppm)	Potassium content (mg/g dry wt.)	Zinc content (ppm)	Succulence	Osmotic potential	Drought Susceptibility Index (DSI)
Every 3 days (control)	4.17	31.72	220.58	13.75	34.74	3.21	6.67	101.84
Every 5 days moderate water stress	4.34	32.29	231.26	12.30	31.36	3.07	7.84	85.19
Every 7 days moderate water stress	4.39	33.91	309.96	11.66	27.74	2.86	9.68	78.47
LSD 5%	0.25	1.92	17.02	0.73	1.90	0.17	0.47	5.26

Table (6) Effect of foliar treatments on some physiological aspects of Jojoba

Foliar tretments	Chlorophyll a+b mg/g fresh wt.	Soluble carbohydrates %	Proline content (ppm)	Potassium content (mg/g dry wt.)	Zinc content (ppm)	Succulence	Osmotic potential	Drought Susceptibility Index (DSI)
Tap water (control)	4.11	33.16	265.88	12.24	28.72	2.92	8.38	85.92
200 ppm Ascorbic acid	4.21	32.79	258.36	12.47	29.77	3.02	8.21	89.19
300 ppm Zn-EDTA	4.39	32.54	248.39	12.55	36.00	3.10	7.95	88.05
2.0% KNO_3	4.49	32.08	243.10	13.01	30.62	3.14	7.70	90.83
LSD 5%	0.27	2.07	15.86	0.80	2.03	0.19	0.50	5.64

Table (7) Effect of interaction between irrigation intervals and foliar treatments on some physiological aspects of Jojoba

Irrigation interval	Foliar treatments	Chlorophyll a+b mg/g fresh wt.	Soluble carbohydrates %	Proline content (ppm)	Potassium content (mg/g dry wt.)	Zinc content (ppm)	Succulence	Osmotic potential	Drought Susceptibility Index (DSI)
Every 3 days (control)	Tap water (control)	3.92	32.13	229.98	13.42	32.00	3.05	6.98	100.00
	200 ppm Ascorbic acid	4.10	31.83	225.25	13.56	33.21	3.20	6.74	102.08
	300 ppm Zn-EDTA	4.23	31.61	215.10	13.67	39.58	3.30	6.55	102.12
	2.0% KNO_3	4.43	31.31	211.99	14.36	34.15	3.31	6.42	103.17
Every 5 days moderate water stress	Tap water (control)	4.13	32.79	247.83	12.08	28.92	3.02	8.14	82.26
	200 ppm Ascorbic acid	4.23	32.50	232.54	12.22	29.89	3.03	8.02	86.13
	300 ppm Zn-EDTA	4.46	32.27	225.53	12.24	35.88	3.06	7.65	84.36
	2.0% KNO_3	4.52	31.61	219.15	12.65	30.74	3.18	7.54	88.01
Every 7 days severe water stress	Tap water (control)	4.27	34.56	319.82	11.22	25.25	2.71	10.03	75.50
	200 ppm Ascorbic acid	4.29	34.04	317.30	11.64	26.20	2.84	9.87	79.37
	300 ppm Zn-EDTA	4.49	33.75	304.54	11.75	32.54	2.93	9.65	77.68
	2.0% KNO_3	4.51	33.31	298.16	12.02	26.98	2.94	9.15	81.32
LSD 5%		0.39	3.01	23.08	1.16	2.95	0.28	0.74	8.21

Moreover, Bybordi (2012) pointed out that ascorbic acid application improved photosynthesis and seed yield and mitigated antioxidant enzyme activity. In addition, nitrate reductase activity and chlorophyll a and b were positively affected by ascorbic acid**.**

Data of the interaction between irrigation frequency and some foliar treatments effects on some physiological aspects on jojoba plants were noted in Table (7). Zinc and potassium concentrations were increased in plant tissues by application of its sources under different irrigation regimes used in this work. It is also shown from these data that the highest values for potassium content, succulence and DSI were recorded in jojoba plants irrigated every three days and sprayed with $KNO_{3.}$ On the other hand, plants irrigated every 7 days and sprayed with tap water recorded the highest values for the content of soluble carbohydrates and proline as well as osmotic potential values.Mean while, the highest values for Chlorophyll a+b were recorded in jojoba plants irrigated every 5 days and sprayed with KNO_3.

Conclusion

Growing of Jojoba in new reclaimed sandy soil could be a good solution to use these unused huge or in the marginal areas beside the desert in Egypt for oil and biofuel production. Foliar application with potassium, zinc or ascorbic acid positively affected all the growth and physiological criteria as well as drought tolerance of the tested plants. Foliar treatments with potassium surpass the other treatment. However, additional research to identify the agronomic treatment for this plant is important in developing strategies for their use for biofuel production. Looking at such promise, it might be an alternative for other oil producing plants such as oil palm, especially for less humid areas.

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