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Evaluation of Growth Parameters for *Jatropha curcas* L. (Biofuel Plant) under Salinity and Water Stress Using Tensiometer for Irrigation Guiding

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Energy and water scarcity has become a major challenge in many regions of the world. Egypt is an arid/semiarid region with limited fresh water resources. So, a field study was conducted to investigate the growth responses of biofuel plant (*Jatropha curcas* L.) to a range of soil matric and osmotic potentials with foliar salicylic acid applications. Waters used were four different salinity levels, ranged from 0.32 to 7.0 dS m-1, and irrigation management was provided three different levels of soil matric potential: -6, -8 and -12 kPa. Irrigation process was guide lined using vacuum-gauge Tensiometer. Lab. pre-experiment indicated that relationship between Tensiometer readings and their corresponding soil moisture contents did not appear variation in the range of -6 to -15 kPa soil matric potential (where irrigation was managed). Therefore, Tensiometer apparatus could be used to guide irrigation process through a wide range of saline water on sandy soil. Obtained results indicated that, on early-growth stage, the most potential vegetative growth was performed when Jatropha irrigated with salinity level of 0.32 dS m-1 under matric potential ranged from -8 to -15 kPa, and there was no significant difference with that irrigated with 2.3 and 4.7 dS m-1. Therefore, and based on relationship among salinity, matric and osmotic potential, soil osmotic potential must be ganged from 2.5 to 7.5 bar to obtain potential vegetative growth. Regardless of salinity level, application of 5 mM SA can increase the vegetative growth characters under -8 to -15 kPa and appeared to give the most potential compared to 0 and 10 mM. Curves of J. crop coefficient, KC, were constructed over four years growing period. Such curves could provide facility for accurate irrigation schedule under similar studied region. Because of obtained results showed that both vegetative growth and seeds achieved the most performance under -8 to -15 k Pa , it is necessary to multiply KC values by 0.65. Additionally, weak sloping of curves indicates that Jatropha shrub already has low water requirements, particularly in the first three years. The most potential growth and capsule yield at mature stage was performed under treatment in which soil osmotic potential reached 2.9 bar (fresh water) compared to that of 7.2 bar (4.7 dS m-1). Application of 5 mM SA had a positive effect on both vegetative growth and capsule yield with 4.7dS m-1 salinity treatment, compared to those with fresh water. Also, values of leaf relative water content calculated at mature stage indicated that, there was no water deficit in leaf tissues between fresh irrigated and salt-stressed plants.

Introduction

Jatropha (*Jatropha curcas* L.) has the potential to become a key biofuel crop with a good production in arid and semiarid regions. Powdered seed coat can be used as an adsorbent for removal of some heavy metals from wastewater, additionally; seed cake could be used as organic manure (Augustus et al. 2002; Jain et al., 2008 and Hsu et al., 2014). Jatropha is native to South America but now thrives in many parts of the tropics and subtropics in Africa and Asia (Kumar & Sharma, 2008 and Niu et al., 2012). To avoid the competition with food production, marginal land and poor quality

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water must be targeted for producing bioenergy crops. Marginal lands are most likely located in the arid and semiarid regions in many parts of the world, characterized with low fertility, and high water quality is not available or extremely limited (Kang et al., 2013).

Rhoades et al. (1992) reported that, water generally classified as unsuitable for irrigation can be used successfully, with the use of improved farming and management practices. According to their classification, three levels of saline water used in the current investigation lying in moderately saline class. In most cases, when saline water used for irrigation, only soil water content is considered, while the effect of salinity on moisture content, particularly, at the low levels is neglected. Beltrao and Asher (1997) found that, as salinity level increase soil water content at wilting point was higher than at low level, resulting in an insufficient amount of available water.

Egypt suffers from limited water resources; in addition it has some marginal lands. Evapotranspiration, consequently, plant growth can be affected by soil salinity since soil water uptake can be drastically reduced due to the higher osmotic potential in soil. Reduced water uptake under saline conditions is shown by symptoms similar to those caused by drought (Katerji et al., 2000). Although, some investigators reported that Jatropha has high yield potential and can be grown well under stress conditions, enough quantitative data have not been presented (Openshaw, 2000, Dagar et al., 2006, Achten et al., 2008, Abou Kheira & Atta, 2009 and Ye et al., 2009). However, it was noted a conflict of research results about the tolerance of Jatropha toward salinity. For example, Dagar et al. (2006) evaluated the utilizing of saline water for an economic use of abandoned semiarid lands. They found that Jatropha was grown successfully with saline water of 12 dS m-1. On the other hand, Aparecida et al. (2009) found that Jatropha irrigated with saline water of 3.0 dS m-1 had significant reduction in growth parameters compared to that irrigated with 0 .9 dS m-1.

Effect of soil moisture content on growth and yield in Jatropha was covered in some studies. For example, Jayasundara et al. (2014) found that decreasing soil moisture content at early growth stage up to 60 – 50% (depletion level) was directly negatively affected the vegetative plant growth, consequently, economic yield. On the other hand, Perez-Vazquez et al (2013) found that Total dry matter and chlorophyll at 40, 60, and 80% soil water content (SMC) were statistically similar, but different from 0 and 20% SMC. In arid regions where irrigation is the most limited factor for crop production, it is imperative to have complete information for economic production of Jatropha for maximum utilization. Kumar and Sharma (2008) stated that Jatropha can be grown in low to high rainfall areas either in the farms as a commercial crop or on the boundaries as a hedge to protect fields from grazing animals and to prevent erosion. According to Achten et al. (2008), and to our knowledge, there are little quantitative or no detailed information on water demand, water productivity, and crop coefficient for Jatropha are available.

Plants initially perceive environmental stresses and activate a range of defensive mechanisms. These mechanisms may also be induced or enhanced by the application of some chemicals to the plants. The application of salicylic acid has reported to induce tolerance in plants to many biotic and abiotic stresses (Raskin, 1995, Sticher et al., 1997, Janda et al., 1999 and Najafian et al. 2009). Salicylic acid (SA) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant (Hussein et al., 2007). Data obtained by Najafian et al. (2009) showed that SA treated plants had greater shoot and root dry weights when exposed to salt stress, where SA increased photosynthetic rates and nutrient uptake. Based on the above mentioned, current investigation aimed to study the following objectives: 1) Effect of salinity on SMC-Tensiometer reading relationship, to detect the suitability to use Tensiometer for guiding irrigation with different salinity water. 2) Improve J. curcas growing by addition SA under saline and water stress and 3) Determine J. curcas coefficient, KC, to facilitate the calculation of irrigation water requirement.

Materials and Methods

Lab. pre-experiment (Tensiometer experiment)

A Lab. experiment was conducted to check the behavior of Tensiometer readings in sandy soil irrigated with different levels of saline water as responded to soil moisture content. Four vacuum-gauge Tensiometers, 60 cm in length, were prepared and sited vertically in 4 well drained sandy soil pots. Each pot was packed with the same field soil (*i. e.,* on which experiment was carried out). Directly before Tensiometer siting, each pot was reached to its field capacity with specified saline water, and then exposed to evaporation. Four different salinity levels were used: 0.32 dS m-1 (fresh water), additionally, 5.7; 10.2 and 14.7 dS m-1 (as diluted sea water). The pots (included Tensiometers) were always refilled by its specified water quality. This experiment was monitored and recorded for five months.

Field experiments: early-growth and mature stages (conducted through four years)

Experiment design and plant material

At the Horticulture Farm, Suez-Canal Univ., Ismailia, Egypt, a field experiment was conducted on sandy soil, from 2012 to 2015. Some physical and chemical properties of soil used are presented in Table 1. Seeds of Jatropha curcas have been planted directly in soil on Mid-October- 2011. In plantations established, spacing applied were 2.5 m between and 2.5 m within rows, giving plant densities of 1600 plants ha-1. As factorial experiment, treatments were achieved in a randomized complete blocks design with three replications (three plants in each replicate). A mixed NPK fertilizer (6:10:6) was added at a rate of 1 g L-1. The micronutrients were also added as mixed fertilizer at a rate of 1 g L-1, foliar sprayed. Then, data obtained for each parameter were subjected to ANOVA using General Linear Model. Means of interaction effects were compared using Duncan at 5% level of probability when F-ratio was significant. Data were analyzed by SPSS program.

Irrigation management and water preparation

Early-growth stage

Based on the results of Tensiometer experiment, irrigation management included three irrigation scheduling ways were achieved. The first was to let soil matric potential ranged from -6 to -15 kPa (represented control: at whole soil field capacity, F.C.); the second ranged from -8 to -15 kPa (represented 0.65 from soil F.C.); and the third ranged from -12 to -15 kPa (represented 0.4 soil F.C.). In order to, create different soil osmotic potentials, three levels of water salinity, EC, were prepared by diluting sea water, and gave 2.3, 4.7 and 7.0 dS m-1, in addition to the control (fresh water, 0.32 dS m-1). Each water quality was applied through the three scheduling ways.

Mature stage:

when plants reached the fourth year, specific treatments (*i. e.* -8 to -15 kPa soil matric potential, 4.7 dS m-1, 0, 5, and 10 mM SA) considered as recommendation from field observations of the first and second year, were applied. For all experiments, amount of water applied under each irrigation scheduling was calculated based on soil moisture depletion (SMD) theory. Meteorological data (from 2012 to 2015) was collected from NASA agency-site online and Ismailia Central Lab. then integrated in Penman-Monteith equation (programmed using C++ language) to obtained ETO values for the study suit. Salt accumulated in soil was periodically leached.

TABLE 1. Effect of acetic acid concentration on mechanical properties of rice straw pulp at 140^{o}C for 90 minutes

Acetic acid concentration	Breaking length, m	Tensile index, Nm/g
30%	441.25	29.43
40%	425.4	28.33
50%	365	24.39

Salicylic acid preparation and spraying rate

SA was dissolved in absolute ethanol and then added drop wise to water (ethanol : water, 1:1000, v/v), according to Williams et al. (2003). Three levels of SA solutions (0, 5 and 10 mM) were prepared as foliar spray, and pH of all solutions was set to 6. SA spraying was applied monthly, while untreated plants received ethanol : water 1:1000, v/v over the application times.

Data recorded

At the end of each experiment the following data were recorded: some vegetative characters such as relative growth rate (RGR), total leaf area (TLA), leaf dry weight (LDW), leaf relative water content (RWCL, calculated according to Yamasaki and Dillenburg, 1999) and seed yield, additionally to Na concentration in leaves.

Results and Discussion

Lab. pre-experiment

Effect of water salinity on moisture-tension relationship

The current field experiment was designed so that irrigation (using different saline waters) ranged from -6 to -15 kPa, where many studies agreed that Jatropha plants can tolerate a lack of soil moisture to degree greater than other crops. The higher concentration of soil solution, the smaller (more negatively) the soil osmotic potential, which means that crop wilts sooner and at higher soil water content than in non-saline soil. Also, based on the findings of Beltrao and Asher (1997), increasing salt concentration in the soil from 1 to 6.2 dS m-1, led to an increase in moisture content at wilting point. They studied three different soil textures: Sand, loam and clay. Their results showed that at high salinity, water content at wilting point was higher than at low salinity, particularly for the clayey soil. Because of soil used in this investigation was sandy, there was an urgent need to know the possibility of confidence in Tensiometer for guiding the irrigation process with different saline waters. So, vacuum-gauge Tensiometers were prepared and sited in pots packed with the same study soil. Each soil pot was binged to its field capacity using specified saline water. Four different salinity levels were used, namely: 0.32 dS m-1 (fresh water), additionally, 5.7; 10.2 and 14.7 dS m-1 as diluted sea water. Curves presented in Figure 1 (a, b, c and d) were plotted on semi log scale, and revealed the relationship between soil moisture contents and their corresponding Tensiometer readings under different saline waters.

Results showed that Tensiometer readings and corresponding soil moisture contents did not appear differences in the range of -6 to -20 kPa when water salinity ranged from 0.32 to 14.7 dS m-1. Figure 1 indicated that, only under 10.2 and 14.7 dS m-1 treatments, results were similar to those obtained by Beltrao and Asher (1997) where soil moisture content closed to wilting point (soil matric potential increased than -20 kPa, i. e. out the rage of irrigation management). Moreover, they found that evapotranspiration has been reduced by 33%, when water salinity increased from 1 to 6.2 dS m-1, and this was similar to that obtained by Jamieson et al (1995). Usually, this behavior resulted in low water consumption, therefore, yield reduction. The obtained results showed that soil moisture contents did not appear differences with the corresponding Tensiometer readings, and it could be explained based on the fact that, clayey soil has precise texture, so it may provide a semi permeable membrane. Such condition permits to appear salts effect, which is in contrast to sandy soil. Also, it could be said that, when saline water add to clayey soil there is a chance for adsorption of cations and anions on clay surfaces, so, hydration and water retention occurred. Based on the above mentioned, it can be argued that it is possible to guide the irrigation process for plants irrigated with different saline waters on sandy soil using Tensiometer apparatus.

Figure 1 Relationship between soil moisture contents and Tensiometer reading under different saline waters in sandy soil.

Field experiment: Early-growth stage

Vegetative growth as responded to soil matric potential (water content)

One aim of this study was to detect the performance of Jatropha under three different ranges of soil matric potential, namely; -6 to -15, -8 to -15 and -12 to -15 kPa. Generally, matric potential increased as the water content decreased, and declined thereafter as water either evaporated or consumed by plants. Table 2 showed the effects of interaction between water salinity and soil matric potential on vegetative growth of Jatropha at early-growth stage, where all data was recorded at 0 mM SA.

Data in Table 2 showed that most vegetative growth characters (*i. e.* total leaf area, leaf dry weight and relative growth rate) were significantly

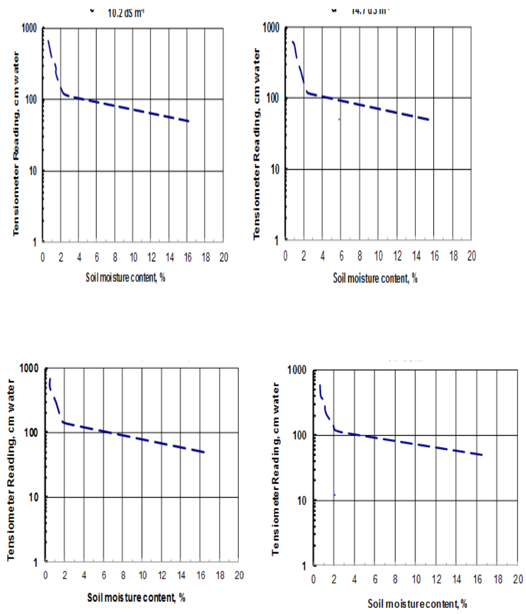

Fig. 1 Relationship between soil moisture contents and Tensiometer reading under different saline waters in sandy soil.

TABLE 2. Effects of interaction between water salinity (EC_w) and soil matric potential (ψ_m) on vegetative growth of Jatropha at early-growth stage.

EC_w, dS m^{-1}	Range of ψ_m, kPa	TLA, cm^2	RWC_L, %	RGR	LDW, g $plant^{-1}$	Na, %
0.32	-6 to -15	437.2d	85.53ab	0.47d	1.79c	0.44
	-8 to -15	5769.a	92.95a	1.76a	33.80a	0.35
	-12 to -15	3559bc	90.15ab	1.39abc	23.98ab	0.40
2.3	-6 to -15	448.7d	85.53ab	0.43cd	1.48c	1.00
	-8 to -15	4767.ab	92.95a	1.60ab	27.93ab	1.06
	-12 to -15	2941. c	90.15ab	1.26bc	19.82ab	0.86
4.7	-6 to -15	300.7d	80.29ab	0.31cd	1.15c	0.98
	-8 to -15	4765.ab	83.84ab	1.56ab	23.07ab	0.80
	-12 to -15	2729.c	86.74ab	1.13c	14.18bc	1.32
7.0	-6 to -15	323.3d	84.63ab	0.23cd	1.78c	1.20
	-8 to -15	3491.bc	77.55a	1.25bc	18.77b	1.00
	-12 to -15	780.7d	87.65ab	0.53cd	4.88c	1.02

All data was recorded at 0 mM SA.
-6 to -15 kPa = soil F.C.
-8 to -15 kPa = 0.65 F.C.
-12 to -15 kPa = 0.4 F.C.

affected by interaction between water salinity and soil water content. Data also indicated that, the most effective treatments for growth characters values were occurred when Jatropha plant irrigated with 0.32 dS m-1 salinity level under 65% soil F.C. (*i. e.* soil matric potential ranged from -8 to -15 kPa), but without significant difference with those irrigated by 2.3 and 4.7 dS m-1.

This result is in good agreement with that reported by Perez-Vazquez et al (2013), who found that total dry matter at 40, 60, and 80% soil water content were statistically similar, but different from 0 and 20% soil water content. On the other hand, reduction in the same vegetative characters under 0.4 F.C. was to somewhat agreed with that obtained by Jayasundara et al. (2014). Reyadh (2002) concluded that Jatropha can stand long periods of drought by shading most of its leaves to reduce transpiration loss, while Jamieson et al. (1995) and Najafian et al. (2009) reported that in case of water shortage, stomata close, resulting in decreased transpiration. Salicylic acid is a central compound in the defense of closes stomata in several species.

The effects of interaction between salicylic acid application and soil matric potential on vegetative growth of Jatropha at early-growth stage are illustrated in Table 3. Data were recorded with fresh water treatment, and showed that most vegetative growth characters (*i.e.* total leaf area, leave dry weight and relative growth rate) were significantly affected by interaction between SA and soil water content. In general, data indicated that the most effective treatment for growth characters was found when plants irrigated with fresh water at 65% F.C., without significant difference with those at 100% F.C. treatment, particularly, with SA spraying.

Data indicated that, SA application either at 5 or 10 mM may be resulted in negatively impact on plant growth. In other words and regardless salinity level, spraying with SA of 0 mM increased the measured vegetative characters under 65% F.C. and appeared to give the potential growth compared to other treatments.

TABLE 3 Effects of interaction between salicylic acid (SA) and soil matric potential (ψ_m) on vegetative growth of Jatropha shrubs at early-growth stage.

SA, mM	Range of ψ_m, kPa	TLA, cm^2	RWC_L, %	RGR	LDW, g $plant^{-1}$	Na, %
0	-6 to -15	437.2c	85.53abc	0.47bc	1.79b	0.44
	-8 to -15	5769.a	92.95a	1.76a	33.80a	0.35
	-12 to -15	3559. b	90.15ab	1.39a	23.98a	0.40
5	-6 to -15	350.8c	76.42de	0.38c	0.61b	0.28
	-8 to -15	484.3c	83.66bcd	0.47c	0.89b	0.31
	-12 to -15	329.5c	77.71cde	0.57b	1.12b	0.40
10	-6 to -15	190.8c	69.81e	0.30c	0.52b	0.42
	-8 to -15	388.0c	80.69cd	0.36bc	0.83b	0.42
	-12 to -15	198.8c	79.00cd	0.39c	0.56b	0.43

All data was recorded under fresh water treatment
-6 to -15 kPa = soil F.C.
-8 to -15 kPa = 0.65 F.C.
-12 to -15 kPa = 0.4 F.C

Vegetative growth as responded to water salinity

Additionally to fresh water (EC of 0.32 dS m-1) three levels of diluted sea water were used for irrigation, namely: 2.3, 4.7 and 7 dS m-1. Table 4 included the above mentioned vegetative growth characters as affected by the interaction between water salinity and SA concentration, when plants irrigated to 100% soil F.C.

Table 4 showed that most vegetative growth characters were significantly affected by interaction between water salinity and SA concentrations. Data indicated that, the most effective treatment for growth characters was found when Jatropha irrigated with water of 4.7 dS m-1, and sprayed with SA of 5 mM. Application of 5 mM SA was positively affected the growth characters at salinity level of 4.7dS m-1 compared with 0 or 10 mM. Similar results were obtained by Rady (1990), Rhoades et al. (1992), Dagar et al. (2006) and Kotoky et al. (2015). At the same effort, Fujimaki and Kikuchi (2010) reported that Jatropha is not more tolerance either to drought or to salinity compared to other major crop such as soybean or wheat.

It is noted from Tables 3 and 4 that Na concentration with 5 mM SA treatment was lower than that with 0 and 10 mM, particularly, under fresh water and 4.7 dS m-1. Abdi et al. (2011) found that plants sprayed with SA showed lowest amount of Na uptake and accumulation. They reported that tolerance to salinity involves processes in many different parts of the plant. One of these mechanisms may be exclusion of Na+ from the shoots by retaining it in root and lower stem. Also, they suggested that alteration of mineral uptake from SA applications may be one mechanism for alleviation of salt stress, and positively affected K+/Na+. Similar explanation was reported by Schachtman et al. (1991) who found that SA application may resulted in restore the ionic homeostasis and to keep the cytoplasm of actively growing or photosynthesizing cells of free of Na+ as possible.

Vegetative growth and yield of mature stage as responded to water salinity and SA

Effects of interaction between water salinity and SA application on some vegetative growth, seed yield and Na concentration of Jatropha shrubs at mature stage are listed in Table 5. Data showed that, both studied vegetative growth characters (i. e. total leaf area, relative growth rate and leave dry weight) and seed yield were significantly affected by interaction between water salinity and salicylic acid concentration.

TABLE 4 Effects of interaction between water salinity (EC_w) and SA concentrations on vegetative growth characters of Jatropha at early-growth stage

EC_w, dS m^{-1}	SA, mM	TLA, cm^2	RWC_L, %	RGR	LDW, g $plant^{-1}$	Na, %
0.32	0	437.2a	85.5ab	0.47a	1.79b	0.44
	5	360.8b	76.4cd	0.38a	0.61b	0.28
	10	190.8b	69.8d	0.38a	0.52b	0.42
2.3	0	448.7ab	85.5ab	0.43a	1.48b	1.00
	5	477.7ab	76.4cd	0.45a	2.10b	0.89
	10	210.0b	69.8d	0.33a	1.7b	1.41
4.7	0	300.7b	80.3bc	0.31a	1.15b	0.98
	5	450.5a	84.5ab	0.61a	2.27a	0.76
	10	269.0b	76.7cd	0.55a	1.90b	1.31
7.0	0	323.3b	84.7ab	0.23a	1.78b	1.40
	5	349.0b	90.3a	0.25a	1.27b	0.72
	10	180.0b	90.3a	0.29a	1.15b	1.10

All data was recorded under 100% soil F.C. treatment

TABLE 5. Effects of interaction between water salinity (EC_w) and SA spraying on some vegetative growth, seed yield and Na concentration of Jatropha shrubs at mature stage

EC_w, dS m^{-1}	SA, mM	TLA, cm^2	RWC_L, %	RGR	LDW, g $plant^{-1}$	Na, %	Seed yield, g $plant^{-1}$
0.32	0	57520 a	83.70 a	2.58 a	496.13 a	0.40	72 c
	5	19050 bc	86.36 a	1.26 c	149.70b	0.52	98.7 a
	10	25274 bc	85.40 a	0.96 c	234.05b	0.46	83.7 ab
4.7	0	17229 bc	84.17 a	1.29 c	129.11b	0.91	58.8 bc
	5	41350 ab	89.83 a	2.25ab	352.17ab	0.88	106 a
	10	12254 c	86.18 a	1.40 bc	123.11b	1.14	83 ab

Mean with different letter in the same column are statistically different ($p \leq 0.05$).
Irrigation management was ranged from -8 to -15 kPa (max. SWC 0.65% soil F.C.).

The most effective treatments for growth characters were occurred when Jatropha shrubs irrigated by salinity level of 0.32 dS m-1, but without significant difference with that irrigated with 4.7 dS m-1, particularly, at 5 mM SA. It's clear that, SA application with 4.7 dS m-1 level increased fruit yield as well as under 0.32 dS m-1 treatment resulted in significantly similar. As regards the impact of water salinity, these results are in agreement with those obtained on Jatropha by (Hussein et al 2013). Application of 5 mM SA affected positively the growth characters at diluted sea water (4.7 dS m-1) compared with 0 or 10 mM SA. The positive effect of SA on growth parameter could be attributed to its bio-regulator effect on physiological and biochemical processes in plants (Raskin, 1992 and EL Tayeb, 2005). Values of RWCL as a character used to assess water status in leaf tissues indicated that there was no water deficits between fresh irrigated and salt-stressed leaves. Some values of correlation coefficient, R2, among the studied characters have been calculated. The values indicated that Na concentration was strong positively correlated with leave dry weight and total leave area, 0.976 and 0.925, respectively. Also, R2 values showed a positive correlation with relative growth rate, 0.510. Also, Significant ($p < 0.05$) positively correlations were found between leaf dry weight and both of total leave area and relative growth rate, 0.955 and 0.500, respectively. This result is in agreement with those obtained by Pinheiro et al. (2008), Saadaoui et al. (2015) and Kotoky et al. (2015). Pinheiro et al. (2008), found that dry matter accumulation of leaves, as well as the total dry matter, increased with plant growth in salt treatments, while, these parameters were lowered in salt-stressed seedlings. Not found correlation between seed yield and any characters may be attributing to genetic variations because original of plant was by seed. Variation is the phenomenon where individuals of a population differ from each other.

Residual soil osmotic potential

Due to irrigation frequency salt tent to concentrate in soil and constitutes salinity hazard. Evapotranspiration, consequently, plant growth could be affected by such condition, since soil water uptake can be drastically reduced due to high osmotic potential build in soil. At moderate salt concentrations of soil solution, plants generally try to exclude unwanted ions, as far as possible, and promote the uptake of nutrients. With increasing salt concentration, the uptake of sodium and chloride ions increases sharply. This luxury consumption of ions is essential for the plants to compensate for the increased outside osmotic pressure but is responsible for growth retardation. According to Roest et al. (1993), the osmotic potential in the root zone is a function of the osmotic potential in the soil solution at field capacity and can be calculated by:

$$\varphi_{as} = \frac{\Theta_{fc}}{\Theta}\varphi_a$$

where = osmotic potential at field capacity (bar), = water content at soil field capacity (m3 m-3), = actual water content at root zone (m3/m3). Using the relationship derived by Abdel-Khalek and Blomer (1984) for saline water used in Eastern Nile Delta of Egypt, value of could be obtained as following:

$$\varphi_a = 0.1409\left[Cl^-\right]^{0.7903}$$

where [Cl-] = Cl- concentration (mol m-3).

At the end of second year, and immediately after fruits collecting, the residual osmotic potential in soil was calculated and listed in Table 6. For both early-growth and mature stages, data indicated that, the higher water salinity, the higher residual osmotic potential in root zone. Moreover, within the same salinity level, soil osmotic potential increased as soil moisture content decreased (*i. e.* increased soil matric potential).

It is well known that there are a magnificent relation between soil moisture content and its osmotic potential. Increasing osmotic potential values under soil matric potential of -12 to -15 kPa compared to the other may built due to the phenomenon of miscible-displacement. In other words, it seems that practice of irrigation that included more water applied may lead to movement and removal of salts for a distance relatively far away from roots. On the other hand, addition of less water may lead to a relative small removal of salts, consequently, increased salt concentration near root zone and thereby raising osmotic potential. This behavior may be supported by the observation of Na concentration determined in plant leaves, where Na was not increased as soil moisture increased (*i. e.* low soil tension).

Figure 2 illustrates the relationship between irrigation water salinity and corresponding osmotic potential residual in soil under the three depletion levels. Curves indicated that, at the same salinity levels, residual soil osmotic potential was increased as depletion level increased. Both horizontal lines a and b represented the values of osmotic potential corresponded to salinity levels from 0.32 to 4.7 dS m-1. Data in Table 2 showed that, the most potential vegetative growth characters were obtained within such salinity levels and soil moisture content of 65% (i. e. -8 to -15 kPa). Therefore, soil osmotic potential must be in the range between 2.5 to 7.5 bar, when soil matric potential ranged from -8 to -15 kPa.

TABLE 6. Values of soil salinity, Cl^- and osmotic potential (calculated using Eq. 1) for early-growth and mature stages

Early-growth stage												
Parameter	EC_{iw} 7.0 dS m^{-1}			EC_{iw} 4.7 dS m^{-1}			EC_{iw} 2.3 dS m^{-1}			EC_{iw} 0.32 dS m^{-1}		
	φ_m Pa			φ_m Pa			φ_m Pa			φ_m Pa		
	-6	-8	-12	-6	-8	-12	-6	-8	-12	-6	-8	-12
EC_{soil}	7.64	9.12	11.4	5.11	5.35	6.04	2.61	4.55	5.59	0.96	1.81	2.63
Cl^-, mol m^{-3}	70	82	110	41	45.5	56.5	20.5	37.5	45.0	5.00	9.00	14.5
φ_s , bar	7.00	10.6	20.9	4.59	6.68	12.3	2.65	5.73	10.3	0.87	1.86	4.21

Mature stage (under -8 to -15 kPa soil matric Potential)			
Treatments (selected)	EC_{soil}, dS m^{-1}	Cl^-, mol m^{-3}	φ_s , Bar
Fresh water: 0.32 dS m^{-1}	2.70	16.0	2.9

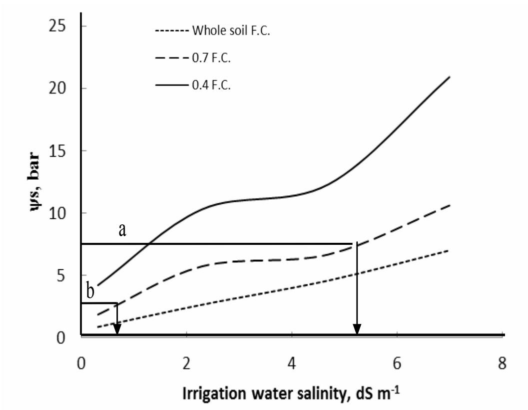

Fig. 2. Relationship between irrigation water salinity, Soil osmotic potential residual and moisture depletion levels

Jatropha curcas crop coefficient, KC.

Optimal water amount at the right time is crucial for optimal plant growth and production. Unfortunately, some investigations reported that limited rainfall amount could be an optimum water requirement for Jatropha, but did not state the growing stage/age for which this amount is required. Therefore, there is no quantitative data on water demand are available at present (Achten et al., 2008 and Sutterer, 2010). Using the actual amounts of irrigation water (at whole soil field capacity) represented J. ETC, and ETO values (obtained using 2012 to 2015 Meteorological data involved in programmed P-M Eq.), J. curcas-coefficient KC values for the four years growing period have been obtained. Figure 3 illustrates changing in KC values throughout the four years. Curves showed that, the decline occurred in crop coefficient values at the beginning and end of each year may attribute to the fact that Jatropha flurried leaves in winter season.

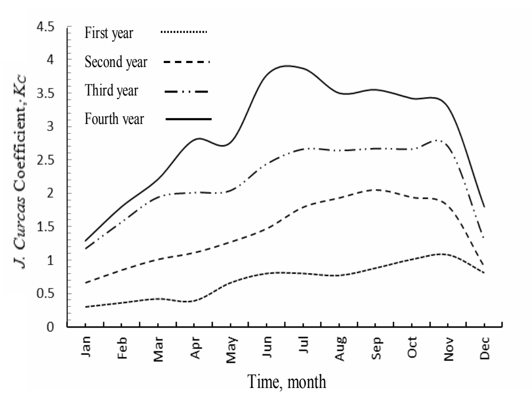

Fig. 3. Change of J. curcas-crop coefficient values through four years growing period

The relatively weak tendency of KC curves, particularly, during the first three years indicates that water consumption for this Shrub is limited. According to what was reported by Jongschaap et al. (2007) that is no study was conducted to evaluate actual water usage in crop production, such KC curves could provide a facility for irrigation water requirement, IWR, calculation. According to the data listed in Tables 2 and 3, the most performance of vegetative growth was obtained when soil irrigated to keep its water content at 0.65 F.C. (*i. e.* -8 to -15 k Pa), therefore, KC values obtained from Fig. 3 must be multiplied by 0.65. Reyadh (2002) explained the extremely low water requirement for Jatropha to that, the shrub can stand long periods of drought by shading most of its leaves to reduce transpiration loss. This species is easy to establish as it has a fast growth, requires minimal amounts of water and survives in poor soils (Henning, 2004 and Valdes et al., 2011). Curve with a solid line shown in Fig. 3 represents the values of crop coefficient for the fourth year. It showed abnormal summits, that is likely attributable to the waves of the high temperatures have occurred in the summer of 2015. Such high temperatures which happened several times may led to high water consumption compared to what happened for ETO values.

Conclusion

To avoid the competition with food production, marginal land and poor quality water must be targeted for producing bioenergy crops. Jatropha can survive and produce full yield with high quality seeds under minimum water requirements compared to other crops. The relationship between compared to other crops. The relationship between Tensiometer readings and their corresponding soil moisture contents did not appear differences in the range of -6 to -15 kPa soil matric potential when salinity level ranged from 0.32 to 14.7 dS m-1. Therefore, Tensiometer could be used to guide irrigation process through a wide range of saline water on sandy soil. The most effective treatment for vegetative growth in early-growth stage was performed when Jatropha irrigated by saline level of 0.32 dS m-1 under soil matric potential ranged from -8 to -15 kPa (0.65% soil F.C.), without significant difference with both irrigated with 2.3 and 4.7 dS m-1. Within such irrigation range, and based on the relationship among salinity, matric and osmotic potential, soil osmotic potential must be ganged from 2.5 to 7.5 bar to obtain the most potential vegetative growth. SA application of 5 mM was positively affected vegetative growth characters, particularly at 4.7dS m-1 salinity level. In mature stage, values of RWCL character indicated that water deficits in leaf tissues did not exist between fresh irrigated and salt-stressed plants. The most potential vegetative growth and capsule yield at mature stage were performed under treatment in which soil osmotic potential reached 2.9 bar (fresh water) compared to that of 7.2 bar (4.7 dS m-1). Application of 5 mM SA had a positive effect on both vegetative growth and capsule yield for 4.7dS m-1 salinity treatment, compared to those for fresh water. It is recommended to interest with breeding for this shrub so can be overcome confusion and mystery resulting from genetic variation because original of plant still by seed.

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تقييم قياسات النمو للجاتروفا (نبات وقود حيوي) تحت إجهاد ملحي ومائي مع إستخدام التنشيومتر لتوجيه عملية الري

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أصبحت أزمة المياه والطاقة واحدة من أكبر التحديات التي تواجه مناطق عديدة في العالم.
تُعد مصر من المناطق التي يتراوح مناخها ما بين الجاف والشبه جاف وذات موارد مائية
محدودة، لذا صُمِمت تجربة حقلية لدراسة مدي إستجابة نمو شجيرة الجاتروفا (Jatropha
كمصدر للوقود الحيوي، وذلك تحت مدي متغير من كلاً من جهد قالب التربة (.curcas L
(ثلاث مستويات رطوبة) والجهد الأُسموزي (أربع مستويات لملوحة ماء الري) في منطقة
جذور النبات. إضافةً لذلك تم رش المجموع الخضري للنبات بثلاث تركيزات مختلفة من حمض
السلسيلك. إستخدم جهاز التنشيومتر ذو عداد تفريغ لتوجيه عملية الري. قبل البدء في الزراعة،
أُجريت تجربة معملية إستمرت خمسة اشهر، كان الغرض منها هو معرفة إلي أي مدي يمكن
أن يؤثر تغير المستوي الملحي للمياه علي العلاقة بين قراءات التنشيومتر والمحتوي الرطوبي
المناظر لها.

دلت نتائج التجربة المعملية لأجهزة التنشيومتر علي أن العلاقة بين قراءات التنشيومتر
وما يقابلها من محتويات رطوبية لم تتغير مع تغير مستويات ملوحة المياه المستخدمة (حيث
تراوحت من 0.32 حتي 14.7 dS m-1)، وذلك خلال مدي من الشد الرطوبي تراوح من
-6 إلي -15 k Pa، وهو نفس المدي الذي كانت تدار فيه عملية الري. مما يدل علي صحة
إستخدام التنشيومتر في أراضي رملية حتي مستوي 14.7 dS m-1 من ملوحة مياه الري. كما
أشارت النتائج إلي أن أفضل معاملة للحصول علي نمو خضري جيد كانت عندما تدار عملية
الري في مدي لجهد التربة يتراوح من -8 حتي -15 kPa وأن النمو الخضري للنبات لم يختلف
معنوياً عندما تراوحت مستويات ملوحة مياه الري من 0.32، 2.3 إلي4.7 dS m-1، وكان
ذلك بالنسبة لمراحل النمو الأولي (حتي عامان). بناءً علي ذلك وعلي العلاقة التي وجدت بين
مستوي ملوحة المياه وجهد قالب التربة والجهد الأسموزي بها، فإن للحصول علي أفضل نمو
خضري يجب أن يتراوح الجهد الأسموزي بالتربة من 2.5 حتي 7.5 بار عندما تدار عملية
الري بين -8 و -15 kPa. أدي الرش بحمض السيلسيلك بتركيز 5 مليمول إلي زيادة خصائص
النمو الخضري تحت مدي جهد قالب التربة -8 إلي -15 kPa مما أعطي أعلي جهد للنمو
مقارنة بتركيز 0 و 10 مليمول. فيما يخص النبات في مرحلة النضج (العام الرابع) تم الحصول
علي أفضل نموخضري وأفضل ثمار "كبسولات البذور" تحت معاملة الماء العذب والتي أدت
إلي جهد أسموزي بمنطقة الجذور يساوي 2.9 بار مقارنة بمستوي 4.7 dS m-1 ماء الري
الذي أدت إلي جهد أسموزي يساوي 7.2 بار. كان للرش بتركيز 5 مليمول حمض سيلسيلك
تأثير إجابي علي النباتات المروية بالمياه المالحة مقارنة بالماء العذب حيث إزداد كلاً من النمو
الخضري وإنتاج البذور. أمكن حساب المحتوي الرطوبي النسبي لأوراق النباتات بإعتباره دليل
علي حالة الإجهاد في أوراق النبات، وذلك للنباتات الناضجة المروية بمياه عذبة مقارنة بتلك
المروية بنفس المقنن المائي من المياه المالحة مع الرش بحمض السلسيليك تركيز 5.0 ملمول.
دلت النتائج علي عدم وجود فروق معنوية بين الحالتين مما يدل علي أن الرش بحمض SA قد
ادي إلي تجنب الإجهاد الناتج عن زيادة الضغط الأسموزي بالتربة. جُمعت بيانات أرصاد جوية
حديثة (من عام 2012 حتي 2015) وذلك من معمل المناخ المركزي للإسماعيلية ومن موقع
وكالة ناسا، وإستخدمت مع لغة البرمجة C++ لتطبيق معادلة بنمان-مونتيث، وتم الحصول
علي قيم شهرية للنتحبخر المرجعي لأربع سنوات الدراسة. بإستخدام كميات المياه المضافة
للنبات في الحقل أمكن إنشاء منحني يبين القيم المختلفة لمعامل المحصول KC علي مدار أربع
سنوات. هذا المنحني من شأنه أن ييسر جدولة المقننات المائية للجاتروفا النامية تحت ظروف
مشابهة لمنطقة الدراسة، حيث أشارت الدراسات السابقة إلي قلة أو عدم إتاحة بيانات دقيقة عن
المقننات المائية لتلك الشجيرة الهامة. إلا أنه من الضروري ضرب قيم KC المتحصل عليها

من المنحنيات في 0.65 حيث أشارت النتائج إلي أن أفضل نمو الخضري وثمري تم الحصول عليه كان عند معاملات الري التي تصل برطوبة التربة إلي 0.65 من سعتها الحقلية (8- حتي -15 kPa). المتحصل عليها أن نبات الجاتروفا KC كما دلت الإنحدارات الضعيفة لمنحنيات