Egypt. J. Soil Sci. **Vol**. **53**, No. 4, pp. 595-611 (2013)

Improving some Physical Properties of Sandy Soil and *Conocarpus erectus* L. Plant Growth by the Application of Hydrogel

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SOIL physical properties of a growing medium are important for optimal plant growth. The present factorial pot experiment was carried out at the Faculty of Agriculture, Cairo University, Giza, Egypt, during two successive seasons of 2010 and 2011. The study aimed at investigating the effects of synthetic commercial amendment (hydrogel) levels applied under two irrigation rates, to assess their influence on some sandy soil physical properties and buttonwood (*Conocarpus erectus* L.) seedlings growth traits. The irrigation rates were 65 and 35% of the available soil moisture depletion (ASMD), whereas the hydrogel levels were 0.00 (control), 0.05, 0.10 and 0.20%. Soil physical properties were evaluated by determining the total porosity, field capacity, wilting point, available water, and soil bulk density. Moreover, the plant height, root length, shoots and roots fresh and dry weights and shoots: roots ratio, as expressions of seedlings growth responses, were also measured. Generally, the sandy soil physical properties as well as the seedlings shoot and root growths were improved by increasing hydrogel concentration in the soil when compared to their controls. The two irrigation rates also affected both of the soil properties and the seedlings growth. Furthermore, the highest concentration of the hydrogel amendment under 35% ASMD prolonged the soil water loss time; increased the field capacity, which reflected on the soil available water; encouraged formation of aggregates that, in turn, decreased the soil bulk densities; and hence improved the seedling shoots and roots growth biometrics. This study demonstrates also that the addition of hydrogel to planting medium under different irrigation rates increases water use efficiency by preventing applied moisture from infiltrating beyond plant root zones and maximizing the portion of applied water available for plant uptake. Thereby amended sandy soil with hydrophilic-gel can be used in arid and semi-arid areas to provide a better environment for seedlings to grow.

Keywords: Soil amendment, Absorbent polymer, Water saving, physical properties, Water use efficiency, Buttonwood.

Fresh water makes up only 0.01% of the world's water and approximately 0.8% of the Earth's surface (Dudgeon *et al.*, 2006). Water is the most important soil physical factor that affects plant growth and survival. Quantification of such growth (*e.g*., height, biomass …, etc.) is relevant to the plant-water relationship

(Orikiriza *et al.*, 2009). Nowadays, one of the global climate change consequences is the increase of drought severity and frequency in many world-wide areas (Luo *et al.*, 2009 and Beniwal *et al.*, 2010). It has been estimated that currently about 28% of the earth's land areas are too dry for plant cultivation and production (Luo *et al.*, 2009).

Reclamation and land utilization of the desert areas are faced by several difficulties. In arid and semi-arid regions, water availability is often the limiting factor determining the size of cultivated areas (Hussien *et al.*, 2012). Thus, conserving irrigation and rainwater for plant growth in water-limiting environments by means of agricultural practices may be an important way to overcome the dilemma of water lack (Al-Humaid, 2005 and Al-Humaid & Moftah, 2007). Otherwise, to make plantation more economically successful, cost effective means that ensure high survival of these newly planted seedlings must be achieved (Thomas, 2008). Early at the end of 1980s, a product called 'moisture retention reagent' (hydrogel) was prepared (Nie *et al.*, 2004). This hydrophilic polymer attracted great deal of research attention due to its intriguing properties and applications especially when the product is applied in planting media (Nie *et al.*, 2004 and Peng *et al.*, 2008). This water-absorbing polymer or soil amendment may enhance plant survival through its ability to imbibe large amounts of water and exhibit high permeability to oxygen, nutrients, and water soluble metabolites, particularly in sandy soils (Al-Humaid, 2005, Al-Humaid and Moftah, 2007, Thomas, 2008; Nguyen *et al.*, 2009, Beniwal *et al.*, 2010, Beniwal *et al.*, 2011 and Guyomard-Lack *et al.*, 2012). In other words, hydrogel functions as an additional water reservoir for the soil-plant-air system (Luo *et al.*, 2009). Due to these properties, hydrogel improves water use efficiency (irrigation effectiveness in terms of plant yield) and dry matter production of plants under drought affected areas (Luo *et al.*, 2009 and Shi *et al.*, 2010). Moreover, hydrogel may last a few years in the soil before they are degraded into non-toxic components (Luo *et al.*, 2009). Encouraging studies were carried out on delaying tree wilting and extending its life and quality during the growth period (Thomas, 2008, Huttermann *et al.*, 2009, Orikiriza *et al.*, 2009, Beniwal *et al.*, 2010, Beniwal, *et al.*, 2011 and Fajardo *et al.*, 2013).

Conocarpus erectus L. is an evergreen dense multiple-trunked shrub (1- 4m tall), which can grow into a tree up to 20m. It belongs to family Combretaceae, is commonly known as buttonwood, and grows in tropical and subtropical regions around the world. The root system consists of lateral and fine roots. The bark is fibrous and moderately thin. Leaves are spirally arranged, somewhat fleshy and with petioles. Inflorescences are terminal and tiny flowers are grouped in spheroidal heads. Buttonwood tolerates compacted soil, air pollution, poor drainage, and drought. It is widely planted as ornamentals in yards, parking lots, streets and parks. The bark and leaves have been used in tannery. Its wood is widely used for high-grade charcoal, as well as for housing constructions. Extracts of the bark are used to treat bleeding gums and skin ulcers. In addition to its ecological and economic importance, Buttonwood is rather frequently used for afforestation in arid and semi-arid areas (Al-Humaid, 2005, Al-Humaid and Moftah, 2007 and Hegazy *et al.*, 2008).

Because of the increasing demand on wood products and biomass for bio-energy, there are currently attempts to increase timber production all over the world. Areas that may be available for this purpose are new desert lands, where lack of water is usually the limiting factor for plantation. To enable poplar cultivation on these water-limiting areas, soil amendment may be required to reduce irrigation frequency and delay the onset of plant wilting. Furthermore, to simulate certain field practices in a controlled and easily managed environment in an attempt to verify certain responses under arid and semi-arid conditions, pot trials are therefore used. Few studies, in this concern, have simultaneously investigated media characteristics and plant growth. Therefore, the main objectives of this study were to: (1) investigate the effect of different hydrophilic polymer (hydrogel) levels on sandy soil physical properties and (2) characterize the growth responses and performances of *Conocarpus erectus* L. seedling shoots and roots to hydrogel amended sandy soils under two irrigation rates in the form of a pot trial.

Material and Methods

Preparation of the soil mixture, plant cultivation, irrigation rates and experimental design

The pot trail was conducted at the experimental field of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza Governorate, latitude 30^o 03' N, longitude 31^o 13' E, altitude 19m ASL, Egypt, during two successive seasons of 2010 and 2011. The weather during the experiment was characterized as sunny hot days and warm nights. Averages of the monthly climatological data of Giza Governorate during both seasons of the experiment are presented in Table 1. Buttonwood (*Conocarpus erectus* L.) seedlings were obtained from a commercial nursery and transplanted to plastic pots (30cm diameter and 21cm height) individually one month prior to the beginning of the experiment. The pots were filled with washed sand, spread outdoors to allow the seedlings to grow under natural conditions and routinely watered two times a week. All seedlings were fertilized with a mixed nitrogen (N), phosphorus (P) and potassium (K) mineral fertilizers (1:1:1) at a rate of 20g/pot as an enrichment dose, according to recommendation rates. NPK sources of the fertilizer mixture were ammonium nitrate (33% N), super phosphate (15% P_2O_5), and potassium sulfate (48% K_2O), respectively. On

April 1st of both seasons as the beginning of the study took place, healthy seedlings of uniformly height were selected (average height was 25±5cm). The soil mixture was then prepared from the previous washed sand and hydrogel (STOCKOSORB cross-linked organic synthetic polymer) in dry form at 0.00 (control), 0.05, 0.10, or 0.20% w:w in the area closed to the seedling roots. Pots were thoroughly watered immediately after placing the hydrogel levels. The layout of the experiment was a factorial randomized complete block design. Initial control pot weight was 24kg of air dry sandy soil. Averages of the physical and chemical characteristics of the soil used at the beginning of the study during 2010 and 2011 seasons are presented in Table 2. Prepared pots were saturated with water by capillarity, drained to the field capacity and subsequently irrigated normally to ensure that all particles had time to become completely wetted. Two irrigation treatments were assessed (65 and 35% of the available soil moisture depletion (ASMD)). Averages of the chemical analyses of the potable tap water used for irrigation during 2010 and 2011 seasons are presented in Table 3. Water application was controlled by daily measurements of the pots soil moistness content through pots daily weighing, in order to detect when the soils need to be irrigated to reach 65 or 35% ASMD and, thereby, determining the total actual evapotranspiration (ETa). Water quantities applied to pots amended with hydrogel at 0.00, 0.05, 0.10, or 0.20% were 0.38, 0.51, 0.62 and 0.87 litres, respectively for 35% ASMD irrigation treatment; whereas they were 0.70, 0.95, 1.15 and 1.62 litres, respectively for 65% ASMD irrigation treatment. These quantities were applied in different irrigation intervals according to irrigation rates and hydrogel levels. Total ETa is calculated by multiplying the values of water quantity/ irrigation by number of irrigations/ season. The irrigation occurred manually to reach the suggested rate. Total ETa under different irrigation rates and hydrogel levels are presented in Table 4.

TABLE 1. Averages of the monthly climatological data of Giza Governorate during 2010 and 2011 seasons.

Months	Temperature (°C)		Relative humidity (%)	Sunshine (h)	ET_0* (mm/day)
	Maximum	Minimum			
April	28.2	12.0	64	9.6	5.1
May	31.7	15.2	60	10.8	6.4
June	34.7	18.8	61	12.0	7.3
July	34.2	20.1	67	11.7	6.8
August	34.3	20.3	70	11.1	6.1
September	32.5	18.5	71	10.3	5.2
October	30.1	16.0	71	9.2	4.2
November	25.3	12.2	79	8.1	2.8

*ET_0: reference evapotranspiration was calculated using Penman-Monteith equation.

TABLE 2. Averages of the physical and chemical characteristics of the soil used at the beginning of the study during 2010 and 2011 seasons.

Parameter	Average value
Physical characteristics	
Practical size distribution (%)	
VCS	5.5
CS	17.7
MS	48.1
FS	24.8
VFS	2.1
Silt + Clay	1.8
Soil texture	Sand
Soil moisture constants (θv %)	
FC (0.1 atm.)	8.2
WP (15 atm.)	2.7
AW	5.5
Chemical characteristics	
pH	7.85
EC (dS/m)	2.03
$CaCO_3$ (%)	0.3
OM (%)	0.05
Soluble cations (meq/l)	
Ca^{2+}	5.7
Mg^{2+}	3.5
K^+	0.2
Na^+	10.9
Soluble anions (meq/l)	
SO_4^{2-}	6.7
HCO_3^-	5.3
Cl^-	8.3

VCS: very coarse sand, CS: coarse sand, MS: medium sand, FS: fine sand, VFS: very fine sand, OM: organic matter.

TABLE 3. Averages of the chemical analyses of the potable tap water used for irrigation during 2010 and 2011 seasons.

Parameter	Average value
pH	7.60
EC (dS/m)	0.45
Soluble cations (meq/l)	
Ca^{2+}	0.8
Mg^{2+}	2.3
K^+	0.1
Na^+	1.3
Soluble anions (meq/l)	
SO_4^{2-}	1.5
HCO_3^-	1.8
Cl^-	1.2

TABLE 4. Total actual evapotranspiration under different irrigation rates and hydrogel levels.

Irrigation rates (%ASMD)	Hydrogel levels (%)	Water quantity/ irrigation (l)	Number of irrigations/ season (2)	Total actual ETa (l) x (2)
65	0.00	0.70	72	50.4
	0.05	0.95	53	50.4
	0.10	1.15	44	50.6
	0.20	1.62	31	50.2
35	0.00	0.38	134	50.9
	0.05	0.51	99	50.5
	0.10	0.62	82	50.8
	0.20	0.87	58	50.5

Soil physical properties measurements

Three samples of each sand-hydrogel mixture were taken at the end of the study of both seasons to determine the soil physical properties according to the methods described by Klute (1986).Volumetric soil water content (θv) was measured by exposing the completely moisture saturated samples to constant atmospheric pressure levels of 0.001 (total porosity (TP) (%)), 0.1 (field capacity (FC) (%)), and 15atm. (wilting point (WP) (%)) using the pressure chamber and membrane. The available water (AW) (%) was calculated by subtracting WP from FC. Soil bulk density (BD) (g/cm^3) was estimated according to a series of cylindrical metallic tubes of 5cm height and 5.1cm diameter with two open ends (core method).

Plant growth traits biometrics

On the end of November, eight plants from each treatment were harvested and separated into shoots (main stem+ branches+ leaves) and roots. Seedling height and root length (cm) were measured, in addition to determining shoots and roots fresh and dry weights (FW and DW) (g). Roots fresh samples were carefully washed thoroughly with tap water in order to get rid of the remaining soil mixture then dried on filter papers and immediately weighed. The seedling parts dry weights were determined by drying samples at 65^{o}C to a constant weight for approximately 48hr. The shoot: root ratio (g/g) was calculated from the obtained dry weights.

Plant water use efficiency calculation

The calculated water use efficiency (WUE) (g/l) of the plant is the outcome of the dried biomass yields (shoots+ roots DWs as average of both seasons) (g) divided by total actual evapotranspirations (ETa) (l) according to Boutraa *et al.* (2010) and Yechun *et al.* (2012) equation as follows: WUE = yield/ ETa.

Statistical analysis

The obtained data of both seasons were statistically analyzed using analysis of variance (ANOVA) to determine the effects of the two factors; the irrigation rates (A) and the hydrogel levels (B) in addition to their interactions. Factor A was comprised of two irrigation rates (65 and 35%) whereas, factor B was comprised of four hydrogel levels (0.00 (control), 0.05, 0.10, or 0.20%), which were replicated four times and each replicate consisted of three seedlings. The total number of seedlings was 96 per season. The ASSISTAT special statistical software was used based on the least significant difference (LSD) test at 0.05 probability level as described by Snedecor and Cochran (1980).

Result and Discussion

Soil physical properties status

Data presented in Table 5 and Figure 1 show the effect of irrigation rates and/or hydrogel levels on the soil physical properties during 2010 and 2011 seasons. Generally, all the soil physical properties measured at the end of the study were positively affected by increasing both the irrigation rates and hydrogel levels as compared to the control soil.

Increasing the irrigation rate to 35% ASMD significantly decreased the soil FC and WP and increased the AW (16.6, 5.0 and 11.6%, respectively for the first season and 17.2, 5.2 and 11.9%, respectively for the second one). Soil amended with high levels of hydrogel, were able to store much more water than those amended with low levels or the control soil. The FC, WP, and AW of pots amended with 0.20% hydrogel were found to hold 131.5, 127.8 and 133.3%, respectively in the first season, and 124.8, 115.4, and 131.1%, respectively in the second one, more than that recorded for the control of both seasons. The interaction of irrigation rate at 65% and hydrogel level at 0.20% presented the highest FC and WP values in both seasons (25.3 and 8.8% in the first season and 25.7 and 9.0 in the second one). On the other hand, the lowest FC and WP values in both seasons were presented from the interaction of irrigation rate at 35% and non-amended soil (10.4 and 3.1% for FC and WP, respectively in the first season and 10.8 and 3.4%, respectively in the second season). The highest AW interacted values (17.1 and 17.4% in the first and second season, respectively) were presented from the highest irrigation rate and hydrogel level during the two seasons. Meanwhile, the lowest AW interacted value (7.1% in the first season) was presented from the 65% irrigation rate and 0.00% hydrogel level.

Regarding the effect of irrigation rates on BD and TP, the results show that increasing irrigation rates from 65 to 35% ASMD decreased both of them during the two seasons. The BD significantly decreased from 1.47 to 1.42g/cm^3 in the first season and from 1.43 to 1.38g/cm^3 in the second one. The TP, on the other hand, significantly decreased from 45.0 to 43.4 and from 45.5 to 44.0% for the first and second seasons, respectively. The highest hydrogel level significantly helped in reducing the BD (1.34 and 1.30g/cm^3 in the first and second seasons, respectively) and increasing the TP (59.7 and 60.1% in the first and second seasons, respectively) of the sandy-amended soil as compared to their controls. Irrigating the non-amended pots at the rate of 65% recorded the highest BD value (1.61 and 1.57g/cm^3 for the first and second seasons, respectively), whereas the lowest BD value was obtained from 0.20% amended pots irrigated at the rate of 35% (1.31 and 1.28g/cm^3 for the first and second seasons, respectively). Otherwise, the highest TP value of the studied soils was obtained from 0.20% amended soil irrigated at the rate of 65% (61.2 and 61.6% for the first and second seasons, respectively) and the lowest TP value was obtained from non-amended soil irrigated at the rate of 35% (29.4 and 30.0% for the first and second seasons, respectively).

TABLE 5. Effect of irrigation rates and/or hydrogel levels on the soil physical properties during 2010 and 2011 seasons.

Irrigation rates (%) (A)	Hydrogel levels (%) (B)	Physical properties				
		TP (%)	**FC (%)**	**WP (%)**	**AW (%)**	**BD (g/cm^3)**
		2010 season				
65% ASMD	0.00	30.1	11.3	4.2	7.1	1.61
	0.05	39.2	15.6	5.9	9.7	1.51
	0.10	49.5	18.4	6.9	11.5	1.41
	0.20	61.2	25.3	8.8	16.5	1.36
Mean		45.0	17.7	6.5	11.2	1.47
35% ASMD	0.00	29.4	10.4	3.1	7.3	1.52
	0.05	38.2	14.1	4.3	9.8	1.45
	0.10	47.9	17.5	5.2	12.3	1.39
	0.20	58.2	24.6	7.5	17.1	1.31
Mean		43.4	16.7	5.0	11.6	1.42
	0.00	29.8	10.9	3.7	7.2	1.57
	0.05	38.7	14.9	5.1	9.8	1.48
	0.10	48.7	18.0	6.1	11.9	1.40
	0.20	59.7	25.0	8.2	16.8	1.34
LSD at 0.05	**A**	**Sig.**	**Sig.**	**Sig.**	**Insig.**	**Sig.**
	B	**0.9**	**0.7**	**0.2**	**0.6**	**0.02**
	AxB	**1.3**	**0.9**	**0.3**	**0.8**	**0.03**
		2011 season				
65% ASMD	0.00	30.6	11.9	4.5	7.4	1.57
	0.05	39.7	16.0	6.1	9.9	1.48
	0.10	49.9	18.9	7.1	11.8	1.37
	0.20	61.6	25.7	9.0	16.7	1.33
Mean		45.5	18.1	6.7	11.5	1.44
35% ASMD	0.00	30.0	10.8	3.4	7.4	1.48
	0.05	38.9	14.8	4.5	10.3	1.41
	0.10	48.6	17.9	5.4	12.5	1.34
	0.20	58.5	25.2	7.8	17.4	1.28
Mean		44.0	17.2	5.3	11.9	1.38
	0.00	30.3	11.4	4.0	7.4	1.53
	0.05	39.3	15.4	5.3	10.1	1.45
	0.10	49.2	18.4	6.3	12.1	1.36
	0.20	60.1	25.5	8.4	17.1	1.31
LSD at 0.05	**A**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**
	B	**1.0**	**0.6**	**0.3**	**0.5**	**0.02**
	AxB	**1.3**	**0.8**	**0.4**	**0.7**	**0.03**

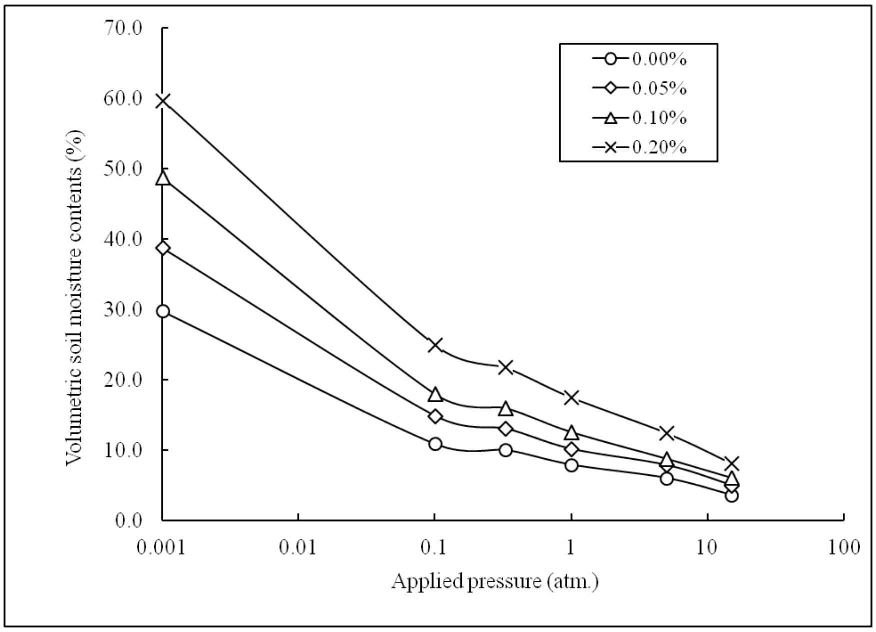

Fig. 1. Soil moisture characteristic curves of sandy- amended soil treated with different hydrogel levels.

The alteration of sandy soil physical properties indicates that adding hydrogel, even at small levels, to the soil increases the period of time at which the soil remains moistness than the control soil. This allows the irrigated water not to be wasted after irrigation, but stored in the soil and released under the mechanism controlled by plant roots absorption and evaporation (Al-Humaid, 2005, Al-Humaid and Moftah, 2007 and Sannino, 2008). In addition, the application of the amendment also encouraged formation of soil aggregates that, in turn, decreased the soil bulk densities. The presented results agree with the findings of Koupai *et al.* (2008) who reported that absorbent polymers positively affect soil density, compactness, texture, aeration, water retention and available water. Bhat *et al.* (2009) also estimated that, in warm and dry climate, applying super absorbent to sandy loam soil at 0.4% lead to 50% lesser irrigation needs of *Conocarpus lancifolius* plants than that of the control and increased the available water capacity from 7.29 (of control) to 18.75%.

Plant growth traits status

The effects of irrigation rates and/or hydrogel levels on growth traits of *Conocarpus erectus* L. seedlings during 2010 and 2011 seasons are shown in Table 6. Generally, buttonwood seedling growth traits were improved by increasing both of the irrigation rates and hydrogel levels as compared to the control.

Plant height and main root length increased as common responses of plants to water availability by increasing the irrigation rates from 65 to 35% ASMD. The plant height significantly increased from 68.64 to 72.88cm in the first season and from 68.28 to 72.65cm in the second one. The noticed significant increases in the root length were from 95.21 to 104.27cm in the first season and from 94.05 to 105.19cm in the second one. Seedlings grown in soil amended with hydrogel exhibited taller seedlings and longer roots percentages than those grown in soil without hydrogel. The highest plant height and root length increment percentages were obtained from soil amended with 0.20% hydrogel more than their controls. They recorded 49.99% in the first season and 43.95% in the second season for the plant height and 51.03% in the first season and 53.46% in the second season for the root length. Regarding the interaction of irrigation rates and hydrogel levels the results show that increasing both factors resulted in the best growth and vice versa. The highest plants and longest roots were recorded for those irrigated with 35% ASMD and grown in sandy-amended soil with 0.20% hydrogel for both seasons (89.38 and 130.60cm, respectively for the first season and 89.60 and 132.60cm, respectively for the second one). The shortest plants and roots were those irrigated with 65% ASMD and grown in sandy-non-amended soil for both seasons (55.25 and 76.30cm, respectively for the first season and 56.85 and 75.00cm, respectively for the second one).

Fresh and dry weights of the shoots and roots were also significantly affected by irrigation rates and hydrogel levels as results of the previous increments. For instance, shoots and roots DWs increased from 62.90 to 66.47g and from 48.21 to 52.13g, respectively in the first season, where they recorded 62.60 to 66.88g and 48.18 to 52.37g, respectively in the second one. By mixing sandy soil with hydrogel at the highest level the shoots and roots DWs recorded increment percentages of 69.48 and 103.52%, respectively in the first season and 74.79 and 98.65%, respectively in the second one more than their control seedlings. Concerning the interaction of the two factors the obtained results show that heaviest shoots and roots DWs were obtained from seedlings irrigated at 35% ASMD and grown in sandy soil mixed with 0.20% hydrogel (85.15 and 70.31g, respectively in the first season and 87.08 and 71.14g, respectively in the second one). Meanwhile, the lightest shoots and roots DWs were obtained from seedlings irrigated at 65% ASMD and grown in sandy soil without hydrogel (47.10 and 31.47g, respectively in the first season and 45.63 and 32.34g, respectively in the second one).

The shoots: roots ratio was insignificantly affected by the irrigation rates during the two seasons (1.33 and 1.30 for 65 and 35% ASMD, respectively in the first season and 1.31 and 1.30 for 65 and 35% ASMD, respectively in the second one). Applying hydrogel at level of 0.20% decreased the ratio to 1.24 and 1.27 for the first and second seasons, respectively whereas, 0.00% hydrogel increased the ratio to 1.49 and 1.44 for the first and second one, respectively. The interaction of 35% ASMD and 0.20% hydrogel level presented the lowest ratio value of 1.21 in the first season. Meanwhile, the interaction of 65% ASMD and 0.00% hydrogel level presented the highest ratio value of 1.50 in the first season.

TABLE 6. Effect of irrigation rates and/or hydrogel levels on growth traits of *Conocarpus erectus* L. seedlings during 2010 and 2011 seasons.

Irrigation rates (% ASMD) (A)	Hydrogel levels (%) (B)	Growth traits: Plant height (cm)	Root length (cm)	Shoots FW (g/plant)	Roots FW (g/plant)	Shoots DW (g/plan)	Roots DW (g/plan)	Shoots: roots ratio (g/g)
		2010 season						
65	0.00	55.25	76.30	98.97	56.50	47.10	31.47	1.50
	0.05	64.55	88.75	113.63	80.58	55.95	44.87	1.25
	0.10	71.90	102.53	138.18	96.51	68.76	53.72	1.28
	0.20	82.85	113.28	177.85	112.77	79.79	62.78	1.27
Mean		68.64	95.21	132.16	86.59	62.90	48.21	1.33
35	0.00	59.58	85.18	105.89	61.19	50.21	33.93	1.48
	0.05	66.78	90.98	120.25	85.24	58.99	47.46	1.24
	0.10	75.78	110.33	143.91	102.09	71.53	56.83	1.26
	0.20	89.38	130.60	189.18	126.30	85.15	70.31	1.21
Mean		72.88	104.27	139.81	93.70	66.47	52.13	1.30
	0.00	57.41	80.74	102.43	58.84	48.66	32.70	1.49
	0.05	65.66	89.86	116.94	82.91	57.47	46.17	1.25
	0.10	73.84	106.43	141.04	99.30	70.14	55.27	1.27
	0.20	86.11	121.94	183.51	119.54	82.47	66.55	1.24
LSD at 0.05	**A**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Insig.**
	B	**4.50**	**4.27**	**7.23**	**5.46**	**4.05**	**3.00**	**0.11**
	AxB	**6.36**	**6.04**	**10.23**	**7.72**	**5.72**	**4.24**	**0.16**
		2011 season						
65	0.00	56.85	75.00	94.93	57.19	45.63	32.34	1.41
	0.05	64.83	88.13	113.04	81.65	55.21	46.17	1.20
	0.10	70.30	100.83	136.97	93.32	69.02	52.73	1.31
	0.20	81.13	112.25	177.21	108.82	80.54	61.51	1.31
Mean		68.28	94.05	130.54	85.24	62.60	48.18	1.31
35	0.00	61.75	84.55	106.44	60.80	50.27	34.44	1.46
	0.05	65.15	91.93	120.78	83.73	59.48	48.62	1.22
	0.10	74.10	111.68	140.81	100.43	70.70	55.28	1.28
	0.20	89.60	132.60	191.99	125.86	87.08	71.14	1.22
Mean		72.65	105.19	140.00	92.70	66.88	52.37	1.30
	0.00	59.30	79.78	100.68	58.99	47.95	33.39	1.44
	0.05	64.99	90.03	116.91	82.69	57.35	47.39	1.21
	0.10	72.20	106.25	138.89	96.88	69.86	54.00	1.30
	0.20	85.36	122.43	184.60	117.34	83.81	66.33	1.27
LSD at 0.05	**A**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Insig.**
	B	**2.69**	**4.05**	**8.21**	**5.87**	**4.21**	**3.24**	**0.11**
	AxB	**3.80**	**5.72**	**11.61**	**8.30**	**5.96**	**4.59**	**0.15**

Optimum plant growth depends on the efficient balance of the roots and shoots. A rapid root system development determines plant growth and survival in any soil type by enhancing lateral and vertical access of water in the soil layers through roots (Thomas, 2008 and Orikiriza *et al.*, 2009). At this concern, and as sandy soil has low water-holding capacity, the hydrogel application at different levels to the rooting medium may absorb and store large amount of water during both irrigation rates and then release water progressively when needed (Al-Humaid, 2005, Al-Humaid and Moftah, 2007, Luo *et al.*, 2009, Lucero *et al.*, 2010 and Shi *et al.*, 2010). This feature of hydrogel helps in improving the root growth and consequently the entire plant growth traits. Moreover, the improved movement of water in the soil-plant continuum would also allow facilitating new root growth which, in turn, decreases in the shoot: root ratio (Viero, 2002). Our data are consistent with previous studies, which demonstrated that application of hydrogels to soil improved plant performance. Al-Humaid (2005) and Al-Humaid & Moftah (2007) indicated that soil amendment at 0.4 to 0.6 % of the hydrophilic polymer can be used in arid and semi-arid areas to provide a better environment for *C. erectus* seedlings to grow. Huttermann *et al.* (2009) grew *Grevillea robusta* seedlings in sand with 0.0, 0.2 and 0.4% amendment polymer under water stress. The results showed that hydrogel amendment enabled the seedlings to survive longer than the control soils. Orikiriza *et al.* (2009) reported that incorporation of either 0.4 or 0.2% hydrogel in sandy soil significantly increased the biomass of roots, stems, leaves and twigs of nine tree species (*Eucalyptus grandis*, *Eucalyptus citriodora*, *Pinus caribaea*, *Araucaria cunninghamii*, *Grevillea robusta*, *Melia volkensii*, *Azadirachta indica*, *Maesopsis eminii*, and *Terminalia superba*) more than the control. In addition to the findings of Fajardo *et al.* (2013) who found that hydrogel improved water supply to seedlings of *Tecoma stans*, *Bulnesia arborea*, *Piscidia carthagenensis*, *Prosopis juliflora* and *Cercidium praecox* that greatly increased their growth and survival.

Water use efficiency status

Impacts of irrigation rates and hydrogel levels interaction averages of both growing seasons on water use efficiency of *Conocarpus erectus* L. seedlings are shown graphically in Fig. 2.

Generally the water quantity per irrigation and number of irrigations per season depended on the hydrogel levels that affected the ETa and in turn affected the WUE. WUE values decreased with increasing ASMD from 35 to 65% and increasing application levels of hydrogel from 0.00% (control) to 0.20%. The interaction values of WUE were 1.67, 2.12, 2.52 and 3.11g/l for 35% ASMD; whereas they were 1.54, 2.01, 2.42 and 2.82 g/l for 65% ASMD at hydrogel levels of 0.00%, 0.05, 0.10 and 0.20%, respectively.

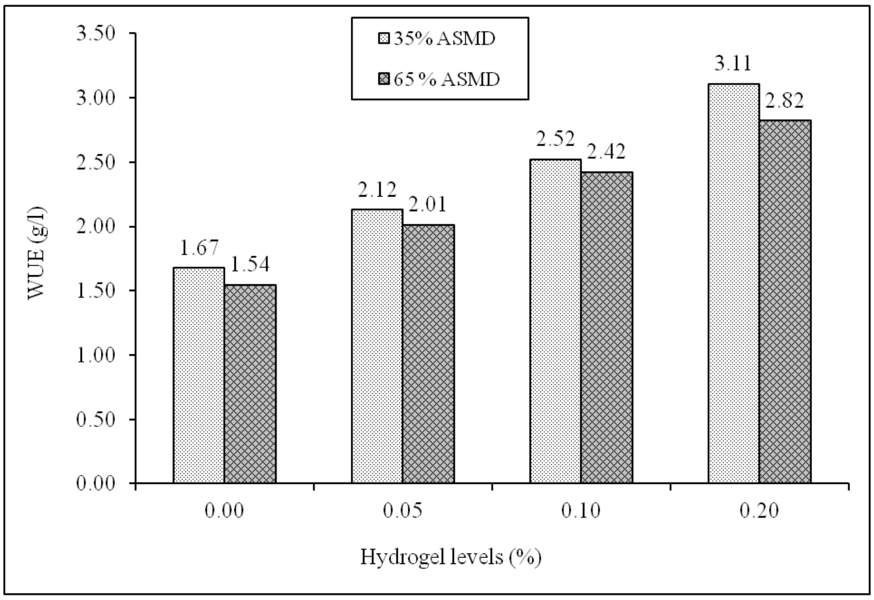

Fig. 2. Impact of irrigation rates and hydrogel levels interaction averages of both seasons on water use efficiency of *Conocarpus erectus* L. seedlings.

The results indicate that irrigating sandy soil at 35% ASMD increases the availability of water for plant to consume, which in turn increases its biomass yield. In contrast, the reduction in yield biomass by increasing soil moisture stress (65% ASMD) may be attributed to the decrease in the soil water availability leading to visible retardation in cell division and elongation (Azab, 1998). Meanwhile the biomass increase by increasing the hydrogel levels may be attributed to decreasing actual evapotranspiration values resulted from encouraging water holding capacity of the sandy soil. This reflects positively on water consumption by roots that help in increasing plant dry matter as compared to the control seedlings. These results were in agreement with Sivapalan (2006) who reported that hydrogel increases water use efficiency of plants and helps in achieving great savings of irrigation water.

Conclusion and Recommendations

The present study is a path to improve water usage in agricultural applications, in terms of water conservation in the soil after irrigation, particularly where water scarcity is a common problem. In conclusion, the hydrogel amended sandy soil for the establishment of *Conocarpus erectus* enhanced both of the soil physical properties and the growth responses of the seedling shoots and roots under the two irrigation rates. The best performance was found to occur at 0.20% hydrogel and 35% ASMD. The available water and soil water retention at suctions of 0.001-15atm. were positively affected. Hydrogel granules increased soil porosity providing a better air to water balance to the roots by its dry form swelling. Moreover, hydrogel increased the water use efficiency of seedlings which helped in improving the entire growth. In addition, the reduction of watering needs may also reduce the labour costs. Further studies should be implemented concerning: field studies, to assess these expectations; the biocompatibility of the hydrogel and how long it last in the soil; and quantifying the costs against the traditional planting methods.

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(*Received* 18 /12/ 2013;
accepted 5 / 1 / 2014)

تحسين الخواص الفيزيائية للتربة الرملية وخواص نمو نبات البيزروميا باضافة الهيدروجيل

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تعد الخواص الطبيعية لبيئة النمو مهمة جدا للنمو المثالى للنباتات . ولذلك صممت تجربة أصص عاملية في كلية الزراعة – جامعة القاهرة – جيزة – مصر خلال الموسميين المتتابعين 2010 و 2011 الهدف منها دراسة تاثير اضافة البوليمرات المحبة للماء (الهيدروجيل) بمعدلات مختلفة تحت معدلين مختلفين لمياة الرى لمعرفة تأثيرهما على بعض الخواص الطبيعية للتربة الرملية وعلى الخواص النباتية لنبات البيزروميا. وكانت معدلات اضافة الهيدروجيل صفر٪ (الكنترول) و0,05 ٪ و 0,10 ٪ و 0,20 ٪ بينما كانت معدلات الرى هى الرى عند استنزاف 35 ٪ و65 ٪ من الماء الميسر.وقد تم دراسة تاثير هذة المعاملات على المسامية الكلية للتربة والسعة الحقلية ونقطة الذبول الدائم ومن ثم الماء الميسر وكذلك الكثافة الظاهرية للتربة.وكذلك تم دراسة بعض الخواص النباتية لنبات البيزروميا مثل طول النبات وطول الجذور والوزن الأخضر والجاف للمجموع الخضرى والجذور وكذلك النسبة بين المجموع الخضرى والجذور. وعموما أظهرت النتائج تحسن كبير في الخواص الطبيعية للتربة وكذلك الصفات الخضرية ونمو الجذور بزيادة اضافة الهيدروجيل. حيث وجد ان أعلى معدل اضافة للهيدروجيل أدى الى زيادة كل من السعة الحقلية للتربة والتى زادت بالتالى من الماء الميسر وكذلك ادت الى زيادة المسامية الكلية للتربة وادت الى نقص قيمة الكثافة الظاهرية للتربة ومن ثم انعكس ذلك بالايجاب على النمو الخضرى والجذرى للنبات. أوضحت الدراسة ايضا ان اضافة الهيدروجيل للبيئة النباتية تحت المعدلات المختلفة لمياة الرى يزيد من كفاءة الاستخدام المائى للنبات حيث انه يمنع فقد الرطوبة من التربة بالرشح ويزيد من درجة تيسر الماء للنبات وبالتالى فان اضافة الهيدروجيل للتربة الرملية وخاصة الموجودة في المناطق الجافة وشبة الجافة يهيأ بيئة صالحة لنمو النبات.