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Water Requirements of Two Landscape Tree Species Grown in Arid Regions

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Abstract. Six-month-old honey mesquite (*Prosopis glandulosa* Torey) and buttonwood (*Conocarpus erectus* L.) tree seedlings were grown under different soil water potentials (Ψ_{soil}) in order to determine the minimum soil water potential at which both species can survive and grow fairly well, and to study the soil-plant water relationship at different irrigation regimes. Results showed that *Prosopis* growth was not affected significantly until soil water potential was lower than -0.12 MPa (between 40 and 30% FC), while *Conocarpus* growth was affected at soil water potential (Ψ_{soil}) of about -0.08 MPa (between 50 and 40% FC). Plant height, leaf area, shoot and root dry weights became disrupted by the interruption in water status as they were severely reduced by soil water deficit. Water stress decreased osmotic potential (Ψ_{π}) of leaves and roots of both species. However, the decrease in Ψ_{π} of *Conocarpus* leaves and roots were much more than that of *Prosopis*. The leaves tended to osmoregulate their cell sap through osmotic adjustment as their content of soluble sugars increased, which was occurred in *Prosopis* at water stress higher than that needed for *Conocarpus*. The positive survival under low Ψ_{soil} could be related to the increased osmotic adjustment. Ψ_{soil} values seem to be a more useful tool than FC values to estimate water requirements, and it can be used over an extended period of time for plant grown under different soil types and different environmental conditions. The study indicates that *Conocarpus* seedlings can withstand reasonable water stress and can survive at moderately low Ψ_{soil}. *Conocarpus* can not be classified as a high drought tolerant or resistant species; while *Prosopis* can survive extremely low Ψ_{soil} and may be classified as drought tolerant species.

Introduction

Honey mesquite (*Prosopis glandulosa*), of family *Leguminosae*, and Buttonwood (*Conocarpus erectus* L.), of family *Combretaceae*, evergreen trees, were found to tolerate extreme desert heat where summer temperature may reach above 50°C and grow in low fertility soil (Levitt *et al.*, 1995). Both species deserve attention because they grow rapidly and can endure the unrelenting fierce tropical sun and can survive the high salinity levels. They provide food and shelter for wildlife, protect the soil from erosion during storms and help fix dunes (Popp *et al.*, 1989). They are widely planted as ornamental evergreen trees in yards, parking lots, streets and parks; and can be used as bonsai potted plants (Gliman and Watson, 1993). The wood is durable and is used to make railroad ties, posts, boat building, fuel and charcoal (Nilsen and Orcut, 1990). The bark and leaves have been used in tannery and folk medicine (Liogier, 1990). Also, they are excellent trees for landscape and afforestation.

Unfortunately, there is little information on the water use and requirements of Buttonwood, as the case in other landscape trees. Most of the information on water requirements of *P. glandulosa* and *C. erectus*, in Saudi Arabia, are based on low-water-use trees recommended by various organizations such as Environmental Protection Agency (Garbesi, 1992) and reported in some literature (Nardini *et al.*, 2000). Lists of these tree species are usually based on empirical observations and the plant's native habitat, due to the lack of data on actual tree water use and requirements. They are also largely based on observations of minimum water requirements and drought survivability rather than actual water use (Levitt *et al.*, 1995). Therefore, some drought-resistant tree species included in these lists may actually be moderate or high water users when water is non-limiting. Mesquite (*Prosopis* sp.) and Buttonwood (*Conocarpus* sp.) trees, for example, are reported to be highly drought tolerant (Gliman and Watson, 1993; Stevens *et al.*, 2001), but their actual water use and requirements are not known.

Most methods of estimating the water use of individually planted trees consist of direct gravimetric measurements such as measuring water consumption or transpiration. Soil moisture readings and potential are useful tools to determine how much water is available for the crop, when to start irrigating, and how much water to apply. The objectives of this study are: 1) to determine the minimum soil water potential at which *Prosopis glandulosa* and *Conocarpus erectus* trees can survive and grow fairly well, 2) to find the relationship between soil water potential and plant water potential at different irrigation regimes, and 3) the comparison between both tree species in response to water stress.

Material and Methods

Field experiments were conducted at the Research Station of the College of Agriculture and Veterinary Medicine in Qassim University, Saudi Arabia during April 5 to September 30, 2006. The weather during the experiment was characterized by sunny, hot, dry days and warm nights. The average daily maximum temperature was 37.6°C with little variation. The daily minimum temperature during the experiment ranged from 15.6 to 28.5°C. No rain had fallen during the experimental period.

Six-month-old honey mesquite (*Prosopis glandulosa* L.) and Buttonwood (*Conocarpus erectus* L.) seedlings were transferred from the nursery and replanted in 30-L plastic containers filled with 40 kg sandy soil each. The seedlings, averaged 84 ± 4.5 cm tall with a caliper of 2.9 ± 0.5 cm at the soil line, were grown outdoors under natural conditions in a shade-free location. The containers were sunken in the ground such that the surface of the potted soil was at approximately the same level of the surrounding ground surface. Empty containers were used as sleeves to line the holes so that the plant-holding containers could be removed and replaced easily. The tops of the containers were covered with white polyethylene film to minimize evaporation.

A completely randomized design with five treatments and six replicates for each treatment was used in this experiment. The seedlings of uniform height (one seedling per container) were located in lines with a spacing of 2 m between lines and 1 m between containers to avoid mutual shading. The ground surface between and surrounding the trees consisted of bare soil. At the time of transplanting, all trees were fertilized with the complete water-soluble fertilizer "Sangral" (William Sinclair Horticulture Ltd., England) compound fertilizer (20N-20P-20K, plus micronutrients) at the rate of 600 kg ha^{-1}. Each tree received a total of 10 g fertilizer.

For the first four weeks, all seedlings were watered to field capacity (FC), supplying an amount of water equal to transpiration losses as the containers were weighed every other day, to ensure the establishment of seedlings and to allow adaptation to the field conditions before drought treatments were imposed. By the end of this period, the containers received an amount of water equal to 100%, 80%, 60%, 40% or 20% of the field capacity and the tree seedlings allowed to grow for eight more weeks. The field capacity was determined gravimetrically and found to be 12%; each water treatment consisted of six seedlings from each species. At the time of transplanting, six seedlings identical to those used in the experiment were separated to roots, stems and foliage, then oven-dried at 70°C for three days until constant weight, and weighed separately.

Measurements

Soil measurements

At each water regime treatment, soil water potential was measured using tensiometers, and soil water content was measured gravimetrically using an electronic balance (Mittler EB60, Hightstown, NJ), as described by (Ranney *et al.*, 1991) and calculated as:

$$\% \text{ moisture} = (\text{soil wet weight} - \text{soil dry weight}) \times 100 / (\text{soil dry weight})$$

The relation between the amount of soil moisture and soil water potential (Fig. 1) was established by the pressure plate apparatus described by (Shock *et al.*, 2002). Briefly, saturated soil samples were set on a plate composed of a porous membrane. The membrane was then placed in a pressure cooker type chamber and sealed. The soil is then subjected to a selected series of pressures. The pressure in the chamber forced the water out the soil through the membrane. After equilibrium was established at each pressure step, a soil sample was taken from the chamber and the amount of water in the soil is determined gravimetrically.

Plant water relations

Leaf water potential was determined in eight randomly chosen leaves from each irrigation regime using a pressure chamber (PMS Instrument Co., Corvallis, OR, USA) as described by (Scholander *et al.*, 1965). The sampled leaves were enclosed in a polyethylene bag just before detaching them from the plant and conserved in a thermal isolated box. The measurements were made as soon as possible using a pressure increment of 0.1 MPa per 2 or 3 s.

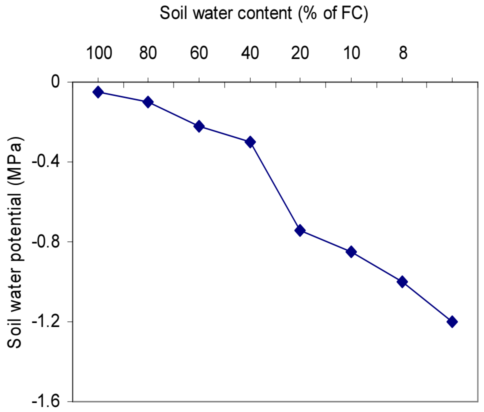

Fig. 1. Relationship between soil water content and soil water potential (MPa).

Osmotic pressure

Osmotic pressure was determined as described by (Ranney *et al.*, 1991). Terminal-fully-expanded and middle leaf and root samples were collected before dawn to minimize variation in solute accumulation during the light period. The roots were excised at a point where the root diameter was 5 mm and included the portion of the root system distal to the excision. Excised tissue was hydrated by re-cutting under water and holding for 2 hours, covered with plastic, in the dark, with the cut end submerged. This method was sufficient to fully rehydrate tissue, i.e., the result in a water potential of 0 MPa. Osmotic potential (Ψ_π) was determined on expressed sap from fully hydrated tissue after freezing and thawing. The osmolality of expressed sap was determined using a vapor pressure osmometer (Wescor Model 5100C, Logan, Utah). Ψ_π of the expressed sap was then calculated for 20°C, based on the van't Hoff relation as given by (Nobel, 1999):

$$\Psi_\pi \text{ (MPa)} = 0.002437 \text{ (m3.MPa.mol}^{-1}\text{)} \times \text{osmolality (mol.m}^{-3}\text{)}$$

Turgor potential (Ψ_p)

Turgor potential was calculated by subtracting Ψ_π from water potential (Ψ_w), and osmotic adjustment was calculated as the difference in Ψ_π at full turgor between control (100% FC) and stressed plants (Blum, 1989).

Soluble sugar analysis

Total soluble sugars were analyzed in terminal leaves, mature leaves and roots after 30 days of irrigation treatments. Soluble sugars were determined using the phenol-sulfuric acid method described by (Dubois *et al.*, 1956) and developed by (Buysse and Merckx, 1993). Briefly, 50 mg of dry leaf powder were extracted with 80% (v/v) ethanol for three times (20 ml). The total volume of the combined and filtered extracts was adjusted to 100 ml using deionized water. One ml of samples was transferred into a glass tube, and 1 ml 18% (w/v) phenol solution was then added. Immediately afterwards, 5 ml of concentrated sulphuric acid were added, and the solution in the tube was mixed using a vortex mixer. The tubes were allowed to stand for 20 minutes, and cooled to room temperature before absorbance was measured with a spectrophotometer at 490 nm (Genesys, Spectronic Instruments, Inc., Rochester, NY, USA). The contribution of soluble sugars to the osmotic potential of the expressed sap was calculated based on the relative dry weight (RDW) at saturation [dry weight / (saturated weight – dry weight)], the solute concentration, and the van't Hoff relation.

Transpiration

Cumulative transpiration was measured gravimetrically and water use efficiency (WUE) was determined by dividing total dry matter production by the cumulative amount of water used throughout the growth period.

Growth analysis

Shoot length, leaf area per plant (measured with a leaf area meter LI-COR Model 3100, Lincoln, NE), and dry weight of plants were recorded at harvest. The decision to harvest any particular treatment was based on the need to do so at the beginning of death symptoms and before deaths began to occur. Dry weights were determined after drying at 70°C for three days till constant weight. The leaves dropped during water-stress treatment were included.

Relative growth rate (RGR)

Relative growth rate was measured according to the equation:

$$\text{RGR} = (\ln W_2 - \ln W_1) / (t_2 - t_1)$$

where "ln" is the natural log and W_1 and W_2 are total dry weight at times "t_1" and "t_2", respectively. The experiment was arranged in a completely randomized design and was analyzed by the analysis of variance.

Statistical analysis

All data were statistically analyzed by the analysis of variance (ANOVA), according to

(Snedecor and Cochran, 1980), with the aid of COSTAT computer program for statistics. Differences among treatments were tested with LSD at 5% level of significance.

Results and Discussion

Soil water at field capacity is readily available to plants and sufficient air is present for root and microbial respiration. The optimum water content for plant growth and soil microbial respiration is considered to be close to the field capacity (FC). Thus, high growth rate is expected to occur at or near FC. The data in Fig. 1 show that, at FC, sandy soil used in this experiment was found to be holding water at a tension of about -0.02 MPa.

Based on our observation, permanent wilting and the symptoms of death didn't appear until soil water potential reached about -1.8 and -1.2 MPa for *Prosopis* and *Conocarpus*, respectively below which plants were not able to tolerate severe drought or re-survive after re-watering. These results indicate that *Prosopis* was able to tolerate higher water stress than *Conocarpus*.

In contrast to (Gliman and Watson, 1993), who reported that *Conocarpus* is a highly drought tolerant trees, the present results indicate that *Conocarpus* seedlings can withstand reasonable soil water stress (less than -1.0 MPa) and can survive at moderately low Ψ_{soil}, but can not be classified as a highly drought tolerant or drought resistant species which can survive at much more lower Ψ_{soil} (Kramer and Boyer, 1995). The differences between the early and the present studies may be attributed to the differences between environmental conditions. Vapor pressure deficit (VPD) between leaves and air is highly depending on environmental parameters that might be differing in both studies.

The seedling growth of *Prosopis* was not affected significantly until soil water content was between 40% and 30% FC (about -0.12 MPa), while *Conocarpus* seedlings were affected at soil water content between 50 and 40% FC (about -0.08 MPa) after which plant height, leaf area, shoot and root dry weights became disrupted by the interruption in water status as they were severely reduced by soil water deficit (Figs. 2 and 3). Leaf area per plant was the most affected growth parameter by low soil-water content causing a considerable reduction in the rate of leaf production, which, in part, accounted for the effect of drought on leaf biomass production. At soil water content of 20% FC (-0.3 MPa) the reduction in leaf area per plant was about 31% and 70% for *Prosopis* and *Conocarpus*, respectively, compared to that at 100%FC (-0.015 MPa). The corresponding reduction in shoot dry weight was about 12% and 40%, respectively, at same soil water content.

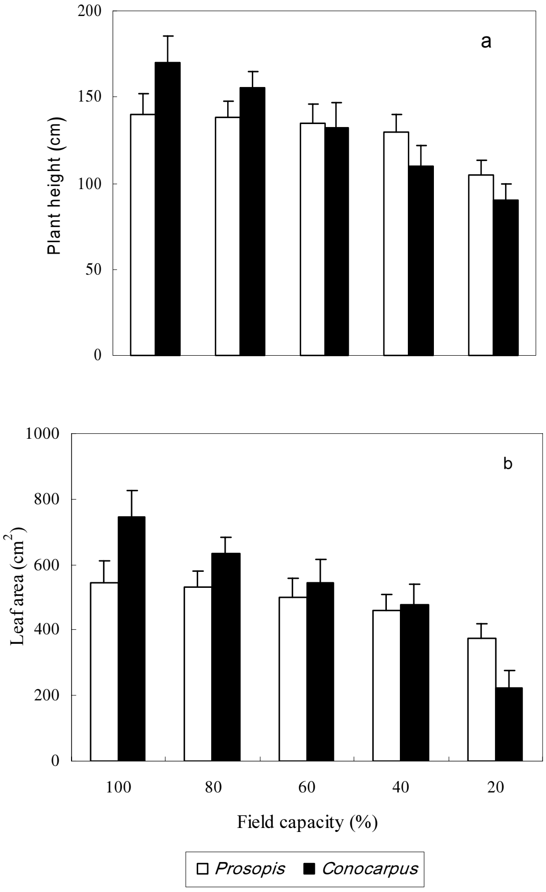

Fig. 2. Effect of soil water content on plant height (a) and leaf area (b) per plant of *Prosopis* and *Conocarpus* seedlings (n = 6).

It is well known that reduction in plant growth is one of the most conspicuous effects of water deficit on the plant and is mainly caused by the inhibition of leaf expansion, and stem and root elongations when water potential decreases below a threshold which differs among species (Kramer and Boyer, 1995; Younis *et al.*, 2000). Because turgor reduction is the earliest significant biophysical effect of water stress, turgor-dependent activities such as leaf expansion and cell elongation are the most sensitive to water deficit. Therefore, a small decrease in plant water content and turgor can substantially decrease the relative growth rate (Fig. 4) and slow down or fully stop growth (Taiz and Zeiger, 2002). Moreover, water deficit episodes in field conditions are frequently associated with high radiation, thus water deficit is an important limitation factor to plant growth and production in arid and semi-arid regions (Delperee *et al.*, 2003).

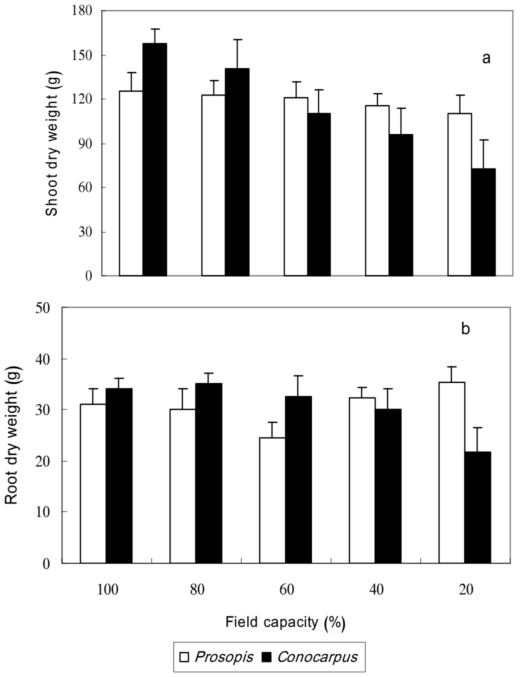

Fig. 3. Effect of soil water content on shoot (a) and root (b) dry weights of *Prosopis* and *Conocarpus* seedlings (n = 6).

Because growth is dependent mainly on cell turgor (Leuschner *et al.*, 2001) and turgor pressure is very sensitive to water deficit, it decreases sharply with little change in plant water content. So, small decrease in water content and turgor can sharply slow down the plant growth of sensitive species such as *Conocarpus*, while the tolerant one such as *Prosopis* can survive comparably higher reduction in turgor.

Root mass production of both species decreases progressively with decreasing soil water potential (Fig. 3). But, the reduction in root mass of *Prosopis* occurred at water potential far less than that of *Conocarpus* which was significantly reduced. This decrease in *Conocarpus* root growth was associated with decreased root osmotic potential (Fig. 5). It appears that osmotic adjustment in roots occurred at soil water potential of -0.6 MPa for *Prosopis* and -0.4 MPa for *Conocarpus* (Fig. 5).

The increase in root/shoot ratio with decreasing water potential indicates the more severe the reduction in shoot than in root growth with decreasing soil water potential (Fig. 4). It is frequently observed that drought increases allocation to roots (Kramer and Boyer, 1995). It may be that abscisic acid (ABA), produced under water stress, plays a role in inhibiting shoot growth, while maintaining root growth (Hsiao and Xu, 2000).

Water stress decreased Ψ_π of *Conocarpus* leaves and roots much more than that of *Prosopis* (Table 1). It is clear that fully expanded upper leaves have higher Ψ_π than lower (older) leaves. Interestingly, when stressed, all leaves tended to osmoregulate their cell sap as leaves adjusted osmotically. As soil water potential fell from -0.02 MPa (100% FC) to -1.0 MPa (40% FC), the upper leaves of *Conocarpus* showed the greatest decrease in osmotic potential (0.60 MPa), while lower leaves typically decreased by 0.47 MPa (Table 2). The leaves of *Prosopis* did not show decrease in their osmotic potential until soil moisture reached about 25% FC.

In both species, roots had substantially higher Ψ_π than leaves. The osmotic potential of *Prosopis* and *Conocarpus* roots were -0.68 and -0.44 MPa, respectively at 100% FC and were -0.67 and -0.83 MPa, respectively at 40% FC (Table 2). The higher osmotic potential of roots than that of leaves is consistent with work done on other woody species, including *Quercus* sp. (Parker and Pallardy, 1988), and *Prunus avium* (Ranney *et al.*, 1991).

In response to water stress, total soluble sugars increased in leaves and roots of both species. However, the increase in sugars were observed in *Prosopis* at water stress values higher than that required for increasing sugars in *Conocarpus*. The estimates of the contribution of total soluble sugars to the Ψ_π of the expressed sap of leaves and roots showed that sugars accounted for a large percentage when plants are exposed to severe drought conditions. At the lowest water regime, the contribution of *Conocarpus* reached about 50-64% in leaves and about 25% in roots (Table 2). Generally, the stress-induced reduction in Ψ_π could be accounted for by increasing the levels of soluble sugars. The capacity for osmotic adjustment via solute, including soluble sugars, accumulation has been reported for many woody plants (Parker and Pallardy, 1988; Ranney *et al.*, 1991). Higher sugars and other solute concentrations contribute to lower tissue osmotic potential, maintenance of turgor potential, and improved tolerance of low tissue water potentials have been also reported (Tyree *et al.*, 2000).

In early studies, Ranney *et al.* (1991) found that the osmotic potentials of expanding terminal leaves of water-stressed apple and cherry trees, respectively, were higher than that of older leaves. Other studies have found that soluble sugars and sorbitol (a sugar alcohol) are synthesized primarily in older leaves. These compounds suggest that osmotic adjustment in expanding leaves resulted either from the increased translocation of soluble sugars and sorbitol to young leaves or from a decreased rate of the metabolism of both compounds. It also resulted in their accumulation in young leaves under water stress conditions without being disruptive to cell organelles, enzymes, and membrane-bound processes (Taiz and Zeiger, 2002; Wang *et al.*, 2003).

Water soluble sugars have been found to be associated with osmotic adjustment in response to water stress in some plant species (Wang *et al.*, 2003; Zhang and Archbold, 1993). In the present study, soluble sugar content was higher under prolonged and severe drought stress conditions than under wet conditions, particularly for *Prosopis glandulosa*. Barathi *et al.* (2001) found that the increases in soluble sugar content during prolonged drought stress were accompanied by decreases of starch, protein, and nucleic acids, which indicates drought injury.

The data in Fig. 6 show that cumulative transpiration was reduced with decreasing Ψ_{soil} particularly at severe drought conditions. The decrease in cumulative water loss was more observed for *Conocarpus* than for *Prosopis*, and may be attributed to the decrease in transpiration rate under water deficit (Kramer and Boyer, 1995). It should be understood that the water potential of the trees was kept relatively high by quite sensitive stomatal control of transpiration (Vogt and Lösch, 1999) and this may contribute to drought survival.

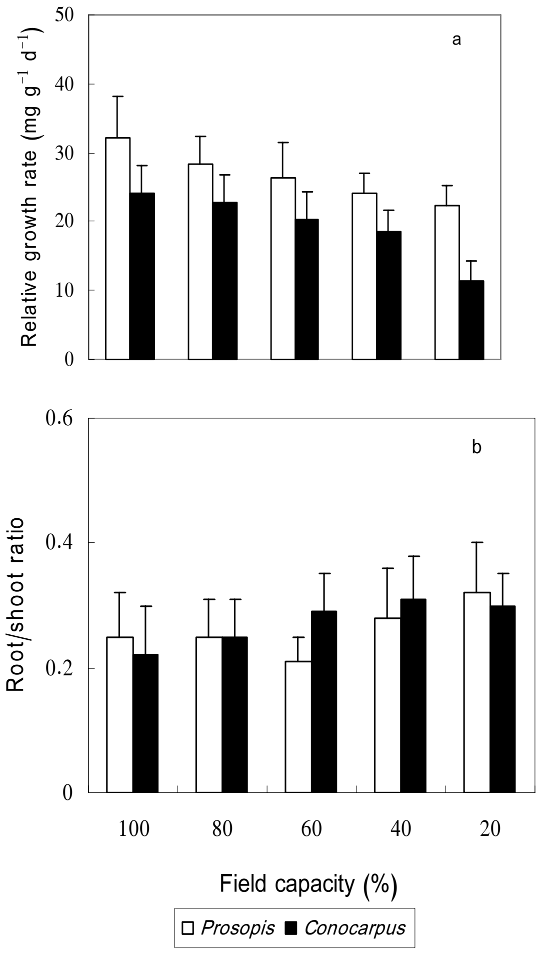

Fig. 4. Effect of soil water content on relative growth rate (a) and root/shoot ratio (b) of *Prosopis* and *Conocarpus* seedlings (n = 6).

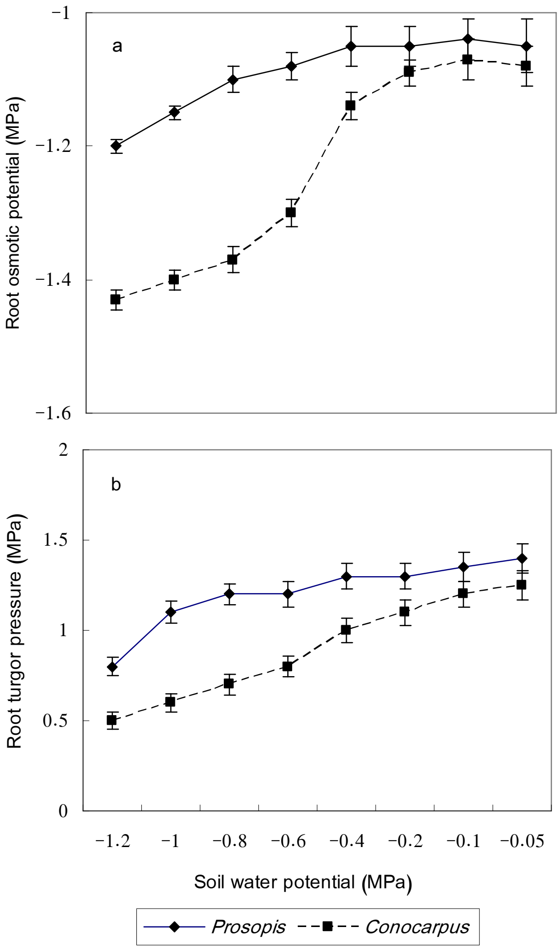

Fig. 5. Effect of soil water potential on root turgor potential (a) and root osmotic potential (b) of *Prosopis* and *Conocarpus* seedlings. Vertical bars indicate standard error of the mean (n = 6).

Table 1. Effect of water regime on total soluble sugar concentration (mmol.kg^{-1} dry wt), and calculated osmotic potential (Ψ_π, equation 2) for fully expanding upper and lower leaves and roots of *Prosopis* and *Conocarpus* seedlings

Water regime (% FC)	Upper leaves		Lower leaves		Roots	
	mmol sugar	**Ψ_π (MPa)**	**mmol sugar**	**Ψ_π (MPa)**	**mmol sugar**	**Ψ_π (MPa)**
			Prosopis			
100	421.3 c	-0.50 c	455.3 c	-0.58 c	166.4 b	-0.15 b
80	442.4 b	-0.62 b	468.8 b	-0.69 b	175.2 b	-0.16 b
60	455.2 b	-0.68 b	471.6 b	-0.74 b	184.8 b	-0.17 b
40	506.8 a	-0.84 a	585.5 a	-1.14 a	322.6 a	-0.20 a
20	525.7 a	-0.87 a	582.4 a	-1.18 a	331.4 a	-0.22 a
			Conocarpus			
100	365.3 c	-0.26 c	415.2 d	-0.41 d	114.5 c	-0.12 c
80	410.7 b	-0.53 b	488.3 c	-0.75 c	165.5 b	-0.14 c
60	482.7 a	-0.88 a	531.5 b	-0.94 b	196.2 b	-0.18 b
40	513.4 a	-0.92 a	622.3 a	-1.22 a	250.1 a	-0.21 a
20	533.5 a	-0.98 a	646.7 a	-1.32 a	271.2 a	-0.23 a

FC = Field capacity; values represent means of 3 measurements. Means followed by the same letter(s) within a column are not significantly different using LSD$_{(0.05)}$ comparisons.

Table 2. Effect of water regime on the contribution of soluble sugars to the measured osmotic potential (Ψ_π) of *Prosopis* and *Conocarpus* leaves and roots

Water regime (% FC)	Upper leaves		Lower leaves		Roots	
	Measu. Ψ_π (MPa)	**%Calc./ Measu.**	**Measu. Ψ_π (MPa)**	**%Calc./ Measu.**	**Measu. Ψ_π (MPa)**	**%Calc./ Measu.**
			Prosopis			
100	-2.6 a	19 b	-2.4 a	24 c	-0.68 a	22 d
80	-2.7 a	23 b	-2.2 b	31 b	-0.67 b	24 c
60	-2.6 a	26 b	-2.1 b	35 b	-0.65 c	26 b
40	-1.8 b	46 a	-2.5 a	48 a	-0.67 b	30 a
20	-2.1 a	38 a	-2.6 a	52 a	-0.66 b	35 a
			Conocarpus			
100	-1.24 c	21 c	-1.45 c	28 c	-0.44 d	27 a
80	-1.46 b	36 b	-1.77 b	42 b	-0.55 c	25 b
60	-1.76 a	50 a	-1.94 a	48 b	-0.64 b	28 a
40	-1.84 a	50 a	-1.92 a	64 a	-0.83 a	25 b
20	-1.88 a	53 a	-1.95 a	73 a	-0.87 a	26 b

FC = Field capacity; Calc. = calculated, Measu. = measured; values represent means of 3 measurements. Means followed by the same letter(s) within a column are not significantly different using LSD$_{(0.05)}$ comparisons.

The results showed a tendency of increasing values of water use efficiency (WUE) with a decrease in the soil water content (Fig. 6). It is clear that WUE increased as Ψ_{soil} decreased till a certain limit then tended to decline at lower water potential. These results agree well with those reported by (Mielke *et al.*, 2000) on *Eucalyptus grandis*. It seems that, under severe drought conditions, *Prosopis* can regulate stomata without prejudicing the amount of water ultimately transpired. It may maintain higher stomatal conductance, and thus probably enables high dry matter accumulation and, as the soil was allowed to dry behind a critical value, both photosynthesis and conductance decreased causing a marked decrease in WUE. Similar relationships were also found on *Quercus alba* (Ni and Pallardy, 1991) and on *Eucalyptus microtheca* (Li, 2000).

Based on the results of this experiment, the use of soil water potential values seems to be a more useful tool than field capacity values for estimating water requirements and use in tree seedlings over an extended period of time. *Prosopis* was found to be drought tolerant species, while *Conocarpus* was found to tolerate a moderate soil water stress over a long period of time than a severe stress for a short time.

Severe drought caused a substantial reduction in the leaf production, which in part account for the effect of drought on plant biomass production. Root elongation decreased progressively with decreasing Ψ_{soil} and was associated with decreased Ψ_π and decreased turgor pressure. The decreased Ψ_π in roots was caused by the accumulation of soluble sugars in the root cells. The relationship between plant growth and WUE may provide a basis for selecting genotypes of trees with improved drought adaptation and biomass productivity.

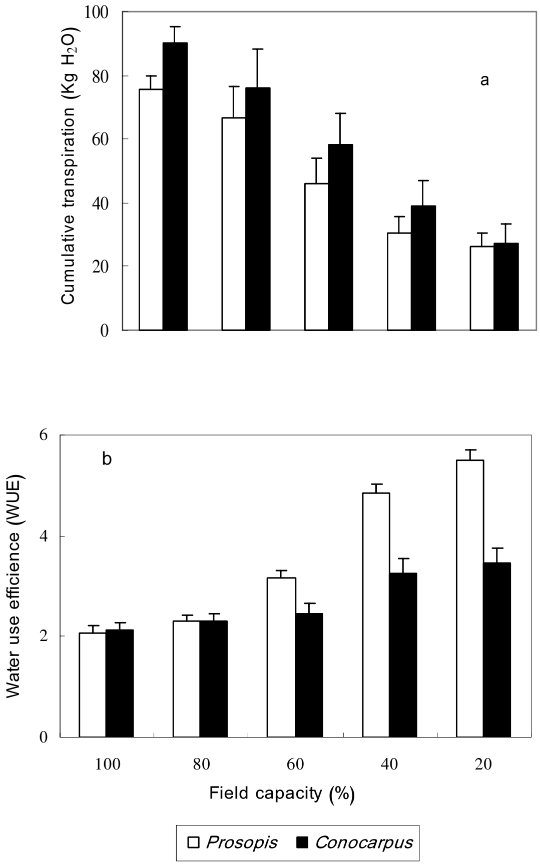

Fig. 6. Effect of soil water content on cumulative transpiration (a) and water use efficiency (b) of *Prosopis* and *Conocarpus* seedlings (n = 6).

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الاحتياجات المائية لنوعين من الأشجار النامية في المناطق الجافة

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كلمات مفتاحية: الإجهاد المائي، البروسوبس، الكونوكاربس، النمو، التنظيم الأسموزي، الجهد الأسموزي.

ملخص البحث. تم تنمية شتلات أشجار من نوعي البروسوبس والكونوكاربس البالغة من العمر ستة أشهر في تربة رملية تحت مستويات مختلفة من الجهد المائي للتربة وذلك بغرض: 1) تقدير أقل محتوى مائي للتربة يمكن لنوعي الأشجار النمو عنده، و2) دراسة العلاقات المائية بين النبات والتربة عند مستويات مختلفة من الجهد المائي، و3) اختبار مقدرة كلاً من البروسوبس والكونوكاربس على التنظيم الأسموزي ومقدرته على تراكم السكريات والمواد الصلبة حتى يتحمل جفاف التربة. وقد وجد أن نمو شتلات البروسوبس لم يتأثر تأثيرًا معنويًّا عند تدني الجهد المائي للتربة حتى -0.12 ميجاباسكال (أي بين 40-30٪ من السعة الحقلية)، بينما تأثر نمو شتلات الكونوكاربس عند جهد مائي -0.08 ميجاباسكال (50-40٪ من السعة الحقلية)، وعندما نقص المحتوى الرطوبي للتربة عن ذلك فإن نمو الشتلات في كلا النوعين، متمثلاً في طول النبات ومساحة الأوراق والوزن الجاف للمجموع الخضري والجذري، قد تأثر كثيرًا بالمقارنة بنباتات المقارنة النامية عند محتوى مائي 100٪ من السعة الحقلية. وقد أدى الإجهاد المائي إلى تناقص الجهد الأسموزي لكل من الأوراق والجذور لكلا النوعين، إلا أنه في الكونوكاربس كان أكثر بكثير من مثيله في البروسوبس. ولجأت الأشجار إلى التنظيم الأسموزي لأنسجتها وذلك بزيادة تركيز السكريات الذائبة فيها، وبالتالي فإن النباتات زادت مقدرتها على النمو تحت ظروف نقص ماء التربة وجفافها. وقد دلت النتائج أيضًا على أن استخدام قياسات الجهد المائي للتربة أفضل بكثيرٍ من الاعتماد على المحتوى المائي للتربة عند دراسة تأثير الجفاف على العلاقات المائية لشتلات أشجار البروسوبس أو الكونوكاربس؛ وعلى هذا الأساس فقد أوضحت الدراسة أن أشجار الكونوكاربس يمكنها تحمل النقص المناسب للماء في التربة لفترات محدودة ولكنها لا تعتبر من الأشجار المقاومة للجفاف، بينما أشجار البروسوبس يمكنها البقاء والنمو تحت مستويات منخفضة جدًّا من الجهد المائي ويمكن تصنيفها ضمن الأنواع التي تتحمل الجفاف الشديد.