Arab Gulf Journal of Scientific Research, 26 (1/2): 1- 9 (2008)

Research Paper **Ref. No 2447**

Regeneration Potential and Growth of Two Indigenous Shrubs in the Desert of Saudi Arabia

إمكانية إكثار ونمو شجيرتان من الشجيرات المستوطنة في صحارى المملكة العربية السعودية

*Ahmed Mohamed Al-Abdulqader *, Tajeldin Hossain Nasroun,*

Shanavaskhan Assnar, and Nasser Salih Al-Khalifah

أحمد محمد العبدالقادر، تاج الدين حسين نصرون،

شانواس خان اسنار، و ناصر صالح الخليفة

**King Abdulaziz City for Science and Technology,*
Natural Resources and Environment Research Institute
P.O. 6086, Riyadh 11442, Kingdom of Saudi Arabia.
Tel. 0096614813302 Fax 0096614813611
E-mail: akader@kacst.edu.sa

Abstract: Ertaa (Calligonum comosum) and Ghada (Haloxylon persicum) are two important multipurpose indigenous shrubs in the deserts of Saudi Arabia, supplying firewood and fodder to the local populations. Their environmental benefits in connection with sand dune fixation and microenvironment improvement are commendable. Due to over-exploitation and habitat destruction, population of these two shrubs have become severely degraded. This study helps in the development of the appropriate propagation techniques for their regeneration and evaluates their relative growth rate under different irrigation schedules. Productivity in the natural population and biological growth under cultivation were also evaluated. Seeds of Ertaa required no special treatment while the seeds of Ghada showed higher percentage of germination when soaked in cold water for 1 hour. The seeds of Ghada are photoblastic, which require adequate light for germination while those of Ertaa are negatively photoblastic. The growth rate of both species under different irrigation schedule proved that the increase of irrigation frequency may not proportionally influence the growth rate. The estimated productivity of natural stands in Saudi Arabia was much less than the productivity of both species from other parts of the world. The estimated biological growth function under cultivation was found to reasonably match with the natural growth for both species, indicating that both species are in their initial growth stage.
Keywords: *Firewood, propagation techniques, irrigation schedules, productivity, biological growth rate, deserts, Saudi Arabia.*

المستخلص: يعتبر الأرطى (Calligonum comosum) والغضا (Haloxylon persicum) من الشجيرات المستوطنة في صحاري المملكة العربية السعودية ذات الإغراض المتعددة الهامة، حيث يتم الاستفادة منهما كمصدر هام لحطب الوقود وأعلاف الماشية إضافة إلى دورهما البيئي كمثبت للكثبان الرملية وتحسين البيئة الطبيعية. لقد أدى الاستغلال المفرط وتدمير المواطن الطبيعية لتجمعات الأرطى والغضا إلى تدهورها الشديد. وتهدف هذه الدراسة إلى دراسة إمكانية استخدام التقنيات المناسبة لإكثار شجيرات الأرطى والغضا وتقييم معدل نموها النسبي باستخدام جدولة مختلفة للري، إضافة إلى تقييم معدل إنتاجية تلك الشجيرات في بيئاتها الطبيعية وتقدير دالة نموها الحيوي. لقد توصلت هذه الدراسة إلى نتائج قيمة ذات أصالة منها أن بذور شجيرات الأرطى لا تتطلب معاملة خاصة للإنبات مقارنة ببذور الغضا التي وجد أن نسبة إنباتها كانت مرتفعة بعد نقعها في مياه باردة لمدة ساعة

واحدة، وأن بذور الغضا تحتاج إلى إضاءة (Photoblastic) كافية للإنبات مقارنة ببذور الأرطى التي تتأثر سلبا في وجود إضاءة (Negatively photoblastic). كما أظهرت نتائج الدراسة عدم تأثر معدل نمو شجيرات الأرطى والغضا بشكل يتناسب مع زيادة فترات الري، وأن متوسط الإنتاجية الطبيعية لشجيرات الأرضى والغضا في المملكة العربية السعودية هي اقل بكثير من إنتاجيتها في أجزاء أخرى من العالم. وبتقدير دالة النمو الحيوي لشجيرات الأرطى والغضا فقد وجد أن الدالة المقدّرة لنمو تلك الشجيرات تتفق إلى حد كبير مع النمو الطبيعي لهاتين الشجيرتين، مشيرة إلى أن شجيرات الأرطى والغضا لا تزال في مراحل نموها الأولى.

كلمات مدخلية : *الحطب، تقنيات الإكثار، جدولة الري، الإنتاجية الطبيعية، معدل النمو الحيوي، صحارى، المملكة العربية السعودية.*

INTRODUCTION

In arid lands, plants play a major role in the productivity and stability of desert environment (Sankary,1978; Farraj, 1989). The vegetation of Saudi Arabia harbors quite a small number of tree species and most of them are indiscriminately exploited for human needs. Forestation is one of the methods used for preventing wind caused soil-erosion and desertification in the sandy deserts (Kebin, 1989). Indigenous multipurpose trees are important natural resources which help arid land populations to combat their major issues like shortage of food, fodder, fuel and other problems related to the harsh environmental conditions (Deborah and Eckman, 1993).

Phog (*Calligonum comosum* L' Her. POLYGONACEAE) also known as Ertaa in Arabic and White saxaul (*Haloxylon persicum* Bunge CHENOPODIACEAE)(Arabic.'Ghada') are two popular psammophytes which are widely distributed throughout arid regions of Asia and Africa. Ertaa, glabrous shrub of about 2m height, have a rigid woody base and very weak green branch-lets, while Ghada, a large shrub or a small tree, 3-4m high, have a woody base and weak pendulous branch-lets. Ertaa and Ghada form the climax vegetation in the sandy soils of the borders between the Saharo-Sindian deserts and the Irano-Turanian steppes, where annual precipitation does not exceed 150mm (Koller, 1956). Both species are considered as perennial pastures, important firewood and excellent binders of shifting sands. They have wide range of distribution in Saudi Arabia, however mainly confined to the sandy areas (Fig.1). Considering the large extent of occurrence, a fairly good area of occupancy and the large number of individuals in the population, Ghada has been regarded at Lower Risk in the Arabian Peninsula. But the poor natural regeneration, seedling mortality, unsustainable exploitation, severe grazing, habitat destruction due to recreational offroad driving, etc., are expediting the population decline. Hence this species in the Arabian Peninsula may be assigned the IUCN status 'near threatened' (Al-Khalifah and Shanavaskhan, 2007). Natural populations of these two species are continuously deteriorating in Saudi Arabia due to anthropogenic interferences viz. illicit cutting of Ertaa and Ghada shrubs to meet the growing demand for firewood. Al-Abdulkader, *et al.* (2004) revealed that demand for firewood products was much higher than the capabilities of the natural vegetation cover, and the extraction rate is much higher than the permissible from these meager natural resources.

There is an urgent need to protect the population of these two important psammophytes in their natural habitats due to different reasons, such as their role in controlling soil erosion, economic uses to mankind, and the threat caused by human interventions. One of the recommended methods for this protection is the development of a vegetation management system. Regeneration capability, productivity for sustainable utilization, investigation of water requirements, estimating the biological growth and demand of the species concerned are the important aspects in the formulation of a vegetation management system.

Analysis of plant growth is an explanatory, holistic and integrative approach to interpreting plant form and function (Hunt, *et al.* 2002), and is an essential step in understanding performance and productivity of plants (Leister, *et al.* 1999), which may reveal different strategies of plants to survive under stringent conditions (El-Lithy, *et al.* 2004). Various parameters have been used to evaluate growth rate, including measurement of fresh or dry weight, root to shoot ratio, shoot number, or shoot length (Li, *et al.* 1998; Leister, *et al.* 1999). The measurement of fresh or dry weight is destructive and hence large numbers of plants are required to properly analyze growth. However, analysis of growth by measuring the area covered by a plant instead of measuring its weight has been applied successfully (Smith and Spomer, 1987; Smith, *et al.* 1989; Motooka, *et al.* 1991).

Regeneration from seeds of Ertaa was never observed and appears to be a chancy and slow process, probably dependent on favorable circumstances (Vesey-Fitzgerald, 1957). Here, an attempt has been made to investigate regeneration, productivity, irrigation requirements and the biological growth of two important psammophytes, Ertaa and Ghada from the sandy deserts of Saudi Arabia for developing a sustainable vegetation management practice.

MATERIALS AND METHODS

This study was conducted in Qassim, located in the central part of Saudi Arabia that falls in the hyperarid zone of the Arabian Gulf, and is characterized by extreme climatic conditions in the form of long hot and dry summers with short cold winters. Fresh seeds of Ertaa (*Calligonum comosum)* were collected in April, 2002, from a few plants in a protected remnant natural population near Qassim. Seeds of Ghada were also collected from the natural population near Qassim in November, 2002. Fresh seeds were subjected to pre-germination treatments such as soaking in cold and warm water for one hour, and acid scarification using concentrated Sulfuric acid (five minutes) along with a control without any pre-treatment. Seeds were then sown in pure sand in containers made of polysterene and watered daily. Five replicates of 50 seeds each were used for every treatment. Data were recorded daily and in the end the results were tested using the methods of analysis of variance and least significant differences (LSD) at 5% probability level ($p<0.05$), according to Snedecor and Cochran (1973).

To evaluate the effect of depth of sowing on seed germination both Ertaa and Ghada seeds were sown in 30 cm high polystyrene pots filled with pure sand at different depths of 0, 1, 2, 3, 5, 10, 15, 20, 25 cm from the surface and watered daily. Five replicates with fifty seeds each were used for every treatment. Seed germination data were recorded daily for a period of one month.

To find out the relative growth rate of seedlings under greenhouse conditions, 40 seedlings of uniform size of each species were transferred to polystyrene pots of 30 cm height containing a mixture of sandy loam, peat moss and perlite in the ratio 2:1:1 as potting medium. All the pots were arranged in a completely randomized design (CRD) with four replicates of 10 pots each were nurtured in a greenhouse with daily watering for one year. After three months, three plants from each set were carefully uprooted and washed. Fresh and dry weights were taken after surface drying and oven drying at 70°C for 72 hours. Fresh and dry weights of the same number of plants were also recorded after 12 months of growth and relative growth rates (RGR) were calculated using the formula $(1/w_1)\ (w_2-w_1/t_2-t_1)$, where w_1 is the dry weight at time t_1, w_2 is the dry weight at time t_2 (Hunt, 1978).

For investigating the water requirement of the two species, an irrigated field plantation trial was established in which seedlings of Ghada and Ertaa were planted in a completely randomized block design (CRBD). The seedlings in each block were subjected to four irrigation regimes, viz., once in a week, once in two weeks, once in three weeks and a control without watering. In each irrigation regime watering was given to the field capacity level. During the course of this experiment, four plants from each block, representing all the treatments were tagged randomly for measuring height and diameter every month. Based on the collected data, the corresponding volume was calculated using the formula $\pi r^2 h$. Data collected from samples after 180 and 360 days were used to calculate relative growth rate using the formula $(1/v_1)\ (v_2-v_1/t_2-t_1)$ where v_1 is the volume at time t_1, v_2 is the volume at time t_2. Relative growth rates were compared by analysis of variance and least significant differences (LSD) at the 5% probability level ($p<0.05$).

Based on the monthly data from the CRBD

experimental measurements over a period of one year (Feb. 2004 – Feb. 2005) and the calculated volume of 'Ghada' and 'Ertaa' specimens, a regression analysis was carried out to estimate the biological growth functions using linear and non-linear functional forms, viz.. linear, cubic, quadratic, and power function forms using SPSS Ver. 14.0 software (2005).

A completely randomized design experiment (CRD) was developed in five natural populations of both the species to estimate the productivity in their natural habitat. Three quadrates of 50x50 m were marked in each population and number of individuals of the species within the quadrate was numbered. Three randomly selected trees were dug out from each population and their fresh and dry weights were recorded

RESULTS

Seed Germination

Results of seed germination tests are presented in Table 1. Fresh seeds of Ertaa sown under greenhouse conditions gave a high percentage of germination without any pre-germination treatments. However, all other samples subjected to other pre-germination treatments responded negatively. In the case of Ghada, cold water treatment was found to be productive. Warm water treatment and acid scarification were found deleterious to both species, though the latter showed a little effect on the germination of Ertaa.

Table 1. Pre-germination Treatments on Seeds of Ertaa and Ghada.

Treatments	**Percentage of germination**	
	Ertaa	Ghada
Control	$74.66^{a} \pm 9.47$*	$40.00^{b} \pm 6.36$*
Cold water	$62.00^{a} \pm 4.24$*	$80.00^{a} \pm 4.24$*
Hot water	0^{b}	0^{c}
Conc.H_2SO_4	$66.00^{a} \pm 5.25$*	0^{c}
LSD P=0.05	13.16	9.6

Numbers followed by the same letter superscript are not significant; * *Standard error*

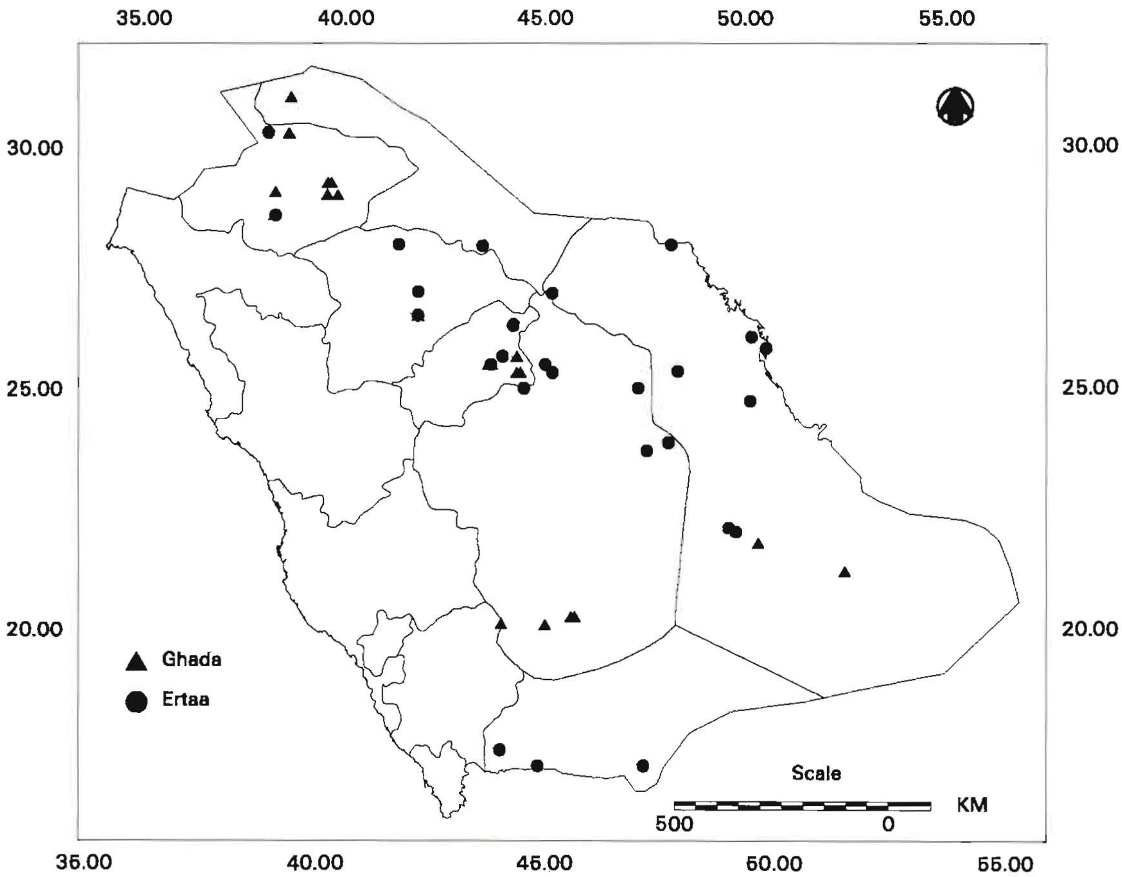

Fig. 1. Natural distribution Map of Ertaa and Ghada in Saudi Arabia. *(Produced by the GIS unit of Natural Resources and Environmental Research Institute, KACST, based on the latitude and longitude of recorded distributions in Saudi Arabia).*

Experiment conducted to detect the effect of burial depth of seeds showed that seeds of Ghada sown in the minimum depth (0 to 1 cm) showed maximum percentage of germination and those sown below 2 cm seldom germinated (Fig.2). However, in the case of Ertaa, maximum percentage of germination was obtained with seeds sown between 2 and 15 cm and all seeds sown above the soil and below more than 15 cm failed to germinate.

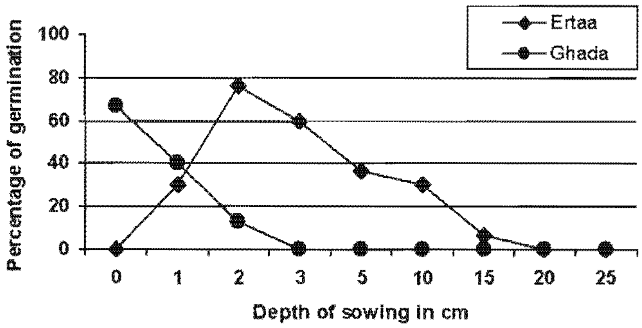

Fig. 2. Effect of Depth of Sowing on the Germination of Ertaa and Ghada..

Table 2. Estimated fresh and dry weights of Ertaa and Ghada seedlings.

	Ertaa			Ghada		
	Fresh weight (kg/plant)	**Dry weight (kg/plant)**	**Population* Density (Plants/2500m²)**	**Fresh weight (kg/plant)**	**Dry weight (kg/plant)**	**Population* Density (Plants/2500m²)**
Mean	8.67	6.57	29.00	6.75	4.75	64.00
SE	3.53	2.60	3.03	0.97	0.70	4.70
Max.	18.50	13.50	32.00	10.00	7.00	70.00
Min.	1.50	0.50	25.00	3.50	2.50	55.00

**Population density: number of trees per 2500 m²*

Productivity Estimation

The difference in estimated mean values of fresh and dry weights of specimens of both the species from natural populations were minimal, i.e., about 1 ton ha^{-1} fresh weight and 0.75 ton ha^{-1} dry weight for Ghada and 1.74 ton ha^{-1} fresh weight and 1.22 ton ha^{-1} dry weight for Ertaa (Table 2).

Relative growth rate (RGR) in response to irrigation frequency

Table 3 shows the effect of irrigation frequency on the relative growth rate of Ertaa and Ghada. During seedling stage, under greenhouse conditions, Ertaa showed significantly higher RGR than Ghada. Relative growth rate of Ertaa under 'once in a week irrigation schedule' was significantly higher than the other irrigation regimes. However, once in two and three week's irrigation treatments did not show any significant influence on the RGR, when compared to control. In Ghada none of these irrigation frequencies produced any significant differences in the RGR. Analysis of RGR between species under field condition showed higher growth rate in Ghada irrespective of irrigation frequencies.

Table 3. Relative Growth rate of Ertaa and Ghada against Irrigation.

Irrigation frequency	**Ertaa**	**Ghada**
	Relative growth rate(RGR)	**Relative growth rate(RGR)**
Daily(Seedling)	0.0359*	0.0227
1/a week	0.0561^{a}	0.0950^{a} **
1/ two weeks	0.0421^{ab}	0.0906^{a} **
1/ three weeks	0.0380^{b}	0.0963^{a} **
Control	0.0392^{b}	0.0948^{a}**
Lsd p=0.05	0.0167	0.0199

RGR for daily irrigation schedule was based on dry weight ($g\ g^{-1}\ d^{-1}$) and weekly schedule was based on volume ($mm^3 d^{-1}$); Numbers followed by the same letter superscript in the same column are not significant;
** Significant at P=0.05; ** significant at p=0.01 based on students t-test between species.*

Estimation of Biological Growth

The estimated biological growth function showed a high level of significance at $p<0.0001$ using the F-test equivalent to 262.98 for Ertaa and 269.95 for Ghada. In addition, the coefficient of determination ($\overline{R}^2$) of Ertaa and Ghada were found to be equal to about 0.963 and 0.964, respectively, indicating that time (the independent variable) explain about 96.3% and 96.4% of the total variation in volume of Ertaa and Ghada, respectively. Figures (3) and (4) illustrate the biological growth functions of Ertaa and Ghada using the power function form.

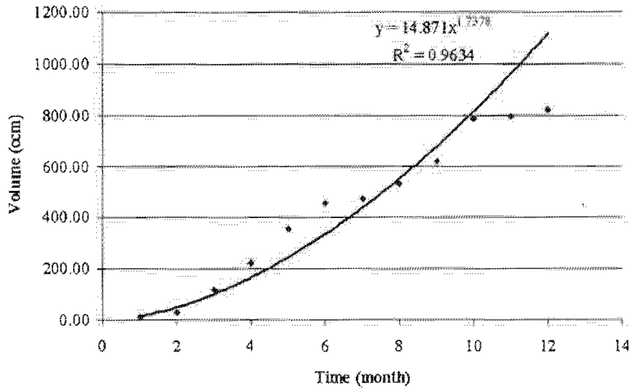

Fig. 3. Estimated Biological Growth Function of Ertaa using Power Function.

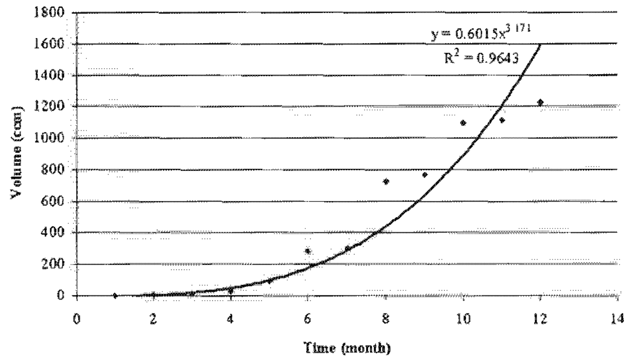

Fig. 4. Estimated Biological Growth Function of Ghada using Power Function.

DISCUSSION

Tobe, *et al.* (2000) have reported a 96% germination of seeds of *Haloxylon persicum* when moistened with de-ionised water under 20°C. The results of the present study also showed quick germination of seeds without any special treatment under greenhouse conditions. Sharma and Sen (1989) have also reported a rapid germination of seeds of *Haloxylon recurvum*, about 75-120 min after initial imbibition and have indicated it as an adaptive strategy to availability of water. Germination of seeds of the two species without any delay rule out dormancy and that germination is solely dependent on availability of favourable conditions. These results support the findings of earlier workers (Koller, 1956; Kumar, *et al.* 1996). However, the natural conditions of their habitats do not favour germination of either Ertaa or Ghada seeds.

Maximum percentage of germination obtained under minimal depth of sowing indicates that seeds of Ghada are photoblastic, they require adequate light for germination and germinates only when they are close to or above the soil surface (Cloudsley-Thompson, 1993). On the other hand, being a negatively photoblastic species, it was observed that light inhibits germination of Ertaa seeds and they need to be covered by sand in order to germinate. Light, high temperature (>30°C), and close contact with water are factors that inhibit germination in *Calligonum comosum* (Koller, 1956).

Among those stimuli that enhance seed germination, light inducible seed germination referred to as photoblastism, has an immense biological significance. Even under favourable growth conditions, photoblastism allows the buried seeds to remain dormant until they are exhumed (Chung and Pack, 2003). *Joel, et al.* (2006) have found that in photoblastic seeds imbibition under darkness had triggered secondary dormancy in cacti seeds. The amount of light penetrating the top layer of the soil is very low and is affected by a number of factors, like size of the soil particle, moisture content, particle colour and presence of organic matter (Tester and Morris, 1987). Based on different studies regarding the penetration of light through soil, Reimens (2003) concluded that physiologically and significantly amounts of light rarely penetrate more than 4-5 mm through soil and that only 0.01% light is transmitted through to a depth of 3mm. Hence, the sensitivity of the seeds after burial needs to be enhanced to achieve high germination levels. Studies have shown that large changes in light sensitivity can be induced when seeds are buried in soil (Baskin and Baskin,1985) which may be linked with seasonal patterns such as temperature changes (Derkx and

Karssen,1993). Being a photoblastic species, seeds of Ghada on the top of the soil and at 1 cm deep germinated fast, while exposure to light inhibited germination of Ertaa on the top of the soil. Utilizing the available darkness at 2 cm depth and other favourable conditions, the negatively photoblastic species Ertaa produced maximum percentage of germination. After a certain level of depth (> 15cm) inadequate soil aeration and heavy pressure from the soil prevents elongation of hypocotyls, which ultimately checked successful seed germination of this epigeous species.

Zohary (1940) reported that in some deserts of Central Asia, Ghada yields up 50 tons of charcoal ha^{-1}. Kumar, *et al.* (1996) recorded an average of 18.9 kg $plant^{-1}$ of wood productivity in *Calligonum comosum* of Indian deserts. The low productivity of both species in Saudi Arabia could be attributed mainly to the harsh environmental conditions, overgrazing and habitat disturbances in the unprotected natural habitat.

Though water is the key factor for plant growth in non-irrigated desert regions (Zengyuan, 1984), growth and establishment of Ertaa and Ghada were not found dependent on irrigation. This may be attributed to the fact that both species are well adapted to their environmental conditions and they can grow and survive with minimal water or without any irrigation. Kebin (1989) reported that trees of *Haloxylon ammodendron* can produce healthy growth only where the soil water content is over 2% (or over 50% relative water content). In the Arabian deserts, availability of good water for irrigation is always a constraint and desalination of water from deep wells for irrigation is always an expensive proposition. The present study clearly indicates that both species can show a fairly good growth rate under cultivation with minimal or even without irrigation.

Estimated biological growth of Ertaa and Ghada using linear and nonlinear functional forms was matching reasonably to the natural growth of a tree stand in general, where very young trees would experience a slow growth in volume, followed by a sustained, rapid growth, and a considerable increase in volume. Finally, the stand would experience slower growth as it becomes fully matured, until the growth either stops or reversed (Tietenberg, 2002). The estimated biological growth of Ghada and Ertaa using power function form, however, showed the best fit of the experimental measurements for both species among the other functional forms, indicating that both species are in their initial growth stage.

CONCLUSIONS

Deserts are regions of low and irregular rainfall in which potential evapo-transpiration exceeds precipitation (Khan and Unger, 1996). Knowing the vegetation management system of water saving plants like Ertaa and Ghada will help greenery programs and improve the socio-economic conditions of the local population. The problems associated with the natural regeneration are mainly due to the deep burial of seeds under shifting sand. Being a photoblastic species Ghada seeds require light for germination and must be on the surface of the soil, while Ertaa, being a negatively photoblastic species must be under the soil to avoid light for easy germination. The low productivity of natural stands in Saudi Arabia may be attributed to the prevailing extreme environmental conditions and uncontrolled grazing. Animals eat the green assimilatory parts as soon as they flush and this affects photosynthetic activities which may ultimately retard growth rate. The estimated biological growth function under cultivation was found to reasonably match with the natural growth for both species, indicating that both species are in their initial growth stage.

ACKNOWLEDGEMENTS

We would like to thank the King Abdulaziz City for Science and Technology (KACST), Riyadh, for providing facilities and financial assistance for the study. Our thanks also go to the GIS unit, Natural Resources and Environmental Research Institute, KACST, Riyadh, for developing the Natural distribution Map of Ertaa and Ghada in Saudi Arabia.

REFERENCES

Al-Abdulkader, AM, Al-Khalifah, NS, Nassron, T, Alfarhan, A, and **Alabasi, T,** (2004) The Present Status of Samar Firewood Markets in Saudi Arabia and its Effects on Vegetation Cover. *Journal of King Saud for Agricultural Research*, **17** (1): 45-60.

Al-Khalifah, NS, and **Shanavaskhan, AE** (2007) On the distribution, status and phenology of Ghada (*Haloxylon persicum* Bunge) in the Arabian Peninsula. *Tropical ecology* **48** (1):1-10.

Baskin, JM, and **Baskin, CC** (1985) The annual dormancy cycle in buried weed seeds: a continuum. *Bioscience* **35** (8):492-498.

Chung, NJ, and **Pack, NC** (2003) Photoblastism and ecophysiology of seed germination in weedy rice. *Agronomy Journal* **95**:184-190.

Cloudsley-Thompson, JL (1993) *Adaptations of Desert Organisms: Seed Germination in Desert Plants*. Springer-Verlag, Berlin, Germany.

Deborah, AH, and Eckman, K (1993) *Species Database Program*. Ottawa, Ontario, Canada. Available:http://www.faw.org/docrep/x5327e/x5327e04.

Derkx, MPM, and **Karssen, CM** (1993) Changing sensitivity to light and nitrate but not to gibberellins regulates seasonal dormancy patterns in *Sisymbrium officinale* seeds. *Plant, Cell and Environment* **16**:469-479.

El-Lithy, ME, Clerkx, JME, Ruys, GJ, Koorneet, M and **Vreugdenhil, D** (2004) Quantitative trait locus analysis of growth-related traits in a new *Arabdiopsis* recombinant inbred population. *Plant Physiology* **135**: 444-458.

Farraj, MM (1989) Disturbances and dangers operating on desert vegetation in Saudi Arabia. *Proc. NCWCD* **3:**164-168.

Hunt, R (1978) *Plant Growth Analysis: Studies in Biology No.96*. Edward Arnold, London, UK.

Hunt, R, Causton, DR, Shipley, B, and **Askew, AP** (2002) A modern tool for classical plant growth analysis. *Annals of Botany* **90**: 485-488.

Joel, F, Enrique, J, and **Alberto, A** (2006) Effect of light on germination of seeds of Cactaceae from the Chihuahuan desert, Mexico. *Seed Science Research* **16** (2):149-155.

Kebin, Z (1989) The growth of man-made forests of *Haloxylon ammodendron* and their soil water content in the Minquin desert region, Gansu province, China. *Journal of Arid Environment* **17:**109-115.

Khan, MA, and **Unger, IA** (1996) Influence of salinity and temperature on the germination of *Haloxylon recurvum* Bunge ex. Boiss. *Annals of Botany* **78:** 547-551.

Koller, D (1956) Germination regulating mechanisms in some desert seeds III *Calligonum comosum* L'Her. *Ecology* **37:** 430-433.

Kumar,V, Nagavani, HC, Kumar, D and Singh, VP (1996) Propagation and Growth Studies of *Calligonum polygonoides. Indian Forester* **122:** 377-382.

Leister, D, Varotto, C, Pesaresi, P, Niwergall, A, and **Salamini, F** (1999) Large-scale evaluation of plant growth in *Arabidopsis thaliana* by non-invasive image analysis. *Plant Physiol. Biochem.* **37:**671–678.

Li, B, Suzuki, J, and **Hara, T** (1998) Latitudinal variation in plant size and relative growth rate in *Arabidopsis thaliana. Oecologia* **115:** 293–301.

Motooka, S, Hayashi, T, Mima, Y, and **Konishi, K** (1991) Measurement of in vitro plant growth by image processing. *Journal of Japan Soc. Hortic Sci.* **60:**677-684.

Reimens, MM (2003) Effects of heating and light exposure on the emergence, germination, viability and dormancy of weed seeds. *Plant Research International Note* 250 (1): 1-21.

Sankary, N (1978) *Managing and Improving Range Lands in the Kingdom of Saudi Arabia.* Arab Center of Dry and Barren Land Research, Damascus, Syria.

Sharma,TP, and **Sen, DN** (1989) A new report on abnormally fast germinating seeds of *Haloxylon* spp.-an ecological adaptation to saline habitat. *Current Science* **58:** 382-385.

Smith, MA, and **Spomer, LA** (1987) Direct quantification of in vitro cell growth through image analysis. *In Vitro Cell Dev Biol.* 23 (1): 67–74.

Smith, MAL, Spomer, LA, Meyer, MJ, and **McClelland, MT** (1989) Non-invasive image analysis evaluation of growth during plant micro propagation. *Plant Cell Tissue Organ Cult.***19:** 91–102.

Snedecor, GW, and **Cochran, WG** (1973) *Statistical Methods*, 6th ed. Iowa State University Press, Ames, Iowa, USA. pp305.

SPSS 14.0 (2005) *Comprehensive Statistical Software for Microsoft Windows.* Available: http://www.spss.gr/products/Base_14.pdf.

Tester, M, and **Morris, C** (1987) The penetration of light through soil. *Plant, Cell and Environment*, **10:**281-286.

Tietenberg, T (2002) *Environmental and Natural Resource Economics,* 6th ed. Addison-Wesley, Boston, USA.

Tobe, K, Li, X, and **Omasa, K** (2000) Effects of sodium chloride on seed germination and growth of two Chinese desert shrubs, *Haloxylon ammodendron* and *Haloxylon persicum* (Chenopodiaceae). *Australian J Botany* **48:** 455-460.

Vesey-Fitzgerald, DF (1957) The vegetation of Central and Eastern Arabia. *Journal of Ecology* **45:**779-798.

Zhengyuan, S (1984) A preliminary report on a study of the relationship between degree of vegetation cover and soil water content in the sand dunes plant community of Yulin region. *J Beijing Forestry Univ.* **3** (1): 29-35.

Zohary, M (1940) On the 'Ghada'-tree of Northern Arabia and the Syrian deserts. *Palestine Journal of Botany* **1:** 413-416.

Ref. No. (2447)
Rec. 18/ 06/ 2007
In- revised form: 01/ 07/ 2008