On the distribution, status and phenology of Ghada (*Haloxylon persicum* Bunge) in the Arabian Peninsula

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Abstract: The distribution and status of *Haloxylon persicum* Bunge (‘Ghada’) have been evaluated for the Arabian Peninsula. Analysis of the data using IUCN guidelines showed that the taxon qualifies for the IUCN status ‘lower risk’ but ‘conservation dependent’. Its geographical distribution is from nearer or above the Tropic of Cancer, up to 50° N latitude. Phenological studies of the natural populations revealed vernal and aestival flowering. Vernal flowers produced viable seeds but aestival flowers were mostly male or very rarely polygamous. Seed germination studies were conducted to probe into the poor regeneration in natural populations. Results indicated that deep burial of seed and the non-availability of adequate moisture in the germination medium are the main limiting factors for the population expansion. Ghada is a C₄ plant showing unusual behaviour of producing C₃ seedlings. These C₃ seedlings produced during winter help the taxon to perpetuate, even in adverse conditions of the desert.

Resumen: La distribución y el estatus de *Haloxylon persicum* Bunge (‘ghada’) fueron evaluados en la Península Arábica. El análisis de los datos usando los lineamientos de la UICN mostró que este taxón merece el estatus de la UICN de ‘bajo riesgo’ pero ‘dependiente de medidas de conservación’. Su distribución geográfica abarca desde cerca o un poco al norte del trópico de cáncer, hasta la latitud de 50° N. Los estudios fenológicos de las poblaciones naturales mostraron floración vernal y estival. Las flores de primavera produjeron semillas viables pero las de verano fueron en su mayoría masculinas o muy raramente polígamas. Se realizaron estudios de la germinación de semillas para examinar la pobre regeneración observada en las poblaciones naturales. Los resultados indicaron que el enterramiento profundo de semillas y la falta de disponibilidad de humedad adecuada en el medio de germinación son los principales factores limitantes para la expansión de la población. Ghada es una planta C₄ con un comportamiento inusual al producir plántulas C₃. Estas plántulas C₃ producidas durante el invierno ayudan a la perpetuación del taxón, inclusive en las condiciones desérticas adversas.

Resumo: A distribuição e status da *Haloxylon persicum* Bunge (‘Ghada’) foram avaliados para a Península Arábica. A análise dos dados, usando os guias da UICN, mostraram que o taxon qualifica para o status da UICN de “baixo risco” mas dependente de conservação. A sua distribuição geográfica é próxima ou acima do Trópico de Cáncer, até à latitude dos 50° N. Os estudos fenológicos das populações naturais revelaram floração invernal e estival. As flores de inverno produzem sementes viáveis enquanto que as flores de verão eram maioritariamente masculinas ou muito raramente polígármicas. Os estudos de germinação de sementes foram efectuados para testar a fraça regeneração nas populações naturais. Os resultados indicaram que o enterramento fundo da semente e a indisponibilidade de humidade adequada no meio de germinação são os principais factores limitantes para a expansão da população. A Ghada é uma planta C₄ mostrando um comportamento não usual de produzir plântulas C₃. Estas plântulas C₃ produzidas durante o

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Inverno ajudam o taxa a perpetuar-se, mesmo nas condições adversas do deserto.

**Key words**: Aestival flowering, longevity, phenology, seed germination, status, vernal flowering, viability.

**Introduction**

*Haloxylon persicum* Bunge (‘Ghada’) is one of the well known saxaul trees of Central Asia, Middle East, Iran, Afghanistan, North West China and near eastern deserts (Butnik *et al.* 1991; Iljin 1936). It is an Irano-Turanian species which apparently originated in Central Asia, where it is an important component of the desert vegetation (Mandaville 1986). In general, it is a plant of sandy habitats growing mostly on the shallow depressions along the slopes of dunes. It is a potential source of firewood, and in some deserts of Central Asia, it yields up to 50,000 kg of charcoal per hectare (Zohary 1940). ‘Ghada’ is one of the dominant trees of the sandy deserts, which spreads over thousands of square km in a region that apparently does not receive more than 25 mm rainfall annually (Zohary 1940). It is very tolerant to environmental extremes in temperature, light and water availability (Casati *et al.* 1999).

Apart from cutting trees for firewood and charcoal, these plants are severely grazed by livestock. The destructive utilization of biological resources, in this part of the world has already resulted in the extinction of many species, endangered many and has adversely affected the biodiversity as a whole. Knowledge of the growth and regulation of populations is a prerequisite to understand the structure and dynamics of the biological community and the ecosystem (Ricklef 1979). The present paper attempts to analyze the distribution and status of *Haloxylon persicum* in the Arabian Peninsula and throws light on the phenological events under the desert climatic conditions of the peninsula. The paper also probes in to the causes of poor regeneration in the natural habitats.

**The study area and the species**

The Arabian Peninsula stretches to a distance of 2254 km, extending from the Gulf of Aqaba in the north to the Gulf of Aden in the south. The distance between the northern portion of the Red Sea and the Arabian Gulf is about 1200 km and in the south the distance between the Red Sea and the Gulf of Oman is about 1930 km (Rashid & Shaheen 1995). The vast landscape of the Arabian Peninsula is composed of a variety of habitats such as sand, rocky deserts, mountains, hillocks, wadis, salt pans, lava areas etc. The Arabian Peninsula comprises arid and extremely arid zones, except the high elevations in the south-west and a small area bordering the Gulf of Oman (Meigs 1953). About 30% of the land area is covered with sand in the form of sea sand (Chaudhary 1999). This vast sandy area provides ample room for the luxuriant growth of several range plants including *Haloxylon persicum*, the Ghada.

Zohary (1940) compiled the previous records of this plant, which appeared in some of the earlier works on the Arabian Deserts (Blunt 1881; Carruthers 1935; Cheeseman 1926; Euting 1896-1914; Lesch 1931; Loew 1924-34; Musil 1927; Pelgrave 1868; Philby 1922; Schweinfurth 1912). Zohary (1945) reported large populations of Ghada from Wadi Araba, a valley between the Red Sea and the Dead Sea. After Zohary (1940, 1945), several other plant explorers and botanists like Al-Rawi & Daod (1985), Batanouny (1981), Chaudhary (1999), Collenette (1985, 1998), De Marco & Denelli (1974), Fitzgerald (1957), Ghazanfar (1992), Heemstra *et al.* (1990), Mandaville (1990), Migahid (1978), Miller & Cope (1996) and Wood (1997) have explored the floristic elements of the Arabian peninsula and mentioned the occurrence of this species from various parts of the region. In almost all literature, the vernacular name of the species was given as ‘Ghada’, but some authors transcribed the Arabic name as ‘Ghadha’, ‘Ghada’, ‘Gada’, ‘Gadha’ or ‘Raza’. Prior to the work of Zohary (1940), this plant was identified as *Euphorbia*! (Euting 1896-1914; Pelgrave 1868),
*Haloxylon articulatum* (Philby 1922), *Arthrocnemum fruticosum* Moq. (Cheesman 1926; Oppenheimer 1930), etc. On the basis of the collections from the Syrian Deserts and the protologues provided by earlier workers, Zohary (1940) confirmed the identity of the Ghada tree as *Haloxylon persicum* Bunge.

The Kingdom of Saudi Arabia shares 80% of the land area of the Arabian Peninsula, which comes to about 2.23 million square km. It lies between 15° 45' and 34° 34' Northern latitude and 34° 40' and 55° 45' Eastern longitude. Migahid (1978) provided a phytogeographical map (Fig. 1) of Saudi Arabia comprising 9 distinct regions. Three important geographical regions like Tihama, Dahna and Summan were either not marked or merged with adjoining regions. The western coastal belt called Tihama, extending along the Red Sea is about 72.5 km wide in the south and narrows down to 48 km near Jizan and further narrows down to 16 km till it reaches the Gulf of Aqaba. Dahna is a crescent shaped sand body connecting Nafud in the north and the great Rub Al-Khali in the south. Migahid (1978) treated Dahna as an extension of Nafud but this narrow sand body possesses distinct vegetation types, different from other sand bodies like Nafud and Rub Al-Khali. The Summan region, running parallel to Dahna and bordering the eastern region on the east is characterized by gentle sloping topography and deeply sloping rocky areas with loamy, shallow soil (Chaudhary & Jowaid 1999).

The three sand bodies and their extensions are important in the distribution of *Haloxylon persicum*. The northern regions are composed of hills, sand dunes and wadis etc. The deep sands along the slopes of the hills and wadis support the growth of *Haloxylon persicum* along with other psammophytes. Hummocks of drifting sands in the eastern coastal regions also harbour small populations of Ghada. Among the three important sand bodies, the great Nafud occupies the north. The large sand dunes of these areas provide the habitat for *Haloxylon persicum* populations on its sloping sides while the top is occupied by its associated species, *Calligonum comosum* L' Her. The northern regions of Dahna possess large populations of Ghada but in the Empty Quarter

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(Rub Al-Khali) it is so far reported from the northwestern regions only. Mandaville (1986) reported these populations as clear cut and conspicuous units of a rather restricted, patchy distribution in a broad belt across the northwestern edges of Rub Al-Khali. In addition to these, some sporadic distributions are also reported from the sandy formations of the Najd region in the central part of Saudi Arabia. In the Arabian Peninsula this species is also reported from Oman and UAE (Miller & Cope 1996). In UAE, a fairly large population is reported from the south of Abu Dhabi, on medium sized grey sand dunes, but its occurrence in Oman is not confirmed by the check list (Ghazanfar 1992). Cornes & Cornes (1989) erroneously reported the occurrence of Haloxylon persicum in Bahrain, but the description and illustrations provided seem to match another widespread species, Haloxylon salicornicum (Moq.) Bunge ex Boiss. Outside the Arabian Peninsula, it is reported from Egypt, Southwest Asia eastwards to Pakistan, North West China and Central Asia. All populations reported so far are from the vicinity of or the north of the Tropic of Cancer, up to 50° northern latitude.

Being a potential plant for firewood and fodder, populations of Ghada are facing threat due to over-grazing, habitat destruction and over-collection for wood and charcoal. In addition, poor regeneration and high level seedling mortality in the natural conditions are aggravating the limiting factors of population expansion. Both man-made and natural barriers have reduced its population size in peninsular Arabia during the last few decades. Its extent of occurrence is right from the northern region, passing through Nafud, Dahna and the northwestern border of Rub Al-Khali to UAE (Fig. 1) exceeding 300,000 km². Despite the wide range of occurrence, the area of occupancy is estimated to be less than 30,000 km². The mean number of mature individuals per 50 x 50 m area was estimated as 23.93 ± 6.28. Considering the large extent of occurrence, a fairly good area of occupancy and the large number of individuals in the populations, this taxon in the Arabian Peninsula has been regarded as Lower Risk. But the poor natural regeneration, seedling mortality, unsustainable exploitation, severe grazing, habitat destruction due to recreational off road driving, etc. are expediting the population decline. Hence this species in the Arabian Peninsula may be assigned the IUCN status ‘near threatened’.

Materials and methods

Plant exploration trips were conducted to various parts of Saudi Arabia to locate the natural populations of Haloxylon persicum. Specimens housed in all the leading herbaria in the Kingdom, such as National Herbarium of Saudi Arabia (RIY), King Saud University Herbarium (KSU), Herbarium of the National Commission for Wild Life Conservation and Development (NCWD), King Abdulaziz City for Science and Technology (KACST) were surveyed and representative specimens collected by the earlier workers were recorded (Table 1). The floristic, accounts given by the earlier workers (Al-Rawi & Daod 1985; Batanouny 1981; Boulos 1985; Chaudhary 1999; Collenette 1985, 1998; Cornes & Cornes 1989; De Marco & Denelli 1974; Fitzgerald 1957; Ghazanfar 1992; Heemstra et al. 1990; Mandaville 1990; Migahid 1978; Miller & Cope 1996 and Wood 1997) were screened for the occurrence of the study material in their respective areas. The data obtained from the above studies were incorporated into a taxon data-sheet (Table 2), prepared according to the guidelines of International Union for Conservation of Nature and Natural Resources (IUCN) (Anonymous 1994). The quantitative values provided in the taxon data-sheet are quite arbitrary and are based on the authors’ experience in the field and in consultations with many other field botanists. The number of mature individuals per unit area was calculated by counting the number of plants in the randomly selected 50 x 50 m plots. Four replicates from each population were counted and five populations were surveyed.

The selected populations were visited regularly at monthly intervals to record the pheno-events taking place in response to seasonal and climatic changes to the environment in which they live. Small pieces of inflorescence collected during vernal and aestival flowering seasons were preserved in formalin–acetic acid–alcohol (FAA) and later studied under a stereo- microscope. Micro-photographs were taken using phototubes and camera. Seeds collected during vernal flowering were cleaned and the diameter was measured using screw gauge. Two hundred seeds were measured and the mean diameter was
calculated. Fresh weight of seeds was taken as batches of 10 seeds, with 5 replicates. They were then oven-dried at 140°C for 1 h, and then the dry weights were taken.

To explore the germination related aspects, four experiments were conducted. Experiments one to three were conducted in a seed germinator at a temperature of 25°C and a photo-period of 16 h light and 8 h dark and the fourth one was done in a greenhouse. In all experiments four replicates were used, each containing fifty seeds. To accelerate the germination process in all the experiments seeds were presoaked in cold water for one hour. The seeds were considered to have germinated when the radicle emerged and the seedlings started uncoiling. Data was recorded daily from the second day of sowing to the day on which germination stabilized.

In order to find out the maximum germination percentage, fresh seeds were sown in 90 mm diameter Petri dishes containing 2 layers of moist filter paper. Petri dishes were sealed with paraffin wax film and kept in seed germinator.

After drying, under shade, seeds were kept in polycarbonate containers and stored under three storage conditions viz. a. laboratory (25°C); b. refrigerator (2°C); c. under shade without temperature control. Seed samples from each storage condition were sown in Petri dishes at monthly intervals to find out seed longevity and best storage condition.
Moisture available on the germinating medium is also a limiting factor for the successful regeneration of desert plants. Seed samples were sown in 90 mm diameter Petri dishes with 2 layers of filter paper soaked with 0, 2, and 4 ml of sterilized distilled water.

Deep burial of the seeds under shifting sand is one of the reasons for the poor regeneration of desert psammophytes. To evaluate the effect of depth of sowing seeds were sown in 20 cm diameter polythene pots filled with pure sand and kept in greenhouse. Seeds were sown at a depth of 0, 1, 2, 3 and 4 cm and watered twice a day using fine water sprayers.

Results and discussion

All plants in a population do not show synchronization in the phenoevents. *Haloxylon persicum* produces vernal and aestival flowering,

![Fig. 2 (A-D).](image)

A. Vernal inflorescence; B. Bisexual flower showing fruit; C. Aestival inflorescence; D. Male flower.

![Fig. 3.](image)

A. Fruit-like gall formation; B. L.S. of a gall showing an insect inside.
which is not common in Chenopodiaceae. Majority of plants in a population produce perfect flowers from the previous year branches (Fig. 2. A & B) during October-November, but their usual flowering period is March–April. During early winter, after vernal flowering, the plant appears to be yellowish in colour and undergoes a somewhat dormant stage and later, by the end of December small shoots and leaves emerge. Flower buds are borne on these small shoots. The aestival flowers produced on new shoots during summer are either male (Fig.2.C&D) or very rarely polygamous. These flowers dry and wither after anthesis. It is also observed that during this period insect attack frequency is very high, which subsequently resulted in the formation of fruit-like galls (Fig.3 A&B). The vernal flowers produce viable seeds, which are situated at the center of the white perianth lobes. On maturity, the perianth lobes become dull-white and later become transparent.

Collenette (1985) explained that ‘flowers reduced to groups of yellow anthers; no scent’. Perhaps she saw only the aestival flowers.

The mean fresh weight of the seed was found to be $5.13 \pm 0.92$ mg and dry weight was $4.8 \pm 0.32$ mg. The mean diameter of the seed was $2.68 \pm 0.24$ mm. Fresh seeds collected during vernal flowering and stored under refrigerator and laboratory conditions provided 100% germination for a period up to 3 months. The imbibed seed starts uncoiling after 4 hours of hydration (Fig. 4A) and then produces the straight radicle (Fig. 4.B). The cotyledonary leaves appear within a day (Fig. 4C) and minute secondary roots produce within a couple of days (Fig. 4D). The very thin seed coat allows absorbing moisture available during sporadic rains, which may generally last for few hours. Being a successful species in a sandy desert the plant has to utilize all available favorable conditions. Tobe et al. (2000) studied the effect of

![Fig. 4 (A-D). Various stages of seedling development. A. Uncoiling cotyledon; B. Emerged radicle; C. Cotyledonary leaves arrived; D. Roots appeared.](image)
temperature on germination percentage using 7 temperature regimes (5, 10, 15, 20, 25, 30 & 35°C) and reported that the optimum temperature for seed germination was nearly 20°C and any further increase in temperature decreases germination percentage. But in this experiment 100% germination was observed at 25°C. Studies conducted on the longevity and storage conditions proved that seeds stored under 2°C were viable even after 21 months of collection and provided 88% germination while the seeds stored under shade without control of temperature lost viability after 15 months. Seeds stored under laboratory and refrigerator conditions provided almost similar percentage of germination for a period of 11 months but after that the seeds stored in the laboratory showed a continuous decline in their viability (Fig. 5), whereas the seed stored under shade, without control of temperature showed continuous decline and within 6 months they lost almost 70% of their viability. These results are in concurrence with the findings of Tobe et al. (2000).

Results of the third experiment showed that even the presoaked seeds failed to germinate on the dry filter paper, while on the moist filter paper soaked with 2 ml and 4 ml of water the germination percentage was 76 and 96 respectively (Fig. 6). From this experiment it is clear that lack of adequate moisture to the germinating medium is another limiting factor for the regeneration in the natural conditions. In the winter season sporadic rains available in the sandy areas facilitate germination but non-availability of water in the following days checked further growth.

In the fourth experiment, seeds sown on the top of the soil gave 66.6% germination, those sown 1 cm and 2 cm below the soil gave 40% and 13% germination respectively and seeds sown 3 cm below the soil gave no germination (Fig. 7). These results indicated that deep burial of seeds by the drifting sand could have been another reason for the poor regeneration. Since this species occupies mostly in the slight depressions of sand dunes, chances of sand accumulation over the fallen seeds are very high and, therefore, the consequent deep burial of seeds in the soil retards germination and further growth. Even though each plant produces innumerable seeds, for the last 3 years, the authors could find only a few seedlings in the natural habitat.

The initial stages of plant development after germination are very important for the survival, growth and reproduction of plant species in desert conditions. *Haloxylon* seeds lack endosperm; therefore, cotyledon photosynthesis is the major source of assimilates for the young plant development. Earlier studies have shown that *Haloxylon* cotyledons have an isolateral mesophyll structure without Kranz anatomy (Butnik et al. 2010).
The possible occurrence of some features of C₃ photosynthesis in cotyledons and C₄ mechanism in assimilating shoots is postulated (Pyankov et al. 1999). Usually within a plant, all photosynthetic tissues have the same photosynthetic pathway, although some deviations are known to exist in epidermal leaf cells and reproductive tissues (Edwards & Walker 1983; Willmer et al. 1973).

The occurrence of C₃ photosynthesis in cotyledons of a C₄ species is an unusual phenomenon. C₃ photosynthesis in *Haloxylon* cotyledons may have important ecological and evolutionary implications (Pyankov et al. 1999). Since the seeds of sexual have no endosperm (Vernik 1983), cotyledon photosynthesis is the only source of new assimilates for the plant growth. In natural populations of Ghada in the Central Asian deserts, cotyledons appear by the end of April (Butnik et al. 1991) when temperatures are low and soil moisture remains high after winter and spring precipitation, conditions favouring C₃ photosynthesis (Black 1973; Ehleringer 1978). In the Arabian Peninsula, winter begins in November and during this period some sporadic rains are also expected. Utilizing these favourable conditions, Ghada of this region produce vernal flowers with viable seeds, which may help them to perpetuate; but during the usual flowering season, i.e. March-April, the climatic conditions are not favourable for C₃ seedlings and hence it produces only sterile flowers.

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**References**


