Flora 205 (2010) 171–178

Contents lists available at ScienceDirect

Flora

journal homepage: www.elsevier.de/flora

Ecological status of the Mediterranean *Juniperus phoenicea* L. Relicts in the desert mountains of North Sinai, Egypt

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ARTICLE INFO

Article history:
Received 24 November 2008
Accepted 29 April 2009

Keywords:
Desert rocks
Juniperus phoenicea
Conservation
North Sinai
Size structure
Tree vitality

ABSTRACT

Juniperus phoenicea L. is listed as threatened tree by IUCN Red List. In Egypt, *J. phoenicea* L. is the only conifer tree that is restricted to the three mountains of northern Sinai: Gabal El-Halal, Gabal El-Maghara and Gabal Yelleq. As a Mediterranean relict it has been included in a national list as target for conservation and management. To provide baseline information for the development of a conservation strategy, the present study aims at comparing the isolated populations of *J. phoenicea* and their associated plant composition and diversity at the three mountains. The application of TWINSPAN and DCA analysis techniques has resulted in identifying of four vegetation types associated with juniper, and each could be related to a specific geomorphologic habitat on a topographic gradient. *Chiliadenus montanus* and *Zygophyllum dumosum* characterized the slopes of smooth-faced rock outcrops in Wadi Abu Seyal (at 350–470 m altitude of Gabal El-Halal), *Deverra tortuosa*, *Ephedra aphylla* and *Gymnocarpos decander* inhabited together with the target species the soil pockets of north-facing slope in Neqeb Abu Hamam (at 600–700 m altitude of Gabal El-Halal), *Stachys aegyptiaca* and *Moricandia nitens* characterized the juniper occurrences in the runnels of Wadi Arar (at 450–560 m altitude of Gabal El-Maghara), and *Artemisia herba-alba, Atriplex halimus* and *Reaumuria hirtella* represent the stands on slope runnels (at 900–960 m) of Gabal Yelleq. The two vegetation types recognized at Gabal El-Halal had, on average, the highest species diversity, juniper density and cover. Juniper shows generally poor conditions of vitality at higher elevation (600–960 m) with a higher proportions of old and recent dead trees, and with the predominance of male individuals, as compared with the populations of Gabal El-Maghara and Gabal Yelleq. In contrast, the juniper populations at lower elevation (350–470 m) of Gabal El-Halal proved to be in best condition with mostly living foliage and reproductive branches. The differences in rock types and elevation among the three mountains reflect serious limitation on recruitment of *J. phoenicea* due to moisture availability. The results of this study showed that *J. phoenicea* is an endangered species and its conservation in northern Sinai mountains is a priority. For a successful conservation of this community it is highly recommended to preserve in particular the suitable habitats at Gabal El-Halal, but also the other stands merit conservation measures.

Introduction

Preservation of isolated populations and defining the geographic range of species is widely demanded in conservation biology (Rojas, 1992; Scott et al., 2001; Sutherland, 2000). Reasons for this are the possible effects on biodiversity elements caused by global and regional climate changes, the need to maintain genetic diversity and the fact that stochastic events may threaten resources restricted to just one area (Jones et al., 2001; Pressey et al., 1993, 1994). Moreover, Lesica and Allendorf (1995) suggest that populations on the periphery of their ranges may be the most genetically variable and thus evolutionarily valuable if they are confronted with contracting ranges, and so may be less vulnerable to anthropogenic or natural changes. Thus, the identification of relict populations, or of refugia of them, can be a valuable tool for conservation purposes in plants.

Juniperus phoenicea L. (family Cupressaceae) is a monoecious or dioecious tree native to the coastal sites of the Mediterranean basin and extends into the mountains of western Arabia (Barbero et al., 1990). According to Zohary (1973), it is not recorded from Syria, Lebanon and Palestine, but it is recorded in the highlands of

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doi:10.1016/j.flora.2009.04.004

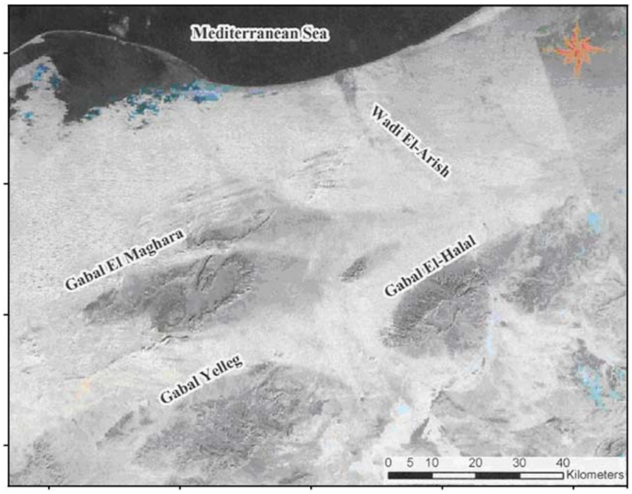

Fig. 1. Map showing the three anticlines in North Sinai.

Edom and extends to western Saudi Arabia (Touchan et al., 1999). In Egypt, *J. phoenicea,* the only conifer tree, is restricted to the three anticlines of northern Sinai (Gabal El-Halal, Gabal El-Maghara and Gabal Yelleq) (Fig. 1). A dendrochronological study of *J. phoenicea* at the three anticlines (Waisel and Liphschitz, 1968) showed that the species seems to represent the oldest trees ever recorded in the Middle East. These investigations also indicated that *J. phoenicea* was once more abundant in the region when environmental conditions were more favorable for tree life (Zohary, 1973). During the last century, due to human influence and environmental changes in habitat and climate, the occurrences of the species became more and more reduced. Therefore, the scattered populations of *J. phoenicea* in the northern Sinai can be regarded as relict patches of a Mediterranean-type vegetation in the Saharo-Sindian region (Danin, 1978).

The northern Sinai arid anticlines are vulnerable ecosystems due to the extreme ecological position, where plants have to withstand the effects of drought, wind and erosion (Zahran and Willis, 1992). Under such harsh conditions, *J. phoenicea* has a high ecological value in relation to its soil-retaining ability, and it can be taken as a keystone species for the associated endemic, rare, vulnerable and endangered flora (Boulos and Gibali, 1993; Danin, 1972). *J. phoenicea* individuals are subjected to intense human interference (cutting) for wood, folk medical uses and religious purposes. Therefore, the species is listed as threatened by IUCN Red List (2007). Despite its ecological value and its threatened status, there are no ecological studies about the current status of *J. phoenicea* in the vulnerable ecosystems of northern Sinai.

In the present study, we provide insights into the vegetation structure and ecological characteristics of *J. phoenicea* stands on the anticlines of northern Sinai. Changes in distribution, population size structure, sex ratios and vitality of stands of *J. phoenicea* are discussed along with the implications for juniper conservation in the region.

Materials and methods

Study sites

The study was carried out at the three anticlines (Gabal El-Halal, 892 m; Gabal El-Maghara, 770 m; and Gabal Yelleq, 1087 m) of the north-central Sinai Peninsula, Egypt (Fig. 1). The three anticlines are built up of limestone, dolomite, chalk and marl of Cenomanian age (Jenkins, 1990; Moustafa and Khalil, 1995). Gabal El-Halal is characterized by large outcrops of smooth-faced limestone, while Gabal El-Maghara and Gabal Yelleq have fissured rocks with limestone and dolomite outcrops (Danin, 1972). The area has an extremely arid climatic condition with rainfall between 80 and 100 mm annually; and the mean temperature is 26.5 °C. It is exposed to northeastern and northern winds with a mean velocity of about 11 knots (Zahran and Willis, 1992).

Vegetation analysis

A total of 35 sampling sites on the three anticlines (15 on Gabal El-Halal, 10 on Gabal El-Maghara and 10 on Gabal Yelleq) were surveyed during April–May 2005, when the evergreen juniper and its associated flora were easier to detect. At each sampling site, three to five plots (5 m × 20 m) were laid out, and the present species were recorded. Voucher specimens of all plant species were collected, identified and deposited in Ain Shams University Herbarium. Species identification followed Boulos (1999, 2000, 2002, 2005). The cover of species was evaluated following the Braun-Blanquet dominance–abundance scale. The number of *J. phoenicea* individuals was counted in each plot. The altitude was obtained in situ with a global positioning system device (model GPS 76, Garmin, Olathe, Kansas, USA). Species richness, Shannon-Weaver index and evenness (Ludwig and Reynolds, 1988) were determined in the different elevation belts.

Following the methodology of Gardner and Fisher (1996), the vitality classes for 100 trees were estimated at each anticline. The vitality estimation consisted of a rank from 1 to 5, according to the proportion of branches in the tree supporting live biomass. A vitality of 5 indicated that between 100% and 81% of the branches of *J. phoenicea* tree supported live biomass; vitality score decreased in 20% intervals, with class 1 for trees having less than 20% of the branches supporting living biomass. Additionally, the number of male and female of individual trees was estimated at each mountain.

In the study area, *J. phoenicea* shows a growth with multiple trunks. Therefore, size was estimated by measuring the height (H) and mean crown diameter (D) (based on 2–4 diameter measurements ind^{-1}), and the size index of each individual was calculated as the average of its height and crown diameter [$(H+D)/2$]. The size estimations were then used to classify the *J. phoenicea* population into ten size classes: the first ($<$0.50 m) and the second ($>$0.50–1 m) were chosen to represent the established seedling and juvenile stages. The absolute and relative frequency of individuals and mean height, crown diameter and size index per individual in each size class were then determined.

Vegetation of the sampling sites was classified and grouped using the TWINSPAN classification method (Hill, 1979), and the Detrended Correspondence Analysis (DCA) (Ter Braak and Prentice, 1988). Species appearing in only one or two sites were eliminated from the analysis. Finally, a floristic matrix of 35 sites and 45 perennial species was obtained.

Results

J. phoenicea had the highest density and cover at Gabal El-Halal and the lowest values of these variables were recorded at Gabal El-Maghara (Table 1). The height/crown diameter ratio attained a value of 0.98 at Gabal El-Halal, and 1.11 and 1.17 at Gabal El-Maghara and Gabal Yelleq, respectively. The sex ratio showed the predominance of males in the populations of Gabal El-Maghara and Gabal Yelleq with a value of 2.3 and 1.8, respectively. At Gabal El-Halal the sex ratio was close to unity (Table 1).

The size distribution diagram of the juniper populations indicated the negatively skewed distributions towards mature and large individuals at G. El-Maghara and G. Yelleq (Fig. 2). The