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Macromorphology and recruitment of *Prosopis cineraria* in the United Arab Emirates

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ABSTRACT

Recruitment frequency of *Prosopis cineraria*in the United Arab Emirates is poorly understood, though heavy browsing by camels is often assumed to be a limiting factor. Macromorphological characteristics were recorded at eight locations from the northern United Arab Emirates. Tree size (canopy diameter, trunk diameter, and tree height) showed conformity within locations. Height of browse line was strongly affected by camels, which removed foliage to a height of 3 meters whenever present. Recruitment by seed was not observed during the study, and observed asexual recruitment was limited to root suckers produced only within the season. Presence of suckers was unrelated to browsing but strongly affected by a shifting ground surface. Viable theories for the absence of sexual recruitment include seedling destruction by herbivores, a lack of safe sites for seedling growth and establishment, and that sexual recruitment events might naturally occur rarely, but produce many recruits in the rare successful seasons. Significant recruitment of new individuals is likely to occur only with protection from current herbivory systems.

Key words : *Asexual reproduction; Ghaf; Browsing; Root sucker*

Introduction

The ghaf tree (Prosopis cineraria) is an important native species to the north-eastern United Arab Emirates (UAE). Its population is centred on the Thar desert of India and Pakistan, but smaller populations occur in Iran, Afghanistan and the Arabian Peninsula (Pasiecznik *et al.,* 2004). Within the UAE it is found on inland sand plains and low dunes of the Northern Emirates and eastern rim of Abu Dhabi emirate, and appears occasionally in wadi beds of the Hajar mountain range (Jongbloed *et al.,* 2003). Similar populations occur in Oman, and the species is also occasionally found around the southern and eastern margins of the Rub' al-Khali desert of Saudi Arabia (Mandaville, 1990).

Culturally in the UAE, it is associated with the landscape and Bedouin traditional lifestyle (Lemons *et al.,* 2003) while ecologically, its leaves and fruit are a food source for a broad range of wild and domesticatedspecies (Brown, 1992). The macromorphological structure of ghaf is affected by browsing, and also by the practice of coppicing, whereby foliage is cut from the tree to feed livestock (Gallacher and Hill, 2005). Little is known about the rate of successful reproduction in the species. It is often assumed that regeneration is prevented by domestic herbivory(Gardner *et al.,* 2009) which has increased over the last several decades (Abdelfattah, 2009; Tourenq and Launay, 2008). Root suckers

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emerge from the base of the tree as well as from surface roots, but the relative frequency of sexual to asexual reproduction is also little understood. One tight cluster of adult trees in Oman was shown by both root excavation and isoenzyme analysis to be a clonal group (Brown, 1988). However, genetic studies in Qatar and Rajasthan have shown that sexual reproduction is common in these habitats (Elmeer and Almalki, 2011; Sharma *et al.*, 2011).

Populations within the UAE can be loosely categorized into two distribution types; open forest and clusters. Open forests are observed on gravel substrate with a shallow water table, such as a wadi fan or near the base of mountains(Jongbloed *et al.*, 2003). Clusters are observed in low dunes(Aspinall, 2001) and may contain just three or four individuals, or several thousand.The mechanism of clustering has received little attention. Well defined clusters were shown to produce flowers, but very few seeds, suggesting that seeds are produced only by inter-cluster out-crossing (Gallacher and El-Keblawy, 2013). However, a causative link has not been proven between mode of reproduction and seed production. The aim of this study was to observe and describe the population structure of *P. cineraria* across its natural range in the UAE, and compare macromorphology with evidence of recruitments.

Methods

Populations at eight locations were studied (Fig. 1), sampling the north-south axis of the species' natural range in the UAE. Three populations were located within the Dubai Desert Conservation Reserve (DDCR), where there is limited access for people and livestock. Two populations were chosen from Dhaid, to represent the variation between trees growing on sand and gravel substrates. The other populations were chosen toward the northern (Ras Al Khaimer), southern (Al Ain) and western (Al Ruwayyah) ends of the species' natural range within the UAE (Table 1).The DDCR was established in 2003, but retained a sizeable camel population until 2008. Currently, it contains free ranging oryx and gazelles, and a small number of camels and horses retained for tourism purposes.

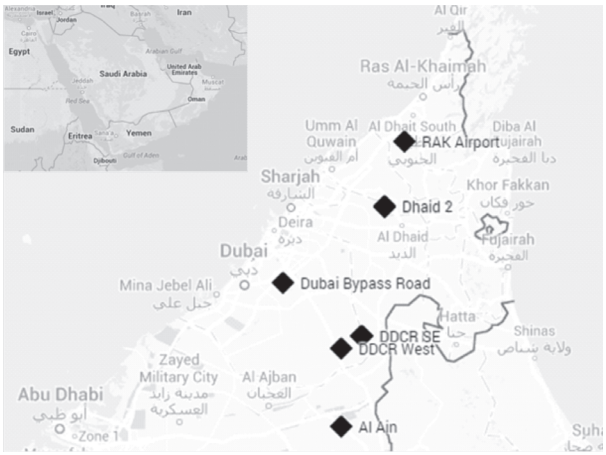

Fig. 1. Locations of the research sites within the United Arab Emirates

Tree density and canopy width were assessed by using freely available satellite data provided through Google Earth. Tree density for each location was calculated as the average of three quadrats, each of 1 hectare. Canopy width was measured for each tree from East to West, to minimize error caused by shadowing. Other data (tree height, trunk diameter, height of lowest foliage, presence of suckers and their distance from the tree base, root exposure, presence of multiple, misshapen or fallen trunks) were collected by observation*in situ*. Trunk diameter was calculated from circumference at breast height, removing trees with a non-circular cross section. Height was measured using a Nikon

Table 1. Characteristics of location and *Prosopis cineraria* populations used for this study.

Location	Public Access	Substrate	No. trees measured	Density(trees / ha)
Ras Al Khaimer	Open	Gravel	34	41.1
Dhaid Gravel	Open	Gravel	28	29.4
Dhaid Sand	Open	Sand	29	93.7
Al Ruwayyah	Open	Sand	21	1.4
DDCR NE	Reserved	Sand	33	45.1
DDCR SE	Reserved	Sand	72	130.7
DDCR West	Reserved	Sand	66	4.5
Al Ain	Open	Sand	26	5.5

Forestry 550 Rangefinder.

Trunk diameter data was logarithmically transformed to reduce heteroscedasticity among locations. Statistical analysis, using IBM SPSS Statistics 20, included analysis of variance of continuous variables (log10 of trunk diameter, height, height of lowest foliage, and depth of root exposure) among locations, Pearson correlations of continuous variables with each other, and Pearson Chi-Square analysis of nominal data (roundness of trunk cross section, sucker presence adjacent, and distant from the tree base, and presence of tree root exposure) among locations.

Results

Trunk diameter, tree height and canopy width all showed significant differences among locations ($P < 0.001$). Tree height was particularly uniform within populations, such that all trees measured from the DDCR West group were taller than trees from the Al Ain group. Canopy width and trunk diameter exhibited similar, though less distinct, uniformity.Tree density was negatively correlated with trunk diameter (Fig. 2) but not canopy diameter or tree height.

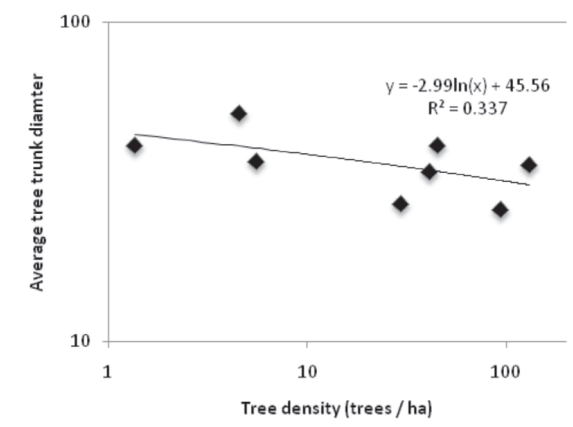

Fig. 2. Relationship between average tree trunk diameter and tree density among the eight study sites.

Height of the lowest foliage differed dramatically between populations. It was significantly higher in the grazed, compared to the protected locations. For example, Mean ± SD was 2.21 ± 0.70 m within the DDCR, but was3.27 ± 0.24 m outside itFig. 3). Thisdemonstrates that almost all foliage within reach of camels had been removed in unprotected locations. Within the DDCR, only 10% of trees had retained their 3 m camel browse line from 2008, though the majority of trees still exhibited a modified canopy structure from this previous herbivory, with few trees extended their foliage completely to the ground. There was ahighly significant negative correlation ($P < 0.001$) between graze height and tree size measures (trunk diameter, r = -0.218; canopy diameter, r = -0.362; tree height, r = -0.146) within the DDCR, indicating that larger trees were extending foliage downward faster than smaller trees (Fig. 4).

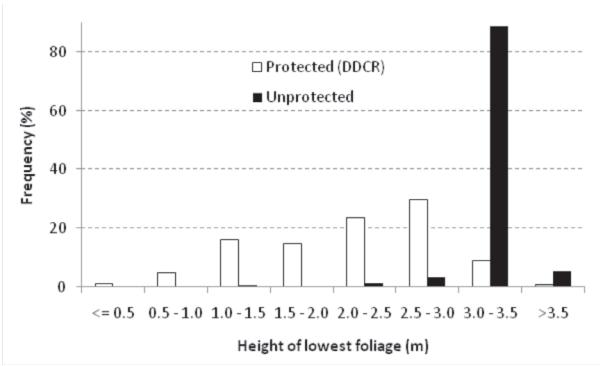

Fig. 3. Effect of camel browsing on lowest foliage height of *Prosopis cineraria* trees.

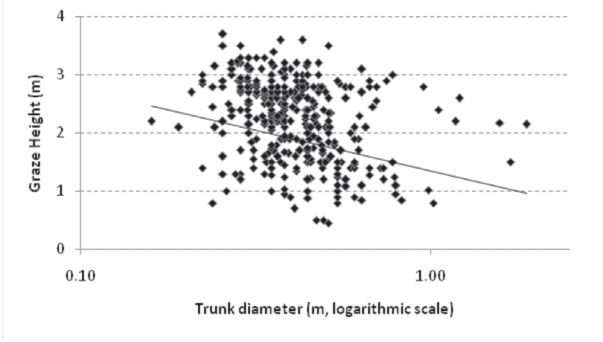

Fig. 4. Relationship between height of lowest foliage and of *Prosopis cineraria* trunk diameter within the Dubai Desert Conservation Reserve.

Vegetative shoots were recorded as present or absent at the tree base, and away from the tree base. Shoots in the latter category ranged in distance of 0.5 to 13.8 m away from the tree. No single ghaf seedling was recorded during this study. There was a strong positive correlation ($r = 0.9040$, $P < 0.001$) between the frequency of basal and distal root suckersamong locations (Fig. 5), which both varied enormously.There was no relationship between

sucker production and either protection from browsing or substrate type (sand or gravel). However, presence of both basal and distal suckers were significantly associated with root exposure ($P < 0.0001$ for each).

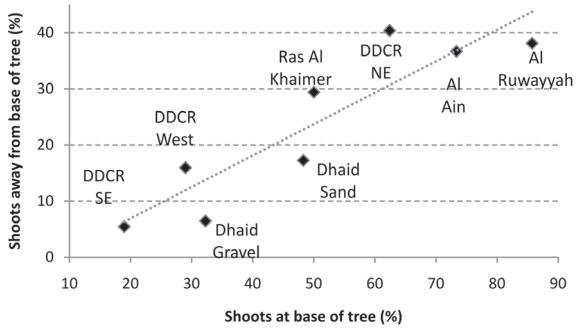

Fig. 3. Relationship between frequency of suckers at the base, and away from the base of *Prosopis cineraria* trees in the eight study sites.

Root exposure occurs when soil is eroded away from the base of the tree, causing the root-stem transition point to be above ground. Root exposure occurred in 15% of trees growing in sandy substrate but only 3% of trees growing in gravel ($P = 0.0072$ using Pearson Chi-Square). At the Al Ruwayyah site, more than half the surveyed trees had exposed roots.Trees with exposed roots were much more likely to have suckers at their base (80%) and away from the trunk (29%) than trees without exposed roots (29 and 14% respectively, $P < 0.0001$ for both), though the extent of root exposure had no significant effect. Of the nine trees observed that were severely bent or fallen, all exhibited shoots at their base even though their root-stem transition point remained at ground level.

Discussion

Animal husbandry practices throughout the UAE have dramatically affected the foliage structure of *P. cineraria* adult trees, but whether these practices have also affected reproduction is less clear. Camels maintain a browse line of 3.0 to 3.5 meters above ground level, which gradually lowers to the reach of another herbivore, or to the ground when camels are removed. Presence of suckers, however, was affected by stability of the ground surface level. When ground level was subject to change, frequency of suckers both near and away from the tree base increased. Consequently the locations with the highest rates of suckers had a sandy substrate. There was no evidence of any increased survival of distal shoots into viable trees in the DDCR, since in all locations there was no indication of shoot survival beyond a single season. No seedlings were observed during this study, hence there was no evidence of successful recruitment by either sexual or asexual means. Nevertheless recruitment was observed to occur occasionally in livestock exclosures that were not part of the study.

Our study indicated that there is almost no *P. cineraria* seedlingrecruitment from sexual propagation (i.e., from seeds). This might be attributed to the lack of safe sites, destruction of the recruited seedlings by herbivores, as occurs with suckers, or seed sterility caused by inbreeding depression. Recruitment of woody plants in arid savannahs is dependent on both bottom-up (resource access) and top-down (fire, herbivory) limitations (Bond, 2008). It requires soil moisture presence in the upper soil layers that are shared with annual species during the first few months, followed by a presence of deeper moisture as the plant establishes its taproot (Resco de Dios et al., 2012).Sand has the poorest water holding capacity of any soil type, due to its coarseness (Hillel, 2003). Overgrazing tends to favor woody perennials over annuals in semiarid grasslands, since it increases the resources available for trees and shrubs (Van Auken, 2000). The opposite occurs in the hyper-arid rangelands of the UAE, since grazing reduces seedling diversity of both annual and perennial species (Gallacher and Hill, 2008), *P. cineraria* is highly palatable (Fagg and Stewart, 1994) and it competes mainly with other woody plants, rather than annual or biennial species (Batanouny, 1987).

Overgrazing is a major problem for the establishment of different plant growth formsin UAE deserts (El-Keblawy et al., 2009; Gallacher and Hill, 2006). However, the lack of sexual propagation in protected areas suggests that safe site availability might be a critical issue in the establishment of *P. cineraria* in the harsh deserts of the UAE. A study in southern Iran found a significantly positive effect of *Salvadorapersica*phytogenic mounds (nebkhas) on the recruitment, growth and survival of *P. cineraria* (Pool et al., 2013).

The uniformity of tree size parameters within locations indicates that there is a site-specific determinant to plant size. Trunk diameter was related to plant density, but other size parameters were not. One possibility is that plant size is related to age,

and that tree recruitment occurs rarely, but in large numbers. This was considered the most likely recruitment pattern for *Prosopisvelutina* seedling emergence in southern USA (Resco de Dios et al., 2012). It is a similar strategy as is used by ephemeral species, but on a much longer timescale. If true, then recruitment would naturally occur only when there is a succession of seasons with good growing conditions and/or low browsing pressure. It would mean that recruitment is unlikely to occur throughout most of the UAE rangeland today, since browsing pressure no longer fluctuates from season to season, but it would also mean that regeneration of an area could be easily managed through the exclusion of livestock during occasional good seasons.

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