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Effects of 'red unit' deposit on Acacia trees in the hyper-arid southern Israel

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ABSTRACT

During the last few decades, populations of the *Acacia* genus across the hyper-arid Arava Valley and southern Negev have faced considerable demographic changes, with high mortality rates as a predominant trend. We suggest that, in addition to the decreasing precipitation rates and the resultant decrease in flood events during this period, these changes are not homogenous across the region but are related to the type of wadis' (ephemeral streams') riverbed. The largest part of the wadis across the region is covered by stony alluvium stratum. At the same time, a small share of the area and some of the wadis are covered by a hard (cement-like) paleo layer of fine-grained reddish sediments ('red unit' deposit, also named the Zehiha Formation). Of the most important observable differences is the high rock fragment (particles >2000 μm) content in the alluvium as opposed to the practically no rock fragment content in the red unit. The Acacia trees and wadi riverbeds (alluvium stratum/red unit deposit) were studied in six wadis during the summer of 2015. Of these wadis, three contain an alluvium stratum and other three, a red unit deposit. The study results revealed very high variability in terms of overall (both alive and dead) tree density in the wadis. Yet, the mean overall tree density was (though not significantly, $P = 0.5463$) 42% greater in the red unit deposit than that in the alluvium stratum. At the same time, mean percentage of alive trees was significantly ($P = 0.0437$) and 9% greater in the red unit deposit than that in the alluvium stratum. Generally, characteristics of the red unit deposit indicated much better soil quality than those of the alluvium stratum. These included the texture (clayey in the red unit vs. sandy in the alluvium), hygroscopic moisture content (fivefold greater in the red unit), soil organic carbon concentration (69% greater in the red unit), and calcium carbonate content (24% smaller in the red unit). Above all, means of both water field capacity and permanent wilting point were approximately threefold greater in the red unit deposit than that in the alluvium stratum, resulting in the mean available water capacity to be threefold greater in the red unit than that in the alluvium. Strongly positive and significant ($P < 0.0001$) correlation was found between the percentage of alive trees and available water capacity ($r = 0.91$), but not between overall tree density and this variable. It is concluded that as long as precipitation regime and flood frequency are normal (similar to the long-term average) in these hyper-arid drylands, the Acacia similarly grow and establish under both the red unit deposit and alluvium stratum. However, once long-term droughts or climatic change occur, with the resultant decrease in precipitation rates and flood frequency, the red unit deposit alleviates water stress, considerably increasing Acacia vitality and survivability.

1. Introduction

Acacia trees encompass an important keystone species across southern Israel, as well as in other hyper-arid regions in the south- and south-eastern- Mediterranean Basin. In southern Israel, the Acacia genus consists of three species: *A. raddiana* (Savi), *A. tortilis* (Forssk.), and *A. pachyceras* (O. Schwartz; formerly *gerrardii* [Benth.]/*negevensis* [Zohary]) (Ashkenazi, 1995). Similar to other vegetation genus, the Acacias are concentrated along the wadis (ephemeral streams), where flood waters are available (Andersen and Krzywinski, 2007). Since the late 20th century, the Acacias across the southern Negev desert and Arava Valley of southern Israel have faced considerable modifications in terms of population structure, of which high mortality rate and low recruitment rate are predominant (Ashkenazi, 1995). These changes in the Acacia population have coincided with a sharp decrease in precipitation, ranging between 30% in the northern Arava Valley to 50% in the

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southern Arava Valley between the mid-20th century and early 21st century (Ginat et al., 2011).

Several studies have investigated the factors regulating the Acacia populations in southern Israel. Of the suggested mechanisms, the most prominently studied anthropogenic-related ones were water drilling from underground aquifers (Sher et al., 2010), and the construction of roads or other infrastructures that modify water courses in the wadis (Ben David-Novak and Schick, 1997). Other, biotic-suggested mechanisms were seed attacks by insects such as bruchid beetles (Or and Ward, 2003), the infestation of trees with hemiparasitic mistletoe (*Plicosepalus acaciae* [Zucc.], formerly *Loranthus acaciae*) plants (Wiegand et al., 2000), and the dramatic decrease in populations of large herbivores that had been a source for seeds endozoochory, i.e., allowed he seed dispersal and germination after passing through the animals' gut (Stavi et al., 2015b).

A recent study showed that in wadis that drained into the Arava Valley, the germination of Acacia seedlings occurs in the streams floor only, and that one year after germination, recruitment rate of seedlings is ~2%. This study reveled that the main impediments to recruitment are fluvial processes, resulting in the seedling removal through soil erosion, or their burial by deposited sediments (Stavi et al., 2015a). Another study in this hyper-arid region showed that mortality of existing Acacia trees in wadis range from ~10 to 70%. This study also reported negative relations between percentage of tree mortality and latitude, but, at the same time, reported no relations between percentage of tree mortality and any such factors as basin size or location of individual trees in certain habitats across the valley floor (Stavi et al., 2014). The high variability of tree mortality reported in the latter study drew attention to the need to search for additional, physical factors which regulate water availability for the Acacias, and determine their vitality and survivability. This was the motivation for searching for possible relations between percentage of Acacia mortality and riverbed features.

The predominant type of riverbed across the region consists of stony alluvium with a high percentage of rock fragment content, and with coarse texture. At the same time, confined areas across the Arava Valley and southern Negev desert are covered with 'red unit' deposit, which is defined with fine texture. Recent, visual observations raised the possibility of a more verdant appearance in wadis with the red unit deposits. Therefore, the specific objective of this study was to assess the impact of riverbed type (alluvium vs. red unit) on Acacia density and vitality. It was hypothesized that the finer texture of the red unit deposit has a greater capacity to retain water, boosting its availability for the trees, increasing their density and improving their survivability. Also, it was further hypothesized that, compared with the alluvium stratum, additional features of the red unit deposit make it more favorable for the growth of Acacias.

2. Materials and methods

2.1. Regional settings

The study was conducted in the south-eastern Negev desert and southern Arava Valley. The length of the Arava Valley is 175 km, stretching between the southern Dead Sea and northern Aqaba Gulf, and its width ranges between 5 and 15 km. The region's height ranges between 350 m below sea level and 270 m above sea level (Ron et al., 2003). Mean daily temperatures are 15 °C in the coldest month (December) and 31 °C in the hottest month (July). Mean relative humidity ranges between 47–58% and 24–33%, respectively (Bitan and Rubin, 1991). Potential daily evaporation ranges between 3.4 and 12.6 mm, respectively (Data obtained from the Central Arava R&D website. Interannual mean for 1994–2012). Mean annual precipitation rates have ranged between 50 mm in the northern Arava Valley and 25 mm at its southern edge (Ron et al., 2003).

Lithology of the uplifted western margins of the Arava Valley is mainly comprised of marine carbonates from the Cretaceous and Tertiary ages. The wadis are covered with coarse gravel, with grain size decreasing upstream. In the inter-stream plains, gypsic–salic soils (Ginat et al., 2002) covered with desert pavement (reg) are predominant (Ron et al., 2003). In addition to the common alluvial soils, remnants of a hard (cement-like) layer of fluvial, fine-grain reddish sediments (the 'red unit', also named the Zehiha Formation) are deposited in some of the stream valleys, overlying the Pliocene Arava Formation or the Cretaceous marine rocks (Ginat et al., 2003). The red unit contains rhizoconcretions and Bk horizons of calcic nodules, and represents truncated calcic paleosols. These reddish sediments are not genetically related to the present drainage system, and are considered relicts of the semi-arid conditions which defined the region during the Early Pleistocene (Ginat et al., 2002). Transects carried out on roads and other engineering infrastructures along the Arava Valley revealed that the depth of the red unit reaches down several meters (unpublished field observations by the authors).

Overall, vegetation across the region mainly occurs along the wadis. In addition to the *A. pachyceras*, *A. raddiana*, and *A. tortilis*, the dominant perennial species consist of *Tamarix aphylla* (L.) Karst., *Tamarix nilotica* L., *Lycium shawii* Roem. & Schult., and *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. Biannual and annual vegetation species consist of *Helianthemum lippii* (L.) Dum.Cours., *Blepharis attenuate* Napper, *Asteriscus graveolens* (Forssk.) Less., *Salvia aegyptiaca* L., *Anastatica hierochuntica* L., *Aaronsohnia factorovskyi* Warb. & Eig, and *Trigonella stellata* Forssk. (Feinbrun-Dothan and Danin, 1991).

2.2 Study design, mapping, sampling, laboratory work, and data analyses

The study was implemented during summer 2015. Location of the wadis with red unit deposits determined the location of blocks, so each block consisted of a pair of one wadi with red unit deposit and a relatively nearby wadi without red unit deposit. Additional criteria for wadi selection were: (1) the absence of anthropogenic disturbances, such as underground water drilling; (2) a distance of at least 500 m from a road transecting the wadi; and (2) a rough similarity—within pair—in terms of basin size. Considering these limitations, three blocks were delineated, consisting of: Shita Wadi (Fig. 1) + Ketura Wadi (the 'Eastern block'); Grofit Wadi (Fig. 2) + Enshem Wadi (the 'Southern block'); and Zihor Wadi + Ketzev Wadi (the 'Western block') (Fig. 3; Table 1).

In the lab, an ArcGIS software was utilized for delineation of a 2-ha plot in each of the six wadis. The plots were delineated along the ephemeral water course, and stretched throughout the wadi width, forming an elongated polygon. Then, GPS points for the four corners of each plot were delineated at the field site to implement the Acacia survey and riverbed sampling. The Acacia survey encompassed all

Fig. 1. Shita Wadi. Note the hard surface of red unit deposit in the wadi's riverbed.