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ASSOCIATION OF *SALSOLA INERMIS* AND SCORPION BURROWS IN LEACHED SOILS IN THE JUDEAN DESERT, ISRAEL

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ABSTRACT

Salsola inermis is a summer annual xerohalophyte confined to somewhat salty loessial soils and to soils disturbed by human activity in deserts of the Middle East. It was found growing on slopes with leached upper soil layers and salty layers at depth, in association with scorpion burrows. It is assumed that the disturbance caused by piles of seedless soil disposed of by the scorpions assists the establishment of *S. inermis* and probably eases its competition with the nonhalophytes typically growing on the slopes.

INTRODUCTION

Salsola inermis is a summer annual halophyte flourishing in desert areas of the Middle East (Negbi and Evenari, 1962; Negbi, 1968; Danin, 1983). It germinates at the beginning of winter, produces a rosette of 6, 10, 14, or 18 small leaves and a deep tap root in winter (Evenari and Gutterman, 1966; Negbi, 1968; Evenari et al., 1982; Danin, 1983), and blooms during July–September. It occupies primary habitats where soil salinity is moderate (Danin, 1983) and secondary, mechanically-disturbed habitats, such as roadsides in desert areas (Evenari et al., 1982; Danin, 1983). Soil salinity at the surface of the disturbed soils may be relatively high if saline layers have been brought up by the disturbing agent from deep parts of the soil profile; it may be low if the disturbance took place long ago and the new surface has already been leached, or if the disturbed part of the soil was not saline to begin with.

Poa eigii dominates north-facing slopes in the Judean Desert east of Jerusalem where the soil surface is leached and has low salinity (Danin, 1978). I was, therefore, surprised to discover *Salsola inermis* plants in the nearly continuous carpet of *Poa eigii* among *Suaeda asphaltica* shrubs during the summers of 1991, 1992, and 1993.

The aim of the present paper is to explain this anomaly of a halophyte prospering in a nonsaline desert habitat.

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LOCATION, VEGETATION, AND SELECTED FAUNA

The site of this study was a steep north-facing slope near the Jerusalem–Jericho road, some 200 m south of the "Sea Level Sign", 8 km SW of Jericho, at coordinates 35°24'20"E/ 31°47'30"N. The north-facing slopes are covered by *Suaedetum asphalticae* (Danin, Orshan, and Zohary, 1975; Danin, 1978, 1983). *Suaeda asphaltica* is almost the only semi-shrub growing there, accompanied by many annual and perennial herbaceous species (Danin, 1978). A microphytic crust, composed of mosses, liverworts, lichens, and cyanobacteria, covers the area among the tufts of the dominant herbaceous perennial grass — *Poa eigii*.

The most prominent animal activity is that of the scorpion *Scorpio maurus palmatus* (Hemprich et Ehrnberg, 1829), which makes holes in the ground and disposes of the soil in a small pile below the entrance to its tunnel.

METHODS

Some 10 scorpion holes and the pattern of their tunnels were excavated at the site of this study and similar sites in the Judean Desert. Soil samples were obtained during the rainy season (January 1993) from 10 piles of soil on the slope below the entrance to scorpion tunnels. Control samples were taken from the soil surface, at a depth of 0–1 cm, among *Poa eigii* tufts, some 5 to 10 cm away from the scorpion piles. An additional 5 pairs of "scorpion piles" and their control were obtained from another slope, 100 m north of that of the winter sampling, in order to represent the status of soil in summer (September 1993). The two slopes had very similar physical conditions, i.e., inclination, aspect, soil type, and geological formation. Vegetation cover and animal activity seem to be similar too. The conductivity of 1:5 soil extracts for winter samples and 1:3 soil extracts for summer samples was measured with a conductivity bridge. Extracts were made by shaking each soil sample with water for 3 h. The differences in the concentration of soil extracts were related to the size of the soil samples. Qualitative observations of the scorpion piles and vegetation on the entire slope were made several times between January 1992 and January 1994.

RESULTS

The scorpion holes are some 20 cm deep and run obliquely or perpendicularly to the soil surface. These tunnels are 1.5–2 cm wide and 0.5 cm high and are elliptic in cross section. The scorpions clean their tunnel and dispose of the soil in a small pile on the slope below the entrance to their tunnel. Hence, the tunnel of an individual active scorpion has a small pile of fresh soil, nearly 2–7 cm in diameter and 1–2 cm high, below its entrance. The holes are found in the areas among the *Poa eigii* clumps and not within these clumps.

The results of soil extracts are presented in Table 1. In 12 of the 15 pairs of "scorpion pile" vs. their control, the salinity of the soil from the pile was slightly lower than that of the control; two pile samples had higher salinity than that of the control, and in one the salinity was equal. However, analysis of variance (ANOVA), using the GLM procedure of SAS, Tukey's grouping test, and t-test, revealed that these differences are not significant ($t = 0.4455$, $DF = 27$, $p < t\ 0.6595$).

Stem remnants of the largest *Salsola inermis* plants which grew in summer 1991, using the rainfall of winter 1990–1991 (111 mm in Jericho), were about 10–15 cm in height. The diameter of the whole plants was 10–15 cm. The largest of those which grew in summer 1992 (345 mm in Jericho) were 20–30 cm in height and diameter, and those of summer 1993 (119 mm in Jericho) were 10–15 cm in height and diameter. Observations made during the summer of 1992 and after the first rain showers of the winter of 1992–1993 revealed the mutual occurrence of adult plants of *Salsola inermis* and scorpion piles. There were some 20 sites where dispersal units of *Salsola inermis* were found near freshly-formed soil piles by the scorpion. At least a few diaspores were covered by the soil.

DISCUSSION AND CONCLUSIONS

Of the many *Salsola* seedlings developing in winter, only a few reach maturity (Evenari et al., 1982). The experimental study of Semach (1974) revealed that *Salsola inermis* cannot compete with nonhalophytic winter (glycophytic) annuals unless the subsoil is saline. In non-saline soils, glycophytic winter annuals use the entire reservoir of soil water, and *S. inermis* fails to establish itself and reach maturity. However, the plant is well known from disturbed habitats (Negbi, 1968; Evenari et al., 1982; Danin, 1983), which requires an explanation. Since the scorpions bring soil without seeds from deep layers up to the relatively leached, compacted soil surface, the following may be suggested. The seedless aerated subsoil covers both diaspores of *S. inermis* and the entire seedbank of glycophytes on the soil surface. The sites appropriate for the establishment of glycophytes are limited by the growth of compact *Poa eigii* clumps (Danin, 1978). It is suggested that the competitive pressure of glycophytes on *S. inermis* seedlings in the scorpion-induced microsites is decreased and they are unable to out-compete this colonizing species. The roots of *S. inermis* seedlings penetrate during winter and reach deeper saline soil layers (Evenari et al., 1982). The water of the latter is not used by the glycophytes, thus enabling the full development of *S. inermis* seedlings, whose roots have passed through the leached soil layers. At least some of the scorpion piles during some of the years may be salty and may therefore not only cause disturbance of the soil, but may also increase soil salinity at the soil surface.

Following the findings of Glinski and Stepniewski (1985), one may suggest that the aeration of the soil in the "scorpion hill" as well as in the mechanically-disturbed habitats may play an important role in the germination and especially in the establishment of *S. inermis*.

The individuals of summer 1991 were relatively small compared with those of 1992 that enjoyed an exceptionally moist year, with ca. 200% the mean annual rainfall. The plants which developed in summer 1993 were as small as those of 1991. It seems that the disturbed scorpion-induced microhabitat controls the establishment of *S. inermis* seedlings on the slope, whereas the amount of rainfall influences the size they may reach. The findings of Evenari and Gutterman (1976) that in *S. inermis* there is a good correlation between plant size and plant density were not studied in the present research.

Other boring animals such as ants or rodents may induce the development of *Salsola inermis* near their living places, but their pattern of distribution may look different. However, *Salsola inermis* plants developing in *Poa eigii*-covered areas of the *Suaedetum asphalticae* of the eastern Judean Desert always indicate the presence of the scorpion *Scorpio maurus palmatus* below the ground.

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