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Spiny plants in the archaeological record of Israel

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A R T I C L E I N F O

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Dedicated to Professor Aharon Horowitz on the occasion of his retirement.

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A B S T R A C T

The flora of Israel, like in other arid regions, has many spiny plants. We describe their existence in the archaeobotanical record of the last 780,000 years. Of 246 spiny/thorny species in the current flora, 19 are trees, 37 are shrubs, 50 are half-shrubs, 83 are perennial herbs and 57 are annuals. Forty-six (18.7%) spiny/thorny species were identified in the archaeobotanical record: 15 tree species (78.9%), ten shrub species (27.0%), six half-shrub species (12.0%), three perennial herb species (3.6%) and 12 annuals (21.1%). Because humans needed wood, trees were taken into their habitats. Since trees are better preserved than herbaceous plants and shrubs their remains are more common. Only a small proportion of the spiny/thorny half-shrubs and perennial herbs was found, probably because they are not a good source of firewood, construction materials, or human food. Spiny weeds, and segetal and ruderal plants entered the archaeobotanical remains either by chance, as seeds contaminating grain and fodder, growing at the sites, or through their deliberate use by ancient peoples as supplementary foods and medicine. The identified spiny/thorny species in the archaeobotanical record of Israel indicates that the flora was always spiny even before the significant human impact in the last several millennia.

1. Introduction

Three terms in English are used to describe sharp defensive plant organs: spines when they are made of leaves; thorns, when they are made of branches; and prickles, when they are made of cortical tissues (e.g., in roses) (Raven et al., 1999). Here, for convenience, we define spiny plants as those producing any type of sharp appendages. Because the aboveground parts of plants are commonly utilized as food by various types of herbivores (Crawley, 1983), there was a permanent evolutionary arms race between plants and their herbivores. On an evolutionary time scale, plants acquire better defenses and herbivores partly or fully overcome them (Cornell and Hawkins, 2003). Among the many types of anti-herbivore defenses that plants use, spines provide mechanical protection against herbivory (Janzen and Martin, 1982; Cooper and Owen-Smith, 1986; Janzen, 1986; Myers and Bazely, 1991; Grubb, 1992; Gowda, 1996; Rebollo et al., 2002) because they can wound herbivores' mouths, digestive systems (Janzen and Martin, 1982; Janzen, 1986), and other body parts. Recently, following the cloning of a large array of pathogenic bacteria from spines and thorns, it has been proposed that plants use spines to infect large herbivores with such bacteria in a form of biological warfare (Halpern et al., 2007a,b; Lev-Yadun and Halpern, 2008). Spines have additional functions, such as reducing sun irradiation (Gibson and Nobel, 1986; Mauseth, 2006) and taking part in seed dispersal (Zohary, 1962), vegetative dispersal (Gibson and Nobel, 1986; Allen et al., 1991; Bobich and Nobel, 2001) and camouflage (Benson, 1982; Mauseth, 2006). Spiny plants are more common in arid regions than in more humid environments (Grubb, 1992). Not surprisingly, the spiniest plant family – the Cactaceae – is mostly found in arid regions of North America (Benson, 1982).

From the evolutionary and ecological viewpoints alike, spininess increases in various ecosystems following long exposure to herbivory by large animals (Zohary, 1983; Janzen, 1986; Givnish et al., 1994; Sternberg et al., 2000). Even during an individual plant's lifetime, spininess may increase following browsing as a genetically fixed induced defense (Milewski et al., 1991; Perevolotsky and Haimov, 1991; Young et al., 2003). The evolution of plants in an arid region like Israel, with constant pressure from

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natural herbivory on the limited amount of vegetation, and the millennia-old history of intensive grazing by goats, sheep, cattle, horses and donkeys as common agricultural practice, selected for plants that are better protected from grazing and induced an increase in their proportion in the plant populations (Zohary, 1983; Noy-Meir et al., 1989; Perevolotsky, 1994; Perevolotsky and Seligman, 1998). Zohary (1982) stated that there are more than 70 species of spiny plants in the flora of Israel. Shmida (1981) identified 86 spiny and thorny species just in the Mediterranean element alone of the flora of Israel, which composes about 30% of the number of species in the flora. In another study we identified 249 spiny, thorny and prickly plant species in the flora of Israel (Ronel and Lev-Yadun, in preparation).

Israel is located at the edge of the desert belt of the Old World. About half the territory (generally south of 31°15′ N, with a northern extension in the Dead Sea region) receives only 30–200 mm annual rainfall on average. The warmer areas in this belt are dominated by Saharo-Arabian vegetation with enclaves or Sudano-Decanian vegetation in oases. Cooler areas are dominated by Irano-Turanian steppe vegetation (Zohary, 1962). Under such arid conditions agriculture is practiced only in niches where runoff water accumulates and not all over the region (e.g., Evenari et al., 1982). Another section, north of the first (generally south of 31°38′ N, with a northern extension in the Jordan Valley up to the Sea of Galilee), receives 200–400 mm of annual rainfall (a region where agriculture is practiced everywhere, but risks of crop failure are high). This belt is covered by Irano-Turanian steppe vegetation in the more arid parts and by Mediterranean vegetation in the less arid parts (Zohary, 1962). The rest is considered less arid, usually with 400–800 mm annual rainfall during winter but with no summer rains, is dominated by Mediterranean vegetation (Zohary, 1962, 1973; Precipitation Map, 1987). These rainfall belts practically correspond to the dominance of phytogeographical elements in the flora. The driest belt corresponds to the Saharo-Arabian and Irano-Turanian territory, the most humid belt corresponds to the territory where Mediterranean maquis and forest may grow if not degraded by human activity, and in between there is a transition zone with rich, mixed vegetation types (Zohary, 1959, 1962). From early summer (May) to the early winter (November) the non-forested and non-irrigated landscape, even of the less arid region of Israel, is generally yellow without much edible green plant material. Under the local climate, without modern methods of water pumping, grazing was a very important practice, using natural vegetation resources spread at low density (Perevolotsky and Seligman, 1998). The impact of herding in the last several millennia (Sasson, 1998), especially in the long and dry summer, followed millions of years of grazing by large mammals that thrived in the country during the Pleistocene (e.g., Tchernov, 1979; Davis, 1987; Bar-Oz, 2004; Steiner, 2005).

Because of the millennia-old history of grazing, we outline the basic size of human populations and present some published reconstructions of the level of their impact on the environment. The size of the human population of Israel down the ages has changed dramatically. A slow rise from fewer than several thousand people in pre-agricultural periods (ending ca. 10,500 years ago), to about 100,000–200,000 in the more populated phases of the Bronze Age (ca. 5500–3200 years B.P.) was followed by an increase to about 1,000,000 people in the Byzantine period (ca. 1500 years B.P.) (e.g., Broshi, 1980, 1993; Shiloh, 1980; Broshi and Gophna, 1984, 1986; Gophna and Portugali, 1988; Finkelstein, 1990; Broshi and Finkelstein, 1992; Finkelstein and Gophna, 1993; Zorn, 1994). The environmental impact of these populations varied accordingly (e.g., Gophna et al., 1986/1987; Liphschitz et al., 1989; Lev-Yadun, 1997, in press; Lev-Yadun and Weinstein-Evron, 2005). In the Chalcolithic period, beginning ca. 6500 years ago, herding seems to have become a major component of the economy (Levy, 1983; Gophna et al., 1986/1987). This must have considerably intensified the impact of grazing by farm livestock above the natural level of herbivory by large wild herbivores, a trend that has continued, with fluctuations, ever since. Southern Samaria (The Land of Efraim, stretching from Shechem in the north to Beth Horon in the south, and from the foothills in the west to the desert fringe in the east, an area of 1050 km^2, now in the territory of the Palestinian Authority), which has been studied thoroughly (Finkelstein et al., 1997), can thus be used as a test case for population increase for the whole country and for the level of impact of human activity on the vegetation. For instance, the proportion of the land used for agriculture, pasture and wood supply ranged between 0.1% and 15.4% during the Chalcolithic and Late Bronze Age (6500–3200 years B.P.); it was ca. 23% during Iron Age I (ca. 3000 years B.P.) and 81% during Iron Age II, then dropped to 22–40% during the Persian and Hellenistic periods (ca. 2400–3100 years B.P.), rose to 63% during the Roman period (ca. 2000 years B.P.) and to 93% during the Byzantine period, and dropped to ca. 10% during the Umayyad/Abbasid period; it has ranged between 80% and 98% in the last 800 years (Lev-Yadun, 1997). Palynological data from both the Sea of Galilee from the last five millennia (Baruch, 1986) and the Birket Ram crater lake in the northern Golan Heights (Neumann et al., 2007a) indicate a similar process of the degradation of the natural vegetation, namely that the most drastic human impact started some 2500 years ago.

Plants were used by humans for many purposes and here we mention only the major ones. Wood from trees (wild and domesticated) was regularly used for fire, construction and tool making (Meiggs, 1982) and fruits were collected from many of the local wild tree species. Certain shrubs (e.g., *Retama raetam* (Forssk.) Webb and *Sarcopoterium spinosum* (L.) Spach) were commonly used for firewood (Bailey and Danin, 1981; Zohary, 1982). Hundreds of plant species in the Land of Israel and adjacent countries were traditionally used for food, medicine, production of various tools, fencing and other purposes (e.g., Moldenke and Moldenke, 1952; Thalen, 1979; Bailey and Danin, 1981; Palevitch et al., 1982; Zohary, 1982; Dafni, 1984; Weinstein-Evron, 1998), and such uses introduced many of these plants into the archaeobotanical record. Plant material could also have entered the archaeological record via animal dung (Miller, 1984; Charles, 1998; Albert et al., 2008) and by growing wild at the sites.

Here, we discuss the finds of spiny and thorny plants in the archaeobotanical record of Israel in relation to the current richness of spiny plants in the flora of Israel and the Palestinian Authority. We consider the significance of the relative abundance of specific groups.

2. Materials and methods

As part of a broader study on the biology of plant protection by spines (e.g., Lev-Yadun, 2001, 2003a,b, 2006; Lev-Yadun and Ne'eman, 2004, 2006; Halpern et al., 2007a,b; Ronel et al., 2007, 2009; Lev-Yadun and Halpern, 2008) we studied the presence of spiny and thorny species in the archaeological record of Israel by reviewing all the published data of the archaeobotanical remains from Israel and the Palestinian Authority. When a certain taxon was found in more than one archaeological excavation we cite only the earliest find. When only the genus was identified at sites of earlier periods we cite finds from later periods as well if identification was on the species level. The thorny or spiny organs for each taxon are specified in brackets when the taxon is described for the first time. We use very little palynological data because pollen identification is usually possible only to the family or genus level. However, of the spiny taxa, oaks (some of which are spiny) *Olea europaea* L.,