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Signs of soil fertigation in the desert: A pigeon tower structure near Byzantine Shivta, Israel

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ABSTRACT

This article explores a means used by Byzantine agriculturists in the Negev in southern Israel to achieve sustainable soil improvement: pigeon manure. We found high concentrations of manure in ancient pigeon towers strewn across the Byzantine agricultural landscape, characterized by the widespread construction of terraces and dams to manage runoff and floodwater. We show that nitrogen (N), phosphate (P) and organic matter (OM), reliable and recognized indices of soil characterization used by both practical agriculturists and archaeologists, are associated with such towers. The distribution patterns of these indicators have shown congruent and significant perturbations north of the pigeon tower at Shivta. Comparisons with other ancient Levantine installations of this type suggest that the perturbations we identified are associated with a single, above-ground opening that did not survive the destruction of the tower. The door facilitated the controlled, periodical extraction of accumulated manure from inside the tower. This study supports the suggested importance of pigeon manure, evidently used to ameliorate local desert soils, and stresses the usefulness of chemical tests, traditional quantifiers of agricultural soil quality, and anthropogenic interference in identifying pigeon towers and clarifying archaeological problems in a desert environment.

1. Introduction

Agriculture in the Negev desert during the Byzantine period (4th–7th centuries CE) demonstrates the existence of professionally designed, complex agricultural systems that altered local landscapes and which involved the widespread construction of terraces and dams to control runoff and floodwater. Such farming practices during the Byzantine period have been revealed during numerous archaeological surveys conducted in the Negev desert in southern Israel (see: Kedar, 1957; Evenari et al., 1982; Haiman, 2012; Avni et al., 2012; Ashkenazi et al., 2012 and references therein). However, little is known on how soil fertility was maintained by farming communities in the Negev. A physical study aiming to date past anthropogenic influences on Negev soils (Avni et al., 2012) did not search for traces of soil amelioration. Similarly, a small-scale study of soil fertility in the Negev used conventional soil chemistry parameters, but mentioned no evidence for past attempts at manuring those soils by adding essential nutrients, e.g., nitrogen (Ward et al., 2001). In an attempt to address this problem, we studied a Byzantine pigeon tower, an isolated structure used for husbanding pigeons near Shivta, a large, ancient village in the Israel's southern Negev. Initially, we will describe some relevant aspects of the environment in which it was constructed and functioned. This will be followed by the methods used to identify pigeon towers as such, and a brief description of the role and importance of these structures.

Arable soils in the Negev, including those around Shivta, are poor in organic material and essential nutrients, notably nitrogen (Singer, 2007). In the Negev, as in most deserts throughout the world, water availability is the prime limiting factor for plant growth, while the presence of nitrogen is probably the second (Vitousek and Howarth, 1991; Sher et al., 2013). Ancient systems for the acquisition and management of water to enable agriculture in the Negev have been studied to a significant extent (e.g., Evenari et al., 1982; Bruins, 2012). However, only a few studies have reported signs of attempts to ameliorate Negev soils in ancient times

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(e.g., Bruins, 1986: 81,103; van Asperen et al., 2014; Shahack-Goss et al., 2014).

Manuring of cultivated soils to retain their fertility is an ancient, well known, universal, practice. Studies of past manuring, mostly in Europe, have shown that manuring Mediterranean agricultural soils with mammal dung was probably practiced as early as Middle-Late Neolithic Greece (Vaiglova et al., 2014). By the 1st century BCE, Roman writers discussed manuring (Fenton, 1981), indicating that this practice had become widespread in Roman agronomic practices.

Manure production in Byzantine Sagalassos (in modern Turkey) exemplifies its importance for a Levantine site contemperaneous with Shivta and within the same empire ruled from Constantinople (Baeten et al., 2012). Contemporary indigenous Bedouin from Egypt's Sinai peninsula, related to semi-nomadic populations in the Negev, have been documented as habitually using goat manure to fertilize traditional gardens (Perevolotsky, 1981). Visible traces of dung, mainly spherulites derived from excrement, have been found in Negev soils associated with various archaeological sites, possibly indicating the intentional manipulation of dung (Shahack-Gross, 2011; Shahack-Goss et al., 2014 and references therein). However, such finds in themselves do not necessarily reflect intentional manuring.

Investigation of Roman and Byzantine (4th–7th century CE) Negev farmsteads displaying evidence of herding have yielded inconclusive information on the presence of manure and the possible attempt to ameliorate soil (Evenari et al., 1982; Rosen, 1987; van Asperen et al., 2014). This ambiguity regarding fertilization of Negev soils, in conjunction with the discovery of evidence for local pigeon husbanding, has led to examinations of whether pigeon manure might have been systematically gathered and stored by the local population. Such practices, characteristic of a valuable commodity, might indicate its use in increasing the fertility of local fields (see also: Hirschfeld and Tepper, 2006; Tepper, 2007).

The efficacy of pigeon manure as a fertilizer is superior, from the point of view of the nitrogen it supplies, to that of mammals. Mammals excrete nitrogen as urine, a diluted solution of urea. Being a liquid, urine is difficult to collect, handle, and store, and the nitrogen in it is rapidly depleted by associated enzymes and microorganisms. Birds, on the other hand, excrete nitrogen as uric acid, a solid and relatively stable compound, easily handled, stored, and utilized. As with mammal dung, mentioned above, the use of pigeon manure for soil amelioration is also referred to by Roman writers from the 1st century BCE (Fenton, 1981).

Nowadays, pigeon manure is used as a fertilizer in some traditional Levantine agricultures, especially in small-scale intensive gardening (Husselman, 1953; Amirkhani et al., 2010; Ibrahim and Eleiwa, 2008). This suggests a similar role for Levantine pigeons in earlier times. The pigeon towers discovered in the Negev, and specifically in the area of Shivta (Fig. 1–2), may have served as a source of fertilizer for the local fields. Pigeon husbandry in the ancient southern Levant is presently identified mainly by architectural remains, including constructed pigeon towers and quarried subterranean installations. Some of these remains are well preserved, while others are barely recognizable ruins.

Many pigeon towers are dated to the Roman-Byzantine periods (1st–7th centuries CE; e.g., Zissu, 1995; Hirschfeld and Tepper, 2006; Tepper and Bar-Oz, 2016), and several have been found in the arid zones of the Negev desert (Fig. 1; Table 1). Pigeon towers are generally located at a distance from the inhabited area, close to the cultivable land. Their prevalence attests to the valuable economic role played by pigeons during those times, as the possible source of manure, meat, entertainment, and cultic needs. However, identifying a ruined ancient pigeon tower often relies on architectural considerations along with visible macro remains like bones and egg shells. When such remains are absent, a secure identification of a pigeon tower is currently impossible.

Studies of the effects of birds on their environment have shown that ornithogenic soils contain high amounts of phosphate (P) and organic matter (OM) (Bolter, 2011). OM and P content have been recognized as indicators of anthropogenic interference in archaeological sites (Homburg et al., 2005; Goldberg and Macphail, 2006: 344; Aderley et al., 2008). In the search for additional aids to identify pigeon towers, it has been suggested that the chemical analysis of soil associated with securely identified pigeon towers be examined in order to provide a characteristic profile with which other, less securely identified, sites could be compared.

For that purpose we focused on a securely identified pigeon tower situated near the UNESCO world Heritage site of Shivta in the Negev desert (Fig. 2). Shivta and the ancient farmlands around it have been explored since the latter half of the 19th century (See: Palmer, 1871; Segal, 1983; Hirschfeld, 2003 and references therein). The site contains remnants of 170 houses and three churches from the Byzantine period, dated to the 4th–7th centuries CE.

The ancient agricultural lands associated with Shivta include fields and dams in the Lavan Valley basin (over 197 km^2; see Kedar, 1957). They are accompanied by sophisticated systems for collecting and distributing runoff water indicative of advanced agricultural practices. Four pigeon towers have been identified within this vicinity until now, all less than one km from the settlement site, and three of them are dated to the Byzantine period (see Table 1). Like many of the pigeon towers of that period, these four were built as free standing structures, rectangular or circular in plan with an estimated height of c. 6–9 m, and containing hundreds of pigeonholes for the birds to nest (see: Netzer, 1991: 370–373, 637; Zissu, 1995; Foerster, 1995: 219–223; Hirschfeld and Tepper, 2006 and references therein).

Previous field studies of ancient Shivta have revealed extensive agricultural development in its vicinity (see: Kedar, 1957; Evenari et al., 1982; Hirschfeld and Tepper, 2006). This has led to speculation that the inhabitants utilized animal manure, particularly pigeon dung, to correct the inherent shortage of nitrogen in the local soil (Tepper, 2007). For the present study, one of Shivta's four pigeon towers was selected for further investigation (Fig. 3). This selection was based on the tower's relatively good state preservation and thus its potential for serving as a particularly informative model for verifying the connection between visible pigeon remains (e.g., bones, broken egg shells and manure) and local soil chemistry. It was reasoned that demonstrating a connection by means of such a well preserved and securely identified pigeon tower, could facilitate the identification of pigeon husbandry in other, less well preserved, sites. Furthermore, establishing a positive correlation between the presence of this tower and changes in the chemistry of the soils surrounding it could help our understanding of the role of pigeon towers and the manure they yielded for ancient agricultural systems in general.

2. Material and methods

The pigeon tower studied here was excavated in 2004 and proved to be the best preserved of the four installations in the immediate vicinity of Shivta (Hirschfeld and Tepper, 2006, Fig. 2: PT No. 1; Figs. 3–6). The circular plan structure was built on bedrock and is preserved to a maximum height of 1.2 m above ground level. Its bottom was constructed as a space to store manure by sealing the floor and the inner face of the lower walls with mortar. At its base the external diameter of the structure is 5.2 m and the wall thickness is about 85 cm. The internal space (3.5 m in diameter) is divided by a Y-shaped wall into three rooms (Fig. 4). Four rows of