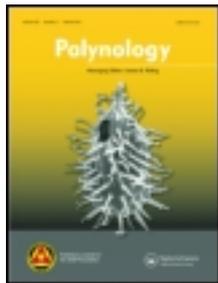


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Fossil pollen reveals the secrets of the Royal Persian Garden at Ramat Rahel, Jerusalem

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The ancient tell (mound) of Ramat Rahel sits on the outskirts of Jerusalem. It features an impressive residency and palatial garden that flourished during the seventh to fourth centuries BCE, when biblical Judah was under the hegemony of the Assyrian, Babylonian and Persian empires. Until recently, the garden's flora has been a mystery, as standard archaeological procedures were unable to retrieve secure archaeobotanical remains. A unique method of extracting fossil pollen from ancient plaster has now enabled researchers to reconstruct the exact vegetation components of this royal Persian garden and for the first time to shed light on the cultural world of the inhabitants of the residence. The plaster layers and garden are dated archaeologically and by Optically Stimulated Luminescence (OSL) methods to the Persian period (fifth to fourth centuries BCE), and produced evidence of importation by the ruling Persian authorities of special and highly valued trees to the garden from remote parts of the empire. The most surprising find, and marking its earliest appearance in the southern Levant, was the citron (*Citrus medica*), which later acquired a symbolic-religious role in Judaism. Other imported trees found to have been grown in the garden are the cedar, birch and Persian walnut. The pollen evidence of these exotic trees in the Ramat Rahel palatial garden suggests that they were probably brought to flaunt the power of the imperial Persian administration. Native fruit trees and ornamentals that were also grown there include the fig, grape, olive, willow, poplar, myrtle and water lily. The identification of the ancient garden's plant life opens a course for future research into the symbolic role of flora in palatial gardens. It also offers new opportunities for studying the mechanism by which native flora was adopted in a particular geographical area and proliferated by humans across the world.

Keywords: pollen; citron; ancient gardens; Persian Period; Ramat Rahel; exotic trees; Israel

1. Introduction

Pollen grains, the fingerprints of plants, are extremely helpful in reconstructing ancient natural vegetation and climate conditions (Bryant 1990). This paper documents how pollen fossils can contribute to the reconstruction of environments fashioned by man that long ago disappeared – in our case, gardens. It is well attested in historical, as well as archaeological, records cross-culturally that artificially planted gardens were part of many palatial edifices and that usually they displayed the capacity of the palace owner to import rare and exotic plants and to sustain these plants in their adopted, unnatural habitat (Foster 2004; Conan 2007; Avasaf 2010).

The tell (mound) of Ramat Rahel is located 4.5 km south of the ancient city of Jerusalem, in the southern Levant (Figure 1a–c). The site features a royal residency that flourished during the seventh to fourth centuries BCE (Aharoni 1962, 1964; Lipschits et al. 2009, 2011). Adjacent to this impressive residency a notable garden was discovered; this is the only palatial

garden in the Levant known to date, prior to the classical period (Lipschits et al. 2009, 2011). Until recently, the garden's flora has been a mystery, as standard archaeological procedures were unable to retrieve secure archaeobotanical remains. The soil of the garden was examined for pollen and phytoliths but yielded no results. However, pollen originating from the flora of the garden may have also been trapped within the garden's different facilities (Fish 1994). Since some of the garden's walls were covered by layers of plaster, the study's hypothesis was that if the plaster had ever been refurbished when the garden was in bloom, the wet plaster surface would have trapped pollen. Previous studies have extracted pollen from Levantine ancient plasters yielding natural vegetation components which represent either the surrounding vegetation or products of different human activities within the site (e.g. Weinstein-Evron & Chaim 1999; Schoenwetter & Geyer 2000).

This research aims to reconstruct for the first time the botanical components of a Near Eastern ancient

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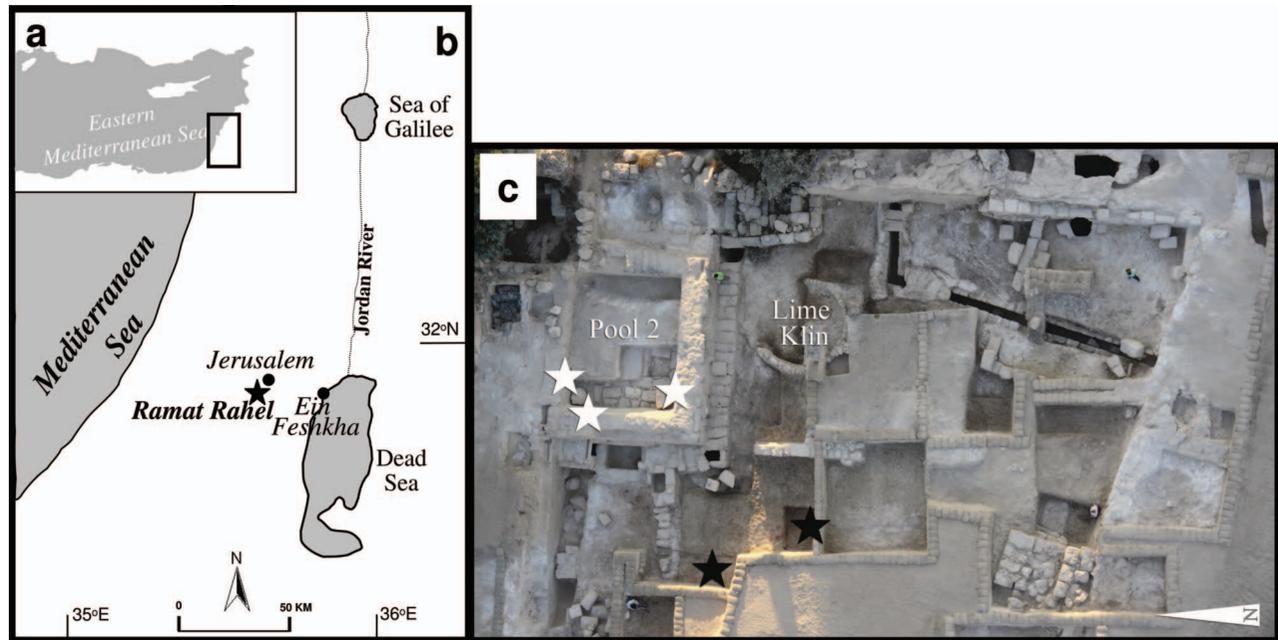


Figure 1. (a) Map of the southern Levantine region; (b) location map showing the site of Ramat Rahel together with other locations mentioned in the text; (c) aerial view of Area C1: the garden and some of its facilities. Notes: black stars mark the location of soil samples taken for Optically Stimulated Luminescence (OSL) dating, and white stars mark the location of samples taken for pollen analysis from the inner plaster layers of Pool 2. Its inner measurements are ca. 7×7 m.

garden based on trapped pollen that originated in layers of plaster. In order to determine the exact period when this palatial garden existed, in addition to the archaeological finds, an independent radiometric dating method based on Optically Stimulated Luminescence (OSL) was performed.

2. Research area

2.1. Climate and vegetation

Ramat Rahel is located in the semi-arid Mediterranean climate zone. Winter (November–March) constitutes the rainy season, with annual rainfall amounting to c. 550 mm (Shahar & Sofer 2011), which rapidly decreases closer to the Judean Desert to the east. Winter is preceded and followed by short transitional seasons – autumn (September–October) and spring (April–May) – in which occasional rains occur, as well as very hot episodes. Summers are hot and dry (Eshel 2002).

The Ramat Rahel site is situated on the border between the Mediterranean vegetation territory to the west and the Irano-Turanian vegetation belt to the east (Zohary 1973; Danin & Plittmann 1987).

- (1) Common trees in the Mediterranean vegetation territory are *Quercus calliprinos* (evergreen oak), *Quercus boissieri* and *Q. ithaburensis* (deciduous oaks), *Olea europaea* (olive), *Pistacia*

(*P. lentiscus* and *P. palaestina*; = pistachios), *Ceratonia siliqua* (carob tree) and *Pinus halepensis* (Aleppo pine). In between the trees or in the clearing semi-shrubs and herbs are common, forming a batha stage. The dominant families within this formation are Poaceae, Caryophyllaceae, Brassicaceae and Asteraceae. Recent plantations of oaks, *Pinus halepensis* and *Cupressus sempervirens* (Italian Cypress) as well as exotic trees, *Eucalyptus*, *Casuarina* and others, have transformed the landscape of the Judean Hills mainly during the previous century.

- (2) The Irano-Turanian vegetation occurs in the research area mainly on the eastern slopes of the Judean Hills. It is characterised by steppe vegetation with dwarf shrubs, e.g. *Artemisia herba-alba* (white wormwood) and grasses.

2.2. The Ramat Rahel site and its palatial garden

The site is located on a prominent hill to the south of ancient Jerusalem, close to the main roads connecting Jerusalem to the south and the west and to major arable lands. The favourable conditions enjoyed by the site are hampered by the absence of a permanent water source.

Archaeological excavations at the Ramat Rahel site exposed a royal edifice that was first built at the end of the eighth century BCE; it went out of use in the third

century BCE, after a few phases of rebuilding and expansion (Figure 3; Aharoni 1962, 1964; Lipschits et al. 2009, 2011). The edifice is composed of two ceremonial courtyards, built quarters and a projecting tower surrounded by an artificial garden. To date, this is the only known palatial garden in the Levant prior to the classical periods.

The garden was spread over 0.5 ha, possibly even more. In order to create it, the natural terrain of the hill had to be reshaped to prepare it for landscaping. Large amounts of rock, a flint and soft limestone formation, were hewn away from the north, west and south sides of the tower, flattening the surface around it and creating artificial scarps close to three metres high that separated the tower from its surroundings. The artificially flattened bedrock was then topped with a layer of soil about 50 cm deep brought from elsewhere (Figure 4). Its placement upon the levelled limestone surfaces was artificial and the soil was designated by the excavators as 'garden soil' (Lipschits et al. 2009, 2011). Other features that were added include at least three water pools, three well-built water tunnels, carved stone drains and possibly an underground reservoir. Pool 2 (Figure 1c and Figure 2) is the better preserved of the garden's pools. The walls of the pool are completely plastered and the plaster layer runs continuously from the walls to the floor of the pool, creating rounded edges. Two openings in pool 2 channeled water into the garden to the west through especially esthetic stone drains.

The primary function of the pool had been as a water distribution device. Its use for gathering water should be viewed as less important. In later periods this pool went out of use.

3. Materials and methods

3.1. Palynology

3.1.1. Field sampling

Since Pool 2 is the better preserved of the garden's facilities, it was chosen to be sampled for pollen analysis (Figure 1c, Figure 2); two well-preserved layers of plaster from this pool were sampled. Ten plaster samples were collected: five from Layer I (today an interior plaster) and five from Layer II (the exterior plaster, today covered by slaked lime). In order to sample Layer I, large pieces of the pool wall were taken out. Later at the laboratory, the interior plaster (= Layer I) was gently, and quite easily, separated from Layer II. The slaked lime that covered the exterior plaster was gently scraped at the laboratory. The working hypothesis was that the pollen grains had been caught during the preparation of the plaster, when it was still wet. In order to evaluate this hypothesis sub-sampling was undertaken: each plaster sample, 0.8 cm in width on average, was divided into two samples: the outer part (<0.2 cm) which was peeled away using a knife and the second sub-sample which included only inner filling material. However,



Figure 2. A cross-section in the pool. I = Layer I, the interior plaster; II = Layer II, the exterior plaster, covered partly by slaked lime.

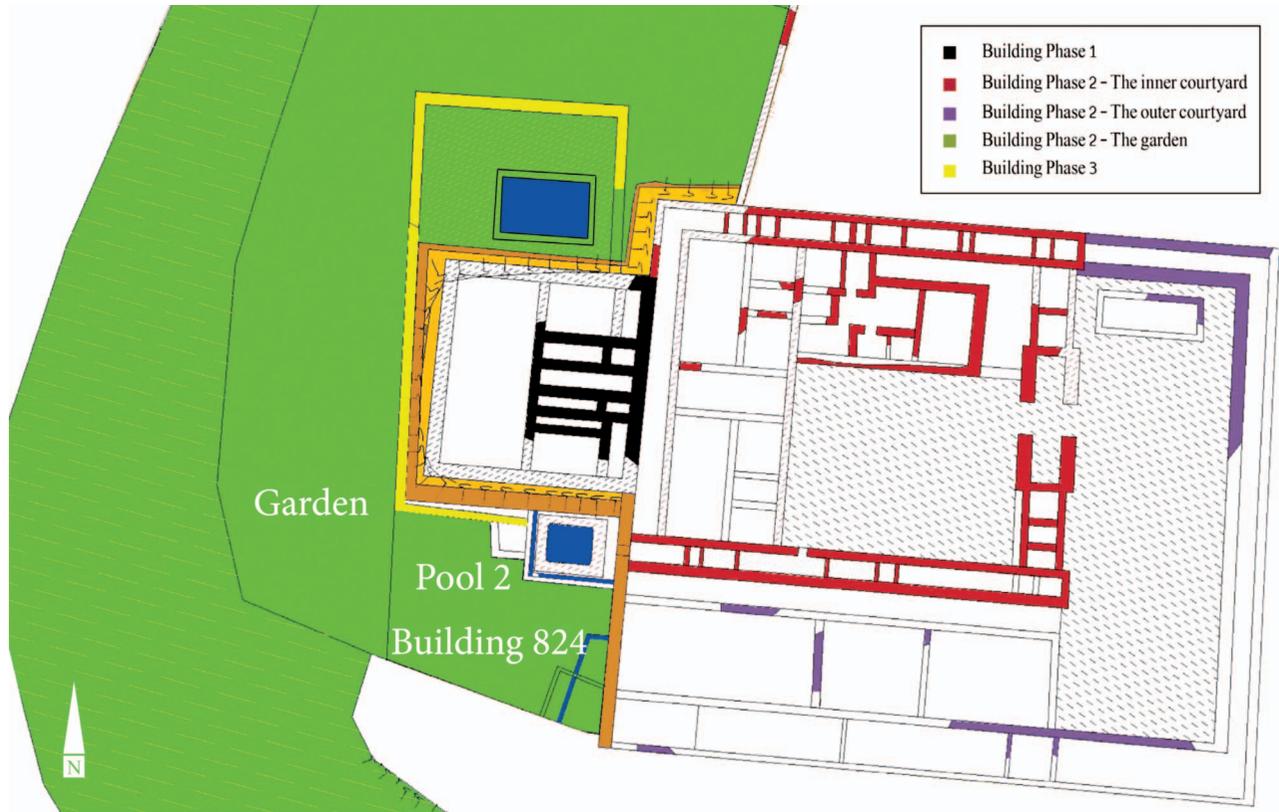


Figure 3. A schematic plan of the Ramat Rahel edifice during the Iron and Persian periods. Phase I was built at the end of the eighth century BCE; the construction of Phase II is dated to the last third of the seventh century BCE; Phase III is an expansion of Phase II dating to the fifth to fourth century BCE.



Figure 4. A section in the garden. The artificially flattened white bedrock (right image) at the bottom is topped by a 50-cm deep layer of soil brought here from elsewhere. The hole (left image) marks the place where one of the Optically Stimulated Luminescence (OSL) samples was taken.

this subdivision was not always easy to achieve and therefore the two groups (outer layer and inner filling material) were not sterile and some mixing had to be taken into consideration.

3.1.2. Pollen extraction

Samples were treated with the following preparation procedure: One *Lycopodium clavatum* C. Linnaeus tablet ($10,679 \pm 953$ spores in average) was added to

each sample. Then 10% HCl was gradually added in order to dissolve the *Lycopodium* tablet and to remove the calcium carbonates within the sample, until the reaction between the acid and carbonates ceased. Samples were rinsed with distilled water several times until pH 7 was achieved. Next, a density separation was carried out by using zinc bromide (ZnBr_2) solution with a specific gravity of 1.95. After stirring well and vortexing, samples were placed in an ultrasonic water bath. Sonication was used to loosen fine organic debris and separate the microscopic particles. Since prolonged and high frequency sonication treatment may result in damage to pollen, a frequency of 20 KHz was used for a maximum of two minutes. After sonication, samples were centrifuged for 20 minutes at 3500 rpm (all other steps were followed by only five minutes of centrifuging at the same rpm). The floated suspension was then sieved through a 150- μm mesh screen and rinsed with distilled water. The sieved material was treated with acetolysis mixture: nine parts acetic anhydride to one part sulphuric acid. Samples were incubated at 80°C for five minutes. Before and after adding the acetolysis mixture the residue was washed with glacial acetic acid. After rinsing the samples with water and then ethanol they were mounted in glycerin.

3.1.3. Pollen identification

A light microscope, with magnifications of 200 \times , 400 \times and 1000 \times (immersion oil), was used for identifying the pollen grains. In each sample all the pollen grains extracted were counted and identified. For pollen identification a comparative reference collection of the Israel pollen flora (Steinhardt National Collections of Natural History at Tel Aviv University) was used as well as pollen atlases (Reille 1995, 1998, 1999; Beug 2004).

The identification of olive was done to the species level since *Olea europaea* is the only wild-occurring species in Israel (Zohary 1973). This is also the case with *Pinus halepensis*, which is the only naturally-occurring pine species in the southern Levant (Weinstein-Evron & Lev-Yadun 2000). The oaks were distinguished into evergreen and deciduous trees: while *Quercus calliprinos* is the only evergreen oak tree in the area. Among the *Q. ithaburensis* type, some may have been *Q. boissieri* which is a deciduous oak species of the upper mountain zones of the Upper Judean Hills (Zohary 1973); *Q. ithaburensis*, on the other hand, is a tree of lower elevations. However, the two deciduous species are palynologically indistinguishable.

Due to difficulties in the discrimination of the Chenopodiaceae and the genus *Amaranthus* these two groups of plants are presented together as Cheno-Am. The Family Asteraceae family was divided into two pollen types: A. Asteroideae and A. Cichorioideae

(Van-Zeist & Bottema 1977). Cereal type pollen, which is distinguished from other grasses by its larger size (at least 37 μm , e.g. Beug 2004), has thick pollen walls and a pronounced annulus around the pore, includes wild and cultivated cereals in addition to several other Near Eastern grasses. From regular pollen grain identification one cannot tell whether they are wild or domesticated cereals (van Zeist et al. 2009). Wild cereals (namely *Triticum dicoccoides*, *Hordeum spontaneum*, *H. glaucum*, *H. bulbosum*, *Avena sterilis* and *A. wiestii*) grow naturally in the Judean Hills (Danin 2004). However, high cereal percentages with no ecological explanation might be connected to human activity.

Results of the terrestrial pollen counts are given in Table 1 and are presented in percentages. The total number of terrestrial pollen grains counted in each sample is given at the bottom of each column. The various pollen types presented in Table 1 are arranged in two groups: (1) native Mediterranean maquis/forest plants; (2) fruit trees and ornamentals. Unrecognisable pollen includes damaged or degraded grains that were unidentifiable.

Aquatic pollen as well as fern spores were excluded from the terrestrial pollen sum and are presented in absolute numbers in Table 2 together with palynomorph concentration values.

Only samples with over 200 pollen grains are presented in Table 1 and discussed in the text. Several other samples were barren or were found to contain too little terrestrial pollen to enable in-depth consideration and discussion. Pollen counting stopped only when 500 *Lycopodium* spores and not less than eight slides were reached.

3.2. OSL dating

Luminescence methods date the time that passed since the last event of signal resetting by sunlight or heat (Aitken 1998) and they are applied mostly to the ubiquitous quartz and feldspar minerals. Optically stimulated luminescence (OSL) dating is based on solar resetting (or bleaching) of the luminescence signal during sediment transport and the OSL age gives the last event of deposition (Wintle 2008). The luminescence signals grow over time from the natural environmental ionising radiation, and the laboratory-measured signal intensity is a function of both age and environmental dose rate. The OSL signals are measured in the laboratory and the equivalent dose (D_e), the amount of irradiation that the sample absorbed since it was last reset, is determined using the single aliquot regenerative dose (SAR) protocols (Murray & Wintle 2000). The environmental dose rates (d) are measured in the field and in the laboratory. The age is calculated from the ratio D_e/d .

Table 1. Terrestrial pollen from the pool plaster at Ramat Rahel.

		Plaster Layer and Field ID				Blooming: Calendar month ¹											
		Layer Ia	Layer Ib	Layer IIa	Layer IIb	1	2	3	4	5	6	7	8	9	10	11	12
Mediterranean maquis/forest (in %)	<i>Quercus calliprinos</i> type	0.9	2.0	1.2	0.4	█											
	<i>Quercus ithaburensis</i> type	0.9	0.0	0.0	0.4	█											
	<i>Pinus halepensis</i>	3.2	25.7	10.5	42.2	█											
	<i>Pistacia</i> (Anacardiaceae)	0.0	0.0	0.6	0.0	█											
	<i>Phillyrea</i> (Oleaceae)	0.0	3.0	0.6	0.0	█											
	Poaceae	1.4	0.0	2.9	0.9	█											
	Cerealia type (Poaceae)	4.6	5.9	4.7	0.9	█											
	Asteraceae Asteroideae	6.9	0.0	0.0	1.3	█											
	Asteraceae Cichorioideae	6.5	5.9	0.6	0.4	█											
	<i>Artemisia</i> (Asteraceae)	0.0	0.0	0.0	2.6	█											
	Apiaceae	0.9	0.0	0.0	0.0	█											
	Cheno-Am	42.4	36.6	5.2	1.3	█											
	Caryophyllaceae	4.6	0.0	1.2	0.4	█											
	Liliaceae	0.5	2.0	1.2	0.0	█											
	<i>Salvia</i> (Lamiaceae)	2.3	0.0	0.0	0.0	█											
	Brassicaceae	5.5	0.0	1.7	3.5	█											
	<i>Plantago lanceolata</i> (Plantaginaceae)	0.5	0.0	1.2	0.0	█											
	Rosaceae	1.4	0.0	0.6	1.3	█											
	Urticaceae	0.5	3.0	0.6	1.7	█											
	Solanaceae	0.0	1.0	1.2	0.4	█											
Rubiaceae	0.5	0.0	0.0	0.0	█												
Fabaceae	0.0	0.0	0.0	0.9	█												
Fruit trees and ornamentals (in %)	<i>Salix</i> (Salicaceae)	0.0	0.0	9.3	0.9	█											
	<i>Populus euphratica</i>	0.0	0.0	0.6	0.9	█											
	<i>Vitis vinifera</i>	0.0	0.0	1.2	0.9	█											
	<i>Juglans regia</i>	0.0	0.0	1.2	0.0	█											
	<i>Citrus medica</i>	0.0	0.0	32.0	22.2	█											
	<i>Ficus carica</i>	0.0	0.0	2.3	0.9	█											
	<i>Olea europaea</i>	1.8	2.0	2.9	1.3	█											
	<i>Cedrus libani</i>	0.0	0.0	0.6	0.4	█											
	<i>Myrtus communis</i>	0.0	0.0	0.6	2.2	█											
	<i>Betula</i> (Betulaceae)	0.0	0.0	0.0	1.3	█											
	Unrecognisable	14.7	12.9	15.2	10.4	█											
	Total terrestrial pollen	100.0	100.0	100.0	100.0	█											

Notes: (1) Green bars represent the blooming season. (2) Percentages represent the occurrence of certain pollen taxa and do not necessarily point to its "real" relative frequency since the latter is influenced by wind direction, pool wall facing and the distance of the growing taxa from the pool.

Table 2. Non terrestrial pollen from the pool plaster at Ramat Rahel and palynomorph concentration values.

Plaster layer	Layer Ia	Layer Ib	Layer IIa	Layer IIb
<i>Lemna</i> (Lemnaceae)	2	71	101	15
<i>Nymphaea</i> (Nymphaeaceae)	0	2	1	0
Fern spores	1	74	3	20
Total palynomorphs Sum (terrestrial pollen + aquatic pollen + fern spores)	227	248	286	229
<i>Lycopodium</i>	280	461	2039	1443
Weight (g)	5.4	0.2	0.7	1.6
Palynomorph concentration values (g/sediment)	1603.2	28,724.4	2,139.8	1,059.2

3.2.1. Field sampling

Four samples were collected for OSL dating from two excavation pits in the garden soil. The soil is about 50 cm thick, and one sample was taken from the top

(at a depth of 10–15 cm) and a second one from the bottom (at a depth of 35–50 cm) of each section (Figure 1c, Figure 4). The sediment was drilled with a 1 inch diameter spiral hand-held auger. To prevent any

exposure to sunlight, samples were collected under a cover and placed immediately in light-tight bags. An additional sediment sample was collected from each locality for dose rate assessments.

3.2.2. Sample preparation and measurements

Quartz in the size range of 74–125 μm was extracted using routine laboratory procedures (Porat 2007) in appropriate lighting. After wet-sieving to the desired grain size, carbonates were dissolved with 10% hydrochloric acid (HCl). The rinsed and dried sample was passed through a Frantz magnetic separator to remove undissolved carbonates, heavy minerals and most feldspars (Porat 2006). A 40-minute rinse in hydrofluoric acid (HF) (42%) was used to dissolve remaining feldspars and etch the quartz grains, followed by rinsing in 16% HCl to remove any fluorides which may have precipitated.

OSL measurements were carried out on Risø DA-20 TL/OSL readers (Bøtter-Jensen et al. 2010), equipped with an integral strontium-90 (⁹⁰Sr) calibrated beta source with dose rates of ~2.5 Gy/min. Stimulation was with blue light-emitting diodes (LED) and detection was through 7-mm U-340 filters. The SAR protocol (Murray & Wintle 2000) was used to determine the D_e on 17 aliquots from each sample, and aliquot size was 5 or 3 mm. Each aliquot was irradiated stepwise and normalised until the natural signal was regenerated. Dose response curves were constructed from five dose points, two of which were repeats (a regular recycling point and an IR-depletion ratio point), and two zero-dose points. The most representative D_e ± 1σ value for each sample was calculated using the central age model (Galbraith et al. 1999). The scatter in the D_e values in each sample (noted in Table 3 as ‘over-dispersion’, an indication of the scatter within the sample beyond that which would be expected from experimental uncertainties) was used to assess whether the sediment was well bleached, and the reliability of the age.

Alpha, beta and gamma dose rates were calculated from the concentrations of the radioactive elements uranium (U) and thorium (Th) measured by inductively coupled plasma (ICP)-mass spectroscopy, and potassium (K) measured by ICP-atomic emission spectroscopy. The cosmic dose rate was evaluated from burial depth, including the archaeological overburden. Water contents were estimated at 10 ± 3%, reflecting seasonal variation.

4. Results

4.1. Palynology

All subsamples of Layers I and II from the inner filling material contained only a few terrestrial pollen grains

Table 3. Ramat Rahel garden soil OSL dating results.

Lab Code	Locus	Depth (m)	K (%)	U (ppm)	Th (ppm)	Ext. α (μGy/a)	Ext. β (μGy/a)	Ext. γ (μGy/a)	Cosmic (μGy/a)	Dose rate (μGy/a)	No. of aliquots	O-D (%)	De (Gy)	Age (years b. 2010)
RMR-24	L036	0.13	0.91	2.35	7.1	11	1006	740	172	1929 ± 50	16/16	9	4.48 ± 0.11	2320 ± 80
RMR-25	L036	0.36	0.83	2.15	7.4	11	939	715	166	1831 ± 49	15/17	26	6.52 ± 0.27	3560 ± 180
RMR-26	L008	0.15	1.00	2.7	8.5	13	1135	855	171	2174 ± 43	17/17	10	5.27 ± 0.14	2420 ± 80
RMR-27	L008	0.50	1.00	2.3	9.6	13	1112	862	164	2150 ± 44	16/17	28	6.54 ± 0.31	3040 ± 160

Notes: Grain size of extracted quartz is 74–125 μm. Time-averaged water contents were estimated at 10 ± 3%, reflecting seasonal variations. De average and errors were calculated using the central age model (Galbraith et al. 1999). Locus - in the excavation; Depth - from the top of the soil; Ext. - external; Cosmic - the cosmic dose rate that takes into account the archaeological overburden; No of aliquots - the number used for De calculations out of those measured; O-D - over-dispersion, the scatter within sample.

and some of aquatic origin. In most cases, the subsamples taken from the outer part of each of the plaster layers included higher pollen concentration values (Table 1).

The pollen assemblages of Layer I include only plants belonging to native Mediterranean maquis/forest. Typical wind-pollinated Mediterranean trees, common to the Judean Hills, constitute up to 32.7% of the total pollen sum (calculated from Table 1), e.g.: *Quercus calliprinos* < 2.0%, *Pinus halepensis* < 25.7% and *Phillyrea* < 3%. The pollen of herbs and shrubs is common to the steppe-like open land flora (also called batha – a degradation stage of woodland and maquis under typical Mediterranean climate) but can also be ruderal (plants that adapted themselves to man-made habitats; Zohary 1962). This group of plants is dominated by Chenopods (up to 42.4%).

The pollen data derived from Layer II are divided into two groups (Table 1):

- (1) Typical Mediterranean maquis/forest and batha members: most of those taxa were identified in the plaster of Layer I; for instance, Mediterranean trees like *Quercus calliprinos* (<1.2%) and *Pinus halepensis* (<42.2%). Chenopods appear in significantly lower percentages than in layer I – not exceeding 5.2%.
- (2) Fruit trees and ornamentals: *Olea europaea* is the only pollen taxon identified in both layers, reaching values of 2.9% in Layer II. Both samples of Layer II are dominated by the insect-pollinated tree *Citrus medica* (up to 32.0%). All other fruit trees and ornamentals appear only in Layer II: *Salix* (up to 9.3%), *Populus euphratica* (up to 0.9%), *Vitis vinifera* (up to 1.2%), *Juglans regia* (up to 1.2%), *Ficus carica* (up to 2.3%), *Cedrus libani* (up to 0.6%), *Myrtus communis* (up to 2.2%) and *Betula* (up to 1.3%).

The state of preservation of the pollen within the different samples was quite similar and unrecognisable pollen percentages therefore appear similar as well (10.4–15.2%; Table 1). The pollen concentration values ranged from 1059.2 (Sample IIB) to 28,724.4 (Sample IB) (Table 2). In two cases in Sample IIB, pollen grains appeared in clumps: a cluster of four grains of *Myrtus communis* and another cluster which included three grains of *Vitis vinifera*. Differences in the amount of the samples derived from technical limitations during field sampling (Table 2).

4.2. Chronology

The OSL ages from the upper samples in the two sections in the garden soil are the same within errors,

2320 ± 80 and 2420 ± 80 yr (years before 2010, the year of measurement). This places the time when the garden was covered by the overlying layers to roughly the fourth century BCE – the transition between the Persian and Hellenistic periods – and it matches the stratigraphical and typological age established for the end of the garden's use. The samples from the base of the sections are older and their ages are 3560 ± 180 and 3040 ± 160 yr, providing an age for the original garden soil.

5. Discussion

5.1. The palynological evidence

It is clear that the abundant, well-preserved pollen in the outer part of the plaster samples reflects the period during which the plaster was applied. The plasters were not exposed to pollen from later periods since the pool went out of use in the early Hellenistic period (third century BCE) and was covered by a fill of slaked lime (Lipschits et al. 2009). Our assumption that most of the pollen grains were trapped during the preparation of the plaster, when it was still wet, is most probably correct since samples of inner filling material contained only few terrestrial pollen grains and some of aquatic origin. Those grains probably made their way into the plaster via the garden pool water used to prepare the plaster. That can be part of the explanation of the occurrence of pollen of hydrophilous plants and of insect-pollinated plants, which is not airborne. It may also possibly be the reason for the identification of the two clumps (of *Myrtus* and *Vitis*) and of the surprising evidence of fig pollen.

The two plaster phases, which reflect maintenance of the garden's facilities, were most probably prepared in the spring according to the overlap in blossoming months (April–May; Table 1) of all identified pollen taxa. The differences in percentages of the same taxa in different plaster samples from the same layer (I and II; Table 1) are due to differences in the aspect of the plaster sample in relation to dominant wind direction. Since the prevailing winds in the spring are mainly of western and northwestern origin (Eshel 2002; Dayan et al. 2007), more pollen would be expected to be deposited in the pool walls facing west and north than those facing east and south (Figure 1c). However, the west-facing wall was not sampled for pollen analysis since its plaster was not well preserved. The highest pollen concentrations appeared in the four samples from the north-facing wall, which are presented in Table 2 and discussed below. Samples from the other two walls were found to contain low pollen concentrations, probably due to wind direction, and are not discussed further.

5.1.1. Native Mediterranean maquis/forest plants

The natural Mediterranean maquis/forest pollen elements extracted from the two plaster phases are typical of recent Judean Hills vegetation (Zohary 1973) and are considered part of the Late Quaternary Levantine natural flora (Horowitz 1979; Weinstein-Evron 1983; van-Zeist & Bottema 2009; Langgut et al. 2011). The arboreal vegetation is dominated by pine, evergreen oak, deciduous oak, olive and *Phillyrea* while the most widespread herbs and shrubs belong to the goosefoot, pink, cabbage, cereals and aster families.

The native Mediterranean maquis/forest plant identifications emerging from the palynological data are not only corroborated by modern natural vegetation cover (Zohary 1973) but also by pollen assemblages dated to the same period under discussion, taken from an outcrop in Ein Feshka (Neumann et al. 2007), an oasis located at the northwest margins of the Dead Sea, 25 km east of Ramat Rahel (Figure 1a). After excluding the local desert and oasis vegetation within the Ein Feshka samples, the palynological data reflect the Mediterranean pollen grains carried from the Judean Hills by the predominant westerlies (Neumann et al. 2007). The vegetation reconstructed for the Iron Age and the Persian period from pollen at Ein Feshka points towards climatic conditions similar to those of the present, prior to the increasing humidity characterising the Roman and Byzantine periods (Bar-Matthews & Ayalon 2004; Neumann et al. 2007). The Mediterranean elements reflected in the Ein Feshka pollen spectrum, such as oaks and pines, are in good agreement with the natural vegetation pollen components at Ramat Rahel. The differences in percentages between the natural vegetation of the two plaster layers and of those from Ein Feshka can be attributed to the distance of the growing vegetation from the pool. That

might explain, for example, the high pine percentages characterising Samples Ib and IIb (Table 1). Some of the herb taxa within the Ramat Rahel pollen assemblages can also be ruderal pollen indicators, pointing to managed landscape in the immediate vicinity of the site.

5.1.2. The unique pollen spectrum of plaster Layer II

After excluding the native Mediterranean maquis/forest components from the two samples belonging to the outer plaster layer (Samples IIa and IIb), an interesting pollen assemblage emerged. It comprised fruit trees and ornamental plants – some of local origins while others were imported from far-off lands. Native fruit trees and ornamentals included the common fig, grapevine, olive, willow, poplar, myrtle and water lily. Imported trees were the citron, cedar of Lebanon, birch and Persian walnut. Yet, since the *Cedrus* and *Betula* appear in very low percentages, long-distance transport must be taken into consideration.

5.1.2.1. Imported trees

Citron (*Citrus medica*)

This is the most surprising find among the Ramat Rahel samples (Plate 1), since it is the earliest botanical evidence of cultivating citron in the southern Levant. Its name, *C. medica*, suggests Media (Persia), and it is the only citrus crop that was grown in Southwest Asia and the Mediterranean basin in Greek times (Late fourth to late second centuries BCE). Several other citrus crops (e.g. lemon, bitter orange, lime and pummelo) apparently arrived in the Mediterranean basin only much later, in early Islamic times (seventh century AD; Ramón-Laca 2003). The citron tree seems to have made its way to Ramat Rahel from India via Persia. The fruit, with its characteristic thick aromatic

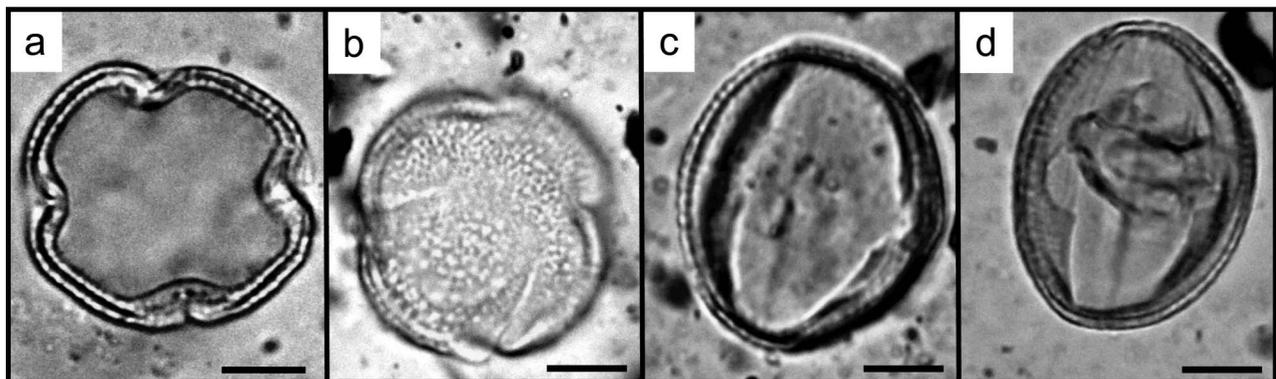


Plate 1. *Citrus medica* pollen grains from the ancient garden of Ramat Rahel. Each bar = 10 μ m. (a–b) – polar view. (c–d) – equatorial view.

rind, was appreciated medicinally (Zohary et al. 2012). The citron (named *etrog* in Hebrew, a word of Persian origin) is not mentioned in the Old Testament, and the association between the citron and the *Pürî 'êc hädär* (Leviticus 23:40), translated 'fruit of the goodly tree', was made hundreds of years later. During the Hellenistic period, the citron acquired a symbolic-religious role in Judaism, especially related to the Jewish holiday the Feast of Tabernacles. The detailed description of Theophrastus (c. 371–287 BCE) in *Historia Plantarum* shows that in his day, *Citrus medica* (named by him Persian or Median apple) was already well established in the Middle East (Zohary et al. 2012; but see Biger & Liphshitz 1997). A single archaeobotanical find suggests an even earlier arrival: Hjelmqvist (1979) uncovered a few charred citrus seeds in ca. 3200 BP Bronze Age Hala Sultan Tekke, Cyprus. But these remains have not yet been directly dated to confirm their antiquity (e.g. by radiocarbon dating; Zohary et al. 2012). In addition, the presence of seed or fruit remains can point to fruit importation rather than tree cultivation. Better identified and dated finds have come from three different Roman sites in Egypt (Van der Veen 2001, 2003; Van der Veen & Tabinor 2007). The appearance of fossil citron pollen at Ramat Rahel, dated to the fifth to fourth centuries BCE (Plate 1), seems to resolve the historical debate (Biger & Liphshitz 1997; Felix 1997) over the first appearance of citron in ancient Israel. It should be noted that although *Citrus* pollen is hardly ever airborne, it appears in high percentages within the palynological assemblages (up to 32.0%). Therefore it can be argued that at least one citron tree was located near the pool.

The Ramat Rahel *C. medica* pollen grains (Plate 1) are subprolate-spheroidal in shape (as was already reported by others – e.g. Grant et al. 2000; Lippi 2000); all grains are colporate with a colpus number of four and their polar axes frequently measure more than 32 µm. In general, *C. medica* grains are larger in size in comparison to other species in the genus *Citrus* and characterised also by slightly coarser surface ornamentation (Xianghong 1982).

Cedar (*Cedrus libani*)

The majestic conifer, the cedar of Lebanon, was never a native forest-tree in Israel. Scattered cedars are still found in the mountains of Lebanon, probably relics of formerly more widespread distribution. Other remnants are found in northwestern Syria and in the mountain ranges of southern Turkey (Beals 1965). From early times, the cedar of Lebanon symbolised strength, dignity and grandeur, and was considered the prince of trees (Zohary 1982). Egyptian and Assyrian royal reports as well as the Old Testament (2 Kings

19:23) extol cedar wood from Lebanon and Amanus, and the Ugarits have left poetic testimony to its supremacy (Zohary 1982). The Old Testament also mentions the use of cedar for prestigious building enterprises. Whether historical or not, these references testify to the high value in which the tree was held. At present, this evergreen conifer tree is widely planted in gardens and parks for ornamentation because of its beauty, robustness and longevity; in the last century cedars were also planted in Jerusalem as ornamentals. Although *Cedrus* is a heavy pollen-producing tree, it appears in relatively low percentages in our pollen assemblages (0.4–0.6%). There are some possible explanations for the low frequencies: the *Cedrus* was not at its peak of blooming when the plaster was maintained; the wind direction, tree location in the garden and the pool wall facing it were not in optimal conditions for the *Cedrus* pollen to be trapped within the plaster; long-distance transport from the mountains of Lebanon could also be a possibility.

Persian walnut (*Juglans regia*)

The Persian walnut tree is not native to the flora of Israel. It is a traditional nut of Old World agriculture which produces beautiful hard timber in addition to its fruit. *J. regia* grows naturally in the temperate forests of Western Asia (e.g. the Balkans, eastern Turkey and northern Iran). Walnut thrives best in cool, hilly areas and its cultivation usually benefits from supplementary irrigation in summer (Zohary et al. 2012). Remnants of wood of *J. regia* in Israel are very rare. The earliest evidence was found in Middle Bronze Age strata at Megiddo (Liphshitz 2000). However, the first appearance of walnut pollen in Israel is dated only to the Iron Age II (Langgut in press), pointing to intended cultivation of that tree in the Judean Hills. Based on Ein Feshka pollen assemblages, *J. regia* was cultivated in the region only since the Hellenistic period (Neumann et al. 2007). Zohary et al. (2012) claim that walnut cultivation probably started before Roman times, most likely in northern Iran, northeastern Turkey and the Caucasus. Its Hebrew name (*'égôz*, again a word with a Persian origin) appears only once in the Old Testament (Song of Solomon 6:11). Walnut comprises up to 1.4% of the Ramat Rahel pollen assemblages.

Birch (*Betula* spp.)

The genus *Betula* contains more than 30 taxa, palynologically indistinguishable. It is widespread in mountainous and temperate zones. *Betula*'s nearest occurrence is more than 600 km to the north, at Anatolia (Ercyas Dağı near Kayseri; van Zeist et al. 2009). Despite this remoteness, there is some evidence of a very long-range transport of *Betula* pollen (e.g.

Hjelmroos 1991). Since *Betula* appears in low percentages in the Ramat Rahel assemblages (1.3%), whether *Betula* was present in the garden area in the past or it arrived by long-distance transport is still questionable.

5.1.2.2. Native fruit trees and ornamentals

Several fruit trees and ornamentals of local origin were found in the Ramat Rahel garden. The first two taxa, willow and poplar, inhabit banks of permanent and intermittent streams. Therefore, their occurrence within the Ramat Rahel pollen assemblages represents directed planting and controlled irrigation regarding those trees.

Willow (*Salix*)

Although the willow is insect-pollinated, its pollen dispersal is relatively good and its appearance in the pollen spectrum is pronounced (up to 9.3%). Willows are very cross-fertile, and numerous hybrids occur, both naturally and in cultivation. A well-known ornamental example is the Weeping Willow. Unfortunately willow pollen cannot be identified to the species level (Van-Zeist et al. 2009). Like the citron, willow is one of the 'Four Species' used ritually during the Jewish holiday, the Feast of Tabernacles.

Poplar (*Populus*)

Many poplar species are grown as ornamental trees. They have the advantage of growing very tall, very fast. The only poplar species that grows in Israel is *P. euphratica*. Although poplar is wind-pollinated, it is present in very low values in Ramat Rahel samples (up to 0.9%). One explanation for the low frequency might be connected to the blooming season: while all other plants revealed from the palynological spectrum are spring bloomers (mainly April to June, with some taxa continuing to flower also during the summer; Table 1), *P. euphratica* blooms from the end of the winter until the beginning of spring (February to April). In addition, the poplar probably did not grow near the immediate vicinity of the pool but in a more remote area since it has a very vigorous and invasive root systems stretching up to 40 m from the tree; planting poplar close to buildings may result in damaged foundations and cracked walls due to its search for moisture.

Grapevine (*Vitis vinifera*)

Grape is one of the most important classical fruits of the Old World. Nearly all domesticated grapes are monoecious (they produce male and female flowers at different locations on the same plant) and are self-pollinated, while wild grapes are dioecious plants (they have unisexual flowers) with obligatory

cross-pollination (Zohary et al. 2012). Therefore, wild grapes account for better pollen distribution. Wild *Vitis* plants in Israel are a constituent of bank vegetation (Zohary 1973); hence, the grapevine pollen grains found at Ramat Rahel samples are probably from cultivated plants that were irrigated. The low pollen dispersal efficiency characterising domesticated *Vitis*. Van Zeist et al. (2009) indicates that the grapes probably grew near the pool. The appearance of *Vitis* pollen in a clump of three grains corroborates this assumption.

Olive (*Olea europaea*)

Olive occurs today in Israel in the Mediterranean territory both as a cultivated and natural element (Zohary 1973). Before man's interference with native vegetation, the wild olive was a component of the native Mediterranean *Quercus calliprinos*–*Pistacia palaestina* association, but in small percentages (Horowitz 1979; Weinstein-Evron 1983; van-Zeist & Bottema 2009; Langgut et al. 2011). This evergreen tree was one of the first domesticated horticulture species in the Old World. Olive has been the most prominent, and probably economically the most important, fruit tree of the Mediterranean basin (Zohary et al. 2012). Over the years, the olive has been the symbol of peace, wisdom, glory, fertility, power and purity. Pollen grains (2.8%) of this wind-pollinated tree could possibly have found their way to the plaster from several origins: native or natural (escapees) of the Mediterranean maquis/forest characterizing the Judean Hills, from a nearby olive orchard or directly from the garden.

Common fig (*Ficus carica*)

The Mediterranean fig (*F. carica*) is the third classical fruit crop – after olive and grapevine – associated with the beginning of horticulture in the Mediterranean basin and southwest Asia (Zohary & Spiegel-Roy 1975). It is a native fruit tree in the region; the oldest known fig pips came from the ca. 800,000 BP Acheulean Geshur Benot Ya'akov site, Israel (Melamed et al. 2011). The fig has been part of regular food production in the Levant since the Early Bronze Age, providing fresh fruit in summer and storable, sugar-rich dry fruit all year round (Zohary et al. 2012). Wild common figs grow mainly in the low altitudes of the Mediterranean vegetation belt, occupying streamsides but also habitats like rock crevices and gorges. Therefore the figs of Ramat Rahel might have depended on irrigation. The common fig is pollinated by an elaborate symbiosis with a particular species of wasp (*Blastophaga psenes*); the flower is not visible, as it blooms inside the syconium (Galil & Neeman 1977). Therefore, the common fig is usually extremely

underrepresented in the pollen spectrum. The appearance of fig pollen within the plaster samples, although in very low values (not exceeding 2.3%) is therefore surprising. Fig fruits may have fallen and decomposed into the water pools that were later used to mix the plaster.

Myrtle (*Myrtus communis*)

The Myrtle is a cultivated native evergreen shrub and the only member of the Myrtaceae family that grows naturally in Israel, mainly in the north. The pollen within the plaster could be from the surroundings of the site or from the garden itself. The latter is more likely because myrtle is insect-pollinated and therefore has low dispersal efficiency. In addition, in one case it appeared in a clump of four pollen grains, which probably indicates the close proximity of myrtle shrub(s) to the pool. Because of its deep evergreen color, appealing odor and amenity to clipping to form a hedge, the myrtle was (and is) an indispensable feature in ornamented gardens. Like the citron and willow, it is one of the 'Four Species' used ritually during the Feast of Tabernacles. Furthermore, in the Book of Esther, Hadassah is the Hebrew name for Esther (Aester) which is Persian, because both names have the same meaning, that is, myrtle.

Water lily (*Nymphaea*)

There are two species of water lily that are native to Israel aquatic flora: star lotus (*N. nouchali*) and white lotus (*N. alba*), which are palynologically indistinguishable. Both species are valued in water gardening and pond decoration because of their spectacular flowers. Like the pollen of the duckweed (*Lemna*), the pollen of the water lily probably made its way into the plaster by the garden water used in plaster preparation. Unlike other ornamentals, these two aquatic plants also appear in the inner plaster of Layer I, which means that pond ornamentation preceded the rearrangement of the impressive garden. The occurrence of *Nymphaea* pollen grains also indicates that the pools within the garden were used not only as a water distribution device (Lipschits et al. 2011) but also for aesthetic purposes. The presence of decorated stone-built drains in Pool 2 corroborates this assumption.

5.2. The dating of Pool 2 and the garden

Based on pottery and other related material culture items found in the soil layer used for the garden, as well as fills found under the floors of other architectural structures of Building Phase II at the site (Figure 3), Pool 2 constructions (from which the pollen samples were taken) date the garden to the end of the seventh century BCE. The several plaster layers on the pool's

walls testify that the pool was maintained and renewed over a long period.

There are some clues that in the Hellenistic period (third century BCE) the pool was transformed into a vat for lime production: the openings of the drains were sealed from within by plaster when the final coat of cement was poured. A second clue is that a thick layer of inert quicklime that filled the pool was found and this also attests to the latest use of the pool. The quicklime in the pool was probably produced in a nearby lime kiln to the south of the pool (Figure 1c). The kiln, which was built after the garden was already abandoned, was dated by pottery found in it to the Hellenistic period.

Building 824, located farther to the south (Figure 3), was built into the garden enclosure, cutting into its soil and reusing the southeastern corner of the garden's enclosure. It is therefore clear that the garden predates the building. A small but significant pottery assemblage was found resting on the floor of the building. The pottery dates to the end of the Persian period (mid-fourth century BCE) which means the garden has to date to the Persian and/or the Iron periods. Finally, the entire garden enclosure, including Pool 2, was covered by an earth fill more than 2 m thick. The latest pottery sherds and other indicative finds found within the fill date to the second century BCE (Late Hellenistic period).

Evidently all archaeological finds point towards dating the garden and Pool 2 to between the seventh and fourth centuries BCE. The OSL dating obtained in this study verifies the archeological dating and places the time when the garden was covered by the overlying layers to roughly the fourth century BCE – the transition between the Persian and Hellenistic periods. Therefore, the plaster was most probably applied to the walls of Pool 2 in the fourth century BCE or earlier.

It is worth noting the differences between the upper and lower OSL samples from each section (Table 3): the upper samples have low over-dispersion (O-D) of the De values (9–10%) and very similar ages. The lower samples have high O-D values (25–28%); they are significantly older, and with substantially larger errors on the ages. The low O-D values for the upper samples indicate that they were sufficiently well bleached before they were covered by the overlying sediment; this can be explained by constant mixing of the soil by ploughing during the period that the garden was cultivated, allowing each quartz grain to be exposed to sunlight over time and ensuring that the OSL ages are indeed burial ages. The ages of the underlying samples, much older than the archaeological context, suggest that they were not bleached when the garden soil was brought to the site, or after that during the cultivation period. The substantially higher

O-D values reflect their source, probably mixed sediments from a stream terrace nearby.

6. Summary and conclusions

Our palynological study offers a window into a past that is at least 2400 years old and that not only enables us to scientifically identify ancient flora and visualise a reconstruction of life much as it was in a Royal Persian garden; it also gives us a glimpse into the mechanisms by which native flora was adapted and finally disseminated throughout the world.

The two plaster layers were put in place when typical Mediterranean vegetation existed in the Judean Hills with the occurrence of some ruderal plants within the immediate vicinity of the site, representing human interference on the nearby vegetation. Climate conditions at that time were similar to those of today. When Layer I plaster was formed, only Mediterranean vegetation existed in the surrounding areas of the site; at the time that the plaster of Layer II was created, the royal garden had already been established.

Various trees identified in the palynological spectrum (e.g. willow, poplar) naturally inhabit river banks. In order to grow those trees, as well as some of the fruit trees at Ramat Rahel, an intensive and controlled irrigation system was most probably required. The site of Ramat Rahel has no natural water source and is completely dependent on the collection of rain water. The sophisticated water installations that make up a complex water collection and storing system revealed during the excavations at the site (Lipschits et al. 2011) testify to the high investment needed in order to sustain the garden and its flora.

Reconstruction of the layout and landscaping of the garden is within our reach. Undoubtedly, spectacular aquatic plants like the water lily floated in the garden's pools. The soil located around the pools was probably used for shrubs or small trees like the myrtle and the grapevine. The citron and other insect-pollinated plants were probably planted in the near vicinity of the pool. Some of the great trees (e.g. poplar with its invasive root system) were probably planted farther away, at the outer perimeter of the garden.

The garden was lush with local fruit trees, local ornamentals and also exotic trees brought from afar. This choice of flora to be planted in the garden fits our knowledge of Persian royal gardens and the concept of *pardesu* (paradise = garden; Foster 1998, 2004; Hunt 2011). Accordingly, royal palatial gardens of the Achaemenid empire had to be planned artificially and their cultivation would have been both practical and aesthetic. The Ramat Rahel garden as observed through the pollen spectra fulfills all these requirements.

The Persian association of the garden can be further linked to the species recognised in the pollen spectrum that were probably brought from the territory of the Persian empire: the Persian walnut and the citron – which both also preserved their Persian origin in their Hebrew name. The birch and the cedar, which are also not native members in the study area, might have been imported from mountainous areas of the provinces of the Persian empire; however long-distance pollen transport could also be a possibility for their occurrence in the Ramat Rahel palynological spectrum.

Finding trees from remote places at the Ramat Rahel garden located in Judah, a distant province of the Persian empire, may help to illustrate the mechanism through which elite gardens contributed to the spread of flora across the globe (Foster 1998). The desire to present in gardens trees from the distant parts of the empire was part of the royal display of power and propaganda. Some of those trees, first brought for their symbolic value, became part of the local religious symbolic world and economic horticulture, as in the case of the citron.

The well-watered imperial Persian garden at Ramat Rahel must have left a lasting impression on viewers in this relatively arid environment. Its imported trees from far-off lands, aromatic plants and impressive fruit trees, together with its aesthetic architectural features, symbolised the power and affluence of the Persian-period rulers who reigned at the Ramat Rahel palace.

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