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ORIGINAL ARTICLE

Invading a new niche: obligatory weeds at Neolithic Atlit-Yam, Israel

Anat Hartmann-Shenkman · Mordechai E. Kislev · Ehud Galili · Yoel Melamed · Ehud Weiss

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Abstract A characteristic group of obligatory weeds was found in the well of the submerged Pre-Pottery Neolithic C site of Atlit-Yam, Israel. Identifying these finds to species level was crucial for defining them as obligatory weeds. We deal here with the earliest and largest assemblage of obligatory and facultative weeds in the southwest Asian Neolithic. Atlit-Yam may reflect a stage in the establishment of weeds in cultivated fields. Weeds are an important resource for reconstructing the agricultural situation in archaeological sites, as weed-crop interactions reflect an agricultural lifestyle. Some of the weeds of Atlit-Yam grow in fields as well as in Mediterranean herbaceous habitats. This may indicate that the local herbaceous ecosystem was the original habitat of the weeds and the place where the first fields were planted. Presence in a single context of the earliest identified obligatory grain pest beetle (*Sitophilus granarius*) along with obligatory weeds reflects a novel change made to the ecosystem by the farmers, in which stored crops were invaded by pests.

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A. Hartmann-Shenkman · E. Weiss (✉)
The Martin (Szusz) Department of Land of Israel Studies and Archaeology, The Institute of Archaeology, Bar-Ilan University, 5290002 Ramat-Gan, Israel
e-mail: eweiss@biu.ac.il

M. E. Kislev · Y. Melamed
The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University, 5290002 Ramat-Gan, Israel

E. Galili
Israel Antiquities Authority and Zinman Institute of Archaeology, The University of Haifa, POB 180, 3030000 Atlit, Israel

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Introduction

Weeds invade most agricultural land and are therefore considered to be characteristic of cultivated fields. The prehistoric establishment by humans of tilled fields (as well as other disturbed habitats) enabled numerous *unwanted* plants to invade these newly made habitats and evolve as weeds. Although our herbicide-addicted agriculture is troubling, weed control in ancient farming was an even greater problem. Since weed evolution went hand in hand with crop cultivation, our ancestors had to invest greater efforts to control these field invaders as agriculture advanced. The evolutionary adaptation of these weeds to the agricultural niche moved along multiple paths, which included increasing seed numbers, mimicking cultivars, adapting to the cultivars' growth cycles, and developing dormancy. We can therefore use weeds as "index fossils" of agricultural ecosystems. In addition, some common weeds are native to southwest Asia, and their origin may be linked to the beginning of cultivation (Harlan 1995; Willcox 2012; Zohary 1950; Zohary et al. 2012).

Botanists and ecologists have long dealt with the issue of weeds and their evolution. Generally, weeds were described negatively as being useless, injurious, obnoxious or harmful (Webster 1966), and even homeless (Zohary 1950). For some, like Pieters (1935), weeds took on an anthropocentric cast with epithets such as "evil" or creatures that "should be destroyed". However, weeds are not always the farmer's nemesis, as they sometimes turn out to produce valuable seeds. The farmer could then plant weed seeds, which could then lead to species domestication. For example, several Old World crops are regarded as "secondary crops," which entered domestication through the back door of weed evolution. Such cases are *Avena sativa* (oat), *Secale cereale* ssp. *cereale* (rye) and *Camelina sativa* (gold of pleasure), which actually turned from weeds into domesticated plants (Vavilov 1949–1950, 1987; Zohary et al. 2012). In addition, several facultative weed taxa found at the site are edible, for example *Chenopodium album*, *Chrozophora tinctoria*, *Emex spinosa*, *Hordeum spontaneum*, *Scorpiurus muricatus* and *Silybum marianum* (Zohary 1966, 1972; Feinbrun-Dothan 1978, 1986; Dafni 1984; Feinbrun-Dothan and Danin 1998). Therefore we need to consider the possibility that they may also have been gathered for consumption. Importantly, this does not change their role as weeds if they were gathered in the fields.

We present here the weed assemblage from Atlit-Yam. The main importance of this paper is that it presents the earliest and largest assemblage of obligatory and facultative weeds in the southwest Asian Neolithic. Moreover, Atlit-Yam is a Pre-Pottery Neolithic C (PPNC) site in the heartland of the Levantine Neolithic, and therefore belongs to a stage following the establishment of the full-fledged agricultural economy of the PPNB. This economy is manifested in the site's complex of crop plants, weeds and a particular insect pest.

The site of Atlit-Yam

The village of Atlit-Yam is currently a submerged PPNC settlement (Fig. 1), radiocarbon dated to 9,200–8,500 cal BP. It is located 200–400 m west of the present Mediterranean coastline of Israel, 8–12 m below current sea level. The site was excavated by E. Galili on behalf of the Israel Antiquities Authority and the University of Haifa. It was a coastal agro-pastoral village that subsisted on agriculture and marine resources.

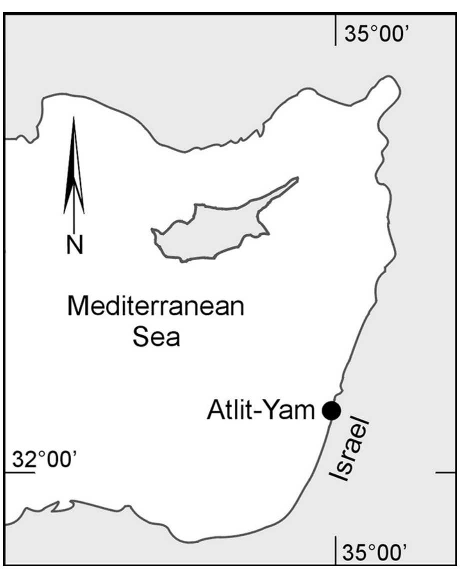

Fig. 1 The location of the Atlit-Yam site near the coastal plain of Israel

The plant material under discussion, mostly waterlogged, was taken from a single well, Structure no. 11. The fill of the well contained plant remains, large quantities of animal bones and various flint, bone and stone artefacts (Galili and Nir 1993; Galili et al. 1993; Galili and Rosen 2011). It included thousands of seeds and fruit remains belonging to about 90 species. The finds include:

- Grains of domesticated cereals: *Triticum dicoccum* (emmer wheat), *T. parvicoccum* (small-grained wheat), *T. durum* (durum wheat) and *H. vulgare* (two/six-rowed barley);
- Pulses: *Lens culinaris* (lentil) and *Cicer arietinum* (chickpea);
- Fruits: *Ficus carica* (fig), *Pistacia atlantica* (atlantic pistachio), *P. palaestina* (terebinth tree), *P. lentiscus* (lentisk), as well as *Vitis sylvestris* (wild grape vine);
- Wild vegetables: *Malva parviflora* (small-flowered mallow) and *Rumex pulcher* (fiddle dock); and
- Herbs and weeds.

This rich assemblage of wild and domesticated crop plants indicates the centrality of agriculture to the inhabitants' life style. Other material remains, such as dwellings and domesticated animal bones, further demonstrate the site's domesticated culture.

Since the crop remains are an admixture with a large assemblage of weeds, we have a unique opportunity to deal with the evolution of weeds and their early appearance during the Neolithic period.

The definition of "weed"

The term "weed" has many definitions. In 1935, Pieters (1935) quoted a restricted definition of weeds from the *Farmers' Bulletin*: "A plant that does more harm than good and has the habit of intruding where not wanted".

Harlan's (1965) use of the term was broad:

"For the purpose of this discussion, the word *weed* is taken to mean a species or race which is adapted to conditions of human disturbance (Harlan and DeWet 1965). By this definition, weeds are not confined to plants. Animals such as the English sparrow, the starling, the 'statuary' pigeon, the house mouse, *Drosophila melanogaster*, and others are especially fitted to environments provided by human disturbance".

These definitions imply that the appearance and abundance of weeds in archaeological material can influence our understanding of ancient cultures. For example, several generations of archaeobotanists have shown methodologically that finding weeds with crop plants in an archaeological assemblage can indicate that grain remains were grown in planted fields. In other words, the presence of weed species in crop remains is associated with past agricultural activities (Zohary 1950; Harlan 1965; Harlan and DeWet 1965; Wasylikova 1981; Greig 1990; Hillman 1991; Fahmy 1997; Colledge 1998; Jones 2002; Kreuz et al. 2005; Fuller 2007; Eliáš et al. 2010; Jones et al. 2010; Kreuz and Schäfer 2011; Willcox 2012; Riehl et al. 2013). Since obligatory weeds (see below) are clearly associated with contemporary farming, they are acceptable indicators for past agricultural activities. Because obligatory weeds do not grow outside fields, their presence in an archaeobotanical context strongly indicates that these plants had already entered the favourable niche of farmed lands. Unfortunately, once there, they have remained an agricultural curse for thousands of years, through to our own times.

Classification of weeds

In weed research, weedy taxa are clustered into several categories. The main groups are obligatory and facultative weeds, which were defined by Michael Zohary (1950):

Obligatory weeds are "not found as yet outside segetal [field] habitats. Many of them are rather widespread…. These are, undoubtedly, ancient plants which have lost their primary habitats [i.e. natural vegetation] during the long history of cultivation. Many of them are known from prehistoric times. They have been termed archaeophytes…"

Facultative weeds are "plants occurring in both segetal and primary habitats."

We relate here to both of these groups. However, following the terminology of Zohary and other previously mentioned researchers, obligatory weeds are the best markers for agricultural activity in archaeobotanical assemblages. This is because, in most cases, their only habitats are cultivated fields.

Materials and methods

Sampling

The first stage of sampling was on site. The samples were excavated underwater with dredger suction, mostly in 20 cm layers of the well depth. The divers took the samples to shore in bags, which were placed separately into plastic boxes with fresh water. On the shore, large stones and artefacts were removed manually from the boxes and the fine material underwent several stages of sieving: floating and hovering waterlogged organic material was collected in a 0.5 mm strainer, while the heavy material sank to the bottom of the box. Some of the material was collected by picking. The waterlogged organic material was kept in sealed jars for wet storage and analysis.

Laboratory work

The analysis work was conducted in the laboratory. The carbonized material was taken out of the water and dried. The waterlogged material was left in the water. To prevent mould development, we replaced the original water with a 4 % solution of the fungicide Nipagin (methyl paraben/para-hydroxybenzoic acid methyl ester; 4 g of Nipagin per 1 l of water). Sorting the samples was carried out using a stereoscopic microscope at a magnification of up to 50×; mainly seeds and fruits were sorted out (other types of remains were mostly disregarded). The plants were identified mainly on the basis of their morphology, following sorting into types, sizes, shapes and surface textures. The identification was aided by our reference collection. We followed Fragman-Sapir et al. (1999) for English plant names.

Finally, some of the seeds were photographed by stereoscopic light microscope using an Olympus SZX10, or by SEM using an XL 30 FE (field emission), FEI. The SEM samples were coated with gold and examined at 200–500x magnifications.

Results

Some 8,500 seeds and fruit remains representing some 90 species were identified from the well. The implication of the large number of weed species there is discussed below.

The weed assemblage

The obligatory and facultative weeds from Atlit-Yam are an important resource for reconstructing the agricultural activities of its inhabitants. Following Zohary's grouping (1950), we found remains of weeds representing some 35 species representing two groups, five obligatory and 30 facultative weed species (Table 1; Figs. 2, 3, 4, 5 and 6). The weeds and other finds were distributed throughout the various depths of the well assemblage (Table 2).

As far as we know, this is the earliest and largest assemblage of weeds from the southwest Asian Neolithic. Furthermore, identifying these five obligatory weeds to species level is significant, as all of them are non-monotypic, so they have other species in their genera. Undoubtedly, another species of the genus could have a

Table 1 The weeds of Atlit-Yam; all these species still function as weeds in cultivated fields, those with an asterisk also grow in Mediterranean semi-steppe herbaceous habitats (see text; see Figs. 2, 3, 4, 5 and 6)

Scientific name	Common name	Quantity
Obligatory weeds		
Bupleurum subovatum	False thorow-wax	2
Lolium temulentum	Darnel	2
Phalaris paradoxa	Bristle-spiked Canary grass	9
*Raphanus raphanistrum**	Wild radish	4
*Tordylium aegyptiacum**	Egyptian hartwort	6
Facultative weeds		
Adonis annua	Autumn adonis	11
Alcea acaulis	Stemless hollyhock	7
Anthemis palestina	Chamomile	3
Avena sterilis	Wild oat	5
Brachypodium distachyon cf.	Purple false-brome	1
Carthamus tenuis	Safflower	51
Chenopodium murale	Nettle-leaved goosefoot	31
Chrozophora tinctoria	Dyer's litmus plant	6
Crepis aspera	Rough hawk's beard	1
Daucus bicolor	'Carrot'	43
Daucus carota ssp. *maximus*	Wild carrot	137
Emex spinosa	Spiny dock	5
Erucaria hispanica	Spanish pink mustard	2
Euphorbia helioscopia	Sun spurge	15
Euphorbia microsphaera cf.	Spruge	1
Euphorbia peplus	Petty spurge	7
Fumaria parviflora	Small-flowered fumitory	50
Heliotropium europaeum	European turnsole	54
Hordeum spontaneum	Wild barley	82
Hymenocarpos circinnatus	Disk trefoil	1
Linum nodiflorum cf.	Common flax	51
Lolium rigidum	Rigid rye-grass	3
Mandragora autumnalis	Autumn mandrake	4
Mercurialis annua	Annual mercury	103
Moluccella spinosa	Molucca balm	2
Scabiosa prolifera	Prolific scabious	1
Scorpiurus muricatus	Two-flowered caterpillar	2
Silybum marianum	Holy thistle	40
Thymelaea passerina	Plax-leaved stellera	1
*Torilis nodosa**	Knotted bur parsley	2

totally different ecological signature and could not serve as a proxy for agricultural activity. Luckily, the excellent preservation of these waterlogged samples allowed for species level identification.

The identification to species also provides us with an improved understanding of weed emergence. Some of these weeds (see Table 1, the asterisked species) still grow in local fields, as well as in Mediterranean semi-steppe herbaceous habitats (Zohary 1962). These examples may indicate that the herbaceous ecosystem was their original,

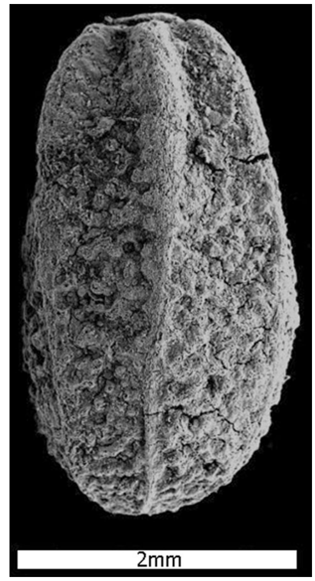

Fig. 2 *Bupleurum subovatum*. Mericarp, *dorsal view*. The fruit is long, ovoid, prominently ribbed and densely tuberculate in the wide, shallow furrows (SEM)

Fig. 3 *Lolium temulentum*. Grain, *ventral view*. The narrow ventral furrow becomes wider and shallower on the upper part of the grain (SEM)

pre-weed habitat, and that the first fields originated in this ecosystem.

The obligatory weeds

The following are the descriptions and the identification criteria of the obligatory weeds from Atlit-Yam.

Fig. 4 *Phalaris paradoxa*. Grain, side view. The fertile grain is enveloped by the lemma and the palea. The minute two lemmas (at the *bottom*) are actually reduced sterile florets (SEM)

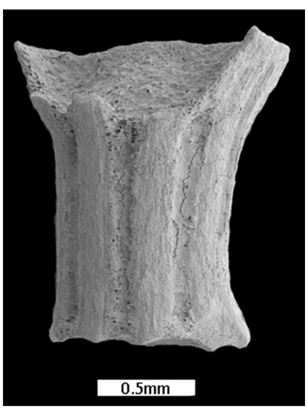

Fig. 5 *Raphanus raphanistrum*. Sterile portion of the siliqua upper joint, *side view*. The neighbouring joints are fertile (SEM)

Bupleurum subovatum *Spreng. (*=Bupleurum lancifolium var. lancifolium; B. intermedium *Poir.) (Apiaceae), False thorow-wax*

Two mericarps were found (Fig. 2), one at a well depth of 310–350 cm, and the second is from an unknown depth. They are characteristic in shape and pattern (Zohary 1972).

Beupleurum subovatum was formerly the typical variety of *B. lancifolium*, of which the other varieties are non-weedy, wild plants, and which still belong to the last species. A 4 mm long mericarp is one of the two main

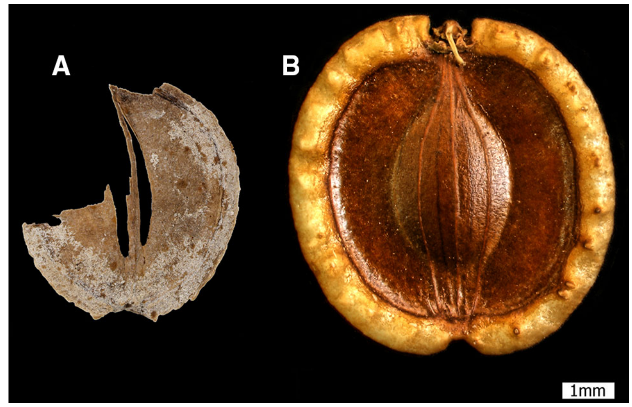

Fig. 6 *Tordylium aegyptiacum*. **a** ventral wall of flattened, *small mericarp*; **b** recent mericarp with distinct, somewhat moniliform margin for comparison, *dorsal view*. Unfortunately, the delicate mericarp was broken during photo processing, revealing the dorsal ridge. The inner part of the margin is viewed at the perimeter, while its moniliform outer part is missing (stereo microscope photo)

characters that distinguish this species, which is exclusively segetal in Israel. The second character is the fusion of two mericarps into a single dispersal unit (Zohary 1972; Danin 2004), which are similar in length and width to those of *T. parvicoccum* grain. The fused mericarps, which are unique to the genus and also unusual in the Apiaceae, suggest that the fruit of the segetal *B. subovatum* adapted to the *T. parvicoccum* grain in shape and size. Moreover, the wide and generally perfoliate shaped leaves of the two species are unique to their genus. This resemblance might suggest that *B. subovatum* evolved from the closely related *B. lancifolium*.

Lolium temulentum *L. (Poaceae), Darnel*

A single carbonized grain without hulls was identified (Fig. 3), found at an unknown depth in the well. *Lolium* grains have a small and elliptic embryo, and a hilum in a longitudinal furrow which equals the length of the grain (Bor 1968). The grain was identified to this species because of its relative size, width and elliptic shape.

Phalaris paradoxa *L. (Poaceae), Bristle-spiked Canary grass*

Nine carbonized hulled grains of *Phalaris paradoxa* were found (Fig. 4), all of them from a depth of 250–270 cm. It was easy to identify its genus, thanks to the characteristic shape of the grain, where its thickness is much greater than its width. In addition, the grain is tightly enclosed by the palea and glossy lemma, which are clearly visible in the archaeological find. One of the grains was subtended at its base by 2 min, unequal lemmas of sterile florets (Feinbrun-

Table 2 Crop and weed species (+pest beetle) with depth (cm) in the Atlit-Yam well

Species	0–200	190–210	210–230	230–250	250–270	270–290	310–350	410–430	470–510
Crop									
Triticum dicoccum	x	x	x		x	x	x		x
Triticum durum					x				
Triticum parvicoccum	x	x	x	x	x	x	x	x	x
Hordeum vulgare	x	x	x		x	x	x		x
Lens culinaris		x	x		x		x	x	x
Linum usitatissimum					x		x		
Obligatory weed									
Bupleurum subovatum							x		
Lolium temulentum	x								
Phalaris paradoxa					x				
Raphanus raphanistrum					x				
Tordylium aegyptiacum					x				
Facultative weed									
Adonis annua					x				
Alcea acaulis					x			x	
Avena sterilis		x			x				
Brachypodium distachyon cf.					x				
Carthamus tenuis	x		x		x			x	
Chenopodium murale					x			x	
Chrozophora tinctoria				x	x	x			
Crepis aspera					x				
Daucus bicolor					x				
Daucus carota ssp. *maximus*					x			x	
Emex spinosa	x								
Erucaria hispanica					x				
Euphorbia helioscopia		x	x		x				
Euphorbia microsphaera cf.					x				
Euphorbia peplus					x			x	
Fumaria parviflora	x	x			x	x	x	x	
Heliotropium europaeum					x			x	x
Hordeum spontaneum			x						
Hymenocarpos circinnatus		x							
Linum nodiflorum cf.					x	x	x	x	
Lolium rigidum					x				
Malva parviflora	x				x			x	
Mandragora autumnalis					x				
Mercurialis annua	x				x	x	x	x	
Moluccella spinosa					x				
Scorpiurus muricatus			x			x			
Silybum marianum		x			x	x		x	
Torilis nodosa					x				
Pest beetle									
Sitophilus granarius					x			x	

Dothan 1986). Based on these sterile lemmas, other *Phalaris* species were rejected.

Raphanus raphanistrum L. (Brassicaceae), Wild radish

Two carbonized and two waterlogged degraded portions of the siliqua upper joint were found (Fig. 5), all of them from a depth of 250–270 cm. They are characteristic of this species in shape, pattern, texture and dimensions. The upper joint has 2–8 seeded portions (and sometimes a few sterile ones) with constrictions between them, readily breaking into longitudinally ridged 1-seeded (or sterile) portions. In Israel, this species is common in the coastal plain (Zohary 1966).

Tordylium aegyptiacum *(L.) Lam. (Apiaceae), Egyptian hartwort*

Six waterlogged umbel peripheral mericarps were found (Fig. 6), all of them from a depth of 250–270 cm. They are strongly flattened, orbicular to suborbicular, somewhat notched at base and apex.

The middle dorsal ridge can be observed. We compared our remains with all local species of the tribe Peucedaneae, especially the other species of *Tordylium*, as well as the closely related *Peucedanum junceum*, but they were not similar to our finds.

Discussion

This large group of weeds from Atlit-Yam is a case-study for weed research, because it represents their very early establishment in cultivated fields. In addition, the weeds provide persuasive evidence for the antiquity of the interrelationship between weed flora and agricultural fields. There are several broad implications of this study.

(a) Atlit-Yam is the earliest known assemblage of obligatory weeds: In order to understand the obligatory weed community from Atlit-Yam in relation to contemporary agricultural communities, we checked archaeobotanical assemblages from other Pre-Pottery Neolithic southwest Asian sites. Although many PPN sites revealed domesticated crops, their weed finds are remarkably limited. In most reports, obligatory weeds are completely absent. Some PPN sites include finds which can potentially be regarded as obligatory weeds. However, these taxa were only identified to genus or sp./cf. level, not to species level (Table 3). As we mentioned earlier, weeds are useful ecological markers only if they are identified to species level.

There are several earlier reported cases where obligatory weeds were identified to species level, all in southwestern Asian Pre-Pottery Neolithic B agrarian sites. *Galium tricornutum* was found in Can Hasan III, Turkey (Hillman 1972, 1978), and in Yiftah'el, Israel (Garfinkel et al. 1988). *Lolium temulentum* was found at Ramad; *Vaccaria hispanica* was found at Aswad and Ramad, Syria (van Zeist and Bakker-Heeres 1982 (1985)), and also in PPNA M'lefaat (Savard et al. 2003). Two possible additional sites are Tepe Ali Kosh, Ali Kosh phase, where *Phalaris* cf. *paradoxa* was found (Helbæk 1969) and Nevali Çori where *Lolium* cf. *temulentum* was found (Damania et al. 1998).

The comprehensive ensemble of weeds from Atlit-Yam includes five obligatory and 30 facultative weeds. It represents, therefore, the establishment of weeds as a *characteristic group* within the agricultural cycle. This is, of course, not the "beginning of weeds," but rather the earliest representation of a complex weed population and not the sporadic appearance of a single weed.

(b) Weed-crop relationships reflect local agriculture: Contemporary observations have shown that particular weeds have a preference, or adaptation, for specific crops, or group of crops (Harlan 1965). At Atlit-Yam, we can distinguish a group of obligatory weeds, typical of cereal fields with *P. paradoxa*, *L. temulentum*, *B. subovatum*, *R. raphanistrum* and *T. aegyptiacum* (Zohary 1941).

Therefore, the combined plant assemblage of crops and weeds from Atlit-Yam can give additional information regarding the establishment of agriculture in the PPNC. Even in this prehistoric period we can see the state of co-evolution between certain obligatory weeds and their crops.

(c) A grain pest beetle and obligatory weeds invade the same human-made ecological niche: Interestingly, in addition to the noxious weeds from Atlit-Yam, we also identified the remains of some 27 specimens of *S. granarius* (granary weevil). Their numbers are based on finds of the prothorax, the fore segment of the thorax, which is the largest and hardest part of the insect and bears the front pair of legs (Fig. 7). In addition, the samples also contained six elytra, the protective wing cases that generally protect the functional wings, the latter being only vestigial in this species. *Sitophilus granarius* is a locally extinct pest beetle of stored grains, reviewed by Kislev et al. (2004). Together with contemporary finds from Hacılar, southwest Anatolia, Turkey (Helbæk 1970), these remains are the earliest known evidence of a pest associated with domesticated grains. Today, this beetle is widespread, mainly in the north temperate zone, and it is naturally absent from our warmer region. The best conditions for its development are cool environments, down to 11 °C, with high relative humidity, and the beetle is therefore more successful in temperate regions (Howe 1965; Dobie et al. 1991). It seems that the cooler and more humid climate prevailing in the prehistoric southwest Asian Neolithic (Bar-Matthews et al. 1997; Kislev et al. 2004), along with human grain storage, enabled the spread of *S. granarius* to our region. Later, when the area became warmer and drier, *S. granarius* suffered extinction.

The remains of obligatory weeds together with grain weevils suggest that Atlit-Yam represents an advanced agricultural economy of crop growing and storage. In addition, agriculture not only served to provide food, but also functioned as a significant ecological factor that influenced a vast array of organisms taking up residence in new human-made ecological niches.

Conclusions

Atlit-Yam was occupied some 2,000 years after the beginning of sowing and some 1,000 years after the first morphological signs of domesticated cereals.

Table 3 Potential obligatory weeds in Pre-Pottery Neolithic southwest Asian sites

Period/Sites	Potential obligatory weeds	Reference
PPNA		
Dja'de el-Mughara	*Galium* sp. *Vaccaria* sp.	Willcox et al. 2008
Jerf el Ahmar	*Bupleurum* sp. *Galium* sp. *Lolium* sp. *Phalaris* sp.	Willcox et al. 2008
Mureybit	*Galium* sp.	Van Zeist and Bakker-Heeres 1984 (1986); Willcox 2008
Netiv Hagdud	*Phalaris* sp.	Kislev 1997
Tell 'Abr	*Galium* sp.	Willcox et al. 2008
Tell Qaramel	*Bupleurum* sp. *Galium* sp. *Lolium* sp. *Phalaris* sp. *Vaccaria* sp.	Willcox et al. 2008; Willcox and Herveux 2013
PPNA/EPPNB		
Göbekli Tepe	*Galium* sp.	Neef (2003)
PPNB		
Abu Hureyra	*Galium* sp.	De Moulins 2000
Ali Kosh	*Galium* sp. *Lolium* sp.	Helbaek 1969
Aşikli Höyük	*Galium* sp.	Van Zeist and de Roller 2003a
Aswad	*Galium* sp. *Lolium* sp. *Phalaris* sp.	Van Zeist and Bakker-Heeres 1982 (1985)
Çatalhöyük East	*Phalaris* sp.	Fairbairn et al. 2007
Çayönü	*Galium* sp. *Phalaris* sp. *Vaccaria* sp.	Van Zeist and de Roller 2003b
Ghoraifé	*Galium* sp. *Lolium* sp. *Phalaris* sp.	Van Zeist and Bakker-Heeres 1982 (1985)
Nevali Çori	*Galium* sp.	Pasternak (1998)
Ramad	*Bupleurum* sp. *Galium* sp. *Phalaris* sp.	Van Zeist and Bakker-Heeres 1982(1985)
Shillourokambos	*Galium* sp. *Lolium* sp.	Willcox 2001
Tell Bouqras	*Galium* sp. *Lolium* sp. *Phalaris* sp.	Van Zeist and Waterbolk-van Rooijen (1985)

Studying the site has enabled us to demonstrate aspects of the complex interactions operating in a more advanced agriculture. Aside from the domesticated cereals and pulses found there, we have identified the earliest and largest weed assemblage from the southwest Asian Neolithic.

There are several plant associations where herbs could have turned into weeds. These include semi-steppe and savanna-like vegetation, such as the *Ziziphus spina-christi* vegetation association in the southwest Golan and eastern lower Galilee, and open woods, such as the *Quercus ithaburensis-Styrax officinalis* and *Ceratonia siliqua-Pistacia lentiscus* associations, both of which can be found near Atlit-Yam (Zohary 1962). Some of these weeds may indicate that the original habitats of various contemporary weeds were in the Mediterranean herbaceous ecosystem, which was also the ecosystem of the first fields.

D. Zohary described the adaptation of annual crops to their new field habitats" as follows: "Unconscious or automatic selection brought about by the fact that the plants concerned were taken from their original wild

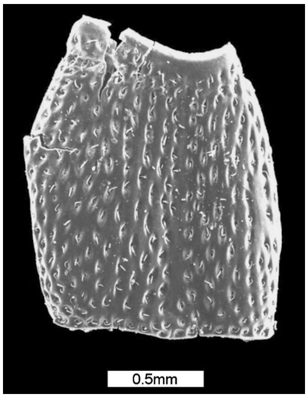

Fig. 7 *Sitophilus granarius*. Prothorax of an adult beetle, *dorsal view*. The punctures are distinctly oblong. In each of them there is a short hair, most of them are preserved (SEM)

habitat and placed in new (and usually very different) human-made or human-managed environments. The shift in the ecology led automatically to drastic changes in selection pressures. Numerous adaptations vital for survival in the wild environments lost their fitness under the [new] sets of conditions" (Zohary 2004).

We suggest that the weeds-to-be were also adapted to the field habitat by similar unconscious selection. Only those herbs that succeeded in adapting to their new ecosystems could pass over various ecological (and possibly evolutionary) barriers and become weeds.

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