THE RECONSTRUCTION OF AGRICULTURAL PRACTICES IN ANCIENT EGYPT: AN ETHNOARCHAEOBOTANICAL APPROACH

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ABSTRACT: Archaeobotanical research which is aimed at the reconstruction of former agricultural practices is based mainly on the interpretation of samples from domestic areas. This is rather problematic, as it implies that on-site information is used for off-site interpretations. To solve this problem, the reconstruction of agricultural practices is based on ethnographic research and experimental archaeology. However, the selection of suitable archaeobotanical samples has received little attention in both these approaches.

In this article, a model is presented for the reconstruction of cereal cultivation in ancient Egypt with special emphasis on the linkage of the vegetation outside the settlement (off-site vegetation) with the selection of archaeological features within a settlement (on-site sampling). The model is based on 'judgement sampling' of specific contexts, taking account of the stratified occurence of weed plants in cereal fields and of the processes by which plant parts are transported from fields to settlements. In the context of the unique system of exploitation of the fertile soil in ancient Egypt, in which flooding, harvesting methods and grazing of fields play an important role, it is shown that a reconstruction of agricultural practices can be based on the analysis of food stocks and identifiable plant remains in, specifically, building materials and ash layers.

The model is illustrated with the botanical analysis of samples from the Roman settlement Medinet Watfa (Fayum) and of modern samples of grains and accompanying threshing remains (stalks, chaff, rachis fragments and remains of weed plants).

KEYWORDS: Egypt, threshing remains, mud brick, dung cake, ash layers, cereals, weed flora.

1. INTRODUCTION

One of the aims of archaeobotanical research is to reconstruct former agricultural practices. This may include evidence about land-use strategies, such as ploughing, weeding and irrigation, as well as a reconstruction of the different stages of crop processing, such as the reaping method and the efficiency of threshing. Our understanding of these stages in plant husbandry will depend highly on the quality of subfossil plant remains that may be available as proxy data. This approach therefore places great demands on the sampling method.

It is a serious problem that most of the agricultural practices are located off-site, whereas most of the archaeobotanical samples are collected within settlement areas. Kreuz (1995) already pointed to the complementary character of off-site and on-site research in the study of early Neolithic environments, in which off-site analysis is mostly based on micro-remains and off-site analysis on macro-remains. Pollen analysis is mostly based on corings at off-site locations and are therefore useful for the reconstruction of the vegetation development, including the impact of man (Behre, 1986). The study of macro-remains, on the other hand, mostly depends on 'on-site' sampling and may be regarded as a form of remote sensing when a reconstruction of agricultural practices is a research aim.

Studies dealing with former farming practices are characterized by a versatile approach and include metrical and statistical analyses of subfossil assemblages, ethnographic models of present-day crop husbandry, experimental archaeology and ecological studies of weed floras. Metrical analyses and multivariate analysis have been applied to subfossil seeds from particular archaeological contexts as tools in reconstructing various crop-processing activities (*e.g.* Dennell, 1974; Jones, 1987; Van der Veen, 1992). Ethnographic models of agricultural practices relating to cereals and pulses have been published and provide much information on the botanical composition of the products and by-products of each stage in processing (*e.g.* Hillman, 1984, 1991; Pasternak, 1991; Davies & Hillman, 1992; Jones, 1984; D'Andrea *et al.*, 1999; Butler *et al.*, 1999). An ethnographic study by Miller (1984) has demonstrated that the use of dung cakes, fuel made from a mixture of dung and threshing remains, is an important source of charred grains and weed plants within a settlement. The presence of complete cereal grains in dung cakes is explained by the undamaged passage of some of the grains through the gastrointestinal tract of domestic animals that are fed on grain, as could be demonstrated by experiments conducted by Neef & Bottema (1991). Extensive experiments on the cultivation of ancient crops, such as emmer and spelt, have been conducted by Reynolds at Butser Farm. One of the outcomes is an alternative explanation for the presence of charred grains in settlement areas outside storage facilities. Reynolds (1993) is of the opinion that such charred seeds may also be waste products of roof thatching, in which bonfires are responsible for the dispersal of the burnt plant remains. Recently, standardised information on crop husbandry practices has become available by autecological studies of weed plants. These studies provide useful information on, for example, the intensity of crop husbandry (Jones *et al*., 1999), crop rotation schemes (Bogaard *et al*., 1999), irrigation regimes (Jones *et al*., 1995; Charles *et al*., 2003), fertility and soil disturbance (Jones *et al*., 2000) and crop sowing time (Bogaard *et al*., 2001).

The reconstruction of former husbandry practices is also dependent on sampling procedure. 'Judgemental sampling' is a common practice in archaeobotanical research and is mostly applied to contexts rich in plant remains. Analysis of such rich contexts ensures that substantial records of plant species will be available. Such records will, therefore, allow a good interpretation of the different uses of economic plants. Even the proportions in which, say, different cereals were grown might be inferred from such rich samples. But rich samples have the disadvantage that they are mostly unsuitable for the reconstruction of specific agricultural practices. When it comes to relating weed plants to specific crop plants, which is a precondition for the reconstruction of specific practices, it is obvious that samples containing a range of different crops are difficult to interpret.

In probability sampling, also known as random sampling, each spot has the same probability of being sampled. Random sampling is especially recommended for large sites, to guarantee that the data are representative for the whole site (*e.g.* Van der Veen, 1984; Jacomet & Kreuz, 1999). Another advantage is that random samples can be easily assessed statistically. A disadvantage of random sampling is, however, that it does not take account of formation processes of the archaeobotanical record. Knowledge of such processes can be used to select particular samples that may provide relevant plant remains, even if they are not visible during excavation. In this way, judgement sampling can be much more efficient than random sampling.

Hillman (1991) already pointed to the importance of looking for the pathways by which specific plant remains entered the settlement area. Only in this way might it be possible to decide upon the composition of former weed communities, though all kinds of taphonomic processes may obscure the picture. In discussing charred plant remains in particular, Hillman concentrates on the specific taphonomic processes that are linked with this type of preservation mode. Although it is mentioned that the implications of this approach extend to many waterlogged assemblages as well, it is limited in its validity for interpreting plant assemblages preserved by desiccation.

This article presents a model for the study of the cultivation of cereals in ancient Egypt based on judgemental sampling. It is shown that a combined analysis of samples representing food stocks, building materials and ash layers will provide the desired information for reconstructing former agricultural practices. Results of an analysis of modern threshing remains obtained from cereal fields in the Fayum, and from some archaeological contexts in the Roman settlement Medinet Watfa, on the western shore of Lake Qarun and excavated on a limited scale in 2002 by the UCLA / RUG, are presented to illustrate the model.

2. STRATIFIED PRESENCE OF DIASPORES IN CEREAL FIELDS

Since information about agricultural practices has to be obtained from archaeological contexts within settlements, it is of interest to determine the representativeness of plant assemblages in well-defined archaeological contexts. It is particular important to examine to what extent subfossil assemblages resemble the original standing vegetation of cereal fields. The degree of correspondence between both kinds of plant assemblages is determined by contemporary processes of harvesting, transport of plant remains and soil to the settlement and their use within the latter. Additionally, post-depositional processes will affect the preservation and mixing of plant remains.

The dispersal units of the arable weeds (*e.g.* seeds, fruits and false fruits) can be correlated with four different layers of a cereal field (fig. 1). This vertical distribution is linked to the life form characteristics and the dispersal strategies of the weed species. For a good understanding of the composition of the archaeobotanical record in different archaeological contexts, a brief description of each of these layers in the standing vegetation and their presence in modern threshing samples is presented, as well as the process by which

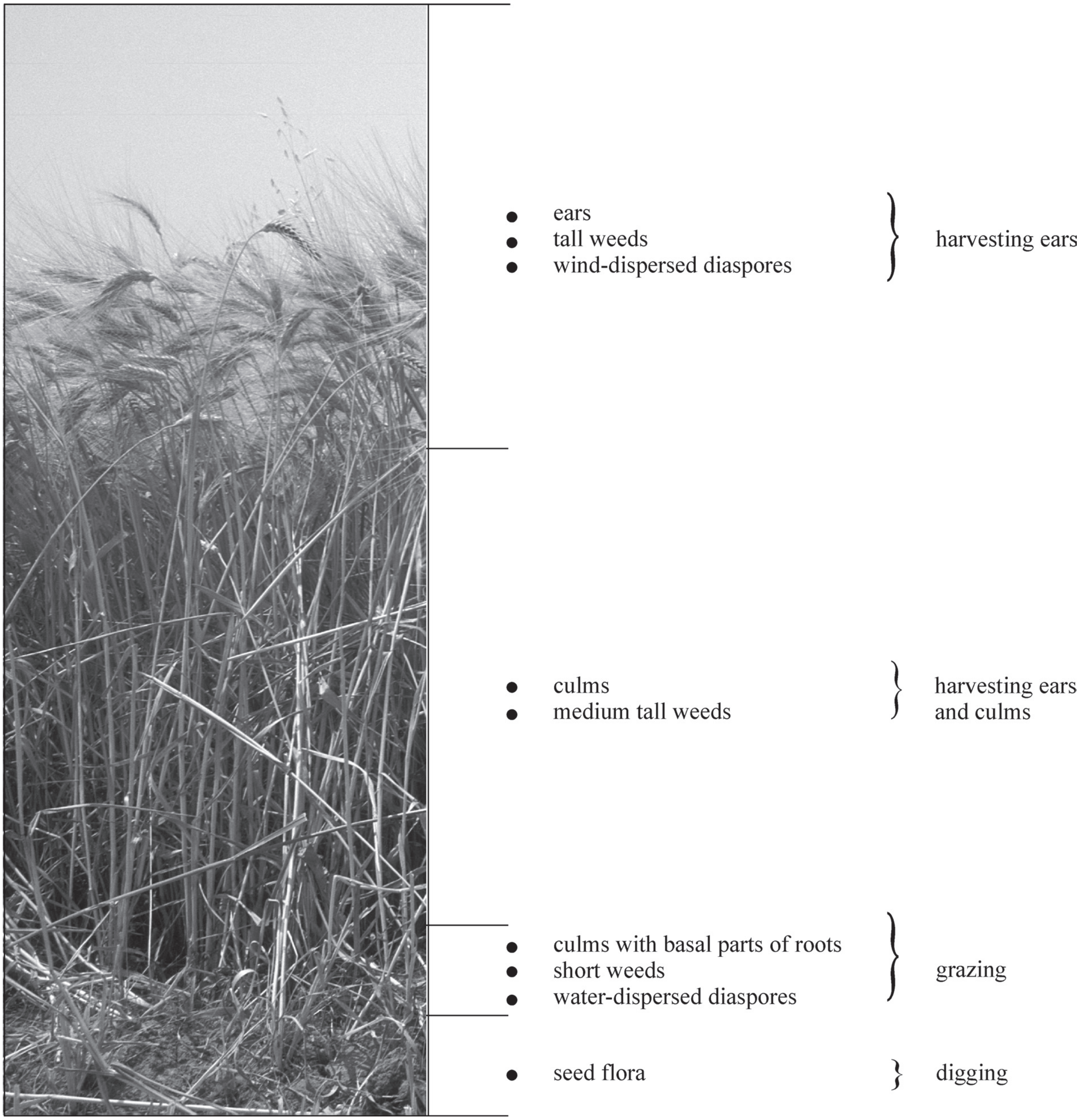

Fig. 1. Stratified presence of diaspores of weed plants in a cereal field (photo R.T.J. Cappers).

the diaspores are brought to the settlement.

The upper level in a cereal field is defined as the layer in which the ears are present. Until recently, this level was rather variable. Reynolds (1993) emphasizes that old landraces are characterized by their disparity in stand heights. The current cultivars of wheat and barley especially have a uniform culm length, making it easy to harvest ears and culms separately. Two kinds of weed plants are present in this upper layer: the tallest species, such as the noxious oats (*Avena* spp.), and species whose diaspores become attached to the chaff. It is obvious that the indicative value of these two kinds of weed species is not the same. The tall weed plants are adapted to the environmental conditions, and plant remains of these species appearing in the subfossil record can be used to infer ecological conditions. Plant species whose diaspores are trapped in the chaff are problematic in this respect, as they may be either part of the local weed flora or originate from a neighbouring vegetation type. Fruits of Sow-thistles (*Sonchus* spp.) may serve as an example of diaspores that are predominantly found in the upper level of a cereal field. Reynolds (1981) mentions that occasionally fruits of the Perennial sow-thistle (*S. arvensis*) were found in ears of emmer and spelt. Fruits of another species, the Prickly sow-thistle (*S. asper*), were frequently found in ears of wheat in the reference collection of the Groningen Institute of Archaeology, originally grown in Wageningen. Because the fertile soil in Egypt is for the most part used as arable, the trapped diaspores of potential weeds can be safely attributed to the arable flora.

A second level in the cereal fields is that of the culms, starting from some distance above the soil surface up to the level where the lowest ears are present. Its lower limit is determined by the unevenness of the soil, in particular when sickles are used for harvesting, and may vary between 5 and 30 cm from the ground. At this level the inflorescences of the taller weed species are found, including climbing species such as Bedstraws (*Galium* spp.), Peas (*Lathyrus* ssp.), Vetches (*Vicia* spp.) and Bindweeds (*Convolvulus* spp.).

The third level concerns the lower end of the culms. Small weed plants such as Fluellens (*Kickxia* spp.), Swine-cress (*Coronopus squamatus*), Pimpernel (*Anagallis arvensis*) and Spurges (*Euphorbia granulata* and *E. Prostrata*), are virtually confined to this level and will therefore be underrepresented in the harvest. This is also true when the cereals are harvested by uprooting.

The lowest level in cereal fields is the actual soil. This layer is of particular interest for two reasons. First, it is a well-known phenomenon that there may be a strong dissimilarity between the seed content in the soil, with ‘seeds’ standing for all kinds of diaspores, and the standing vegetation. Dominant weed species in a cereal field may be underrepresented or even completely absent in the soil seed bank. Conversely, plant species present in the seed bank may be poorly represented or even absent in the established vegetation. Analysis of the soil flora will therefore improve our knowledge of the potential weed flora (Cappers, 1995). Second, analysis of the soil may reveal species indicative of irrigation. Archaeobotanical evidence of cereal irrigation may be based on the composition of the weed flora, of the marshy plants that grow along irrigation channels and of the water plants. The first group of plants are adapted to inundation of the fields and to moist soil conditions. Where irrigation channels display an intricate structure within the agricultural area, as can still be observed in Egypt, marshy plants fringe the fields on a large scale and their proximity may be partly reflected also in the archaeobotanical record. Seeds of water plants may enter the fields with flood water, to be deposited on the soil surface. Eventually, they may become buried in the soil by the activity of animals, by ploughing or by the deposition of silt during new inundations.

3. ANALYSIS OF MODERN GRAIN AND THRESHING SAMPLES

It has become clear from ethnographic studies of crop processing that different stages of processing can be recognized by the botanical composition of their (by-)products, of which size, weight and shape of the diaspores are the most important determinants (*e.g.* Hillman, 1984; Jones 1984). Unfortunately, detailed information on a species level is only sporadically presented.

To determine the composition of wild-plant remains in grain samples and associated samples of threshing remains, a series of samples of Bread wheat (*Triticum aestivum*) were collected at some threshing sites in the Fayum. Additionally, a sample of threshing remains was collected from a heap to be used for the production of mud bricks. In contrast to the other samples, this sample was not taken at the threshing location, but in a settlement where mud bricks were produced. The samples of threshing remains that were analysed, were a mixture of wheat straw and chaff remains. All identifiable plant remains up to 0.5 mm in size were picked out for analysis.

It is realized that this ethnographic study is based on current practices and that this material, therefore, cannot reflect the ancient practices. Not only is the replacement of Hard wheat (*Triticum turgidum* ssp. *durum*) by Bread wheat of recent date. Also the use of the threshing machine is different from the traditional way of threshing, as this machine produces only one type of by-product. When the complete plants are harvested, the traditional threshing method produces three different by-products: the winnowing by-products, the coarse-sieve and the fine-sieve by-products. These by-products may be amalgamated, or some may be kept apart, for example the fine-sieve by-products for the tempering of pottery. It is assumed that differences in the weed assemblages will still mirror the basic principles of the processing of free-threshing wheat, as modern threshing is still based on differences in size, weight and shape between plant remains of cereals and arable weeds.

The results of the analyses are summarized in table 1. As the samples of grain and threshing remains differ in size, the degree to which a specific plant part is present in each of these samples may be obscured. An accurate comparison can be obtained by standardizing the counts of plant remains in both types of sample. The unit of comparison is the rachis node, which is the part of the rachis to which the spikelets (and grains) are attached. For free-threshing wheat, there is no fixed number of grains that corresponds with a rachis node. Its number depends in part on the tillering capacity of the wheat plant, the location of the rachis node within the ear and the length of the internodes. It was found that lax-eared varieties, with long internodes, produce more grains per internode than dense-eared varieties. An analysis of 40 ears of Bread wheat, collected in two different fields in the Fayum and representing the observed variety in terms of ear length, revealed that the mean grain weight is 0.042 gr and that the mean number of grains per rachis node is 2.4. This means that a grain sample of 250 gr is equivalent to a sample of threshing remains containing about 2500 rachis nodes. Based on these data, a conversion factor was calculated for each sample of threshing remains. The conversion factor for sample no. 6, the sample of threshing remains used for mud brick production, was based on a conversion to 5000 rachis nodes. These conversion factors have been applied to the plant remains in the samples of threshing remains and the conversions are presented in round figures (table 1).

The number of rachis nodes in samples of threshing remains varies greatly compared with the volume of these samples. This difference in the number of rachis-nodes is possibly caused by a difference in culm length. The number of wheat kernels in the samples of threshing remains is almost negligible if broken and unripe specimens are ignored and the same is true for rachis fragments in the grain samples. This indicates that the grains are effectively separated from their vegetative parts.

A number of weed species are present in both the grain samples and the samples of threshing remains: Pimpernel (*Anagallis arvensis*), Wild oat (*Avena fatua*), Beet (*Beta vulgaris*), Field bindweed (*Convolvulus arvensis*), *Emex spinosa*, Rye-grasse (*Lolium* sp.), Lesser canary-grass (*Phalaris minor*), Awned canary-grass (*P. paradoxa*) and Charlock (*Sinapis arvensis*). Seeds and other types of diaspores of these weeds are conspicuously present in the grain samples, whereas fruit parts and other remains of these weed plants are more often found in the threshing remains. For the weed plants this separation of plant parts is functional, as the presence of their seeds in the grain implies that they will also be among next year's seed grain. This is of special importance when the seed is used for sowing in new fields. It should be realized that the modern sieves with standardized mesh sizes are much more effective in separating weedy seeds by their size than the old-fashioned ones. Most of the sieves that are currently used in Egypt are made from fine-mesh wire-netting, whereas the traditional ones were made from donkey leather (fig. 2).

Although weed plants may be well represented in grain and threshing remains, it is still possible that a major part of the diaspores will escape harvesting. This can be illustrated by Beet (*Beta vulgaris*) and Wild oat (*Avena fatua*). A wild beet plant has several decumbent stems and a long erect main stem, which may reach a height of 80 cm. Both types of stem produce many fruit clusters. Those from the decumbent stems are dispersed as soon as they are ripe and, despite their large size, may easily become buried in the cracks formed in the soil surface during the weeks prior to the harvest, when irrigation water is no longer brought into the fields (fig. 3). Only the fruit clusters of the erect stems will be harvested with the cereal crop.

Egyptian farmers consider Wild oat to be the most troublesome weed and considerable effort is put into the control of this plant. The spikelets are produced in a panicle at the top of the culm, which may reach a length of 160 cm. Only the spikelets of the smaller plants will become part of both the grain and threshing remains. The tall plants easily outgrow the wheat and their spikelets will escape harvesting and be dispersed in the field proper. To reduce seed loss, free-threshing wheats are harvested before the grains are dead-ripe. After-ripening in the fields takes a couple of weeks, for which the plants are either spread out in rows or are tied up in bundles. Spikelets of oat are easily released from the panicle during this phase and especially those from tall plants become easily buried in the soil.

Only a few weed species are present in the grain samples but absent in the accompanying threshing remains. The most conspicuous example is Small melilot (*Melilotus indica*), the diagnostic character of the syntaxon *Melilotion indici* and typical of irrigated winter-crop vegetations (Kosinová, 1975).

The fruits of Smooth sow-thistle (*Sonchus oleraceus*) are frequently found in the threshing samples, though in small numbers. As mentioned above, these fruits are effectively caught from the air by the prickly chaff. The pappus is removed from the fruit during threshing and most of the fruits end up in the threshing remains. The small but long-awned spikelets of Annual beard-grass (*Polypogon monspeliensis*) are often found inside remains of wheat spikelets. It is

Table 1. Weed composition of grain samples and samples of threshing remains from Bread wheat (*Triticum aestivum*) collected at six locations in the Fayum. Samples no. 1-5 were collected on the 5th of May 2004 during threshing. Sample no. 6 was collected on the 26th of October 2003 from a heap to be used for making mud bricks (G = grain sample; T = threshing sample; RN = rachis node; CN = culm node; CB = culm base; * = not counted). Unripe plant remains are underlined.

		Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
		29º20.22' N		29º20.31' N		29º22.38' N		29º23.06' N		29º23.13' N	
		30º35.49' E		35º35.07' E		30º35.46' E		30º34.29' E		30º33.53' E	
Plant species	**Plant part**	**G**	**T**	**G**	**T**	**G**	**T**	**G**	**T**	**G**	**T**
Anagallis arvensis	seed			1	2			7	20	6	5
	fruit		1						4		1
	receptacle				1			1		1	
	pedicel								2		
Avena fatua	fruit	2		4				2			
	spikelet	79	2	281	37			3	1		
	pedicel		15		30				1		2
Avena sativa	spikelet								1		
Avena sterilis	spikelet	9									
Beta vulgaris	fruit cluster			186	11+3	4	3	6	5+3	1	
Caryophyllaceae	seed				1		3		1		
Chenopodium	seed				2						
Chenopodium murale	seed				1+2		4				
Compositae	receptacle								2		
Convolvulus arvensis	seed			22		2	1	73+1	1		
	fruit			5	2	1	2				
	pedicel+fruit								3		
Echinochloa colona	spikelet									1	
Emex spinosa	fruit	1		2+1			2				
Euphorbia	fruit		1						1		1
Euphorbia helioscopia	seed				1						
Gramineae	spikelet										2
Hordeum vulgare ssp. vulg.	spikelet			7					1	7	
	RN	11							4		
Indet.	-		1	1							2
Lolium	spikelet	12	33				1	2	2		
	infloresence		30								
Medicago intertexta	seed									1	
Melilotus indica	fruit										
	fruit+seed					1		1		2	
Melilotus messanensis	seed								1		
Phalaris canariensis	spikelet							1			
Phalaris minor	spikelet	1	1		3+25						
	diaspore			2	15						
Phalaris paradoxa	spikelet								1	3	8
Plantago	infloresence								1		
Polypogon monspeliensis	spikelet		4		3						
Rumex	fruit						1				
	perianth						1				
Sinapis arvensis	seed			17	2	3		6			
	valve			3	16				1		1
	beak				10						
	pedicel				6				2		
Sonchus oleraceus	fruit and seed				3				1	1	1

		Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
		29º20.22' N		29º20.31' N		29º22.38' N		29º23.06' N		29º23.13' N	
		30º35.49' E		35º35.07' E		30º35.46' E		30º34.29' E		30º33.53' E	
Plant species	**Plant part**	**G**	**T**	**G**	**T**	**G**	**T**	**G**	**T**	**G**	**T**
Trifolium	seed									1	3
Trifolium resupinatum	seed				1						
	fruit and seed		1		3				1		1
Triticum aestivum	grain				6.5+4		14+11		0.5+2	5+3	
	RN		84	42	772	2	373		315	19	730
	CN		*	27	*	15	*		*	9	*
	CB		*		*	2	*		*	1	*
Umbelliferae	fruit				2					2	13

assumed that the wind-borne spikelets of *P. monspeliensis* only become incorporated in the wheat chaff during threshing. In this way a small part of the spikelets of *P. monspeliensis* are mixed with the threshing remains, whereas most of its spikelets will be wind-dispersed.

Unripe diaspores are conspicuously present in the samples of threshing remains. Most of these diaspores are from weed plants that also leave some ripe diaspores, such as Field bindweed (*Convolvulus arvensis*), Nettle-leaved goosefoot (*Chenopodium murale*) and Lesser canary-grass (*Phalaris minor*). The only exception in the investigated samples is Bullwort (*Ammi majus*). The life cycle of this plant is obviously not synchronized with the current wheat-growing regime in the Fayum.

The composition of the weed assemblages indicates that a qualitative analysis can be obtained by the analysis of either grain samples or threshing remains as most of the species are present in both of them. But when a quantitative study of the weed composition is desired, it will be necessary to study both the grain samples and the threshing remains as the proportion of most of the species differs between the grain and threshing remains.

4. ROUTES OF PLANTS AND SOIL FROM THE FIELD INTO THE SETTLEMENT

Given the different levels from which plant remains can be gathered from a cereal field, it is also important to know how plant remains from each of these levels may enter the settlement. As plant remains are present both in the standing vegetation and in the upper soil layer, their transport will depend on how the plants and the clay are exploited (fig. 4). In this section, the transport of plant parts from the standing vegetation and the top-soil will be briefly discussed in relation to the exploitation methods of plants and soil.

The transport of weed plants from the standing vegetation is related to the harvesting of the crop and the grazing of fields after the harvest. The harvesting method will determine what kinds of weed plants will be gathered in the crop. When the ears are reaped separately, whether or not followed by the harvest of the straw, only tall weeds and wind-dispersed diaspores such as those from Sow-thistles (*Sonchus* spp.) will be harvested together with the ears. The harvesting of both ears and straw will increase the number of weed species that may be brought to the settlement.

The harvesting of the straw can be related to the economic value of the culms and chaff (especially from free-threshing cereals) and to the properties of the cereal plants. Straw and chaff are not just waste products but can be used in several ways, the most important ones being fodder, temper and fuel (Smith, 1998; Van der Veen, 1999). For this reason the designation of 'crop-processing remains' (or: 'by-products') is more appropriate than 'crop-processing waste'. In Egypt, where threshing remains are still highly valued, there is a traditional preference for tall strains of wheat and barley. Heaps of threshing remains, produced during the end of April and the beginning of May, can still be seen on the threshing floors at the end of the year awaiting the right moment to be brought on the market. Today, large quantities of threshing remains are even exported to Jordan and Libya.

When harvesting is done with a sickle, the variable culm length, which is believed to be quite common in old strains, forces the farmer to cut rather low. Also the cultivation of free-threshing cereals finds benefit in harvesting the plants close to the soil surface or even by uprooting the complete plants. The problem of free-threshing plants is that, in contrast with hulled cereals, seed-dispersal is possible. For this reason one

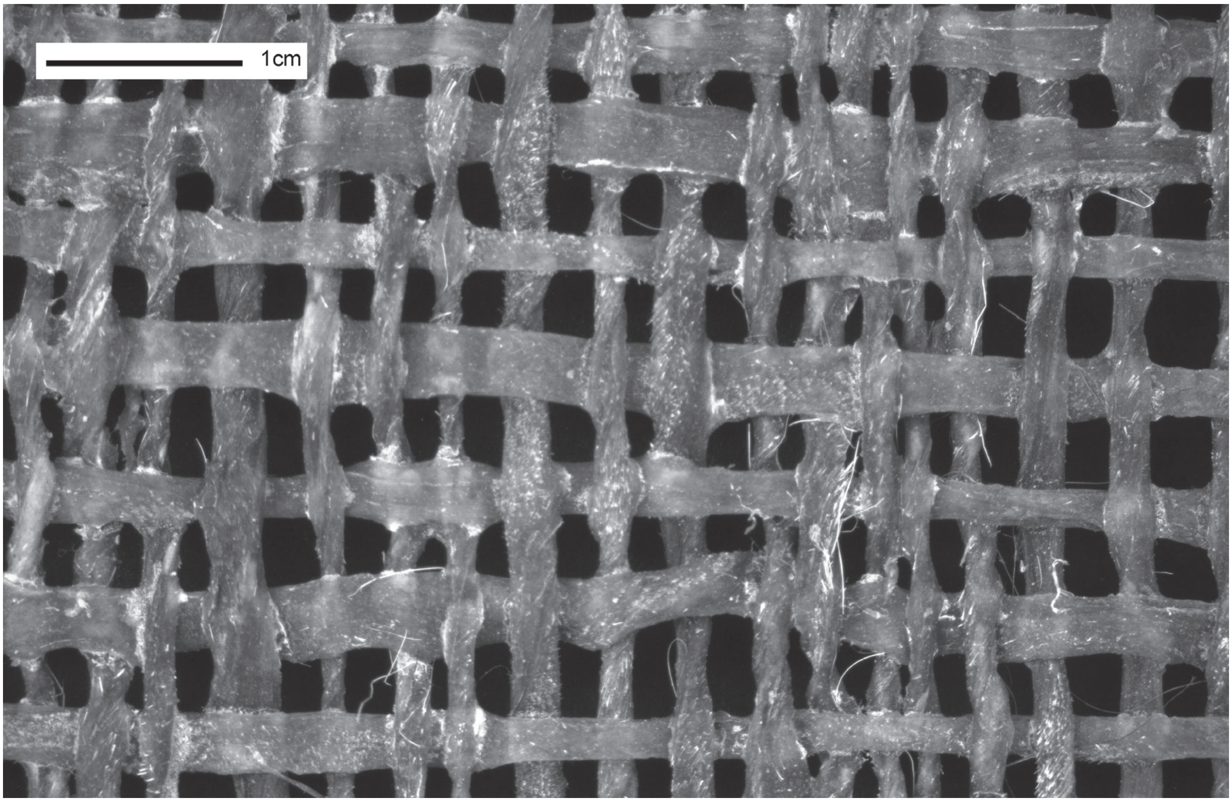

Fig. 2. Detail of a traditional sieve used for sieving grain (Fayum, May 2004) (photo R.T.J. Cappers).

might even suggest that they are not fully domesticated (Cappers, in press). To reduce the loss of grains during harvesting, plants are harvested before the grains are dead-ripe. In this way there is a span of time between harvesting and threshing, during which moisture from the grains can be absorbed by the vegetative parts. The harvesting method, being either reaping with a sickle or uprooting, will determine the assemblage of weed plants that will be subjected to further crop processing (Hillman, 1981).

Most of the small weed plants growing in a cereal field will not be collected along with the cereal crop. But as livestock are allowed to graze stubble and fallow fields and untilled areas, weed diaspores may become part of the dung. Dung is mixed with threshing remains and used as a fuel in the settlement (fig. 5). The botanical composition of dung cakes can be quite complex. Threshing remains in the dung cakes could have been added as a kind of filler, but they may also have been part of the fodder. Additionally, wild plant remains in dung cakes may originate from untilled areas that were grazed and from water plants used as fodder. Zahran and Willis (1992) mention that Curled pondweed (*Potamogeton crispus*) is collected as a fodder from submerged land on the River Nile in the Aswan area. According to Täckholm *et al*. (1941) this pondweed is widespread throughout the Nile region, where it grows in slowly-flowing water and often chokes small irrigation channels. Curled pondweed is in fact considered one of the worst submerged weeds of Egypt (Zahran & Willis, 1992). For this very reason it may have been collected on a regular basis as a source of fodder and it is very likely that the hard endocarps of Pondweed will in part have ended up in the dung. In Egypt, the untilled habitats will be mainly the narrow verges bordering the fields and their flora will largely resemble the arable weed flora with some bias towards plants that are adapted to trampling, such as Plantains (*Plantago*). But in areas where pastures are present, the wild plants in the dung cakes may be a mixture of arable weeds and grassland plants.

Of particular interest is the transport of clay to the settlement. Clay is an important raw material and can be used for making all kinds of building materials and pottery. Before the construction of the High Aswan dams, the annual flooding of the Nile supplied the fields with water and clay sediment rich in minerals. This flooding was also practised in the Fayum, where Nile water enters the depression via the canalized river Bahr Yûsuf. Although both water and minerals were

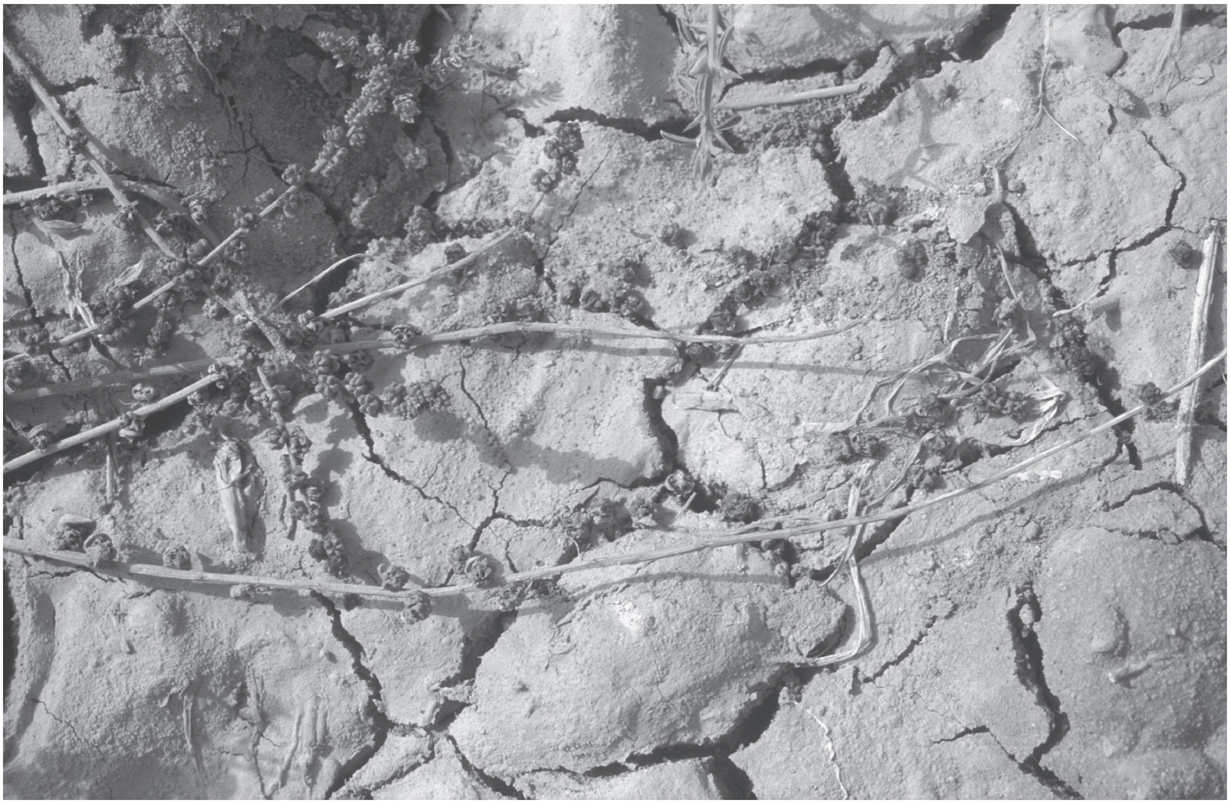

Fig. 3. Fruit clusters of Beet (*Beta vulgaris*) on the soil surface (Fayum, May 2004) (photo R.T.J. Cappers).

preconditions for successful crop production, the clay sediment itself could also be used. The accumulation of sediments in the fields allowed farmers to exploit the clay from their land, either by scraping off a thin layer over a large area or by digging clay from a pit (fig. 6). Alternatively, clay could be obtained from pits dug in the village itself. Such clay pits (*birka*), filled with water, are still found in many villages (Fathy, 2000). It is also suggested by Kemp (2000) that crumbled mud bricks were partly recycled. Because clay sedimentation has been greatly reduced since the construction of the High Aswan dams, the production of mud bricks is now officially forbidden in Egypt.

It is also possible that some mud is transported with the harvested grain. The presence of root remains with adhering mud is not uncommon in cereals reaped with a sickle, as is the case in currently harvested wheat in Egypt. Although this indicates that the uprooting method is not a precondition for the transport of clay, it is only when the threshing floor is located within the domestic area that the mud from the field will actually become part of these cultural layers. Murray (2000) has suggested for the Pharaonic period that threshing floors were mostly located outside the settlements, as threshing produces much dust, especially when trampling by animals is practised.

Clay used as a raw material for the production of building material, such as mud bricks, mortar and plaster, and for constructing facilities for the storage of food, can be mixed with a temper to improve its elasticity. This may consist of ash, pottery, stones or threshing remains, the last type being the preferred one (Kemp, 2000). Also clay to be used for making pottery may be tempered with chaff. When only the fine-sieve fraction of the threshing remains is used for the production of pottery, an analysis of potsherds will not add substantial evidence for the reconstruction of former agricultural practices.

5. SELECTION OF SAMPLES

For the reconstruction of past agricultural practices, samples should be collected which as much as possible represents the original crop plants and associated weed plants. The most promising samples are those from storage facilities, building materials and ash layers (fig. 4). This preference contrasts with samples from, for example, rubbish dumps. Such samples are rich in plant remains, but the presence of a range of

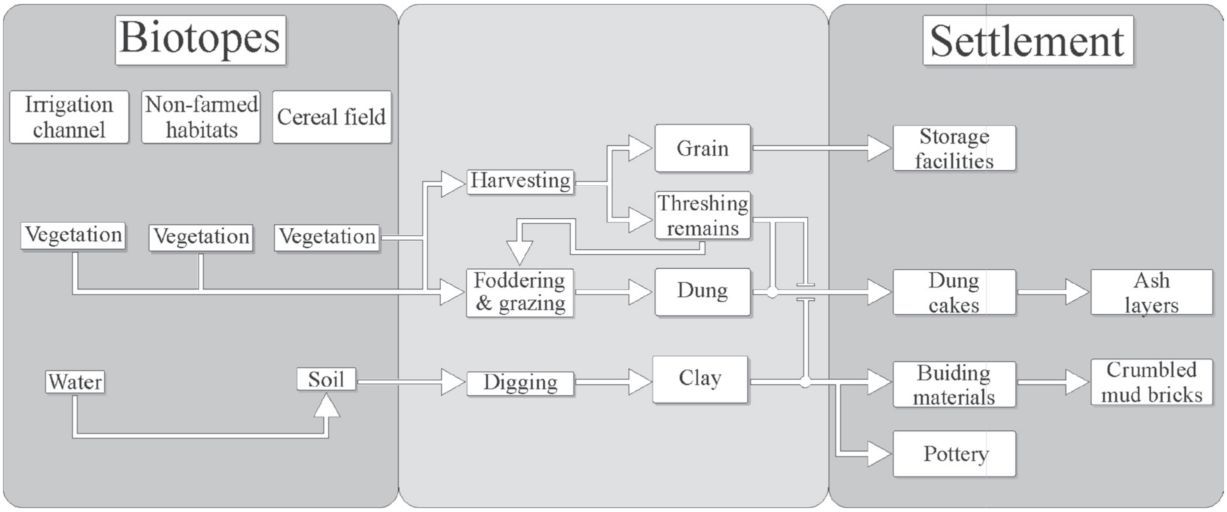

Fig. 4. Possible pathways for diaspores from off-site biotopes into archaeological features in settlements (drawing E. Bolhuis).

crop plants is at odds with the aim of reconstructing agricultural practices, as this primarily depends on the correlation between a particular crop plant and its associated weeds.

Food stocks can be found in storage facilities, but also in contexts related to offerings and in graves, which may contain food prepared for the dead. The storage of staple food is of particular interest, as it may reveal the quality of winnowing and sieving. When large supplies are still present, for instance in granaries, a large number of samples should be taken at different levels to take into account the possible storage of different harvests. This sampling method also overcomes the uneven distribution of small diaspores, which tend to move downwards during the filling of the granaries.

Unfortunately, the recovery of substantial food stocks is the exception rather than the rule and one has to focus on other archaeological contexts containing plant remains from fields, among which building materials and ash layers may be considered the most promising. In settlements where buildings are made of mud, the sampling for archaeobotanical research should include mud bricks, mortar and plaster. Although the use of organic temper is not a prerequisite, it is clearly present in many buildings (fig. 7). If possible, mud bricks, mortar and plaster should be analysed from standing walls, because plant assemblages from these well-preserved contexts will be neither contaminated nor reduced by erosion. Mounds of rubble will contain plant remains that primarily originate from bricks, mortar and plaster, but are likely to incorporate remains from other contexts as well. Furthermore, the impact of wind erosion on crumbled walls will be much more serious than on exposed but still standing walls, as plant remains will be partly blown away while plant remains from elsewhere may cause contamination. As a consequence, the scale of resolution for the interpretation has to be enlarged when disintegrated building material is analysed.

By analysing a well-chosen selection of mud bricks and samples of mortar and plaster, it will be possible to obtain a good record of the weed assemblage relative to the density of the crop. Because walls are liable to wear, replastering may have occurred in the course of time and as a consequence the botanical composition of the plaster may differ from that of the mud bricks and mortar. If all three components are still present, separate sampling and analysis may also contribute to the architectural interpretation of the settlement.

To determine the origin of the plant remains in the building materials, it will be necessary to analyse – if possible – these features both with and without temper. Mud bricks without temper will only contain plant remains that are part of the soil flora and include diaspores of the standing vegetation, possibly those of previous vegetations, as well as diaspores that entered the soil from outside the fields. When irrigation was practised, the last group would include diaspores from riparian plants and aquatic plants. Obviously, the burial of diaspores into the soil is not a precondition for their ending up in a mud brick wall. The botanical composition of tempered mud brick is more complex, as it comprises both the diaspores of the soil flora and the diaspores present in the threshing remains. A plant record of both types of mud bricks, *viz.* those with and without temper, will allow to distinguish between the soil flora and the temper, which has been used.

Fig. 5. Dung cakes with imprints of the maker's hand drying on a wall (Fayum, October 2002) (photo R.T.J. Cappers).

As in the analysis of building materials, the analysis of dung cakes is preferably based on complete specimens or recognizable fragments. In Egypt, unused dung cakes may be preserved by desiccation and their analysis offers a unique opportunity to obtain information from a small sample of threshing remains used as a filler in a particular piece of dung cake. But as the recovery of unused dung cakes in an archaeological context is rare, a practical alternative is to study the ash layers. The botanical content of ash layers should include seeds from arable weeds to ensure that ash layers represent burnt dung cakes. As is clear from figure 4, these weed remains may originate from either the dung or the threshing remains used as filler. The interpretation of plant remains from untilled habitats in ash samples may be problematic and depends on the ecological range of the plant species concerned. To optimize the interpretation of field weeds and those of untilled habitats, it will be necessary to investigate ash layers from different locations within the settlement. The presence of tall field weeds can be related to the admixture of threshing remains, whereas remains of small field weeds are indicative of the grazing of newly harvested fields or of fallow fields.

The analysis of plant remains in pottery as a contribution to the reconstruction of agricultural practices can be regarded as of minor importance. Even in coarse ware, which may have been tempered with a coarse fraction of the threshing remains, plant remains will be burnt out during the firing process. Only imprints of large plant remains, such as grains and culm fragments, may display diagnostic features. The imprints of smaller plant parts will remain unidentifiable, even in fine ware.

The analysis of a complete mud brick and a sample from a rubbish layer, both from the Roman settlement Medinet Watfa, located on the western shore of Lake Qarun, may serve as an example of their suitability for the reconstruction of agricultural practices (table 2). The mud brick originates from a well-constructed building at the centre of the site, uncovered in trench MW-02. The mud brick weighed over 9 kg and about 45 g of organic material was recovered on a 0.5 mm sieve. The rubbish sample comes from a small test trench (MW05) in a dump area located on the southern edge of the site. This sample was dry-sieved through a 1.0 mm mesh sieve. Both samples are dated to the 4th century AD.

The plant remains from the mud brick represent a typical combination of cereals, field weeds, riparian

Fig. 6. Clay pit in a field (Fayum, November 2003) (photo R.T.J. Cappers).

plants and water plants. Both Hard wheat (*Triticum turgidum* ssp. *durum*) and Hulled 6-row barley (*Hordeum vulgare* ssp. *vulgare*) are present, the former predominating. The presence of a fair number of complete barley and wheat kernels indicates that threshing was less effective than modern threshing. The number of field weeds does not differ much from those of riparian and water plants. Looking at the representativeness of the remains by species, it is obvious that field weeds are outnumbered by the riparian and water plants. Only fruits of Nettle-leaved goosefoot (*Chenopodium murale*) were quite frequently found. The mud brick proved to be rich in plants indicative of irrigation and included both riparian plants and water plants. The riparian plants are represented by several members of the Sedge family (Cyperaceae), and include Club-rush (*Scirpus supinus*), Galingale (*Cyperus* sp.) and Spike-rush (*Eleocharis* sp.). Water plants that were retrieved from the mud brick sample include Water-plantain (*Alisma* sp.), Water-crowfoot (*Ranunculus* subg. *Batrachium*), Naiad (*Najas* sp.) and Horned pondweed (*Zannichellia paslustris*). Apart from the riparian and water plants, also animal remains indicative of irrigation were found in the brick and include different types of small snail shells and *ephippia* of the Water flea (*Daphnia*).

The botanical composition of the rubbish sample differs from that of the mud brick in several respects. Whereas the mud brick only contains desiccated plant remains, the rubbish sample also produced charred remains, especially of cultivated plants. In the rubbish sample, several field and garden crops were represented as well as edible fruits from different trees. The analysis of rubbish layers is therefore of interest when the range of cultivated plants is to be reconstructed, but it will not be of much use in analysing agricultural practices, as no definite links can be demonstrated between weed and crop plants. Although riparian plants were not found in the rubbish sample, the presence of Naiad (*Najas* sp.) and Fennel pondweed (*Potamogeton perfoliatus*) clearly demonstrates that the rubbish was mixed up with disintegrated mud brick walls. These water plants are common in irrigation channels (fig. 8 and 9). The absence of riparian plants and the presence of only two water plants in the rubbish sample is partly due to using the 1.0 mm sieve. Most diaspores of both groups of plants present in the mud brick sample appeared to be quite small in size.

Fig. 7. Threshing remains are clearly visible in the mud bricks and mortar from a wall in Roman Karanis (Fayum, November 2003) (photo R.T.J. Cappers).

7. DISCUSSION AND CONCLUSIONS

It is obvious that archaeobotanical research aimed at the reconstruction of agricultural practices suffers from a sampling method which takes into account all possible archaeological contexts that might contain useful information. Random sampling might be at odds with the uneven distribution of plant remains from fields within a settlement, whereas judgemental sampling is mostly focused on samples rich in botanical remains. A disadvantage of rich samples is that they mostly comprise various crop plants, as a result of which it is impossible to decide which weed plants are associated with a particular crop (*e.g.* Cappers, 1998; Smith, 2003).

Rubbish deposits are well-known for their botanical richness, but despite their incorporation of crop and garden plants, they are often of no value for the reconstruction of agricultural practices. This kind of context is more suitable for random sampling and will produce an extensive archaeobotanical record of both economic and wild-plant species. Such a list of economic plants can be used to infer, for example, the standard of living, but if a clear correlation between crop plants and weed plants cannot be made, it will be impossible to infer specific farming practices. The recovery of diaspores of riparian and aquatic plants in rubbish layers can be explained by the disintegration of mud brick structures. Recurrent deflation and sedimentation of light particles on the surface of a settlement will result in the loss of plant remains or admixture from different origins and even of different ages. Only when the surface becomes covered with a layer of large and heavy fragments, such as potsherds, stones and bones, may a specific layer become consolidated. Because most heavy fragments would only sink in the course of time, the underlying layer's range in dating may reflect a time-span that covers the plant remains that are present in a particular rubbish layer. In this way, it is possible that plant remains from domestic rubbish may be mixed with threshing remains, remains of fodder and plant remains from grazed vegetations.

Ash layers are also complex in their botanical composition and their suitability for the reconstruction of past agricultural practices is not unequivocal. On the one hand, their analysis is of importance, as the plant record might include plant species from untilled

Table 2. Plant species present in a mud brick (MB) and a sample from the trash area (TA) of the Roman settlement Medinet Watfa. Unripe specimens are underlined, charred specimens are presented in bold.

		Biotope						
		Fields & gardens		Irrigation channels				Settlement & orchard
				Riparian plants		Waterplants		
Plant species	Plant part	MB	TA	MB	TA	MB	TA	TA
Chenopodium murale	fruit	161						
Gramineae	fruit	29						
Labiatae	fruit	1						
Rumex	fruit	1						
	perianth	2						
Echium rauwolfii	fruit	1	1					
Hordeum vulgare	Spikelet/grain	4	19+**24**					
ssp. vulgare	RN	33	139+**2**					
	chaff	X	X					
Lolium	spikelet	2	2					
Malva parviflora	fruit+seed	14	1					
Phalaris paradoxa	spikelet	1	10					
Raphanus raphanistrum	fruit	1	3					
Sinapis arvensis	pedicel	1	2					
Triticum turgidum	grain	16+2	1+**102**					
ssp. durum	chaff	X	**X**					
	RN	791	940+**57**					
	CN		**23**					
Avena	spikelet		**1**					
Beta vulgaris	fruitcluster		1					
Brassica nigra	pedicel		2					
Carthamus tinctorius	fruit		25					
Convolvulus arvensis	seed		4					
Coriandrum sativum	fruit		3					
Cucumis sativus	seed		48					
Cuminum cyminum	fruit		3					
Galium	fruit		7+**1**					
Lens culinaris	seed		5+**9**					
Medicago polymorpha	fruit		1					
Linum usitatissimum	seed		1					
	fruitfragments		X					
Lupinus albus	seed		3					
Torilis	fruit		2					
Trifolium	inflorescent		1					
Trigonella foenum-graecum	seed		2					
Vicia faba	seed		7					
Scirpus supinus	fruit			1015				
Cyperus	fruit			308				
Cyperaceae	fruit			14				
Eleocharis	Fruit			129				
Alisma	seed					183		
Characeae	oogonium					15		
Ranunculus subg. Batrachium	fruit					252		
Zannichellia palustris	fruit					311		
Najas spp.	seed					515	1	
Potamogeton perfoliatus	fruit						1	

		Biotope						
		Fields & gardens		Irrigation channels				Settlement & orchard
				Riparian plants		Waterplants		
Plant species	Plant part	MB	TA	MB	TA	MB	TA	TA
Citrullus lanatus	seed							0.1
Ficus carica	fruit							1
Olea europaea	fruit							6+**1**
Phoenix dactylifera	seed							0.1 +**0.5**
	pedicel							1
	leaf							X
Ziziphus spina-christi	fruit							2+**0.5**
Vitis vinifera	seed							13+**0.5**
	pedicel							1

habitats, including even some water plants, along with field-weed species. On the other hand, charring may have reduced the subfossil record as it is destructive in character. Nevertheless, the analysis of a sufficient number of ash samples may reveal information about threshing remains used as fodder and about small field weeds grazed after harvesting. A study of land use during the 2nd Intermediate Period at Tell el-Maskhuta, located in Wadi Tumilat between the Nile Delta and the Sinai, surprisingly revealed that charred diaspores of both riparian and water plants, the latter represented by *Najas*, *Potamogeton* and *Myriophyllum*, were present both in middens and ash layers (Crawford, 2003). Small dung pellets of goat and sheep as well as large herbivore dung has been used as a source of fuel. With reference to Zahran and Willis (1992), Crawford suggests that dried Pondweed (*Potamogeton*) plants were used as a fodder. In a similar way, seeds of Naiad (*Najas*) and fruits of Water-milfoil (*Myriophyllum*) may have become part of the ash deposits.

Fig. 8. Diaspores of water plants found in a rubbish layer at Medinet Watfa. Left: Naiad (*Najas* sp.; length: 2.8 mm); right: Perfoliate pondweed (*Potamogeton perfoliatus*; length: 2.5 mm) (photo R.T.J. Cappers).

Although mud bricks have been dealt with in previous archaeobotanical studies of Egyptian material, they have only been used on a minor scale to reconstruct agricultural practices. The archaeobotanical analysis of building materials from Egyptian sites dates back to the late nineteenth century. Unger (1862; 1866; 1867) studied a single mud brick from el-Kab, one and a half mud bricks from the Dashur pyramid and fragments of two mud bricks from Tell el-Maskuutah. The plant remains comprise field crops, including cereals, pulses and flax, weed plants, marsh plants and some trees. Unger correctly explains the presence of these plants by assuming that they represent an admixture of threshing remains and plant remains present in the mud, as for example Sea Rush (*Juncus maritimus*). Unger also concluded that the absence of culm fragments with root remains indicates that the cereals were harvested by reaping and not by uprooting. But Unger links the interpretation of the weed plants only to the problem of tracing the origin of the recovered crop plants.

Van der Veen (1999) discusses the economic value of threshing remains, in which she distinguishes three different types of use which can be linked to scales of production and organization of the agricultural system. Dealing with the large quantities of chaff and straw in Mons Claudianus, a Roman quarry settlement in the Eastern Desert of Egypt, she demonstrates that threshing remains were imported on a large scale and were used as temper, fodder and fuel. Thanheiser and König (in press) analysed complete mud bricks as well as mud from crumbled bricks from Kellis in the Dakhleh Oasis. In some domestic areas both types of context proved to be rich in cereal straw and chaff, but also contained household rubbish such as charcoal remains, bone fragments and crushed pottery. Mud bricks and mud soil from another area, on the other hand, were rather poor in botanical remains, possibly

Fig. 9. Pondweed (*Potamogeton* sp.) growing in an irrigation channel (Fayum, November 2003) (photo R.T.J. Cappers).

as a result of ant activity. Recently, Newton (2004) studied in situ contents of *pisé* linings of the late Predynastic site of Adaïma in Upper Egypt in order to identify possible contamination of pit fillings, to improve our knowledge of building technology and to infer agricultural practices. The *pisé* samples contained desiccated remains of cereals and wild plants, partly also preserved by charring, and included a fair number of remains from wetland species. In addition to the threshing remains, dung pellets of sheep/goat and possibly also floor or street sweepings had been used as temper. Newton discusses a shift in cereal composition in the *pisé* material both through time and between sites in relation to the availability and preference of particular crops. The study is not however aimed at reconstructing particular field-weed vegetations, which would be difficult indeed as the mixture of threshing remains and dung hampers the linkage of particular crop plants with specific assemblages of weed plants.

When mud is used as the principal building material, it will also be the main constituent of cultural layers from the domestic area. Horne (1994), for example, calculated that the levelling of all mud brick structures of the Baghestan village in North-Eastern Iran, would result in a deposit about 0.4 m deep. The straw fraction would account for up to one fifth of the volume in crumbled mud bricks and for about one third up to one half up in the case of mud-straw plaster, the proportion being larger when the softer barley straw is used instead of the more resistant wheat straw. A random sampling of such disintegrated deposits may produce a representative list of crop plants and field weeds, but such a record will be of limited use when it comes to reconstructing weed vegetations and specific agricultural practices. The search for intact building materials, preferably those tempered only with threshing remains, will be much more informative.

When rubbish is burnt close to mud brick walls, it is possible that also the plaster becomes burnt. The burning of rubbish may be practised outside the building, maybe in a particular area enclosed by a low wall, or inside an abandoned house. In this way, some organic temper will be preserved by charring, whereas that of most mud bricks and mortar will be preserved in a desiccated form. If such a house is replastered in a later stage, the burnt plaster may become part of cultural layers outside the building. Alternatively, the house may be pulled down and levelled, or be allowed to collapse, resulting in a mixture of desiccated and charred temper. In areas where charring is the only mode of preservation, it is likely that the burnt organic temper of plaster layers in particular can be retrieved and analysed.

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