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ORIGINAL ARTICLE

Informal intercropping of legumes with cereals? A re-assessment of clover abundance in ancient Egyptian cereal processing by-product assemblages: archaeobotanical investigations at Khentkawes town, Giza (2300–2100 BC)

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Abstract The possibility that legumes were specifically cultivated as a separate fodder crop in ancient Egypt has been inferred, usually on the basis of abundance of both legume seeds and or dung in charred macro-botanical samples, combined with a lack of wood charcoal; the implication being that a scarcity of wood led to the use of dung as fuel, and that the legumes in the assemblage derive from livestock which had been fed with cultivated fodder. The archaeobotanical remains from excavations at the Old Kingdom 'Khentkawes town' (2300–2100 BC) on the Giza plateau in Egypt contained an abundance of legumes, but also much wood charcoal, and preservation of many fragile and 'green' seeds and plant parts. This assemblage has led to questioning of the theory of specific fodder cultivation in Pharaonic Egypt. In this article, alternative interpretations of legume-rich assemblages of cereal processing by-products are investigated. Intercropping of legumes with cereals is one of the most widespread and effective methods of improving crop value and security, and fodder/forage quality. Analysis of this assemblage has led to a hypothesis that *Trifolium* sp. and other 'weeds' may well have been viewed as integral plants within ancient Egyptian cereal fields, due to an awareness of the benefits of intercropping legumes with cereals—as opposed to having been specifically cultivated as a monocrop.

Keywords Intercropping · Clover · Legumes · Egypt · Fodder · Agriculture

Introduction

The issue of detecting fodder cultivation is closely connected with discussions regarding the use of dung as fuel in the ancient world. Research undertaken in the 1980s at the Old Kingdom site of Kom el-Hisn in the Egyptian Nile Delta (Fig. 1) drew on ethnographic work being done at the time in Iran, which looked at the use of animal dung as fuel in domestic fires (Miller 1984; Moens and Wetterstrom 1988).

At Kom el-Hisn small legumes (cf. Trifolieae tribe) comprised 21 % of the total seed count in the entirely charred assemblage; this specification is based on the unrevised data (Wetterstrom personal communication 2015). The abundance of legumes and an absence of wood charcoal led Moens and Wetterstrom to the conclusion that dung had been the primary fuel. The site is thought to have been a major cattle-rearing centre during the 5th Dynasty, and the faunal analyses corroborate that theory (Moens and Wetterstrom 1988). Their conclusion was that the abundance of taxa recognized as good fodder plants such as legumes in samples from Kom el-Hisn might be indicative of their specific cultivation for use as fodder, which then appears in the charred plant assemblage as a result of the use of dung as fuel (Moens and Wetterstrom 1988; Wetterstrom 2013 personal communication). Crawford's work at Tell el-Maskhuta in the Tumilat (2003) showed that *Trifolium*-type clover represented 19 % of the overall total

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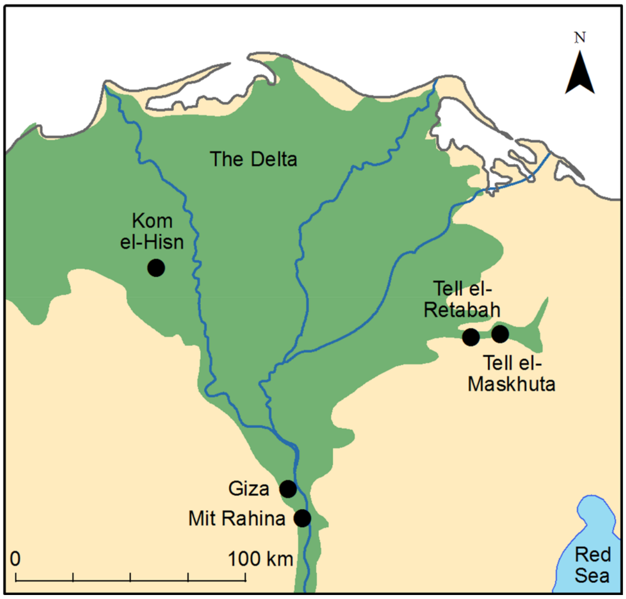

Fig. 1 Map of Lower Egypt. Map by R. Miracle 2015

seed count (based on data presented in Crawford 2003), and she identified it as a possible economic crop alongside emmer wheat and barley. The results show that wood charcoal was only sparsely present, whilst intact and fragmented dung pellets were present in most samples. Her interpretation of the assemblage was based on an understanding that the majority of the plants present represented the diet of local animal herds, consisting of crop processing by-products (cereal chaff and weeds of cultivation) and local grazing along the edges of waterways, and she stated that that 'Clover was most likely *provided as a supplement* to natural forage either as a crop or a wild resource' (Crawford 2003, p. 116, my emphasis).

Caution regarding this interpretation of legume abundance being an indication of fodder cultivation has been noted by Butler (1995), Charles (1998) and Murray (2009). Butler (1995) highlighted several cases in which the abundance of legumes in an assemblage could not readily be interpreted as evidence of the cultivation or utilization of legumes as fodder, suggesting that they were introduced as either human food, or fuel. She pointed out that monocropping of legumes for fodder was relatively rare until recently, and that intercropping with cereals is far more common (Butler 1995, p. 111). Charles (1998) lists the criteria for the identification of dung derived plant materials, including the presence of seeds of plants potentially eaten by livestock, but he also notes that it is a 'problematic assumption that species eaten by livestock have always been animal fodder' (Charles 1998, p. 113). Murray (2009) highlighted the fact that although the cultivation of legumes as fodder is attested for the Greco-Roman periods, the antiquity of the practice in Egypt is not yet understood. She notes that an abundance of legumes does not necessarily indicate their use as fodder, but that it is accepted that a correlation between the presence of dung and legumes can provide indications of patterns of animal husbandry and foddering practices at sites. Murray points out that legumes are also common weeds of cultivation, and discusses the use of cereal processing residues as fodder, highlighting the alternative explanation for the entry of legumes into fodder/dung-fuel assemblages of crop processing by-products (Murray 2009, p. 253).

This debate essentially revolves around determining the origin (crop weed v. cultivated) of specific plants within any charred assemblage. Discussions are naturally complex due to the difficulties of determining the field-to-fire pathway of plant materials, which is always complicated if dung was a fuel. The remains may either represent cereal processing by-products (mixtures of chaff and weeds) used directly as fuel, by-products fed as fodder which were preserved via the use of dung fuel, by-products used as dungcake temper, specific fodder plants preserved via the use of dung as fuel, wild plants gathered as fodder, plants consumed by grazing livestock, or any combination of the above (Cappers 2006; Charles 1998; Fuller and Stevens 2009; Murray 2009; Thanheiser personal communication 2015; Valamoti and Charles 2005; van der Veen 1999, 2007).

A great deal of work has been done on the study of dung in archaeobotanical assemblages; two volumes of *Environmental Archaeology* have been dedicated to the topic (1998 and 2013) (see also Bottema 1984; Valamoti and Charles 2005). Studies have looked at the recognition of dung-derived material in samples, the detection of dung in samples using various chemical analyses, and the survival of different plant parts and taxa in the digestive processes of different animals (Anderson and Ertung-Yaras 1998; Bottema 1984; Charles 1998; Gardener et al. 1993; Lancelotti and Madella 2012; Russi et al. 1992; Shahack-Gross 2011; Valamoti 2013; Wallace and Charles 2013). Following the work done by Moens and Wetterstrom (1988) and Crawford (2003), only Murray (2009) specifically touched upon these issues regarding dung, fodder and fuel with respect to ancient Egyptian materials of the traditional Pharaonic periods (Old—New Kingdoms). Later Greek and Roman materials have been studied by Cappers (2006) and van der Veen (1999), but by this point in Egyptian history agriculture had undergone a revolution due to changes in irrigation practices and the replacement of emmer with free-threshing wheat, dramatically changing the ecology of crops and cereal processing technology.

Whilst the use of both dung and chaff as fuels in ancient Egypt is unequivocal (Cappers 2006; Moens and Wetterstrom 1988; Murray 2009; van der Veen 1999, 2007), the origin of legumes in assemblages of Pharaonic Egyptian charred plant materials has never been rigorously questioned. The issue is of major significance, as it has implications for understanding agricultural patterns and practices, aspects of animal husbandry and aspects of routine activities within settlements.

Introduction to Khentkawes town

Since 2005, as a part of their ongoing work examining settlement activities on the Giza plateau, Ancient Egypt Research Associates (AERA) have been conducting excavations at the 'Khentkawes town' (see www.aeraweb.org for publications, field reports etc.). This settlement was a pyramid/priests' town constructed as part of the Khentkawes I monument complex on the Giza plateau, dating to around 2300 BC. The large mastaba-like monument and the associated town complex lie to the east of the pyramid of Menkaure (the 'third' (smallest) pyramid on the Giza plateau) (Lehner 2011, p. 15; Lehner et al. 2011). In 1932–1933 Egyptian archaeologist Selim Hassan discovered a small complex of large houses formally laid out along the causeway of the Khentkawes I monument (Hassan 1943). Hassan mapped the architecture, but published no material culture and left his excavations open, thus some 73 years later there was only a trace of the standing remains preserved and very little was really known about the town. The goal of AERA's work has been to determine how much material culture was still preserved and to conduct detailed stratigraphic analyses of the area, allowing us to study the life of the settlement and the relationships between this town and the adjacent Menkaure valley temple town (Lehner et al. 2011). Systematic mapping and clearance, combined with targeted excavations conducted over five seasons has enabled AERA to produce detailed new plans of the town, a site-wide analysis of the stratigraphy of the area and material culture studies.

During clearance work in 2009 one house was selected for more complete excavation (Lehner 2011; Yeomans and Mahmoud 2011). Archaeobotanical samples taken from within this house (Fig. 2) have proven to be extraordinary in many ways, and provide an exceptionally valuable insight into household activities, not least because unlike the majority of material, such as ceramics, Hassan left floors and charred deposits in situ and they remained intact. One advantage of this site is that it lies well above the floodplain and water-table, and as a result the charred plant macrofossils are much better preserved than those found at many sites in Egypt affected by fluctuating water-table levels, saline conditions and modern root disturbance. The lack of desiccated remains is a little unusual for such a site in Egypt, but the fact that the excavated area had been left exposed for so long could be responsible for that factor, as could the regular winter rainfall in the area.

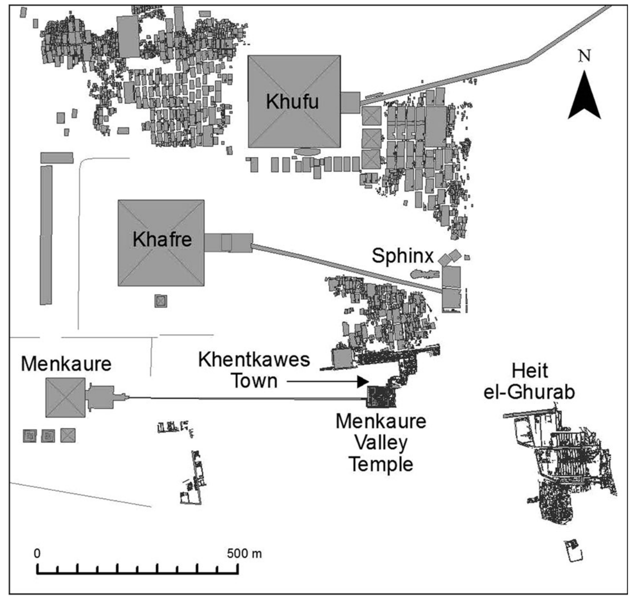

Fig. 2 Map of the Giza Plateau. Map by R. Miracle 2015

An initial assessment of the samples from House E (Fig. 3) was conducted in 2010 by Mary Anne Murray and Rebab el-Ghandy (a student in the AERA/ARCE (American Research Center in Egypt) field-school program for archaeologists in the Egyptian Ministry of Antiquities (MoA)) (Murray and Ghandy in press). This work was followed up with an intense period of study in (2013) (Malleson in preparation). The detailed results of the analyses are presented in full in those reports. The assemblage consists almost entirely of the residues of crop

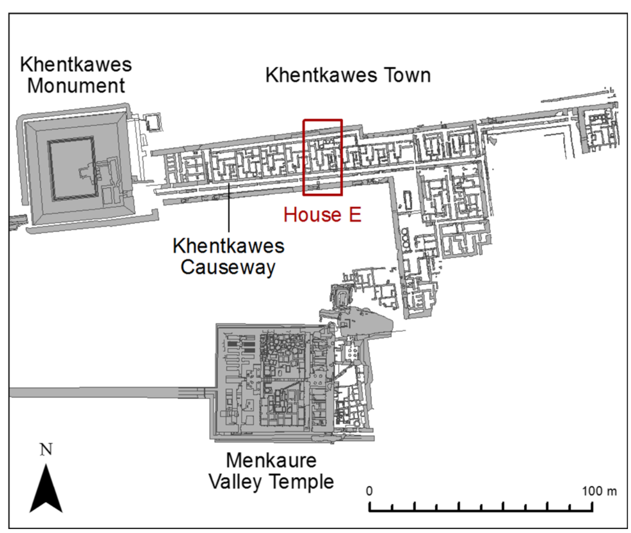

Fig. 3 Plan of Khentkawes town showing location of House E. Map by R. Miracle 2015

processing used as fuel in domestic heating installations, supplementing wood (or charcoal), the primary fuel at the site, which has not yet undergone analysis.

Materials and methods

During the 2009 excavations, samples from 41 discrete archaeological features were collected from every deposit (walls, floors, layers, hearth/fireplaces, foundations, dumps, collapse and some plaster) using Museum of London Archaeology (MoLA) single context excavation and recording methodologies and processed by flotation on site, using 250 µm mesh to collect the charred materials—no desiccated materials were preserved at this site. Seven samples from features described as being 'ash-rich' by the excavators were analyzed by el-Ghandy and Murray in 2010. They ascertained that the material consisted of the charred remains of cereal crop processing by-products, with an average of 925 items per litre (IPL), and 37 taxa present (Murray and el-Ghandy in press).

During the 2013 analysis (January 19th–May 8th), in the AERA/MoA workroom on the Giza plateau), 48 samples from 38 features were analyzed. Sample sizes ranged from 1 to 6 litres and a total of 57,041 individual items were identified (Table 1, ESM). One sample from each feature was examined, the size of some necessitating sub-sampling, with the exception of a dense layer of ash laid down as a foundation beneath a set of four grain silos (Feature [31130]), from which 35 samples had been extracted. Eleven of these were arbitrarily selected for analysis and were sub-sampled; 25 % of each was analyzed. For all sub-samples, the sample volume recorded equals the appropriate percentage of the original sample volume. The flots (the dried, floated materials) were measured for volume and dry-sieved through a stack of brass Endecott sieves (1 mm, 500 and 250 µm) to facilitate sorting. The flots were examined under a Nikon SMZ zoom stereo microscope using 6–30× magnification. All individual identifiable items were collected and counted—partial seeds or grains were recorded as such. Charcoal and culm fragments (straw) collected from the 1 mm sieve were separated and measured by volume separately; fragments under 1 mm were measured together. All specimens were identified on the basis of morphology and comparison with reference illustrations (http://www.plantatlas.eu/ *Digital atlas of economic plants in archaeology* and the *Digital atlas of economic plants*; Cappers et al. 2004; Nesbitt 2006; Smith 2003) as well as the *Flora of Egypt* (Boulos 1999–2005). As it is not possible to remove specimens from the AERA field laboratory, which is an Egyptian Ministry of Antiquities workroom, a photographic record was made of all uncertain identifications and examples of most taxa. This record was used to assist with the identification of uncertain specimens by comparison with the botanical reference collection held in the Institut Francais d'Archaeologie Orientale, Cairo, courtesy of C. Newton and N. Mournier. Nomenclature of wild plants follows Boulos (1999–2005).

Results

The House E assemblage contained a mix of taxa and plant parts which are commonly found in ancient Egyptian settlements—emmer wheat and hulled barley chaff, wild grasses such as darnel and canary grass, 'wild' legumes (Trifolieae and Vicieae tribes) and other weeds of cultivation as well as some fruits, such as fig (Cappers et al. 2004; Cappers 2006; Clapham and Stevens 2012; Crawford 2003; Fahmy 1997; Malleson 2011, 2012, 2013; Moens and Wetterstrom 1988; Murray 2009; Newton 2007; Stevens and Clapham 2014; Thanheiser 1992, 2004; van der Veen 1999).

The average number of identified charred seeds and plant parts is 389 per litre of soil sampled, with a maximum of 4375 IPL in one sample. The taxa count is c. 54. The condition of the material was exceptional. A large number of fragile items such as flowers and fine chaff were found in many samples, as well as many examples of immature seeds (Malleson in preparation). To illustrate the richness of these remains, as a comparison, sites at which directly comparable methods of quantification of primarily charred assemblages are used, and from which data are published or are available to the author: Kom el-Hisn (Old Kingdom) samples have an average of 22 IPL (Wetterstrom personal communication 2013), Abydos (1st Intermediate Period) has 144.4 IPL and just under 5 taxa (Murray 2009, p. 252). Mit Rahina Middle Kingdom samples had 46.4 IPL and 22 taxa, New Kingdom samples had 91.5 IPL and 20 taxa (Murray 2009, p. 252). Tell el-Retaba (2nd–3rd Intermediate periods) has an average of 194 IPL and around 50 taxa (Malleson 2011, 2012, 2013).

The assemblage in House E contained the remains from all stages of cereal processing, including heavy, light, small and large seeds/chaff and other plant elements, of a crop harvested low on the culm, as both low-growing weeds and cereal culm bases were present.

Legumes

The identification of charred seeds of small legumes in archaeobotanical samples is notoriously difficult, and it is rarely possible to establish beyond a general classification of 'small legume', or to tribe, Vicieae or Trifolieae (Butler 1996). Under certain circumstances the seed morphology is sufficiently well-preserved to identify the genus, for

Table 1 Taxa present in the House E assemblage identified to date

Item	Plant element	Total items
Cereals and wild grasses		
Hordeum vulgare L.	Grain	1,119
	Terminal grain	45
	Rachis internodes	3,741
	Proximal rachis intern.	362
Triticum turgidum (L.) ssp. *dicoccum* (Schrank) Thell	Grain	536
	Spikelet	3
	Spikelet forks	1,913
	Terminal spikelet forks	83
	Proximal spikelet forks	197
	Glume base	1,600
	Rachis internodes	142
cf. *Triticum monococcum*	Grain	5
Lolium temulentum L.	Grain	5,672
	Immature grain	199
	Rachilla	536
	Glume	236
	Rachilla & glume	13
	Rachis internode	312
Phalaris paradoxa L.	Grain	3,136
	Spikelet	23
	Glume base	276
	Glume fragments	716
	Lemma	30
Bromus sp.	Grain	660
cf. *Desmostachya bipinnata* (L.) Stapf *in* Dyer	Grain	85
cf. *Imperata cylindrica* (L.) *Raeusch.*	Pedicel	7
Avena cf. *fatua* L./*sterilis* L.	Grain	16
	Pedicel	176
cf. *Sorghum halepense* (L.) Pers/ *arundinaceum* (Desv.) Stapf	Grain	2,351
Cereal indet.	Grain	357
	Culm base	128
	Rachis internode	158
	Embryo	301
Poaceae indet.	Grain	246
	Grain - type B	22
	Rachis internode	39
	Spikelet forks	7
	Glume base	4
	Culm nodes	1,537
Reeds and sedges		
cf. *Juncus* sp.	Seed	139
Schoenoplectus sp.	Fruit	3
Schoenoplectus cf. *praelongatus* (Poir.)	Fruit	4
Eleocharis palustris (L.) Roem. & Schult.	Fruit	1,663
	Immature fruit	21
	Seed	772
Fimbristylis bisumbellata (Forssk.)	Fruit	7
cf. *Cyperus alopecuroides* Rottb.	Fruit	224
cf. Cyperus articulatus L.	Fruit	5
cf. *Cyperus rotundus* L.	Tuber	1
cf. *Cyperus esculentus* L.	Tuber	8
Cyperaceae	Fruit	23
	Culm base	11
	Culm fragment	79
Legumes		
Medicago polymorpha L.	Seed	603
	Seed with pod fragment	359
	Pod fragment	138
	Intact fruit	59
Melilotus sp.	Seed	713
Trifolium alexandrinum L.	Calyx with seed	203
	Immature calyx with seed	551
	Calyx	108
Trifolium sp. (cf. *alexand.*)	Seed	16,682
Scorpiurus muricatus L.	Seed	392
	Immature seed	93
	Fruit fragment	72
	Immature fruit fragment	29
	Seed with pod fragment	25
Vicia ervilia (L.) Willd.	Seed	40
Vicia cf. *faba*	Seed	1
Lathyrus cf. *hirsutus* L.	Seed	9
Lathyrus sp.	Seed	14
Lens culinaris Medic	Seed	17
Vicieae tribe	Seed	765
Fabaceae - large	Seed	1
Fabaceae - small	Seed	70
Fabaceae	Pod fragment	29
Fruits, nuts, oils, woody taxa		
Ficus carica L.	Fruit	14
cf. *Ficus sycomorus* L.	Fruit	9
Phoenix dactylifera L.	Fibres	1
	Perianth	1
Linum usitatissimum L.	Seed	23
	Capsule fragment	1
Acacia nilotica (L.) Delile	Seed	15
	Pod fragment	24
	Inflorescence	2
Tamarix aphylla (L.) Karst.	Leaf	6
Tamarix nilotica (Ehrenb.)	Leaflet	4
	Twig	36
Other wild taxa		
Polygonum sp.	Fruit	4
	Fruit with tepals	51
	Tepals	14
Rumex dentatus L.	Fruit	1,548
	Calyx with tepals/perianth	63
	Calyx	583
	Tepals/perianth	485
	Intact diaspore	154
	Twigs	23
Glinus lotoides L.	Seed	7
Brassicaceae	Pedicel	110
Portulaca oleracea L.	Seed	25
Silene sp.	Seed	5
Chenopodium sp.	Seed	7
Beta vulgaris L.	Nutlet	11
Chenopodiaceae	Seed	9
Rosaceae	Seed	7
cf. *Rubus* sp.-type	Seed	3
Malva parviflora L.	Mericarp	6
Malvaceae	Seed	13
Trachyspermum ammi	Fruit	24
Echium rauwolfii Delile	Mericarp	1
Boraginaceae	Mericarp	2
Primulaceae cf. *Anagallis* sp.	Seed	2
cf. *Ziziphora* sp.	Seed	1
Anthemis cf. *pseudocotula* Boiss	Fruit	55
	Capitulum	28
Centaurea sp.	Fruit	1
cf. *Picris* sp.	Fruit	2
Crepis sp.	Fruit	4
Asteraceae	Fruit	21
Apiaceae	Seed	2
Scrophulariaceae	Seed	1
Indeterminate items		
Fruit / nut fragment		1
Root / tuber		12
Seed indet.		91
Seed head indet.		10
Possible bread fragment		12
Indet. 'twigs'		209
Flowers		2
Indet. capitulum base		10
Dung fragments		268
Rhizome		226
Vesicular fragments		1,870

example as *Trifolium* sp. or *Medicago* sp. (Butler 1996). The small legume (Trifolieae tribe) seeds in the House E samples were exceptionally well preserved, with very little distortion. There were many specimens of *Medicago* sp. and *Scorpiurus* sp. pods which enabled a refinement of identification to species—*Medicago polymorpha* and *Scorpiurus muricatus* There were specimens of *Trifolium* sp. which retained sufficient morphological characteristics making it possible to identify *T. alexandrinum* based on comparison with modern reference specimens, illustrations in the *Flora of Egypt* (Boulos 1999, pl. 49, p. 11) and images in the different series of the *Digital atlas* http://www.plantatlas.eu/ (Fig. 4).

Only *T. alexandrinum* and *T. resupinatum* are attested in archaeological samples from Egypt (de Vartavan et al. 2010; Fahmy 1997). This identification as *T. alexandrinum* is based upon the distinctive toothed calyx with prominent veins, neither of which is found in *T. resupinatum*. *T. alexandrinum* is usually regarded as a wild field weed which was later cultivated as a fodder crop, but recent DNA work suggests that it is in fact a Near Eastern domesticate, thought to have been introduced into Egypt alongside wheat and barley (Badr et al. 2008). The difficulty of determining the status of *T. alexandrinum* serves to highlight the complexity of the question of what can be considered wild or a weed, and what is domesticated or cultivated. These issues underpin notions of what is considered to be a crop, which was perhaps less clear-cut in the past.

During analysis it became immediately apparent that legumes were extraordinarily abundant (Fig. 5). 30 % of the overall item count consisted of the seeds of *Trifolium* sp. (Fig. 6). *Trifolium* sp. was present in 96 % of the samples, whilst Viciae tribe, *Scorpiurus muricatus*, *Medicago polymorpha* and *Melilotus* sp. were less abundant, but ubiquitous (Fig. 7). The density of *Trifolium* sp. (120 IPL) is more than double that for any other taxon. Clovers overwhelm the item counts here even more than at Kom el-Hisn (21 %) and Tell el-Maskhuta (19 %)—but many aspects of the assemblage rule out the possibility that this abundance is a result of the consumption of cultivated clovers by local livestock and subsequent use of dung fuel in House E. Other interpretations need investigating.

Field to fire pathway

In other similar charred assemblages, the dominance of *Trifolium* sp./small legumes and a lack of wood charcoal led to an inference that the primary fuel was dung, and conclusions that the seeds most likely derived from cultivated fodder crops (Crawford 2003; Moens and Wetterstrom 1988; see discussion in Murray 2009, p. 253). However, the lack of dung, the abundance of wood charcoal and the exceptional level of preservation of so many of the specimens—indicating that they are highly unlikely to have ever passed through the gut of any animal—instantly

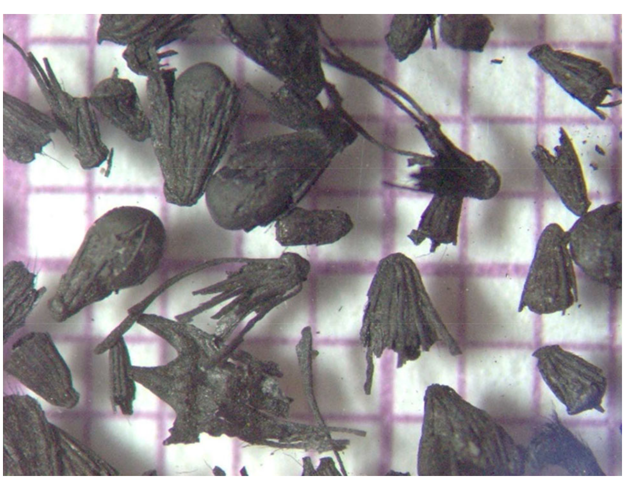

Fig. 4 Charred *Trifolium alexandrinum* specimens with calyx. Photograph by Malleson (2013)

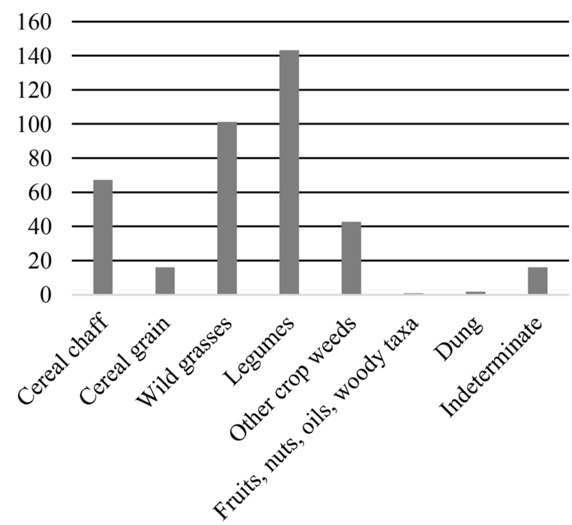

Fig. 5 Density of items per litre of major taxa groups in the House E assemblage

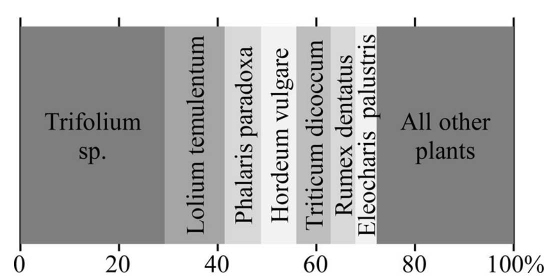

Fig. 6 Most common taxa, shown as percentages of the House E assemblage

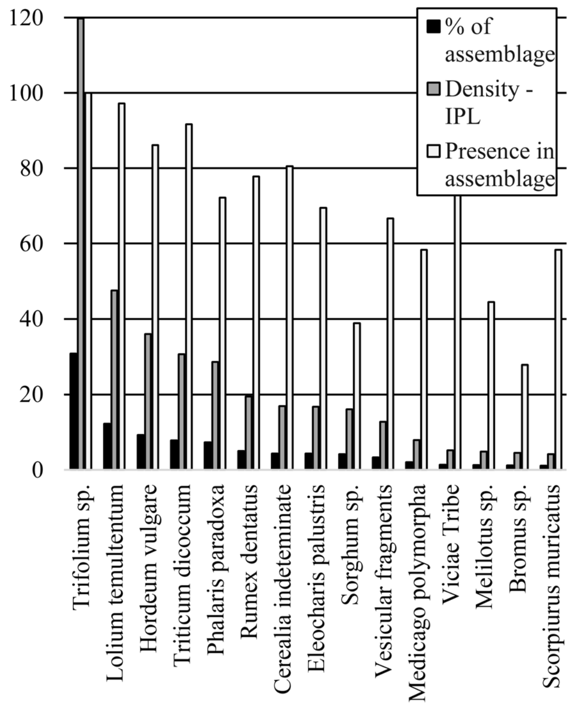

Fig. 7 % of assemblage of taxa, density (IPL) and ubiquity (% of features containing taxa)

led to questioning the source of these remains in the House E assemblage.

In order to determine the origin of the legumes as either cultivated or crop 'weed', the route from field to fire needs to be considered. Were the plants used directly as tinder, or are they present as a result of the use of dung as a fuel?

The House E samples derived from clearly definable context types; deposits of ash in hearths and associated dumps, and the 'background noise' of ash trampled into floors within the house or wind-blown into construction materials at their point of origin. These deposits all contained a mix of cereal chaff, as well as the grains, fruits, seed heads and seeds of a broad range of crop weeds and other wild plants. Because this mixture of materials was consistently found in all features it must represent the remains of daily routine activities, (Fuller and Stevens 2009; Fuller et al. 2014; van der Veen 2007).

It was clearly apparent throughout the deposits that wood (or charcoal) was the primary fuel material; present in 100 % of the samples, representing up to almost 100 % of charred materials in some flots with an average of nearly 68.5 % (10 ml per litre of sample). The charcoal fragments ranged in size from c. 1 mm^3 to c. 2 cm^3.

Dung comprised only a very low percentage of the overall assemblage, present in just 25 % of the samples with an average density of 1.8 IPL. The majority of the small quantities of dung in the samples were identifiable as fragments of sheep/goat pellets, and contained no identifiable seeds or grains, appearing to consist almost entirely of pulverized grass culms. The occasional fragments of looser-looking dung material may be cattle dung; these fragments contained very occasional heavily damaged Poaceae-type grains.

The absence of dung fragments does not automatically rule out the possibility that this material is dung-derived. The absence of physical fragments of dung cannot be assumed to be evidence for the absence of dung in an assemblage, as most livestock dung will disintegrate and often turns to a dusty residue. Whilst the presence of fragments of dung in charred samples can be taken as unequivocal proof for the use of dung as a fuel, there are various other techniques for detecting the presence of dung in archaeological samples in the absence of this solid evidence, involving the identification of spherulites or phytoliths (Lancelotti and Madella 2012). However, many of these techniques (summarized in Shahack-Gross 2011) rely not only on excellent preservation of organic compounds, but also on complex laboratory-based chemical analyses. To date, none of these techniques have been carried out on ancient Egyptian samples. In order to really eliminate dung as the source of the Trifolieae in the absence of any chemical analyses, other aspects of the assemblage need investigating. One factor which almost certainly rules out the likelihood of this material deriving from plants consumed as fodder is the exceptional preservation of fragile and 'soft' plant elements throughout the samples.

Preservation of material

It was noted during the sample sorting process that there was a significant quantity of very fragile and 'soft' or 'green' plant elements preserved in the plant remains from House E. This suggests that the burned remains had undergone little or no post-charring or post-deposition disturbance, and more significantly for this debate—that it is exceptionally unlikely that this material ever passed through the digestive system of any animals. Valamoti (2013) has established that it is possible to identify whether or not materials, specifically glume bases, had been digested prior to deposition, by examining features revealed in SEM images. Furthermore, there have been many ethnographic and experimental studies of the preservation or lack thereof of various plant taxa and chaff elements that have been digested by sheep, goats or cattle (Gardener et al. 1993; Russi et al. 1992; Valamoti and Charles 2005; Valamoti 2013). Whilst these studies have yielded varying results, what is obvious is that plant elements which do survive digestion are considerably 'worse for wear' and often tricky to identify due to the damaging actions of mastication and digestive enzymes.

The House E specimens generally displayed low levels of distortion, and not only fragments but also many intact legume pods as well as *Trifolium alexandrinum* calyx and in some cases even flowers, were found to be intact in up to 32 % of the samples (Figs. 8, 9). Additionally, many other non-legume plant elements were also exceptionally well preserved, including almost perfectly preserved emmer glumes, intact/joined rachis nodes of barley which retained their fragile glumes and 'hairs', intact spikelets of *Phalaris paradoxa* with glumes and what appear to be immature ('green') fruits of *Eleocharis palustris* with their styles and sometimes even bristles, intact diaspores of *Rumex dentatus* with calyx and tepals/perianth and some exceptionally fragile items of wild grass chaff (Figs. 8, 9).

It should be noted here that the majority of the most fragile items preserved did derive from the large foundation deposit of 'insecticidal ash' beneath the granaries (Feature [31130]). Ash is known to be an effective insecticide, scouring the carapace of grain weevils leading to their dehydration and death, thus significantly reducing infestation, and it seems there was an awareness of this in ancient Egypt as there are other examples of the use of ash as an insecticide. The assemblage in this feature was almost identical to those from elsewhere in the house, containing charcoal, chaff and weeds, and was mixed with general domestic waste such as broken mud sealings, ceramics and lithics (Malleson in preparation). This granary foundation ash did, however, also contain a large volume of intact cereal culm fragments which occurred only very sparsely elsewhere in the house. It seems that domestic ash was mixed with a large and specifically burned deposit of cereal crop processing by-products, which may be the source of the majority of the most remarkably well-preserved items. The conditions under which this additional ash was produced must have been low in oxygen and it must have charred slowly to result in this level of preservation (Boardman and Jones 1990). However, it is not the case that fragile items occurred only

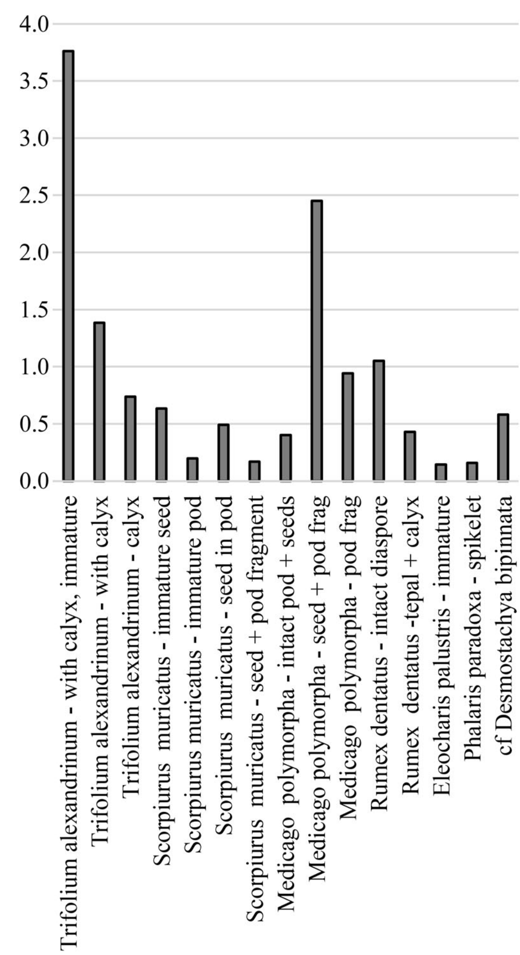

Fig. 8 Density (IPL) of fragile, intact and immature specimens in the House E assemblage

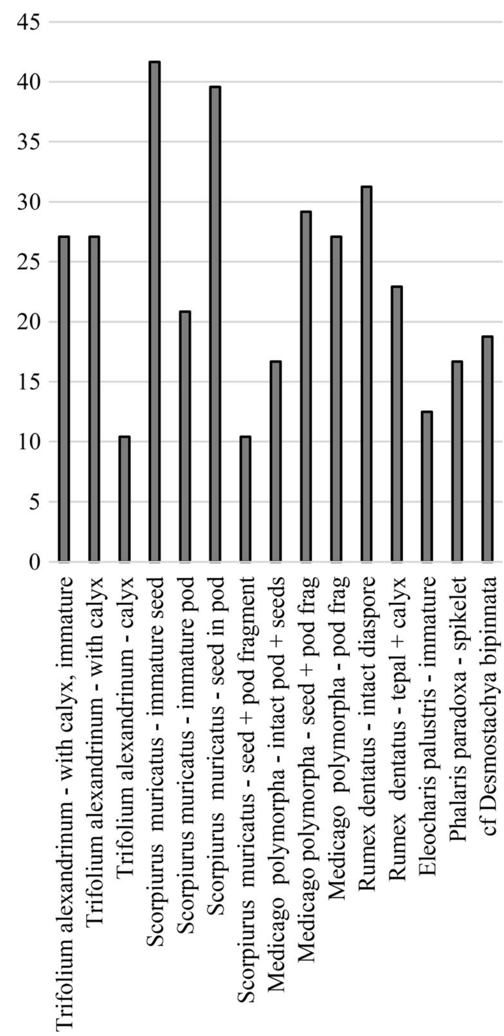

Fig. 9 Ubiquity (% of samples containing taxa) of fragile, intact and immature specimens in the House E assemblage

in this feature; legume pod fragments, intact diaspores of *Rumex dentatus* and immature fruits and seeds did occur elsewhere.

The critical factor for this debate is the simple fact that this material is preserved. It is unthinkable that this material survived the mastication and digestion process of sheep, goats or cattle in such immaculate condition, and as such, cannot be present in the assemblage as a result of the fodder—dung pathway.

The dominance of wood (or charcoal) and lack of dung does suggest that dung was not a major fuel at the site, therefore the legumes and weeds must surely derive from the direct use of cereal processing by-products as domestic tinder.

The widespread abundance of a wide range of weeds and all elements of chaff throughout the charred deposits in the house leads to a hypothesis that, unless the inhabitants of the house were regularly deliberately choosing to burn their cultivated fodder crops, the presence of the clovers in the assemblage has to be interpreted as a result of their having been a major part of the field assemblage.

Discussion

The hypothesis presented here is that the majority of the House E assemblage is formed of cereal processing by-products produced on a routine basis throughout the year in the house, as partially threshed grains mixed with other plants such as weeds and chaff were taken from granary stores and pounded/sieved/hand-cleaned, the by-products then being used as a domestic fuel. The high density of well-preserved specimens of legumes (*Trifolium* sp.), combined with many other crop 'weeds' and plentiful wood-charcoal points to a conclusion that the clover is part of what is traditionally viewed as an assemblage of cereal processing by-products and wood (or charcoal) used directly as fuel and tinder, rather than specifically cultivated or collected fodder plants appearing in the assemblage via the fodder—dung route. The fact that the 'blurring' factor of dung is clearly not an issue in this assemblage considerably simplifies the interpretation of the field to fire pathway.

Even taking into consideration the fact that the charred assemblage cannot be 100 % representative of the field assemblage, the fact that clovers represent such a large proportion of the charred assemblage in the House E samples has to indicate that they were a very common plant. It seems entirely plausible to suggest that clovers were as ubiquitous as wild grasses in some crops, if not more so. One explanation for this abundance of legumes in cereal processing by-product assemblages is that they may have in fact been an integral part of the crop, due to an appreciation of the value they added to the harvest products.

Intercropping

Whilst non-cultivated non-cereal plants are viewed as unwanted contaminants in modern arable agriculture, in a culture where 'clean' crops are seen as being ideal, the 'weeds' in ancient Egyptian cereals were clearly viewed in a very different way. 'Weeds' are certainly detrimental to the development of young cereal plants: they lower grain yields and in un-managed fields can constitute a greater portion of the harvest than the actual cereals—a situation which is perpetuated when part of the crop is retained as seed for the following season (Murray 2000, p. 520). *Lolium* sp. is another very common and often very dominant weedy grass found in assemblages from ancient Egyptian sites, and has been cited as having possibly 'infested' cereal crops (Samuel 2000, p. 559). Indeed, it is the most ubiquitous plant found in all other samples from AERA excavations at Giza away from Khentkawes town House E (unpublished data, AERA).

Conversely, intercropping is seen as an efficient and beneficial system which involves growing two different types of plant in one field, as opposed to a maslin which involves growing two or more crops together—usually two cereals (for studies of maslins in archaeobotany, see Jones and Halstead 1995; van der Veen 1995). Intercropping cereals with legumes remains the most common and popular cropping system employed by small-holding farmers in Africa, Asia and Latin America (Edje 1990). This combination not only improves soil fertility by increasing nitrogen levels, but also decreases soil erosion and reduces damage by pests, disease and weeds. Importantly it also significantly increases the crop by-product yield and nutritional value; in the current British dairy industry, farmers are increasingly turning to legumes to boost protein in the diet of their herds (Gregson 2015, pp. 22–23). This is of particular importance to farming systems that rely heavily upon crop by-products (residues) as a vital animal food resource: cereal processing by-products are the most important ruminant feed in Asia and Africa (Reddy et al. 2003). Intercropping cereals with legumes fulfils the nutritional needs of livestock without the need for separate fodder cultivation, making it an exceptionally efficient farming system, integrating crops with livestock (Eskandari et al. 2009; Kahurananga 1991; Reddy et al. 2003; Schulthess et al. 1994, p. 169). In some instances cereals are intercropped with both legumes and grasses; experiments conducted mixing oats with *Lolium perenne* (ryegrass) and *Trifolium repens* (white clover) actually increased the yield of the subsequent crops (Hauggaard-Nielsen et al. 2012). Of most relevance to this specific question of legumes in ancient Egyptian cereal crops is a note by Kahurananga (1991) who observed that farmers in the Gojam, Ethiopia, did not weed out clover, and this apparent lack of crop husbandry was *'akin to intercropping'* (Kahurananga 1991, p. 390, my emphasis).

It seems likely that this is exactly what was being practised in ancient Egypt. Wild clovers and other 'weeds' were allowed to grow amongst the cereal crops, in recognition of the fact that they would significantly improve the quality and quantity of the valuable by-products; a practice which could perhaps be termed 'informal intercropping'.

Whilst the economic importance of cereal processing by-products has been recognized for some time (van der Veen 1999), the implications of this hypothesis regarding agricultural strategies may affect the way in which we interpret other legume-rich or weed-rich fuel assemblages from sites in Egypt and in fact from sites throughout the ancient world. At both Kom el-Hisn and Tell el-Maskhuta the dominance of *Trifolium* sp. was interpreted as being a result of specific cultivation of clover as fodder, which was combined with grazing and cereal chaff (processing by-products), resulting in a mix of these products in the dung-fuel assemblage (Crawford 2003; Moens and Wetterstrom 1988). Whilst the fact that dung was likely to have been the primary fuel at both sites—and thus the clover does probably derive from dung—the exact source of the plants (cultivated v. 'weeds') can be reconsidered in the light of this line of research. It seems entirely plausible that the clovers in dung-rich assemblages from ancient Egypt are present as a result of 'informal intercropping'; the line between 'weed' and 'crop' really not existing in the past as it does today.

The recognition that these non-cereal plants ('weeds') were allowed to grow so abundantly in ancient Egyptian cereal crops highlights the productivity of the Nile Valley and Delta, and the ease with which ancient Egyptian farmers produced sufficient grain crops. This acceptance could in fact point towards a scenario in which the crops were not viewed as monocrops of wheat and/or barley, but that fields were all accepted as mixes of cereals, wild grasses and legumes along with any other prevalent 'weeds'. The crops were valued not only for their food components, but also for the (by-) products; a heavily 'contaminated' field would yield a rich harvest of food, fodder and fuel.

Conclusions

The results from Khentkawes town indicate that a rich mass of grain, chaff and other plants from an 'informal intercrop' of cereals and legumes was used year-round as a supply of products for use as food, domestic fuel, and (when needed) as 'naturally enriched' fodder. It seems plausible that this could well have been the situation in many settlements throughout Egypt during the Pharaonic period. Ultimately it seems possible that the fields (and granaries) were actually seen as reservoirs (thanks to M. Lehner for suggesting this term) of many different products; cereal grains for human food and animal fodder, as well as chaff and weeds which could be used as either fodder or fuel—both types of product having equal value on a household level. The routine processing of the materials was perhaps seen more as a way of separating the grains from all the other (by-)products rather than being a matter of needing to 'clean' the cereals. In some instances the by-products provided legume-rich fodder for livestock, whilst elsewhere they were simply used as fuel. The modern perception of non-cereal plants being perceived as problematic weeds, causing detrimental reductions in crop yields, has to be forgotten when we analyze the contents of ancient fields, the ancient farmers perhaps engaging actively in 'informal intercropping' of cereals and fodder in an integrated farming system.

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