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INSECT IDENTIFICATION AND SIGNS OF DAMAGE ON ORGANIC MONUMENTS FROM ANCIENT EGYPT-SAQQARA

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Abstract

Organic monuments are very susceptible to insect damage. The cumulative effects of this damage can ultimately destroy the organic object. Therefore, it is important to constantly monitor collections for evidence of insect activity. This study aims to identify the insect species that attack the organic monuments in the Saqqara site and storerooms, as well as discuss the significance of insects and the changes they cause to the organic monuments. To achieve these aims, sticky traps for crawling insects were distributed in storeroom halls and the conservation lab for twelve months. The isolated insects have been identified by visual investigation, including a stereo microscope and a USB digital microscope. The identified insects include white ants (Psammotermes), spider beetles (Gibbium psylloides), silverfish (Thermobia eagyptiaca), powder post beetles (Lyctus brunneus), cigarette beetles (Lasioderma serricorne), larder beetles (Dermestes lardarius), black carpet beetles (Attagenus unicolor), and larvae of varied carpet beetles (Anthrenus verbasci The studied organic monuments showed different signs of deterioration and degradation caused by insects, such as holes, tunnels, gaps, missing parts, and accumulated dust.

Keywords*: Organic monuments; Insects; Psammotermes; Lyctus brunneus; Saqqara*

Introduction

Organic cultural heritage objects (such as wood, textiles, bones, ivory, horn, papyrus, mummies, etc.) are very susceptible to various deterioration agents like atmospheric agents, condensation or capillary humidity, temperature range, human action, and insects. All insects are members of the class Insecta, belonging to the vast phylum Arthropoda. A wide variety of insect orders like *Coleoptera*, *Isoptera*, *Zygentoma*, etc. have been reported in the degradation of organic monuments [1-3].

Insects are a more important biological deterioration agent than other agents in Saqqara; the intensity of damage is determined by the species of insects involved, the kind of material used, and the level of pollution. Deteriorating agents can modify the composition and structure of organic artefacts. The in-situ deterioration process is influenced by the vital activity of living insects. Although bio-deterioration is an essential process in the environmental cycling of matter, this may lead to the loss of valuable cultural property [4].

Insect monitoring traps for crawling insects commonly referred to as "sticky traps" have been used in this study. Sticky traps are the most common types of traps used in museums and storerooms; they are used to pinpoint infestation hot spots, identify sites where insects enter an area, and discover which insects are present and in what quantities; besides, insect traps are a continuous monitoring device, and they catch a wide variety of pest species in their mobile stages of larvae and adults [5-7].

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The purpose of this paper is to identify the insects that attack the organic monuments in the Saqqara storerooms and site, as well as examine the signs of the damage and deterioration caused by those insects. This study will help in associating the signs of deterioration with the insects that caused this damage, as well as provide conservators with information on the most common insects that attack organic monuments in Saqqara's site and storerooms, which will be helpful in remedial and preventive conservation procedures.

Materials and Methods

Sampling

Trapping is known to play an important role in the management of insect pests, particularly in museums and storerooms. In this study, sticky traps for crawling insects were located in the storerooms and conservation lab monthly for twelve months (Figure 1), and signs of deterioration on organic monuments were examined. In order to identify termites, specimens of termites were collected from the Saqqara site. Insects were isolated and identified by comparison with insects' identification guides and websites [8, 9].

Visual assessment

Visual assessment, by the critical eye of the author, was applied to determine the aspects of deterioration found on the studied organic objects. This method is very effective because the causes and signs of deterioration may be easily identifiable.

Photography

Aspects of deterioration and damage caused by insects were recorded using a high-resolution digital camera (Canon EOS 8xi).

Optical Microscopy

Stereo microscopy, using a Zeiss Stereo DV 20, equipped with an Axio Cam MRC5, was used to study the morphology of isolated insects and the features found on their exoskeleton, as well as signs of damage caused by those insects.

Digital Microscopy

For the identification of insects, the insects were carefully isolated and mounted on glass slides to be observed under reflected light using a USB Dino-Lite digital microscope. USB digital microscopy was also used for photographing and studying the characteristics of the damage caused by those insects.

The observation and description of anatomical features allowed the identification of the taxon of insects' species through comparison with the descriptions available in textbooks and databases.

Preliminary identification of the collected termites was made using the available termite keys [10-14].

Fig. 1. Steps of insect identification: (a) distribution of sticky insects' traps,
(b) Investigation of insects by USB digital microscope

Results and Discusion

Insects are identified by the various features found on their exoskeleton, and this can be relatively easy if they are adult insects, larval stages are much less well known scientifically than adults and hence are more difficult to identify [15]. In this study, ten of the insects' species were identified: nine adult insects' species and the larvae of one species. The isolated insects represent a wide variety of insect orders, including *Coleoptera*, *Isoptera*, *Zygentoma*, and *Isopoda*, that attack organic monuments, particularly textiles and wooden objects, besides horn.

White ants (*Psammotermes* (Desneux))

White ants are one of the most important insect groups that caused severe damage to cellulosic materials for both buried wooden objects and wooden elements of the modern buildings in Saqqara, as shown in Figure 2 and Table 1. Show the taxonomy, anatomical features, food sources, and signs of damage caused by termites at the Saqqara site.

Table 1. White ants (termites)

Taxa	Order	Anatomical features	Food sources	Signs of damage
White ants *Psammotermes*	*Isoptera*	They are social insects that have a caste system where particular termites perform distinct functions: workers (Fig. 2a), soldiers (Fig. 2b), and the separate reproductive (Fig. 2c): primary, secondary, and tertiary. **Shape**: soft-bodies and prone to desiccation; these are the termites that feed on wood and cause damage. **Color**: workers are creamy white in color, 3 – 6mm in length. The studied termites belong to the Family: Rhinotermitidae *Psammotermes* are subterranean, forming huge colonies which can reach over 105 individuals with the nest located in the ground (Fig. 2c) [16].	The main source of food is cellulosic materials, including wood, paper, and cloth made of cotton or other plant-based materials. Damp wood sitting in the soil is their preferred food source [17]. The main source of food for this species in Saqqara is the buried wooden objects and wooden elements of modern buildings (Fig. 2e and f).	One distinct sign is the formation of various styles of tunnels or "mud tubes" that termites build to protect themselves from desiccation (Fig. 2e and f). Termite alate "swarms" are also an indication of an infestation [18].

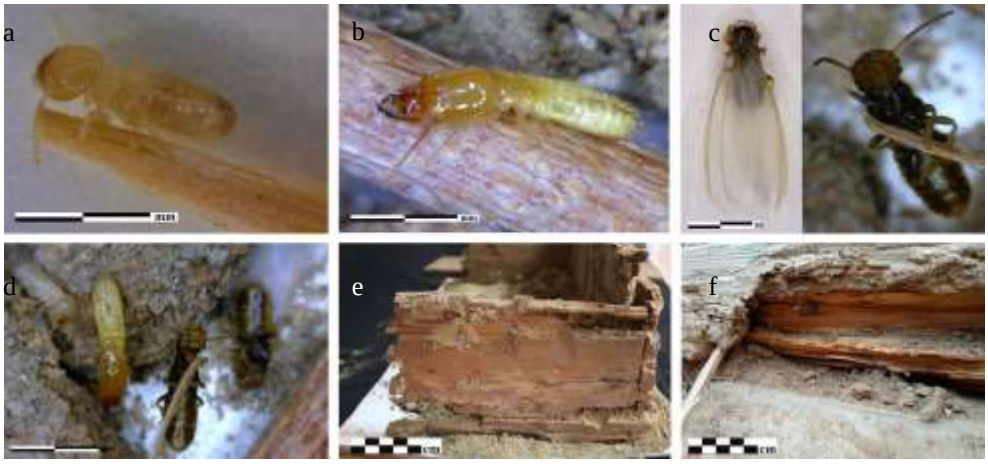

Fig. 2. White ants (Psammotermes) have a caste system where particular termites perform distinct functions: a. workers; b. Soldiers; c. Separate reproductive: tertiary; d. a colony of white ants (termites); e. a wooden corn mummy box attacked by white ants; f. Signs of damage to wooden elements in modern buildings (Saqqara)

Spider Beetles (*Gibbium psylloides* (Czenpiński))

Spider beetles are usually found inside anthropoid wooden coffins, suggesting that those species are attacking the mummies, as shown in Figure 3 and Table 2. Show the taxonomy, anatomical features, food sources, and signs of damage caused by spider beetles.

Table 2. Spider beetles

Taxa	Order	Anatomical features	Food sources	Signs of damage
Spider beetles *Gibbium psylloides*	*Coleoptera*	**Shape**: The body is formed like a droplet, is humped, has long legs that resemble spider legs, and the head is concealed behind the thorax. **Color**: Beetle antennae and legs are dark brown and coated with yellowish scales. **Antennae**: long and not clubbed. Other characteristics include polished, extremely glossy, pit- and line-free wing casings. **Length of the body:** 2.5mm approx. (Fig. 3a) [3].	The larvae have been reported to attack Egyptian mummies in addition to a variety of preserved food items, vegetables, and animal components. [3, 19] The isolated insects have been found inside an anthropoid wooden coffin, they attack mummies (Fig. 3b and c).	The holes and frass that the larva has created are indicators of infestation. Since larvae eat undercover in food, they are typically invisible. When preparing pupation sites, they create a spherical cocoon that may bore into and harm adjacent items [3].

Fig. 3. Spider beetles (Gibbium psylloides): (a) adult spider beetle (b) ***the*** inside surface of an anthropoid wooden coffin contains dead spider beetles (c) A human mummy attacked by spider beetles

Powder post beetle (*Lyctus brunneus* (Stephens))

The powder post beetles (*Lyctinae*), which are brown and just a few millimetres long, as shown in Figure 4, cause serious damage to buried wooden objects in Table 3 and Figure 4. Show the taxonomy, anatomical features, food sources, and signs of damage caused by those beetles.

Table 3. Powder post beetles

Taxa	Order	Anatomical features	Food sources	Signs of damage
Powder post beetles *Lyctus brunneus*	*Coleoptera*	**Shape**: flattened, parallel-sided, and lengthy body. **Color**: reddish-brown. **Antennae**: short and compact club. Other features include wing casings with little grooves. **Length of the body:** 3-7mm approx. [20] (Fig. 4a).	Various types of deciduous hardwoods are consumed by larvae, mainly fresh sapwood with a high starch or sugar concentration [4]. These species are noticed attacking softwood of remains of wooden coffin in Saqqara (Fig. 4b).	The exit holes (1.5–2mm in diameter) and fine, powdery frass discharged by the adult leaving the wood are indicators of infection (Fig. 4c). Larvae eat secretly in the wood, therefore they are typically invisible [3].

Fig. 4. Powder post beetle (*Lyctus brunneus)*: (a) Adult powder post beetle (b) Remains of a wooden coffin attacked by powder post beetles (c) Corridors, exit holes, and heavy damage caused by powder post beetles

Larder beetles (*Dermestes lardarius* (Linnaeus))

Larder beetles are cosmopolitan, distributed around the world in both tropical and temperate regions. Larder beetles usually attack skin and horn, as shown in Figure 5 and Table 4. Show the taxonomy, anatomical features, food sources, and signs of damage caused by larder beetles.

Table 4. Larder beetles

Taxa	Order	Anatomical features	Food sources	Signs of damage
Larder beetles *Dermestes lardarius*	*Coleoptera*	**Shape**: little oval. **Color**: black body with a pattern of grey hairs at the base of the wing casings. **Antennae**: short with a compact club. Other features include the absence of a spine at the end of each wing case (Fig. 5a; compared to Dermestes maculatus) [3, 21].	Feed on skins and feathers such as dead birds or mouse carcasses in attics, stuffed animals in museum collections and in birds' nests. Both the adult and larval stage damages materials [4, 22]. Signs of damage by larder beetle were noticed on a horn from Saqqara (Fig. 5b).	Frass and cast larval skins are indications of infection in addition to cleanly bitten holes (Fig. 5b) [3].

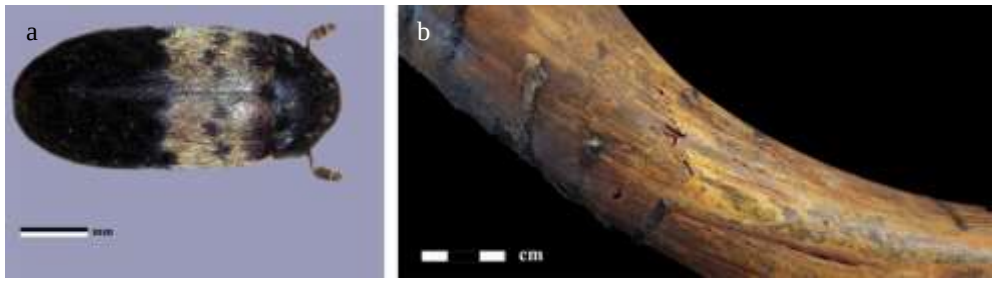

Fig. 5. Larder beetles (*Dermestes lardarius)*: (a) Adult larder beetle (b) The horn attacked by larder beetles

Carpet beetles

Carpet beetles are one of the species of *dermestes* beetles that can cause considerable damage to textile artifacts and dead beetles in storerooms, as shown in Figure 6d and g. Two species of carpet beetles were identified: the black carpet beetle (*Attagenus unicolor* (Brahm)) and larvae of the varied carpet beetle (*Anthrenus verbasci* (Linnaeus)) in Table 5 and Figure 6. Show the taxonomy, anatomical features, food sources, and signs of damage caused by those beetles.

Table 5. Carpet beetles' species

Taxa	Order	Anatomical features	Food sources	Signs of damage
Black carpet beetles *Attagenus unicolor*	*Coleoptera*	**Adult**: Adults have a colour of dark brown to black. The terminal antennal segment in males is twice as long as in females (Fig. 6a). **Larva:** brown to tan carrot-shaped with long tufts of hairs extending from the abdomen (Fig. 6b). **Length of the body**: larva can reach 13mm in length; adults 3-5mm long [23].	Black carpet beetles feed on a wide range of food materials including woollen rugs, clothing, silk, feathers, insect specimens, hair-filled mattresses and upholstery, animal mounts and carcasses. The larvae feed on the shed feathers and hair [23]. These species were noticed attacking dead beetles and linen textiles in Saqqara storerooms and site (Fig. 6d and g).	Loss and cleanly bitten holes are indications of infestation (Fig. 6d and g).
Varied carpet beetles *Anthrenus verbasci* (Larvae)		**Shape:** elongate and covered in hairs, with dense stiff bristles extending from the rear. **Length of the body**: The larvae are roughly 4–5mm in length [24, 25]	Varied carpet beetle larvae can damage fabrics, furnishings and clothing that contain cotton, wool, silk, hair, fur or feathers [24]. These species were noticed attacking dead beetles and linen textiles in Saqqara storerooms and site (Fig. 6d and g).	Cleanly bitten holes and loss are indications of infestation (Fig. 6d and g).

Fig. 6. Carpet beetles: (a) Adult black carpet beetle (b) molt of black carpet beetle larva (c) Larva of a varied carpet beetle (d) Carpet beetle larvae feeding on a dead beetle (e) and (f) carpet beetles' molts and larvae found on the dead beetle (g) Linen textiles attacked by carpet beetles

Silverfish (*Thermobia eagyptiaca* (Lucas))

Silverfish insects are signs of high humidity and can cause considerable damage to cellulosic-based manuscripts and textiles in storerooms, as shown in Figure 7 and Table 6. Show the taxonomy, anatomical features, food sources, and signs of damage caused by silverfish.

Table 6. Silverfish insects

Taxa	Order	Anatomical features	Food sources	Signs of damage
Silverfish *Thermobia eagyptiaca*	*Zygentoma*	**Shape**: The body is shaped like a carrot and has a long, three-filament tail. More or less silvery scales that are readily removed cover much of the body. six legs. **Antennae**: Long, thin, and segmented filaments make up the antennae and tail. **Length of the body**: 20 mm approx. [3] (Fig. 7a). The species was described by Hippolyte Lucas in 1840 based on specimens collected in Egypt [26].	eats a variety of starchy foods, including morning cereal, wet papers, glue, fabrics, specimen labels, and even dead insects. It feeds through surface abrasion [3]. Those insects were noticed attack papyrus and modern cellulosic paper labels in Saqqara storerooms (Fig. 7b and c).	Infestation symptoms include surface degradation, gnaw marks, and holes. Tolerating reduced humidity (Fig. 7b and c).

Fig. 7. Silverfish: (a) adult silverfish, (b) remains of papyrus attacked by silverfish, (c) modern paper label attacked by silverfish

Cigarette beetle (*Lasioderma serricorne* (Fabricius))

Cigarette beetles are frequently seen in storerooms attacking stored stuff (Fig. 8a). Those insects were noticed attacking mummified birds found in King Tutankhamen's tomb. Table 7 shows the taxonomy, anatomical features, food sources, and signs of damage caused by those beetles.

Table 7. Cigarette beetles

Taxa	Order	Anatomical features	Food sources	Signs of damage
Cigarette beetles *Lasioderma serricorne*	*Coleoptera*	**Shape:** oval in shape, with a conspicuously humped thorax, and with the head concealed underneath. **Color:** reddish-brown. **Antennae:** distinct serrations (saw-like). **Length of the body**: 2-3mm approx. (Fig. 8a) [3, 27]	The larva feeds on a wide range of materials e.g. tobacco, dried foods, preserved plants, dried animals, and taxidermy mounts [3]. The larvae may attack the stored mummified stuff in Saqqara storerooms.	The holes and frass that the adult leaves behind when it leaves the food are indicators of infestation. Since larvae eat invisibly within food, they are often invisible [3].

Other insects

Other beetles, such as woodlice (*Hemilepistus reaumuri* (Audouin)) (Fig. 8b) and dried-fruit beetles (*Carpophilus hemipterus* (Linnaeus)) (Fig. 8c), are frequently seen in storerooms as environmental indicators of damp conditions inside buildings. Table 8 shows the taxonomy, anatomical features, food sources, and signs of damage caused by those beetles.

Table 8. Other insects

Taxa	Order	Anatomical features	Food sources	Signs of damage
Woodlice *Hemilepistus reaumuri*	*Isopoda*	**Shape**: Oval and flattened body with a mottled armoured surface coated in grey. Fourteen legs. **Length of the body**: 10mm approx. [3].	Residing in fallen leaves and wet, decomposing wood [3].	Considered as demonstrating signs of inadequate waterproofing or moisture within museums or storerooms [3].
Dried-fruit beetle *Carpophilus hemipterus*	*Coleoptera*	**Shape**: oval, flattened and light brown to black in color. Elytra are often shortened, exposing 2 or 3 abdominal segments. Elytra often with 1 or 2 yellow to reddish brown spots. **Antennae**: end in 3-segmented, flattened club. **Length of the body:** Adults are 2 to 4mm [3, 28-29].	Living in damp areas [3]. Feed on stored grain, dried fruit, fresh fruit, flowers, fungi, carrion [29].	Environmental indicators of damp [3]. *Carpophilus* beetles are a highly mobile and a major vector of brown rot [30, 31].

Fig. 8. Other insects: (a) Adult cigarette beetle (b) Adult wood louse (c) Adult dried-fruit beetle

Conclusion

The Saqqara site and storerooms contain a wide variety of organic artefacts (wood, textiles, bones, ivory, horn, papyrus, mummies, etc.). Those objects are very susceptible to a wide range of insect species.

Sticky traps for crawling insects are effective in pinpointing infestation hot spots, identifying sites where insects enter an area, and discovering which insects are present and in what quantities; besides, insect traps catch a wide variety of pest species in their mobile stages of larvae and adults.

In this study, ten insect species have been reported as biological degradation agents of organic monuments in Saqqara, including white ants (*Psammotermes*), spider beetles (*Gibbium psylloides*), powder post beetles (*Lyctus brunneus*), larder beetles (*Dermestes lardarius*), black carpet beetles (*Attagenus unicolor),* and larvae of varied carpet beetles (*Anthrenus verbasci*), silverfish (*Thermobia eagyptiaca*), and cigarettes beetles (*Lasioderma s*erricorne).

The most severe signs of damage to wood are caused by termites and powder post beetles. In diverse wood species, this study found that spring wood is more prone to damage

than autumn wood, which may be explained by the fact that spring wood cells have thinner and weaker walls than those of autumn wood. While severe damage to textiles is caused by carpet beetles, the mummies found inside the coffins are attacked by spider beetles. Additionally, woodlice insects (*Hemilepistus reaumuri*) and dried fruit beetles (*Carpophilus hemipterus*), which are considered environmental indicators of dampness,

In conclusion, this initial study provides conservators and conservation scientists with information on the most common insects that attack organic monuments in the Saqqara site and storerooms.

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