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TREATMENT OF A DIFFERENT PATTERN OF INSECT DAMAGE ON DOUM PALM WOOD (*HYPHAENE THEBAICA. L*)

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Abstract

This work aims to study the appearances of damage and the treatment of a wooden object. It isn't an archaeological piece, but it was very interesting to study this object because of the spread of a remarkable pattern of insect damage throughout all the parts of the statue. What type of insect that caused this damage is one of the most important questions that have been asked when this statue was seen for the first time and if this damage resulted from one or more insects? Due to the deteriorated case of this statue, all its components (wood, colors and adhesives) and the remains of insects were examined very carefully. In this examination, it was used the USB digital microscope for several purposes such as: getting a clear picture of the damage, of the insects, and of the anatomical structure of the Doum Palm (Hyphaene thebaica L.). The X-ray radiography was also used to clarify the extent of penetration and the spread of insect damage inside the wood mass. The X-Ray Fluorescence (XRF) was used to recognize the composition of the paint layers. Fourier-transform infrared spectroscopy (FTIR) was used for identifying the medium of colors and for identifying the adhesive materials. There are many stages of the treatment processes, but the disruption of the insect activity inside this statue was the first and the most important. Then all the treatment processes had been completed.

Keywords*: Doum Palm; Insect; Damage; Wood; Treatment; Statue*

Introduction

The Doum palm (*Hyphaene thebaica L*) is one of the most valuable plants in the world [1]. It was listed as a useful material for combating starvation in underdeveloped countries [2]. It belongs to the Arecaceae family [3]. This desert palm has an African origin, and it grows in Upper Egypt and in the Nile Valley [4-6]. The Doum palm has a great importance in many countries of the world. For example, its wood is used in construction work, the leaves are used in crafts and the fruits are used as food and in medicine [7].

In medicine, it is used for the treatment of hypertension [8]. The roots are specifically used for the treatment of Bilharziasis which is a parasitic infection [9]. In Ancient Egypt, the Doum palm had many uses. In the ancient era of pre-family, its fruits were found in the tombs of the Badari civilization. The first picture of the Doum palm was found in the tomb of "KA. AAM. NAFRAT" from the era of the ancient state. The trunk was used for making columns of the roofs and for making ship masts. Leaves were used for making many useful items, such as mats, baskets, plates, insoles of shoes and slippers. Outer fibers were used to make the cords [10]. Presently in Egypt, Doum palms are used in making sculptures, in the construction of some buildings at villages and its fruits are used as food and drink.

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The height of the Doum palm (*Hyphaene thebaica L.*) is between 6-17m and its girth is up to 90cm. The trunk splits often into two branches with a form of (Y) letter (Fig.1). This form repeats several times during the growth of the tree giving it a distinct appearance [5, 11, 12]. The color of Xylem wood is brown with black fibers, and it is hard to be formed [7]. It is resistant to insect damage [10].

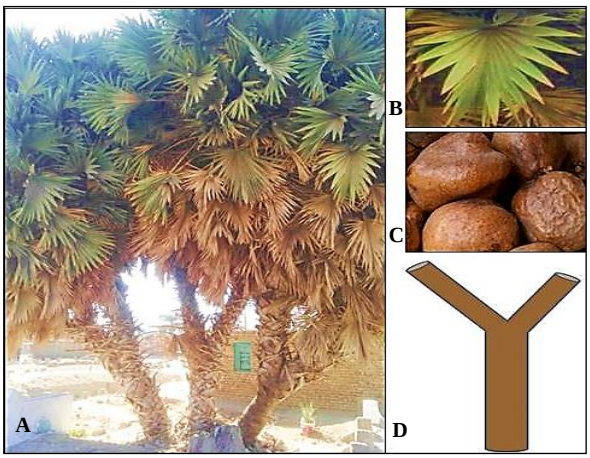

Fig. 1. Doum palm (*Hyphaene thebaica L.*): A. The tree in nature; B. The leaf of Doum palm; C. Doum palm fruits; D. The shape of letter (Y) in the trunk branches

Materials and Methods

Description of the statue

This statue (made about 40 years ago by one of the most famous sculptors in Qurna city at the governorate of Luxor in Egypt, who is called Sayed Mahmoud ALI (known as Sayed Abu Sherifa, 1953-2002) appears as a man in middle-age with Nubian features (Figs. 2 and 3).

Fig. 2. The statue (object of study)

It looks ahead and takes a step forward with its left foot. It is standing barefoot on a rectangular base. Its head is elongated and without hair. The face has a conspicuous chin, a long and big nose, a mouth with big lips, big and streamlined eyes. At the neck, there is a necklace that is divided into three circular and colored rows (green, red, yellow). There is also a black color, which was used to make some lines between each color, and some decorative shapes within each row. The statue has a slim and strong body. It has broad shoulders and its arms are held to the sides of the body. Its hands end with clenched fists. It wears a short kilt with a decorated belt. The statue was formed of several parts of Doum palm wood, where we find that both arms, the legs, and the rectangular base are separated parts which are attached to the body with pine wooden dowels and an adhesive material (This is a familiar method that is followed in making the wooden statues).

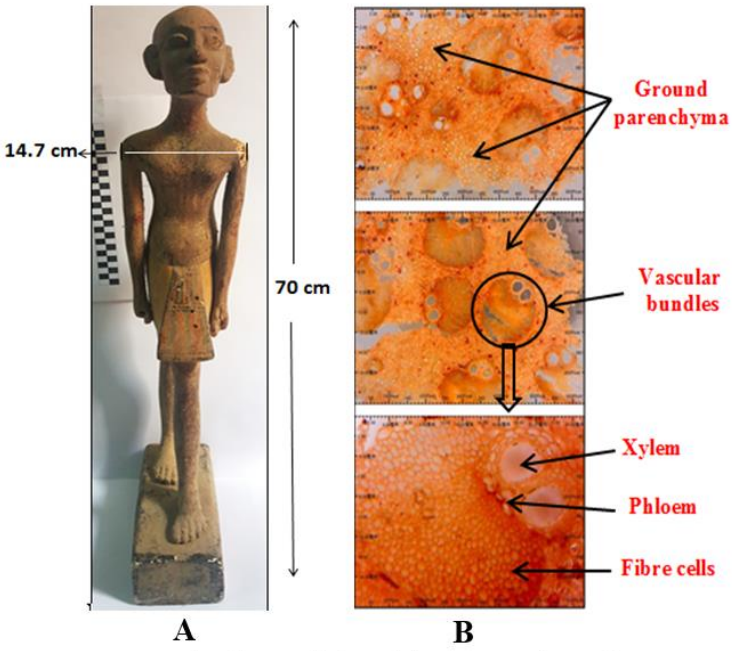

Fig. 3. The characteristics of the statue:
A. The dimensionse; B. A cross-section of the Doum palm (*Hyphaene thebaica L.*).

The deterioration appearances on the statue

The insects damage and the extent of its effect on the wood is the main reason for this study. It was noticed the spread of a new and a distinct pattern of the insect damage on this wooden statue. The aim of this study is to identify the insects causing this new and distinct pattern of damage. The damage of this wooden statue can be described as follow:

- The exit holes are spread out at all the statue parts with different sizes and shapes (Circular and semi-circular). The Measurement of these circular shapes diameter is between 0.5 to 2 millimeters, and there are other exit holes that can be observed in semi-circular shapes with a diameter between 3 to 5 millimeters (Figs. 4 and 5).
- The erosion of most of the Doum palm ground parenchyma, but the fibrovascular bundle (fvb) remained separated without effect. This erosion is clearly found in these areas: head, eye, ear, neck and shoulder (Figs. 6).
- The erosion and loss of some of the statue parts as a result of the insect damage, especially in the left ear, left-hand, and right foot (Figs. 6 and 7).

Fig. 4. The different appearances of damages: A to H. The devastating damage of insect; A-H. The loss of paint layers; A, E and F. The loss, erosion and breaking of some parts

Fig. 5. The insect damage existed on the head of the statue

Fig. 6. The insect damage on the statue

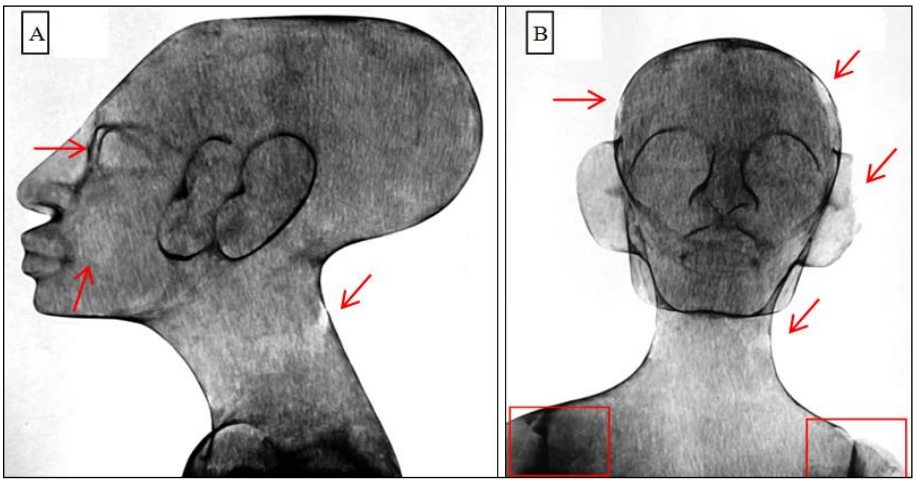

Fig. 7. X-ray radiography that shows the damage of the statue.
The arrows point at the damage areas and the squares show
the areas of the arms attachment with the statue's body

In this sense, some series of damages made over time by xylophagous insects were also clarified by the experimental technique of USB Digital Microscope (Figs. 8, 9 and 10) to highlight the differences between the characteristics of flight holes and the dust and the ellipsoidal frass pellets of insects.

Also, there are a lot of other deterioration appearances that are spread on the surface of this statue such as:

- The adhesion of dust particles (Fig. 11A-D) and of crystallized salts on the statue surface (Fig. 11E and F).
- The spread of various cracks and checks (Fig. 11A-D), in addition to the separation and the loss of some color layers (Fig. 11G-H).

Fig. 8. The insect damage effect on the anatomical structure of Doum palms wood. The fibers are separated from each other as a result of the loss of all Doum palm and the ground parenchyma, but the fibrovascular bundle (fvb) remained unaffected.

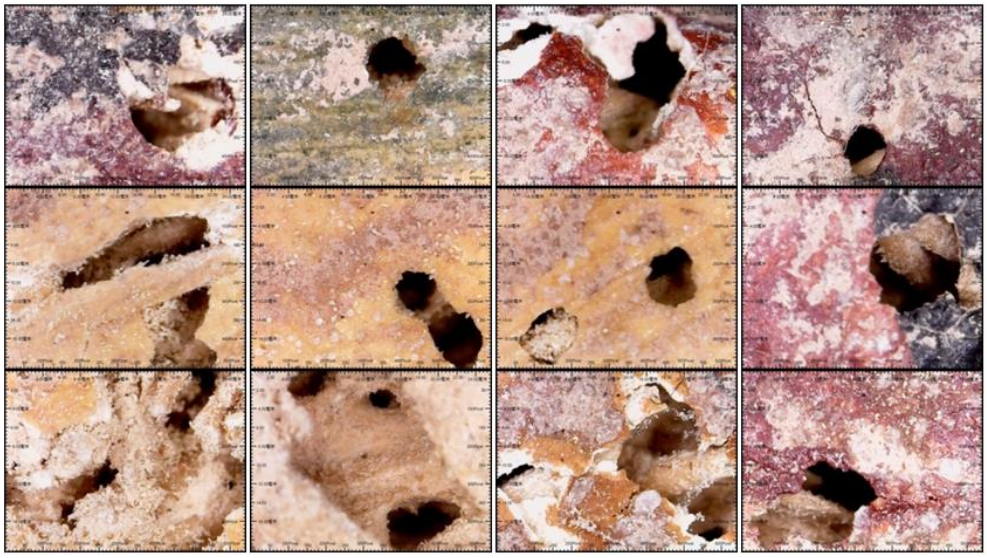

Fig. 9. The spread of exit flight holes with different diameters and shapes on the surface (USB Digital Microscope)

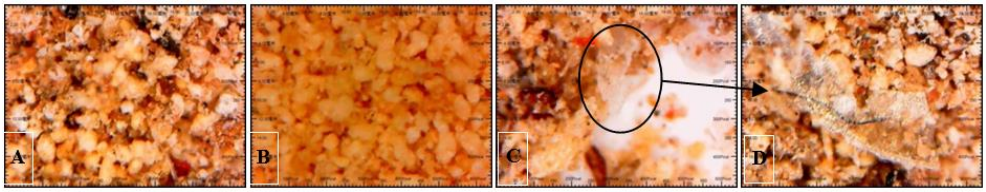

Fig. 10. The dust and the ellipsoidal frass pellets of insects: A and B. Some parts of insect eggs; C and D. Details of the ellipsoidal frass pellets of insects

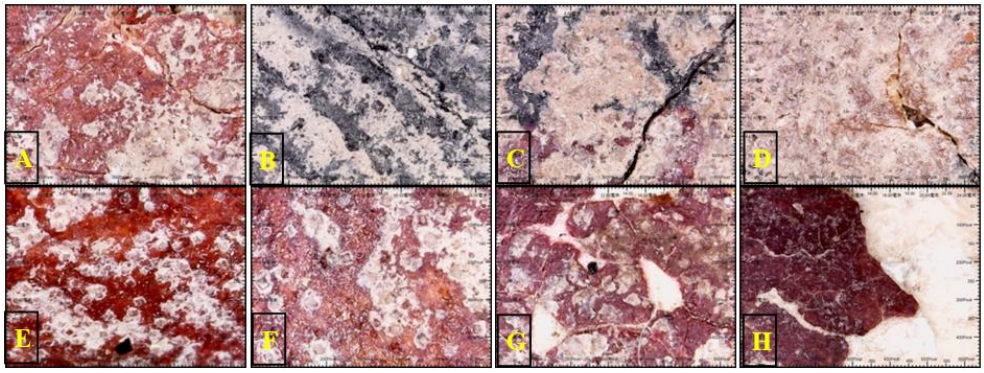

Fig. 11. The different damage appearences such as: A,B,C and D. Spread of cracks in the paint layers, the accumulation and the adhesion of dust particles on the outer surface; E and F. The adhesion of some salt crystals on the surface; G and H. The loss of some color layers parts (USB Digital Microscope)

Results and discussion

A general examination of the statue shows that it is made of several pieces of Doum palm wood. We find that all the arms, legs, and statue base are separated parts that are attached to the body with wooden dowels made of pine wood, using polyester adhesives (Fig. 12). The left-arm is made of two pieces of wood, attached with polyester adhesives.

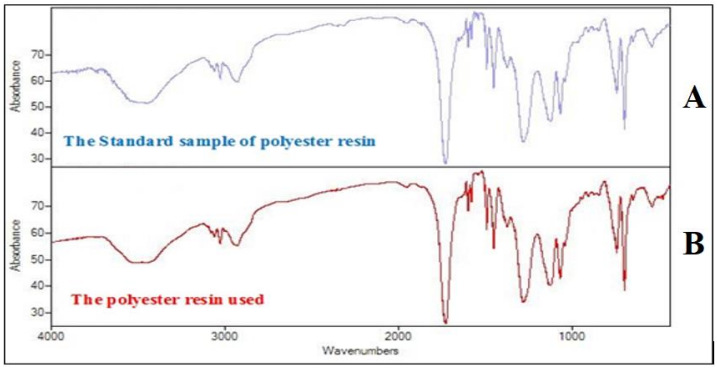

Fig. 12. FTIR spectra of the polyester resin used in the adhesion of the statue parts: A. standard sample; B. The polyester resin sample of the statue

Paint layers

The analysis using X-ray fluorescence (XRF) clarified the components of the ground layer and the paint layers, which we can mention as follow:

XRF Analysis of the ground layer shows the presence of (Ca) as a main element in its composition (Fig. 13A), which indicates that Calcium carbonate ($CaCO_3$) mixed with animal glue (as a bonding material) were used to make this ground layer (Fig. 13F).

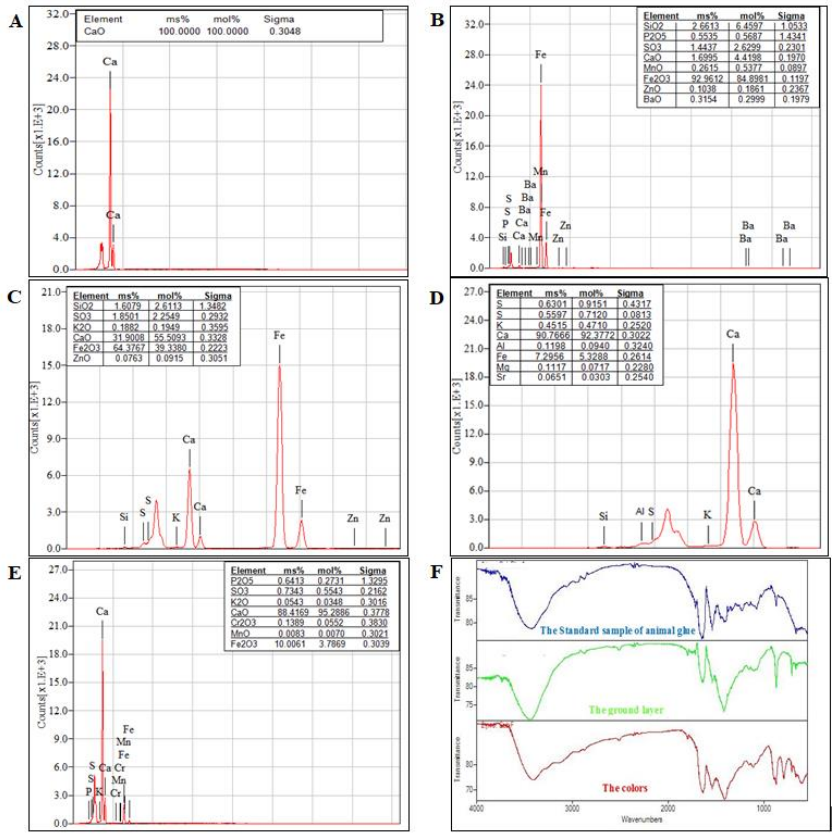

Fig. 13. X-ray fluorescence analysis of the paint layers: A. The ground layer. B. The red color. C. The yellow color. D. The green color. E. The black color, F: FTIR spectra of the animal glue used as a binding medium of the color layers in the statue. standard sample, the ground layer, the colors

This mixture is known as gesso and it has been used since ancient Egyptian civilization. Hatchfield and Newman stated that the Egyptian (ground layer) consists of a white filler of calcium carbonate or calcium sulphate and an organic binder [13]. also, the calcite $CaCO_3$ was used as a white pigment in ancient Egypt [14, 15].

The XRF analysis of the red color has shown the presence of (Fe) as a main element (Fig. 13.B), which indicates that the red color is red ochre (hematite) Fe_2O_3 [16]. The yellow color consists of several elements as (Fe, Ca, K and S) (Fig. 13C), which indicates that the yellow color is yellow ochre (Goethite) FeO(OH) [17].

The green color consists of some elements: (Fe, Mg, Al, K and Si) (Fig. 13D), which indicates that this color is the green earth [18]. The absence of Na element indicaters that Celadonite was used to get this color. The chemical components of celadonite are approximately $K(Mg,Fe^{2+})(Fe^{3+},Al)[Si_4O_{10}](OH)$ [19]. The black color consists of some elements: (Ca, Fe, S, Mn and S) (Fig. 13E), the presence of manganese indicates that this color is manganese dioxide (MnO_2).

On the color layer, there is a fine shiny and yellowish layer which was irregularly distributed. The examination with Fourier Transform Infrared Spectroscopy (FTIR) showed that this layer is a layer of Shellac (Fig. 14). This layer was used for the protection of the color layer from the moisture effect (this is due to the use of animal or acrylic glue as a binder material ″binding medium″) and to give a bright appearance to the colored sculptures [20].

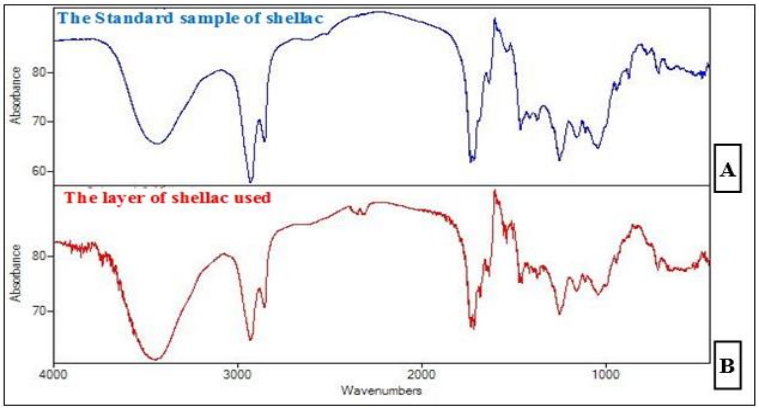

Fig. 14. FTIR spectra of the shellac resin used for the protection of the color layer: A. Standard sample; B. The shellac resin of the statue

Identification of insects found inside the statue

By using USB digital microscope and to identify the insects causing this considerable damage in the statue, it was examined all of exit flight holes of the adult insect, the highly damaged areas by the insects: the head, eye, and neck. Also, it was examined the bore dust of the expendable wood, the remains of the insects and Larvae and the separate ellipsoidal frass pellets.

Due to the presence of this statue, for many years, in a plastic bag and as a result of the insect's activity inside the body of the statue, a large amount of the bore dust of the expendable wood, some insects remains and Larvae were found. This examination took several months in order to identify all types of insects. Through this examination process, a lot of adult insects, insect remains, and Larvae were found:

Black carpet beetle

Order: Coleoptera; Family: Dermestidae; Species: *Attagenus megatoma F*

It's a very dangerous pest for textiles, the adult beetle is elliptical. Its color is dark brown-black [21]. Its length is approximately 3.0 to 5.0mm [22]. It is one of the most

destructive types of carpet beetles [21]. Larvae have carrot-shaped and they are curved with tufts of hair at the end of the tail. Its length may reach to 8.0mm, with bright brown (yellowish-brown) to black color (Fig. 15) [21-23]. The black carpet beetle is one of the most common insects in Egypt. It spreads in many places as grain stores, flour mills [24] and industrial buildings. Also, they feed on the bodies of dead insects. Therefore, they are very common in grain which is infested with grain pests [21].

Fig. 15. The remains of the black carpet beetle Larvae found inside the statue

Varied carpet beetle

Order: Coleoptera; Family: Dermestidae; Species: *Anthrenus verbasci L*

The Varied carpet beetle attacks the museums' collections containing wool, feathers, fur, and skins [25, 26]. This beetle belongs to the genus Anthrenus [21] which is covered with irregular patches that have different colors like white, brown and yellow and different shapes (Fig. 16C and D). The length of this beetle is 2 to 3mm. The rear portion of the larvae body is wider than the front. The larvae length is about 4.5mm [27]. It is also characterized by the presence of hair tufts at the two sides of its rear portion (Fig. 16A and B) [21].

The presence of these insects in this damaged wooden statue is only to hide in the tunnels made by some other insects. The reason for the spread of the black carpet beetle inside this statue is to feed on the remains of red flour beetle and that was mentioned by *D.J. Hopkins* [21].

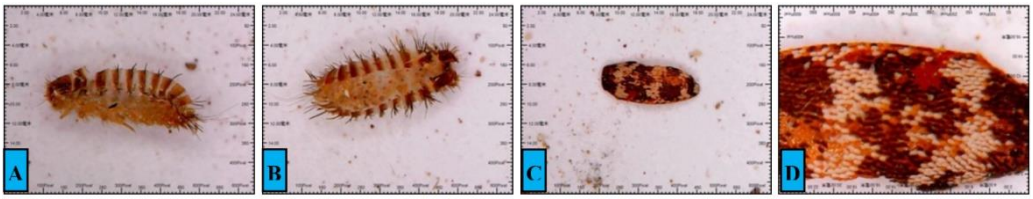

Fig. 16. The remains of the varied carpet beetle Larvae and the outer wing of this beetle (elytra) found inside the statue

The Red flour beetle

Order: Coleoptera; Family: Tenebrionidae; Species: *Tribolium castaneum (Herbst)*

It's a small pest with a length of about 3 mm. It is a very destructive insect for stored and milled grain [28, 29]. The damage of this pest is caused by each of its adult insects and larvae [30]. The adults are characterized by reddish-brown color [31] (Fig. 17). Its larvae are about 3/16″ (4-5mm) long, with light yellow color [32].

This insect attacks mainly the flour and cereal grains, nevertheless it has been found active and with abundance at all the parts of this statue. This is surprising and raises an important question about the role of this insect in causing more damage to this statue.

Through the long and accurate examination of the statue, it can be concluded that the red flour beetle has a big and remarkable role in causing more damage to the wood. This conclusion can be based on the activity and the spread of this insect at all the parts of this statue, especially

in the highly infested areas such as the head, eye, and neck (Fig. 5 and 6). There is a very distinct pattern of the insect damage in this statue, which is a loss of all ground parenchyma of the Doum palm, which is surrounding the fibrovascular bundle (fvb) that remained separated and without being attacked (Fig. 8). The presence of this insect with activity and with abundance indicates that there is a source of food for this insect. We can guess that this source of food is the ground parenchyma because the starch and sap in the Doum palm tissue are stored in this area [33].

Fig. 17. The adult of red flour beetles found inside the statue

But it is possible that this insect crept into this statue through the exit holes of other insects. This is noticed through the different shapes and sizes of the exit flight holes.

It is clear from the foregoing, the extent of the destructive effect of the insects on the Doum palm wood (*Hyphaene thebaica L.*), contrary to what *W. Nazir* [10] said about the resistance of Doum palm wood to the insect damage.

Treatment processes

After the extreme damage of this statue caused by the insect activity, the most important thing was how to stop immediately this activity. For this purpose, the cinnamaldehyde in ethanol 2% [34] has been used. It was injected to the interior areas through the exit flight holes spread in the statue body. The cinnamaldehyde is used as an effective insecticide on the red flour beetle (*Tribolium castaneum. Herbst*) [35, 36]. It is used also as an antifungal against moulds and against the species of wood-decay fungi (soft, brown and white rot) [34, 37]. After the injection process with cinnamaldehyde in ethanol 2%, the statue was left under observation inside a closed glass box at room temperature for two months to make sure of the termination of insect activity inside the statue. During this period, it was not noticed any sign of insect's activity inside the statue such as falling of the sawdust, but a lot of dead *Tribolium castaneum* insects were observed inside the glass box.

Cleaning processes

Mechanical cleaning: Many types of brushes with different sizes have been used to remove dirt stuck to the outside surface of the statue by unbundling the dirt particles. Through this process, all dirt was easily removed, but a very fine layer of dirt remains on the surface.

Chemical cleaning: In this process, ethyl alcohol was used to clean and disinfect the interior parts of the statue. That was by injecting the exit holes to remove the remains of the ellipsoidal frass pellets and the dust which accumulated in the tunnels. Distilled water was also

used to remove the fine layer of dirt that remained on the surface after the mechanical cleaning process. In this case, it was difficult to use an organic solvent that can affect the layer of Shellac which protect the paint layers (Fig. 18).

Fig. 18. The statue after the cleaning processes

Consolidation processes

This process included the consolidation of fragile areas that had been highly damaged such as the head and the neck. It also included the consolidation of insect damage areas spread throughout the statue.

This process has begun by injecting all the inner parts, through the exit holes of insects, with the solution of Paraloid B.72 dissolved in acetone with a concentration of 3% [38]. This solution was also used to adhesive the paint layers.

The areas which had been highly damaged by the insects (head, eye, neck and the big exit holes) were consolidated and filled with a mixture of glass microballoons and Paraloid B.72 in acetone/ethanol (1:1) [39] at a concentration of 15%. These supplemented parts had been colored by using Acrylic colors (Fig. 19).

The left ear and right toes were supplemented with the same shape and size of the missing parts by using pieces of the Doum palm wood (*Hyphaene thebaica L.*). Then, these parts had been adhered to the statue by using Paraloid B.72 dissolved in acetone at a concentration of 15% [40]. These parts had been also consolidated and filled with a mixture of glass microballoons and Paraloid B.72 in acetone/ethanol (1:1) at a concentration of 15% [38]. These supplemented parts had been colored by using Acrylic colors. After all these stages, all the statue parts were consolidated using paraloid B 72 dissolved in acetone with a concentration of 2% (Fig. 20).

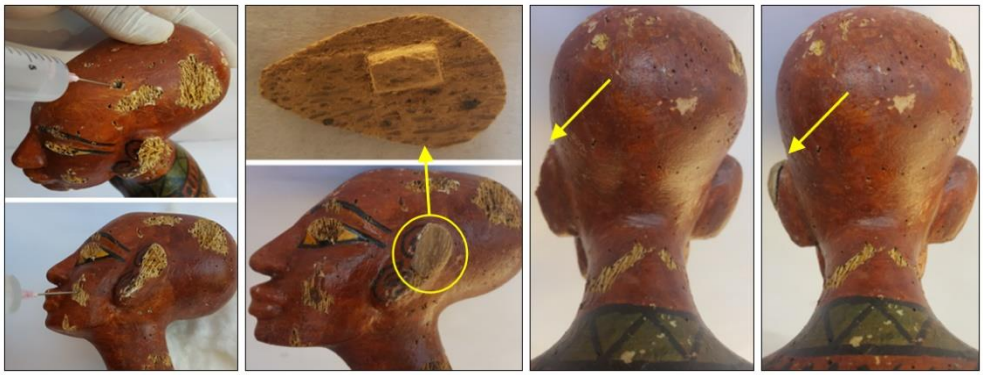

Fig. 19. The statue during the consolidation processes

Fig. 20. The statue before and after the treatment processes

Conclusions

At the end of this research, we can say that the art of sculpture of wooden statues is an inherited craft from the ancient Egyptians. The artist who made this statue was inspired a lot from the civilization of his ancestors. This can be seen clearly in the shape, in techniques, and in some materials used by ancient Egyptians.

According to the results of the study, the Doum palm wood (*Hyphaene thebaica L.*) was used to make this statue. It is one of the domestic types of wood used by ancient Egyptians for many purposes. Also, the artist used many materials like gesso, green earth, yellow ochre, and the red ochre which were extensively used in ancient Egyptian civilization.

Through this study, it can be emphasized that the insects are one of the most dangerous enemies for the old wooden objects. In this statue, the only insect that had been found in a state of activity is the red flour beetle (*Tribolium castaneum*). The attack of this insect to the ground parenchyma led to the loss of a big part of the wood mass. This insect feeds mainly on the flour which is one of its components is the starch. This can be the main reason of the attack of this insect to the ground parenchyma which is a storage area of the starch.

There were many difficulties during the treatment processes. One of these difficulties is to terminate the insect activity. For this process, the cinnamaldehyde in ethanol 2% was used. It has provided us with positive results in the eradication of the red flour beetle (*Tribolium castaneum*).

Paraloid B.72. (3% in acetone) has given good results in the consolidation and in the bonding of separated wood fibers. The mixture of glass microballoons and Paraloid B.72 dissolved in acetone at a concentration of 15%, has given a good result in making a supplementary of the missing parts caused by the insect damage.

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