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Gill Morphology in the Red Swamp Freshwater Crayfish *Procambarus clarkii* (*Crustacea: Decapoda: Cambarids*) (Girard 1852) from the River Nile and its Branches in Egypt

Morfología de las Branquias del Cangrejo Rojo de Pantano de Agua Dulce *Procambarus clarkii* (*Crustacea: Decapoda: Cambarids*) (Girard 1852) del Río Nilo y sus Ramas en Egipto

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SUMMARY: The aim of the present study was focused on and describes the gross morphological and scanning electron microscopical features of the gill of the red swamp freshwater crayfish. Our results noted that: all gills have the same general structure and appearance. The gill consists of axis with numerous finger-like filaments, having three morphological types; round, pointed and somewhat hooked shaped. There is a variation in the direction of filaments according to their position, in middle part were nearly perpendicular to gill axis while in the apex were nearly parallel to axis. There were characteristic system of gill spines on central axis, basal plate, setobranch and on the bilobed epipodal plate. There are four shape of spinated-like parts of setobranch seta, two pointed processes and two broad processes. The bilobed epipodal plate is devoid from any filaments and under SEM, its apical part has serrated free border and corrugated surface while the middle part has no serrated free border.

KEY WORDS: Crayfish; Filaments; Spines; Setobranch setae.

INTRODUCTION

There are three families of crayfish, *Astacidae, Parastacidae* and *Cambaridae*. The red swamp freshwater crayfish belonging to *Procambarus clarkii* (Girard 1852) species belonging to *Cambaridae* family (Huner & Barr, 1991; Fishar, 2006), and it is currently considered one of the most abundant and commercial crustacean species worldwide (Henttonen & Huner, 1999).

The red swamp crayfish *P. clarkii* has been introduced latterly in Egypt, exactly in the early 1980s (Ibrahim *et al*., 1997), when this species was first introduced to the Egyptian freshwater systems from Northeast Mexico and south central USA for aquaculture (Fishar), it rapidly expanded in all aquatic ecosystems including streams, ponds, and marshes with polluted or clean waters from the northern Delta to Assuit (Saad & Emam, 1998).

In Egypt, in the last decades, crayfish research has become important as their persistent presence is related to important economic problems, having the ability to attack fish inside nets and damage nets used by fishermen in the Nile River (Fishar). Health problems caused by their presence have also been reported, as they act as a host for some protozoa and may act as an intermediate host for some parasitic helminthes (Ramadan, 1997), the only two benefits of these crayfish from a medical viewpoint is in that they may help control certain human diseases caused by helminthes parasites, as they feed on the vectors for such pathogens. The other benefit is that they can be used as bio-indicator of trace metals pollution in aquatic environment because they tend to accumulate metals in their tissues (Huner & Barr; Fishar).

The presence of fresh water Crayfish were related to many problems as it is considered as a keystone species, affecting many components of the ecosystem habitat and changes the nature of native plant and animal communities. It may also cause many agricultural problems by consuming invertebrates and macrophytes and degrading river banks due to its burrowing activity which leads to reduce the value of the freshwater habitats (Fishar).

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The mode of respiration differs between the large and small crustacea; in small crustacea, there was no special organs for respiration but the exchange occurs across body surface, while in larger crustacea, respiration usually occurs by gills. The crustacean gill act as multifunctional organ, ion regulation, osmolyte transport, acid-base regulation respiration, and nitrogenous waste excretion (Henry & Wheatly, 1992; Taylor & Taylor, 1992; Péqueux, 1995). The process of respiration in decapod crustaceans takes place by drawing the water stream into the branchial chamber as it is circulated over gill surfaces where the exchange of gases occurs.

Although crayfish are widely distributed in the Egyptian freshwater systems, there is a little information about this species (IAA, 1995). Therefore, in the present investigation conducted, we show the morphological and scanning electron microscopic features of the gills in the red swamp freshwater crayfish (*P. clarkii*).

MATERIAL AND METHOD

Samples. The present study was carried out on the gills of twelve red swamp freshwater crayfish (*P. clarkii*), that were collected after catch from the Nile river and its branches from Desouk, kafre El-sheik Governorate, Egypt and transported in plastic aquariums to our lab within two hours to carry out the gross morphological, scanning electron microscopic studies on their gills. This study followed the guidelines for the care and use of laboratory animals and the animal welfare and Ethics Committee of the Faculty of Veterinary Medicine, Alexandria University and approved according the Egyptian's laws.

For gross morphology. Eight red swamp freshwater crayfish (*P. clarkii*) were used to display the morphological features of the gills. The branchial cavity was opened after ascending or removing the branchiostegite (gill cover) of the branchial chamber, and then the gross morphological features of the gills and associated accessory respiratory organs were examined in situ by the naked eyes, next dissected, and the findings obtained were imaged by means of a Digital Camera (Sony Inc., Japan).

For scanning electron microscopy. Four red swamp freshwater crayfish (*P. clarkii*) were used. Gills were fixed in (2.5 % formaldehyde, 2.5 % glutaraldehyde in 0.1 M sodium cacodylate buffer, pH 7.2) for 4 h at 4 °C. Once fixed, the samples were washed in 0.1 M sodium cacodylate containing 5 % sucrose, processed through tannic acid, and finally dehydrated in increasing concentrations of ethanol (15 min each in 50, 70, 80, 90, 95 and 100 % ethanol). The samples were then critical point dried in carbon dioxide, attached to stubs with colloidal carbon and coated with gold palladium in a sputtering device. Specimens were examined and photographed with a JEOL JSM 5300 scanning electron microscope operating at 15 KV, at the faculty of science, Alexandria University.

RESULTS

A-Gross morphological studies of the gills of the red swamp freshwater crayfish *P. clarkii*: The red swamp freshwater crayfish (Fig. 1) was breathing through the feather-like gills (Fig. 2) on the bases of the walking legs (Fig. 1/W). The feather-like gill system of red swamp freshwater crayfish was confined within a two separated elongated hallow narrow spaced branchial chambers (Fig. 2A). These two branchial chambers were bounded ventrally by bases of the walking legs, dorsally by the median groove on back of crayfish and laterally by the gill covering (branchiostegite), while medially by thoracic body wall.

The gill covering (branchiostegite) of the branchial chamber was continuous with that of the rest of the body (Fig. 1/Lt) (Fig. 2A/br). The red swamp freshwater crayfish possess a trichobranchiate gill type, which consists of three types according to their place of attachment on the body; podobranchiae (Fig. 2E), arthrobranchiae (Fig. 2F) and pleurobranchiae (Fig. 2D). All the feather-like trichobranchiate gills consisted of a central shaft (gill axis or gill arch) bearing numerous smooth, relatively uniform in size and cylindrical filaments. All gills have the same general structure and appearance; all were plume-like with a single broad setiferous base, tapering to a narrow branchial apex (Fig. 2 and 3B).

The podobranchiae were characterized by the presence of the well-developed fan-like accessory structure called bilobed epipodal plate (Lamina or double-bladed epipods) (Fig. 2/L). The bilobed epipodal plate extended from the outer side of the basal part of the podobranchiae directly under the branchiostegite as triangular basal part (Fig. 2B and 2C/Lb) then extended dorsally between the two gill arch as cord-like middle part (Fig. 2B and 2C/Lm) then it passed under the gill arch to lies against the thoracic body wall. In which the basal and middle part which can see from outside represented the $^{1/3}$ of the lamina length while the apical part which lies against the thoracic body wall represented $^{2/3}$ the length of lamina. Its basal triangular part (Fig. 2B and 2C/Lb) have three border; craniodorsal, caudoventral and ventral border. The caudoventral and ventral border were free and have ventrally directed laminar setae (Fig. 2B and 2C/Lst). The craniodorsal and the cord-like middle part (Fig. 2B and 2C/Lm) were devoid from any laminar setae.

B-Scanning electron microscope of the gills of red swamp freshwater crayfish *P. clarkii*: The gill consists of gill axis (central shaft or gill arch) with numerous relatively uniform in size, smooth cylindrical, finger-like filaments, which were arranged in transverse rows across each gill. There are three morphological types of filaments according to the shape of its apical ends; round, pointed and somewhat hooked shaped, in which by high magnification the external surface of each filaments appear to be corrugated by micro-longitudinal line (Fig. 3).

Each gill can be subdivided into three parts; basal plate, body and apex. The basal plate of the gills called the setobranch, was curved anteriorly and devoid of any gill filaments but have number of the basal spines and hair-like setobranch setae towards their outer edge, while the apex and body (middle) parts have high number of filaments which were being arranged in rows across the gill axis and were originated from the anterior and posterior surface of the gill axis in body and apex, in addition to apical border of apex of the gill axis, while the lateral and medial surfaces of body and apex were devoid from any filaments. The filaments in the middle part were nearly perpendicular to the gill axis while the filaments in the apex do not extended perpendicularly from the surface of the gill axis, but over most of their length were deflected dorsally in a plane nearly parallel to the gill axis (Figs. 3A and 3B). This high number of filaments to increase the surface area of gas exchange.

Gill axis (central shaft or gill arch): Its anterior and posterior surfaces represented the origin of the gill filaments, while its medial and lateral surfaces were devoid of any gill filaments. The medial surface was lay against the thoracic body wall while the lateral surface was lay against the gill covering (branchiostegite) and characterized by the presence of two distinct types of axial gill spines (Fig. 3B, 4A and 4B) according to the shape of its origin; the first and the most obvious type

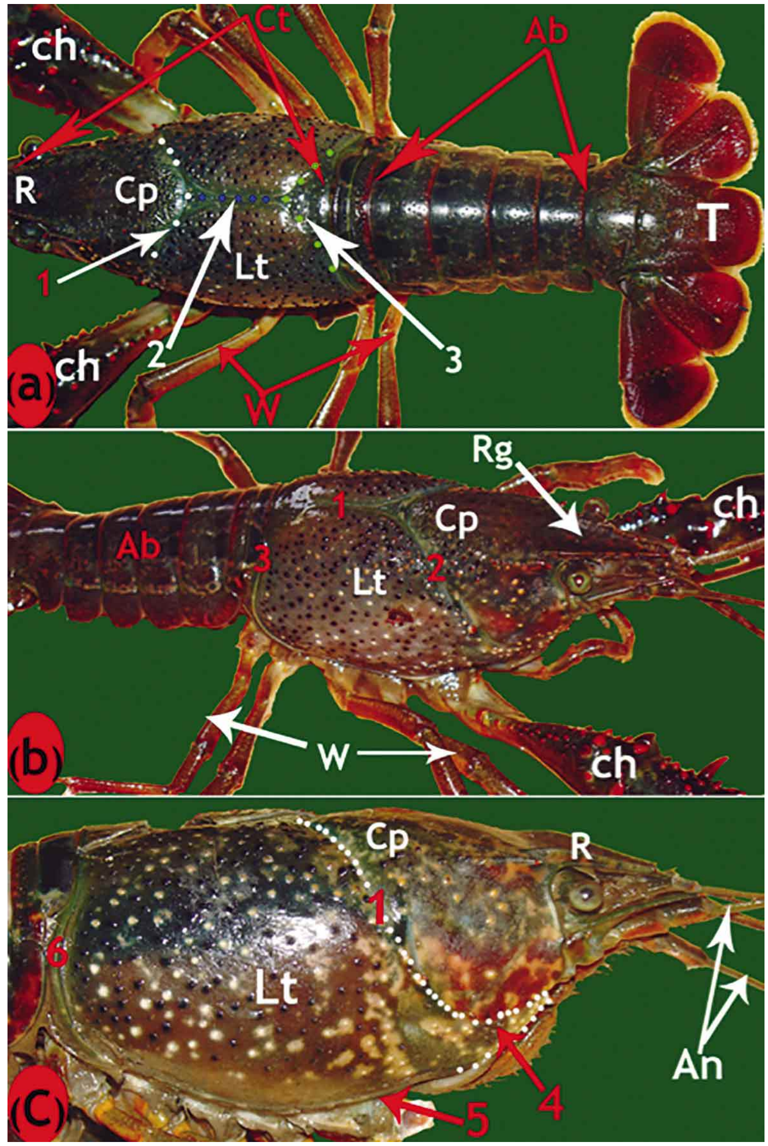

Fig. 1. photographs showing the external appearance of the red swamp freshwater crayfish P. clarkii; slide (a) dorsal view, slide (b) dorsolateral view and side (c) lateral view to show; cephalothorax (Ct), abdomen (Ab), tail (T), rostrum (R), cephalic tubercle (Cp), lateral tubercle of branchiostegite (Lt), walking legs (W), cheliped (ch), cervical groove (1), median groove (2), caudal groove (3), rostral angle of lateral tubercle (4), lateral border of branchiostegite (5), caudal border of branchiostegite (6), rostral groove (Rg), antennae (An).

was appeared along the lateral surface of the gill axis and was comparatively large and appear to be standing on a small hillock, which surrounded by micro-elevated rim and were scattered randomly on the gill axis (Fig. 4C). The second type was appeared to be projected from a specialized elevated socket region (may be described as it projected from the volcanic crater), which surrounded by micro-elevated rim and were found mainly lateral to the midline of the gill axis, in which these spines were arranged in a row (Fig. 4D). These two types of axial gill spines were shared in that; the axial gill spines were conical projection scattered

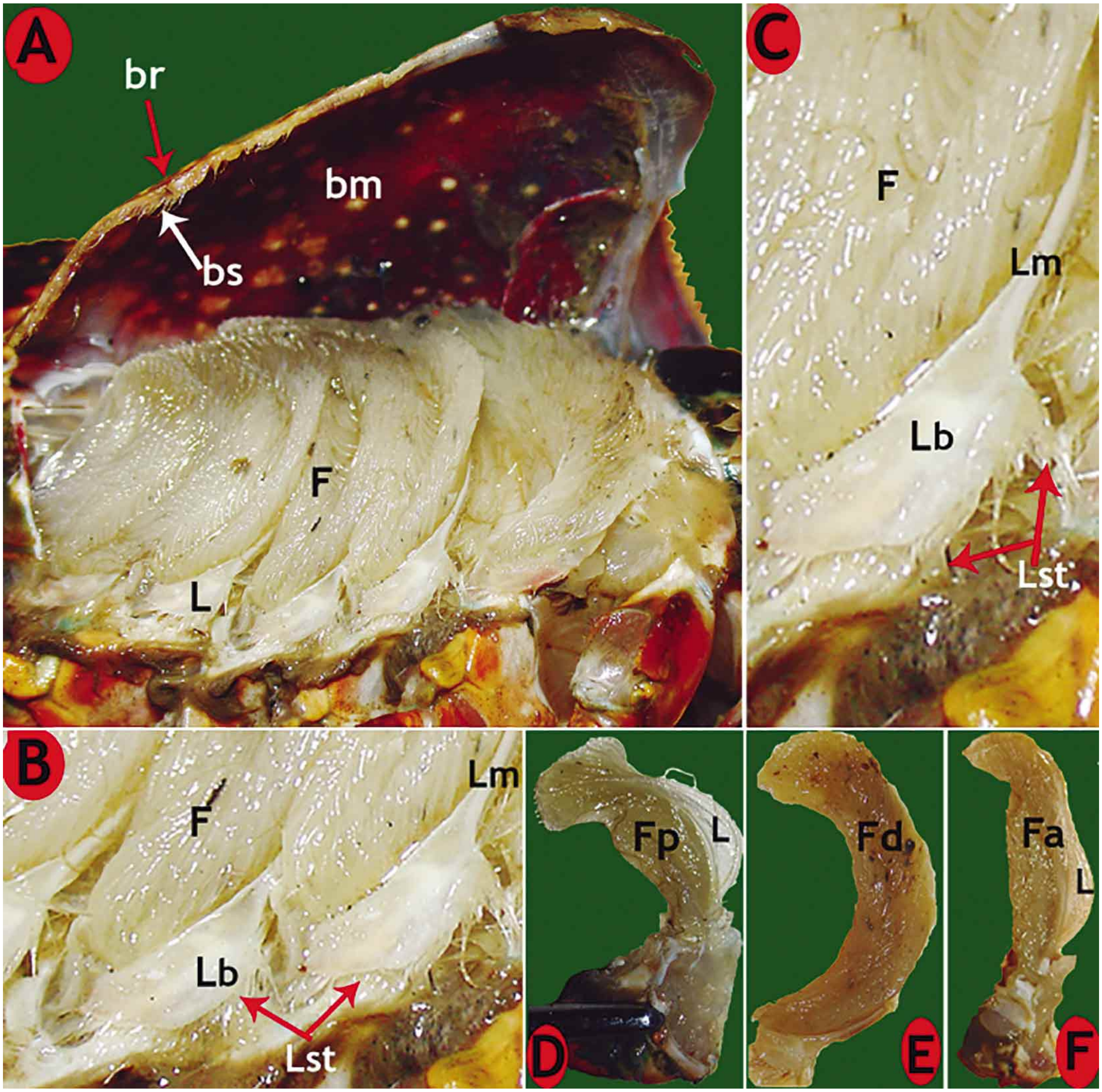

Fig. 2. Photographs showing the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) lateral view of the opened branchial cavity, slide (B) magnification of from slide (A), slide (C) magnification of from slide (B), slide (D) to show one of the pleurobranchiae, slide (E) to show one of the podobranchiae, slide (F) to show one of the arthrobranchiae; branchiostegite (br), branchiostegite setae (bs), branchiostegite membrane (bm), gill arch with gill filaments (F), bilobed epipodal plate or Lamina (L), basal triangular part of the lamina (Lb), cord-like middle part of lamina (Lm), epipodal laminar setae (Lst).

along the length of the lateral surface of the gill axis and pointing toward the apex of the gill but were distinguishable externally by the presence of the socket.

Setobranch (basal plate of the gill). The setobranch (Fig. 5A) was devoid of any gill filaments but on its most basal rim (towards their outer edge) was carried a number of the hair-like setobranch setae (Fig. 5A/ss). The setobranch has four surfaces; medial (attached) surface was free from any filaments and spines, while the anterior, posterior and lateral surfaces were devoid from any gill filaments but have two types of setobranch gill spines; 1st type was the little long non-branched setobranch spines, appeared to be projected from non-elevated round socket (Fig. 5B/sp2). The

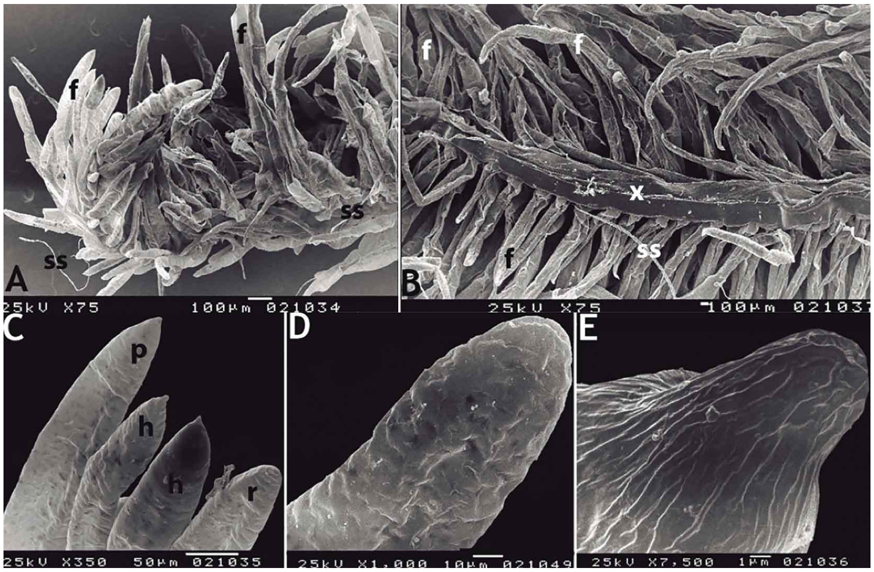

Fig. 3. SEM photographs of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) to show; the filaments (f) in the apex region of the gill, which are deflected dorsally in a plane nearly parallel to the axis of the shaft toward the opercular opening, and also setobranch setae (ss) are present over and among the gill filaments (f). Slide (B) to show; the filaments (f) in the middle region of the gill, which are nearly perpendicular to the central axis (x) of the gill, and also setobranch setae (ss) are present over and among the gill filaments (f). Slide (C) to show; there are three morphological types in the shape of the apical end of the filaments; round (r), pointed (p) and hooked shaped (h). Slide (D) to show; magnification of the apical end of the filament and slide (E) to show; high magnification of the apical end of the filaments, which appear to be corrugated by micro-longitudinal line.

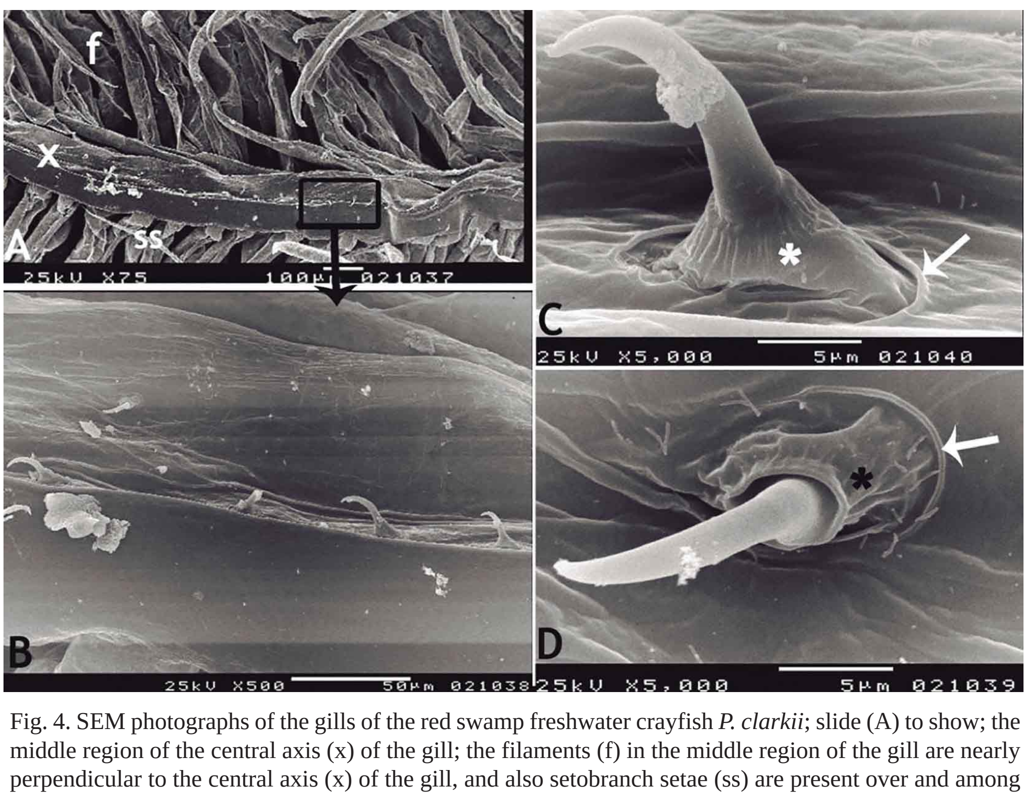

Fig. 4. SEM photographs of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) to show; the middle region of the central axis (x) of the gill; the filaments (f) in the middle region of the gill are nearly perpendicular to the central axis (x) of the gill, and also setobranch setae (ss) are present over and among the gill filaments (f). Slide (B) is magnification of part of central axis to show; the conical projections of the axial gill spines. Slide (C and D) to show; two distinct types of the axial gill spines according the shape of its origin; the first type (slide C), appear to be stand on a small hillock (white star), while the second type (slide D), appear to be projected from a specialized elevated socket region (black star), and the two types of axial gill spines are surrounded by micro-elevated rim (white arrow).

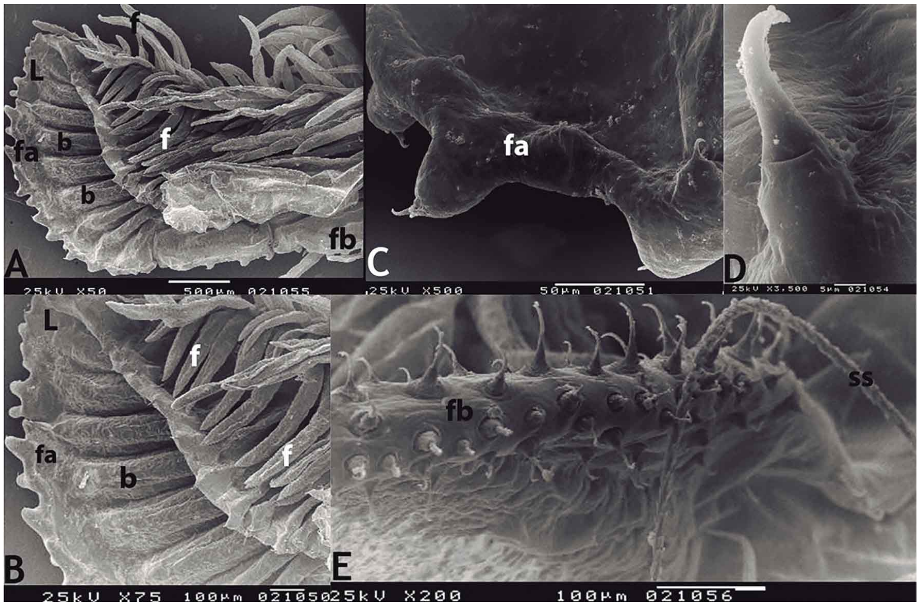

Fig. 5. SEM photographs of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A and B) to show; podobranchiae and its filaments (f) with the well-developed fan-like accessory structure (bilobed epipodal plate or Lamina or double-bladed epipods) (L), which appear as double membranous lamina, in which the body of the bilobed epipodal plate consist of number of transverse lobes (b) which separated by transverse grooves, while the free border (fa) is serrated at the apex of the bilobed epipodal plate and carries few number of gill spines (slide C), and the slide (D) to show the high magnification of the one of the spines at the free border of the bilobed epipodal plate, while free border (fb) at the base of the bilobed epipodal plate is not serrated and carry high number of well-developed spines and appear also that the setobranch setae (ss) between the spines (slide E).

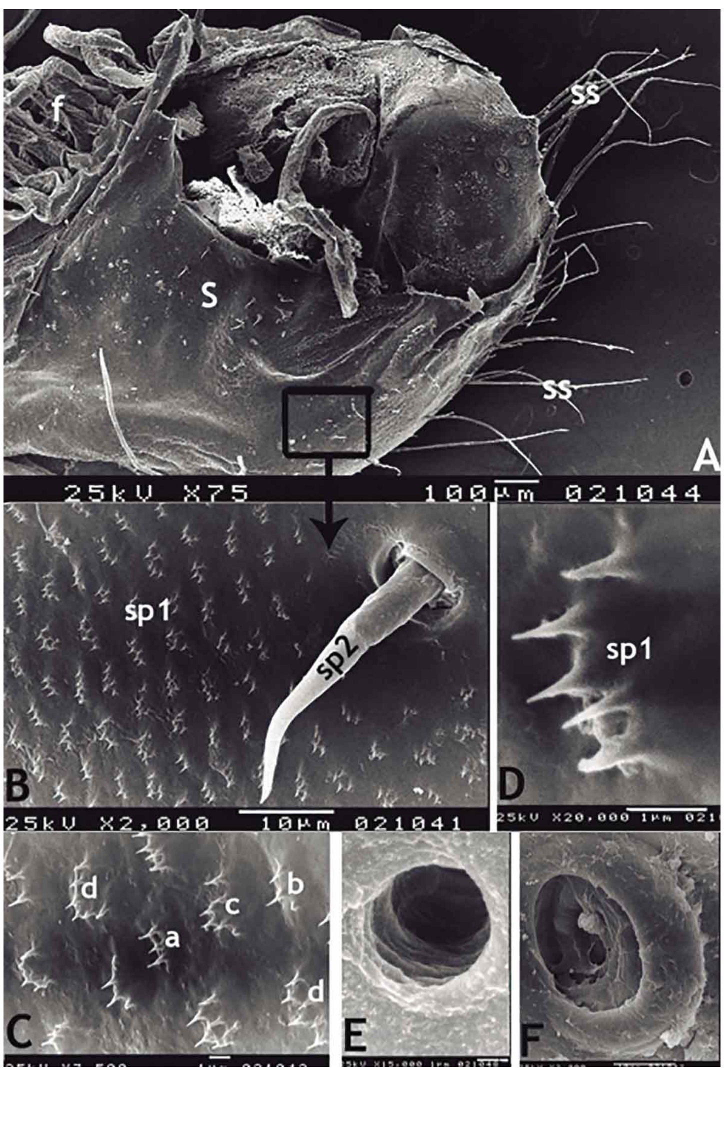

Fig. 6. SEM photographs of the setobranch of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) to show; the setobranch (S) with its spines and also the setobranch setae (ss) present on the most basal rim of setobranch. Slide (B) to show that, there are two types of setobranch spines; 1st type is the little long non-branched spines (sp2), appear to be projected from non-elevated round socket, while the 2nd type is the numerous very short multidenticulate spines (sp1), which in the (Slide C and D) show that, the multidenticulate setobranch spines, may be tri (a) or quadri (b) or Penta (c) or hexa (d). Slide (E and F), mention that there are two types of gill pores on the setobranch.

2nd type was the numerous very short multidenticulate or multifid setobranch spines (tri or quadri or Penta or hexa) (Fig. 5C/a, b, c and d). The second type filled all the anterior, posterior and lateral surfaces of the setobranch (Fig. 5B, 5C and 5D/sp1). The two types of the setobranch gill spines were pointed dorsally toward the apex of gill and also these spines were present by high number on the lateral surface than the anterior and posterior surfaces. In podobranchiae only, there were two types of unknown functioned pores, in which each one of the podobranchiae carry only one from each unknown functioned pores (Fig. 5E and 5F).

Setobranch setae. Two types of setobranch setae were appeared on the setobranch; well-developed hair-like setobranch setae and the newly formed small hair-like setobranch setae. The well-developed hair-like setobranch setae extended over and among the gills and gill filaments to share in the gill-cleaning mechanism, nearly all gills were in contact with at least one type of the well-developed hair-like setobranch setae (Figs. 3A, 3B, 4A, 5A, 6 and 8E).

The newly formed small hair-like setobranch setae (Fig. 6B/ white arrow) were completely smooth, while the well-developed hair-like setobranch setae were divided into two parts; basal part and body (shaft). The basal part represented by round hair-like follicle, which originated and fixed into the deep round cuticular socket (sunken basal socket) on the surface of the setobranch. The round shape of the origin of the basal part of setobranch setae and its position into the deep round cuticular socket, this demonstrate the free movement of setobranch setae in all direction with the limb movement during locomotion, feeding, or other activities. The body or shaft was subdivided into two halves according the surface appearance; the first half was the smooth basal half (Fig. 6B/s1), was devoid from any processes while the second half was the spinated-like half (Fig. 6B/s2).

The setobranch setae were of one type; brush setae. The spinated-like half has many processes of scale setules of four shapes in the same gill in which each setobranch seta has only one shape of its spines with two shapes of pointed processes and two of broad process. The 1st type was a pointed-like process longitudinal rows arrangement (Fig. 7A). The 2nd type was irregularly arranged long pointed-like process, take the shape of setal outgrowths, which appears to be adapted for brushing or scraping fouling matters off the gill and filaments surfaces (Fig. 7B). The 3rd type was the transverse triangular broad-like process, which originated from the lateral and medial surface of the segmented half (spinated-like half) of the setobranch setae, while dorsal and ventral surface was smooth and devoid of any process. The segmented appearance of setobranch setae due to the presence of many clear annulus ring, in which segmented appearance of the spinated-like half of the setobranch setae with the transverse broad-like process lead to the spinated-like half take the shape of the lumbar vertebrae (Fig. 7C). The 4th irregular arrangement type was the broad multidenticulate processe (digitate scale setules or brush-like appearance), each broad-like process ended by serrated border with 8-12 small teeth processes (Fig. 7D).

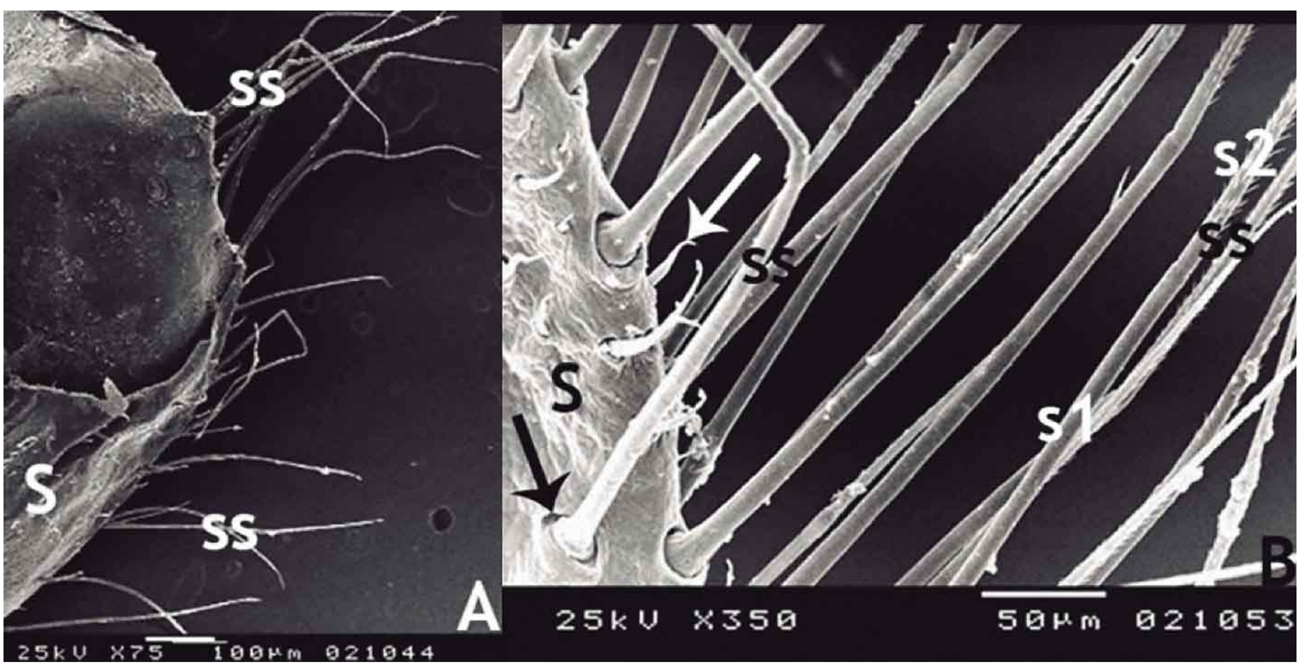

Fig. 7. SEM photographs of the setobranch of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) to show; the setobranch (S) with its spines and setobranch setae (ss) on the most basal rim of setobranch. Slide (B) is a high magnification of the setobranch to show; the setobranch setae (ss), which are surrounded by number of newly formed small setobranch setae (white arrow) which are completely smooth. The completely formed setobranch setae (ss) consists of body and basal part; the basal part of each setobranch setae is represented by round hair-like follicle which is originated from deep cuticular socket (black arrow), while the body is subdivided into two halves according the surface appearance; the smooth proximal basal region (s1), is smooth and devoid of any processes and the spinated-like distal region (s2).

Bilobed epipodal plate or Lamina or double-bladed epipods. The apical part of the bilobed epipodal plate appeared as double membranous lamina, which devoid from any filaments has body and two borders (free and attached border) (Fig. 8A and 8B). The apical part consisted of a corrugated surface and a number of transverse lobes separated by transverse grooves and was devoid of any spines (Fig. 8A and 8B/b) while its free border (Fig. 8A/fa) was serrated and carried few numbers of gill spines (Fig. 8C and 8D).

The cord-like middle part of lamina was characterized by its free border was not serrated, it carried high number of well-developed spines (if this is compared with the free border of the apical part) (Fig. 8E/fb). The presence of the high number of the gill filaments and the presence of well-developed bilobed epipodal plate on the podobranchiae, to increase the surface area of gas exchange.

DISCUSSION

Despite the recent little interest on the respiration of the decapod crustacea, particularly the poorly reported data in the morphology of thegills, especially morphological studies of the gills of the red swamp freshwater crayfish *P. clarkii*, previous published data, illustrated the morphology of the crustacean gills (Huxley) which represent the first study of the branchial complement of Astacopsis, while the first study of the Parastacoides by Clark (1936), and subsequent studies as Batang & Suzuki, (2000) on red claw crayfish (*Cherax quadricarinatus*), Lindhjem *et al*. (2000) on freshwater crayfish (*Cherax tenuimanus*), Batang & Suzuki (2003) on amphibious freshwater crab (*Geothelphusa dehaani*), Price *et al*. (1995) on marron (*Cherax tenuimanus*), Bubel & Jones (1974) on Jaera nordrnanni (Rathke), Fisher (1972) on freshwater crayfish (*Astacus pallipes Lereboullet*), and Burggren *et al*. (1974) on brine shrimp (Artemia) and on Procambarus.

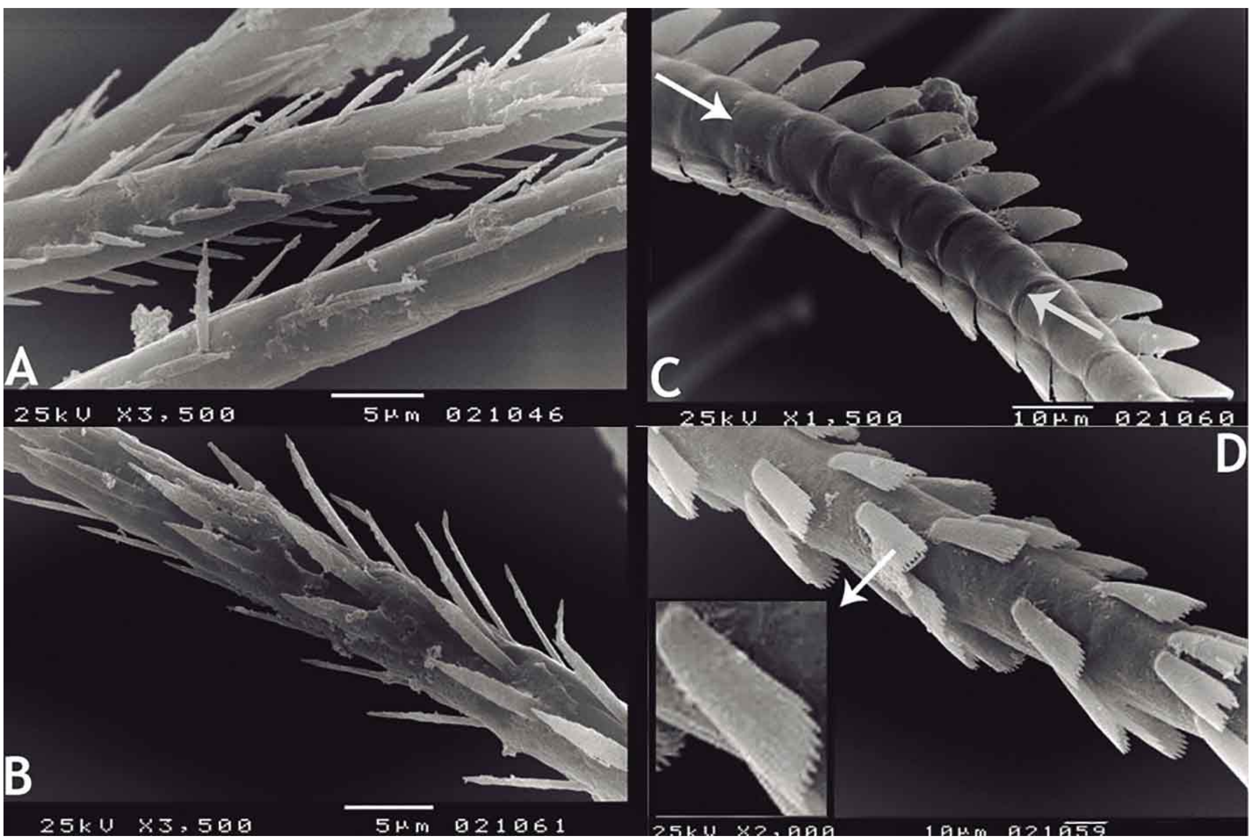

Fig. 8. SEM photographs to show the different four types of the setobranch setae of the gills of the red swamp freshwater crayfish *P. clarkii*; slide (A) to show the 1st type of the setobranch setae, pointed processes-like of longitudinal rows arrangement, in which between these longitudinal rows of pointed process-like there are rows of smooth surface without any processes. Slide (B) to show the 2nd type, the long pointed processes-like of irregular arranged, appear as the setal outgrowths. Slide (C) to show the 3rd type, the transverse triangular broad processes-like, originated from the lateral and medial surface of the segmented apical region of the setobranch setae due to presence of annular ring (white arrow). Slide (D) to show the 4th type is the broad multidenticulate processes-like (digitate scale setules or brush-like appearance), as each broad process-like was ends by serrated border with 8-12 small processes.

From available literature, it is well known that there were special anatomical characters of the respiratory adaptations of crustacea to terrestrial and amphibious life, in which the crayfish can live for weeks in burrows without free water and adapt to survive for long periods of hypoxia that occur within this burrows due to the large surface of respiratory gill area (Swain *et al*., 1988).

The present study confirmed the previous published data (Swain *et al*.; Bauer, 1989; Fleischer *et al*., 1992; Bauer, 1998; Lindhjem *et al*.) that, one of the unique features of decapod crustaceans as shrimps, lobsters, crabs and crayfishes which breath through feather-like gills. These are enclosed in two separated elongated hallow branchial chambers, the chambers being covered by the gill covering (branchiostegite) which is continuous with that of the rest of the body. From the background of available data of the gills of decapod, our study confirmed that the type, number, structure and arrangement of the gills (branchial formula) inside the two separated branchial chambers are considered as a major diagnostic feature of many decapod groups (Taylor & Taylor).

There are three classification of decapod according to the morphology of gills as noted by Barnes (1968); the first type is the phyllobranchiate (lamellar), was found in the Caridea and some anomurans and brachyurans, and by Taylor & Greenaway (1979) in amphibious fresh water crab (*Geothelphusa dehaani*). The second type is the trichobranchiate (filamentous), as in the present study and also in most macrurans, few anomurans, dromiid crabs, crayfish and shrimp (Fisher; Burggren *et al*.), but the third type is the dendrobranchiate (branched filamentous) and found in the brown shrimp, *Penaeus aztecus* (Foster & Howse, 1978). The present study showed that the trichobranchiate gills as demonstrated by Burggren *et al*. were divided into podobranchiae, arthrobranchiae, and pleurobranchiae.

Our study agrees with Swain *et al*., that the gills were consisted of a gill axis bearing uniform distributed, numerous smooth, cylindrical filaments, but our results added that this filament has two arrangement according to its position. The filaments in the middle part of the gill axis were nearly perpendicular to the gill axis while the filaments in the apex of gill axis were deflected dorsally in a plane nearly parallel to the gill axis. Our results were contrast to that reported by Lindhjem *et al*. on freshwater crayfish (*Cherax tenuimanus*) and Price *et al*. on marron (*Cherax tenuimanus*), the gill filaments were not uniformly distributed on the main stem. Moreover Foster & Howse reported that the dendrobranchiate gills of the brown shrimp (*Penaeus aztecus*) consisted of a gill axis with biserially arranged branches that subdivide into bifurcating filaments, while Barra *et al*. (1983) noted that phyllobranchiates gills of a crab acclimated to fresh water were consisting of a double row of lamellae extending laterally from a gill axis. The red swamp freshwater crayfish as all *Astacopsis* and *Parastacoides*, that the trichobranchiate gills type were composed of numerous non-branched feather-like gills filaments arising from a main gill axis, which was noted by Huxley, Burggren *et al*. and Swain *et al*.).

Scanning electron microscopic studies of the red swamp freshwater crayfish is identify some level of structural variation, particularly in theshape of the apical region of gill filaments. Our study agrees with that noted by Smith (1912) in freshwater crayfishes of Australia, that there were three morphological types of the apical part of the gill filaments: rounded, pointed, and hooked, while Lindhjem *et al*. in freshwater crayfish noted that there were four filament types: alar, hooked, pointed, and rounded. However, Swain *et al*. noted that there was only one rounded type. In addition, our study noted that by high magnification, the external surface of each gill filament appeared to be corrugated by micro-longitudinal line.

The present study reported that there was a well-developed fan-like accessory structure (bilobed epipodal plate), which appeared as double membranous lamina, in which grossly, the bilobed epipodal plate extended from the outer side of podobranchiae as triangular basal part, then extended between the two gill arch as cord-like middle part then passed under the gill axis as the apical part which lies against the thoracic body wall. Moreover, the free caudoventral and ventral border of the basal triangular part have ventrally directed epipodal laminar setae, while the cord-like middle part was devoid from any setae, Batang & Suzuki (2000) in Cherax quadricarinatus noted that, there was a wing-like laminar extension of epipods. Our study agrees with Burggren *et al*., that the bilobed epipodal plate was devoid of any filaments but, in contrast to our result Huxley and Batang & Suzuki noted that it carries filaments. In addition to this, our data by scanning electron microscope, clearly demonstrated that the first record of the apical part has a corrugated surface and consisted of a number of transverse lobes and was devoid from any spines while its serrated free border carries few number of spines. On the other hand the cord-like middle part carry high number of well-developed spines but was characterized by non-serrated free border. In our study, we related the presence of the high number of the gill filaments and the presence of well-developed bilobed epipodal plate of the podobranchiae, to increase the surface area of gas exchange.

In the present study, the presence of system of spines was the characteristic features of all gills structure on gill axis, setobranch, setobranch setae and bilobed epipodal plate, while Swain *et al*., in *Parastacidae* noted that, spines present on many of the podobranchiae, while the filaments of the podobranchiae of astacid and cambarid crayfishes do not possess apical spines. Our study agrees with Laverack & Saier (1993), that the gill spines were short, stout and conical and possessed a socket, also similar conical shape spines were reported in *Homarus gammarus* by Laverack & Barrientos (1985), while in green shore crab (*Carcinus maenas*) Goodman & Cavey (1990) noted that the gill spines are not conical but cuspidate.

Previous published data agrees with the present study that the setae are the most distinguishing feature of crustaceans and this system of setae is varying in styles, directions and designs and was absolutely ubiquitous in the group. Our results demonstrated four different types of gill setae system may have a major role in gill cleaning mechanism.

Previously published data classified the setobranch setae into four types; anchor, scale setule, simple scale setule, and digitate scale setule setae as described by Matsuokaa & Suzukib (2011), while in *G. dehaani*, Batang & Suzuki noted that the setobranch setae were of two types: anchor and brush setae. However, in the present study, there was only one type of setae, the brush setae. In the present study, the setobranch setae body was subdivided into two halves according the surface appearance; the first half was the smooth basal half, while the second half was the spinated-like half, while in dehaani Batang & Suzuki noted that the anchor setae were proximally naked, but distally bear two rows of anchor-like outgrowths. In the present study, the annulation was present in one type of the setae, which have the segmented appearance, while in *G. dehaani* Batang & Suzuki, noted that the setal shafts of anchor setae have no annulus while the brush setae bear an annulus.

Our study agrees with Batang & Suzuki, that the setobranch setae originated from deep cuticular socket (sunken basal sockets), moreover, our study added that the proximal shaft of setae appeared as a round hair-like follicle, while in G. dehaani Batang & Suzuki, noted that the proximal shaft of anchor setae was cylindrical, and slightly compressed for brush setae.

It was well known that from the previous data and the present study that, the setobranch setae was appeared as a rasping microstructure arise from setobranch, and extended up between and on the gill filaments (Bauer). In our study, the setobranch setae were classified into four types; two types of pointed-like process and two types of broad-like process; first type is pointed process of longitudinal arranged rows, and the second type is the long pointed process irregularly arranged. The third type is the transverse triangular broad-like while the fourth type is the broad-like multidenticulate process. In *G. dehaani* Batang & Suzuki, noted that the distal part of anchor setae bears two rows of anchor-like outgrowths while the brush setae have dense needle-like setules surrounding the distal shaft portion.

ABUMANDOUR, M. M. Morfología de las branquias del cangrejo rojo de pantano de agua dulce *Procambarus clarkii* (*Crustacea: Decapoda*: *Cambarids*) (Girard 1852) del Rio Nilo y sus ramas en Egipto. *Int. J. Morphol., 34(1)*:168-178, 2016..

RESUMEN: El objetivo del presente estudio fue describir las características morfológicas macroscópicas y mediante microscopio electrónico de barrido las branquias del cangrejo rojo de pantano de agua dulce. Nuestros resultados señalan que todas las branquias tienen la misma estructura y apariencia general. Las branquias se componen de ejes con numerosos filamentos similares a dedos, que tiene tres tipos morfológicos; redondo, punteado y con forma de gancho. Hay una variación en la dirección de los filamentos de acuerdo con su posición, en la parte media eran casi perpendicular al eje branquial, mientras que en el ápice fueron casi paralelas al eje. Hubo un sistema característico de espinas branquiales sobre el eje central, placa basal, espinas dorsales y sobre las placas epipodales bilobuladas. Se observaron cuatro formas de las ramas similares a espinas, dos procesos apuntados y dos procesos amplios. La placa epipodal bilobulada estaba desprovista de filamentos bajo microscopía electrónicas, su parte apical tiene una margen libre aserrado, con una superficie ondulada, mientras que la parte media no tiene margenes aserrados.

PALABRAS CLAVES: Cangrejos; Filamentos; Espinas; Espinas dorsales.

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