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STRUCTURE OF THE MALE AND FEMALE REPRODUCTIVE AND DIGESTIVE SYSTEMS OF *RHIZOGlyphUS ROBINI* CLAPAREDE (ACARI, ACARIDAE) 

BY G. T. BAKER and G. W. KRANTZ

**ABSTRACT** : The anatomy and histology of the female and male reproductive and digestive systems of *Rhizoglyphus robini* are described. The female reproductive system consists of paired ovaries and oviducts, accessory glands, oviporus, receptaculum seminalis, and terminal bursa copulatrix. Paired testes and vasa deferentia, sperm sac, ductus ejaculatoris, accessory gland and penis constitute the male reproductive system. The female and male reproductive systems are similar in their basic anatomy to those of other acarids but differences exist between *R. robini* and other species in the family Acaridae. The digestive system resembles the typical acarid form consisting of a pharynx, oesophagus, ventriculus, paired caeca and Malpighian tubules, colon, and rectum.

**RESUME** : L'anatomie et l'hystologie des systèmes reproducteur et digestif de la femelle et du mâle de *Rhizoglyphus robini* sont décrits. Le système reproducteur femelle consiste en ovaires et oviductes pairs, en glandes accessoires, ovipore, receptaculum seminalis, et une bursa copulatrix terminale. Des testicules et des vasa deferentia, un sac spermatique, un ductus ejaculatoris, une glande accessoire et un pénis constituent le système reproducteur mâle. Les systèmes reproducteurs femelle et mâle sont semblables par leur anatomie fondamentale à ceux des autres acaridides mais il existe des différences entre *R. robini* et d'autres espèces de la famille des Acaridae. Le système digestif ressemble à la forme typique des acaridides, qui comprend un pharynx, un ventricule, des cæcums et des tubes de Malpighi, un colon et un rectum.

**INTRODUCTION**

The family Acaridae is a cosmopolitan group of sarcoptiform mites found in a wide variety of organic substrates. Members of the acarid genus *Rhizoglyphus* are often associated with plants or plant products (MANSON, 1972) and occur with ornamental and vegetable bulbs in the field, in the greenhouse and in storage. *R. robini* Claparede, a common contaminant of lily bulbs in Oregon, was the subject of in-depth behavioral and anatomical studies during 1978-1982. The results of one of these studies has been published elsewhere.

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There are relatively few studies of acarid internal anatomy, probably due in part to their minute size (<1000 μm) and the consequent difficulties in application of routine histological techniques. Most of our information to date has been derived from the studies of Nalepa (1884, 1885), and Michael (1901), and from Hughes (1950), Rohde and Oemick (1967), Boczek et al. (1969), Kuo and Nesbitt (1970) and Vijayamkika and John (1975b, 1977a, c). This paper describes the anatomy and histology of the female and male reproductive and digestive systems of *R. robini*.

**Materials and Methods**

*R. robini* was maintained on an artificial medium (Bot and Meyer, 1967) in petri dishes held in a culture chamber at 24°C. For light microscopy, adult male and female mites were fixed in 10% acrolein in sodium cacodylate buffer pH 7.2 for 24h at 4°C. The specimens were dehydrated in ethanol and embedded in glycol methacrylate. A modified rotary microtome with a glass knife holder was used to cut 2-3 μm sections that were affixed to glass slides. Aqueous toluidine blue 0, and haematoxylin and eosin were employed for staining the sections. Photomicrographs were recorded on Panatomic X film using a Zeiss photomicroscope.

Mites were fixed in 2.5% glutaraldehyde, 2% paraformaldehyde, and 1% acrolein in 0.1M sodium cacodylate buffer, pH 7.2, at 4°C for 24h. The specimens were washed three times in buffer (15 min. for each change) and then post fixed in 2% OsO4 in sodium cacodylate buffer pH 7.2 for 1h at room temperature. Specimens were dehydrated in ethanol and then critical point dried. The mites were attached to aluminium stubs with silver paint and then coated with carbon and gold. An AMR 1000 scanning electron microscope was used to record the images on Polaroid P/52 or P/N 55 film.

**Results and Discussion**

**Female Reproductive System**

The female reproductive system of *R. robini* consists of a *bursa copulatrix*, *receptaculum seminalis*, paired ovaries and oviducts, oviporus and a pair of accessory glands. The *bursa copulatrix* is situated on the posterior margin of the opisthosoma, behind the anal opening. Externally it is covered by a cuticular flap (Fig. 1A, 2) while internally a short duct runs dorsally to the *receptaculum seminalis*, a sperm storage organ which illustrates its ectodermal origin in having a cuticular lining. The *receptaculum seminalis* occupies a large portion of the female opisthosoma, and is connected to the ovarial region by a short pair of ducts (Fig. 1A).

The ovary wall consists of the *peritoneum* and *tunica propria*, the latter of which projects into

![Fig. 1: Diagrammatic illustration of the female and male reproductive system of R. robini.](image-url)
Fig. 2-5: *Rhizoglyphus robini* :

2. — The cuticular flap covering the opening of the bursa copulatrix of the female. × 875. 3. — Developing ova in the female reproductive system; the star indicates immature ova while the arrow shows a mature ovum. × 1,150. 4. — Accessory gland (Ag) and ovary (OV) of the female. The rectum (R) appears in the upper right. × 1050. 5. — Section of the oviporus area of the female reproductive system; the two triangular valves an outer pair (Ovl) and inner pair (Ivl). × 1250.

The ovarial lumen and forms a stalk from which primary oogonia bud. The mature oogonia are arranged in rows on the periphery, while the maturing oogonia are located closer to the stalk (Fig. 3, arrow). The ovarial stalk eventually ruptures and releases the mature oogonia into the lumen of the ovary.

The ova are fertilized by sperm from the receptaculum seminale, and pass into the oviduct. The epithelium of the oviduct may be involved in secreting material for yolk deposition. It was observed in the sections that the mature eggs further down the oviducts have more yolk granules. The distal portion of the oviduct secretes the cho-
Fig. 6-8: *Rhizoglyphus robini*:

6. — Ventral surface of the female with extended oviporus apparatus lying between legs III and IV. × 650. 7. — Higher magnification of Figure 6, showing the triangular outer valves (Ovl) and inner valves (Ivl) and the pleated cuticular extension of these valves known as the labia (L). There are two pairs of genital acetabula (Ga). × 1025. 8. — TEM micrograph of the pleated cuticle of the labia. × 10,600.

The eggs then pass to the oviporus which consists of two pairs of cuticular valves (Figs. 5, 6, 7). A pleated membranous labia extending from the oviporal valves (Fig. 7, 8, L) expands as the eggs through it just prior to deposition. There are several pairs of muscles associated with the oviporus region and these muscles probably aid in the extrusion of the eggs (BAKER, unpublished). Two pairs of genital acetabula are associated with the oviporus region (Fig. 7, Ga); the function of these structures is unclear.

A pair of spherical accessory glands are located in the dorso-posterior portion of the opisthosoma. They lie against the body wall and are surrounded by a thin membrane (Fig. 4, Ag). The glands are divided into many sections and a nucleus is locat-
ed in the base of each cell. The ducts from the accessory glands open into the system just above the opening of the oviducts.

MALE REPRODUCTIVE SYSTEM

The male reproductive system of *R. robini* consists of a pair of testes, *vasa deferentia*, an ejaculatory duct, a penis, and an accessory gland that is also called the "chamber organ" (Fig. 1B). The testes lie on either side of the rectum and occupy the posterior portion of the opisthosoma. The testes are bound by a thin membrane and, in the central portion, each contains many small cells with deep staining, small nuclei (Figs. 9, 10). The nuclei are larger at the periphery of the testes than at the center. These spermatocytes divide, forming smaller, teardrop-shaped mature sperm.

A *vas deferens* arises from the anterior portion of each testis and extends anteriorly for a short distance. The *vasa deferentia* join together at the level of legs IV, forming a common duct which runs anteriorly to unite with the duct from the accessory gland, forming the *ductus ejaculatoris*. The walls of the *vas deferentia* are composed of flattened cells with dark staining nuclei. The male accessory gland (Fig. 11) is located in the lateral dorsal area of the opisthosoma. It was observed that males secreted a fluid during copulation in which the sperm are found (BAKER, unpublished). This fluid may be a product of the accessory gland.

The *ductus ejaculatoris* terminates at the base of the penis which is a hollow, double-walled, cone-shaped chitinous structure (Figs. 12, 13). Several pairs of muscles associated with the male genital area are responsible for the extension and retraction of the penis. A pair of copulatory suckers are located on the opisthogaster on either side of the anal opening (Figs. 12, 14). These suckers, along with the modified setal suckers on tarsi IV (Fig. 15), assist the male in holding the female during copulation.

The basic structural plan of the male and female reproductive systems of *R. robini* is similar in many ways to other acarids but there are several aspects in which the reproductive system differs from other acarids. NALEPA (1884, 1885) and ROHDE and OEMICK (1967) described a pair of prochorion and chorion sacs that are associated with the ovaries of *Tyroglyphus* and *Caloglyphus* spp. These ovarian structures are absent from the female reproductive system of *R. robini*.

Accessory glands are not present in the female reproductive system of *Lardoglyphus konoi* (Sasa and Asanuma) and *Aleuroglyphus ovatus* Troupeau (VIJAYAMBIKA and JOHN, 1975b, 1977c). These glands are found in *Caloglyphus mycophagus* (Megin) (ROHDE and OEMICK, 1967, KUO and NESBITT, 1970) and are similar to the accessory glands in *R. robini*. The male accessory gland of *R. robini* is histologically and anatomically similar to other acarids but *L. konoi* is the only acarid in which two accessory glands are associated with the male reproductive system (VIJAYAMBIKA and JOHN 1975b).

Various functions have been ascribed to the genital acetabula associated with the oviporous region. MICHAEL (1901) considered the acetabula to be some sort of copulatory suckers while HUGHES and HUGHES (1939) and KUO and NESBITT (1970) referred to the genital acetabula as mushroom-shaped sense organs that are involved in oviposition. Sense organs must have neural connection and neural connections to the genital acetabula of *R. robini* are absent. VERCAMMEN-GRANDJEAN (1975) considered the genital acetabula in oribatid and actinedid mites to be involved in respiration, while ALBERTI (1979) showed that the acetabula are involved in osmotic regulation in water mites and in water uptake in Bdellididae, a terrestrial actinedid family.

DIGESTIVE SYSTEM

The digestive system of *R. robini* (Figs. 16, 17) consists of a pharynx, cesophagous, ventriculus, a pair of lateral caeca, a pair of Malpighian tubules, colon and rectum. The pharynx (Figs. 17, 17a) is a short, invaginated ectodermal tube lined with a thin sheet of cuticle. Several groups of muscles are attached to the roof of the pharynx and insert
9. — A phase-contrast micrograph of a transverse section of the male testis (T). × 675. 10. — Higher magnification of Figure 9 showing the variation in the size of the cells in the testis (T). × 1950. 11. — A phase contrast micrograph of the male accessory gland or chamber organ. × 1800.
FIG. 12-15: *Rhizoglyphus robini*:

12. — SEM micrograph of the ventral surface of the male of *R. robini* showing the genital region (GR) lying between legs IV, the anal region (AR) posterior to the genital region, and the copulatory suckers (CS).  × 350.  13. — The penis (Pn) of the male lying in the genital sheath.  × 1225.  14. — Higher magnification of Figure 12 showing the genital region (GR), the anal region (AR) and the copulatory suckers (CS).  × 975.  15. — Modified setae on legs IV of the male, used as suckers for clasp­ing the female during copulation.  × 1750.
on the labrum. These muscles act as a pharyngeal pump that forces the food posteriorly into the oesophagus and ventriculus.

A valve at the junction of the pharynx and oesophagus prevents the re-entry of food into the pharynx. A similar type of valve occurs in Glycyphagus domesticus (Hughes and Hughes, 1939) and in Caloglyphus mycophagus (Kuo and Nesbitt, 1970). The oesophagus, like the pharynx, is lined with a cuticular sheath, and passes through the central nervous mass. As the oesophageal leaves the mass posteriorly, it begins to widen until it reaches the ventriculus.

The ventriculus of R. robini is an oval-shaped pouch about 250 μm long and 100 μm wide. There are two types of cells comprising the ventricular lining of the stomach (Fig. 18). The squamous cells (Sc) have a dark staining nucleus and a basophilic cytoplasm, while the cuboidal cells (Cc) are heavily vacuolated and project into the lumen of the stomach. The cytoplasm is faintly basophilic and contains many crystalline granules. The cell nucleus is located in the base of the cell. The vacuolated portion of the cuboidal cells buds off during feeding, and may be found in the lumen of the ventriculus (Fig. 18).

The gastric cæca arise from the lateral walls of the ventriculus and are approximately 275 μm long and 75 μm wide. The cæcal lining consists of a single layer of cells with three cell types. Two of these, i.e. squamous and cuboidal, are similar to those found in the ventriculus (Fig. 19). The third type of cell is globular (Gc), with the cytoplasm and nucleus confined to the basal portion of the cell, and the globular portion projecting into the cæcal lumen. The globular portion
18. — A section of the ventriculus showing the cuboidal cells (Cc) and squamous cells (Sc) composing the lining of the midgut. The star is a budded off cuboidal cell.  \( \times 2050 \). 19. — A section of the caecum with three types of cells making up the caecal lining, cuboidal cells (Cc), squamous cells (Sc) and globular cells (Gc). The cuticle (C) may also be seen.  \( \times 1876 \). 20. — A phase-contrast micrograph of the globular cells (Gc) with their larger vacuole.  \( \times 2950 \). 21. — A section showing the cells lining the rectum; squamous cells (Sc) and conical cells (Cnc) have a brush border (BB) and the food bolus (FB) may be seen in the rectal lumen.  \( \times 1300 \). 22. — A high magnification phase contrast micrograph of the rectal squamous cells (Sc) with their brush border (BB). The caecal squamous cells (Csc) may also be seen.  \( \times 3100 \). 23. — The lining of the Malpighian tubules (MT) showing the brush border (BB). The rectum (R) appears on the right side of the photograph.  \( \times 1425 \).
contains one large membrane-bound vacuole that extends into the caecal lumen (Figs. 19, 20).

The colon of *R. robini* is about 75 μm long and 40 μm wide and extends from the posterior aspect of the *ventriculus* to the rectum. The colon lining consists of tall columnar and squamous cells. The nuclei of these cells are located in the basal portion; the cytoplasm is strongly basophilic. The columnar and squamous cells have a brush border which increases the surface area (Fig. 17c). The rectum is an oval-shaped entity which is about 120 μm long and 40 μm wide in the adults of *R. robini*. The columnar cells (Cnc) of the rectum are more conical than those found in the colon (Fig. 17d, 21). The nucleus of each cell is located basally and the cytoplasm is basophilic as is the case with the columnar cells in the colon. The squamous cells are similar to those of the colon but the brush border (BB) of the rectal cells is more dense than that of the cells in the colon (Figs. 17d, 21, 22). The rectum terminates at the anal opening on the posteroventral surface of the opisthosoma.

*R. robini* has a pair of Malpighian tubules that arise from the dorsolateral surface of the *ventriculus* near the junction of the stomach and colon. The tubules are approximately 225 μm long and 30 μm wide and consist of small squamous cells with a brush border (Fig. 23).

*Kuo* and *Nesbitt* (1970) described three cell types in the *ventriculus* of *C. mycophagus*. *R. robini* has only two types of cells, a condition which is similar to that described in other acarids. The caecal lining, however, consists of three cell types. *Baker* (1975) showed that the cuboidal and gobular cells in the caeca of *Histiogaster carpio* (Kramer), which are similar to those in *R. robini*, contain alkaline and acid phosphatase, and that these enzymes are involved in the breakdown of ingested food particles.

The cells lining the colon and rectum of *R. robini* resemble those in other acarids. *Hughes* (1959) and *Baker* (1975) considered the colon and rectum to be sites of water absorption. The Malpighian tubules associated with the digestive system of *R. robini* are present in some acarids (absent in *A. ovatus* (Vijayambika and *John* 1977a)), and function as excretory organs (Hughes, 1950, 1959).

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