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Grooming Behavior and a Possible Morphological Structure for Secretions from Abdominal Glands of a Korean Wood-eating Cockroach, *Cryptocercus kyebangensis* (Insecta: Blattodea)

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ABSTRACT

Cryptocercus nymphs periodically groom ventral surface of their parents. The grooming might be licking-behavior to obtain secretions from the ventral surface of their parents, and some essential nutrients or hormones that facilitate nymphal development might be included in the secretions. We tried to find morphological structures for secretion outlets on the ventral surface. The deep depressions around setae were present, and their shape was an external morphological structure that liquid secretions from internal glands are likely to be well seized. There were also small holes on the depressions that might be external openings for secretions from the sternal glands. Another possible region on body surface for outlets of secretions might be the apophyses. In *Cryptocercus* individuals, mucous liquid on body surface was relatively highly present around coxa. The intercoxal apodemes, to which muscles are attached and which open externally between the mid and hindcoxae, might have evolved a secondary function of producing nourishment for the young.

Key words: Grooming behavior, *Cryptocercus*, sternal gland, coxa, apodemes

INTRODUCTION

Subsociality of wood-eating cockroaches *Cryptocercus* is peculiar and one of classical topics to understand insect social evolution, especially in termite sociality, because of some interesting life historical characteristics not observed in other subsocial wood-eating cockroaches (Liechti and Bell, 1975; Roth, 1981; O'Neill et al., 1987; Matsumoto, 1988, 1992). *Cryptocercus* is distributed in temperate forests (Bey-Bienko, 1950; Scudder, 1862; Nalepa et al., 1997, 2001; Burnside et al., 1999; Grandcolas, 2000; Grandcolas et al., 2001; Park et al., 2002; Park and Choe, 2003a). Distributions of *Cryptocercus* cockroaches are limited to some high mountainous forests in Northeast Asia (South Korea, Manchuria and eastern Russia), West China and North America (Cleveland et al., 1934; Bey-Bienko, 1950; Nalepa, 1984; Nalepa et al., 1997; Burnside et al., 1999; Grandcolas et al., 2001; Park et al., 2004). There are four Asian species currently recognized. *Cryptocercus primarius* and *C. matilei* are found in Sichuan Province, West China (Bey-Bienko, 1950; Grandcolas, 2000) and *C. primarius* was also recently rediscovered in two forests within the Hengduan Mountains of the northwestern Yunnan Province, West China (Nalepa et al., 2001). *Cryptocercus relictus* is found in Russia (Ussuri region and Siberia) and eastern Manchuria (Bey-Bienko, 1950). Grandcolas et al. (2001) recently described a new Asian species, *C. kyebangensis* from South Korea. In the Nearctic, there are five species of a species in northwestern US (*C. clevelandi*) and four species in eastern US (*C. punctulatus, C. wrighti, C. darwini* and *C. garciai*). Despite the geographical disjunctions, their distribution is restricted within the limited-zone of only temperate forests.

Wood-feeding cockroaches of the genus *Cryptocercus* are very special among cockroaches because of their unusual life history. *Cryptocercus* cockroaches is the only known oviparous cockroach with well-developed parental care and to show nesting behavior (Ritter, 1964; Seelinger and Seelinger, 1983; Nalepa, 1984; Park et al., 2002). Especially, since the xylophagy shown in *Cryptocercus* is not common in cockroaches, it has long been considered as a trait associated to their social behavior and to gut flagellate symbiosis (Cleveland et al., 1934; Seelinger and Seelinger, 1983; Nalepa, 1984, 1988, 1994). In addition to xylophagy, a pair of *Cryptocercus* adults lives with their offspring over an extended period (Seelinger and Seelinger, 1983; Nalepa, 1984; Park et al., 2002; Park and Choe, 2003b). Woodroaches of the genus *Cryptocercus* is also well known

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because of its proctodeal feeding behavior. Previously, proctodeal feeding behavior has been well described in a North American species, *C. punctulatus* (Cleveland et al., 1934; Seelinger and Seelinger, 1983; Nalepa, 1984). *Cryptocercus punctulatus* adults provide essential nutrients and symbiotic gut protozoa to their young via proctodeal feeding behavior (refer to Nalepa, 1984).

Since the proctodeal materials appear to contain some nutritious materials and the gut protozoa are required in the early stages of nymphal development (Nalepa, 1990), it is apparent that requirement of proctodeal feeding may cause the obligatory association between adults and their young at the early stages of nymphal development (see Cleveland et al., 1934; Nalepa, 1984), resulting in the evolution of subsociality in *Cryptocercus* spp. (Cleveland et al., 1934; Seelinger and Seelinger, 1983; Nalepa, 1984). Thus, the studies on *Cryptocercus* social behavior have been mainly focused on the role of proctodeal trophallaxis, depending on the proctodeal feeding (Cleveland et al., 1934; Seelinger and Seelinger, 1983; Nalepa, 1984, 1988).

While a *C. punctulatus* provides proctodeal feeding to its offspring, young nymphs gather in semicircle around the adult's anal (Seelinger and Seelinger, 1983). According to Park et al. (2002), young nymphs of *C. kyebangensis* show enthusiastic grooming behavior around adult anal in semicircle position. The proctodeal materials were provided to their offspring in semicircular position by form of liquid droplets.

In this paper, we present a different pattern of grooming behavior displayed in a Korean *Cryptocercus*, *C. kyebangensis*. The Korean *Cryptocercus* nymphs displayed licking-behavior grooming on abdomen surface as well as the semicircular feeding behavior previously described (Seelinger and Seelinger, 1983; Park et al., 2002). If the grooming of abdominal surface is licking behavior to obtain liquid materials secreted from adult's abdominal glands, there might be likely morphological structures for secretion outlets. We examined whether fine morphological structures for the secretion outlet occur on the external body surface of *Cryptocercus*.

MATERIALS AND METHODS

Collection

Colonies of wood-feeding cockroaches *C. kyebangensis* were collected from rotting logs in Gygbang-san, Gangwon province, South Korea (40 km northeast of Seoul), during late-mid October 2000. All the connecting chambers in a gallery system were opened with a hammer and wood chisel. All roaches that were found in the connecting chambers were considered to be a family unit (Fig. 1). These field-caught *C. kyebangensis* woodroaches were maintained in transparent artificial chambers, a round plastic case 7 cm in diameter and 1 cm in depth. The chambers were provided with rotten woody fragments of the original logs from which the cockroaches were collected.

Fig. 1. Nesting behavior of *C. kyebangensis* adults. A pair of *Cryptocercus* adults and their young live in complex system of woody galleries in rotten logs in the temperate forests.

Laboratory Observation

The artificial chambers containing the cockroaches were kept in a 12 : 12 h light:dark cycle at 22-25°C. During preliminary tests, the behavioral patterns of cockroaches did not appear to differ between day and night. Thus, observations of behavior were performed during the period of 13:00-16:00 hours for one week. Cockroaches of two families were used for observations of behavior. Most nymphs are composed of 3rd and 4th instars. The cockroaches were allowed to accustom themselves to the artificial chambers for at least 1 week before any experiments or observations were started.

Morphological Examination

For the SEM examination, a female adult specimen was fixed for 12 h in 2.5% glutaraldehyde in 0.1 M phosphate buffer, washed in buffer, postfixed for 12 h in 2% osmium tetroxide in the same buffer, dehydrated in a graded series of ethanol solutions. The specimen was mounted on stubs, coated with gold using an ion coater (Eiko Model IB-3), and examined with an SEM (Akashi Model SR 50A) operated at an accelerating voltage of 15 KV.

RESULTS AND DISCUSSION

The current study includes some patterns of nymphal grooming behavior that is unknown to date in the genus *Cyptocercus* species. During our laboratory observations,

the Korean *Cryptocercus* nymphs display the behavior grooming on abdomen surface of their parents (Fig. 2), as well as the anal feeding behavior previously described (Seelinger and Seelinger, 1983; Park et al., 2002). Mean numbers of the abdominal grooming behavior per day (13:00-16:00) were 2.16 (1.2SD, n=7) and 2.76 (1.8SD, n=7) in both families during the observations, respectively. Such the behavior is uncertain whether to obtain some liquid secreted from body glands of their parents, or whether to stimulate the adults' physiological system for facilitating parental anal secretion or other caring to be enforced. Cockroachs' abdomen includes various sternal glands required for multifunctional system, like tergal feeding (Farine et al., 1989), communication and sexual pheromone (Barth, 1970; Sreng, 1993). Cockroaches of *Blatta orientalis* and *Periplaneta americana* discharge secretions for sex attraction, aggregation and trail pheromones from the sternal glands (Ishii and Kuwahara, 1968; Barth, 1970; Krivosheina and Shatov, 1995). Ventral abdominal glands of *Eurycotis floridana*, which is a flightless cockroach ranging from the South-East United States to the Caribbean (Brenner and Pierce, 1991), secrete defense allomone (Turnbull and Fashing, 2002). The species has a large abdominal gland which opens at the midline between the sixth and the seventh sternites and is functional only in adults. The secretion is biphasic, consisting predominantly of a very complex organic phase and an aqueous phase present in small quantities (Farine et al., 1997).

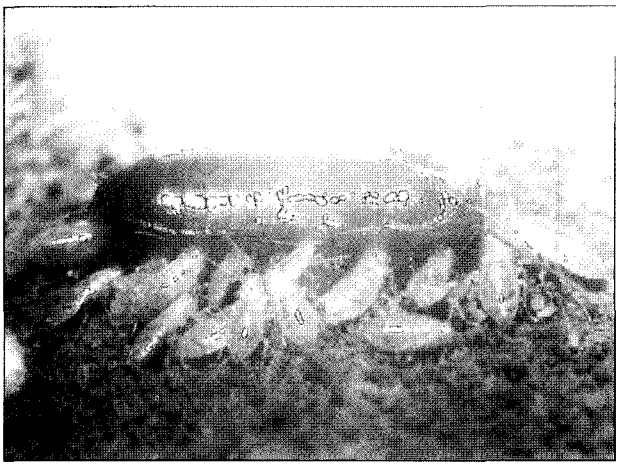

Fig. 2. Nymphs licking on the abdominal surface under the abdomen of an adult. Nymphs appear to lick around coxal areas or intercoxal areas as well as ventral surface. In addition, nymphs licking around joints between dorsal and abdominal sternites.

In the case of *Cryptocercus*, if the grooming behavior is to obtain some secretions from the abdominal surface of their parents, there might be differentiated morphological structures on the abdominal surface. The abdomen houses most of the visceral organs, including components of the digestive, excretory and reproductive systems, and they are protected by dorsal and ventral sclerites. The typical structure of a cockroach integument comprises three principal layers (Mills, 1981): the epidermis, the basement membrane below the epidermis and the cuticle outside of the epidermis that is secreted by the cells of the epidermis. The cuticle is a chemically complex layer, not only differing in a structure from one species to another, but also even differing in its

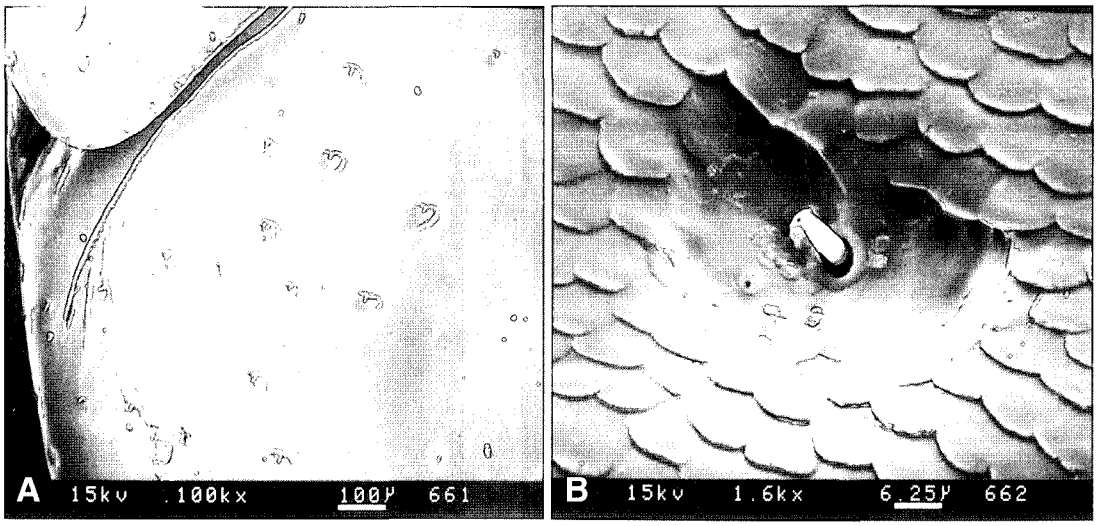

Fig. 3. Fine morphological structure in the abdomen surface of *C. kyebangensis*. Setae and morphological structures around them on the abdominal surface of a *C. kyebangensis* adult (A) and the fine morpholgical structure of them (B).

characteristics from one part of an insect to another (Rodriguez et al., 2004). In the examinations of body surface, an interesting fine morphological structure was observed around setae on body surface. Setae, body hairs, are sclerotized hairlike projections of cuticula arising from a single trichogen cell and surrounded at the base by a small cuticular ring. In *C. kyebangensis*, the abdominal sterna are lined with roughly regular patterns of scales (Fig. 3A). Setae are distributed mainly on marginal edges of abdominal sternites (Fig. 3A). Around a seta, several scales appear not to be differentiated and remained in fusion, forming a depressed disc structure of a little irregular round shape (Fig. 3B). Small holes also occur on the depressed disc. Since a little projection of a hairlike seta was observed in a tiny hole in one of the depressed discs on the abdomen surface, the hole may be simple outlets used for the protruding setae. However, functional roles of the holes might be possible for the outlets of secretions as well. Shape of the depressed discs might be the external morphological structure that liquid secretions from internal glands are likely to be well seized. The morphological characteristics drive us to infer a likely scenario to explain the abdominal licking behavior. In the depressed round-shape discs, holes without setae are relatively very small sizes than those in projection of a seta, and the holes are likely too small to function as the setal outlets. Thus, a possible inference of its function might be external openings for secretary materials from the sternal glands rather than only the seta outlets. Further studies have to be conducted for any possible relations between the holes in the discs and internal glands in the morpho-anatomical aspects.

Another possible region on body surface to be outlets of secretions is the apophyses. In ovoviviparous cockroach *Perisphaerus* species (Roth, 1981), nymphs cling to the undersurface of the mother for at least two instars. Since these small nymphs are blind, obtaining their nourishment appears to be dependent on their mother. *Perisphaerus*'s apophyses, to which muscles are attached and which open externally between the mid-and hind-coxae, may have evolved a secondary function of producing nourishment for the young. The apodemes between femur and tibia, which joins between the two, are also opened externally as well. The morphological structure like intercoxal apodemes and apodemes are well not studied in *Cryptocercus*, as in *Perisphaerus*. However, observations of the grooming behavior (Fig. 2) indicate that presence of such the morphological structures could be possible.

In *Cryptocercus* individuals maintained in artificial chambers, mucous liquid on body surface was relatively abundantly present around coxa rather than other areas. When the abdominal surface of adults was examined, semi-opaque mites occurred in various regions on adult body surface, with their body soaked in mucous liquid, and appear to feed on mucous materials secreted out from body. Especially, most of mites are highly distributed around coxa, narrow grooves between intercoxa and joints between femur and tibia. Mites also occurred highly on soft membranes connecting abdominal sternites and combining dorsal and abdominal sternites. Such the distributions of mites are highly related to the grooming areas of *Cryptocercus* nymphs. If the areas might be related to the secretion, nymphs appear to obtain some secretions via the grooming behavior on the joint areas.

The symbiotic gut protozoa which are required at early stages of nymphal development must be transferred via proctodeal feedings since the gut protozoa have been seized within adults' mid-gut. Thus, if the abdominal grooming behavior of young *Cryptocercus* is to lick some mucous materials, young nymphs are likely to obtain some nutrients or hormones for facilitating nymphal development, like protein and ecdysteroid secretory products from prothoracic glands which function to promote the series of molts, as known in *Periplaneta americana* (Richter and Baumann, 1997).

CONCLUSIONS

The current study includes nymphal grooming behavior on adult abdomen that is unknown to date in *Cyptocercus* species. During our laboratory observations, the Korean *Cryptocercus* nymphs display the behavior grooming on abdomen surface of their parents, as well as the previously described anal feeding behavior. Such the behavior is uncertain whether to obtain some liquid secreted from body glands of their parents, or whether to stimulate the adults' physiological system for facilitating anal feeding or other caring to be enforced. If the nymphal grooming is liking-behavior to obtain materials secreted from the visceral glands in adult abdomen, young nymphs appear to obtain some essential material, like nutrients or hormone required for their development via the grooming. A few morphological structures, like holes present on the irregular-depressions of ventral surface, or intercoxal apodemes, might function as outlets for the materials secreted from internal glands.

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