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〈Report〉

Biology of *Platydema nigroaeneum* Motschulsky (Coleoptera: Tenebrionidae) from Korea: Life History and Fungal Hosts

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ABSTRACT: We conducted field and laboratory observations of the life histories and fungal hosts of the darkling beetle, *Platydema nigroaeneum* Motschulsky. *P. nigroaeneum*, a fungivorous tenebrionid beetle, was a widespread inhabitant of fungi on deciduous trees (*Quercus*, *Salix*, *Alnus* and *Carpinus* etc.) in Korea. Development from egg to adulthood took 4～11 months in nature and about 66 days in the laboratory at 25.5～26.1℃ and 63.5～64.5% relative humidity. Both larvae and adults overwintered in their host fungi or beneath the bark of the host tree near the host fungi. Sporophores of *Coriolus* Quélet, *Bjerkandera* Karst., *Daedaleopsis* Schroet. and *Merulius* were common feeding and breeding sites in Korea.

Key words: Host fungi, Korea, Life history, *Platydema nigroaeneum*, Tenebriondae

INTRODUCTION

Fungi of the order Aphyllophorales, especially the woody and perennial forms, provide microhabitats in which many arthropod species spend their entire lives (Klimaszewski and Peck 1987, Leschen 1990). These fungi provide their inhabitants with food, shelter, and breeding places either directly or indirectly (Graves 1960). The fungivorous tenebrionids, which spend their whole lives in the sporophores associated with dead trees, play an important role in their forest communities (Jung et al. 2007).

It is difficult to study the ecology of fungivorous tenebrionids and other fungivorous beetles because they usually feed on the same sporophores until the fungi are completely destroyed and they also breed in the fruiting bodies of fungi, concealing their life histories. Thus, the biology of mycophagous tenebrionoids is poorly understood, although there have been several studies of their life histories and larval development stages (e.g., Lily 1956, Kompantseva 1987a, Leschen 1990, Nadovornaya and Nadvornyy 1991).

Platydema nigroaeneum Motschulsky, a fungivorous tenebrionid in the tribe Diaperini (Coleoptera: Tenebrionidae), is common in Korea, and is found in various habitat types from mountain forests to urban gardens. *P. nigroaeneum* is morphologically recognized by its oblong-oval body with a shiny, convex dorsum, and its head with a pair of straight horns in males and a pair of blunt tubercles in females (Kim and Jung 2005). This species is associated with host fungi, generally Aphyllophorales but rarely Agaricales, throughout its life span (Kim and Jung 2005, Jung 2008).

The purpose of this study was to describe the biological characteristics of Korean *P. nigroaeneum*, and to provide comprehensive information on *P. nigroaeneum* life cycles and host-fungi relationships by rearing *P. nigroaeneum* in the laboratory and observing it in the field. This study is the first research on mycophagous tenebrionids associated with fungi in Korea. We provide a description of *P. nigroaeneum*'s life history, fungal hosts, and developmental characteristics.

MATERIALS AND METHODS

Sampling

We collected 212 fruiting bodies of fungi associated with *P. nigroaeneum* from 2005 to 2007. To collect material effectively, we removed the host fungi from the substrate on the forest- floor with cloth or vinyl cloth and quickly transferred them into vinyl bags and sealed the bags. Eggs, larvae, and adults found on the fungi were brought to the laboratory and transferred to plastic containers (30 × 25 × 20 cm) or zippered vinyl bags, which were covered with black cloth to maintain darkness, and were subsequently sorted, identified, counted, and reared.

Identification of Fungi

Host fungi collected for this study were identified using several illustrated mushroom books (Lincoff and Nehring 1981, Breitenbach and Kränzlin 1986, Imazeki and Hongo 1987, 1989, Lee 1988, Kim et al. 2004) with the assistance of a mushroom taxonomist, Dr. Seok S. J. (NIAST).

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Rearing and Observation

P. nigroaeneum was reared in the laboratory in petri dishes (diameter = 9 cm, height = 1.5 cm) at room temperature (25.5～26.1℃) and at a relative humidity of 63.5～64.5%, and provided with pieces of the host fungus. Behavioral and developmental observations were made in the petri dishes. Head width and body length of specimens were measured using an ocular grid micrometer. Field observations were also carried out once a week from April to August of 2006 in the Kildong Ecological Park, Seoul. We observed the behavior and development of *P. nigroaeneum* in host fungi associated with rotten trees in the forest, and collected specimens and cast exuviae, which were then preserved in 70% ethanol and dry-mounted and deposited in Sungshin Women's University Insect Collection (Seoul, Korea). We used a Stereomicroscope (MZ APO; Leica, Switzerland), a digital camera (Nikon D 200, Japan), and a thermometer (Extech 4465CF) for measurements.

RESULTS AND CONCLUSION

The Egg Stage

Freshly laid eggs (n = 10) were 0.1～0.2 mm (mean = 0.15 mm) in length and 0.05～0.06 mm (mean = 0.05 mm) in diameter, oval or oblong in shape, opaque white in color, and had a smooth, shiny surface. Egg development under laboratory conditions lasted 3～5 days (Table 1).

Larvae and Feces

The Larval Stage

Most larvae passed through 4 instars, or rarely 3 or 5 instars. The body length of newly hatched instars (n = 10) averaged 1.8 mm, and the head capsule averaged 0.2 mm in width. The size of the last instar was an average of 11.25 mm in length and 0.98 mm in head width (Table 2). The larval stage took about 41 days in the laboratory: the first larval stage took 8～10 days (mean = 9 days), the second larval stage took 9～11 days (mean = 10 days), the third larval stage took 9～13 days (mean = 12 days), and the last larval stage took 11～12 days (mean = 12 days; Table 1). The early first instar does not feed, is not sclerotized in its mouthparts, and the inner part of its body ranges from transparent to visible. The last instar is cylindrical in shape (Fig. 2) and strongly sclerotized on its surface, with a well-developed anal tube in the ninth abdominal tergite. After hatching, *P. nigroaeneum* in the first instar remained under the egg capsules for a while before moving into the fruiting body, after which they moved freely and actively in the fruiting body. While molting, instars of each developmental stage moved rapidly and fed during the trophokinsese period and moved slowly, did not feed, and evacuated food residues during the apolysis period. The post-molting period was characterized by a pale color and less sclerotization (Fig. 2).

Feces

Larvae principally lived and fed in the hymenium of the fruiting body. After feeding, larvae produced hair-like filament-feces about 0.2 mm in diameter and over 10 cm in length that formed a 3-dimensional mass. As a result, the host fungi of *P. nigroaeneum* became densely covered with filament-feces, which were produced through all larval stages. We examined feces of *P. nigroaeneum* that had been fed the host fungus *Daedaleopsis tricolor* (Bull.: Fr.) Bond. et Sing. under the optical microscope and did not detect spores and clamps of the hyphal structure in the feces. This suggests that *P. nigroaeneum* larvae may have selected sterile structures rather than fertile hymenium including spores (Fig. 1). Their dung resembled the color of their host fungi: they produced the brown feces after feeding on *D. tricolor* and pink feces after feeding on *Merulius tremellosus* Fr. The filamentous feces might confuse predators and

Table 1. Average developmental period of *P. nigroaeneum* under laboratory conditions from early June to early August, 2006

Stage	Egg	Larval stage				Prepupa	Pupa	Pigmentation	Life cycle (d)
		1st	2nd	3rd	4th				
Duration (days)	4	9	10	11	11	4	9	8	66

Table 2. Size of each larval and pupal stage of *Platydema nigroaeneum* (N = 10)

	Larval stage				Pupae
	1st	2nd	3rd	4th	
Body length (mm)	1.83 ± 0.06	3.47 ± 0.46	8.50 ± 1.00	11.25 ± 0.87	6.20 ± 0.20
Head width (mm)	0.20 ± 0.10	0.27 ± 0.12	0.85 ± 0.10	0.98 ± 0.17	3.90 ± 0.10

at the same time create a 3-dimensional medium into which the agile *P. nigroaeneum* larva can escape, as well as a barrier to entry for other insects, thus restricting competition for food and space in the chamber (Borden et al. 1969).

The Pupal Stage

Prepupae

The C-shaped prepupal body was smaller than the last instar, and developed in the laboratory for 3～5 days (mean = 4 days; Table 1). *P. nigroaeneum* prepupae rarely moved, and did not feed. If touched, they stretched their C-shaped bodies and then twisted from side to side and shook violently.

Pupae

The body size of pupae ranged from 6.0～6.5 mm in length (mean = 6.2 mm, $N = 10$; Fig. 2), and their development in the laboratory took 8～10 days (mean = 9 days). Pupae did not move or feed, but if disturbed, they became very active, rapidly rotating clockwise and counter-clockwise and thrashing their abdomens. With the approach of eclosion, their eyes, mouth parts, elytra, tarsal claw and pronotum developed a dark brownish tinge and became visible through the integument.

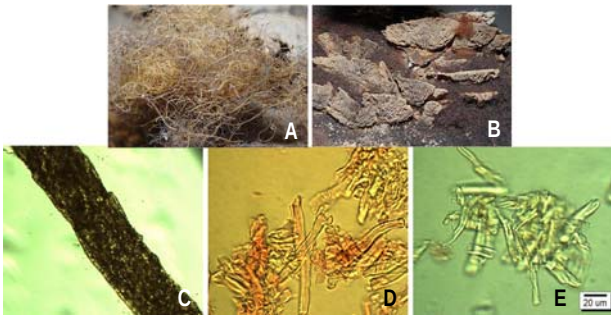


Fig. 1. Feces of *Platydema nigroaeneum.*
A: After feeding on *Merulius tremellosus*, B: After feeding on *Daedaleopsis tricolor*, C～D: After feeding on *Daedaleopsis tricolor* (20 um), E: After feeding on *Bjerkandera adusta* (20 um).

Fig. 2. *Platydema nygroaeneum.*
A: After molting, B: Last instar, C: Pupae in the dung, D: Imago, E: Adults.

The Adult Stage

Imagines

Young adults emerging from pupae were pale with a soft integument and gradually became yellowish-brown, reddish- brown and then shiny and black (Fig. 2). Normal sclerotization and color were acquired within 7～9 days (mean = 8 days; Table 1). During this period, they usually remained in the area of overlap of the host fungi and the mass of filament-feces. If disturbed, they rapidly retreated and hid in a dark place.

Mating and Oviposition

We were unable to observe mating patterns in detail or to determine the number of eggs deposited during a season in nature because reproductive events were concealed in fungal fruiting bodies. The occurrence of fungi at any time of the year and the concurrent collection of instars of different larval stages suggests that *P. nigroaeneum* mate and deposit eggs repeatedly during the season. Mating was first observed in April～May in nature, while in the laboratory, *P. nigroaeneum* copulated year-round. Most mating occurred at night in this nocturnal species, but mating also occurred in daytime under overlapping fungi, in the bottom of fungi, and in crevices in the tree bark attached to the fungi. In the laboratory, *P. nigroaeneum* copulated for a few minutes in dark areas formed by overlapping fungi. After mating, they deposited their eggs in fungal tissue one at a time. We dissected *P. nigroaeneum* ovaries and found 15～23 eggs.

Ecological Characteristics

Overwinter

P. nigroaeneum was observed overwintering in both the larval and adult stages in rotten wood and beneath the bark attaching fungal fruiting bodies and mycelia to trees. Overwintering larvae and adults were collected beginning in late October to November in 2005～2007 in Gyeonggi-do province (Table 3).

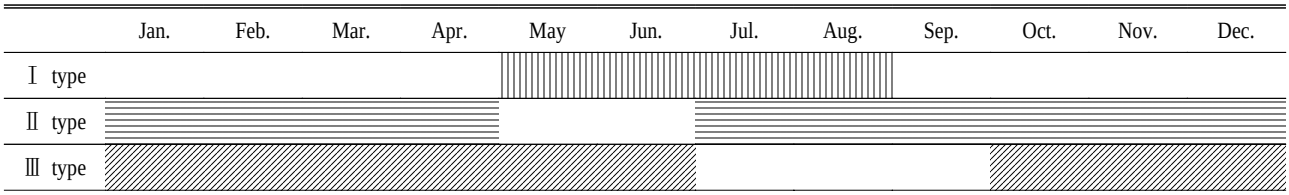
Generation time

Development from egg to adulthood in nature took 4～11 months and developmental patterns could be classified into three types. Overwintering adults took about 4 months to complete their development

Table 3. Observation of overwintering *Platydema nigroaeneum*

Date	Distribution	Host fungi	Host tree	Life stage
21-10-2006	Donggureung, Guri-si, Gyeonggi-do	*Bjerkandera adusta*	*Carpinus laxiflora*	Adult/Larvae
24-10-2006	Gwangreung, Namyangju-si, Gyeonggi-do	*Bjerkandera adusta*	*Carpinus laxiflora*	Adult/Larvae
30-10-2006	Donggureung, Guri-si, Gyeonggi-do	*Bjerkandera adusta*	*Carpinus laxiflora*	Adult/Larvae
31-10-2006	Mt. Yongmunasn, Gyeonggi-do	*Bjerkandera adusta*	*Alnus japonica*	Adult
01-11-2006	Jije-myeon, Gyeonggi-do	*Daedaleopsis congragosa*	*Alnus japonica*	Adult/Larvae

Table 4. Larval stage of *Platydema nigroaeneum*



(type Ⅰ, Table 4), while individuals hatching from the spring eggs of overwintering larvae took 11 months to complete their development (type Ⅱ, Table 4). Finally, larvae hatching from early summer eggs deposited by overwintering larvae took 10 months to complete their development (type Ⅲ, Table 4). In the laboratory, development from egg to adulthood took about 66 days.

Habits

Instars of all larval stages freely moved around the fruiting bodies of fungi without forming chambers and tunnels. They rapidly moved back and forth in the fruiting body while developing an anal tube on their abdominal tergite. When disturbed, they shook violently and fled to dark places in their host fungi or the fecal mass. Dung of adults is granular, while larval dung forms a filament. Adults and larvae display negative phototropism and have cryptic lifestyles, preventing detailed observation of their lives.

Behavior. Pupae were observed feeding on larvae in laboratory cultures, and multiple adults typically colonized the same host fungus. We recorded an average of 8 individuals per 2.5 × 4 cm section of fungus (n = 15) from the bottom of fruiting body. *P. nigroaeneum* was nocturnal, and was most active and frequently observed feeding and mating from 8:00 pm to 4:00 am. During the daytime they mostly hid under their host fungi, in the filament-feces, and in crevices of tree bark attached to their host fungi. They are believed to occasionally move to other nearby locations by walking, and more rarely to fly to more distant places (Heatwole and Heatwole 1967).

Relationships with host fungi. *P. nigroaeneum* was observed feeding and breeding on sporophores of *Daedaleopsis tricolor* (Bull.: Fr.) Bond. et Sing, *Bjerkandera adusta* (Willd.: Fr.) Karst., *Merulius tremellosus* Fr., *Cerrena unicolor* (Fr.) Murr., *Coriolus versicolor* (L: Fr.) Pilát, *Coriolus brevis* (Berk.) Aoshi., and *Stereum gausapatum* Fr.: Fr. associated with old dead trees. *P. nigroaeneum* was most frequently found on *Daedaleopsis and Bjerkandera*, and was observed mainly in old broad-leaf forests dominated by *Quercus*, *Salix*, *Carpinus* and *Alnus* (Krasutskii 2007). Larvae and adults were also observed feeding on *Lampteromyces japonicus* (Kawam.) Sing and *Amillaria* (= *Armillariella) mellea* (Vahl: Fr.) P. Kummer of Agaricales on rare occasions but have not been observed breeding in these host species.

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