The Fascinating Behaviors of Endocoprid Dung Beetle:*Aphodius elegans*Allibert

Abstract

Based on the literature referred, dung beetles (Scarabaeidae~~: Scarabainae~~) are divided into three behavioral groups, the endocoprid, paracoprid and telecopied. The dung beetles are fascinating insects that demonstrate and perform various behaviors. The dung roller beetles rolling the dung ball and the tunnelers digging the tunnels to hide the dung were studied. The studies focused less on the endocoprid, the dweller dung beetle due to its less fascinating behaviors. The Aphodius elegans ~~Allibert~~ of the family Aphodiidae~~family~~ is the endocoprid dung beetle~~s~~ that are abundantly found in the spring season. It locates the dung using antennae and ~~a~~ shovel inside the dung. The shoveling behavior of Aphodius elegansAllibert is similar to the boat propelled by oars. The specialized morphological features of the beetle help to succeed in its survival. They are alert and active during the warm weather while they bury themselves under the dung and retract their appendages during the cold. The specialized mouth parts favor Aphodius elegans ~~Allibert~~ as the scrapper and filter feeders. They defecate fine and semi-solid faeces that convert the dung pat into soil. The adults prefer moist and fresh dung pats for their burial. The quick burial of the pronotum under the dung pat, retraction of the appendages, and mimicking death are the defensive behaviors of Aphodius elegans~~ Allibert~~. The repeated attempts and stronghold out of the elytra and hindwings help reposition the beetles' body posture and~~. And~~ it initiates the flight. The hindwing is the main flying wing while the forewing elytra generates the body lift in the air.

Key words: *Aphodius elegans* Allibert, Behavior, Dung beetle, Endocoprid.

Introduction

Dung beetles are insects of order Coleoptera, consisting the species of the subfamilies; Scarabaeinae, Geotrupinae, and Aphodiinae (Huerta, Oca, Rosales, & Favila, 2013) that partly orexclusively feeds on faeces throughout their lifecycle(Holter & Scholtz, 2007; Huerta et al.,2013).They are found in ~~habitats~~ every continent except Antarctica. ~~And~~ Africa is considered to have the most diverse population of dung beetles (Whipple, 2011). Historically, since ancient Egyptian, dung beetles were believed as the representation of rebirth and rejuvenation (Hanski &Cambefort 1991). They were revered as the symbol of the god of the sun, who rolled the sun across the sky each day and buried it in the evening, only to emerge again the next morning (Whipple, 2011).

Ecologically, dung beetles are a major component of biological dung removal (Byk &Piętka, 2018) and controllers of pests and parasites that breed in dung (Fincher, 1975; Byk &Piętka, 2018). Dung beetles help farmers in agriculture production, by reducing the yield loss for pests, cost of pesticide applications, and fertilizer use. They are considered bioengineers of the environment and health giver for the population (Whipple, 2011). Besides their role as decomposers, dung beetles maintain biodiversity. They are involved in the Pollination and

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seed dispersal of some plants (Shepherd & Chapman, 1998; Griffiths, Bardgett, Louzada, & Barlow, 2016).

Dung beetles are adapted to a wide variety of ecosystems and many are highly specialized (Hanski &Cambefort 1991). Many specialist dung beetle species can feed on resources other than dung (Holter & Scholtz, 2007). Depending upon the species, dung beetles have a specific preference towards dung, dung condition, and the dung odor (Dormont, Epinat&Lumaret, 2004). Dung beetles can be segregated based on habitat and soil type. The activity and the behaviour exhibition of dung beetles varies with species, the season and the seasonal activity, and the light and light intensity (Hanski &Cambefort 1991). Additionally, beetles respond differently to elevation and temperatures (Whipple, 2011).

Most dung beetles are generalist (coprophagous) feeders and the specialization occurs as a result of reduced dung availability (Hanski &Cambefort 1991). Feeding preferences are also influenced by factors such as predation and competition, and abiotic factors such as weather and climate (Whipple, 2011). Dung beetles have detritus-feeding habits and a dung resource contains all the nutrition that the beetles require. Adults have filtering mouth parts that feed on a "dung ~~Slurpee~~Slurpie", the primary moisture within the dung (Hanski &Cambefort 1991). While larvae have biting mouthparts, that makes it possible to feed on both moisture and the fiber of the dung within the brood balls (Whipple, 2011).

Dung beetles are divided into three behavioral groups; rollers, tunnelers, and dwellers. The beetles that roll dung into round balls, used for food sources or brooding chambers are **rollers**. The **tunnelers** make a tunnel and bury the dung wherever they find it. The **dwellers** neither roll nor burrow the dung, but they simply live-in dung (Hanski &Cambefort 1991). The dung beetles are also known as Endocoprid (dwellers), Paracoprid (tunnelers) or Telecoprid (rollers) insects (Halffter& Edmonds, 1982; Hanski &Cambefort 1991; Byk &Piętka, 2018).

The fascinating behavior of the two groups of the dung beetle, the roller and tunneler were widely studied. Rollers form a bit of dung ball, roll it away and bury it. The dung balls are used either by females for laying the egg as a brood ball or as a food source for adults (Hanski & Cambefort, 1991; Holter & Scholtz, 2007). The male and female rollers establish a pair bond after encountering the dung pat. The male prepares the giant dung ball and offers it to the female as the brood ball. If she accepts, then they roll it away together or the female beetle rides on the top of the ball (Hanski &Cambefort 1991). They cooperatively defend their ball from stealing by other beetles (Baird, Byrne, Smolka, Warrant, & Dacke, 2012). The warfare and the battle between the males are fought to show strength and bravery (Halffter& Edmonds, 1982). The new pair bond and find a suitable and safe place to bury the ball before mating. The male leaves the scene, while the female lays a single egg and prepares another brood ball. The brood ball is then coated and sealed with a mixture of dung and saliva. Some mothers stay with the ball till the larvae hatch (Hanski &Cambefort 1991; Baird et al., 2012).

The tunnelers dive into the dung and tunnel directly into the soil to start the family (Bertone et al., n.d; Hanski &Cambefort 1991). Storing the dung underground helps to protect the developing larvae from predators and also to keep the nutrients, in the dung pile fresh

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and digestible (Holter & Scholtz, 2007). The female arranges and sorts the dung in the tunnel while the male carries the fresh dung to the home. The parents stay with the larvae until they are matured (Hanski &Cambefort, 1991; Dabrowski, Venter, Truter, & Scholtz, 2018). The dweller neither rolls nor makes tunnels. The female lays eggs on the top of the dung and the larval development takes place inside the dung pat (Whipple, 2011).

The behavior of the dweller beetles was not exclusively studied as it has no fascinating behavior like that of roller and tunnelers. Therefore, the study focuses on the different behaviors shown by the dweller dung beetle *Aphodius elegans* Allibert. The different behaviors performed was observed and explained accordingly. The behaviors of hunting the dung pat, shoveling the dung pat and their burial, their feeding habits, the defecation of feces, and also their defensive behaviors were explained in the study.

Methodology

a. Study Site

The dung beetles were collected from the small cow herds of the Betsamang village, Bumdeling gewog under Trashi Yangtse Dzongkhag. The small study site was created by a collection of fresh dung pats of the cow. The dung inhabited with the *Aphodius elegans* Allibert was collected and kept in the study site. The study was carried out during the spring season (March and April) of 2020. The region falls under Bumdeling Wildlife Sanctuary at elevations between 1500 meters (4,900 ft) and 6000 meters (20,000 ft). The mean annual summer temperature is 22.6 °C and the mean annual winter temperature is 15 °C.

b. Materials: Fresh dung pat, a spade, Gloves, Camera (Mobile camera).

c. Sample collection

The fresh cow dung was collected and kept on the specific site as the habitat for the dung beetles. The dung inhabited with *Aphodius elegans* Allibert beetles were also collected and kept at the study site for observation. The different behaviors shown by *Aphodius elegans* Allibert were described and confirmed in the literature available. The videos of different behaviors portrayed by *Aphodius elegans* Allibert were recorded for further study and future reference. Dung beetles were counted and identified with their identificationcharacters~~points~~. Then subsequently beetles were released in an open area.

d. Procedure to hunt dung beetles

Walk near cow herds and pastures. Examine the dung pats. If one finds holes in the surface of the dung pat, or pats appear to be shredded. Then, probably it indicates the presence of dung beetles. To confirm, open the pats gently with ~~a~~ hand or a spade to minimize the disturbance, and look for adult beetles. Closely examine the presence of larvae in dung pat. It can be also hunted by observing the activity of any insects immediately following the dung deposition. It is stated that dung beetles usually arrive within minutes of dung deposition when the temperatures are still above 70^{o}F (Bertone et al., n.d.). *Aphodius elegans* Allibertappears twice a year, in spring and summer (Bang, Han, Kang, & Lee, 2017).

Result and Discussion

a. General body anatomy of dung beetle

Body composed of 3 main segments; head, thorax and abdomen. A typical characteristic of beetles is the hard elytra that varies in color from black, brown, yellow or purple, depending on the species of dung beetle. A pair of wings folded under the elytra and hardened forewings covers the body. It possesses 3 pairs of legs terminated with appendages specialized for shoveling the dung and earth. Some species have a pair of horns on their head, used for defense. The size of dung beetle varies from the smallest species 2mm long to the larger species up to 30mm long (Thomas & Darren, 2012).

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b. Taxonomy of *Aphodius elegans* Allibert

Class: Insecta
Order: Coleoptera
Superfamily: Scarabaeoidea
Family: ~~Aphodiidae~~ Scarabaeidae
Subfamily: Aphodiinae
Genus: *Aphodius*
Species: *Aphodius elegans*Allibert

c. Identification features of *Aphodius elegans* Allibert

The identification features of the studied dung beetle are in accordance to Italian Entomologist Forum, (2017). *Aphodius elegans*Allibert possesses the following characteristics features confirming its taxa. Auriculate genae with flat scutellum. Elytra interstices are nearly flat, shiny, sparsely, finely but distinctly punctured.Blackish, elytra pale yellowish with bands usually widened till suture.The first segment of the hind tarsi conical, is slightly longer than the following three combined. Fore tibia, apical spur, in males outwardly hooked.

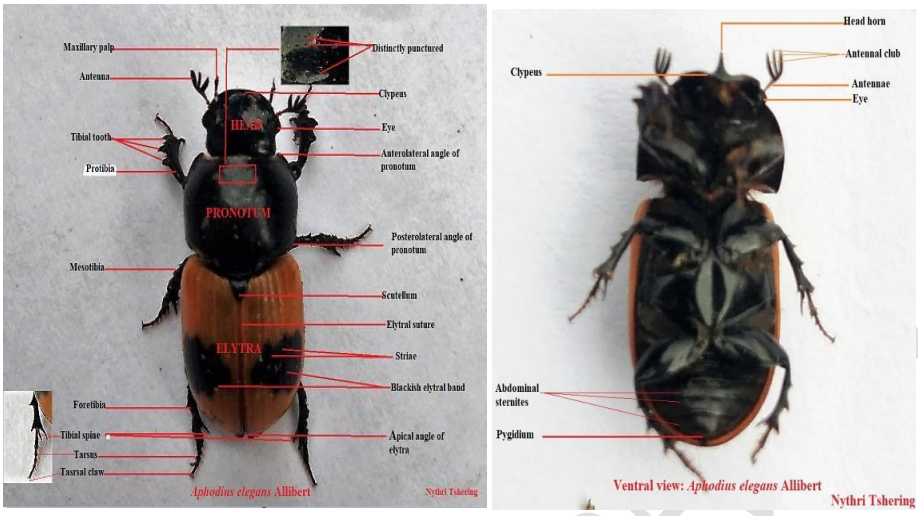

Figure 1: Morphological Feature of *Aphodius elegans*Allibert.

d. Behaviors of *Aphodius elegans* Allibert

i. **Dung pat hunting behavior:**

Adult beetles locate the food source by smell. It is detected during flight by the antennae. Once located, it lands close to or directly upon dung. The food is consumed in situ. ~~And i~~It may be transported above or below ground for subsequent consumption (Halffter& Edmonds, 1982). The adults of *Aphodius*used antennae to locate the dung pat and they flew and fed on the liquid content of the dung (Finn & Gittings, 2003). The adult of ~~*Aphodius* A~~*elegans* Allibert directs themselves towards the fresh cow dung when they are openly kept near the dung. The beetles were found actively moving toward the freshly scattered cow dung. The adults started to occupy the fresh and moist dung pat on the second day of the observation made on freshly collected cow dung pats at the study site.

The adults shift their habitat to new fresh dung pats after several weeks in summer, depending on the weather and the condition of the dung pats. Dormont et al., (2004), mentioned that different dung beetle species have a specific preference towards dung, dung condition, and the dung odor. Adult *Aphodius elegans*Allibertleaves the dung pats when the fresh dung turns hard and dry without any moisture. The observed groups of beetles had vacated the earlier inhabited dung pat~~s~~ 9 days after its first observation on the dung pat. According to Yoshida & Katakura, (1985), *Aphodius*are widely found on scattered and ephemeral kinds of dung as a food source.

ii. **Dung excavation and shoveling behavior:**

When the adult dung beetles are kept on the surface of the dung, they direct or orient themselves toward the dung. They move and quickly get buried under the

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dung. They prefer the fresh or soft part of the dung for their burial. They used antennae for sensing the food source (Finn & Gittings, 2003). They set their antennae in motion when they are released in the open area. After encountering the dung pat, they examine the dung pat for fresh and semisolid parts of the dung pats for their entrance. The morphological adaptive features of the beetle assist its success in inhabiting the dung pat.

The dung beetle quickly buries its clypeus and head under the dung pat with the help of protibia~~l~~ and gradually, it buries its pronotum inside the dung. The pronotum burial inside the dung was instant and quick behaviors performed by the beetles. Slowly, with the rhythmic contraction and relaxation of the protibia, mesotibia, and metatibia, the beetles make succeed in entering the dung pat. The protibia with numerous protibial spurs and protibial teeth helps in clearing the path and also pulls the body in the forward direction. The tibial spur and tibial teeth of the tibia help in attachment to the surface(Figure 1~~Figure 1~~). The strong specialized tibia helps in forward propelling of the body inside the dung. The excavation of dung and the front and back movement of *Aphodius elegans*Allibertdung beetle can be described as similar to the boats propelled using oars in the sea. Each of the six legs is terminated with an appendage, specialized for shoveling dung and earth. It acts like an oar, allowing them to rapidly dive inside the dung. The fossorial and rake-like legs of dung beetle are adapted for digging (Kerbtier, 2007).

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iii. **Hibernating behavior:**

According to Yoshida & Katakura, (1985) and Finn & Gittings, (2003), adults of *Aphodius*were observed twice a year. The first flight is in spring (July), where the adults fly synchronously and abundantly. The second flight appears during the autumn (September to October). It is the peak of the reproduction and female contains a mature egg (Yoshida & Katakura, 1985). The adult *Aphodius elegans* Allibert excavate a chamber under a dung pat where they feed on the liquid content of the dung.

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Inside the dung pat, the adult beetles retract their appendages and live motionlessly like they are dead. The indolent act of the beetle reserves its energy and prevents cold. It also acts as a defensive mechanism. Adult dwellers are mostly found in fresh, moist droppings and larvae in dung that are drying out (Yoshida & Katakura, 1985). The studies found out that the *Aphodius elegans* Allibert hibernate as a mature larva. The busy schedule of the mature larvae and adult beetle are seized in the early morning before the sun rise and also during the cold weather. It was stated that from mid to late May every year, the spring-occurring species often aggregate beneath the dung when it is cold (Yoshida & Katakura, 1985).

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iv. **Feeding behavior:**

Inside the dung, the beetles busily scrabble the dung and consume it. The mouth part of the dung beetles is well adapted to manipulate the soft, pasty food, usually

the dung (Miller, 1961; Hata & Edmonds, 1983). Nutrients are primarily derived from the microorganisms present in the food that are broken and ingested. The mandibles are prominently present in the *Aphodius**elegans* Allibert. According to Hata & Edmond, (1983), the molar lobes of mandibles are specially designed to grind the particulates, and molae functions as a pestle mortar system. It can be made through the grinding and squeezing action of the dung beetle. These actions can also be observed in adult *Aphodius elegans* Allibert.

The scraping action of the beetles was alsoobserved. The distinct maxillary palp that aids in the food scrapping with mandibles is observed in *Aphodius elegans* Allibert. However, the soft mandible of adult *Aphodius elegans* Allibert depicts that they cannot feed on large particles of dung (Finn & Gittings, 2003). They prefer moist and fresh dung pats making them feed on a "dung ~~slurpees~~lurpie" (Hanski &Cambefort 1991). Accordingly, the feeding habits of *Aphodius elegans* Allibertare scrapper and filter feeder.

v. **Defecating Behavior:**

The observation of the excretion of the waste, and faeces of the dung beetles cannot be made clearly in thehabitat. ~~And the~~ The dung beetles turning the dung pat into the soil remains absurd. It was observedthat the *Aphodius elegans* Allibert defecates while it still actively feeds on the dung pat. It can be made throughcareful observation while the beetles are actively feeding on the dung pats. The traces of the defecation can also be observed during the movement of *Aphodius elegans* Allibert and its active locomotion on the white paper. The very fine and semisolid faces were excreted by the *Aphodius elegans*Allibertdung beetle, leaving the mark on the path that they followed. It looks like the patterns of ink leaked from the pen. Later, the dung pat inhabited by the *Aphodius elegans* Allibert turns into very fine soil.

vi. **Defensive behavior; the death mimic**

When beetles are kept in the open space, they orient themselves towards the dung and move until they find a suitable hiding place (preferably the piece of dung) to avoid the danger. The touch on their body, makes them retard their appendages and mimic the death until they assure their safety. The quick burial under the dung pile prevents them from predation and environmental effects. They have spurs on their legs that assist them to hold strongly to the substrate. The strong appendages of dung beetles are good for fighting as well as digging.

The *Aphodius elegans* Allibert is always found buried under the dung pat. They avoid direct sunlight and mostly prefer dark and shaded areas**.** The quick burial under the dung pat and the rapid repositioning of the body while it falls on the ground are also defensive behaviors of the beetle. They start their flight after repositioning the body during sunny days to avoid danger and in search of fresh dung pat.

vii. **Body repositioning and flight start behavior:**

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When adult *Aphodius elegans* Allibert is kept ventrally upside down or when they accidentally fall from the dung pat. They use the tibia and its associative appendages to regain their normal walking position. The tibial spur and tibial teeth help in attaching its body to the ground surface. The strong specialized tibia helps its success in repositioning the body. They set their tibia in motion and wave in every direction with the hope of holding on to some lifesaving support. If they find one (especially dung pieces), then it is their first attempt and success.

The second attempt of body repositioning and flight start behaviors can be observed when *Aphodius elegans* Allibert beetles fall on or when it is intentionally kept upside down on the smooth surface. After repeated first attempts and failure, they use elytra and hindwings in repositioning their body. Elytra are hardened structure that protects the flying wings and the body of the beetle (Westheim et al., 2012). The sudden held-out and strong flapping behavior of the elytra uplifts the thorax and abdomen but pushes the head toward the ground. It makes the fore tibia closer and accessible to the ground surface. They stretch fore tibia forwardly to hold on to the supports. They repeat the behavior at regular intervals of time until they can reposition their body and resume their work or initiate the flight.

viii. **Flight behavior:**

The active flight and other fascinating behavior of the *Aphodius elegans* Allibert can be mostly observed during bright sunlight or warm weather. The beetles first held out the forewing elytra and gradually held out the hindwing while they prepared the flight. The elytra held out and flapping during the flight generates the lift for the body to stay in the air (Westheim et al., 2012). The hindwing is the main flying wing of *Aphodius elegans* Allibert which rigorously flaps during the flight.

Conclusion

Dungbeetles are groups of coprophagous insects that demonstrate and perform various fascinating behaviors. The interesting behaviors of the dung roller and the tunneler dung beetles were well studied, explained, and analyzed by the earlier studies. The different behavior of the dweller dung beetles the endocoprid needs more focus. Therefore, the *Aphodius elegans* Allibert of the family Aphodiidae is used for behavioral studies. Due~~And also due~~ to its abundance during the study time-bound *Aphodius elegans* Allibert is found abundantly during the spring and autumn seasons. They are found active during the spring season across the Bumdeling region. *Aphodius elegans* Allibert can be easily identified through its distinctive blackish, elytra pale yellowish with bands usually widened till the suture. It is the endocoprid dung beetle.

The adult beetle~~s~~ prefer~~s~~ the moist and fresh dung pats for habitat. When the adult beetles are kept near the dung pat, the beetles set their antennae into motion in search of

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the food source. On encountering the dung pat, the adult *Aphodius elegans* Allibert directs and orients its bodytowards the dung. It preferably searches the soft and moist part of the dung for shoveling and burial. The quick burial of the head region inside the beetle is all assisted by the strong pro tibia specialized with the tibial spurs and tibial teeth. It helps in shoveling the dung pats. The protibia pulls the body forward into the dung while the mesotibia and metatibia push the body forwardly. The rhythmic contraction and the relaxation of the tibia helps in propelling the body inside the dung similar to the boat propelled using oars in the sea.

The specialized mouth of the *Aphodius elegans* Allibert makes them scrapper and filter feeder. The excretion of semisolid faeces after dung consumption helps in removing the dung pats and conversion of dung into fertile soil. The death mimic and retracting of its appendages under the hard elytra on touch are the defensive mechanisms observed against the danger. The quick burial of the head under the substrate or inside the dung pats is meant to avoid danger and overcome extreme weather. The elytra of the *Aphodius elegans* Allibert is found to be one of the structurally and functional body parts that are extensively used in defensive mechanisms. They retract their tibia under the elytra on the stimulus or to avoid the bright sunlight. It is used in repositioning of the body by lifting the body. The strong outlet and flapping of the elytra initiate the flight andgenerate the body lift in the air.

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*Aphodius elegans*Allibertare found active during warm weather. The dung beetles vary with the season and the diversity of the species is specific to the time. Therefore, the other behaviors of *Aphodius elegans* Allibert like the mating behavior, the competition or warfare battles, and the lifecycle of *Aphodius elegans* Allibertwere not able to be observed and studied during the time-boundstudy~~time-bound~~. The extensive study regarding the feeding behaviors and the flight of *Aphodius elegans* Allibert remains unsatisfactory due to a lack of the tools and techniques for detailed anatomical studies and behavior analysis. The explanations of the different behaviors of the *Aphodius elegans* Allibert are solely based on the daily and timely observation of the beetle kept in the study site. Therefore, the portrayal of other fascinating behaviors of the beetles may be hindered due to disturbances in their activity and ~~their~~ habitat.

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Further research and studies are required to explore and explain the mating behavior, competition, the warfare battles among the beetle. The extensive study on the feeding and flying behaviors of the *Aphodius elegans* Allibert can be studied shortly. In future studies, one should take into account the specific seasons and life cycle of the dung beetle to observe and study the different fascinating behaviors performed by the dung beetles. Specifically, the different behaviors of *Aphodius elegans* Allibert can be studied twice a year, in spring and autumn. The dung hunting, dung excavation, and shoveling behavior by adult beetle, the feeding habit of adults and its defecating behavior, the death mimic and quick burial under the dung pat by adults, and the extensive use of elytra in repositioning the body and start the flight can be studied in the spring season. The bright sunny day is the most preferred weather condition to observe, record, and study the behaviors of the *Aphodius elegans* Allibert.

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