Observations on the Life History of *Onthophagous depressus* (Coleoptera: Scarabaeidae)[1]

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ABSTRACT Adult *Onthophagus depressus* Harold constructed brood cells of cattle dung 15 to 30 cm below the soil surface. These brood cells averaged 23.1 mm long and 16.1 mm wide. Adult females deposited a single egg in the egg chamber of each brood cell. Eggs were 2.3 to 2.5 mm long and 1.1 to 1.4 mm wide. Embryonic development required 2.5 to 4.3 d; larval development (three instars) 27 d, and pupal development about 12 d. Development from egg to adult averaged 46.3 d at 25-27°C. Adult beetles were captured in all months except February with peak flight activity between 2000 and 2100 h (EST). Overwintering occurred in the adult and/or pupal stage in southern Georgia.

KEY WORDS Dung beetle, introduced species, Scarabaeidae, *Onthophagus depressus*, life history.

Onthophagus depressus Harold is a South African dung beetle species that has become established in Florida, Georgia, and South Carolina (Hunter and Fincher 1996). This exotic species was first collected in the United States in 1937 at light in Vidalia, GA, and was found in large numbers later that year associated with cattle dung in nearby Lyons, GA (Cartwright 1938). This beetle species was also found in Florida in 1947 at the Archbold Biological Station in Lake Placid (Robinson 1948). Woodruff (1973) described the limited distribution of this species in Georgia and Florida, but information on the life history of *O. depressus* is lacking.

Previous interest in native dung beetles has been mainly taxonomic, and biological data for many species remain unrecorded. However, there has been increased interest in dung beetles during the past few years because some species are considered to have good potential for natural suppression of the horn fly, *Haematobia irritans* (L.), a dung-breeding, blood-sucking pest of cattle (Fincher 1990). Several exotic species of dung beetles have been released in this

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country for horn fly control since the early 1970's (Fincher and Morgan 1990). As part of an ongoing study of insects commonly found in cattle dung, we report herein the results of laboratory and field observations on the life cycle and behavior of *O. depressus.*

Materials and Methods

Specimens of adult *O. depressus* (Fig. 1) were collected on the Coastal Plain Experiment Station in Tifton, GA, for use in establishing laboratory colonies. Some beetles were collected directly from cattle dung pats but most were captured in pitfall traps baited with swine dung. An automated trap (Beerwinkle and Fincher 1980) operated with methods similar to those reported by Fincher et al. (1986) was also baited with swine dung and used to determine the seasonal distribution and diel flight activity of *O. depressus.* Swine dung was used because it is very odoriferous and has been found to be more attractive to coprophagous beetles than dung of 11 other animals, including cattle (Fincher et al. 1970).

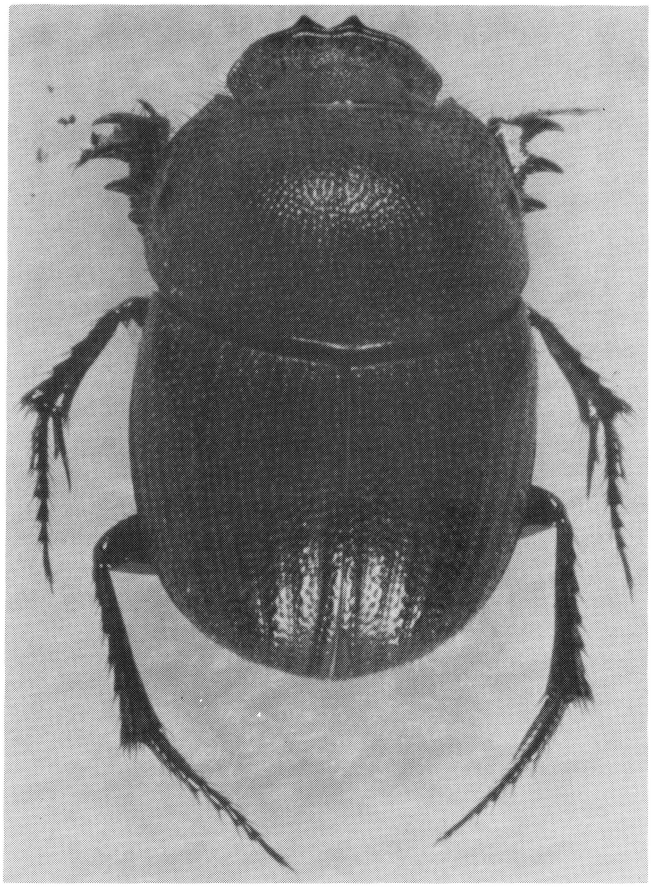

Fig. 1. Dorsal view of adult male *O. depressus.*

Laboratory colonies were maintained by placing 6 to 8 pairs of adult beetles in 20-liter cylindrical plastic buckets (36 cm deep × 27 cm diam) that were filled to within 5 to 6 cm of the top with soil from the collection sites. Approximately 1,500 g of fresh cattle dung were added to each container for use by the beetles as food and for brood cell construction. The old dung was removed and fresh dung was added at 3 to 4 d intervals. Screen mesh lids (3 squares/cm) were used on each bucket to keep the beetles from escaping.

After 4 to 12 d, the dung was removed from the soil surface and containers were inverted on a table. The buckets were removed slowly, gradually exposing their contents, and the soil was examined immediately for adult beetles and brood cells. The depth of each brood cell was recorded and each cell was measured and inspected for immature stages. Brood cells were then placed on end (with the egg chamber on top) in 1.5 to 2.0 cm deep holes in 5 cm deep moist soil in 8.5 cm deep × 25 cm diam plastic containers. The moist soil protected the cells from desiccation and held them in place with the egg or larval chamber in the upper end. A 2 to 3 mm opening was made in the top of each cell with an insect pin to facilitate observations of larval development. Larval stages were easily distinguished through the opening by observing the size of head capsules through a binocular microscope equipped with a micrometer. Upon completion of each observation, the opening was capped with a small amount of fresh cattle dung. When observations were not being made, solid plastic lids were kept on the containers to maintain adequate humidity levels. The containers were held in the laboratory at 25 to 27°C, 60 to 65% RH and a 14:10 (L:D) photoperiod.

Larval chambers would occasionally collapse when preparing brood cells for an observation. When this occurred, an egg was removed from a newly constructed *O. depressus* brood cell and the new cell was used as a "donor" brood cell. The egg chamber was enlarged with a small probe to accommodate the displaced larva. Using this method, immature stages under observation were able to complete development.

The overwintering stage of *O. depressus* was determined by preparing four 20-liter buckets that were filled with sandy loam soil as described and placed in the ground with the soil surface in the buckets flush with the surrounding soil surface. An open area of a pasture on the Georgia Coastal Plain Experiment Station was used as the overwintering site. The soil excavated from the pasture to make holes in the ground for the buckets was placed in the buckets. Cattle dung (1,500 g) was added to the top of the soil in each of the buckets along with eight pairs of beetles. Plastic bottoms of the rearing buckets were replaced with screen mesh (8 squares/cm) to allow for water drainage. Screen lids were placed on the buckets to prevent beetles from escaping. Two buckets with dung, soil, and beetles were placed in the ground on 5 October 1985. The old dung was removed and replaced with fresh dung at 4 to 5 d intervals until 15 November. One bucket was excavated on 3 January 1986 after 90 days and the other on 6 January. Two additional buckets with dung, soil, and beetles were placed in the ground on 15 October 1985. One was excavated after 90 days on 14 January 1986 and the other on 17 January. When the buckets were removed, temperatures were recorded at the soil surface and at the 2.5, 16, and 25 cm depths. Bucket contents were examined in the laboratory for adults and immature stages.

Results and Discussion

Female *O. depressus* constructed compound nests composed of branched galleries as described by Halffter and Edmonds (1982). Oval or pear-shaped brood cells (Fig. 2), averaging 23.1 mm in length and 16.1 mm (n = 20) in diameter (Table 1), were constructed 15 to 30 cm below the soil surface ($\bar{x}$ = 27 cm). The fact that most brood cells were found at the bottom of rearing buckets, suggests that the beetles might have tunneled deeper than 30 cm under natural conditions. When nest construction continued for several days, some of the most recently constructed brood cells were found above 18 cm. However, brood cell construction was not initiated in containers that did not have at least 18 cm of soil depth.

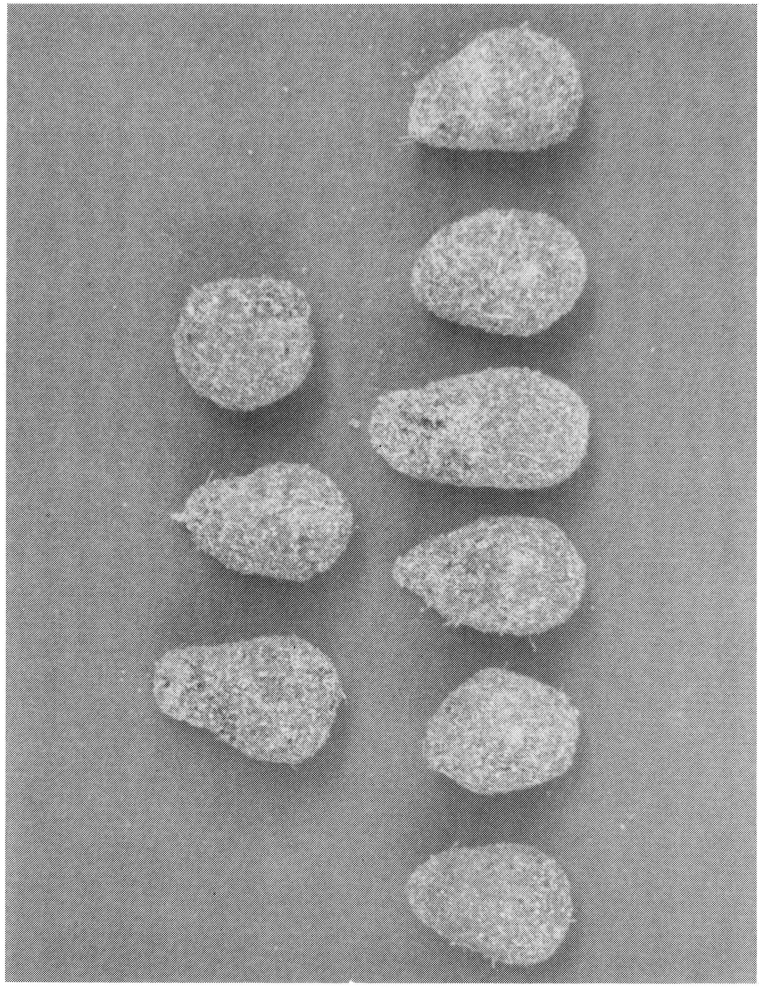

Fig. 2. Brood cells of *O. depressus*.

Adult beetles placed in rearing buckets usually required 3 to 4 d to tunnel beneath the dung, construct brood cells, and oviposit. Brood nests disrupted when they were less than 3-d-old usually contained incomplete cells without eggs. The egg chamber was 5 to 7 mm in diameter and located in the smaller end of each brood cell. A single, yellowish-white egg was attached at one end to the side or bottom of each egg chamber of completed brood cells by a small amount of excrement from the female beetle. Eggs were generally in an upright position and were 2.3 to 2.5 mm long and 1.1 to 1.4 mm (n = 12) wide (Table 1). Increases in length and width of eggs were observed from the time of oviposition until hatching, but mean values for egg length and width were not recorded. Brood cells containing eggs were removed from the soil and placed in observation containers where the eggs were observed until larvae emerged. Embryonic development averaged 3.6 d (Table 2).

Table 1. Measurements of brood cells and developmental stages of *Onthophagus depressus* reared in the laboratory at 25-27°C.

	No observed	Length (mm)		Diameter (mm)	
		Range	Mean ± SD	Range	Mean ± SD
Brood cells	20	19 - 25	23.1 ± 1.5	15 - 17	16.1 ± 0.70
Egg	12	2.3 - 2.5	–*	1.1 - 1.4	–*
1st-instar	15	–**		1.2 - 1.3†	1.27 ± 0.04
2nd-instar	15	–**		1.7 - 1.8†	1.77 ± 0.04
3rd-instar	15	–**		2.1 - 2.3†	2.17 ± 0.07
Pupa	15	5.9 - 7.6	7.0 ± 0.2	–‡	

* Egg growth accounts for variation in length and diameter.
** Measurements of length were not recorded.
† Measurements are of the head capsule at the widest point.
‡ Pupal diameters were not recorded.

Table 2. Time of development for various life stages of *Onthophagus depressus* reared in the laboratory at 25-27°C.

Stage	No Observed*	Time (Days)		Mean ± SD
		Minimum	Maximum	
Egg	18	2.5	4.3	3.6 ± 0.4
1st-instar	15	3.0	4.2	3.7 ± 0.4
2nd-instar	13	3.0	5.0	3.9 ± 0.4
3rd-instar	20	17.0	24.0	20.2 ± 2.0
Pupa	23	11.0	13.0	12.1 ± 0.6
Egg to adult**	15	36.0	57.0	46.3 ± 5.8

* Observations of each consecutive life stage were not always on the same individual.
** Includes 3.0 d for teneral adult.

First instars were creamy white and the conical dorsal hump, which comprised most of the 3rd abdominal segment, was easily visible; this hump is a general characteristic of *Onthophagus* larvae (Howden and Cartwright 1963). Head capsules of first instars averaged 1.27 mm at the widest point (Table 1). Newly-hatched larvae molted after about 3.7 d (Table 2).

Head capsules of second instars were noticeably larger than those of first instars and averaged 1.77 mm in width (Table 1). Larvae were able to excrete digested brood cell material immediately after molting to the second instar and usually could close the observation opening in the larval chamber with excrement. Second instars molted to third instars in about 3.9 d (Table 2). Yellowish orange head capsules of third instars were in sharp contrast to the yellowish white capsules of previous instars, and they averaged 2.17 mm in width (Table 1). Developmental time for this stage averaged 20.2 d (Table 2).

Pupae of *O. depressus* averaged 7.0 mm in length (Table 1); they were light to orange to golden yellow in color until the 9th day when a reddish brown color in the head and thoracic region became visible through the pupal case. This coloration was more pronounced as adult eclosion neared. Developmental time for the pupal stage averaged 12.1 d at 25 to 27°C (Table 2).

Newly-eclosed adults remained inside brood cells for 2 to 3 d before they tunneled to the soil surface. Adult beetles were brownish black to black in color and were 6.0 to 7.7 mm long and 3.7 to 5.0 mm wide - very similar to the measurements by Howden and Cartwright (1963). First flights by new adults were observed 4 d after eclosion.

Individual beetles, observed periodically throughout the life cycle from egg through teneral adult, completed development within 39 to 57 d ($\bar{x}$ = 46.3 d) at

25 to 27°C (Table 2). However, 3 to 5 d were added to the length of the overall adult to adult cycle to account for the time needed in brood cell construction and tunneling to the surface by newly-emerged adults. The length of adult life beyond the date of first emergence from the soil is known only through laboratory observations; most adults used in laboratory rearing lived at least 50 d.

When the first two buckets were excavated for observations of the overwintering stages on January 3 and 6, soil temperature was 0°C at the surface and 9°C at the 25 cm depth. Five live adults were found resting horizontally in the soil in individual elliptical cells located 18 to 24 cm below the soil surface in one of the buckets. These elliptical cells, 9 to 10 mm in length and 7 mm in diameter, were similar to the overwintering cells observed for *Onthophagus gazella* (F.) and *O. bonasus* (F.) (Fincher and Hunter 1989). Two adults found in the second bucket were also in elliptical overwintering cells (20 cm deep) independent of the brood cells. Beetles removed from these overwintering cells were in a protective posture with appendages drawn up against the body; they became active within a few minutes after warming to room temperature. Of the 13 cells found in the second bucket, eight contained dead third instars. Pupation chambers were partially completed in most of the cells that contained dead larvae indicating the larvae were in or near the pre-pupal stage of development at death.

In samples excavated on January 14 and 16, no brood cells or beetles were found in the first bucket but a total of eight brood cells (16 to 25 cm deep) were removed from the second bucket. Soil temperatures were 3°C at the surface, 4°C at 2.5 cm, 6°C at 16 cm, and 9°C at 25 cm. Three brood cells excavated at the 24 to 25 cm depth contained lived *O. depressus* pupae. These pupae were held in the laboratory at 23°C and adults emerged after 15 to 17 d. Two additional cells at 16 cm (6°C) contained immobile third instars within pupation chambers. These larvae showed some movement after several hours at room temperature but died the following day. One teneral adult (red in coloration) also was found alive at 23 cm deep. However, no apparent association with a brood cell or overwintering cell was noted.

In the laboratory, six 1-d-old pupae obtained from the beetle colony were held at 3 to 4°C for 115 d. When the temperature was increased to 23°C, four adults emerge after 16 to 17 d, but adults in the two remaining brood cells did not emerge and may have been injured either by handling or exposure to harmful organisms.

These field and laboratory observations indicate that *O. depressus* most likely overwinters either in the adult or pupal stage. The fact that two third instars were found immobile at 7°C and eight others were found dead at the same temperature, suggests that larvae may not complete development to the pupal stage once a critical low soil temperature is reached. Therefore, the larval stages may not survive the colder soil temperatures that occur during winter in south Georgia.

Seven adult beetles (4 males, 3 females), which were removed from overwintering cells and confined in plastic containers with moist paper toweling, lived for 30 d at 3 to 5°C without the addition of cattle dung for food. These beetles became active within a few minutes after warming to room temperature but did not initiate brood cell construction when placed in soil with fresh droppings.

Onthophagus depressus adults were usually captured in open-pasture habitats either in pitfall traps baited with swine feces or directly from cattle dung. Flight activity was crepuscular/nocturnal with peak flight activity between 2000 and 2100 h (EST). Adults were active from March to January, but were most abundant during June and July. Adult beetles have been observed burying cattle dung during brief warm periods of winter. One of us (JSH) found 20 adults in and under fresh cattle dung in deep sandy soils near Augusta, GA, during the first few days of January, 1993.

Onthophagus depressus also has been reported as an accidental introduction into Australia near Sydney before 1900 and was collected in Madagascar in 1953 (Matthews 1972). The South Carolina populations are probably descendents of beetles from Georgia because the species has only recently been found in that state (Hunter and Fincher 1995). How this species arrived in Australia, Madagascar, and the United States is unknown. Both areas of distribution in Florida and Georgia are inland and the beetle has not been found near the coast (Woodruff 1973). It is doubtful that *O. depressus* occurs between the areas in Florida and Georgia where it is established (separated by approximately 550 km) because it is attracted to light and should be easily detected with blacklight traps (Woodruff 1973).

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