N O T E

Survival and Reproduction of *Trox suberosus* F. (Coleoptera: Trogidae) on Insect Cadavers, Cow Dung, and Mushroom[1]

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Trox suberosus F. (Coleoptera: Scarabaeoidea: Trogidae) has occasionally been collected at vertebrate feces (Fincher et al. 1970, J. Parasitol. 56: 378-383), but typical food choices for this and all other *Trox* species in eastern North America are the dried remains of vertebrates, such as fur, hair, feathers, skin, muscle, and bone (Vaurie 1955, Bull. Am. Mus. Nat. Hist. 106: 1-90). Although *Trox* species have been collected at dead insects (Baker 1968, Bull. U.S. Nat. Mus. 279: 1-79; Young 1984, Environ. Entomol. 13: 1346-1351), only Young and Hamm (1985, J. Entomol. Sci. 20: 90-94) have demonstrated that adult *Trox* (*T. suberosus*) will consume some type of dead insect. Whereas Baker (1968) reared many *Trox* species from egg to adult on a moist diet mixture of cow hair, deer hair, sheep's wool, rabbit hair and skin, and pheasant, quail, and dove feathers and skin, there are no available data indicating that any adult *Trox* can survive or that immatures can develop on a diet of dead insects. The purpose of the experiment herein was to document the survival and reproduction of *T. suberosus* on various dead insects, dung, and fungi, as well as in the absence of food.

Beetles were obtained between 16 April and 5 August 1982 from a walk-in UV-light trap 6 km NW of Tifton, Tift Co., GA. For the feeding experiment, beetles were maintained in the laboratory in metal containers (14 × 12 cm) with fine mesh lids and exposed to ambient room conditions (approx. 25°C and 75% RH) and seasonal photoperiods. Soil from the area of the light-trap was packed into the containers to a depth of 10 cm. Seventeen containers were established with 6 beetles of unknown sex in each (n = 102). The age of these beetles could only be determined as teneral or nonteneral, as indicated by the softness of their elytra, and as young or old, based on the degree of wear of the clypeus and foretibia. In an attempt to control for age, for this experiment only nonteneral and young adults were used. At 5-7 day intervals,

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each container was examined for food consumption, soil condition, and beetle status. At this time, debris was removed, soil repacked, and water-mist and food (if required by the treatment) added. Feeding regimes and food sources are listed in Table 1.

Those *T. suberosus* individuals that initially consumed fall armyworm (*Spodoptera frugiperda* J.E. Smith) larvae infected with nuclear polyhedrosis virus (NPV) were part of a larger experiment previously reported (Young and Hamm 1985), and were unaffected by the virus. They are included here to provide additional data in the 'no food' category. Those beetles alive when all treatments were terminated on 15 November were considered to have died in the next week. The ANOVA Newman-Keuls multiple comparison procedure was used to determine significant differences ($P < 0.05$) between the mean survival periods of the various treatments (Elliott 2004, Winks User's Guide).

No obvious diel activity pattern was observed with the *T. suberosus* individuals in this experiment, although all were collected at a light trap and were expected to be nocturnal or at least crepuscular. Active adults could be expected on the soil surface in the containers at any time of the day or night, particularly as the experiment progressed. Dead or dying individuals also usually occurred on the soil surface, rather than below. One consequence of this was that the remains of beetles also occurred on the soil surface, some dead individuals having been consumed by active beetles, leaving pieces of elytra and pronotum. It is not known whether dismembered beetles were dead before consumption (= scavenged) or were alive and in the final stages of dying when they were consumed (= predated).

When the experiment was terminated in November, those remaining live beetles were found at the bottom of the containers. Immersion in water for 10 min "revived" most, but some required further immersion in 70% alcohol before entering into a "death struggle". Because food and moisture were in ample supply at the termination of the experiment, it appears that the remaining live beetles had entered some quiescent state.

Dissection of individuals alive at the termination of the experiment revealed that most had significant fat deposits, especially females. Examination of those beetles, plus those intact individuals that had died during the experiment, revealed an approximately equal sex ratio overall, with at least one male and one female in each container. There appeared, however, to be an unequal gender death rate, with most males dying before any females in each treatment. Those individuals alive at the end of the various treatments were mostly female (30 of 36).

The typical appearance of the soil in the container after a week of beetle activity indicated much disturbance, with "push-ups" of loose soil, tunnel entrance holes, and a peripheral trough. If dung had been present, some would be buried beneath the central pile and some dispersed in small pieces on the soil surface. If adult moth cadavers were present, they would be partly buried, dismembered on the soil surface, or an abdomen emptied with a large entrance hole. Beetle cadavers offered as food were typically buried and then dismembered. Larval lepidopterans were buried also, with empty skins sometimes reappearing on the soil surface.

Results of the 17 treatments are presented in Table 2. Treatments #1-6 show the varying effects of starvation, with no significant differences in the mean survival period. The mean survival period (39.6 d) for the 6 starvation treatments combined was significantly less ($t = -13.13$; $P < 0.001$) than the mean survival period (143.1 d) for those combined treatments receiving food. The difference of >20 d in survival between the 3 treatments (1-3) receiving no food and the 2 treatments (#4, 5)

Table 1. Feeding regimes and food sources

#	Feeding regime	No. of containers	Food Source and Procedure*
1	No food	3	
2	NPV-killed larvae for 25 days, then no food	2	Laboratory reared 5th instar (30 mm) *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) freshly dead, previously infected with nuclear polyhedrosis virus (NPV).
3	Cow dung at start, then no food	2	Cow dung—moist, less than 2 hrs old, obtained from pasture, container sealed and refrigerated, warmed to room temp, 7 cm diam hemisphere placed in container.
4	Dead adult insects	3	Dead moths in genera *Manduca, Pholus, Celerio, Epistor, Polyphemus, Promethea, Xylophanes;* body lengths 30-50 mm, wings clipped to ½ length. Dead beetles in genera *Alaus, Anomala, Calosoma, Chalcophora, Cotinus, Cyclocephala, Elaterus, Euetheola, Lygyrus, Necrodes, Pelidnota, Phyllophaga, Polyphylla;* elytra separated to expose the dorsal abdominal surface. Other dead *Tibicen, Lethocerus, Neoconocephalus.*
5	Coddled larvae	3	Laboratory reared 5th instar (30 mm) *S. frugiperda* killed by immersing in 90°C water (coddled), refrigerated, warmed to room temp.
6	Hard, dry larvae	1	Laboratory reared 5th instar (30 mm) *S. frugiperda* coddled, air dried until hard and shriveled.
7	Cow dung + coddled larvae	1	Cow dung same as #3, coddled larvae same as #5.
8	Cow dung	1	Cow dung same as #3.
9	Mushroom	1	Sections cap (15 cm diam) of *Chlorophyllum* sp. (Basidiomycetes: Lepiotaceae) obtained from light trap area, left at room temp until softened and discolored.

* All adult insects had been obtained from same light trap as *T. suberosus,* killed by freezing, thawed at room temperature for 24 h prior to placement in containers. At least 4 large *S. frugiperda* larvae, or at least 2 large adult insects (3 or 4 of the smaller beetles) offered at each feeding.

Table 2. Mean (range) survival period and progeny yield of *Trox suberosus* under various feeding regimes

Container #	Initiation	Feeding regime	Survival period (days)*	Progeny
1	20 Apr	No food	32 (29-35)	No
2	8 Jul	No food	30 (25-35)	No
3	23 Jul	No food	36 (14-77)	No
4	23 Jul	Infected FAW larvae at start, then no food	56.2 (29->112) [4 d 29, 1 d 105, 1 > 112]	No
5	23 Jul	Infected FAW larvae at start, then no food	56.2 (29->112) [4 d 29, 1 d 105, 1 > 112]	No
6	16 Apr	Cow dung at start, then no food	41.5 (26-58)	No
7	20 Apr	Cow dung	181.7 (140->209) [2 d 140, 1 d 171, 3 >209]	No
8	28 Apr	Cow dung & FAW larvae	199.2 (82->227) [1 d 82, 1 d 189, 4 >227]	Yes
9	20 Apr	Boiled, refrig. FAW larvae (30 mm)	188.7 (170->209) [2 d 170, 3 d 193, 1 >209]	No
10	16 Jun	Boiled, refrig. FAW larvae (30 mm)	147.0 (137->153) [3 d 137, 3 >153]	Yes
11	23 Jul	Boiled, refrig. FAW larvae (30 mm)	89.8 (21->112) [1 d 21, 1 d 54, 4 >112]	Yes
12	23 Jul	Hard, dry, shriveled FAW larvae (<30 mm)	116.0 (>112) [6 > 112]	Yes
13	20 Apr	Adult insects	117.2 (30->208) [1 d 30, 1 d 40, 1 d 88, 1 d 121, 2 >208]	Yes
14	8 Jul	Adult Lepidoptera	134.0 (>130) [6 > 130]	No
15	23 Jul	Adult *Manduca* sp.	114.2 (105->112) [1 d 105, 5 >112]	Yes
16	5 Aug	*Chlorophyllum* sp. mushroom cap	35.7 (17-60)	No
17	5 Aug	*Chlorophyllum* sp. mushroom cap	36.0 (24-53)	No

* Bracket notations = number of beetles dead on various days after initiation, plus those still alive when experiment terminated.

receiving initial food and subsequently no food suggests that the individuals receiving no food in this experiment had not obtained food just prior to capture.

Mean survival periods showed that beetles fed diets of either cow dung only (# 7), cow dung and *S. frugiperda* larvae (# 8), or larvae only (# 9), were equally adequate in insuring survival. Various combinations of adult insect cadavers likewise were equally adequate in insuring survival (# 13, 14, 15). Mean survival periods of beetles offered either coddled *S. frugiperda* larvae (# 9, 10, 11) or dried and hardened larvae (# 12) did not differ, indicating that differences in the texture and degree of moisture in similar foods did not affect survival. In addition, mean survival periods of those beetles offered adult insect (# 13, 14, 15) and those offered two types of larvae and initiated on the same day (# 11, 12) did not differ significantly.

Several treatments produced progeny (Table 2). Criteria for determination of the presence of progeny were: (1) soil surface holes produced by larvae, of smaller diameter than that produced by burrowing adults, (2) observation of larvae or pupae, (3) presence of teneral adults, and/or (4) more mature adults than originally placed in container. However, an indication that progeny had been produced does not necessarily indicate that a 2nd generation of adults was produced, only that at the least, reproduction had occurred and eggs had hatched.

These results are the first demonstration of a complete life cycle of any North American *Trox* species feeding on dead insects. Progeny were produced with the feeding regimes that included exclusively Coleoptera, adult Lepidoptera, moist and fresh larval Lepidoptera, and dry and hardened larval Lepidoptera. Adult *Trox*, however, were obtained only with the larval Lepidoptera feeding regimes. Immature forms produced in the course of this experiment suffered considerable mortality, as many more containers produced larvae than produced subsequent pupae or adults. Expected duration of the egg-to-adult period is probably about 42 d (Baker 1968), well within the time period encompassed by this experiment. It is thus possible that the parental beetles in effect determined that available dead insect food was of sufficient quantity and quality to warrant the investment in egg production, and that the larvae would be able to develop on that type of food. Experimental conditions were hence sufficient for reproduction to occur, but unfortunately less than ideal for the complete maturation of immature forms.

The ability of *T. suberosus* adults to survive for an extended period of time consuming only cow dung (# 7) is somewhat surprising, given its supposed specialization on old vertebrate carrion (Vaurie 1955). Although *T. suberosus* is occasionally collected in dung-baited traps, dung consumption had previously been confirmed (Fincher et al. 1969, J. Parasitol. 55: 355-358). The absence of progeny in this feeding group (# 6, 7) appears to confirm, however, carrion specialization. The presence of progeny in the cow dung and larvae regimen (# 8) is probably due to the presence of larvae and not cow dung.

Fungi are not known to be a food source for any North American *Trox* species (Vaurie 1955), although it is a common food source for other scarabs (Howden and Young 1981, Contrib. Am. Entomol. Inst. 18: 1-204). The results reported herein are equivocal in this regard. Although the *Chorophyllum* cap tissue appeared to be consumed by the beetles, the survival period of these individuals was about the same as those in other treatments without food, suggesting either the absence of sufficient nutritional value or a lethal effect associated with consumption.

The role of *Trox* species in the final stages of vertebrate carrion utilization has been known for many years (e.g., Walker 1957, Ecology 38: 262-276). A previous

field attempt to delineate the role of arthropods in insect carrion utilization did not reveal a role for *Trox* species (Seastedt et al. 1981, Am. Midl. Natur. 105: 124-129). A Georgia study in field crops demonstrated that *T. suberosus* was one of three scarab species attracted to dead insects, though their role as insect scavengers in that habitat was exceeded by fire ants (*Solenopsis* sp.) and earwigs (*Labidura* sp.) (Young 1984). The ability of typical arthropod scavengers of vertebrate carrion, such as *Trox*, to complete their life cycle on invertebrate carrion may be more widespread than previously known.

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