Survival Rates for Two Dung Beetle Species, *Onthophagus lenzii* HAROLD and *Liatongus phanaeoides* WESTWOOD
(Coleoptera: Scarabaeidae), in the Field

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(Received December 10, 1990; Accepted May 2, 1991)

Survival rates from egg to adult, including the survival rates during winter, were studied in the field for two dung beetle species, *Onthophagus lenzii* and *Liatongus phanaeoides*, from 1984 to 1987. To examine the effect of insects coming into dung pats on the survival rates of the two species, the survival rates were assessed under two sets of rearing conditions, one with a dung pat and the other without a dung pat on the soil surface. The survival rates from egg to adult before overwintering were 50.0% (without dung) in 1985, 52.4% (without dung), 55.0% (with dung) in 1986 for *O. lenzii*. For *L. phanaeoides* the survival rates, including the overwintering larval survival rates, were 32.0% (without dung), 33.6% (with dung) in 1985, 50.0% (without dung) in 1986. For both species the survival rates from egg to adult in the plot with dung were not lower than those without dung. This suggested that the effect of the insects coming into dung pats on the survival rates was negligible. *Onthophagus lenzii* overwinters as an adult, and the overwintering survival rates were 68.0% in 1984/85, 25.0% in 1985/86, and 51.0% in 1986/87 for five pairs, and 63.8% in 1984/85, 12.0% in 1985/86, and 47.0% in 1986/87 for ten pairs. *Liatongus phanaeoides* overwinters as a larva. The survival rates were 52.9% in 1985/86 and 83.3% in 1986/87. The overwintering survival rates for both species were lower in 1985/86 when winter temperature was low. The survival rates from egg to pre-reproductive adult, including the survival rates during winter, were 9.0% in 1985 and 26.0% in 1986 for *O. lenzii*; 33.0% in 1985 and 50.0% in 1986 for *L. phanaeoides*. The higher population density of *O. lenzii*, compared with that of *L. phanaeoides*, may not be attributable to their survival rates.

Key words: survival rate, dung beetle

INTRODUCTION

Coprophagous beetles use dung as food as well as oviposition sites. Some large species construct burrows in the soil, insert a dung ball into each burrow, and lay a single egg in it. This reproductive behaviour is beneficial to the recycling of pasture nutrients and the reduction of pest flies (e.g. WATERHOUSE, 1974). Most of the studies concerning dung beetles have dealt with reproductive behaviour (e.g. KLEMPERER, 1983; SATO and IMAMORI, 1987), pest fly control (e.g. MACQUEEN and BEIRNE, 1975),

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seasonal occurrence (e.g. WHITE, 1960; YASUDA, 1984), movement pattern (e.g. HANSKI, 1980a; YASUDA, 1987), and community structure (e.g. HANSKI, 1980b; HOLTER, 1982), but few studies have been carried out in the field regarding the survival rate from egg to adult.

Onthophagus lenzii and *Liatongus phanaeoides* coexist in cattle dung in the pasture of central Japan (YASUDA, 1984). These two species have similar oviposition modes, and their oviposition periods overlap each other. *Onthophagus lenzii* overwinters in adult stage in the soil. Overwintered adults appear from late May to late August and construct oval-shaped dung balls under a dung pat, laying a single egg in each of them. The developmental period of the larva is about one month, and new adults are seen on the ground in late August to late October. *Liatongus phanaeoides* overwinters as a third instar, which becomes an adult in mid June. The new adult appears from mid June to September. This species also constructs dung balls and lays a single egg in each of them.

The potential life time fecundity of *O. lenzii* was less than that of *L. phanaeoides* (YASUDA, 1986). Nevertheless, the population density of the adults of *O. lenzii* was higher than that of *L. phanaeoides* (YASUDA, 1987). Therefore, the survival rate from egg to adult might be important as a determinant of population density of each species.

This paper describes the overwintering survival rates and the egg-to-adult survival rates of the two species based on two kinds of experiments, one with and the other without a dung pat, assessing the effect of insects coming into a dung pat on the survival rates, and suggests the influence of the survival rates on the difference of population densities of the two species.

MATERIALS AND METHODS

Survival rate from egg to adult. The studies were carried out at the High Land Agricultural Experimental Station of Nagoya University in central Japan (altitude about 650 m). Two pairs of adults of both species were reared in individual experimental containers to obtain dung balls for the survival rate experiment in 1985 and 1986 (see YASUDA, 1989; Fig. 1). The dung balls were taken out of the container after three days, and five or ten balls were put into each of the experimental containers with soil. The containers were placed into the ground at the pasture until the adult emergence. After the adult emergence, the balls were withdrawn from the container to investigate mortality. Experimental periods and replications are shown in Table 1. Since the container used for this experiment was a plastic basket with a 2 mm mesh (26 cm in diameter, 12 cm in depth), large organisms living in the soil would be prevented from reaching the balls. To study the effect of insect intrusion into the dung pats on the survival rates, the survival rates were assessed under two sets of rearing conditions, one with and the other without a dung pat (1 kg) on the soil surface of the containers. The experiment was carried out in 1986 for *O. lenzii* and in 1985 for *L. phanaeoides* (Table 1 (a), (b)). The stages of individuals that had died in the dung balls were determined as follows: (1) egg mortality, when a ball did not contain a dead larva, pupa, or an adult; (2) larval or pupal mortality, when a ball included a dead larva or pupa; and (3) adult emergence, when a ball had a pupating room containing soil caused by adult emergence.

Determination of stadium. I reared two pairs of adults of each species in the experi-

Table 1. Experimental periods and replications of the survival rate experiments for two species, *Onthophagus lenzii* and *Liatongus phanaeoides*

Species	Year		Period	Replication	No. of dung balls
<i>O. lenzii</i>	1985	(a)	1 August–30 October	8	40
	1986	(a)	15 July –15 October	7	70
		(b)	15 July –15 October	8	80
<i>L. phanaeoides</i>	1985	(a)	1 September–1 July	10	100
		(b)	1 September–1 July	11	110
	1986	(a)	10 September–1 June	5	50

(a): plot with a dung pat, (b): plot without a dung pat.

Fig. 1. Distribution of width of larval head-capsules.

mental containers (see YASUDA, 1989; Fig. 1) and picked out five dung balls from the containers every fifth day. I measured the width of the head capsule of the larva with a microscope. The measurements were performed during the period of August 1 to 30, 1985 for *O. lenzii* and August 20 to September 20, 1984 for *L. phanaeoides*.

Using the results obtained by these measurements, I determined the stadium of a dead larva in a dung ball from the width (W) of the head capsule as follows (Fig. 1): for *O. lenzii* (1) $W < 1.70$ mm as the first instar, (2) $2.00 \text{ mm} < W < 2.30$ mm as the second instar, (3) $W > 2.50$ mm as the third instar; for *L. phanaeoides* (1) $W < 1.80$ mm as the first instar, (2) $2.10 \text{ mm} < W < 2.50$ mm as the second instar, (3) $W > 3.00$ mm as the third instar.

Overwintering survival rate. New adults of *O. lenzii* were caught in the field and released into the experimental container with a dung pat (1 kg), similar to the container

for the survival rate experiment, and then the container was covered with a plastic basket. These containers were placed in the field until the following spring, and the number of live individuals in the containers was counted. The experiments were carried out for three successive winters (October 27, 1984–May 8, 1985; October 30, 1985–May 26, 1986; October 27, 1986–April 29, 1987). Numbers of pairs released into each container were 5, 10, 20, and 30 pairs for 1984/85 and 1985/86, and five and ten pairs for 1986/87.

On the other hand, *L. phanaeoides* overwinters as a third instar. The number of individuals overwintered was estimated from the data obtained by the survival rate experiment mentioned earlier. Since the third instar makes a room in a dung ball before overwintering, I examined the dung balls for the presence of this room to determine whether the third instar had died before or during the overwintering.

RESULTS

In *O. lenzii*, the survival rates from egg to adult before overwintering were high (Fig. 2). The mortality at the egg stage was higher than that at other stages in each year. There was no indication that the mortality in the plot with dung was higher than that in the plot without the dung (G -test, $p > 0.05$).

The survival rates of adult *O. lenzii* during overwintering are shown in Table 2. The survival rates at five pairs were significantly higher than those at 30 pairs in 1984/85 and 1985/86 ($p < 0.05$). However, the differences in the survival rates were not significant between other densities ($p > 0.05$) except in 1985/86. There was no significant difference between males and females in the survival rate ($p < 0.05$) except at 30 pairs in 1984/85 (G -test, $p < 0.05$). The survival rates were high in 1984/85 and 1986/87, but low in 1985/86. Figure 3 shows the relationship between survival rates (mean

Fig. 2. Survivorship curves of *O. lenzii* (a) and *L. phanaeoides* (b). (B.O.: before overwintering, D.O.: during overwintering)

Table 2. Overwintering of adult *Onthophagus lenzii*

	No. of pairs added	n	No. of Survivors ^a		Survival rate ^b
			♂	♀	
1984/85	5	5	3.4±1.6	3.4±1.1	68.0 a
	10	4	5.5±0.6	7.3±1.3	63.8 ab
	20	4	13.0±2.0	11.7±3.1	61.7 ab
	30	2	12.0±0.0	20.5±0.7	54.2 b
1985/86	5	7	1.0±0.6	1.0±0.7	25.0 a
	10	7	1.0±0.6	1.2±0.7	12.0 bc
	20	7	3.3±1.3	2.6±1.4	17.1 ac
	30	3	3.0±1.0	3.6±1.0	7.1 b
1986/87	5	6	2.5±0.5	2.6±0.5	51.0 a
	10	7	4.7±0.8	4.9±1.3	47.0 a

^a Mean±S.D.^b Values followed by the same letters are not significantly different by *G*-test ($p>0.05$). Fig. 3. Relationship between mean temperatures from December to February and survival rates during overwintering of *O. lenzii* (●) and *L. phanaeoides* (○).

values of survival rates in five and ten pairs) during overwintering and mean temperatures from December to February. The rate was low in 1985/86 when the temperature during winter was low. In 1985/86, 63% (five pairs), 54% (ten pairs), 55% (20 pairs), 53% (30 pairs) of individuals died at the bottom of the experimental container. In other years, however, this phenomenon was not observed.

In *L. phanaeoides*, the survival rate from egg to adult was also high (Fig. 2). The mortality in the plot with the dung was not higher than that in the plot without the dung (*G*-test, $p>0.05$). The overwintering survival rates were 52.9% in 1985/86 and 83.3% in 1986/87. The survival rate was also low in the winter with low temperatures (1985/86) (Fig. 3).

The survival rate from egg to pre-reproductive adult, including the survival rate during the winter, was calculated by multiplying age-interval survival rates. For *O. lenzii* the mean value of the survival rates in five and ten pairs shown in Table 2 was used as the overwintering survival rate of adults. In the years when two kinds of the

survival rate experiments were carried out, the mean value was used for calculation. The estimated values were 9.0% in 1985 and 26.0% in 1986 for *O. lenzii*, and 33.0% in 1985 and 50.0% in 1986 for *L. phanaeoides*. The values of *O. lenzii* were lower than those of *L. phanaeoides* (*G*-test, $p < 0.001$).

DISCUSSION

No biological mortality factors for *Onthophagus lenzii* and *Liatongus phanaeoides* were revealed in this study, however, the data shown here suggested that insects coming into dung pats, that is, the insects belonging to Scatophagidae, Hydrophilidae, Histeridae, Staphylinidae, and Scarabaeidae, did not play a major role as mortality factors for the two species. Dung-living nematodes destroyed the brood ball of *Copris diversus*, resulting in beetle larvae dying (TYNDALE-BISCOE, 1984), and sometimes earthworms might destroy the eggs of some dung beetles, *Bubas bison* (KIRK, 1983). AOKI (1973) reported that some species of Collembola ate the dung, the pupae of Lepidoptera, nematodes, and other organisms living in the soil. In this study, I found nematodes as well as some species of Collembola in some dung balls in which the eggs had not hatched. Some eggs with nematodes were also observed in other experiments (YASUDA, unpublished). Thus, the effect of organisms living in the soil on the mortality of dung beetles should be made clear in future studies.

The survival rates of *O. lenzii* during winter were 80% for males and 69% for females in south western Japan (HOSOGI et al., 1979), and 62% in Korea (PAIK, 1977). At the former site, the adults of *O. lenzii* overwintered in the soil at a depth of 15 cm, which was the bottom of the cage, at the latter, they stayed in the soil at a depth of 20 cm to 30 cm. The survival rate of adults of *O. lenzii* shown in this study was rather low compared with these results, especially in 1985/86. The depth of the container (12 cm) used in this experiment may be responsible for the low survival rate. The overwintering survival rates of both species were low when winter temperature was low. The low temperature during winter might cause the survival rate to decrease.

The overwintering survival rates decreased with an increase in the number of adults per pat before winter in some years. The food shortage caused by the harsh intraspecific competition for food before the winter may cause the survival rate to decrease. In this experiment, however, beetles could not escape from the experimental container because the container was covered with a plastic basket. Since the beetles can emigrate easily from the pats with high density and immigrate many fresh pats under natural conditions, the food shortage for this beetles before winter may not be common.

Both *O. lenzii* and *L. phanaeoides* showed low mortality in their developmental periods except for the egg stage. The collapse as well as disappearance of larval dead body might be attributable to high egg mortality. The survival rates from egg to adult of *Aphodius haroldianus* and *O. fodiens*, which made dung mass and dung balls, were 77.8% and 73.7%, respectively, at 20°C under laboratory conditions (HOSOGI et al., 1980), and those for *C. diversus*, which made brood balls, were 76% with parents and 32% without parents under field conditions (TYNDALE-BISCOE, 1984). Thus, in the dung beetles, the survival rate from egg to adult is rather high compared with other insects (e.g. PRICE, 1984; ITÔ, 1980). These dung beetles make food provision for each larva. The larva inhabits a dung ball in the soil where the environment might

be stable. These conditions may result in the high survival rates in dung beetles.

As already mentioned, the potential life time fecundity of *O. lenzii* was less than that of *L. phanaeoides* (YASUDA, 1986). On the other hand, this study showed that the estimated value of survival rate from egg to pre-reproductive adult in *O. lenzii* was lower than that in *L. phanaeoides*. Therefore, the population density of *O. lenzii* being higher than that of *L. phanaeoides* may not be attributable to the survival rate from egg to pre-reproductive adult. The data showing the reason for this will be published elsewhere.

ACKNOWLEDGEMENTS

I am deeply indebted to Drs. Y. ITÔ and T. SAITO for their invaluable advice and encouragement during this study. I am grateful to Drs. Y. SAKURATANI, E. HAYAMIZU, and anonymous reviewers for valuable comments. I also thank Dr. A. FONAGY for improving the English of this paper. Thanks are also due to Dr. K. SATO, Dr. H. YOKOTA, Mr. Y. ITÔ, and other members of the High Land Agricultural Experimental Station of Nagoya University for help with the field work.

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