SURVIVAL OF A CARRION BEETLE, *NECRODES SURINAMENSIS* (COLEOPTERA: SILPHIDAE), ON A DIET OF DEAD FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) LARVAE

Orrey P. Young
Southern Field Crop Insect Management Laboratory
USDA-ARS, Stoneville, MS 38776
(Accepted for publication October 15, 1985)

ABSTRACT

In the laboratory, 95 adults of *Necrodes surinamensis* (F.) were maintained in containers with or without soil, either unfed or offered dead fall armyworm [*Spodoptera frugiperda* (J. E. Smith)] larvae, and monitored for survival. Significant differences in longevity were demonstrated within the parameters of diet (19.8 days with food, 3.7 d without), sex (13.7 d ♀, 9.9 d ♂), and generation (14.3 d overwintering, 9.3 d spring). No significant differences in longevity were observed between the two types of substrate, or within the group of unfed beetles. This species is demonstrated to have a wider feeding niche than previously believed and to be potentially vulnerable to entomopathogen and insecticide control programs directed toward lepidopterous larval pests of crops.

Key Words: *Spodoptera frugiperda, Necrodes surinamensis,* scavenger, longevity, carrion.

J. Entomol. Sci. 20(3): 359-366 (July 1985)

INTRODUCTION

Dead insects can be abundant in row crop situations, particularly after applications of insecticides or entomopathogens (Young 1984a). The effect of these potentially toxic or pathogenic dead insects on the scavenger community is of some concern. Scavengers are usually important in the recycling of nutrients (Ricklefs 1973), but their role in agroecosystems has yet to be determined. Some scavengers that are abundant in row crops, such as *Calosoma sayi* DeJean (Coleoptera: Carabidae), are also important predators of crop pests (Young 1984b).

In a recent report concerning the utilization of dead insects in row crop situations, several species of Coleoptera were listed as consumers (Young 1984a). Concurrent observations at a UV-light trap in the same agricultural fields, however, indicated that those same Coleoptera species were relatively rare (Young, unpubl. data). Conversely, the most abundant "carrion" beetle obtained in this light trap was a silphid, *Necrodes surinamensis* (F.), that did not occur in the adjacent row crop experiments. This species is a widely distributed and abundant attendant at vertebrate carcasses (Reed 1958), and would have been expected at large invertebrate carrion. To examine the question of why *N. surinamensis,* though obviously present, was not attracted to dead insects in row crop situations, and to further define its feeding niche, I report herein attempts to feed and maintain this species in the laboratory on a diet of invertebrate carrion.

METHODS AND MATERIALS

Ninety-five adults of *N. surinamensis* were obtained from a walk-in UV-light trap 6 km NW of Tifton, Tift Co., Georgia, during ther periods of 14 - 20 April and 26 May - 6 June 1982. This trap was surrounded by fields of tobacco, peanuts, and corn, with the nearest hedgerow or woodlot 300 m distant. Beetles were brought into the laboratory and examined for age and sex. Male beetles possess dilated protarsi, whereas female protarsi are undilated. These sexual differences can be determined with the unaided eye. Teneral (recently molted) individuals possess brownish elytra which change to black during maturation. Teneral black individuals could be separated from mature black beetles by the degree of hardness of the elytra: tenerals were soft and flexible when pressed by a fingernail, mature elytra were hard and stiff.

Each beetle was placed in a 17 × 12 × 6 cm clear plastic container with a tight-fitting lid and moist paper toweling covering the bottom, maintained at ambient conditions (ca. 25°C and 75% RH), and exposed to the local photoperiod. Paper toweling and debris was removed from each container and fresh toweling and water-mist added at 2 - 3 day intervals. Some beetles were offered at this time 2 coddled (killed in hot water below the boiling point) 5th instar larvae (ca. 30 mm) of the fall armyworm *[Spodoptera frugiperda* (J. E. Smith)]. Some beetles were not offered any food, and other beetles were transferred to individual containers (17 × 12 × 6 cm) with 3 cm of packed soil and offered coddled fall armyworm (FAW) larvae and/or water-mist at 2 - 3 day intervals.

Necrodes surinamensis overwinters as an adult (Ratcliffe 1972). The 54 beetles obtained during the period 14 - 20 April contained no tenerals and thus were considered the overwintering generation. Sixteen of these beetles (8 ♂, 8 ♀) were placed in soil containers and offered FAW larvae until they died. Twenty-six beetles (14 ♂, 12 ♀) were placed in containers without soil and offered FAW larvae. Twelve beetles (6 ♂, 6 ♀) were placed in containers without soil and received no food.

The 41 beetles captured during the period 26 May - 6 June were considered to be the next (spring) generation for the following reasons: (1) the previously documented longevity of adult beetles did not exceed 35 days (Ratcliffe 1972), and (2) 80% of the beetles captured were teneral to some degree. These beetles were placed in individual containers without soil and divided into 2 groups, one group (11 ♂, 14 ♀) receiving FAW larvae, the other group (8 ♂, 8 ♀) receiving no food.

The mean number of days post-capture that a beetle could survive under a particular feeding regime was determined by computing the mid-point (and rounding up) between the last day observed alive and the first day observed dead. Analysis of data was performed utilizing a SAS General Linear Model ANOVA T-test (LSM).

RESULTS

Paired comparisons were performed within the parameters of generation (Table 1), diet (Table 2), and sex (Table 3). Members of the overwintering generation survived significantly longer than members of the spring generation (14.3 vs. 9.3 days, $P < 0.001$). Those beetles which consumed food survived significantly longer than those unfed (19.8 vs. 3.7 d, $P < 0.001$). Females survived significantly longer

Table 1. Paired comparisons of variables within the generation parameter of laboratory-maintained *N. surinamensis*.

	N	Mean survival (days)	Range	Probability*
Overwintering	54	14.3	2 - 45	< 0.001
Spring	41	9.3	2 - 24	
Overwintering				
Male	28	12.3	2 - 34	= 0.05
Female	26	16.4	2 - 45	
Spring				
Male	19	7.5	2 - 21	= 0.08
Female	22	11.1	2 - 24	
Overwintering				
Food	42	24.2	9 - 45	< 0.001
Starve	12	4.4	2 - 7	
Spring				
Food	25	15.5	5 - 24	< 0.001
Starve	16	3.1	2 - 4	
Overwintering				
Food - Male	22	20.5	9 - 34	< 0.001
Female	20	27.9	10 - 45	
Starve - Male	6	4.0	2 - 7	= 0.82
Female	6	4.8	2 - 7	
Spring				
Food - Male	11	12.1	5 - 21	< 0.01
Female	14	18.9	9 - 24	
Starve - Male	8	2.9	2 - 4	= 0.91
Female	8	3.3	2 - 4	

* SAS General Linear Model ANOVA T-test (LSM).

than males (13.7 vs. 9.9 d, $P < 0.001$). Paired comparisons of subgroups within each of the three parameters were not all as significantly different as the above comparisons.

Considering the effect of generation on survival, overwintering fed males survived longer than spring fed males (20.5 vs. 12.1 d, $P < 0.001$), as did overwintering fed females compared to spring fed females (27.9 vs. 18.9 d, $P < 0.001$). Within the overwintering generation cohort offered food, females survived longer than males (27.9 vs. 20.5 d, $P < 0.001$). Within the spring generation cohort offered food, females also survived longer than males (18.9 vs. 12.1 d, $P < 0.01$).

Table 2. Paired comparisons of variables within the diet parameter of laboratory-maintained *N. surinamensis.*

	N	Mean survival (days)	Range	Probability*
Food	67	19.8	5 - 45	< 0.001
Starve	28	3.7	2 - 7	
Food - Male	33	16.3	5 - 34	< 0.001
Female	34	23.4	9 - 45	
Starve - Male	14	3.4	2 - 7	$= 0.80$
Female	14	4.0	2 - 7	
Food - Overwinter	42	24.2	9 - 45	< 0.001
Spring	25	15.5	5 - 24	
Starve - Overwinter	12	4.4	2 - 7	$= 0.57$
Spring	16	3.1	2 - 4	
Food				
Overwinter - Male	22	20.5	9 - 34	< 0.001
Female	20	27.9	10 - 45	
Spring - Male	11	12.1	5 - 21	< 0.01
Female	14	18.9	9 - 24	
Starve				
Overwinter - Male	6	4.0	2 - 7	$= 0.82$
Female	6	4.8	2 - 7	
Spring - Male	8	2.9	2 - 4	$= 0.91$
Female	8	3.3	2 - 4	
Food				
Male - Overwinter	22	20.5	9 - 34	$= 0.001$
Spring	11	12.1	5 - 21	
Female - Overwinter	20	27.9	10 - 45	< 0.001
Spring	14	18.9	9 - 24	
Starve				
Male - Overwinter	6	4.0	2 - 7	$= 0.74$
Spring	8	2.9	2 - 4	
Female - Overwinter	6	4.8	2 - 7	$= 0.64$
Spring	8	3.3	2 - 4	

* SAS General Linear Model ANOVA T-test (LSM).

Table 3. Paired comparisons of variables within the sex parameter of laboratory-maintained *N. surinamensis*.

	N	Mean survival (days)	Range	Probability*
Male	47	9.9	2 - 34	< 0.001
Female	48	13.7	2 - 45	
Male - Overwinter	28	12.3	2 - 34	= 0.02
Spring	19	7.5	2 - 21	
Female - Overwinter	26	16.4	2 - 45	< 0.01
Spring	22	11.1	2 - 24	
Male - Food	33	16.3	5 - 34	< 0.001
Starve	14	3.4	2 - 7	
Female - Food	34	23.4	9 - 45	> 0.001
Starve	14	4.0	2 - 7	
Male				
Food - Overwinter	22	20.5	9 - 34	< 0.001
Spring	11	12.1	5 - 21	
Starve - Overwinter	6	4.0	2 - 7	= 0.74
Spring	8	2.9	2 - 4	
Female				
Food - Overwinter	20	27.9	10 - 45	< 0.001
Spring	14	18.9	9 - 24	
Starve - Overwinter	6	4.8	2 - 7	= 0.64
Spring	8	3.3	2 - 4	

* SAS General Linear Model ANOVA T-test (LSM).

The differences in longevity between starved beetles as compared to fed beetles within each sex or generation were all highly significant. This was not true, however, within the group of starved beetles. There were no significant differences in survival between unfed males and females, or between unfed overwintering and spring generation beetles.

A comparison of survival periods of members of the overwintering generation placed in cages with (25.4 d) or without (23.5 d) soil indicates that no significant differences occurred ($n = 54$, $P = 0.44$).

DISCUSSION

This experiment evaluated the effect of four variables on the longevity of adult *N. surinamensis* in captivity.

Substrate — Substrate differences have previously been demonstrated to have minimal effect on the longevity in captivity of large ground beetles such as *C. sayi* (Young 1985). Thus the failure to demonstrate longevity differences between cohorts maintained on different substrates in this experiment was not surprising and in fact demonstrated considerable adaptability of *N. surinamensis* to environmental conditions.

Sex — Females survived significantly longer than males, both as a group and within the overwintering and spring generations. This sexual difference in survival is not uncommon in insects (Chapman 1982), and may indeed be the rule in predatory beetles (e.g. Kabacik-Wasylik and Stejgwillo-Laudanska 1971).

Generation — Beetles of the overwintering generation, when captured in April, had probably already been adults for at least 6 months and were reproductively mature and active. After capture they continued to feed until death, which in some cases was in early June, 45 days after capture. Members of the spring generation, when captured in late May - early June, were either teneral (< 7 - 10 d as an adult form) or mature young non-teneral adults (as evidenced by minimal wear on tibia and mouthparts). The significantly shorter longevity period for the spring generation is not easily explainable. It is well documented that teneral insects are particularly vulnerable to variations in food availability due to the many physiologically important, and energetically demanding, events occurring at that time (Chapman 1982). In fact, it has already been demonstrated that teneral adult scavenger beetles (e.g. *Ateuchus histeroides)* survive for significantly shorter periods of time without food than mature adults (Young and Hamm 1985). In the present experiment, however, there was no evidence that the spring generation beetles suffered from food deprivation, leading to the conclusion that the demonstrated longevity differences between generations were real.

Diet — A particularly surprising outcome of this experiment was the demonstration that *N. surinamensis* survived for a very short period of time without food. Whereas all beetles that were allowed to feed survived an average of 19.8 d, those not offered food died on the average after 3.7 d. Previous research has demonstrated starvation longevities in the range of 7 - 22 days for predator-scavenger ground beetles (Grum 1966; van Dinther 1964; Burgess and Collins 1917). This suggests that *N. surinamensis* must find some sort of food 3 - 4 days after feeding. The high population densities of this species indicates that it is quite able to do so.

Based on observations at vertebrate carrion, light-trap collections, and the relative frequency of *N. surinamensis* teneral adults in both situations through time (Young, unpubl. data), and the experimental data presented herein, it can be estimated that there are at least two generations per year, one a long-lived overwintering generation of approximately 7 - 9 months (September to May) and the other a short-lived summer generation of 3 - 5 months (May to September). This pattern has also been demonstrated in other species of beetles occurring in agricultural situations of the southeastern United States (Price and Shepard 1978). Thus it would appear that the longevity of a population sample of *N. surinamensis* obtained at one time and place may be determined primarily by its relative position in the life history cycle. For example, members of the overwintering generation obtained in September may indeed survive on a laboratory diet of fall armyworm larvae for 8 months, whereas individuals of the same generation obtained the following April may only survive for one month. This suggests that a comparison of longevities of the overwintering and spring generations should be performed with individuals of the same age, such as tenerals obtained in May and September.

Ratcliffe in 1972 reviewed the literature and presented extensive research results concerning the biology of *Necrodes surinamensis.* He was able to demonstrate that dipterous larvae associated with vertebrate carrion were the preferred food items, though both larval and adult stages would feed on the soft tissues of the vertebrate carrion. He was not able to present records, however, of *N. surinamensis* either feeding on dipterous larvae from any source other than vertebrate carrion or feeding on other insects. A more recent review of the silphid literature indicates that there have been no additions to the knowledge of *N. surinamensis* biology as outlined by Ratcliffe (Young 1983). The data presented herein conclusively demonstrate that *N. surinamensis* can: (1) consume dead insects, (2) consume lepidopteran larvae, (3) survive on dead lepidopterous larvae for a period of time comparable to published survival periods for other diets. Although the extrapolation of laboratory data to field situations is usually tenuous, this experiment may indicate that *N. surinamensis* has a considerably wider feeding niche than previously known and should allow this species to be considered a scavenger as well as a predator.

The original impetus for this experiment was to explain the failure of *N. surinamensis* to be attracted to dead insects on the soil surface in a previous experiment (Young 1984a). Enough information is now available to provide a reasonable explanation. Soft-bodied insect larvae, such as alive dipteran maggots or dead fall armyworms, seem to be easily captured and consumed by *N. surinamensis* and supply sufficient nutrients such that longevity is not adversely affected. Attempts to maintain *N. surinamensis* in the laboratory on a diet of freshly killed adult insects such as beetles, grasshoppers, and moths were unsuccessful, as feeding was not attempted (Young, unpubl. data). These adult insects were the same species utilized in a field experiment that tested their attractiveness to scavenger arthropods (Young 1984a). It is tempting to speculate that if dead fall armyworm larvae had been used as bait in the aforementioned field experiment, *N. surinamensis* would have been a likely participant.

A number of studies (e.g. Shubeck and Schleppnik 1984; Reed 1958) have indicated that *N. surinamensis* is usually the most abundant "carrion" beetle at large vertebrate carcasses. This species may also be the most widely distributed "carrion" beetle in the continental United States (Ratcliffe 1972). The high relative abundance of this species in Tifton light traps situated in row crops (Young, unpubl. data) and its utilization of dead lepidopterous larvae demonstrated herein suggests a potential vulnerability to control measures (entomopathogens, insecticides) directed toward lepidopterous larval pests of crops. Consumption of lepidopterous larvae killed by insecticides or entomopathogens may induce mortality in *N. surinamensis* populations and adversely affect both nutrient recycling in agroecosystems and the removal and recycling of vertebrate carcasses. Future research should address these topics.

ACKNOWLEDGMENTS

The laboratory and field aspects of this research were performed while the author was a member of the Southern Grain Insect Research Laboratory, USDA-ARS, Tifton, GA. The technical assistance of C. Sharp and M. Brown is gratefully acknowledged, as is the manuscript review provided by T. R. Ashley, G. L. Bernon, J. E. Powell, and G. L. Snodgrass.

LITERATURE CITED

Burgess, A. F., and C. W. Collins. 1917. The genus *Calosoma:* Including studies of seasonal histories, habits, and economic importance of American species north of Mexico and of several introduced species. U.S.D.A. Bur. Entomol. Bull. 417: 1-124.

Chapman, R. F. 1982. The Insects. Structure and Function. (3rd ed.). Cambridge, Massachusetts: Harvard University Press. 919 pp.

Dinther, J. B. M. van. 1964. Studies on the starvation capacities of some carabid species. Med. Land. St. Gent. 29: 1088-1096.

Grum, L. 1966. Diurnal activity rhythm of starved Carabidae. Bull. Acad. Pol. Sci. 14: 405-411.

Kabacik-Wasylik, D., and B. Stejgwillo-Laudanska. 1971. Starvation and the average survival time of Carabidae. Ekol. Pol. 19: 419-425.

Price, J. F., and M. Shepard. 1978. *Calosoma sayi:* Seasonal history and response to insecticides in soybeans. Environ. Entomol. 7: 359-363.

Ratcliffe, B. C. 1972. The natural history of *Necrodes surinamensis* (Fabr.) (Coleoptera: Silphidae). Trans. Amer. Entomol. Soc. 98: 359-410.

Reed, H. B. 1958. A study of dog carcass communities in Tennessee, with special reference to the insects. Amer. Midl. Natur. 59: 213-245.

Ricklefs, R. E. 1973. Ecology. Portland, Oregon: Chiron Press. 861 pp.

Shubeck, P. P., and A. A. Schleppnik. 1984. Silphids attracted to carrion near St. Louis, Missouri (Coleoptera: Silphidae). J. Kansas Entomol. Soc. 57: 360-362.

Young, O. P. 1983. The biology of the Silphidae (Coleoptera): a coded bibliography. Maryland Agric. Exp. Sta., Misc. Publ. 981: 1-48.

Young, O. P. 1984a. Utilization of dead insects on the soil surface in row crop situations. Environ. Entomol. 13: 1346-1351.

Young, O. P. 1984b. Prey of adult *Calosoma sayi* (Coleoptera: Carabidae). J. Georgia Entomol. Soc. 19: 503-507.

Young, O. P. 1985. Longevity of adult *Calosoma sayi* under laboratory conditions. Entomol. News 96: 45-48.

Young, O. P., and J. J. Hamm. 1985. The effect of the consumption of NPV-infected dead fall armyworm larvae on the longevity of two species of scavenger beetles. J. Entomol. Sci. 20: 90-94.