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BIOLOGY OF *LABIDURA RIPARIA* (PALLAS) AND ITS PREDATORY CAPACITY ON THE ASIAN CORN BORER[1]

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ABSTRACT

Biological studies on *Labidura riparia* (Pallas) were conducted to determine its life history, fecundity, longevity, feeding and mating habits, predatory capacity, host range, and responses to environmental stress.

Total developmental period under laboratory conditions ranged from 26-33 (mean 28.96 ±1.98) days for females and from 27-36 (mean 20.81± 2.27) days for males. Both sexes passed through five stadia except under drought stress, when all males and 90 percent of females passed through six stadia. Total life span of adults ranged from 30-185 (mean 127.09 ± 34.75) days for males after the last molt and 37-179 (mean 123.95 ±33.4) days for females.

Immatures and adults effectively searched for their host at different heights of the corn plants. They consumed an average of 420 corn borer larvae from hatching to the next egg laying under laboratory condition. Ten other species of insect pests were found to serve as prey. *L. riparia* was observed to be absent in the field when the soil was dry. Drought stress prolonged their development. Insect mortality was also increased by starvation.

INTRODUCTION

In most tropical countries including the Philippines, earwigs have been observed to prey on eggs and immature stages of major crop pests. Some species however are known pests of crop plants while others are simply scavengers.

Very little information is known about the specific role of earwigs in the natural biological control of crop pests. No one has yet studied the possibility of artificially manipulating them as effective biological control agents. It is essential, however, that if earwigs are to be used successfully for pest management, more information must be known of their biology and ecology.

Labidura riparia (Pallas) (Labiduridae, Dermaptera) is one of several earwig species that have been observed to prey on some major corn pests.

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Studies on its biology and behavior have been conducted by Schlinger et al. (1959), Shepard et al. (1973), and Ammar and Farraq (1974). Nobody has studied the biology of this species under local conditions. This paper therefore investigates the biology, feeding behavior, and predatory capacity of *L. riparia* on *Ostrinia furnacalis* (Guenee) (Pyralidae, Lepidoptera), mating behavior and maternal care of the young, host range, responses to environmental stress, and other field activities of this species.

MATERIALS AND METHODS

Rearing, life history and behavioral characteristics

L. riparia were field-collected and healthy individuals were reared singly in glass jars in the laboratory. Observations of the different stages and behavioral characteristics were made in the morning and.at night. Tunneling behavior in the soil was observed at different moisture content and in two soil depths (3-4 cm and 7.5-8 cm).

During the period of study the average temperature was 26.11°C (range 20.6 to 30.9) with an average relative humidity of 75-82% (range 53-89%). Humidity inside the rearing jar was maintained by placing moistened tissue paper in the jar.

Mating behavior was studied by pairing individuals of different ages. Egg laying and maternal care of the young were carefully observed. The number of eggs laid per female and the hatchability of the eggs were determined by two methods; one in which parents were allowed to tend the eggs for four days after laying, and the other without egg tending.

Predatory capacity and host range

The number of four-day-old first instar larvae of corn borer consumed by the earwigs at different developmental stages was determined per feeding. Live preys were given to the earwigs one by one. The number of preys continuously eaten as well as those that were killed but not eaten were counted. In addition, 60 to 100 larvae, which were weakened by pinching them behind the head, were placed in jars to determine the daily consumption of the earwigs.

Other insect species, particularly those occuring in corn fields, were tested as food for the earwigs.

Searching capacity

Four- and six-week-old potted corn plants were placed in fine-screened cages, measuring 45 x 45 x 50 cm or 60 x 50 x 100 cm. A thick plastic sheet was wrapped around the mouth of the pot to prevent the earwigs from leaving the plants. Fifth instar corn borer larvae were placed on each leaf of corn of different heights. The mode of searching for the prey was observed and the number of prey consumed by individual earwig in 24 hours was counted.

A similar study was done using corn borer egg masses. There were two different placement methods for the egg masses. First, corn borer pupae were placed in the cage and after emergence, the moths were allowed to oviposit on the leaves. Second, four egg masses were pinned on each leaf about 5 cm away from the stalk. In the cage, four earwigs were placed in each pot on the soil surface. All earwigs were starved for 24 hours prior to testing.

A gunny sack was placed over each cage to control light inside the cage.

Field observation

Regular field inspections were made to determine the occurrence, habitat and habits of earwigs at various developmental stages. Observation of corn fields for earwig distribution in the soil and on the plants started from the seedling stage up to maturity.

Responses to environmental stress

Upper thermal limit for the immature earwigs was determined by exposing them to increasing temperature at increments of 2°C from 34°C to 44°C in an incubator. Although humidity was not measured, a moistened wad of cotton was always placed inside the jars.

The influence of dry condition and high humidity on rearing was studied. To simulate low humidity, the immature earwigs in the culture jars were kept without water in the container. For high humidity, the immature earwigs were placed in culture jars confined in a 22 x 18 cm airtight container where humidity was controlled with potassium sulfate solution within the range of 82-100 per cent relative humidity.

The effects of delayed food consumption on the duration of immature stages, mortality and survival of the earwigs were studied by giving preys immediately, 2, 4 and 6 days after hatching, while the effect of continuous starvation was observed by providing only water to the insects from the time of hatching until death.

RESULTS AND DISCUSSION

Life history and development

The duration of the different developmental stages of *L. riparia* is shown in Table 1. Total developmental period of the immature stages did not differ markedly between the two sexes. Likewise adult longevity was

Table 1. Duration of developmental stages of *L. riparia* reared in the laboratory at room temperature.[1]

Developmental period	Females Range (days)	Females Average (days)	Males Range (days)	Males Average (days)
Incubation period	5-8	6.46	5-8	6.46
First instar	4-6	4.48	4-6	5.10
Second instar	3-5	4.08	3-5	4.18
Third instar	3-6	4.41	3-6	4.53
Fourth instar	5-9	6.70	5-10	7.20
Fifth instar	7-11	8.91	8-12	9.85
Total developmental period	26-33	28.95	27-36	30.81
Total life span of adult	37-179	123.95	30-185	127.09
Total life span from egg to death of adult	71-214	158.02	56-233	165.83

[1] Based on 173 individuals reared with mortality of 7.51%; 72 females and 88 males.

only slightly longer in males (127 days) than in females (124 days). Both sexes exhibited five nymphal instars and only the so-called "larger type male" was observed." The present investigation also revealed that earwigs reared under dry condition undergo an additional stadium wherein 11% of the females and all males had six stadia

In contrast, Schlinger et al. (1959) observed at least two distinct male forms of *L. riparia;* one was very similar to the female while the other was much larger and longer and had more strongly developed forceps with pointed swellings located on the inner margins on each side, about midway of their length. These same workers further observed that only the smaller of the two male types mated with the females. In contrast, Ammar and Farraq (1974) reported that only the larger type male mated. They also reported that females and the small male passed through five stadia while big males had six stadia. Shepard et al. (1973) reported that both large and small morphotypes mated successfully. Differences between earlier and present findings were attributed to variations in ecological factors such as temperature, humidity and food supply.

Eggs. Newly laid eggs smooth, yellowish white or pale, compact, more or less rounded, and measuring 1.07 (± 0.15) by 0.99 (± 0.04) mm. Pronounced increase in both length and width was observed beginning three days before hatching. The size of the eggs at the time of hatching was 1.77 (± 0.06) by 1.14 (± 0.04) mm. This increase in size is in agreement with the observation of Shepard et al. (1973). The eyes of the developing embryo clearly visible by the end of the fourth day or beginning of fifth day. At this time, the eggs had become translucent.

Hatching started instantly with the delicate shell bursting at the portion above the head of the embryo. Several minutes later, the young had its limbs entirely free. In most cases, all eggs in a batch hatched within two days.

First instar nymphs. Newly hatched nymphs whitish and several minutes later, turning gray, then grayish brown. They all congregated in their cell and crawled around the head and thorax of the mother which was tending them. Any food provided for the young was always eaten greedily, while the mother just watched without attempting to share the food.

One day before molting, the nymphs stopped feeding and their bodies were markedly longer and thinner. Molting started by the splitting of the old integument around the pronotum posteriorly down to the metathorax and anteriorly just behind the head. By bending the head, accompanied by regular peristaltic-like movement from pronotum to antennae, the old integument was released. After further peristaltic movement, the legs and all parts of the body including the forceps were freed from the old integument. The newly molted nymph always stayed close to the exuvia which was eventually eaten the next day.

The molting process took from one to 10 minutes. From white, the nymph became greyish in two hours, then turned brown or dark brown in the next two hours. The average body length was 4.22 (± 0.27) mm., ranging from 3.75 to 4.65 mm.

Second instar nymphs. The nymphs scattered around but were observed hiding together in holes or crevices. At this stage they moved fast and each individual became self-supporting. In test jars, earwigs were observed climbing, running about cautiously, lifting and opening their forceps, searching for food which were placed on the stalks or in old borer holes. They could successfully enter and get the corn borer larvae from the holes. The earwig was frequently observed struggling with the second instar corn borer larvae. Repeatedly the earwig had to pinch the prey with its forceps before finally overcoming it. Other earwigs ran around carrying the prey and struggling with them. If the prey was big enough, a number of earwigs would tear it apart. Second instar nymphs were never found injured by other nymphs. Molting process was similar to the first molt. Average body length 7.31 (±0.37) mm, ranging from 6.90 to 7.80 mm.

Third instar nymphs. At this stage, the nymphs were more active than the second instars. Injury to the legs or forceps were observed as a result of fighting for food. Broken forceps, however, were replaced in the next molt. Predatory activity was more pronounced than in the second instar as shown by their ability to catch larger corn borer larvae. It was also observed that they frequently succeeded not only in overcoming second instar corn borer larvae but also the third instars. The length of the body ranges from 8.55 to 9.50 mm (average 8.97 ± 0.39).

Fourth instar nymphs. Fourth instar nymphs similar to third instar except in size and predatory activity. Body length ranges from 11.71 to 12.40 mm. (12.12 mm average).

Fourth instar nymphs could always paralyze third, and sometimes the fourth instar corn borer larvae. Cannibalistic behavior usually occurred during crowding and lack of food. Occasionally, they fought each other and the injured was eaten by its opponent except for the thorax, head and the forceps.

Fifth instar nymphs. The fifth instar was the last observed under normal laboratory condition. Morphologically, it is similar to the fourth instar nymphs except that it is bigger and stouter and has greater predatory capacity. Average length of the body 14.29 (± 0.78) mm, ranging from 12.98 to 15.42 mm. It was very difficult at this stage to differentiate the sexes. Cannibalistic behavior was occasionally observed as in the fourth instar.

Adults. Both male and female are brown and variegated with yellow along sutures of elytra, sides of abdomen, and forceps. The legs are also yellow. Elytra and wings are normally developed.

Male: Branches of forceps are widely separated at the base, each branch only slightly curved and with an inner tooth beyond the midpoint. In the specimen examined, the length of the body is 14.00 to 21.50 mm and forceps, 4.90 to 6.45 mm long.

Female: Forceps with branches almost straight and contiguous, each branch narrowed distally, inner margin dentated. In the specimen examined the length of the body is from 14.55 to 20.40 mm and forceps are 3.20 to 3.78 mm.

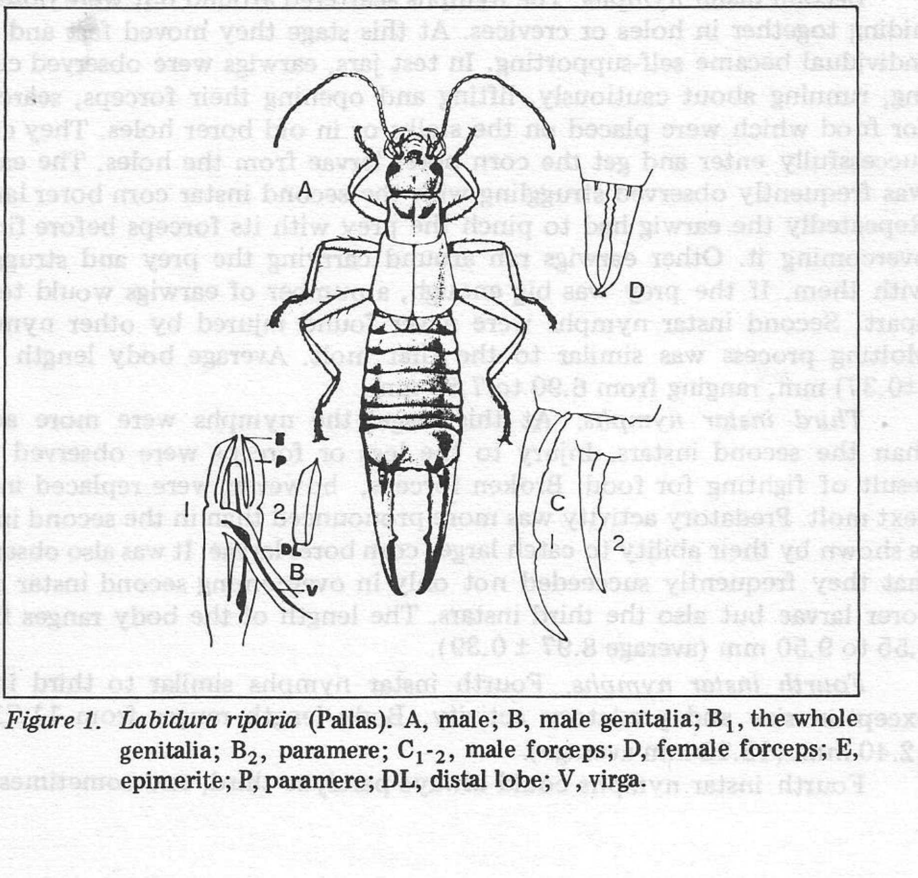

Figure 1. Labidura riparia (Pallas). A, male; B, male genitalia; B_1, the whole genitalia; B_2, paramere; C_{1-2}, male forceps; D, female forceps; E, epimerite; P, paramere; DL, distal lobe; V, virga.

Behavior

The earwigs were more active at night although they were also observed wandering, eating, mating or tunneling during daytime. Walker and Newman (1976) conducted a study on the activity of *L. riparia* in soybeans during a 24-h period. Their findings, represented by a number of individuals captured in pitfall traps, indicated that the greatest activity began one hour after sunset and lasted for four hours, and a smaller peak occurred 2 to 2-1/2 h before sunrise.

Tunneling behavior. L. riparia was observed to make many types of tunnels. In the jars where the soil was maintained at 3 to 4 cm deep and kept moist, several widened tunnels had one or more entrances on the soil surface. In most cases, the chambers which were not occupied by laying females were connected with each other.

Some tunnels were narrow and used only as a hiding or resting place. In the other condition, where the soil in the jar was 7.5 to 8 cm deep and thoroughly moist, only one widened tunnel was observed to reach the bottom of the jars.

Other tunnels were made in random distribution beginning just about 0.5 cm from the bottom. Other smaller tunnels were made as in the previous jars. For the third type, where only the top soil was moist, the tunnels were confined in the upper part, mostly in the form of big chambers just below the tissue paper. Schlinger et al. (1959) stated that when overhead protection was not available, the hole was single and simple, about as deep as the length of the earwig inhabiting it.

Judging from the tunnels built by the earwigs in this present study, this species of earwig apparently preferred moist soil condition. Their preference to build their tunnels in the moist soil was also observed in the field. It was observed that females which were laying or about to lay eggs always cleaned the chambers by removing all dirts and placing them outside.

When tied fourth instar corn borer larvae were inserted into the laying chamber, the larvae were consumed, in the first few minutes but after they were satisfied, the remaining larvae were pushed out of the tunnels. Any additional larvae inserted into the chamber were always removed sooner or later.

Mating behavior. The premating period (from time of hatching to first mating) was different in females and males. In females, it was 4.8 (± 0.46) days with a range of 2 to 4 days after the last molt (Table 2).

The effect of age on pairing the males with females is summarized in Table 3. Although the percent cannibalized males was slightly higher than the percent cannibalized females, fighting among females was observed to be more violent than among males. When a one-day-old male was paired with a one-day-old female, the female would directly seize the male with her forceps and a violent fight would follow. They would pinch one another on the abdomen with their forceps.

In most cases, the larger one would cut the body of the smaller one. Usually the legs were the first to get injured and soon after the body would

Table 2. Some important periods in the life of female *L. riparia* (Pallas)[1]

Periods	Duration Average	Range
Last molting to first mating (acceptance for mating)[2]	4.88 (±0.41)	4-5
Mating to egg laying	6.37 (±1.48)	5-9
Egg laying	2.13 (±0.33)	2-3
Oviposition and caring of eggs	6.46 (± 0.92)	5-8
Hatching to the next egg laying	7.35 (±1.35)	5-12
Between two egg laying	13.82 (±1.49)	12-16
Generation cycle egg to egg in the next generation	47.10 (±2.73)	43-54

[1] Consisted of 45 observations

[2] In males ranging from 2-4 days, with an average of 2.73 (±0.46).

Table 3. The percent of killed (cannibalized) individuals of *L. riparia* as an effect of early pairing among males and females.

Treatment [1]	Percent cannibalized individuals Males	Females
Pairs of one-day-old male and female	30	40
Pairs of one-day-old male and 7-day-old female	50	10
Pairs of one-day-old male and 7-day-old female	10	40
Pairs of 7-day-old female and male	0	0

[1] Each treatment consisted of 10 males and females.

also be pinched. A weakened opponent was eaten by the victor. The pinchers of a female was observed to be very efficient, probably due to the form of the dentated forceps which could be utilized as scissors. Although the forceps of the males were observed to be bigger and longer, only the pointed end of the forceps could be used to attack the opponent.

Different modes of fighting were observed in pairs of one-day-old males and 7-day-old females. The females did not immediately attack the males but specifically wiggled backward toward the male. The male would then move a short distance away to avoid her. After repeating the action two or three times and the male fails to respond, the female would approach the male from behind as if to ascertain whether the male was ready to mate or not. She would then reverse her position and open and raise her forceps for the fight. Fighting was not continuous but with occasional brief pause before resuming the fight.

Fighting was also observed when a one-day-old female was paired with a 7-day-old male. When they meet each other, the female would suddenly raise and open her forceps in a frightening manner. The male would likewise exhibit a similar behavior but more calm. The female always attacked the male whenever the male approached the female. But since the male was older and bigger, the number of cannibalized females was greater than males.

A very different situation was observed when a seven-day-old male was paired with a seven-day-old virgin female. They displayed certain characteristic mode of active courtship before they mate. Upon meeting each other, they usually raised their forceps in a fighting manner. Sometimes the encounter began with little fighting, but this lasted only for a few seconds. Apparently, they could recognize the opposite sex. Either male or female, approached the opposite sex and came in contact with their antennae. In some occasions one would approach from behind with his or her forceps and feeling the forceps with the antennae then turned around to be in a back-to-back position with the opposite sex. While wiggling the posterior parts of their bodies, they came close to each other. The male then twisted its caudal part around until the ventral surface would be upward, matched the tip of the female's abdomen; the two ventral surfaces would be in contact with each other, the forceps of each extended along the ventral side of the other's body. In this position coitus took place and lasted for about 45 minutes. After several seconds they mated again and sometimes lasting up to two hours.

In a virgin 4- to 5-day-old female, the period of copulation may be shorter, but again, after pausing several seconds or minutes, mating could be repeated several times. Mating lasted from three minutes to two hours.

During the period of observations, mating took place any time at night or during the day, either in the tunnel or on the surface. A female may be mated by different males consecutively.

Maternal care of the eggs. Eggs were laid in mass. The female always tried to find a safe place to brood her eggs. If the soil condition was good the female laid her eggs in a chamber it constructed one or several days before egg laying. Throughout the incubation period, the eggs were brooded over by the female, which rarely left the chamber before the eggs hatched. Usually, any entrance to the egg chamber was closed. In this chamber, the female kept moving the eggs from one place to another, licking them, and separating them one by one by means of her palpi. Sometimes she would divide them into two or more piles but would later gather them together under her thorax. These observations agreed with the findings of Schlinger et al. (1959) and Ammar and Farraq (1974). It was frequently observed that when the eggs were about to hatch, the females began to sort and arrange the eggs according to maturity so that the older eggs would hatch ahead of the younger ones. When a heap of eggs was examined in the laboratory the younger eggs were found at the bottom.

Bad eggs were frequently licked sooner or later. The eggs which were immediately transferred after oviposition were mostly attacked by microorganisms. The licking process apparently had an advantageous effect in cleaning or protecting the eggs from microorganisms.

Inspite of the fact that the chamber was normally closed, a male may succeed in finding his way into the egg chamber. Usually, the female tried to drive the male away, but at some instances especially when the male was bigger than the female, the male would always stay and mate with the female. It seems that the male did not harm the eggs. But when the male and the female fought each other, which usually occurred between a male and female of equal size, the eggs would be scattered and may be eaten by the male.

Maternal care of the young. As mentioned before, the newly hatched nymphs were always crawling about together, under the head or body of the mother. A day later, the chamber would usually open. Sometimes the food which was placed on the soil the night before was eaten by the nymph. Apparently the female brought food into the chamber for the nymphs.

By the time the nymphs were about to molt, the mother was ready to be mated again. During molting time the nymphs were still grouped together and the mother still stayed around. But later on, they got out of the chamber and were able to search for food themselves. However, some of them still stayed close to their mother and the mother never drove them away. Usually, two days after the nymphs finished molting, the mother was observed to lay a second batch of eggs (Table 2).

Fecundity and longevity

A female laid an average of 64.74 (± 14.40) eggs, ranging from 24 to 98 per batch. Throughout its life cycle, it could produce an average of 504.42 (± 202.50) ranging from 224-928 eggs. The hatchability of the eggs averaged 96%. However, when the newly laid eggs were immediately removed, the hatchability dropped to 67.7%. Failure of some eggs to hatch was probably due to microorganisms, primarily fungus. Shepard et al. (1973) always washed the eggs in 0.1% chlorox solution to prevent fungal growth, which always occurred when the eggs were removed from the female. This fact suggests that the transferring and licking of the eggs by the female during incubation period cleaned and protected the eggs from the attack of disease agents.

Schlinger et al. (1959) reported that the number of eggs laid was 20 to 50 at one time with an incubation period of 14 days. Shepard et al. (1973) observed that the female *L. riparia* produced an average of 10 egg batches totalling 440 eggs during the adult life with an incubation period of eight days.

The differences in the number of eggs produced by a female and the incubation period of the eggs were probably due to environmental factors such as temperature, humidity and food supply. Painter (1936) attributed differences in fertility and longevity to differences in quantity and quality of food consumed.

A generation cycle (egg to egg in the next generation) took an average of 47.10 days ranging from 42 to 55 days, while the total generation time (egg to death of adult) spanned an average of 158.02 (± 33.07) days (Table 1). Evidently, progenies derived from the first eggs resulted in overlapping progenies before the original parents died. It means that a population of mature earwigs may consist of individuals from at least three generation cyles.

Some important periods in the early life of an adult are summarized in Table 2, particularly regarding the duration from the last molt to the first mating which took an average of 4.88 (± 0.50) days. From mating to oviposition, it took 6.37 (± 1.48) days; oviposition, 2.13 (± 0.33) days; maternal care of the eggs, 6.46 (± 0.92) days; from the hatching of egg laying, 7.35 (± 1.72) days and between two egg laying was an average of 13.83 (± 1.49) days.

The life span of adult females was 123.95 (± 33.4) ranging from 37-179 days while the male life span was 127.09 (± 34.75) ranging from 30-185 days.

Shepard et al. (1973) recorded the average adult longevity of *L. riparia* as 114.80 (± 58.30) and 116.60 (± 37.90) days for males and females, respectively. From the data obtained in the present study, ecological factors under Philippine condition were more favorable for the life and reproduction of *L. riparia*.

Of 173 individual first-instar nymphs reared, 92.49% survived to sexual maturity consisting of 72 females and 88 males giving a female-male ratio of 0.82:1. Mortality during the first stage was 1.73 percent, in the second stage 2.31 percent commonly due to inability to molt; but in the third and fourth stages, mortality was 1 to 2%, respectively which were probably due to attack by microorganisms as they were observed having no appetite before death and soon the corpses became brittle and putrid. Entomogenous fungi attacked the adult earwig.

Predatory capacity and host range

Predatory capacity. *L. riparia* is a very voracious feeder. Last instar larvae of corn borer were easily caught by means of the large caudal forceps. When a prey was strong and tried to fight back, the earwig could easily change its position and resume the attack until the prey would become motionless. Sometimes, the earwig, while pinching the body of the prey, ran to some distance, and as its body and forceps were quite flexible, it could rapidly attack any part of the prey with its mandibles, followed by mastication. When the prey was small such as first and second instar larvae of corn borer and aphids, the earwig used its mandible without the help of its forceps.

L. riparia consumed almost one-half of their daily need in "one feeding" whenever prey was available. It exhibited a "killer instinct", that is, many preys were killed but not eaten. It exhibited a tendency to kill more prey than what was actually consumed. "The killer instinct" was shown at all developmental stages. The average consumption of the first to the fifth instar nymphs were 3.32, 11.95, 25.31, 49.96 and 58.74 late first instar corn borer larvae, respectively.

The average daily consumption of adult females from the last molt to the first mating was 69.21 ranging from 52 to 81; during egg laying, 64.58; during the care of the eggs to next egg laying, 6.05. Daily consumption during maternal care of the nymphs was also high, but since it was difficult to separate the actual number of preys consumed by the female from those of the nymphs, numerical data could not be obtained. The average daily consumption of males was 53.42 individuals.

The data above show that the females recorded the highest rate of daily consumption during the last molting to the first mating while the lowest rate of consumption was recorded during the oviposition to incubation period. The high rate of daily consumption during the early adult life of the female was probably due to physiological processes in the development of reproductive organs where higher demands of nutrition were needed for egg production and energy needs towards the later phase of its life.

Table 4. Number of preys (*Ostrinia furnacalis* larvae) consumed by *L. riparia* from immature to adult stages of development.[1]

Stage	Daily consumption		Total number of prey in each stage	
	Average	Range	Average	Range
First instar[2]	3.325	2-6	13.82	9.23
Second instar	11.95	7.18	37.66	25-56
Third instar	25.31	20-33	78.77	71-100
Fourth instar	49.96	34-62	238.55	200-268
Fifth instar	58.79	47-56	—	—
Female, up to mating[3]	64.58	50-78	515.70	367-577
During egg laying	6.05	0.13	43.29	37-53
From hatching of egg to next egg laying	52.30	32-78	420	298-505

[1] Computation subject to active feeding period.
[2] Based on 12 individuals. First to fifth instar nymphs.
[3] Based on 6 individuals.

It was found that the newly-hatched first instar larvae of corn borer were the most preferred by *L. riparia*. When feeding on these tiny larvae, the earwig just kept standing and greedily devoured them one by one. The earwig sometimes devoured up to 90 individuals at one time. From the above observations, it appears that *L. riparia* is a highly beneficial insect, being predator of several economically important pests.

Host range. Some insects were tested to determine the range of prey consumption of *L. riparia* as follows:

Classification	Stage(s) observed to be attacked
Lepidoptera	
Pyraustidae	
Ostrinia furnacalis (Guenee)	egg, larva, pupa and adult
Crocidolomia binotalis Zeller	larva
Plutellidae	
Plutella xylostella (Linn.)	larva
Noctuidae	
Helicoverpa armigera armigera (Hubner)	larva, pupa
Chrysodeixis chalcites (Esper)	larva, pupa
Spodoptera exempta (Walker)	larva
S. litura (Fabricius)	larva, pupa
Crambidae	
Chilo suppressalis (Walker)	egg, larva
Homoptera	
Aphididae	
Aphis maidis Fitch.	nymph, adult
Delphacidae	
Peregrinus maidis (Ashmead)	nymph, adult

Searching capacity

L. riparia was reported by Ammar and Farraq (1974) to be capable of climbing potted cotton plants and devouring many pinned egg masses and larvae of cotton leaf worm, *Spodoptera littoralis* (Boisduval).

In the present study, the earwig was observed to be very effective in searching the prey placed on the leaves of corn plants at different heights. Both males and females were seen actively climbing the plants. They were more frequently observed feeding on the prey on the proximal part of the leaves, rather than on the apical portion. Sometimes, the earwig was seen in between the leaf sheath, watching stealthily for the prey.

In the field, many individuals were found in stem tunnels made by corn borer, in between the corn husk or in corn cobs feeding on the pupae or larvae.

Data on average number of corn borer that was devoured by one individual earwig is presented in Table 5. Quantitatively, the number of prey

Table 5. Searching capacity of *L. riparia* on leaves of four-week-old and six-week-old potted corn plants

Type of Prey	Four-week-old plants	Six-week-old plants
Healthy third Instar larvae	1.13	1.22
Naturally laid egg masses	1.00	1.19
Pinned egg masses	2.14	2.50

[1] Four individual earwigs released in each pot. Four potted plants per treatment, three replications.

consumed by the earwig in this particular experiment was much lower compared to the daily consumption test, where the prey was always available to the earwig in close proximity, while in the searching capacity test, the probability of a larva being discovered and eaten by the predator, depended on several factors, namely movement, dispersion and density of the larva prey, host habitat finding and host finding process in the earwig, and handling of the experiment (Holling 1961, Price 1975).

The number of prey devoured by the earwigs placed on the leaves of 4-week-old and 6-week-old corn plants was not significantly different. This means that the height of the plants had no effect on the searching capacity of the earwig. As a matter of fact, the earwig was frequently observed climbing the plants easily up to the upper leaves.

In the experiments assigned to determine the searching capacity of the earwig for egg masses, the number of the pinned egg masses consumed by the earwig was greater than that of the naturally laid egg masses which made conditions difficult to control.

From the above observations, it is concluded that *L. riparia* males and females are capable of climbing the corn plants even to the highest leaves, pursuing the prey in corn borer tunnels and devouring the egg masses laid on the leaves.

The olfactory sense was the most commonly used in detecting the presence of the host. When some corn borer larvae were placed on the soil surface in the test jars, the earwigs would come out of the tunnels and move around. When it came close to the prey it moved its antennae then approached the prey. Upon touching the prey with its antennae, it began to masticate. Moving large larval preys were always caught with the earwig's forceps before feeding on it.

Field Observation

Habitat. In corn fields earwigs were found mostly on the hills, on the plant parts, but very few, if any, in the soil along the furrow. Their preference for the hills may be due to the fact that during irrigation, the hills were not entirely flooded and yet the soil in this area was loose because it was well cultivated before planting. In addition, the soil was also occupied by various soil inhabiting insects such as larvae and pupae of armyworms and cutworms which also serve as food for the earwigs. All these factors contributed to the preference of earwigs to stay in the soil.

Earwigs which were found in the plant parts were mostly the immatures. They were found hiding in the corn borer tunnels, in the ear husks, in the leaf sheaths or in any crevices that can serve as good hiding places.

It was also revealed that *L. riparia* occurred in sorghum, cabbage, soybeans, mungbean, and sugar cane fields. During the study, specimens were found only in the burrows which were regularly irrigated. When the fields dried up, they might have migrated from one field to the neighboring fields where a humid micro-climate existed. In some cases, earwigs especially the immature, were commonly found hiding in the remaining green standing crops, in spite of dry soil condition. But they stay there only temporarily because when the crops completely dry up none of the earwigs could be found.

Occurrence and abundance. Data on the occurrence of relative populations of the earwigs associated with the age of corn plants from seedling up to 11-12 weeks old are presented in Figure 2. The earwig population in the field was very low from seedling to three-to-four-week old plants. Apparently the earwig could not rapidly colonize the corn fields from neighboring field crops and their abundance seemed to be associated with the occurrence or presence of insect prey. After the whorl stage, the earwig population rapidly increased continuously up to the period of maturity of the corn plants. All stages of insect development from eggs, nymphs, and adults were present concurrently in the corn fields from 7-8 week old corn plants and up to maturity. They stayed on the plants, and were frequently observed attacking the pupae and other larval instars in their tunnels, in the stalks or in the ear husks.

Response to environmental stress

Effect of temperature. Based on 80 individuals per temperature exposure tested in the laboratory, the upper thermal limit for the survival of two-to-three-day old first instar nymphs of *L. riparia* was between 40-42°C (Table 6). Death of the insects was probably due to faster rate of water evaporation from the body. The higher temperature levels were usually associated with higher rate of evaporation from the body.

Drought stress. The effect of absence of water on the developmental stages and mortality of *L. riparia* are summarized in Table 7. Duration and the number of developmental stages of the earwig were greatly affected. Fifty percent mortality occurred 5-8 days after treatment. All surviving males passed through 6 stadia, while among the females, 88% passed through 6 stadia, while the others had 5 stadia which was normal. For com-

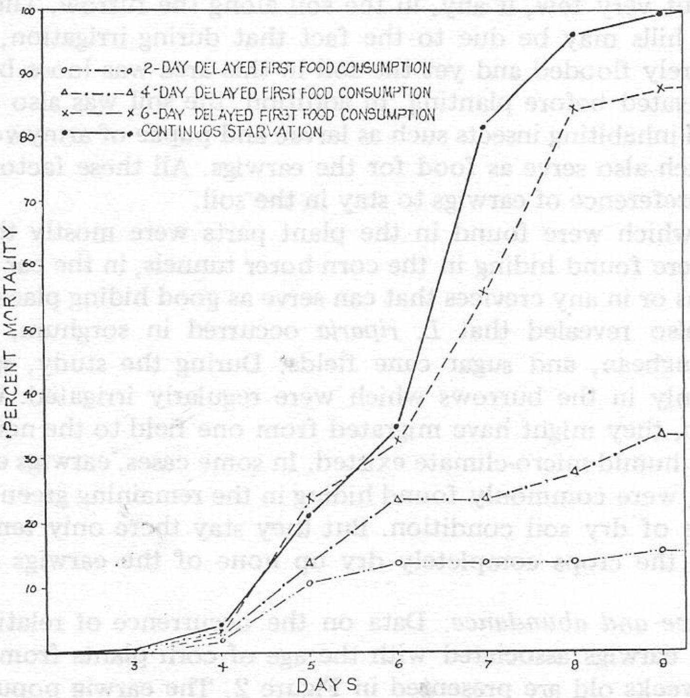

Figure 2. **Mortality in *L. riparia* due to the effect of 2-day, 4-day, 6-day delayed first food consumption and continuous starvation.**

Table 6. **Cumulative mortality of two-to three-day-old first instar nymphs of *L. riparia* exposed to high temperature.**

Temperature °C	Number of instars killed after indicated hours[1] 1 hr	2 hr	3 hr	4 hr	5 hr	6 hr
34	0	0	0	0	0	0
36	0	0	0	0	0	0
38	0	0	0	0	0	0
40	1	1	3	6	9	9
42	68	79	80	—	—	—
44	73	80	—	—	—	—

[1] Based on 80 individuals per level of temperature exposure.

parison, Shepard et al. (1973) noted that the number of nymphal stadia for females were 5, and either 5 to 6 stadia for the males, depending on the specific male morphotype.

Death usually occurred in the first stage when they were supposed to molt but some were dessicated to death one day after molting. Only very few died in the second stage. Those which survived in the second stage were

Table 7. Duration of developmental stages of *L. riparia* under 92-100% humidity regulated by the use of potassium sulfate solution.[1]

Developmental	Females 22 individuals Average (days)	Range (days)	Males 16 individuals Average (days)	Range (days)
First instar	4.45 ±0.69	4-6	4.44 ±0.73	4-6
Second instar	4.91 ±0.54	4-6	4.38 ±0.62	4-6
Third instar	5.36 ±0.81	4-6	5.38 ±0.74	4-6
Fourth instar	6.64 ±0.50	6-7	7.25 ±1.28	5-9
Fifth instar	9.36 ±1.21	8-12	10.63 ±1.85	8-14
Total developmental	31.00 ±2.24	28-35	32.00 ±2.89	28-36

[1]Based on 50 individuals reared with mortality of 24%.

able to reach sexual maturity. They were commonly observed sucking the body fluid of the corn borer larvae. This behaviour was a response to the drought condition which enable the earwig to compensate for water loss in the body.

Effect of high humidity. When *L. riparia* was reared under controlled high humidity regulated with the use of potassium sulfate solution (R. H. 92-100%), each nymphal stage was slightly prolonged resulting in significant increase in total developmental period (Table 8). Mortality increased from 7.57 percent under normal condition to 24 percent under high humidity. The number of nymphal instars in this treatment was not affected. Further investigation is needed to study the combined effect of humidity and temperature on the biology of the earwig for successful rearing in the laboratory.

Effect of delayed first food consumption and continuous starvation

The duration of developmental stages was greatly influenced by the availability and intake of the first food (Table 9 and Figure 2). When food was delayed 4 and 6 days after hatching the period to complete the first stadium was lengthened and the number of survivors that subsequently attained sexual maturity decreased. As the effect of 4-days-delayed food consumption, 8 percent of the laboratory individuals died in the first stadium and 4 percent in the second stadium. Mortality drastically increased when the food was delayed for six days. Five days of food delay appeared to be the most critical, since mortality increased from 30% on the fifth day to 58% on the sixth day. When the starvation of the earwig continued, all the laboratory individuals died on the ninth day (Figure 2). In the treatment where the first meal was delayed for four days, the prolonged first stadium a-parently could be compensated partly by faster development following prey availability immediately in the second stage, but not in the later stages, while the total developmental period under this condition was still significantly prolonged (P 0.05). The effects of 2-day delayed first meal were negligible.

Table 8. Duration of development stages of *L. riparia* in the absence of water.[1]

Developmental period	Female 1[2] (24 individuals) Average (days)	Female 1[2] (24 individuals) Range (days)	Female 2[3] (3 individuals) Average (days)	Female 2[3] (3 individuals) Range (days)	Male (8 individuals) Average (days)	Male (8 individuals) Range (days)
First instar	5.33 ±.77	4-7	6.33 ±0.58	6-7	5.75 ±.57	5-7
Second instar	5.38 ±.89	4-6	4.66 ±0.58	4-5	5.50 ±.84	4-7
Third instar	5.56 ±.96	4-7	5.66 ±0.58	5-6	5.88 ±.93	5-8
Fourth instar	7.25 ±.86	6-9	8.33 ±0.58	8-9	7.38 ±.73	6-9
Fifth instar	8.33 ±1.01	7-10	9.33 ±0.58	9-10	9.88 ±.77	8.11
Sixth instar	9.75 ±1.00	9-12	— ± —	—	10.63 ±.83	9-12
Total developmental period	41.25 ± 2.32	37-45	34.33 ±0.58	34-35	44.88 ±2.06	40-47

[1] Based on 70 individuals reared with mortality of 50%.

[2] Female with 6 nymphal instars.

[3] Female with 5 nymphal instars.

Table 9. The effect of delayed first food consumption on the duration of developmental stages and mortality of *Labidura riparia* (Pallas).

Observation	First instar nymphs fed							
	f-0		f-2		f-4		f-6	
	f	m	f	m	f	m	f	m
Developmental stage								
First instar	4.84	5.10	4.92	5.25	7.50	7.71	9.08	9.63
Second instar	4.08	4.18	4.17	4.06	3.85	3.91	4.69	4.75
Third instar	4.41	4.53	4.58	4.93	4.85	4.75	4.77	4.75
Fourth instar	6.70	7.20	6.58	7.19	6.15	6.63	6.46	7.00
Fifth instar	8.91	9.85	8.92	9.81	8.75	9.41	8.92	9.38
Total developmental period	28.95	30.81	29.17	31.31	31.15	32.38	33.84	35.50
Mortality (%) [1]	7.51		8.00		12.00		58.00	

f-0: immediately fed at one-day-old instar: 173 individuals treated
f-2: Fed 2-days later: 50 individuals treated
f-4: Fed 4-days later: 50 individuals treated
f-6: Fed 6-days later: 50 individuals treated
f: The average duration in female
m: The average duration in male
1: Per cent mortality for both sexes.

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