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BIOLOGY AND INTRINSIC GROWTH RATE OF EARWIG (*Euborellia annulata*)

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ABSTRACT

Earwig (*Euborellia annulata*) is a potential predator of corn borer (*Ostrinia furnacalis*), one of the most important pests of corn. To include the use of predator in integrated pest management (IPM) to control the pest, it is necessary to understand the basic information of the predator. This study aimed to know biology and intrinsic growth rate of the predator feed on an artificial media (dog food). Ten pairs of newly emerging adults of the predator were placed in a small plastic container containing a mixture of soil and sand (1:1 v/v) supplemented with an artificial food. The average temperature and relative humidity during the study were kept at 27.9-30.3°C and 76.7-92.3%, respectively. The biological aspects of the predator evaluated were number of eggs laid, hatched, and died, as well as its oviposition period and adult mortality. The intrinsic growth rate was studied from a group of 200 newly laid eggs and results were analyzed based on the method of Birch. The biological aspects study showed that number of eggs laid by a single female of *E. annulata* was 86-166, which were laid five times in a group of 9-45 eggs. The nymph consists of five instars. Length of nymphs varied ranging from 4 to 13 mm depends on their instar. The fifth instar nymph period was 4-6 days for female and 2-3 days for male. The period of first mating was shorter; the shortest was 2 minutes and the longest one was 70 minutes. Both male and female were able to do mating several times at an interval of several seconds or minutes. Pre-oviposition period was 6-13 days. The eggs were deposited five times, the first, second, third, fourth, and fifth oviposition period were 7-22 days, 7-21 days, 7-18 days, 11-18 days, and 11-21 days, respectively. The oviposition period was 32-59 days and postoviposition period was 21-51 days. Ratio between male and female was 1.4:1.0. The average natural mortality of *E. annulata* was 10.5% which means that 89.5% of deposited eggs hatched became nymphs. The study also revealed that the intrinsic growth rate (r) of the predator was 0.0772, net reproductive rate (R_0) 80.16, limited growth rate (λ) 1.17, nymph stage period 39-46 days, and adult longevity of male and female were 57-75 and 61-89 days, respectively. The study implies that *E. annulata* is potential to be incorporated in IPM for controlling corn borer.

[***Keywords:*** *Euborellia annulata*, earwig, mass rearing, biological aspect]

INTRODUCTION

Corn borer (*Ostrinia furnacalis*) is one of the important pests of corn in Asia and Australia. In Indonesia, Philippines and Malaysia, yield loss due to the pest has been reported up to 80-90% (Hussein 1986; Teng *et al.* 1992; Nonci 2004). Corn borer is found almost in every corn plantation in South Sulawesi (Nonci 2004). The pest is commonly controled by using insecticides because plant resistant is limited (CABI 2004).

Increasing awareness on the environmental problems due to insecticides, it is necessary to reduce the use of insecticides for controlling pests. One of potential control methods of the corn borer is using predator such earwig (*Euborellia annulata*). *E. annulata* is one of effective predators of *O. furnacalis* (Senguttuvan and Danakodi 1997). The predator is able to prey not only corn borer, but also ear borer (*Helicoverpa armigera*), aphids, and mites (Situmorang and Gabriel 1988a; Capinera 1999). Nonci *et al.* (2000) found that *E. annulata* preyed larvae and eggs of *O. furnacalis*. The predator was found in corn plants grown in irrigated lowland, rainfed land, and upland in Tempe lake area of South Sulawesi. They also preyed aphids, leaf hopper, caterpillar, larvae of beetles, centipede, and small insects.

E. annulata is able to breed in laboratory on artificial media such as dog food. This media is effective and efficient because it is cheap and easily available (Morallo-Rejesus and Punzalan 2002). Moreover, mass production of *E. annulata* done in laboratory using 73 cm x 37 cm x 28 cm galvanized box containing soil-sand mixture (3:1) supplemented with a mixture of (1:1) ground dog food and corn cobs resulted in 2000 *E. annulata* can be produced per box in a month from initial 50 male and 150 female. The experiment aimed to study the biology and intrinsic growth rate of *E. annulata* in artificial media (dog food).

MATERIALS AND METHODS

The study was conducted in the laboratory of Entomology and Plant Pathology Division, Indonesian Cereals Research Institute (ICERI) from November 2004 to June 2005. *E. annulata* adults and larvae were

collected from ICERI experimental farm and mass reared in the laboratory then placed in plastic container (13 cm in height, 20 cm in diameter) containing soil and sand (1:1 v/v) and added with 5 g of dog food. Dog food is a ready to used Pedigree@, available in the market. Its ingredients were cereal and vegetable by-product, meat and meat by-product from chicken and/or mutton, vegetable oil, iodized salt, vitamins and minerals, preservatives, and anti-oxidants. The predator was reared until adult emerged. Range of temperature and relative humidity during the experiment were 27.9-30°C and 76.7-92.3%, respectively.

Biology of Earwig

One pair of newly emerging nymphs of the last instars were placed in a small plastic container (8 cm in height, 10 cm in diameter) containing a mixture of 50 g of soil and 50 g sand (v/v). The insect was fed with 1 g dog food. The container was covered with muslin cloth. The experiment was arranged in a completely random design with 10 replicates. Food was changed everyday. Observation was done everyday until adults were dead. Parameters observed were number of egg laid, size of egg, nymph and adult, egg and nymph period, and egg and nymph mortality.

Intrinsic Growth Study

Life probability of the earwig was studied from a group of 200 newly laid eggs of *E. annulata* reared in the laboratory as described before. After hatching, the newly emerging nymphs were placed in small plastic container (5 cm in height, 7 cm in diameter) containing 30 g of soil and sand mixture.

The nymphs were fed with 1 g of dog food. Food was changed everyday. The following parameters were observed everyday, i.e. pre-oviposition, oviposition period, postoviposition, number of eggs laid, number of eggs hatched, longevity of male and female, period of egg stadium, nymph and adult period, mortality of the eggs, nymphs, and adults, as well as their sizes.

The data were analyzed based on Birch (1948) and Tarumingkeng (1994) methods containing age range (x), number of a life individual at age x (lx), and number of female off-springs at age x (mx). By this mean, intrinsic growth rate (r), net reproductive rate (R_0), average period of one generation (T), a moment birth value (b), a moment death value (d), and limited growth rate (λ) could be calculated using formula as follows:

Net reproductive rate (R_0):

$$R_0 = \Sigma lx.mx$$

Average period of one generation (T):

$$T = \frac{\Sigma lx.mx.X}{\Sigma lx.mx}$$

Intrinsic growth rate (r):

$$r = \frac{Ln\ R_0}{T}$$

Limited birth value (β):

$$\frac{1}{\beta} = \sum_{x=0}^{m} lx.e^{-r(x+1)}$$

A moment birth value (b):

$$b = \frac{r\ \beta}{e^r - 1}$$

A moment death value (d):

$$r = b - d.$$

Limited growth rate (λ):

$$\lambda = \text{antilog } e^r$$

RESULTS AND DISCUSSION

Egg Development

Results showed that one adult female of *E. annulata* laid a group of 6-45 (average 21-31.9) eggs mass five times during its generation (Table 1). Newly deposited eggs were clear white, with smooth surface and rounded (Fig. 1), 0.8-0.9 mm in length and 0.5-0.7 mm in diameter (Table 2).

The size and color of the eggs changed in times. Embryo was seen 3-4 days after the egg was laid. When embryo was developed, the egg size turns from semispherical (0.75 mm) to ellipse (1.25 mm), and the color was changed from creamy white to brown. The egg was hatched within 7-8 days after laid (Table 2).

One female of *E. annulata* laid 86-166 eggs in its lifetime. Situmorang and Gabriel (1988b) reported that

Table 1. Average number of egg laid by one female of *Euborellia annulata* in every oviposition period.

Oviposition period	Number of eggs mass per group		
	Range	Average	Standard deviation
First	6-42	30.5	8.84
Second	9-44	29.2	13.28
Third	19-45	31.9	8.45
Fourth	18-34	21.0	12.50
Fifth	10-40	25.0	12.91

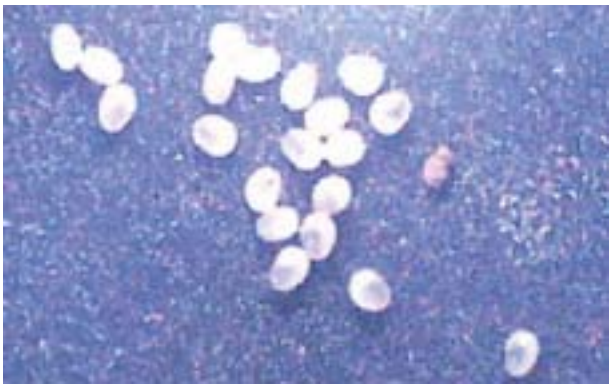

Fig. 1. Newly deposited eggs of *Euborellia annulata*.

Table 2. Size of egg, nymph, and adult of *Euborellia annulata*.

Stadium	Length (mm)		
	Range	Average	Standard
Newly laid eggs	0.8- 0.9	0.88	0.06
Eggs ready to hatch	1.1- 1.5	1.27	0.12
First instars nymph	4.0- 4.5	4.35	0.33
Second instar nymph	5.5- 8.0	6.90	0.83
Third instar nymph	8.5-10.0	9.63	0.46
Fourth instar nymph	10.0-11.0	10.06	0.06
Fifth instar nymph	11.0-13.0	11.47	0.11
Female adult	12.0-16.0	14.00	1.13
Male adult	11.0-13.0	11.93	0.88

number of eggs laid was 40.13 eggs per group in one oviposition period and the total was around 320.74 eggs. Other reported 50 eggs were laid each time with the total of 100-200 eggs in 6-17 days of oviposition period (Moran 1997).

After the eggs were deposited, they were protected by their parent until hatched in a cell from natural enemies such as mites and fungi. The eggs were also cleaned and transferred when they were disturbed. Kulzer (1996) reported that the parent did not only clean their eggs but also cover the eggs with liquid as protector.

Nymph Development

E. annulata had five nymphal instars. The first to fifth instars can be differentiated from their size and color (Fig. 2) and eating behavior. Length of nymphs varied ranging from 4 to 13 mm depends on their instar (Table 2). The nymphs grew bigger and darker as they were developed. The fourth instar started to have predation capability. Each nymphal period last for 7-8 days, except the fifth which was shorter (2-6 days) (Table 3). Physically, it is difficult to differentiate between the female and male during the first to fourth nymphal instars, but at the fifth instar the female had different form and size of forceps. Female forceps were longer and sharper than those of male.

Female and male had first mating after their last molting (adult stage). They mated several times and laid first egg at 6-13 days after the fifth nymphal instar. Oviposition period was 32-59 days. After oviposition, the female protected its eggs until the first nymph emerged. After the nymph was molted, the adult female was mated again until died. Post-oviposition period lasted 21-51 days. Ratio between male and female was 1.4:1. Average of the eggs mortality of *E. annulata* was 10.5% (Table 4), which means that 89.5% of laid eggs would hatch to become nymphs.

Adult

The form of adult was similar to the nymphs except their size. Female abdomen length varied ranging from 12 to 16 mm with the average of 14 mm, while the male ranging from 11 to 13 mm with the average of 11.93 mm (Table 2). Both female and male were shiny black with a pair of dark brown antenna (Fig. 3).

The period of first mating was shorter, the shortest was 2 minutes and the longest was 70 minutes. Both

Fig. 2. The first to fifth instar nymphs of *Euborellia annulata*.

Table 3. Egg and nymph periods of *Euborellia annulata*.

Stadium	Period (days)		
	Range	Average	Standard deviation
Egg	7-8	7.10	0.30
First instar nymph	7-8	7.35	0.48
Second instar nymph	7-8	7.15	0.36
Third instar nymph	7-8	7.16	0.37
Fourth instar nymph	7-8	7.24	0.43
Fifth instar nymph (female)	4-6	4.73	1.14
Fifth instar nymph (male)	2-3	2.76	1.40

Fig. 3. Male and female adults of *Euborellia annulata*.

male and female were able to do mating several times at interval of several seconds or minutes. The ability of mating increased in time and the time consumed for mating was also longer. After mating, the females gave the first oviposition. Preoviposition period was 6-13 days. After that they started to deposit their eggs for five times. The first, second, third, fourth, and fifth oviposition period were 7-22 days, 7-21 days, 7-18 days, 11-18 days, and 11-21, respectively. After oviposition period, the female protected and care its eggs and first nymphs from the enemies. After the first nymph molted, the adult female ready to do mating again and again until both adult female and male were died. The oviposition period was 32-59 days and post oviposition period was 21-51 days. Ratio between male and female was 1.4:1.

The average natural mortality of *E. annulata* was 10.5% (Table 4). This means that 89.5% of deposited eggs hatched became nymphs.

Intrinsic Growth Rate

Before the intrinsic growth rate (r) was determined, the net reproductive rate (R_0) was counted. The adults began to deposite their eggs at day 44th (x = 44). Result indicated that the life probability (lx) of adult was 0.81 and number of female off-springs (mx) at 44th day was 31.40. The beginning of life table of adult (lxmx) was 0.81 x 31.40 = 25.43 and ∑lxmx was 80.16. This means that female population of *E. annulata* increased 80.16 times in every generation when environmental condition is unlimited (Table 5). At temperature of 27.9-30.3^{o}C and relative humidity of 76.7-91.3%, a female of *E. annulata* had five peaks of female off-spring numbers at age x (mx). Among the peaks, there were three high peaks which occurred at day 44, 52, and 62. After reaching three oviposition peaks, the mx curve declined at day 82

Table 4. Mortality of eggs and nymphs of *Euborellia annulata*.

Stadium	Mortality (%)	Standard deviation
Egg	10.50	0.23
First instar nymph	0.00	0.15
Second instar nymph	1.12	0.15
Third instar nymph	1.14	0.13
Fourth instar nymph	4.76	0.09
Fifth instar nymph	1.82	0.05

Table 5. Life table and fecundity rate of *Euborellia annulata* feed on dog food.

x (day)	lx	mx	lxmx	x lxmx
42	0.81	0.00	0.00	0.00
44	0.81	31.40	25.43	1119.10
46	0.81	0.00	0.00	0.00
48	0.79	0.00	0.00	0.00
50	0.79	0.00	0.00	0.00
52	0.77	29.20	22.48	1169.17
54	0.76	0.00	0.00	0.00
56	0.76	0.00	0.00	0.00
58	0.73	0.00	0.00	0.00
60	0.71	0.00	0.00	0.00
62	0.67	32.40	21.55	1335.85
64	0.67	0.00	0.00	0.00
66	0.67	0.00	0.00	0.00
68	0.65	0.00	0.00	0.00
70	0.64	0.00	0.00	0.00
72	0.64	0.00	0.00	0.00
74	0.64	0.07	0.04	3.29
76	0.62	0.00	0.00	0.00
78	0.58	0.00	0.00	0.00
80	0.56	0.00	0.00	0.00
82	0.54	12.49	6.93	568.42
84	0.54	0.00	0.00	0.00
86	0.54	0.00	0.00	0.00
88	0.54	0.00	0.00	0.00
90	0.50	0.00	0.00	0.00
92	0.47	0.00	0.00	0.00
94	0.46	0.00	0.00	0.00
96	0.46	8.17	3.72	356.87
98	0.41	0.00	0.00	0.00
100	0.41	0.00	0.00	0.00
.	-	-	-	-
.	-	-	-	-
.	-	-	-	-
.	-	-	-	-
134	0.02	0.00	0.00	0.00
		Σmx = 113.73	R_0 = 80.16	Σxlxmx = 4552.69

lx = life probability
mx = number of female off-springs
R_0 = net reproductive rate

and 96. At this time, a female of *E. annulata* still alive for long time and its pre-oviposition period was 21-25 days (Fig. 4).

T value was determined by formula:

$$T = \frac{\Sigma x\ lx\ mx}{\Sigma\ lx\ mx} = \frac{4552.69}{80.16} = 56.80 \text{ days}$$

The r value was counted by:

$$r = \frac{\ln R_0}{T} = \frac{\ln 80.16}{56.80} = 0.0772$$

The r value is constant, when the environmental condition changed, the r value also changed (Birch 1948). After determining the r value, the limited growth rate (λ) was determined by formula: λ = antilog e^r = antilog $e^{0.0772}$ = 1.1669, which mean that number of population was 1.1669 times per day.

Based on the r value, the exponential growth of population was determined by formula: $N_t = N_0\ e^{0.0772t}$ (Fig. 5). This result indicated that a female of *E. annulata* could give 37,421 off-springs in 135 days, indicating that increasing population of *E. annulata* every time was high.

The population attributes of *E. annulata* are presented in Table 6. The table showed that the average time of every generation was 56.80 days. One female produced 80.16 female off-springs in the next generation. This value was lower than that of gross reproduction rate of 113.73. The study implies that *E. annulata* is potential to be incorporated in the integrated in IPM for controlling corn borer.

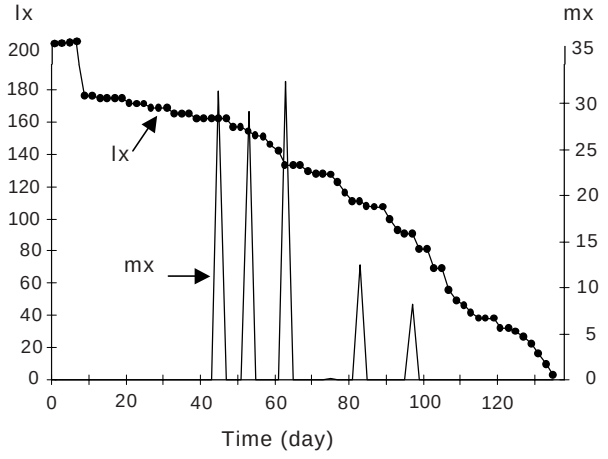

Fig 4. Life probability (lx) and fecundity (mx) curve of *Euborellia annulata* in each age x group feed on dog food (200 samples).

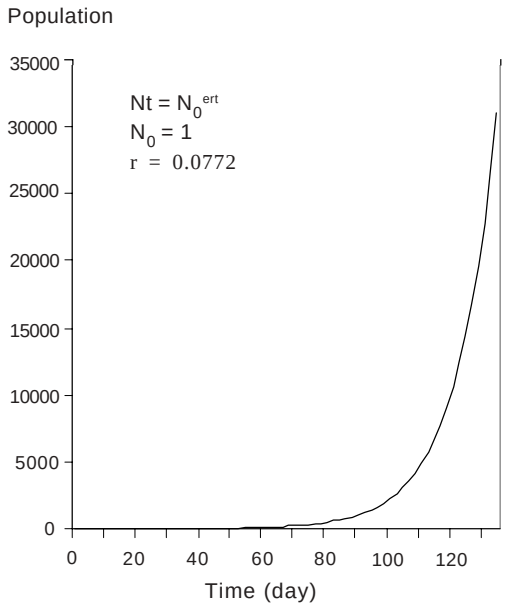

Fig. 5. Population growth rate of *Euborellia annulata* feed on dog food in laboratory.

Table 6. Population attributes of *Euborellia annulata*.

Attribute	Value	Remark
Gross reproductive rate (Gr)	113.73	mx
Net reproductive rate (R_0)	80.16	Σ lx mx
Generation time (T)	56.80	$\frac{\Sigma x\ lx\ mx}{\Sigma lxmx}$
Intrinsict growth rate (R)	0.0772	$\Sigma e^{-rx}lxmx = 1$
Limited growth rate (individu) (l)	1.17	e^r
Birth rate (b)	0.56	$b = \frac{r - B}{e^r - 1}$
Mortality rate (d)	0.48	d = b - r

CONCLUSION

Number of eggs laid by a single female of *E. annulata* was 86-166, which were laid five times in a group of 9-45 eggs. The egg size increased as increasing of its age. The nymph consists of five instars. Length of nymphs varied ranging from 4 to 13 mm depends on their instar. When adults emerged, they did not mate yet until their last molting which was 4-6 days for female and 2-3 days for male. Preoviposition period was 6-13 days. The eggs were deposited five times, the first, second, third, fourth, and fifth oviposition period were 7-22 days, 7-21 days, 7-18 days, 11-18 days, and 11-21 days respectively. The oviposition period was 32-59 days and postoviposition period was 21-51 days. Ratio between male and female was 1.4:1.

The intrinsic growth rate (r) of the predator was 0.0772, net reproductive rate (R_0) 80.16, limited growth rate (λ) 1.17, nymph stage period 39-46 days, and adult longevity of male and female were 57-75 and 61-89 days, respectively.

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