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STATUS OF INFESTATION AND BIOLOGY OF PEPPER FRUIT FLY, *Atherigona orientalis* (Schiner) (DIPTERA: MUSCIDAE)

Febrina Herawani[1], Aunu Rauf[2], & Sugeng Santoso[2]

[1]Entomology Study Program, Graduate School, Bogor Agricultural University, Indonesia
[2]Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University, Indonesia
Jl. Kamper Kampus IPB Darmaga Bogor 16680
E-mail: aunu@indo.net.id

ABSTRACT

Status of infestation and biology of pepper fruit fly,* Atherigona orientalis *(Schiner) (Diptera: Muscidae). Numerous muscid flies *Atherigona orientalis* (Schiner) (Diptera: Muscidae) emerged from fruit fly-infested pepper fruits. Research was conducted to determine the status of infestation of *A. orientalis* on pepper fruits, and to study its biology. Field survey was conducted in the pepper fields in Bogor, whereas study on its biology was done in laboratory. Field surveys showed that flies emerged from fruit fly-infested fruits consisted of 86.1% *A. orientalis*, 4.8% *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), and 9.1% lonchaeid fly (Diptera: Lonchaeidae). Fruits yielding only *A. orientalis* represented 79.7% of the infested fruits. The number of *A. orientalis* flies emerged per fruit ranged 1–24, with an average of 3.5 individuals. Laboratory study showed incubation period of eggs was 1.62 d, larva development lasted 11.93 d, and pupa 5.08 d. Longevity of female adult was 32.85 d and male 31.40 d. The number of eggs laid by a single female ranged 12–191, with an average of 83.80. Net reproductive rate R_0 =36.052, intrinsic rate of increase r_m = 0.136, mean generation time T = 26.482, doubling time D_t = 5.098, and finite rate of increase λ= 1.145. Overall, our research indicated that *A. orientalis* can be a primary pest of pepper fruits, with a high potential of population increase.

Key words: *Atherigona orientalis*, fruit fly, pepper

INTRODUCTION

Pepper is one of the important horticultural crops in Indonesia. Nationwide, its productivity for the past 5 years is about 6 ton/ha. To fullfill monthly needs of urban communities, it requires about 11,000 ha/month of harvested area of pepper. However, during party season such as Idul Fitri about 12,100–13,300 ha/month of harvested area is needed (Kementerian Pertanian, 2016). Major obstacles of pepper cultivation are plant pests and diseases, and one of them is the fruit fly. The principal fruit fly species infesting chilli pepper fruit in Indonesia has been considered to be *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) (Kalshoven, 1981; Nismah & Susilo, 2008). Other fruit fly species reported infesting chilli pepper in Malaysia (Vijaysegaran & Osman, 1991), Thailand (Wingsanoi *et al*., 2013), and Hawaii (Vargas & Nishida, 1985) is *B. latifrons* Hendel. In recent years, from samples of chilli pepper showing fruit fly infestation, numerous smaller yellowish flies emerged from the infested fruits. Further examination of these specimens revealed them to be *Atherigona orientalis* (Schiner) (Diptera: Muscidae).

Geographic distribution of *A. orientalis* is mainly pantropical, found within 20° north and south of the equator (Skidmore, 1985), which include various countries in Asia, Africa, America, Australia, and Oceania region (Suh & Kwon, 2016). Outside of that range it has been reported from Korea (Suh & Kwon, 2016), China, Florida, California, Texas (Hibbard & Overholt, 2013), and Argentina (Patitucci *et al*., 2012). *A. orientalis* is highly polyphagous. Larvae feed and develop on decaying plant materials, feces, and carrion (Bohart & Gressitt, 1951; Pont, 1986; Pont & Magpayo, 1995). Because of its food preferences and abundance, *A. orientalis* is considered to be an important species in the transmission of faecal pathogens and filth-borne diseases (Bohart & Gressitt, 1951). Larva of *A. orientalis* is facultatively predacious on living larvae of other insects including *B. cucurbitae* (Coquillett) (Yamamura & Iwahashi, 1982).

Major host plants of *A. orientalis* include cabbage and cauliflower (*Brassica oleraceae* L.), pepper (*Capsicum* spp.), orange (*Citrus* spp.), melon (*Cucumis melo* L.), tomato (*Lycopersicon esculentum* Mill.), beans (*Phaselous* spp.), and sorghum (*Sorghum* *bicolor* (L.)) (Hibbard & Overholt, 2013). Other host plants are bitter gourd (*Momordica charantia* L.), sponge gourd (*Luffa cylindrica* (L.) Roem.), eggplant (*Solanum melongena* L.), mango (*Mangifera indica* L.) (Kalshoven, 1981; Suputa *et al*., 2010), and soursop (*Annona muricata* L.) (Ogbalu *et al.,* 2016).

There are many records of *A. orientalis* reared in plants attacked by other insect pests (Pont & Magpayo 1995; Kalshoven, 1981). Thus *A. orientalis* could be considered a secondary pest. However, it can sometimes be a primary pest of certain agricultural crops in the family Solanaceae (Hibbard & Overholt, 2013). Ogbalu & Bob Manuel (2014) reported that *A. orientalis* is a major primary pest of bell pepper in Nigeria, and for that reason *A. orientalis* is called pepper fruit fly (Hibbard & Overholt, 2013; CABI, 2018).

Although our preliminary survey and previous studies (Kalshoven, 1981; Suputa *et al*., 2010) reported numerous *A. orientalis* flies emerged from fruit fly-infested pepper fruits, the status of *A. orientalis* whether as a primary or secondary pest is not known. Likewise, not much information available on the biology of *A. orientalis*. Study was conducted with the objectives (1) to determine the status of infestation of *A. orientalis* on pepper fruit, and (2) to study its life cycle and population growth parameters.

MATERIALS AND METHODS

Research Sites. Surveys were conducted in the red and curly pepper fields in Villages of Tenjolaya (Subdistrict Tenjolaya), Rancabungur (Subdistrict Rancabungur), Dramaga (Subdistrict Dramaga), Megamendung (Subdistrict Megamendung) of the District of Bogor; Bantarkemang (Subdistrict East Bogor) of the Municipality of Bogor; Cipanas (Subdistrict Cipanas) of the District of Cianjur. Insect rearing was done in the laboratory under room temperature of 25–27 °C and relative humidity (RH) of 60%. Research was conducted from November 2016 until December 2017.

Field Surveys. Surveys were conducted in two stages. The first stage was to determine the level of infestation of fruit fly. For this purpose, pepper field plots (each 100–500 m^2) showing fruit fly infestation were selected, and all uninfested (healthy) and infested pepper fruits were counted and recorded. The second stage was to determine fly species composition that emerged from the infested fruits. For this purpose, 50 fruit fly-infested fruits from each selected field were picked and put into the plastic bag with a label of the date and location, and brought to laboratory for adult emergence. Each infested pepper fruit was separately kept in the plastic glass (diameter = 9 cm, height = 12 cm) containing moist sterile sawdust at the base as a place for pupation. Flies emerged from the pupae were counted, recorded, and identified. Identification of Tephritidae was based on pictorial keys provided by the Plant Health Australia (2018), and of Muscidae based on Pont & Magpayo (1995), Moophayak *et al*. (2011), and Suh & Kwon (2017).

Biology of *A. orientalis*. Some of flies emerged from the infested fruits were used for life cycle study. For this purpose, 20 pairs of *A. orientalis* were collected and each pair was placed in a cylindrical plastic cage (diameter = 10 cm, height = 20 cm). The lid of each cage had a hole (4 × 4 cm) which was covered with organdi cloth as a ventilation. On the lower surface of the lid, a cotton wool was suspended inside the cage with the aid of a string. The cotton was moistened daily with a mixture of yeast, powdered sugar, and water (1:1:5) as food for adults. In addition, a mixture of yeast and powdered sugar (1:1) was also placed in the petri dish (diameter = 4 cm) as food. For oviposition site a fresh green pepper fruit, with a stalk submerged in the water filled-glass vial (diameter = 1.5 cm, height = 5.5 cm), was placed inside the cages. Each vial was placed in the middle of little plastic container and filled with cotton to make it stay firmly. The pepper fruit was replaced daily with the fresh one. The number of eggs laid by each female, as well as adult mortality were recorded every day.

To observe development of immature stages, 5 eggs laid by each 20 adults were left intact on the calyx. Therefore, the total number of eggs used for this study were 100 eggs. The development of eggs were observed every day until the eggs hatched, characterized by the presence egg shells. The 1st instar larvae, which fed and developed inside pepper fruits, were reared until the 3rd instar larvae exited from the fruits. Those emerged 3rd instar larvae were observed every day until pupation. Pupae were transferred into a transparent plastic container (diameter = 6.5 cm, height = 4.5 cm) and observed every day until adult emergence.

Data Analysis. Data on fruit fly infestation were tabulated based on sampling locations. Composition of fruit fly species emerged from the infested fruits was presented on the basis of sampling location and varieties of pepper. In addition, fruit flies emerged from the infested fruits were separated into those single (only one species) and mixed infestation (more than one species). If only *A. orientalis* emerged from an infested pepper fruits, it suggested that *A. orientalis* was a primary pest of pepper fruit. The immature developmental time, longevity of adults, and fecundity were presented as $\bar{x} \pm$ SE. Data of survivorship and daily fecundity was built into a fertility table, and combined with immature developmental time to determine various population growth parameters. Those parameters were net reproduction, $R_0 = \sum l_x m_x$; intrinsic rate of increase, $r_m = \sum l_x m_x \exp(r_m x) = 1$; mean generation time, $T = \sum \ln(R_0)/r_m$; finite rate of increase, $\lambda = \exp(r_m)$; and doubling time, $D_t = \ln(2) / r_m$ (Birch, 1948). Mean and variance of all those parameters were analyzed using LIFETABLE.SAS (Maia *et al.*, 2000) with the help of statistical package SAS version 9.0 for MS Windows.

RESULTS AND DISCUSSION

Status of Infestation Infestation Level and Fly Species Composition. Our field survey showed that the infestation level of fruit flies in the pepper fields ranged 2% in Megamendung and 16% in Rancabungur (Table 1). Herlinda *et al*. (2007) reported infestation level of 13.2% in Lahat District, South Sumatera. Such data represented infestation level occurred only at a specific date. In the fields, fruit fly infestation continues during growing season, and thus the cumulative infestation levels kept increasing. In addition, the infested pepper fruits generally fall to the ground and are not usually counted. Therefore, the cumulative yield losses must be higher than those predicted from a single observation. Hasyim *et al*. (2014) reported that yield losses of pepper caused by the fruit flies ranged from 20 until 60%.

There were 598 flies emerged from the infested pepper fruits, with *A. orientalis* having the highest proportion (86.1%), followed by lochaeid flies (9.1%) and *B. dorsalis* (4.8%) (Table 2). In each location, both for curly and red peppers, *A. orientalis* always showed the highest proportion of all the flies emerged from the fruits. This is in contrast with the current opinion that *B. dorsalis* was the main insect pest causing damage to pepper fruits. In fact, the proportion of fruits infested by *B. dorsalis* ranged 0–10%. In this study, we did not collect samples from the hot chilli pepper (*Capsicum futescens* L.) since it was rarely infested by *B. dorsalis*. According to Ogbalu (1989), hot chilli pepper was not preferred by *A. orientalis* for oviposition. Similarly, Suputa *et al*. (2010) reported that more *A. orientalis* flies emerged from red pepper. In Nigeria, *A. orientalis* was reported to be the major pest of bell pepper that cause yield losses up to 93.5% in certain varieties (Ogbalu *et al.*, 2005c).

Single and Mixed Infestation. Based on 158 infested fruits, 126 fruits (79.7%) yielded only *A. orientalis*, 6

Table 1. Level of fruit fly infestation in various pepper fields in Bogor

Villages	Field size (m^2)	Observed fruits	Infested fruits	Level of infestation (%)
Bantarkemang	300	2281	121	5.3
Tenjolaya	250	377	44	11.67
Megamendung	500	8802	211	2.4
Rancabungur	250	473	77	16.28
Darmaga	100	129	15	11.63

Table 2. Composition of species of flies emerged from infested fruits (n = 50 fruit samples from each village)

Villages	Pepper cultivars	Species*			Total
		A. orientalis	*B. dorsalis*	Lonchaeidae	
Cipanas	Curly	56 (96.6)	0	2 (3.5)	58
Bantarkemang	Curly	30 (96.8)	1 (3.2)	0	31
Tenjolaya	Red	76 (71.0)	11(10.3)	20 (18.7)	107
Megamendung	Curly	61 (72.6)	8 (9.5)	15 (17.9)	84
Rancabungur	Red	267 (91.1)	9 (3.1)	17 (5.8)	293
Dramaga	Curly	25 (100.0)	0	0	25
Total		515 (86.1)	29 (4.8)	54 (9.1)	598

* numbers in parentheses indicates percentage (%).

fruits (3.8%) only *B. dorsalis*, and 4 fruits (2.5%) only lonchaeid flies (Figure 1). Mixed infestations occurred on 6 fruits (3.8%) by *A. orientalis* and *B. dorsalis*, 10 fruits (6.3%) by *A. orientalis* and lonchaeid flies, 1 fruit (0.6%) by *B. dorsalis* and lonchaeid flies, and 5 fruits (3.2%) by all three species of flies. A high percentage of pepper fruits yielded only *A. orientalis* showed that the insect can infest the pepper fruits without being accompanied or preceded by *B. dorsalis* or other species. This might indicate that *A. orientalis* can be a primary pest on pepper fruits as previously reported on bell pepper in Nigeria (Ogbalu & Bob Manuel, 2014). According to Ogbalu (1989) during heavy infestation whih was generally occured in the rainy season, *A. orientalis* attacked both unripe and ripe pepper fruits. Heavy infestation of *A. orientalis* was related to use of chicken droppings as manure that attractive to *A. orientalis* flies (Iheagwam & Nwankiti, 1980).

Not only on pepper, *A. orientalis* has been reported to be a primary pest of several commodities. In Australia, *A. orientalis* is listed as a primary pest on tomato fruit because the female will lay eggs in the cracks of the fruit and the developing larvae will ruin the fruit (Queensland Government, 1998). Ogbalu *et al.* (2005c) reported that infestation level of *A. orientalis* on tomatoes in Nigeria reached 51%. Infestation level of *A. orientalis* on melon fruits in Pakistan ranged from 25 until 85% (Chughtai *et al.*, 1985). Status of *A. orientalis* as a primary pest on melon had been reported earlier in Florida by Butcher (1954).

Based on observation of 148 fruits infested only by *A.orientalis*, the number of flies emerged per infested fruit varied from 1 until 24 with an average of 3.5 flies (Figure 2). Eighty two or 55% of infested fruits yielded 1–2 flies. Further examination on raw data indicated that number of emerged flies seemed to depend on size of fruits. On average, 2.0 ± 0.1 flies emerged from curly pepper, while from red pepper having larger size the number of emerged flies doubled to 4.9 ± 0.6 flies. Differences in level of infestation among varieties are related to morphological factors such as shape, size, and colour, nature of calyx, and presence/absence of grooves (Ogbalu, 1989). The number of emerged flies indicates the total number of eggs laid per fruit. Ogbalu *et al*. (2005a) found the average number of egg was 75 eggs per 15 fruits, which was generally laid on calyx of fruit. On melon, *A. orientalis* laid 15–95 eggs per fruit (Chughtai *et al*., 1985).

Biology of *A. orientalis* Morphology. Laboratory observation showed that *A. orientalis* egg is white in colour and cylindrical in shape. It measures about 0.82 mm long and 0.20 mm wide. A number of parallel ridges run on the dorsal surface of the egg (Figure 3A). The ridges converge posteriorly, but at the anterior end of the egg remains tightly fitted with a thin lid. On the midventral side of the egg, a flat area is present with a pattern of small hexagonal markings. Generally, those descriptions are similar to *A. oryzae* Malloch egg described by Srivastava & Pandey (1968).

We did not make a detailed observation of the larval development, but it is known that *A. orientalis* has three larval instars (Couri & de Araujo, 1992; Grzywacz & Pape, 2014). According to Skidmore (1985) the first and second instar larvae are small and undescribed. The third instar larvae, which have just

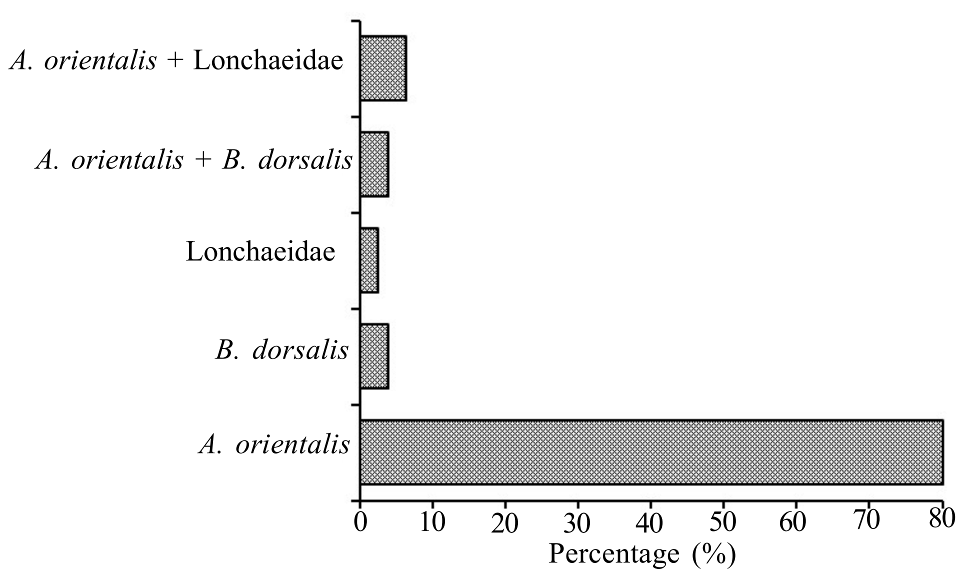

Figure 1. Proportion of pepper fruits infested by single and mixed species of flies

emerged from the infested fruit, measured 7.78 mm long and 0.95 mm wide (Figure 3B). A full description of larvae has been given by several authors (Bohart & Greesitt, 1951; Skidmore 1985; Couri & de Araujo 1992; Grzywacz & Pape, 2014). In laboratory rearing, the mature third instar larvae pupated in sawdust. In the field, pupation took places in the soil or inside the infested fruits (Ogbalu, 1999).

The puparium was initially light brown, but it becomes dark brown with age (Figure 3C), measured 4.03 mm long and 1.62 mm wide, and smaller than *B. dorsalis* pupae (±6 mm) that also infest pepper fruits. It as slightly tapered at the posterior end where

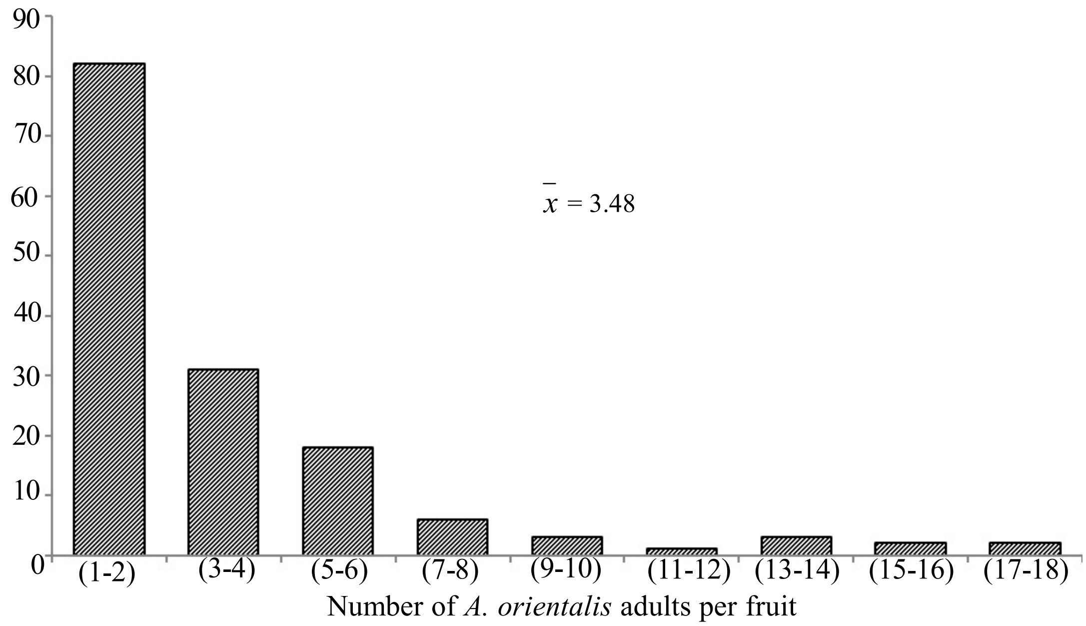

Figure 2. Frequency of infested pepper fruits based on the number of flies emerged per fruit

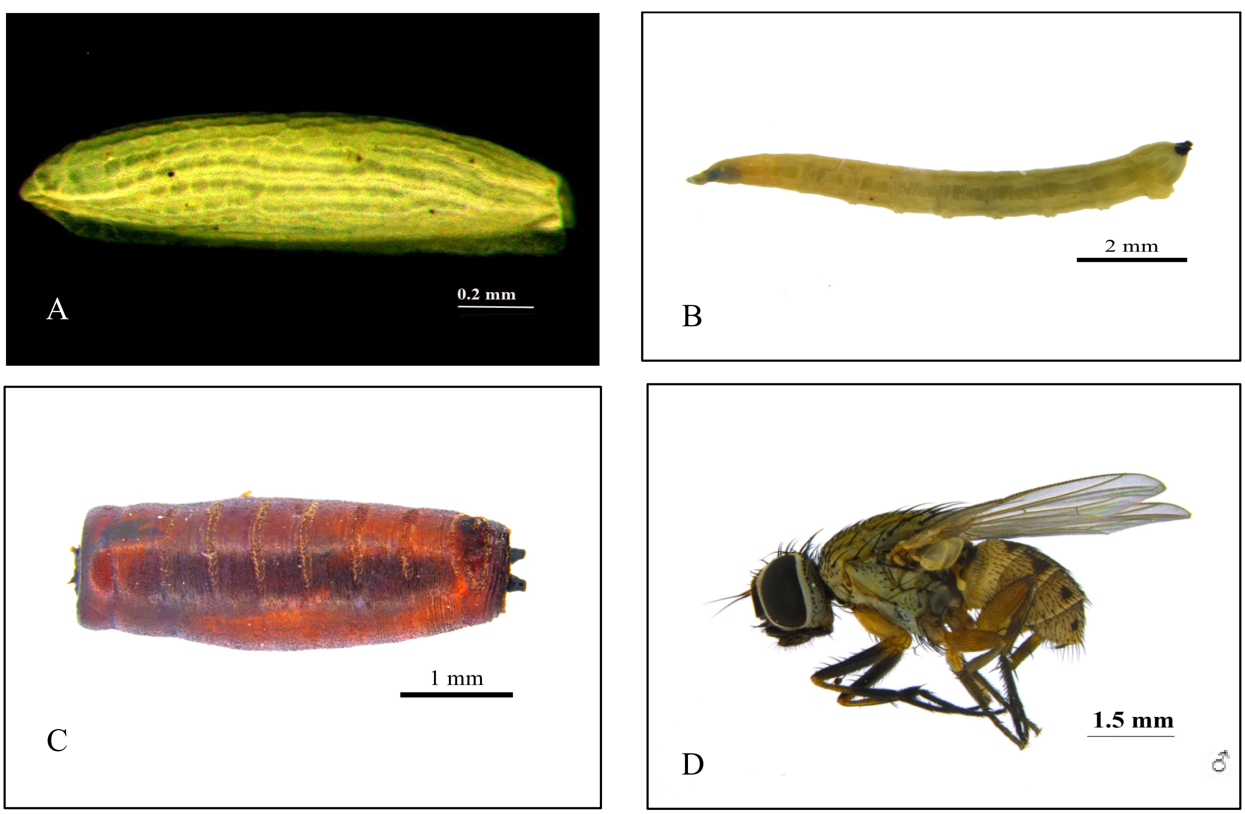

Figure 3. *Atherigona orientalis*: (A) egg, (B) larva, (C) puparium, and (D) adult

spiracular lobes are located, but is flat to slightly concave on the anterior end.

In general, adult of *A. orientalis* looks similar to housefly, *Musca domestica* L., but it is smaller. Malviya *et al.* (2015) reported that both species had a genetic similarity. *A. orientalis* adult has grey thorax, yellowish abdomen, and two pair black small dot in the dorsal abdomen (Figure 3D). The male and female flies can be easily distinguished by size. The male was 2.92 mm long and 1.28 mm wide. The female is slightly larger than the male, the body was 3.35 mm long and 1.57 mm wide.

Life Cycle. The immature developmental time of *A. orientalis* is presented in Table 3. The incubation period of eggs was 1.62 days. The developmental periods of larvae and pupae were 12 and 5 days, respectively. Therefore, their total developmental period from egg until adult emerged was 18.63 days. Chughtai *et al.* (1985), who studied *A. orientalis* on melon, reported the incubation period of eggs was from 36 to 58 hours, the larval period was 7 to 8 days, and the pupal period lasted for 5–6 days. The results are in conformity with observations on other species. Sileshi (1997) studied the biology of *A. hyalinipennis* van Emden on a cereal *Eragrostis tef* (Zucc), and reported that the average incubation period of eggs, developmental periods of larvae and pupae were 3, 10–15, and 8–11 days, respectively, with a total immature developmental period was 25.34 days. Karibasavaraja *et al*. (2007) studied *A. soccata* Rondani on sorghum and found that the egg incubation period was 2.10 days, duration of larval and pupal stages were 9.10 and 8.50, respectively; and total immature developmental period was 20.4 days.

From a total of 100 eggs of *A.orientalis* incubated, only 60 eggs hatched into larvae. The remaining of 40 eggs did not hatch that might be laid by unmated females. All those 60 larvae survived until become adults, with a sex ratio of male to female was of 1:0.77. The longevity of male adults was 31.4 days ranging from 12–41 days, while female adults lived 32.8 days ranging from 20–44 days. The preoviposition period was 5.7 days and oviposition period was 16.2 days. Ogbalu *et al.* (2005b) found the longevity of male and female adults, preoviposition period, and oviposition period was shorter than those in our study, i.e. male 7.4 days, female 14.5 days, preoviposition 1.7 days, and oviposition 8.9 days. These differences might be due to different laboratory temperature and food composition for adults used in the experiment (Ogwaro, 1978).

A single female of *A. orientalis* laid 12–191 eggs with an average of 83.8 eggs during its entire life span (Table 3). This is less than those reported by Ogbalu *et al*. (2005b) who found 2465 eggs from 21 female adults or average fecundity was 117.4 eggs per female. Studies by earlier workers also showed a variation in fecundity. Raina (1982) reported an average fecundity of *A. soccata* was 78.4 eggs, while Ogwaro (1978) found a slightly lower (62.8 eggs) for the same species. In contrast, Meksongsee *et al*. (1978) reported that an average fecundity of *A. soccata* in Thailand was 235 eggs per female. The variation in fecundity could be due to differences in duration of exposure, length of time to locate the host plant, adult longevity, food sources for adults (Nwanze *et al*., 1998), and preference for host plants (Ogbalu *et al*., 2005a).

Under laboratory condition, eggs were laid singly or in cluster on the calyx or pedicle (stalk) of fruits. We

Table 3. Development period (day) and fecundity of *Atherigona orientalis*

Stadia Immature	n	Range	$\overline{X}$ ± SE
Egg	60	1–2	1.62 ± 0.05
Larva	60	9–17	11.93 ± 0.29
Pupa	60	3–8	5.08 ± 0.19
Total of immature development	60	15–24	18.63 ± 0.27
Adult			
Male	20	12–41	31.40 ± 2.06
Female	20	20–44	32.85 ± 1.51
Preoviposition	19	2–19	5.79 ± 1.19
Oviposition	19	4–31	16.16 ± 1.81
Postoviposition	19	0–26	11.37 ± 1.91
Fecundity* (eggs/female)	19	12–191	83.80 ± 11.92

*One female laid only one egg and not included in estimating fecundity did not find eggs on smooth surface of fruit. Ogbalu *et al*. (2005a) who studied oviposition prefrences of *A. orientalis* on bell pepper, found most of the eggs (40–75%) were laid on the calyx and the rest on grooves.

Survivorship and Daily Fecundity. Daily survivorship curve (l_x) of *A. orientalis* showed type I (Figure 4) characterized by high age-specific survival probability in early and middle life, followed by a rapid decline in survival in later life. Fly mortality started at 21-day-old and then increased with the inceasing of age. Daily reproduction curve showed that oviposition period occurred when females were 2 until 34 days old. Average number of eggs laid per day (m_x) fluctuated, with the highest peak (8.3 eggs) occurred at 9-day-old females (Figure 4). Other peaks of oviposition occurred at 4, 12, 16, 20, 22, and 27 days old females. Examination on raw data showed that a female laid a maximum 58 eggs per day, and after that the female quited ovipositing for 2–3 days. Such a substantial fluctuations of egg laying was also reported for *Synthesiomyia nudiseta* (Wulp) (Diptera: Muscidae) (Rabinovich, 1970; Aruna *et al*., 2011).

Parameters of Population Growth. Various population growth parameters which include net reproduction (R_0), intrinsic rate of increase (r_m), mean generation time (T), doubling time (D_t), and finite rate of increase ( ) are presented in Table 4. R_0 represents the average number of offspring that a female produces during its entire life. In our study, the R_0 was 36.052 offspring per female per generation. Parameter r_m is the rate of increase per female per day under the constant environment, unlimited resources, and in the absence of external mortality factors. The r_m of *A. orientalis* under the given condition was 0.136 female/female/day. The average generation period (T) was 26.482 days. The time required for the population to double in number (D_t)was 5.098 days.The finite rate of increase ( ), which is the number of times that the population is multiplied per unit of time, was 1.145. Among all those parameters, r_m is the most important parameter obtained from a life table since it allows the comparison of potential increase among

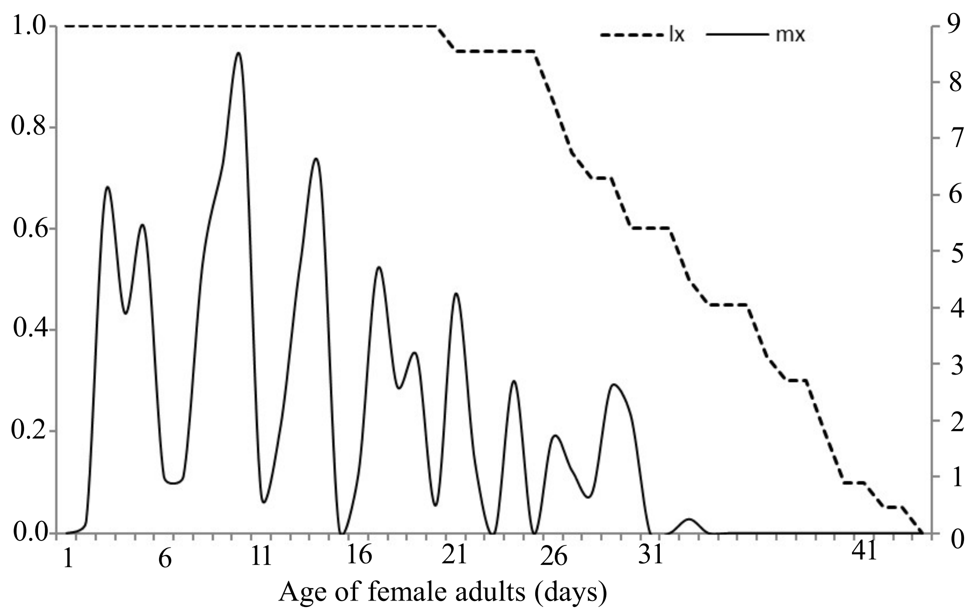

Figure 4. Survivorship and reproduction curve of *Atherigona orientalis*

Table 4. Population growth parameters of *Atherigona orientalis*

Parameters	Mean	95% Confidence interval	Corresponding unit
Ro	36.052	25.128 – 46.977	individual/female/generation
r_m	0.136	0.121 – 0.149	individual/female/day
T	26.482	24.533 – 28.430	days
D_t	5.098	4.555 – 5.641	days
λ	1.145	1.129 – 1.162	per day

species (Birch, 1948). The value of r_m in our study is nearly close to those other flies. Rabinovich (1970) reported the r_m of *Synthesiomyia nudiseta* fly (Wulp) (Diptera: Muscidae) was 0.11 and 0.18, respectively under temperature 20 °C and 28 °C.

Is *A. orientalis* a Primary Pest? *A. orientalis* is usually considered as secondary pest, since it is typically found in already damaged fruits, acting as a saprophagous (Pont & Magpayo, 1995). However, it can sometimes be a primary pest of certain agricultural crops, such as on cantaloupe in Florida (Butcher, 1954), melon in Pakistan (Chughtai *et al*., 1985), and bell pepper in Nigeria (Ogbalu & Bob Manuel, 2014). Our field surveys revealed status of *A. orientalis* on chilli pepper in Bogor. There was strong indication that *A. orientalis* can be a primary pest on pepper fruit, as also reported previously on bell pepper in Nigeria (Ogbalu & Bob Manuel, 2014). This was based on the fact that many fruit fly-infested pepper fruits yielded only *A. orientalis* flies. To ensure that *A. orientalis* is a primary pest on pepper fruit, it would be good to set up an artificial infestation experiment by adding pairs of *A. orientalis* flies into a cage with fruiting-pepper plants inside.

According to Ogbalu *et al.* (2005a), female of *A. orientalis* generally laid eggs under the calyx of pepper fruits and at the apical portion of the fruits where the freshly emerging 1st instar larvae make entry into pepper fruits, causing serious damage to both the unripe and ripe fruits. On tomatoes, the eggs were laid as soon as the fruit begins to crack or has any indentations at the flower end (Bohart & Gressitt, 1951). In cucurbits, the fly oviposited eggs in the wounds left by the ovipositor of *B. cucurbitae*, and it is suspected that the larvae of *A. orientalis* feed on the larvae of *B. cucurbitae* (Bohart & Gressitt, 1951; Yamamura & Iwahashi, 1982).

The increase of fruit fly infestation on pepper fruit caused by *A. orientalis* lately, most likely due to the increasing use of manure and compost in vegetable cultivation. Chilli pepper farmers are generally apply chicken or goat droppings as manure. According to Bohart & Gressitt (1951) the adults of *A. orientalis* feeds on a wide variety of substances, including carrion and rotting fruit and vegetables. Ogbalu's study (1999) revealed that plots having received chicken dropping as manure suffered the highest percentage of fruit infestation than plots treated with NPK chemical fertilizer. Furthermore, *A. orientalis* infestation also depend on the pepper varieties grown. Ogbalu (1989) reported a heavy infestation on bell pepper variety of Nsukka Yellow and Ataruga that both varieties have raised calyx, and females of *A. orientalis* preferred to lay eggs on such calyx. In addition to manure and variety, level of infestation was also affected by climate. *A. orientalis* severely attack pepper and tomato fruits mostly during rainy seasons (Ogbalu *et al*., 2005c). The correlation between climate and level of infestation was also reported on *A.soccata* (Singh *et al*., 2018). The high infestation of *A. orientalis* in the pepper fields is an evidence that the species has a potential to increase rapidly, as indicated by all population growth parameters.

CONCLUSION

Proportion of *A. orientalis* that outnumber other fly species and a high frequency of single infestation indicate that *A. orientalis* can be a primary pest of the pepper fruits. A short life cycle (21 days), a high intrinsic rate of increase r_m (0.136), and a polyphagous feeding behavior contribute to the rapid population growth and high infestation of *A. orientalis* in the fields.

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