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Effect of delayed mating on reproductive performance of *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae)

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Abstract

With the ban of methyl bromide and the many problems associated with the use of other synthetic chemicals, current research have focused on non-chemical alternatives and integrated pest management approach for the control of stored product insect pests. Mating disruption is one technique being investigated for its effect on stored product insects. In this study, we determined the effect of age at mating on the reproductive rate and longevity of the cigarette beetle, *Lasioderma serricorne* (Coleoptera: Anobiidae). We disrupted the mating approach by delaying the insects from mating for different time periods in days. Same age virgin male and female cigarette beetles were paired to mate soon after emergence (0 d old), or delayed from mating for 1–14 d. In another experiment, we maintained the age of the male at 0 d old and varied the age of the female from 0–14 d old and vice versa. Insects were observed daily for longevity and F_1 progeny was recorded 7–10 weeks after mating pairs were put together. Progeny production generally decreased with age of adults at mating. The number of F_1 progeny produced by same age adults varied from 10 per female to 59 per female. Similarly, the number of progeny decreased the longer one sex was delayed from mating. Findings from this study may provide information for the development of mating disruption techniques that can delay mating and may be effective in keeping populations of *L. serricorne* below levels that would warrant a control action.

Keywords: cigarette beetle, stored products, mating disruption, progeny production, methyl bromide alternatives

1. Introduction

Lasioderma serricorne (F.) (Coleoptera: Anobiidae), commonly known as the cigarette beetle or the tropical warehouse beetle, is a common stored product insect pest of feed mills and retail stores. *L. serricorne* causes significant damage to grain-based products, tobacco products, and other commodities of animal or vegetable origin (Arbogast, 1991; Dimetry et al., 2004; Mahroof and Phillips, 2008). The damage caused by this pest can account for millions of dollars in the Food and Feed Industries (Arbogast, 1991).

The ban of methyl bromide and the development of resistance to phosphine by the cigarette beetle (e.g. Savvidou et al., 2003; Sağlam et al., 2015; Fukazawa and Takahashi, 2017), has resulted in the search for potential non-chemical alternatives for the control of this pest (including Adler, 2003; Roesli et al., 2003; Conyers and Collins, 2006; Yu, 2008; Mahroof and Phillips, 2014).

Delayed mating techniques have been widely studied and used successfully in the control of many insect pests (including Ellis and Steele, 1982; Lingren et al., 1988; Fadamiro and Baker, 1999). Mating disruption involves the use of synthetic pheromones that mimic the natural sex pheromone normally released by the female. The release of high concentrations of the synthetic chemical 'confuses' the male which expends energy in finding the source of the pheromone and ends up delaying mating or not mating all together. To our knowledge, however, limited studies have been carried out on stored product beetles on mating disruption and mating delays. Few studies have been carried out on lepidopteran insects including the Indian meal moth, *Plodia interpunctella* (Hübner) (including Mbata, 1985; Huang and Subramanyam, 2003), with only one published studies on *L. serricorne* (Mahroof and Phillips, 2014). Mbata (1985) reported that a delay in mating resulted in a significant reduction of the number of eggs laid by *P. interpunctella* female as mature eggs were retained in the ovaries. Huang and Subramanyam reported that fecundity in female *P. interpunctella* significantly decreased by about 25 eggs for each day mating was delayed. The authors also reported that delaying mating in both sexes for 5 d resulted in the production of non-viable eggs by the female. Mahroof and Phillips (2014) studied the effect of the synthetic form of the predominant sex pheromone, serricornin, on the mating disruption of *L. serricorne*. The inhibition of proper orientation behavior of the males to females disrupted mating, resulted in delay in mating, and reduced the mating success. As a result, a significant reduction in the population size of subsequent generations was reported. From this study it was not clear why males fail to locate females in an environment purged with high concentration of synthetic pheromone. False trail following, masking of natural female pheromone or habituation of olfactory receptors may delay the age of mating (Mahroof and Phillips, 2014). The objective of this study was therefore to

investigate the effect of adult age at mating on the fecundity of females and the longevity of adult *L. serricorne*.

2. Materials and Methods

2.1. Insects

L. serricorne used for this study were from colonies which had been maintained at the Stored Products Entomology Research Laboratory at South Carolina State University since 2010. Prior to the bioassays, new colonies were established by transferring newly emerged adults to 473 ml rearing jars (Ball Corporation, Broomfield, CO, USA) with food made of 95% whole wheat flour and 5% yeast. The adults were allowed to lay eggs for 48 h and the rearing jars were then incubated for 31–35 days to attain the pupal stage of the insect. Cigarette beetle pupae were sexed using differences in the genital papillae (Halstead, 1963) and kept separately in jars containing some food. The jars were checked daily for adult development. Adults that developed in each jar were collected daily and kept in separate jars to be used when required. Adults of 0–14 d old were used in this study.

2.2. Mating of insects

One male and one female adult cigarette beetles of the same age were paired in a 5 cm high, 2 cm diameter plastic vial that contained 2 g of the diet mix. Same age insects (0-14 d) were paired up in a 5 cm high, 2 cm diameter plastic vial that contained 2 g of the diet mix. For each of the 15 ages, ten vials were set up. The vials were kept in an incubator at approximately 27.6 ± 0.1°C and 60.8 ± 0.8% RH. We determined the longevity of mated adult insects. The vials were checked daily until all adults died.

In another set of experiments, newly emerged (0-d old) virgin males were paired up with newly emerged virgin females or with 1–14 d old virgin females. Also, newly emerged virgin females were paired up with newly emerged virgin males or with 1–14 d old virgin males. Each mating treatment was done in a 10 cm high, 2 cm diameter plastic vial that contained 5 g of the diet mix. Each mating treatment was replicated 10 times.

2.3. Data analyses

The number of adults that developed in each vial was recorded weekly beginning 7 weeks after set up until 10 weeks. Data on the number of F_1 progeny produced in each mating treatment were subjected to one-way ANOVA and means were separated using Tukey's Honest Significant Difference (HSD) test when the ANOVA was significant at $P \leq 0.05$ (PROC GLM, SAS Institute, 2013).

We also determined the relationships between the longevity of the adults and their age at mating using regression analysis in TableCurve 2D software (Systat Software Inc., 2002).

3. Results

3.1. Effect of delayed mating on progeny production

The number of F_1 progeny produced by same age adults was significantly different as delay in mating increased ($F = 33.36$; $df = 14, 135$; $P < 0.0001$). Fewer progeny were produced by newly emerged adults (0-d old), with the highest progeny production by adults delayed from mating for 1- or 2-d. Delaying mating for two days significantly reduced the number of progeny produced (Fig. 1). The number of progeny produced by 6–11 d old adults did not differ significantly among each other.

The number of F_1 progeny produced when newly emerged males (0-d old) were paired with newly emerged females or with 1–14 d old females was significantly different ($F = 39.47$; $df = 14, 135$; $P < 0.0001$). The highest number of progeny were produced when both parents were 0 d old but it was

not significantly different from when the female was 1 d old. The number of offspring produced by 1–4 d old females were similar. The longer mating was delayed, the fewer the offspring produced (Fig. 2).

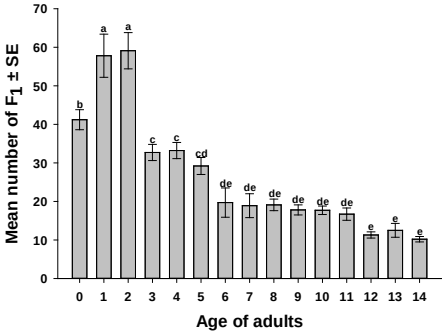

Fig. 1 Mean progeny production ± SE in same-age adult *Lasioderma sericorne* delayed from mating for different days. Bars with different letters represent means that are significantly different (Tukey's Honest Significant Difference test, $P < 0.05$).

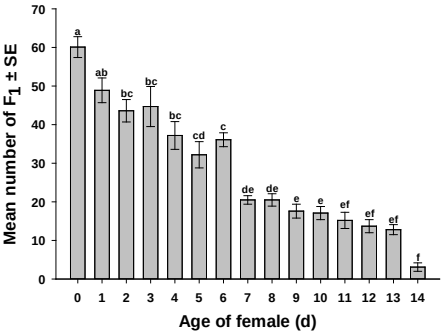

Fig. 2 Mean progeny production ± SE in adult *Lasioderma sericorne* delayed from mating for different days. Newly emerged (0-d old) males were mated with 0–14 d old females. Bars with different letters represent means that are significantly different (Tukey's Honest Significant Difference test, $P < 0.05$).

When 0-d old females were mated with 0–14 day old males, the number of F_1 progeny produced varied significantly ($F = 10.31$; df = 14, 135; $P < 0.001$) (Fig. 3). The trend was similar to that of the mating treatments where females were delayed from mating with newly emerged males. Similarly, newly emerged adults produced the highest number of progeny, however, not significantly different from progeny produced as a result of mating 0 d females with 1 d old males. Generally, the older the male, the fewer the number of progeny produced.

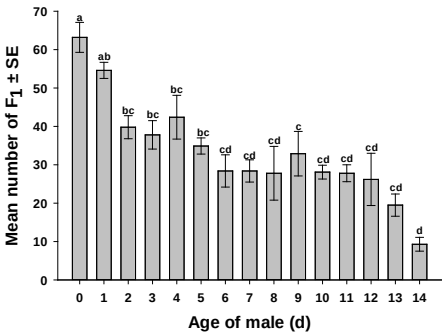

Fig. 3 Progeny production in adult *Lasioderma sericorne* delayed from mating for different days. Newly emerged (0 d old) females were mated with 0–14 d old males. Means followed by different letters are significantly different (Tukey's Honest Significant Difference test, $P < 0.05$).

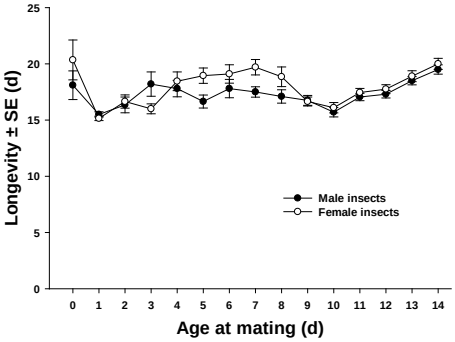

Fig. 4 Longevity of same-age adult *Lasioderma sericorne* mated at different ages. Longevity data accounts for their age at mating and the number of days they lived post-mating.

3.2. Effect of delayed mating on adult longevity

Average longevity ranged from 15.5 ± 0.2 to 19.5 ± 0.4 d in mated males and 15.2 ± 0.2 to 20.4 ± 1.8 d in mated females. Longevity was reported as the total lifespan of the insects, accounting for their

age at mating and the number of days they lived post-mating. There was a weak relationship between female longevity and age at mating ($y = 17.77 + 0.0000019^{x}$; $n = 20$; $r^2 = 0.14$) but a moderate relationship between male longevity and age at mating ($y = 17.05 + 0.0000022^{x}$; $n = 20$; $r^2 = 0.42$) (Fig. 4).

4. Discussion

The effect of delayed mating on progeny production in *L. serricorne* was investigated in this study. Progeny production was highest when there was no mating delay. Mating without delay may encourage multiple mating, probably because the adults are able to start mating early, subsequently resulting in an increase in the number of progeny produced (Huang and Subramanyam, 2003). As either sexes (Fig. 1) or one of the sexes (Figs. 2 and 3) age, fewer progeny was produced. Our findings were similar to those of other authors that reported the significance of multiple mating in progeny production in insect pests (including Huang and Subramanyam, 2003; Jiao et al. 2006; Yu, 2008). Huang and Subramanyam (2003) reported a significant reduction in fecundity of *P. interpunctella* for each day mating was delayed. The authors also reported that the majority of eggs laid by the female were laid within 4 d of mating. Jiao et al. (2006) reported a significant decrease in fecundity with increasing age at mating in the rice stem borer, *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae). Yu (2008) reported a significant decline in daily egg production in *L. serricorne* females 7 d after being paired with males. In our study, for each day that mating was delayed in any of the two sexes, 8–57 less progeny were produced. Delaying male or female mating for 2 d or more may have a significant impact on fecundity of *L. serricorne* and this could lead to a significant suppression in the population size of subsequent generations.

Studies have shown that increased fecundity in some multiple-mated females, and therefore increase in progeny production, may be due to the repeated transfer of some compounds including nutrient secretions and other hormones from the male to the female during copulation (Benz, 1969; Henneberry and Clayton, 1984; Park et al., 1998).

Many factors including mating status and diet have been reported to affect the longevity of stored product insect pests. Huang and Subramanyam (2003) reported that mated *P. interpunctella* moths lived for approximately 4–7 d. Yu (2008) reported that mated *L. serricorne* adults lived for 17–23 d, while unmated adults lived for 29–35 d. Findings in our study are similar to those of Yu (2008). In our study, we reported longevity of approximately 15–20 d in mated males and 15–22 d in mated females. Although not presented here, we observed that unmated males lived for approximately 28 d while unmated females lived approximately 3 d longer. The mating status of *L. serricorne* therefore seems to have an effect on the longevity of the insect. Adult longevity in *L. serricorne* has also been reported to be influenced by the diet on which the insect is raised (Mahroof and Phillips, 2008). The authors reported that adult longevity varied from 10–20 d depending on the food source.

Although the age of insects at mating has been established to be important in determining the fecundity (Mbata, 1985; Makee and Saour, 2001; Huang and Subramanyam, 2003), other factors such as diet, temperature, light have been shown to be equally important as well (Mbata, 1985; Shinoda and Fujisaki, 2001; Mahroof and Phillips, 2008; Vukajlović and Pešić, 2012). These factors may also be investigated to help develop pest management techniques. Findings in this study may be useful in the development of mating disruption techniques as an alternative control method that may be essential in managing *L. serricorne*.

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