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Susan Bjørnson [a]

[a] Department of Biology, Saint Mary's University, 923 Robie Street, Halifax, Nova Scotia, Canada, B3H 3C3

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SHORT COMMUNICATION

Fecundity of commercially available convergent lady beetles, *Hippodamia convergens*, following shipment

Susan Bjørnson*

Department of Biology, Saint Mary's University, Halifax, Nova Scotia, Canada

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The fecundity of *Hippodamia convergens* following shipment did not exceed 1.2 ± 0.5 eggs/female/day during 7-day trials. Fecundity was higher (7.4 ± 1.8 and 7.6 ± 1.6) in 14-day trials. If beetles do not disperse, egg production may be expected 5 days following their release if an adequate food source and favorable local environment are provided.

Keywords: *Hippodamia convergens*; biological control; fecundity; shipment

The collection and redistribution of convergent lady beetles, *Hippodamia convergens* Guérin-Méneville, for augmentative biological control is a practice that has persisted for almost 100 years (Carnes 1912). Each year, large quantities of beetles are collected from their overwintering sites in the Sierra Nevada Mountains of California. These beetles are then sold to growers and home gardeners for aphid control. The tradition of using *H. convergens* for biological control has continued despite reports that field-collected beetles harbour a wide array of natural enemies that may be inadvertently imported and released along with the beetles themselves (Lipa and Steinhaus 1959; Sluss 1968; Bjørnson 2008). Some of these natural enemies (the endoparasitoid *Dinocampus coccinellae* (Schrank) and a microsporidium) have relatively broad host ranges and may reduce the fitness of *H. convergens* and other coccinellids (Ceryngier and Hodek 1996; Saito and Bjørnson 2006). The effects of other natural enemies associated with commercially available *H. convergens* (eugregarines and a fungus of the genus *Verticillium*) have yet to be determined.

Another concern associated with the use of *H. convergens* is the tendency of beetles to disperse once they are released in the field (Davis and Kirkland 1982). Although some beetles are likely to remain in the local environment following their release, the use of convergent lady beetles for inoculative biological control may be better suited for confined areas such as greenhouses. Regardless of their application, fecundity is often an important measure of efficacy. Therefore, the objective of this study was to examine the fecundity of commercially available *H. convergens* immediately following shipment. Fecundity of released *Hippodamia* as reported here is relevant to inoculative biological control, where pest control is provided by the progeny of the released individuals.

Hippodamia convergens females were obtained from three commercial sources on a biweekly basis from mid-July to mid-August 2004. Beetles from Source A were purchased online and shipped by Priority Post (Canada Post Corporation). Beetles from Source B

*Email: susan.bjornson@smu.ca

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were shipped directly from the supplier to a horticultural retail outlet. These beetles were kept under refrigeration until they were picked up in person. Beetles from Source C were shipped by courier. Females from seven shipments were used to determine fecundity during 7-day trials: three shipments from Source A, two from Source B and two from Source C. Females from another three shipments were evaluated for fecundity during 14-day trials (Source C). Beetles from Source A arrived in small cardboard boxes that did not contain other packing materials or cold packs. Several holes had been punched in the sides of each box to provide ventilation during transit. Shipments from this source took 3 or more days to arrive. Beetles from Source C arrived in cardboard boxes that contained cold packs.

Upon receipt, beetles were removed from their shipping materials (small, burlap sacks that contained paper strips or wood shavings) and released into a 30.5-cm (W × H × D) cage equipped with 70-μm mesh netting and a clear, plastic side panel (Bioquip, CA). Water was provided through cotton wicks (1.5 × 3/8″, Crosstex International, NY) that were saturated in deionised water. After 1h had lapsed, an insect vacuum (Bioquip, CA) was used to remove live beetles from the cage at random. Beetles were placed into clear, polyethylene cups (120-mL; Marivac Canada Inc., QC) so that each cup housed about 125–200 beetles. Each cup had a 2.5-cm diameter hole in its side that was fitted with a fine-mesh screen (80-μm mesh, Bioquip, CA). This allowed air movement while preventing beetles from escaping. Live beetles were stored in a Sanyo MLR-350H environmental test chamber for 24 h (10°C, dark) until they were removed and used in the fecundity trials.

Individual females that were used in the fecundity trials were chosen at random from cups of refrigerated beetles. During the 7-day trials, each female was isolated in a polyethylene cup and water was provided through a saturated cotton wick. Beetles were fed an *ad libitum* diet of rose aphids (*Macrosiphum rosae* L.) that were collected from cultivated roses on the Saint Mary's University campus and were maintained in an environmental chamber (16L: 8D; 25°C). Fecundity was recorded daily.

Females were not given the opportunity to mate during the 7-day trials; therefore, it was not determined whether females failed to produce eggs because they were unmated or whether their infertility was due to other reasons. To determine if there was a mating effect, females from an additional three shipments (Source C) were further evaluated during 14-day trials. Some females were isolated within polyethylene cups for the duration of this trial (control), whereas others were isolated with a male for 24 h and given the opportunity to mate (treatment). Upon death or at the end of each trial, all females were dissected and examined for invertebrate parasites. Smear preparations were fixed in methanol, stained in 10% buffered Giemsa and examined for microorganisms by light microscopy. A two-way analysis of variance was used to test for significance on log-transformed mean fecundity data (variates: shipment, treatment, and interaction of shipment*treatment). A statistical power analysis was used to determine if there was sufficient power to reject the null hypothesis.

Mean fecundity during the 7-day trials was 1.2 ± 0.5 eggs per day or less (Table 1). With one exception, females began to produce eggs on or after Day 5. Although the majority of females (161/185, 87%) failed to produce eggs during these trials, some were gravid when dissected at the end of the trial. Eight females that did not produce eggs were parasitised by *D. coccinellae*.

During the 14-day trials, the majority of females (40/62, 65%) laid eggs but none were produced before Day 5 (Table 1). No significant differences were found for source ($F_{[2,1]} = 3.03$, $P = 0.06$), treatment ($F_{[1,2]} = 0.001$, $P = 0.98$), and source × treatment interaction ($F_{[2,56]} = 1.441$, $P = 0.25$). A statistical power analysis determined that source, treatment and interaction had sufficient power ($P > 0.80$) to reject the null hypothesis. As a result,

Table 1. Fecundity (eggs/female/day) of commercially available *Hippodamia convergens* following shipment.

Trial length	Source	First day of oviposition	Fecundity (Grand mean ± SE)	*n*	Ovipositing females	Gravid females[1]	Parasitised females[2]	Females alive at end of trial
7 days	A	Day 5	1.2 ± 0.5	20	8	1	0	18
	A	Day 4	0.1 ± 0.1	26	3	1	0	23
	A	Day 5	0.1 ± 0.1	29	2	2	1	26
	B	Day 5	0.3 ± 0.2	30	5	3	0	28
	B	n/a	0.0 ± 0.0	28	0	1	0	28
	C	Day 5	0.7 ± 0.6	23	3	3	4	23
	C	Day 6	0.2 ± 0.1	29	3	4	3	29
14 days	control	Day 5	7.4 ± 1.8a	30	20	0	0	26
	treatment	Day 5	7.6 ± 1.6a	32	20	0	0	27

[1]Gravid females that did not oviposit; [2]parasitism by *Dinocampus coccinellae* (Shrank); control, isolated females; treatment, females that were isolated with males for the first 24 h of the trial. Means with similar letters do not differ significantly ($P > 0.05$).

data for control and treatments were pooled. Females from control and treatment groups produced 7.4 ± 1.8 and 7.6 ± 1.6 eggs/female/day, respectively (Table 1). Microsporidia or other microorganisms were not detected in any of the beetles used to assess fecundity. However, the majority of dissected beetles had prominent fat bodies.

Hippodamia convergens females that are collected from their aggregation sites are known to disperse once they are released in the field (Hagen 1962; Davis and Kirkland 1982). Eggs are produced only after females migrate and feed on aphids (Hagen 1962) and their ovaries become mature (Davis and Kirkland 1982). In general, egg laying females in this study did not begin to produce eggs until Day 5 of the fecundity trials even though they were provided an *ad libitum* diet of aphids. In contrast, aphid-fed females that are collected from mountain aggregations begin to oviposit after about 10 days (Hagen 1962) and ovary maturation occurs in fed females about 8 days after being removed from cold storage (Davis and Kirkland 1982).

Beetle fecundity increased when beetles were confined with aphids for 14 days (rather than 7); however, this improvement appeared to be associated with the prolonged length of the trial. It is unlikely that the lower mean fecundity values observed during the 7-day trials were due to a mating effect because mean fecundity during the 14-day trials was similar for females that were isolated with a male and for those that were not. Like the females in the 7-day trials, females evaluated during the 14-day trials did not produce eggs before Day 5. An increase in the number of eggs produced during the second week was responsible for the noted increase in mean fecundity. Mating is thought to occur shortly before beetles disperse from their mountain aggregations in the spring (Hagen 1962) and results from the 14-day trials suggest that imported females have already mated prior to shipment and are capable of producing eggs once released.

Large fat stores are associated with dormancy (Hagen 1966) and in this study; dissected *H. convergens* females had prominent fat bodies. The length of time needed for beetles to use this stored fat and the relationship between ovarian development and fat storage is not known. Beetles with large fat stores may feed less on aphids than will beetles with little or no fat storage; however, the relationship between the two is unclear.

Hippodamia convergens have a tendency to disperse following release (Davis and Kirkland 1982). Although the inundative release of large numbers of *Hippodamia* outdoors has been reported to provide temporary aphid control (Raupp, Hardin, Braxton, and Bull 1994; Dreistadt and Flint 1996; Flint and Dreistadt 2005), it is unlikely that beetles will remain in a given area long enough to produce large numbers of eggs unless they are released in a greenhouse or other confined area. Egg production cannot be expected for a minimum of 5 days following release and because eggs take several days to hatch, aphid control by beetle larvae could be expected about 10 days after adult beetles are released. These estimates are based on laboratory findings and this scenario is also contingent on other assumptions (the provision of temperatures favourable for development and the continual supply of an adequate food source). Commercial greenhouses are likely to provide beetles with less than optimal conditions for development. Under these circumstances, beetles are likely to require additional time for locating prey and for oviposition.

Field-collected *H. convergens* arrive in poor condition and produce eggs within 4–5 days if they are confined and fed an excess diet of rose aphids. Some beetles harbour natural enemies (Bjørnson 2008) and this further reduces the efficacy of *H. convergens* as a biological control agent.

Hippodamia convergens are widespread in their natural distribution with a range that extends throughout most of the continental United States and the southernmost regions of

the Canadian Provinces (Gordon 1985). However, convergent lady beetles are not native to Nova Scotia (Gordon 1985; Majka and McCorquodale 2006). The practice of releasing *H. convergens* for aphid control outside of their natural range is unwise in the context of conserving beetle biodiversity and preventing the dissemination of coccinellid natural enemies.

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