TEMPERATURE RELATIONS OF ADULT *COLEOMEGILLA MACULATA LENGI* AND *C. M. MEDIALIS* (COLEOPTERA:COCCINELLIDAE) AND RESPONSES TO OVIPOSITIONAL STIMULANTS

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Abstract

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An adult of either *Coleomegilla maculata lengi* or *C. m. medialis* ate about 280 mg dry *Acyrthosiphon pisum* in its lifetime at various constant temperatures. Total food consumption and rate of intake increased with temperature and rate did not vary with age. The average ages attained by field-collected and laboratory-reared adults were greatest at temperatures of 17° and 23°C, respectively, for *C. m. lengi* and at 23°C for *C. m. medialis*. Neither subspecies laid any eggs at 17°C, *C. m. lengi* laid some eggs at 23°C, and both subspecies laid the largest number of eggs at 25°C. Fertility as percentage of eggs hatched was lower in both subspecies at 34°C (30%) than at 23° and 25°C (100%). Ethanol extracts of teak, cinnamon, clove, guaiacol, and resorcinol were the most effective ovipositional stimulants for *C. m. lengi* when formulated in water. Exposure to the ethanol extracts of different plants increased the incidence of oviposition by 19% and the number of eggs/♀/day by 36% in *C. m. lengi*.

Introduction

In the development of pest control programmes using methods that make the best possible use of coccinellid predators, more information is needed on the limiting effects of temperature on their reproduction and on the feasibility of applying ovipositional stimulants to crops to increase the local density of coccinellids. Extracts of *Juniperus virginiana* L. and various chemicals act as oviposition stimulants for *Coleomegilla maculata lengi* Timberlake (Smith *et al.* 1973), which is a predator of various aphids, scales, and mites and of insect eggs including those of the cereal leaf beetle (Shade *et al.* 1970). This paper describes the effects of constant temperature on age attained, food consumption and rate of intake, fecundity, fertility and food efficiency for egg production in adult *C. m. lengi* and *C. m. medialis*. The latter is a large subspecies which might be more effective than *C. m. lengi* in biological control. It also describes the effects of spray materials on the ovipositional behaviour of *C. m. lengi*.

Materials and Methods

Temperature Effects

Adult *C. m. lengi* were collected from corn near Belleville, Ont., and *C. m. medialis* from sugarcane in Trinidad. Adults of both subspecies were also reared from larvae fed on live *Acyrthosiphon pisum* (Harris) according to the method of Smith (1965*a*). Adults were confined singly in petri dishes in darkness to eliminate the possible effects of light and each was fed until death dry powdered *A. pisum* provided in lots of 5 and 15 mg. Drinking water was supplied via wicks. Adults were weighed when food was added. Sets of 8 ♀♀ and 8 ♂♂ of each subspecies from the field and from the laboratory were maintained under each of the following conditions of temperature and humidity: 17±1°C, 75±10% R.H.; 23±1°C, 60±10% R.H.; 25±1°C, 60±10% R.H.; and 34±1°C, 45±10% R.H. Records for each insect were kept concerning: length of body, live and dry weight, laboratory age, total food consumption, rate of food intake, fecundity as total number of eggs laid by a female in the laboratory, and fertility as percentage hatch of eggs incubated at the laying temperature. Rate of food intake and food efficiency for egg production were calculated each time that food was added.

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Ovipositional Stimulants

Additional sets of female *C. m. lengi* from the field and laboratory were used to bioassay chemicals which might affect oviposition. The laboratory females were reared as larvae on live *A. pisum* at 25°C and 60% R.H. in darkness. When not in a test these insects were kept singly in dishes at 23°C and 60% R.H. under fluorescent light with a light-cycle at 16:8 h. The bioassay has been described in detail (Smith *et al.* 1973). A 5×10×10 cm cage with end walls of glass, one of which was sprayed with 0.4 ml of a test formulation was used. When the formulation dried, 1 ♀ and its food (10 adult *A. pisum*) were released into a cage. A test lasted 24 h. Each formulation was usually tested with the same 12 ♀♀ in 3 replicated tests yielding a maximum of 36 egg batches. The locations and numbers of all *C. m. lengi* egg batches in the cages were recorded. An egg batch consisted of a group of eggs usually in contact with each other and laid on one occasion. Results of tests on a formulation were averaged and are summarized as percentage of females ovipositing, the ratio usually expressed as a quotient of egg batches and eggs in the cage half adjacent to the formulation to those in the other half (response ratio), and the mean number of eggs/♀/day. A formulation was considered to have affected the selection of oviposition sites, and the response to it was considered to be positive when the ratios for batches and eggs were ≥ 2 and negative when the ratios were < 0.5 in 24 of 36 tests.

Only materials relatively innocuous, commercially available, and suitable for spraying as emulsions on crop plants were selected for testing (Table III). These included several adjuvants that are used in chemical formulations, ethanol extracts from various plants, and other chemicals including several phenolic substances. The extracts were prepared as described by Smith *et al.* (1973). All water formulations contained the emulsifying agent Tween 80 (Atlas) at a concentration of 0.1 ml/l. Age, fecundity, ovipositional period (period when at least one egg was laid in 10 days), numbers of eggs laid in test and holding cages, and numbers of eggs laid in treated and blank areas of cages were recorded for each female of the ovipositional bioassay sets. This was done to determine a possible relationship between a test chemical and survival and fecundity, and to assess variation within the subspecies.

Results

Temperature Effects

No differences between female and male in total food consumption or rate of intake were observed for the subspecies. The total food consumptions of *C. m. medialis* and *C. m. lengi* based on the pooled data for temperatures, origin, and sex were 130.5±12 and 150.1±18 (mean and s.e.) mg dry *A. pisum*/adult, respectively, and the difference was not significant by analysis of variance with $P < 0.05$. Total food consumption increased in both subspecies with temperature. The pooled relationships at various constant temperatures between food consumption (in mg) of dry powdered *A. pisum* (Y) and laboratory age (X) for *C. m. lengi* and *C. m. medialis* that were collected in the field and reared in the laboratory were: 17°C, $Y = .4X + 29.9$; 23°C, $Y = 1.2X - 6.4$; 25°C, $Y = 1.3X + 37.0$; and 34°C, $Y = 1.8X + 29.6$.

The rate of intake of dry *A. pisum* varied much between individuals and increased with temperature. The means in mg/day/mg adult weight for field and laboratory (in parentheses) *C. m. lengi* at various temperatures were: 17°C, .07(.04); 23°C, .11(.11); 25°C, .13(.13); and 34°C, .16(.18). Similarly the means for *C. m. medialis* were: 17°C, .03(–); 23°C, .07(.06); 25°C, .10(.10); and 34°C, .14(.10). The variances of the intakes for both the *C. m. lengi* sets were still heterogeneous after square root transformation but this was not considered of great importance in the analyses. The rate of intake by field and laboratory *C. m. lengi* showed quadratic responses to

temperature, field *C. m. medialis* showed cubic responses, and reared *C. m. medialis* showed linear response only. The equations of the relationships between rate of food intake (in mg) of dry *A. pisum* eaten/day/mg of adult weight (Y) and temperature (X) for *C. m. lengi* (L) and *C. m. medialis* (M) from the field (F) and laboratory (L) were LF, $\hat{Y} = .02X - .0003X^2 - .09$; LL, $\hat{Y} = .05X - .001X^2 - .46$; MF, $\hat{Y} = 4.1 - .52X + .02X^2 - .003X^3$; and ML, $\hat{Y} = .01X + .11$. Food intake rate did not vary with age except in reared individuals where it was higher during the first 15 days of adult life than later (Smith 1965*b*).

There was much variation in the fecundity of females fed on live *A. pisum* (Fig. 1). The mean and range of period of egg-laying for the combined field and reared *C. m. lengi* used in the ovipositional studies was 50.7 (4–168) days. Correlation between time lived and period of egg laying was high ($r = 0.87$) and fecundity (Y) is expressed best by period of egg laying (X) in quadratic model. The equation is: $Y = 6.8 + 5.4X - 0.01X^2$ with the correlation coefficient = 0.72.

C. m. medialis did not live longer than *C. m. lengi*. Differences in sex did not affect the maximum age attained. Field adults of *C. m. medialis* survived at 17°C but reared adults did not. Maximum age attained was smaller for all sets except the reared *C. m. medialis* at 34°C than at the other temperatures (Table I). The maximum age attained by field *C. m. lengi* decreased with increased temperature, but for reared *C. m. lengi* and field and reared *C. m. medialis* it was greatest at 23°C and smaller at other temperatures. The field set of *C. m. lengi* used to bioassay water formulations lived 44.4 (16–99) days and the reared set lived 71.4 (14–193) days (mean and range).

The fertility of mated females of both subspecies was about 30% at 34°C and 100% at 23° and 25°C. Food efficiency for egg production varied much in both subspecies and the mean with range was 0.3 (0.02–1.6) eggs/♀/day/mg of *A. pisum*.

Neither subspecies laid eggs at 17°C and *C. m. medialis* laid no eggs at 23°C (Table II). The field set of *C. m. lengi* that was used in the bioassay of ovipositional materials laid 152.5 (2–525) and the reared set laid 249.9 (12–875) eggs/♀.

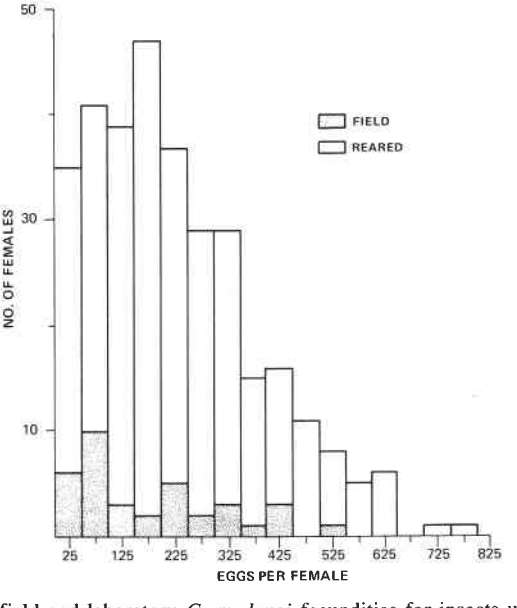

FIG. 1. Distribution of field and laboratory *C. m. lengi* fecundities for insects used to test ovipositional stimulants in water formulations.

Table I. Age attained[a] by adult *C. m. lengi* and *C. m. medialis* from the field and from laboratory rearing at various temperatures and fed on dry *A. pisum*

	Temperature (°C)			
	17	23	25	34
C. m. lengi, field	226.7(197–252)	109.0 (87–138)	102.6(38–211)	85.8(47–127)
C. m. lengi, lab.	78.3 (74– 84)	130.7 (95–186)	106.0(41–187)	74.7(31–115)
C. m. medialis, field	124.0 (82–147)	166.3(138–195)	100.0(52–144)	80.0(55–106)
C. m. medialis, lab.	0	85.7 (50–114)	79.31(71–100)	83.7(73–105)

[a]Means and ranges in days with $N \geq 12$.

Females of both subspecies were similar in body length: ♀ *C. m. lengi* were 5% longer and ♀ *C. m. medialis* were 12% longer than males. Males and females of *C. m. medialis* were similar and those of *C. m. lengi* were dissimilar in weight. Female *C. m. medialis* were about 18% heavier and male *C. m. medialis* were about 21% heavier than those of *C. m. lengi*. The mean lengths (in mm) for ♂ and ♀ *C. m. lengi* (L) and *C. m. medialis* (M) with means followed by the same letter not significantly different by analysis of variance and multiple range test ($P < 0.05$) were: ♂ L, 5.9*a*; ♀ L, 6.2*b*; ♂ M, 5.6*c*; and ♀ M, 6.3*b*. The mean live weights (in g) were: ♂ L, 8.7*a*; ♀ L, 9.5*b*; ♂ M, 10.5*c*; and ♀ M, 11.0*c*. The mean dry weights (in g) were: ♂ L, 1.8*a*; ♀ L, 1.9*b*; ♂ M, 2.2*c*; and ♀ M, 2.3*c*.

Ovipositional Stimulants

Several formulations with different ovipositional stimulants influenced *C. m. lengi* to lay eggs on or near treated surfaces. Ethanol extracts of teak, cinnamon, clove, guaiacol, and resorcinol were the most effective when formulated in water (Table III). S. M. 134 is a borderline deterrent. The number of eggs laid by females that were tested on the seven of eight ethanol extracts from various plants (Table III) with response ratios > 2.0 was significantly larger than the number laid by females tested on water and various adjuvants ($P < 0.05$ in analysis of variance); the means are 9.1 and 6.7 eggs/♀/day, respectively. There was a significant difference between these groups in the proportion ovipositing ($P < 0.05$ in analysis of variance of percentage transformed to angles). The respective means are 90.0% and 75.8% for the groups with response ratios > 2 and < 2.

Discussion

Temperature Effects

C. m. lengi and *C. m. medialis* are very widely separated geographically but large consistent differences in their temperature relationships were not observed. The most

Table II. Fecundity[a] of *C. m. lengi* and *C. m. medialis* from the field and from laboratory rearing at various temperatures and fed on dry *A. pisum*

	Temperature (°C)		
	23	25	34
C. m. lengi, field	15.3(14–27)	70.1(39–109)	51.0 (2– 70)
C. m. lengi, laboratory	31.3(12–61)	60.0(44–75)	57.0 (4–152
C. m. medialis, field	0	88.0 (3–140)	41.5(28–53)
C. m. medialis, laboratory	0	9.3 (3– 28)	0

[a]Means and ranges with $N = 6$.

important was the failure of laboratory-reared *C. m. medialis* to survive and the failure of all test females of this subspecies to reproduce at 17°C. These failures and the relatively low fecundity of *C. m. lengi* at 23°C are probably attributable to low total food consumption and low rates of food intake. In spite of control over physical and nutritional factors, there was a high level of variation between and within subspecies in the effects of temperature on food intake rate and fecundity. This probably reflects large individual differences in the test insects. *C. m. medialis* would probably not be able to survive Canadian conditions . If we assume that the most favourable climatic conditions for the reproduction of *C. m. lengi* include a mean temperature of at least 25°C then southern Ontario is below optimal. The four warmest climatic regions of Ontario and their mean summer temperatures are: Leamington, 20.5°C; Kent and Essex, 20.2°C; Niagara, 19.7°C; and Lake Erie counties, 19.4°C (Ontario Ministry of Agriculture and Food).

Ovipositional Stimulants

More than one class of compound in water formulation can influence the ovipositional behaviour of *C. m. lengi*. Concentrations of active material ranging from

Table III. Oviposition responses of *C. m. lengi* to water formulations of various materials[a] with Tween 80 at a concentration of 0.1 ml/l.

Material	Concn. (%)	Proportion ovipositing (%)	Response ratio[b]		Eggs/ ♀/day
			Egg batches	Eggs	
Adjuvants[c]					
Controls	Water	73.3	0.9	1.1	6.3
S.M. 134[d]	0.1	80.6	.6	.4	8.2
Spreader-sticker[e]	.5	72.2	1.2	1.4	5.5
Triton B-1956[f]	.5	77.8	1.3	1.9	6.9
Tween 80[g]	.1	75.0	1.0	1.1	6.5
Ethanol extracts from various plants					
Cinnamon zeylanicum Nees (wood)	.2	86.1	5.2	4.9	6.9
Coriandrum sativum L. (fruit)	.5	90.6	2.9	3.3	8.6
Eugebia caryophyllata Thumb (flower)	.2	97.3	4.8	4.8	9.5
Juglans nigra L. (wood)	.1	87.0	2.3	4.1	8.6
Juniperus virginiana L. (wood)	.1	73.1	3.7	5.2	8.6
Prunus serotina Ehrh (wood)	.1	76.9	1.8	1.7	8.6
Tectona grandis L. F. (wood)	.1	100.0	11.0	9.1	11.0
Zingiber officinale Roscoe (root)	.2	96.3	3.3	4.8	10.4
Various chemicals					
Carvacrol	.05	81.8	3.5	8.2	8.8
Fluorescein	.05	50.0	2.4	3.8	4.5
Guaiacol	1.0	81.8	5.0	7.5	5.7
O-Coumaric acid	.5	90.3	2.1	3.4	7.8
Piperidine	2.0	80.5	3.1	3.2	6.8
Resorcinol	.2	52.9	6.0	10.5	4.2
Tannin	.05	100.0	2.2	2.4	9.2
L-Tyrosine	.02	81.5	2.7	1.8	6.3
Vanillin	.05	87.5	1.4	1.8	6.6

[a]Each material assayed in 36 tests with 12 adults.
[b]Ratio expressed as quotient of egg batches and eggs in the cage half adjacent to the material to those in the other half and halves significantly different ($P < 0.05$) with ratio ≥ 2 or < 0.5.
[c]Tested individually.
[d,e,f,g]Chase Organies, Dupont de Nemours, Rohm and Haas, and Atlas, respectively.

0.1% to 2.0% are effective. Some plant materials that stimulate *C. m. lengi* to lay eggs in a particular place also increase the number of eggs laid/♀/day, and the proportion of females that oviposit. Variation among ♀ *C. m. lengi* that were provided with standardized and near optimal conditions for reproduction probably reflects individual differences that are independent of nutrition and temperature. More work is needed to describe these differences as it may be possible to select and breed females that are more fecund and easier to manipulate using ovipositional chemicals.

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References

Ontario Ministry of Agriculture and Food. *Publication* 552.

Shade, R. E., H. I. Hansen, and M. C. Wilson. 1970. A partial life table of the cereal leaf beetle, *Oulema melanopus* in northern Indiana. *Ann. ent. Soc. Am.* **63**: 52–59.

Smith, B. C. 1965*a*. Growth and development of coccinellid larvae on dry foods (Coleoptera: Coccinellidae). *Can. Ent.* **97**: 760–768.

——— 1965*b*. Effects of food on the longevity, fecundity, and development of adult coccinellids (Coleoptera: Coccinellidae). *Can. Ent.* **97**: 910–919.

Smith, B. C., A. N. Starratt, and R. P. Bodnaryk. 1973. Oviposition responses of *Coleomegilla maculata lengi* (Coleoptera: Coccinellidae) to the wood and extracts of *Juniperus virginiana* and to various chemicals. *Ann. ent. Soc. Am.* **66**: 452–456.

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