Comparative biology of *Cycloneda sanguinea* (Linnaeus, 1763) and *Hippodamia convergens* Guérin-Méneville, 1842 (Coleoptera, Coccinellidae) focusing on the control of *Cinara* spp. (Hemiptera, Aphididae)[1]

Josiane Teresinha Cardoso[2]
Sonia Maria Noemberg Lázzari[2]

Abstract. The giant conifer aphids *Cinara pinivora* (Wilson, 1919) and *Cinara atlantica* (Wilson, 1919) (Hemiptera, Aphididae) have been observed attacking *Pinus* **spp.** in Southern and Southeastern Brazil. The coccinellids, on the other hand, were found feeding on these aphids in the field, which can be regarded as potential biological control agents. The biological cycle and mortality rate of larvae of *Cycloneda sanguinea* (Linnaeus, 1763) and *Hippodamia convergens* Guérin-Méneville, 1842 (Coleoptera, Coccinellidae) were evaluated using twenty larvae of each predator species fed with nymphs of *Cinara*. The vials with the insects were kept under 15 ºC, 20 ºC and 25 ºC, with 12h photophase and 70 ± 10% relative humidity. The consumption was evaluated every 24 hours and the nymphs replaced. For *C. sanguinea*, the egg incubation time was 10.5, 5.0 and 4.0 days; the average larval development period was 33.3, 15.8 and 8.6 days and the larval mortality rate 20%,0% and 15%, respectively at 15 ºC, 20 ºC and 25 ºC. For *H. convergens*, the larval development time was 41.9, 19.3 and 10.9 days at 15 ºC, 20 ºC and 25 ºC, respectively. The larval mortality rate was 35%, 15% and 0% under the three temperatures. Both species developed adequately when fed nymphs of *Cinara*, however, *C. sanguinea* performed better than *H. convergens*, even at 15 ºC, at which temperature the biological cycles of the coccinellids are prolonged, but the temperature is favorable for the development of *Cinara* populations in the field.

Keywords. Biological control; coccinellid development; giant conifer aphids; *Pinus*.

INTRODUCTION

In the mid 1990's, the giant conifer aphids *Cinara pinivora* (Wilson, 1919) and *Cinara atlantica* (Wilson, 1919) were detected in Southern Brazil attacking *Pinus* **spp.** in reforestation areas, causing severe damage (Penteado *et al.* 2000). Biological control is the best measure for suppressing such insects and avoids the disadvantages of chemical insecticides. Some predator species and entomopathogenic fungi have been observed attacking these aphids, but no parasitoids have been found so far.

Larvae and adults of coccinellids are common predators on aphids and have been observed feeding on *Cinara* colonies on pine trees. There are several studies on their biology, but little is known about their predatory action. Obrycki & Kring (1998) reviewed this topic and mentioned that it is difficult to determine the predator's efficiency in natural systems due to their mobility and polyphagy.

The development of predators is affected, mainly, by the prey quality and by temperature (Canard & Principi 1984; Frazer 1988; Venzon & Carvalho 1993; Canard 1997). The efficiency of a predator for biological control purposes should be evaluated based on development and mortality rates at different temperatures before field work is undertaken.

This research examines biological aspects and mortality rate of the coccinellid predators *Cycloneda sanguinea* (Linnaeus, 1763) and *Hippodamia convergens* Guérin-Méneville, 1842 provided with *Cinara* **spp.** nymphs, under different temperatures, in order to generate information for the biological control of these aphids.

MATERIAL AND METHODS

Aphids and predators were collected directly from *Pinus* trees, in Curitiba and Rio Negro, State of Paraná, and reared in laboratory. The aphids were kept on pine seedlings inside

1. Contribuição nº 1377 do Departamento de Zoologia, Universidade Federal do Paraná.
2. Departamento de Zoologia, Universidade Federal do Paraná. Caixa Postal 19020, 81531-980 Curitiba-PR, Brasil. Bolsistas do CNPq.

screened cages. The egg batches of *C. sanguinea* and *H. convergens* were maintained in plastic vials at 15 ºC, 20 ºC and 25 ºC, with 12h photophase and 70 ± 10% relative humidity. Egg development was evaluated twice a day for *C. sanguinea* only. After hatching, 20 larvae of each coccinellid species were isolated in 150 ml transparent plastic cups with filter paper on the bottom, and fed mixed nymphal instars of *C. atlantica* and *C. pinivora*. The vials were placed under the same rearing conditions of the eggs. The larvae were observed every 24 hours to evaluate their development, and the aphids replaced daily to keep plenty of food for the larvae.

During pupation, the coccinellids were maintained under the same conditions as the larvae and observed daily until adult emergence. To record longevity, adults of *C. sanguinea* were kept individually at 20 ºC and fed indiscriminately on both nymphs and adults of *Cinara* **spp.** to record their longevity.

The mortality rate was registered for each larval instar and pupae, for both coccinellid species. For *C. sanguinea*, egg viability and adult longevity were evaluated at the three different temperatures, this was not possible for *H. convergens* due to problems with the chamber. The data were analyzed using the Tukey test at 0.05% of probability.

RESULTS AND DISCUSSION

Development and mortality rate of *Cycloneda sanguinea*

The average egg incubation period for *C. sanguinea* was 10.5 days (the range was 10 to 11 days) at 15 ºC. The time decreased with increasing temperature, with 5.0 and 4.0 days, respectively, at 20 and 25 ºC. Arnt & Fagundes (1982), working with *C. sanguinea* eggs reared at temperatures between 22 ºC and 28 ºC, found an average incubation time of 3 to 4 days, a little less than the values found in this research. Gurney & Hussey (1970), working with this coccinellid species, observed the same inverse relationship between incubation time and temperature, but the average was much lower: 4 days at 16 ºC; 3 at 21 ºC and only 2 at 24 ºC. Egg viability for the species was generally high: 92.8% at 15 ºC; 78% at 20 ºC and 93.3% at 25 ºC, except for the value obtained at 20 ºC, attributable to a particularly weak egg batch reared at this temperature.

The mean larval development period was 33.3 days at 15 ºC, 15.8 days at 20 ºC and 8.6 days at 25 ºC, about a 100% reduction in time with an increase in temperature (Table I). Gurney & Hussey (1970) found, for this same predator reared on the aphid *Myzus persicae* Sulzer, 1776, an average of 25, 16 and 15 days at 16 ºC, 21 ºC and 24 ºC, respectively. The great difference found in the developmental time by the authors, when compared to this work, can be due either to population variability or to the prey species that may not be the preferred one. Santos & Pinto (1981), evaluating the development of *C. sanguinea* reared on the aphid *Toxoptera aurantii* (Boyer de Fonscolombe, 1841), recorded a larval development period of 9.3 days, but there is no information about the temperature during that period. Arnt & Fagundes (1982), working at 22 ºC and 28 ºC, found an average larval period for *C. sanguinea* of 11.6 days, when reared on nymphs of *Rhopalosiphum maidis* (Fitch, 1856) and *Sitobion avenae* (Fabricius, 1775), in laboratory.

The period from larva to adult was 49.8, 24.0 and 13.3, respectively at 15 ºC, 20 ºC and 25 ºC. A longer period was observed for the first and fourth instars at all three temperatures, but without statistical differences (Table I). Similar data were obtained by Santos & Pinto (1981) for *C. sanguinea*; Naranjo *et al.* (1990) for the coccinellid *Scymnus frontalis* (Fabricius) at four temperatures; and Xia *et al.* (1999) for *Coccinella septempunctata* (Linnaeus, 1758) at two temperatures.

The mean pupal development time was significantly different at three temperatures: 16.5, 8.2 and 4.7 days for 15 ºC, 20ºC and 25 ºC, respectively. Other authors found the same tendency, but with slightly shorter periods for corresponding temperatures. Santos & Pinto (1981) recorded an average of 3.4 days pupation period, in field conditions, while Gurney & Hussey (1970) recorded an average of 5 days at 24 ºC; 6 days at 21 ºC and 6 days at 16 ºC, without significant differences among temperatures. Arnt & Fagundes (1982) found a pupal development time of 4.2 days when the temperature changed from 22 ºC to 28 ºC.

The total developmental time of *C. sanguinea*, from egg to

Table I. Mean developmental time (and standard deviation) and mortality rate of *Cycloneda sanguinea* (initial n = 20), reared on nymphs of *Cinara* spp., under three temperatures, 12h photophase and 70 ± 10% relative humidity.

	Development (days)			Mortality (%)		
Temperature	15 ºC	20 ºC	25 ºC	15 ºC	20 ºC	25 ºC
Egg	10.5 (0.5) a	5.0 (0.0) b	4.0 (0.0) c	7.2	22	6.7
1st instar	10.4 (3.9) Aa	5.0 (0.7) Ab	2.5 (0.5) Ac	10	0	5
2nd instar	6.4 (1.8) Ba	2.8 (0.3) Bb	1.7 (0.5) Bc	0	0	10
3rd instar	6.2 (0.9) Ba	3.1(0.3) Bb	1.6 (0.4) Bc	10	0	0
4fh instar	10.3 (0.8) Aa	4.9 (1.1) Ab	2.8 (0.3) Ac	0	0	0
Pupa	16.5 (0.9) a	8.2 (0.5) b	4.7 (0.6) c	0	0	0
Total Period	60.3 (5.8) a	29.0 (1.6) b	17.5 (0.6) c	27.2	22	21.7

[1]Capital letters in the columns indicate differences among the developmental time of the four larval instars, lower cases in the lines indicate differences for the eggs, larval instars or pupal periods among temperatures, by the Tukey test (p <0.05).

adult, was 60.3 days at 15 ºC, 29.0 at 20 ºC and 17.5 at 25 ºC; decreasing with increasing temperature. Gurney & Hussey (1970) found the same pattern for the biological cycle of three coccinellid species: *C. sanguinea* varied from 34 to 22 days, *Coleomegilla maculata* (DeGeer, 1775) from 48 to 22 days and *Adalia bipunctata* (Linnaeus, 1758) from 24 to 16 days under temperatures ranging from 16 ºC to 24 ºC. Xia *et al.* (1999) observed that the development of *C. septempunctata* varied from 65.1 to 9.4 days when reared at five temperatures, varying from 15 ºC to 35 ºC. Cheah & McClure (1998) presented the total developmental time of 39.6 and 23.7 days for *Pseudoscymnus tsugae* Sasaji reared at 20 ºC and 25 ºC, respectively. Naranjo *et al.* (1990), on the other hand, found a variation, for *S. frontalis*, of 79.7 to 17.2 days at four temperatures between 15 ºC and 30 ºC. Variations observed for the same species may be due to differences in the prey or methodologies used.

Adults of *C. sanguinea* presented a mean longevity of 167.1 days at 20 ºC. On the other hand, Santos & Pinto (1981) found a much shorter longevity of about 63 days at 21.9 ºC, when the adults were reared on *Toxoptera citricidus* (Kirkaldy, 1907).

The total mortality rate for *C. sanguinea* was influenced by temperature as shown on Table I. It was accentuated during the egg stage at 20 ºC and during the early instars at the other two temperatures.

Development and mortality rate of *Hippodamia convergens*

The larval period for *H. convergens* was 41.9, 19.3 and 10.9 at 15 ºC, 20 ºC and 25 ºC respectively, decreasing with temperature elevation by about 100% at each 5 ºC, similar to what happened with *C. sanguinea*. The duration of each instar also decreased with increasing temperature. The differences were significant for the first and fourth instars compared with the other temperatures (Table II).

The larval development time also decreased with increasing temperature for larvae of *Hippodamia parenthesis* (Say, 1824) when subjected to five temperatures, between 14 ºC and 30 ºC, varying from 38.7 to 7.0 days (Orr & Obrycki 1990), and for *Hippodamia sinuata* Mulsant, 1850 when subjected to six temperatures, from 10 ºC to 35 ºC fed with two species of aphids (Michels & Behle 1991).

The mean pupal development time for *H. convergens* reduced significantly with the elevation of temperature, as shown on Table II. The same pattern was found by Michels & Behle (1991) for *H. sinuata* and by Orr & Obrycki (1990) for *H. parenthesis*, but with values slightly different as a function of the predator and prey species used in the experiments.

The species *H. convergens* presented the developmental time from larva to adult of 63.7 days at 15 ºC; 30.4 days at 20 ºC and 17.2 days at 25 ºC, being significantly longer than the same period for *C. sanguinea* under the three temperatures. Michels & Behle (1991) found the same pattern for *H. sinuata*, with shorter developmental time when reared on the aphid *R. maidis*: 55.4; 18 and 16.2 days at 15 ºC; 20 ºC and 25 ºC, respectively. The development of *H. parenthesis* was also shorter than observed in this research: 53.6 days at 14 ºC; 28.8 at 18 ºC; 18.1 days at 22 ºC and 13.1 at 26 ºC (Orr & Obrycki 1990), but also showed an inverse response relative to temperature.

For each instar, except the third, the total larval mortality rate was higher at 15 ºC (35%) than at the other two temperatures (Table II). At 20 ºC, the mortality of larvae was reduced to 15% and it was zero at 25 ºC. The pupal mortality was also higher at the lowest temperature (Table II). Orr & Obrycki (1990) also found a high mortality for *H. parenthesis* at 14 ºC (67%), especially in the 4th instar; at 22 ºC the larval mortality was about 7%. Michels & Behle (1991), evaluating the development of *H. sinuata* reared on two aphid species observed that, when fed with *Schizaphis graminum* (Rondani, 1852), the larvae died by the third instar, not completing their development at 15 ºC, this shows that when the prey species is inadequate, the mortality may be particularly high at the lower temperatures.

In summary, the predator *C. sanguinea* performed better than *H. convergens*, and even at 15 ºC the mortality was not as high as it was for the second species. This fact should be considered for the control of *C. pinivora* because this aphid species has its population peak in the winter months in Southern Brazil. Larvae and adults of *C. sanguinea* were observed amid colonies of *Cinara* **spp.** during the coldest periods of 1999 and 2000, when the average temperature in Curitiba was 15 ºC

Table II. Mean developmental time (and standard deviation) and mortality rate of *Hippodamia convergens* (initial n = 20), reared on nymphs of *Cinara* spp., under three temperatures, 12h photophase and 70 ± 10% relative humidity.

	Development (days)			Mortality (%)		
Temperature	15ºC	20ºC	25ºC	15ºC	20ºC	25ºC
1st instar	10.3 (3.2) Aa	5.1 (0.6) Ab	3.0 (0.3) Ac	10.0	0	0
2nd instar	6.6 (2.1) Ba	3.7 (0.9) Bb	2.0 (0.0) Bc	15.0	5.0	0
3rd instar	8.7 (1.1) ABa	4.1(0.5) Bb	1.9 (0.2) Bc	0	5.0	0
4fh instar	16.3 (6.2) Ca	6.4 (0.6) Cb	4.0 (0.3) Cb	10	5.0	0
Pupa	21.8 (0.8) a	11.1 (0.9) b	6.3 (0.5) c	35	0	5.0
Total Period	63.7 (2.2) a	30.4 (1.5) b	17.2 (0.5) c	70.0	15	5.0

[1]Capital letters in the columns indicate differences among the developmental time of the four larval instars, lower cases in the lines indicate differences for the larval instars or pupal periods among temperatures, by the Tukey test ($p < 0.05$).

(personal observations). Despite the high mortality at low temperatures, *H. convergens* had a low mortality rate and a fast larval development at higher temperatures. This predator would be more appropriate for the control of *C. atlantica*, which occurs throughout the year, and extends into warmer areas of the country. Overall, both species develop well when fed *Cinara* **spp.**, especially at 20 and 25 ºC, and can be regarded as potentially effective and complementary biological control agents of giant conifer aphids in Brazil. Studies on prey consumption are been carried out and will support the information presented here for biological control programs against these aphids.

Acknowledgements. To Dr. Lúcia Massutti de Almeida, Universidade Federal do Paraná, for the confirmation of the Coccinellidae species.

REFERENCES

Arnt, T. A. & A. C. Fagundes. 1982. Observações sobre a biologia e ação predadora da larva de *Cycloneda sanguinea* (L.) (Coleoptera: Coccinellidae) sobre pulgões. **Trigo e Soja. 62:** 33-35.

Canard, M. & M. M. Principi. 1984. Development of Chrysopidae, p. 57 – 75. *In*: M. Canard, Y. Séméria & T. R. New (eds.). **Biology of Chrysopidae**. The Hague, Dr W. Junk Publishers, 294 p.

Canard, M. 1997. Can lacewings feed on pests in winter? (Neuroptera: Chrysopidae and Hemerobiidae). **Entomophaga 42**: 113-117.

Cheah, C. A. S. J. & M. S. McClure . 1998. Life history and development of *Pseudoscymnus tsugami* (Coleoptera: Coccinellidae), a new predator of the hemlock woolly adelgid (Homoptera: Adelgidae). **Environmental Entomology 27**: 1531-1536.

Frazer, B. D. 1988. Predators, p. 217-230. *In*: A. K Minks. & P. Harrewijn. (eds). **Aphids, their biology, natural enemies and control**. Amsterdam, Elsevier. Vol. 2B. 364 p.

Gurney, B. & N. W. Hussey. 1970. Evaluation of some coccinellid species for the biological control of aphids in protected cropping. **Annals of Applied Biology 65**: 451-458.

Michels, G. J. & R. W. Behle. 1991. Effects of two species on the development of *Hippodamia sinuata* (Coleoptera: Coccinellidae) larvae at constant temperatures. **Journal of Economic Entomology 84**: 1480-1484.

Naranjo, S. E.; R. L. Gibson & D. D. Walgenbach. 1990. Development, survival and reproduction of *Scymnus frontalis* (Coleoptera: Coccinellidae), an imported predator of Russian wheat aphid, at four fluctuating temperatures. **Annals of the Entomological Society of America 83**: 527-531.

Obrycki J. J. & T. J. Kring. 1998. Predaceous Coccinellidae in biological control. **Annual Review of Entomology 43:** 295-321.

Orr, C. J. & J. J. Obrycki. 1990. Thermal and dietary requirements for development of *Hippodamia parenthesis* (Coleoptera: Coccinellidae). **Environmental Entomology 19**: 1523-1527.

Penteado, S. R. C.; R. F. Trentini; E. T. Iede & W. Reis-Filho. 2000. Pulgão do Pinus: nova praga florestal. **Série Técnica IPEF 13**: 97-102.

Santos, G. P. & A. C. Q. Pinto. 1981. Biologia de *Cycloneda sanguinea* e sua associação com pulgão em mudas de mangueira. **Pesquisa Agropecuária Brasileira 16**: 473-476.

Venzon, M. & C. F. Carvalho. 1993. Desenvolvimento larval, pré-pupal e pupal de *Ceraeochrysa cubana* (Hagen) (Neuroptera: Chrysopidae) em diferentes dietas e temperaturas. **Anais da Sociedade Entomológica do Brasil 22**: 477-483.

Xia, J. Y.; W. V. D. Werf & R. Rabbinge. 1999. Temperature and prey density on bionomics of *Coccinella septempunctata* (Coleoptera: Coccinellidae) feeding on *Aphis gossypii* (Homoptera: Aphididae) on cotton. **Environmental Entomology 28:** 307-314.

Received 10.IX.2002; accepted 30.V.2003