Trends in Entomology
Vol. 9, 2013

Short Communication

Relationship between the size of the parasitoid wasp *Dinocampus coccinellae* (Hymenoptera: Braconidae) and host ladybird species (Coleoptera: Coccinellidae)

Satoshi Koyama[1,*], Cathleen E. Thomas[2] and Mamoru Takata[1]

[1]Graduate School of Agriculture, Tokyo University of Agriculture and Technology, 3-5-8 Saiwai, Fuchu, Tokyo, Japan. [2]LIFElab, International Centre for Life, Newcastle upon Tyne, NE1 4EP, UK

ABSTRACT

Native to Asia, the harlequin ladybird (*Harmonia axyridis*) was introduced into Europe and North America as an aphid biocontrol agent. The species has become invasive in many countries, negatively affecting native species in the introduced areas, and its spread is characterized by rapid increases in population size. In its native range, *H. axyridis* is parasitized by the wasp *Dinocampus coccinellae*, which may control the *H. axyridis* population. However, *D. coccinellae* cannot parasitize *H. axyridis* in introduced areas. The resistance of *H. axyridis* to parasitization by *D. coccinellae* may be key to the rapid invasion of *H. axyridis*. Knowledge of the fundamental ecology of *D. coccinellae* is needed to learn more about the relationship between the parasitoid wasp and the ladybird species it uses as hosts. In this study, we used the hind tibia length of *D. coccinellae* and pronotal width of host ladybirds as body size indicators, to test for a size correlation. We found a significant positive relationship between the sizes of *D. coccinellae* and multiple host ladybird species including *Coccinella septempunctata*, *Coccinella undecimpunctata*, *Tytthaspis sedecimpunctata*, *Myrrha octodecimguttata*, *Harmonia quadripunctata*, and *H. axyridis* from British populations and *C. septempunctata brucki*, *H. axyridis*, and *Propylea japonica* from Japanese populations. These results indicate that there is a positive correlation in body size between *D. coccinellae* and host ladybird species.

*Corresponding author: skoyama@cc.tuat.ac.jp

KEYWORDS: Braconidae, *Dinocampus coccinellae*, parasitoid wasp, body size correlation, ladybird, *Coccinella septempunctata*

INTRODUCTION

Invasive species are contributing to biodiversity loss, ecosystem degradation, and impairment of ecosystem services worldwide [1]. One of the most invasive ladybird species is the harlequin ladybird *Harmonia axyridis* [2]. Native to Asia, *H. axyridis* was introduced into Europe and North America as an aphid biocontrol agent, and has since spread across the globe [3] where it has had a detrimental impact on native species [4, 5]. Many studies have been conducted on the causes of the establishment and rapid increase of *H. axyridis* populations in the introduced area.

Dinocampus coccinellae (Schrank) (Hymenoptera: Braconidae) is a solitary parasitoid of coccinellids of the sub-family Coccinellinae [6]. It has been reported that *D. coccinellae* parasitizes over 50 ladybird species [7]. We previously reported that *H. axyridis* in Europe shows higher resistance to parasitization by *Dinocampus coccinellae* than the native *H. axyridis* in Japan [8]. The parasitization of *D. coccinellae* has had a major negative impact on the growth of *H. axyridis* populations in Japan, since about 10% of *H. axyridis* are parasitized by *D. coccinellae* [9]. Thus, the change in the relationship between *H. axyridis* and *D. coccinellae* may be a key to the rapid spread of invasive ladybirds. The relationship between *D. coccinellae* and its host ladybird species is not fully understood.

In some parasitoid wasp species, body size is related to fitness [10]. Parasitoid size is determined by the total amount of nutrients available during larval development [11]. Large hosts presumably possess more resources inside their body, and should be of higher quality compared to small hosts. Thus, large hosts are predicted to produce large wasps. In this study, we investigated whether the body size of *D. coccinellae* is correlated with that of the host ladybird.

MATERIALS AND METHODS

The ladybirds used in this study were either field-collected or F1 adults from samples collected in London; UK; and Fuchu, Tokyo, Japan, in 2005 and 2006. The ladybirds were fed on *Acyrthosiphon pisum* (Harris) (pea aphids) at 21°C with 16L-8D photoperiods.

To analyze body size correlations, *Coccinella septempunctata* (n = 28), *Coccinella undecimpunctata* (n = 9), *Tytthaspis sedecimpunctata* (n = 2), *Myrrha octodecimguttata* (n = 1), *Harmonia quadripunctata* (n = 1), and *H. axyridis* (n = 1) from British populations and *C. septempunctata brucki* (n = 6), *H. axyridis* (n = 8), and *Propylea japonica* (n = 3) from Japanese populations were used as host ladybirds. The *D. coccinellae* adults were obtained either from *C. septempunctata* caught in Cambridgeshire or from *C. septempunctata brucki* caught in Fuchu. Ladybirds from British populations were attacked by *D. coccinellae* of British origin and those from Japanese populations were attacked by the wasps of Japanese origin. Ladybirds were parasitized by *D. coccinellae* in the laboratory and kept until emergence of the wasp. After emergence, the hind tibia length of *D. coccinellae* and the pronotal width of ladybirds were measured with digital calipers to evaluate the body size of the organisms.

For statistical analysis, a Pearson's correlation test was used to analyze the relationship between the body sizes of *D. coccinellae* and the host ladybird.

RESULTS AND DISCUSSION

First, the relationship between the body sizes of *D. coccinellae* and *C. septempunctata* caught in the UK was tested. The hind tibia length of *D. coccinellae* was 0.97 ± 0.08 cm (mean ± SD, ranged from 0.84 to 1.16 cm) and the pronotal width of *C. septempunctata* was 3.44 ± 0.14 cm (mean ± SD, ranged from 3.11 to 3.78 cm), both of which were normally distributed (Kolmogorov-Smirnov test, $P > 0.50$). The *D. coccinellae* tibia length was significantly correlated with *C. septempunctata* pronotal width (Pearson's correlation test; $r = 0.581$, $P = 0.001$; Fig. 1A).

Second, the body size correlation was examined using multiple host species. The mean values of the hind tibia length of *D. coccinellae* and the pronotal width of each host ladybird species were used for this analysis. The hind tibia length of *D. coccinellae* ranged from 0.82 cm in *Myrrha octodecimguttata* to 0.97 cm in *C. septempunctata* (mean ± SD; *C. septempunctata*: 0.97 ± 0.08 cm, *C. undecimpunctata*: 0.89 ± 0.04 cm, *Tytthaspis sedecimpunctata* 0.83 ± 0.02 cm, *Myrrha octodecimguttata* 0.82 cm, *H. quadripunctata*: 0.96 cm, *H. axyridis* from the UK: 0.96 cm, *C. septempunctata brucki*: 0.94 ± 0.05 cm, *H. axyridis* from Japan: 0.96 ± 0.06 cm, and *Propylea japonica*: 0.86 ± 0.02 cm). Pronotal width ranged from 1.74 cm in *Tytthaspis sedecimpunctata* to 3.71 cm in *C. septempunctata brucki* (*C. septempunctata*: 3.44 ± 0.14 cm, *C. undecimpunctata*: 2.29 ± 0.15 cm, *T. sedecimpunctata* 1.74 ± 0.06 cm, *Myrrha octodecimguttata*: 2.16 cm, *H. quadripunctata*: 2.80 cm, *H. axyridis* from the UK: 3.40 cm, *C. septempunctata brucki* 3.71 ± 0.21 cm, *H. axyridis* from Japan: 3.28 ± 0.27 cm, and *Propylea japonica*: 2.11 ± 0.10 cm). Similar correlations were detected between the sizes of *D. coccinellae* and host ladybirds collected in the UK and Japan (UK population, $r = 0.92$; Japanese population, $r = 0.98$). Thus, we mixed the data from populations in the UK and Japan and analyzed the size correlation. A strong, significant correlation was found between the sizes of

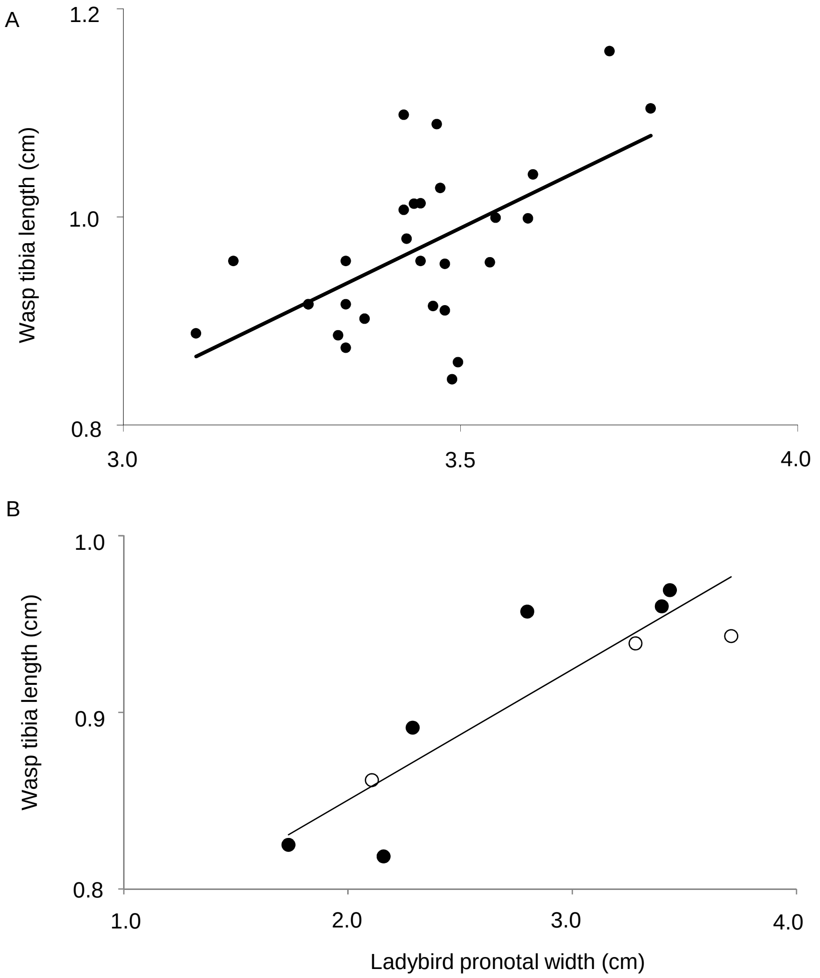

Fig. 1. Correlation between the body sizes of *Dinocampus coccinellae* and host ladybirds. (A) Correlation between the body sizes of *Dinocampus coccinellae* and *Coccinella septempunctata* from the UK. (B) Correlation between the body sizes of *Dinocampus coccinellae* and ladybird species from the UK and Japan. Filled symbols indicate ladybirds and *D. coccinellae* from the British population. Unfilled symbols indicate those from the Japanese population.

D. coccinellae and host ladybird species (Pearson's correlation test; r = 0.889, P = 0.001; Fig. 1B).

Since sample sizes were small in some host species, we calculated the correlation with host species of sample sizes ≥ 3. Again, a strong positive correlation was detected in this analysis (Pearson's correlation test; n = 5, r = 0.928, P = 0.02).

Body size correlations between hosts and parasitoid wasps have been demonstrated for some species [12]. We investigated body size correlations between *D. coccinellae* and their hosts. Since *D. coccinellae* parasitizes many ladybird species, we used 9 different ladybird species to analyze the body size correlation between *D. coccinellae* and host ladybirds. We found positive body size correlations in the analyses with single and multiple host species. Our results strongly support a positive correlation in body size between hosts and parasitoid wasps.

D. coccinellae shows adaptive host choice. *D. coccinellae* prefers to parasitize large coccinellid species [13] and large females over small males [14]. Host suitability is greater in these hosts [14]. The preferences may occur because larger ladybirds possess more resources in themselves [14], and *D. coccinellae* are able to evaluate host quality. *D. coccinellae* larvae absorb nutrition from host ladybirds through teratocytes [15], and nutrition at the larval stage determines the body size of adult parasitoid wasps [11]. In some parasitoid wasp species, body size is correlated with fitness, such as fighting ability [16], dispersal capability [17], mating success, fecundity [18, 19], and longevity [20, 21]. The fitness of female wasps is more dependent on body size than that of males [12]. *D. coccinellae* produces only females through thelytokous parthenogenesis [22]. Thus, large wasps from large ladybirds may show higher fitness than small wasps from small ladybirds. However, small ladybirds such as *C. undecimpunctata* are often parasitized in the field, and yield small wasps [23]. This may happen because a *D. coccinellae* did not find a larger ladybird host, or small wasps adopt alternative strategies to compensate for fitness losses caused by small host body size. Further investigation is needed to reveal whether small wasps show different behaviour than large ones.

In this study, the sample size was small for some host species. Large variability has been observed in the rate of successful parasitization by *D. coccinellae* in host ladybird species. For example, 1 adult *D. coccinellae* successfully emerged from more than 400 parasitized *H. axyridis* in the UK [8]. To ensure that a positive correlation in body size was not detected simply due to small sample sizes, we calculated the correlation for host species with larger sample sizes. A significant positive correlation was still observed in this analysis. This strengthens our findings of a body size correlation between *D. coccinellae* and host ladybirds.

Invasive *H. axyridis* is parasitized by *D. coccinellae* at a very low rate in Europe [8]. Although the mechanism of its resistance is not known, it may occur because of the change in the relationship between host ladybirds and *D. coccinellae* caused by a bottleneck effect during the invasion [8]. Since the ecology of *H. axyridis* has been well studied, information on *D. coccinellae*, as reported here, is needed to understand the relationship between the parasitoid wasp and invasive ladybirds. Understanding this interaction may help to control the expansion of invasive ladybirds.

CONCLUSION

Harmonia axyridis (*harlequin ladybird*) are widespread in Europe and North America, with populations also invading South Africa and South America. The parasitoid wasp *Dinocampus coccinellae* shows high prevalence in *H. axyridis* in its native range in Asia, while almost no parasitization is observed in the introduced area. Thus, further knowledge of the ecological traits of *D. coccinellae* is required. In this study, we investigated the body size correlation between *D. coccinellae* and host ladybird species. A significant correlation was observed between the hind tibia length of *D. coccinellae* and the pronotal width of the suitable host *Coccinella septempunctata*, *along with 9 other host ladybird species* from the UK and Japan.

ACKNOWLEDGEMENTS

This study was entirely supported by Micheal Majerus who passed away in 2009. We thank Ian Wright for technical support and Yoshiaki Obara and Toshiyuki Satoh for their help in collecting samples. We also thank Lori Lawson Handley for useful comments on our previous manuscript.

REFERENCES

1. Pysek, P., Richardson, D., Gadgil, A. and Liverman, D. 2010, Annual Review of Environment and Resources, 35, 25-55.
2. Roy, H., Brown, P. and Majerus, M. 2006, An ecological and societal approach to biological control, J. Eilenberg and H. Hokkanen (Eds.), Kluwer Academic Publishers, Netherlands, 295-310.
3. Brown, P., Thomas, C. E., Lombaert, E., Jeffries, D. L., Estoup, A., Lawson Handley, L. J. 2011, Biocontrol, 56, 623-641.
4. Koch, R. and Galvan, T. 2008, Biocontrol, 53, 23-35.
5. van Lenteren, J., Loomans, A., Babendreier, D. and Bigler, F. 2008, Biocontrol, 53, 37-54.
6. Ceryngier, P. and Hodek, I. 1996, Ecology of Coccinellidae, I. Hodek and A. Honek (Ed.), Kluwer, Dortrecht, 319-350.

7. Shaw, S. 1988, Ecological Entomology, 13, 323-335.
8. Koyama, S. and Majerus, M. 2008, Biocontrol, 53, 253-264.
9. Maeta, Y. 1969, Kontyu, 37, 147-166.
10. Godfray, H. 1994, Parasitoids: Behavioral and Evolutionary Ecology, Princeton University Press, Princeton, N.J, 475.
11. Sequeira, R. and Mackauer, M. 1993, Canadian Entomologist, 125, 423-430.
12. King, B. 1987, Quarterly Review of Biology, 62, 367-396.
13. Richerson, J. and DeLoach, C. 1972, Annals of the Entomological Society of America, 65, 834-839.
14. Davis, D., Stewart, S., Manica, A. and Majerus, M. 2006, European Journal of Entomology, 103, 41-45.
15. Kadono-Okuda, K., Sakurai, H., Takeda, S. and Okuda, T. 1995, Entomologia Experimentalis et Applicata, 75, 145-149.
16. Hartley, C. and Matthews, R. 2003, The Journal of Hymenoptera Research, 12, 272-277.
17. Boldt, P. 1974, Annals of the Entomological Society of America, 67, 706-708.
18. Rosenheim, J. and Rosen, D. 1991, Journal of Animal Ecology, 60, 873-893.
19. Visser, M. 1994, Journal of Animal Ecology, 63, 963-978.
20. West, S., Flanagan, K. and Godfray, H. 1996, Journal of Animal Ecology, 65, 631-639.
21. Bezemer, T., Harvey, J. and Mills, N. 2005, Ecological Entomology, 30, 571-580.
22. Balduf, W. 1926, Annals of the Entomological Society of America, 19, 465-498.
23. Majerus, M. 1997, British Journal of Entomology and Natural History, 10, 15-24.