Relative strength of direct and indirect interactions of mutualistic ants and a large sized ladybird on the fate of two small sized ladybirds

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Introductions

Direct and indirect interactions influence abundances of aphidophagous insects. Recently, intraguild predation (IGP) is thought to be one of important factors influencing the abundance of aphid predators (Rosenheim et al. 1993, Yasuda and Shinya 1997) and the fact that small sized and less active predators tend to be IG prey is well known (Lucas et al. 1998). In addition, mutualisms between aphids and ants are also possible interactions which influence aphid predator abundance because aphid-attending ants often attack aphid predators, as the result they reduce prey consumptions (Vinson and Scarborough 1991, Katayama and Suzuki 2003) and predator abundance (Kaneko 2003). It seems that IGP and attacks by mutualistic ants would occur simultaneously in the interactions with aphids, ants, and aphidophagous insects which in turn would influence on abundance of aphid predators (Fig. 1). However, there are few studies to reveal how the relative strength of these interactions functions to reduce aphid predator abundance. This study examined the effects of IGP due to a large sized ladybird and attacks by mutualistic ants on abundance of two small sized ladybird species, *Scymnus hoffmanni* and *S. posticalis.*

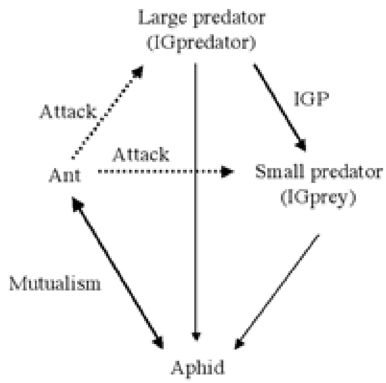

Fig. 1 Diagram of interspecific interactions affecting abundance of ladybirds

Materials & Methods

Field experiments

To study the effects of *Coccinella septempunctata* larvae which is a potential intraguild predator of *Scymnus* larvae, and mutualistic ants, *Lasius japonicus,* on abundance of two *Scymnus* larvae on broad bean plants, field experiments were conducted. The broad bean plants were categorized concerning to occurrence of the larvae and the adults of the *Scymnus* ladybirds; (1) “larval present plant” is one on which at least one individual larva of each *Scymnus* species was observed, while (2) “larval absent plant” is one on which no larva of each *Scymnus* species was found, although adults were observed. The differences in numbers of *C. septempunctata* larvae, ants, and aphids between larval present and absent plants were compared by Mann-Whitney U-test.

Laboratory experiments

A series of laboratory experiments using potted plants were conducted to examine the effects of *C. septempunctata* larvae and ants on the survivorships of two *Scymnus* larvae. Each plant with aphids (112 ± 3 individuals) and 5 individuals of second instar larvae of *S. hoffmanni* or *S. posticalis* was assigned to following treatments: 1) control, 2) *C. septempunctata*, 3) ants, 4) *C. septempunctata* and ants.
Five second instar larvae of *C. septempunctata* were released on each plant in the treatment with *C. septempunctata*. The plants in the treatment with ants were attached with a plastic tube connected to an

ant nest. The survivors of *Scymnus* larvae were recorded everyday. The number of *C. septempunctata* larvae and ants were also counted. Survival rates of each *Scymnus* larvae were analyzed by two-way ANOVA (with or without *C. septempunctata* larvae and with or without ants) after Arcsin transformed.

Results

Field experiments

There was no difference in the number of *C. septempunctata* larvae between "larval absent" and "present plants" of *S. hoffmanni* (Fig. 2a; $U = 81.0$, $P = 0.13$). "Larval absent plants" tended to have higher number of the ants than "larval present plants" ($U = 73.0$, $P = 0.068$). In addition, the number of aphids did not differ between "larval absent" and "present plants" ($U = 104.0$, $P = 0.55$).

The number of *C. septempunctata* larva on "larval absent plants" of *S. posticalis* tended to be higher than those on "larval present plants" (Fig. 2b $U = 32.0$, $P = 0.20$), while "larval absent plants" of *S. posticalis* had lower number of the ants than "larval present plants", although the difference was not significant ($U = 40.5$, $P = 0.52$). The number of aphids on "larval absent plants" was significantly lower than that on "larval present plants" ($U = 14.0$, $P = 0.009$).

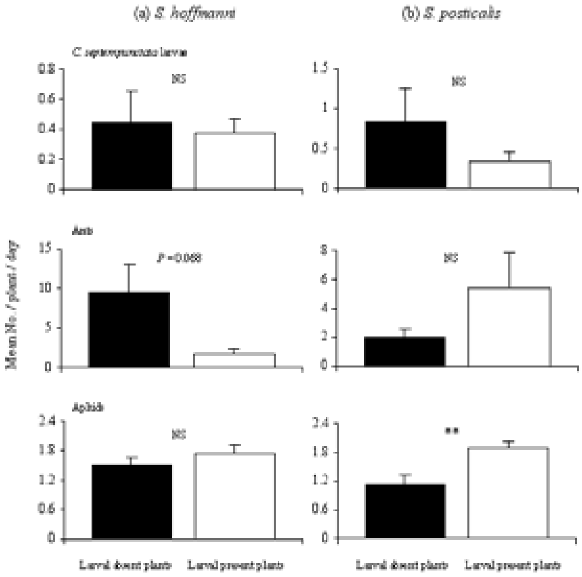

Fig. 2 Mean number (± 1 SE) of *C. septempunctata* larvae, ants and aphids on larval absent plants and larval present plants of (a) *S. hoffmanni* and (b) *S. posticalis*
NS: Mann-Whitney U-test $P > 0.05$, **: $P < 0.01$

Laboratory experiments

Survival rates of *S. hoffmanni* were lower on the plants with *C. septempunctata* larvae and/or ants than the control treatment (Fig. 3a, Table 1a). In addition, the survival rates of *S. posticalis* also decreased on the plants with only *C. septempunctata* larvae than other treatments (Fig. 3b, Table 1b), while the rates in the treatments with ants was not significantly different from the control.

Throughout these experiments, the number of *C. septempunctata* larvae on the plants with ants was lower than those on the plants without the ants, while the number of ants on the plants with *C. septempunctata* larvae did not significantly differ from those without *C. septempunctata* larvae.

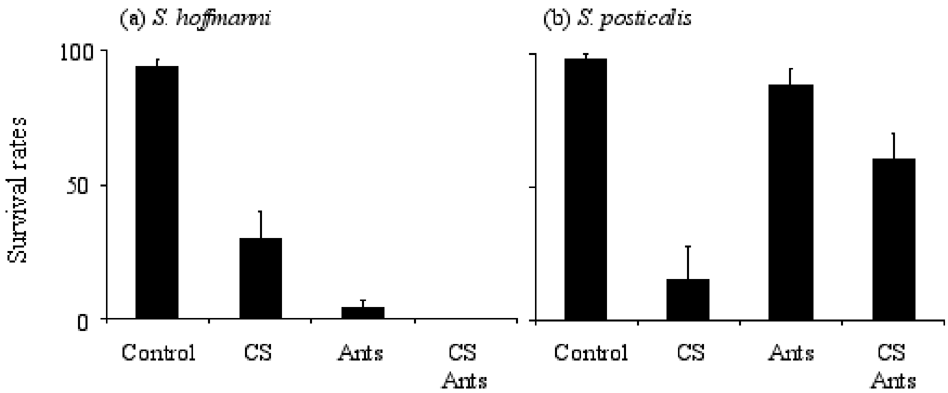

Fig. 3 The survival rates (Average ± 1 SE) of (a) *S. hoffmanni* and (b) *S. posticalis* larvae

Table 1 Two-way ANOVA for the effects of *C. septempunctata* larvae and ants on the survival rates of (a) *S. hoffmanni* and (b) *S. posticalis*

	df	*F*	*P*
(a) *S. hoffmanni*			
C. septempunctata	1	95.02	<0.001
ants	1	102.29	<0.001
C. septempunctata * ants	1	95.02	<0.001
(b) *S. posticalis*			
C. septempunctata	1	36.43	<0.001
ants	1	1.12	0.30
C. septempunctata * ants	1	7.44	<0.01

Discussion

This study revealed that the direct interaction of the ants rather than that of *C. septempunctata* larvae more influenced the abundance of *S. hoffmanni* since the ants reduced the number of *C. septempunctata* larvae on the plants (Fig. 4a), while the direct interaction due to *C. septempunctata* larvae functioned negatively on survivorship of *S. posticalis* larvae. In addition, ants had a positive indirect interaction on the survivorship of *S. posticalis* through reducing the opportunity of IGP by *C. septempunctata* larvae (Fig. 4b), while not for *S. hoffmanni*. Therefore, this study suggested that we had to pay much attention not only direct interactions such as competition, predation including IGP but also indirect interactions which would work through mutualistic ants in order to understand the mechanism how aphid predator abundance is decided in an aphidophagous insect guild.

(a) *S. hoffmanni* (b) *S. posticalis*

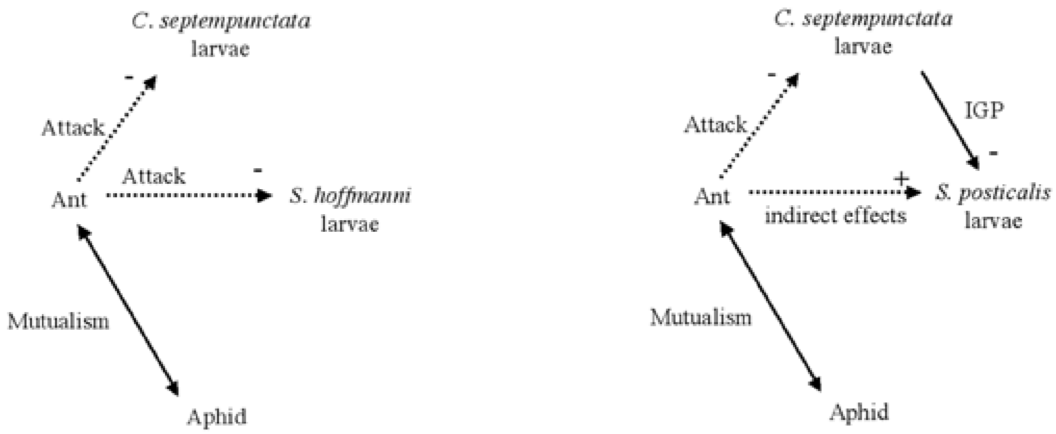

Fig. 4 Diagram of the effects of *C. septempunctata* larvae and ants on (a) *S. hoffmanni* and (b) *S. posticalis* larvae

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