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Adaptation of *Rodolia cardinalis* (Mulsant) (Col., Coccinellidae) to *Icerya aegyptiaca* (Douglas) (Hom., Margrodidae) as compared with *Icerya purchasi* Mask

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Abstract: The Coccinellid beetle, *Rodolia cardinalis* (Mulsant), was introduced into Egypt in 1902 to control *Icerya purchasi* Mask. Developmental stages of *R. cardinalis* have been found to be associated with populations of *Icerya aegyptiaca* (Douglas) on *Ficus nitida* trees in the Mansoura district of Egypt. The present work throws more light on the adaptation of this predator when feeding on *Icerya aegyptiaca* as compared with feeding on *I. purchasi*. Choice of prey type was found to have a marked effect on egg coloration but appears to have no effect on hatching success or incubation period. The development of *R. cardinalis* larvae when reared in culture on *I. aegyptiaca* was significantly faster than that fed on *I. purchasi*. The fecundity of *R. cardinalis* females was not affected by the prey type consumed as adults, and although the longevity of males and females was shorter in association with *I. purchasi*, this difference was not significant. The results indicate that *R. cardinalis* is well adapted to *I. aegyptiaca* in Egypt.

1 Introduction

The Coccinellid beetle, *Rodolia cardinalis* (Mulsant) was introduced into Californian citrus orchards in the late 1880s for the control of the margarodid *Icerya purchasi* Mask. (Caltagirone and Doutt, 1989). According to Kamal (1951), *R. cardinalis* was introduced into Egypt from California in 1902 to control *I. purchasi*, which at that time was a serious pest in Egypt. *Rodolia cardinalis* became established and currently is common all over the country. As a result, the population of *I. purchasi* has dropped to non-economic levels and it is now very rare in Egypt. However, in recent years, serious infestations of *I. aegyptyiaca* (Douglas) and *I. seychellarum* (Westwood) have occurred on various species of fruit trees and ornamental plants (Hamed and Saad, 1989). Hamed and Saad (1989) found that both *I. aegyptiaca* and *I. seychellarum* are preyed upon by *R. cardinalis* in Egypt, neither of which had been recorded previously as prey for this predator in Egypt.

Vesey-Fitzgerald (1940, 1953) reported that *R. cardinalis* feeds on *I. seychellarum* in the field and in the laboratory, but failed to become established when liberated in the Seychelles. Another species, *R. pumila* (Weise), was reported attacking *I. aegyptiaca* on Carolina Island (Beardsley, 1955). The history of use of *R. cardinalis* against *I. purchasi* and the problems of its use to control the pest on citrus in Italy have been discussed by Viggiani (1989).

The author observed that developmental stages of *R. cardinalis* were found associated with the population of *I. aegyptiaca* on *Ficus nitida* trees in the Mansoura district. Therefore, in the present work, the adaptation of this predator to *I. aegyptiaca* as prey was investigated and compared with the predator's adaptation to *I. purchasi*.

2 Material and methods

Two stock cultures of *R. cardinalis* were reared and maintained separately on *I. aegyptiaca* and *I. purchasi* at a constant temperature of 25°C and 60% RH. Two groups of newly hatched larvae of the predator, each of 25 individuals, were reared individually on gravid females of *I. aegyptiaca* and *I. purchasi* that were collected daily from *Ficus nitida* and *Erythrina caffra* trees, respectively. The prey was carefully examined to be free from any predators. Each larvae of *R. cardinalis* and its prey were placed in a glass tube (2.5 cm diameter and 8.0 cm long) and covered with a piece of muslin that was held tightly by a rubber band. The larvae were examined daily and their moulting dates were recorded.

To estimate the fecundity and longevity of the predator, 15 newly emerged pairs obtained from each stock culture were fed daily on either *I. aegyptiaca* or *I. purchasi*. Each pair was placed in a petri dish of 10 cm diameter with a filter paper in the bottom and provided daily with fresh supply of the prey. The materials in each dish were examined daily using an electrical binocular microscope, and the numbers of eggs deposited by *R. cardinalis* were recorded until the death of the adults. The data were analyzed statistically using an F-test.

3 Results and discussion

3.1 Effect of prey on the egg stage

The females of *R. cardinalis* deposit their eggs singly, in pairs or in irregular groups. Most eggs are laid among the waxen caudal filaments of the bodies of living *I. aegyptiaca* and *I. purchasi* but some are laid on leaves, beneath and on the remains of the ovisacs of the prey. The eggs attained different shades when the females of *R. cardinalis* fed on the different species of *Icerya*. They were pinkish red when fed on *I. purchasi* and pale orange when fed on *I. aegyptiaca*.

Infertile eggs were laid vertically on the surfaces and

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Table 1. *Effect of prey species on larval, pre-pupal and pupal duration of* R. cardinalis

Prey	Duration (days)							
	Larval stage					Pre-pupal stage	Pupal stage	Total
	1st	2nd	3rd	4th	Total			
I. purchasi	6.08 ± 0.2	2.75 ± 0.13	3.83 ± 0.37	5.0 ± 0.40	17.66 ± 0.63	2.75 ± 0.25	5.91 ± 0.25	26.33 ± 0.71
	(4–6)	(2–4)	(1–6)	(3–8)	(11–24)	(2–4)	(4–7)	(20–32)
I. aegyptiaca	4.36 ± 0.2	2.04 ± 0.09	2.16 ± 0.26	2.36 ± 0.27	10.88 ± 0.44	2.44 ± 0.17	6.44 ± 0.18	19.76 ± 0.49
	(3–5)	(1–3)	(1–3)	(1–4)	(10–12)	(1–4)	(5–8)	(17–23)
F-value	24.30**	19.84**	18.46**	30.07**	78.12**	1.033NS	2.87NS	57.50**
Probability	0.00	0.0001	0.0008	0.000	0.000	0.316	0.099	0.00

**$P < 0.001$
NS, non-significant difference

shrank and collapsed within 24 h of deposition; fertile eggs were laid horizontally and maintained their shape. These results are in agreement with those of HAMED and SAAD (1989).

The incubation period of the eggs ranged from 3 to 5 days with an average of 4.04 ± 0.14 and 4.16 ± 0.14 days when the females fed on *I. purchasi* and *I. aegyptiaca*, respectively. There is no significant difference between these two means.

The hatching success of the eggs produced by the females fed on *I. purchasi* and *I. aegyptiaca* was 77.14% and 73.35%, respectively. It is of note that HAMED and SAAD (1989) recorded a relatively low hatching success of *R. cardinalis* feeding on *I. aegyptiaca* (48.4%) and *I. seychellarum* (32.09%) at 27.0°C and 60% R.H.

3.2 Effect of prey on larval, pre-pupal and pupal duration

Data presented in table 1 show that the duration of larval development of *R. cardinalis* differed when feeding upon the two species of the genus *Icerya* tested. Highly significant differences were recorded between the means of the four larval instars, total larval period and the total developmental period of the two. The development of the predator culture reared on *I. aegyptiaca* was relatively faster than that fed on *I. purchasi*.

The larval mortality of *R. cardinalis* during the present work was 40% and 3.44% in association with *I. purchasi* and *I. aegyptiaca*, respectively. HAMED and SAAD (1989) recorded high mortality percentages (44% and 62%, respectively) in association with *I. aegyptiaca* and *I. seychellarum*. Also, KUWANA (1922), in Japan, recorded high percentages of larval (27%) and pupal (47%) mortalities when *R. cardinalis* was reared on *I. purchasi*.

3.3 Effect of prey species on the adult stage

3.3.1 Fecundity of female

Data in table 2 indicates that the average total number of eggs laid by the females of *R. cardinalis* throughout the oviposition period was not affected by the type of prey consumed by these females. In Japan, KUWANA (1922) reported that female *R. cardinalis* fed on *I. purchasi* deposited as many as 5.4 eggs day^{-1} in summer, while in spring and autumn sometimes only one egg was laid per day. In Egypt, HAMED and SAAD (1989) found that the average total number of eggs laid by female *R. cardinalis* throughout its life span was affected significantly by prey type. The results in table 2 also indicate that the differences between the pre-oviposition and post-oviposition periods in the two trophic conditions were non-significant. On the other hand, the oviposition period was longer in the case of females feeding on *I. aegyptiaca* than that of females fed on *I. purchasi* and this difference, was significant.

3.3.2 Longevity of adults

As seen in table 2, females *R. cardinalis* lived an average length of 31.54 and 37.11 days when fed on *I. purchasi* and *I. aegyptiaca*, respectively; these periods are not significantly different. The males lived for 25.73 and

Table 2. *Effect of prey species on fecundity and longevity of* R. cardinalis

Prey	Number of eggs per female	Ovipositional periods (days)			Longevity (days)	
		Pre-oviposition	Oviposition	Post-oviposition	Female	Male
I. purchasi	331.0 ± 0.42	3.09 ± 0.29	25.54 ± 1.97	2.90 ± 0.41	31.54 ± 2.09	25.73 ± 2.48
	(195–534)	(2–4)	(13–43)	(1–6)	(21–52)	(11–38)
I. aegyptiaca	423.0 ± 33.63	2.33 ± 0.32	32.22 ± 2.18	2.55 ± 0.045	37.11 ± 2.31	32.0 ± 3.92
	(242–555)	(1–5)	(26–37)	(1–4)	(28–43)	(8–45)
F-value	4.13NS	3.02NS	5.14*	0.33NS	3.18NS	1.45NS
Probability	0.057	0.099	0.035	0.89	0.091	0.242

NS, non-significant difference
*$P < 0.05$

32 days, respectively; showing the same non-significant trend as females. According to KUWANA (1922) in Japan, when *R. cardinalis* were fed on *I. purchasi* the life spans of female and male were 40 and 23 days in spring, and 23 and 13 days in summer. MATSUKA et al. (1982), also in Japan, found that the females of *R. cardinalis* fed on lypophilized drone honey bee (*Apis mellifera* L.) brood fortified with sucrose, survived longer but laid fewer eggs than others fed on living examples of *I. purchasi.* In Egypt, HAMED and SAAD (1989) found that the longevity of females and males of *R. cardinalis* is comparatively shorter when fed on *I. seychellarum* as compared with *I. aegyptiaca.*

The present results confirmed that *R. cardinalis* is well adapted to feeding on *I. aegyptiaca* in Egypt.

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