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Host Range and Host Suitability of *Anagrus incarnatus* HALIDAY (Hymenoptera: Mymaridae), an Egg Parasitoid of Delphacid Planthoppers[1]

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Anagrus incarnatus, a mymarid egg parasitoid of hemipterous hoppers, strongly attacked eggs of the 3 species of rice planthoppers (*Nilaparvata lugens*, *Sogatella furcifera* and *Laodelphax striatellus*), showing no preference among these hosts. Additionally, 7 species of other delphacid planthoppers indigenous to wild grasses, and 2 species of cicadellid leafhoppers were also attacked by this parasitoid. Per cent parasitism of *Nephotettix cincticeps* eggs was lower than that of the others. Thus, *A. incarnatus* has a rather wide host range, but is mainly specific to delphacid species. This parasitoid is able to attack host eggs of any stage of development, even those containing well developed embryos.

INTRODUCTION

Mymarid wasps belonging to the genus *Anagrus* are known as common egg parasitoids of plant- and leafhoppers and have worldwide distribution (CLAUSEN, 1940). In Asia, several *Anagrus* species have been recorded as natural enemies of delphacid planthoppers of rice (CHIU, 1979). *A. flaveolus* WATERHOUSE has long been recorded as an egg parasitoid of delphacid planthoppers in Japan (DOUTT, 1961; YASUMATSU and WATANABE, 1964; KAWASE and ISHIZAKI, 1965). Recently, *A. incarnatus* HALIDAY was recognized for the first time from different countries of Asia, including Japan (SAHAD, 1983).

This paper reports the host range and host suitability of *A. incarnatus*. The experiments were conducted during 1979–1980 at the Kyushu National Agricultural Experiment Station, Chikugo, Fukuoka. This work was part of the study of the biology and ecology of this parasitoid as an important natural enemy of rice planthoppers.

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MATERIALS AND METHODS

A. incarnatus used were from laboratory stock cultures reared successively on eggs of *Nilaparvata lugens* which were deposited on rice seedlings and maintained in a glass jar. Parasitoid adults from the rearing stock were randomly selected for use in the experiments. Host eggs other than the rice planthoppers (*Nilaparvata lugens*, *Sogatella furcifera* and *Laodelphax striatellus*) were obtained by collecting adult insects from the paddy fields or grass fields near the Kyushu National Agricultural Experiment Station during the summer. These insects were then reared in the laboratory on rice seedlings or the indigenous host plant specific to each species. Experiments were conducted both in the laboratory at 25°C under continuous fluorescent lighting and in the field.

Host preference of *A. incarnatus* for eggs of the 3 species of rice planthoppers was investigated. About 40 females of each planthopper species were released into a glass jar containing rice seedlings for oviposition for 2 days. In the laboratory experiment, eggs of the 3 host species were put together in a jar, and then three groups of parasitoid females, 10, 18 and 25 in number, were released per jar and allowed to oviposit for 3 days. After exposure, the rice seedlings bearing those host eggs were transferred to a test tube incubated at 25°C for insect development. Each experiment was repeated 3 times. In the field experiment, eggs of the rice planthoppers were placed together in metal trays and exposed in the paddy field for parasitization under natural conditions for 3 days. Trays were placed at the base of rice plants at 3 sites in a 300 m^2 field. After exposure, the rice seedlings were brought back to the laboratory and the same procedures followed as in the laboratory experiment. The field experiment was carried out twice, in early August and mid-September, 1979.

The parasitic ability of *A. incarnatus* on other host species was also investigated; an additional 8 species of delphacid planthoppers and 2 species of cicadellid leafhoppers were tested. Field-collected adult insects were allowed to deposit eggs for 2 days on rice seedlings or on their specific host plants in a glass jar; again, experiments were conducted both in the laboratory and the field. In the laboratory, females were allowed to parasitize host eggs for 3 days in a glass jar. For the field test, eggs of each host species were exposed to parasitization under natural conditions in the paddy field for 3–4 days. After exposure, these eggs were brought back to the laboratory and the same procedures followed as above. Field experiments for each host species were done at different times depending on whether the field-collected adults of host insects were available.

In all experiments daily recording was made of the number of adult parasitoids emerged and host nymphs hatched. No attempt was made to count the actual number of total host eggs exposed and those parasitized, because this could not have been done without dissecting the host plant, a procedure which is also very time consuming. Thus, the per cent parasitism was estimated from the number of parasitoids emerged and host nymphs hatched, and the immature mortality of insects was excluded. Since *A. incarnatus* is a solitary parasitoid, per cent parasitism was estimated as follows;

$$P=\frac{W}{W+H}\times 100$$

where, P is per cent parasitism, W is the number of parasitoids emerged and H is the number of host nymphs hatched.

Table 1. Host preference of *Anagrus incarnatus* on three species of rice planthoppers (in the laboratory)

Host species	Parasitism (%)		
	10[a]	18[a]	25[a]
Nilaparvata lugens	49.8 (260/522)[b]	48.7 (213/437)	91.9 (194/211)
Sogatella furcifera	56.5 (335/593)	43.6 (380/871)	72.5 (211/291)
Laodelphax striatellus	57.4 (178/310)	40.6 (159/392)	88.0 (220/250)

[a] Numerals indicate no. of ovipositing parasitoid females per jar.

[b] Numbers in parentheses respectively indicate parasitoids emerged and host nymphs hatched + parasitoids emerged.

Data were compiled from 3 replicates.

Table 2. Host preference of *Anagrus incarnatus* on three species of rice planthoppers (in paddy fields, 1979)

Host species	Parasitism (%)	
	Aug. 6–9	Sept. 10–13
Nilaparvata lugens	20.2 (92/456)[a]	89.3 (241/270)
Sogatella furcifera	13.1 (41/314)	69.8 (148/212)
Laodelphax striatellus	33.9 (81/239)	76.2 (192/252)

[a] Numbers in parentheses indicate respectively parasitoids emerged and host nymphs hatched + parasitoids emerged.

Data were compiled from 3 replicates.

To determine the host stage suitable for the parasitoid, *N. lugens* eggs of different ages, 0–24 hr, 3, 5, 7 and 9 days, were exposed for oviposition by *A. incarnatus* over a 24 hr period. These eggs were held at 25°C until day 8 or 9 after oviposition and the number parasitized was examined by dissecting the host plant under a binocular stereomicroscope. Parasitized eggs were then kept in plastic petri dishes with moist filter paper for further development of the parasitoid. Emergence success and the sex ratio were recorded.

RESULTS

Host preference on the 3 species of rice planthoppers

The results shown in Tables 1 and 2 indicate that *Anagrus* vigorously attacked eggs of all 3 rice planthopper species. The per cent parasitism with 25 ovipositing female parasitoids was higher than with 10 or 18 parasitoids in all 3 species (Table 1). In the field test (Table 2), the per cent parasitism of all host species in September was higher than in August, apparently reflecting the seasonal abundance of the parasitoid in the paddy field. Parasitism in mid-September was as high as 70 % or more. The per cent parasitism in the rice planthopper species did not greatly differ in either laboratory or field experiments. Thus, overall results indicate that *A. incarnatus* attacked eggs of all the rice planthoppers with no preference among them.

Parasitism on other delphacid and cicadellid species

Seven out of 8 species of delphacid planthoppers other than the rice planthoppers were also found to be attacked by *A. incarnatus*, although the per cent of parasitism

Table 3. Host range of *Anagrus incarnatus* other than the rice planthoppers

Host insect species	Laboratory test		Field test	
	Host plant	Parasitism (%)	Host plant	Parasitism (%)
Delphacidae				
Nilaparvata bakeri MUIR	Rice	71.4 (5/7)[a]	—	—
N. muiri CHINA	*Leersia japonica*	39.9 (69/173)	*L. japonica*	32.4 (12/37)
Harmalia albicollis MOTSCHULSKY	Rice	93.8 (30/32)	*Cynodon dactylon*	0 (0/109)
Sogatella longifurcifera ESAKI et ISHIHARA	Rice	65.8 (48/73)	*Digitaria adscendens*	26.0 (80/308)
S. panicicola ISHIHARA	Rice	17.8 (8/45)	*Echinochloa oryzicola*	18.1 (135/748)
Terthron albovittatum MATSUMURA	*Paspalum distichum*	40.0 (8/20)	*P. distichum*	64.7 (11/17)
Zuleica nipponica MATSUMURA et ISHIHARA	—	—	*Zizania latifolia*	8.8 (68/776)
Cicadellidae				
Nephotettix cincticeps UHLER	Rice	5.3 (6/113)	—	—
Macrosteles orientalis VILBASTE	Rice	63.0 (75/119)	—	—

[a] Numbers in parentheses indicate respectively parasitoids emerged and host nymphs hatched + parasitoids emerged.

Table 4. Parasitism of host eggs (*Nilaparvata lugens*) of different ages by *Anagrus incarnatus*

Age of host egg (days)	No. of eggs parasitized	No. of parasitoids emerged	Emergence (%)	Sex ratio (% female)
0–24 hr	275	226	82.2	73.5
3	351	281	80.0	77.4
5	275	232	84.4	69.4
7	265	237	89.4	72.7
9	290	266	91.7	59.4

varied considerably (Table 3). It is interesting to note that *Harmalia albicollis* eggs were often attacked when rice seedlings were used as a host plant, while they were unparasitized when deposited on *Cynodon dactylon*, the indigenous host plant of this hopper. The reason for this is unknown.

Of all 8 species of delphacid planthoppers tested, only *Saccharosydne procerus* parasitization by the parasitoid was unsuccessful. The natural features of egg deposition of this planthopper were quite different from the others. Eggs are deposited in the hollow air-filled space of leaf-sheath or axil of leaf blade of the host plant, *Zizania latifolia*, and the surface of the plant tissue where they are embedded is covered with a white mealy-like powder so that the eggs are absolutely hidden. This led the authors first to think that the manner of egg-laying of this planthopper might protect the eggs from attack since they were not directly exposed to the parasitoid. In both field and laboratory experiments no parasitized eggs were found at all, indicating that *A. incarnatus* does not attack eggs of *S. procerus*.

The two species of cicadellid leafhoppers, *Nephotettix cincticeps* and *Macrosteles orientalis* are usually abundant in the field. Their economic importance is that the former itself is a rice insect pest and both species are vectors of certain virus diseases. Table 3 shows that the eggs of both leafhoppers were attacked by the parasitoid but that parasitism of *N. cincticeps* was rather low, 5.3% (6/113). When exposed eggs were examined, about half of them (50/113) were found to have died with no evidence of being parasitized. Another experiment was conducted in which the eggs of this leafhopper were directly exposed to the parasitoid by dissecting the rice plant, and parasitization took place in a plastic petri dish. In this case parasitism reached 72 % (60/83). Eggs of the other leafhopper, *M. orientalis*, were 63 % parasitized (75/119).

Results of the experiment on host suitability are shown in Table 4 and host eggs at any stage of development are seen to have been strongly attacked by *A. incarnatus*. In all egg stages tested, more than 80 % of them were parasitized and immature parasitoids developed to the adult stage. It should be noted that per cent adult emergence in 9 day-old host eggs was somewhat higher than in the others, but the ratio of female progeny to male was considerably lower (Table 4). From the point of view of population multiplication or mass rearing of the parasitoid, 9 day-old host eggs are therefore less suitable.

DISCUSSION

ÔTAKE (1967, 1968, 1969 and 1970) studied the biology and ecology of *A.* nr. *flaveolus* WATERHOUSE intensively and reported this parasitoid to be a dominant species among egg parasitoids of the rice planthoppers in Zentsuji, Kagawa Prefecture. KAWASE and ISHIZAKI (1965) found that several species of delphacid planthoppers were attacked by *A. flaveolus* but no parasitism was detected in the eggs of *N. cincticeps*. ÔTAKE (1967) also noted that *A.* nr. *flaveolus* was seldom trapped in eggs of *N. cincticeps* in the field in contrast to the trichogrammatid, *Japania andoi*, and he found that laboratory parasitization by this parasitoid on eggs of this leafhopper was unsuccessful. However, in our experiment eggs of *N. cincticeps* were parasitized by *A. incarnatus* with particularly high efficiency when the eggs were directly exposed to the parasitoid.

As reviewed recently by CHIU (1979), *Anagrus* species are dominant among the mymarid and trichogrammatid egg parasitoids of *N. lugens* in Southeast Asia. During the course of this study *A. incarnatus* was observed to be a dominant egg parasitoid of the rice planthoppers in paddy fields in the Chikugo area, Fukuoka Prefecture.

DOUTT (1964) considered that the behavior in host selection of insect parasitoids was four orderly steps: (1) locating a host habitat, (2) host finding, (3) host acceptance and (4) host suitability. He felt that the first factor eliminating many species from being potential hosts of a parasitoid is the failure to locate the habitat of the host. Evidence from several reports of parasitoids being attracted to a habitat, regardless of the presence or absence of the host, caused VINSON (1981) to conclude that the host plant plays a role in orientation to the habitat. ARTHUR (1962) reported that *Itoplectus conquisitor* attacks hosts on Scots pine but does not attack the same hosts on red pine.

A. incarnatus attacked *H. albicollis* eggs when they were deposited on rice plant and were confined together in the laboratory, but did not attack them in the field when the eggs were deposited on the indigenous host plant, *C. dactylon*. It is probable that in natural conditions the host habitat location of *H. albicollis* in which the eggs of this planthopper are laid does not attract *Anagrus*.

The results of our observations indicate that *A. incarnatus* has a rather wide host range. Successful cases in biological control projects seem to favor highly host-specific natural enemies (DOUTT and DEBACH, 1964). However, HUFFAKER et al. (1971) state that conditions in a given situation may be such that strict monophagy is not conducive to good control and that alternate host species may be required at times when a given host is unavailable. DOUTT and DEBACH (1964) also state that if a host population is periodically depressed by other factors, a specific natural enemy will suffer most, whereas a more general feeder will maintain itself on other hosts during adverse periods. This consideration is likely to be true for *A. incarnatus* in the environmental situation in Japan.

In regard to the host suitability for the parasitoid, all stages of development of *N. lugens* eggs were attacked by *A. incarnatus*. HIRAO (1972) found that at 25°C the egg period of *N. lugens* averaged 11.3 days; thus, in our experiment, 9 day-old eggs contained well developed embryos. WHALLEY (1969) found that *A. incarnatus* could successfully parasitize fully developed eggs of *Tettigella viridis*, and the parasitoid in the host eggs of 'well-developed embryos' developed at an equal rate to that in the newly-laid egg. This behavior was also observed in the present study. However, ÔTAKE (1968) reported that development of *A.* nr. *flaveolus* was to some extent prolonged in older *L. striatellus* eggs. Among other mymarid species, *Prestwichia aquatica* is said to oviposit on host eggs of all stages of development but cannot mature in those containing well-developed embryos; *Anaphes nipponicus* limits its oviposition to *Lema* eggs one to three days old (CLAUSEN, 1940).

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REFERENCES

ARTHUR, A. P. (1962) Influence of host tree on abundance of *Itoplectus conquisitor* (SAY), a polyphagous parasite of the European pine shoot moth *Rhyacionia buoliana* (SCHIFF). *Can. Ent.* **94**: 337–347.

CHIU, S. C. (1979) Biological control of the brown planthopper. In *Brown Planthopper: Threat to Rice Production in Asia*. IRRI, Los Baños, pp. 335–355.

CLAUSEN, C. P. (1940) *Entomophagous Insects*. McGraw-Hill, New York and London, 688 pp.

DOUTT, R. C. (1961) The hymenopterous egg parasites of some Japanese leafhoppers. *Acta Hymenopterologica* **1**: 305–314.

DOUTT, R. C. (1964) Biological characteristics of entomophagous adults. In *Biological Control of Insect Pests and Weeds* (P. DEBACH, ed.), Chapman and Hall, London, pp. 145–167.

DOUTT, R. C. and P. DEBACH (1964) Some biological control concepts and questions. In *Biological Control of Insect Pests and Weeds* (P. DEBACH, ed.), Chapman and Hall, London, pp. 118–142.

HIRAO, J. (1972) Bionomics of the two injurious planthoppers in a paddy field and suitable timing of insecticide application. *Bull. Chugoku Nat. Agr. Exp. Sta. Ser.* **E7**: 19–48 (in Japanese with an English summary).

HUFFAKER, C. B., P. S. MESSENGER and P. DEBACH (1971) The natural enemy component in natural control and the theory of biological control. In *Biological Control* (C. B. HUFFAKER, ed.), Plenum Press, New York, pp. 16–67.

KAWASE, E. and H. ISHIZAKI (1965) Parasitic natural enemies of delphacid planthoppers. In *Ecological and Physiological Studies on Sogatella furcifera* HORVÁTH *and Nilaparvata lugens* STÅL *with Special Reference to Their Overwintering and Forecasting Their Occurrence. Special Report on Disease and Insect Outbreak Forecasting Work* **20**: 276–279 (in Japanese).

ÔTAKE, A. (1967) Studies on the egg parasites of the smaller brown planthopper, *Laodelphax striatellus* (FALLÉN) (Hemiptera: Delphacidae). I. A device for assessing the parasitic activity and the results obtained in 1966. *Bull. Shikoku Agric. Exp. Stn.* **17**: 91–103.

ÔTAKE, A. (1968) Ibid. II. Development of *Anagrus* nr. *flaveolus* WATERHOUSE (Hymenoptera: Mymaridae) within its host. *Bull. Shikoku Agric. Exp. Stn.* **18**: 161–169.

ÔTAKE, A. (1969) Ibid. III. Longevity and fecundity of *Anagrus* nr. *flaveolus* WATERHOUSE (Hymenoptera: Mymaridae). *Jpn. J. Ecol.* **19**: 192–196.

ÔTAKE, A. (1970) Ibid. IV. Seasonal trends in parasitic and dispersal activities, with special reference to *Anagrus* nr. *flaveolus* WATERHOUSE (Hymenoptera: Mymaridae). *Appl. Ent. Zool.* **5**: 95–104.

SAHAD, K. A. (1983) Biosystematic studies on the genera *Gonatocerus* NEES and *Anagrus* HALIDAY of Japan and adjacent regions (Hymenoptera, Mymaridae). Dr. thesis, Kyushu University, Fukuoka, p. 222.

SAHAD, K. A. (1984) Biology of *Anagrus optabilis* (PERKINS), an egg parasitoid of the rice planthoppers (Hymenoptera, Mymaridae). *Esakia* **22**: 129–148.

VINSON, S. B. (1981) Habitat location. In *Semiochemicals: Their Role in Pest Control* (D. A. NORDLUND, R. L. JONES and W. J. LEWIS, eds.), John Wiley & Sons, New York, pp. 51–77.

WHALLEY, P. E. S. (1969) The mymarid egg-parasites of *Tettigella viridis* (Hom., Cicadellidae) and embryo-parasitism. *Entomol. Month. Mag.* **105**: 239–243.

YASUMATSU, K. and C. WATANABE (1964) *A Tentative Catalogue of Insect Natural Enemies of Injurious Insects in Japan.* Part 1. *Parasite-Predator Host Catalogue.* Kyushu University, Fukuoka, 166 pp. (in Japanese).