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Parasitism of Brown Planthopper and Whitebacked Planthopper by *Agamermis unka* in Korea

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Abstract: Adults of the brown planthopper (BPH) and the whitebacked planthopper (WBPH) that migrated into Korea from China were not parasitized by the mermithid, *Agamermis unka*. BPH and WBPH collected from Korean rice fields were parasitized. Parasitism of BPH in the 1st–3rd, 4th, and 5th instars, and adults was 31.5%, 61.5%, 66.4%, and 45.5%, respectively, whereas parasitism of the same stages of WBPH was 50%, 50%, 100% and 90.7%, respectively. Parasitism of BPH by *A. unka* significantly reduced the number of eggs. Only 4.2% of the parasitized females contained eggs, whereas 85.6% of unparasitized females had eggs. Tilling of rice fields significantly increased mermithid parasitism of BPH. Mermithids parasitized 39.3% of caged adults in the untilled field and 77.8% in the tilled field.

Key words: Agamermis unka, biological control, brown planthopper, entomogenous nematode, mermithid, *Nilaparvata lugens,* rice pest, *Sogatella furcifera,* whitebacked planthopper.

The brown planthopper (BPH), *Nilaparvata lugens* (Stal), and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath), are serious pests of rice in Korea. Neither insect can survive the Korean winters and their annual influx is dependent on adult dispersal from southern China during tropical storms in June and July. The reestablished planthoppers reproduce and cause extensive damage through their feeding activity and transmission of viral diseases to the rice plants (9). Application of chemical insecticides remains the main control strategy in Korea; and in 1987, ca. 65,000 t valued at $18 million was applied for control of these insects (1).

Recently, mermithid nematodes (3–5,11,15,16) have received attention as possible biological control agents of BPH. In Korea, the naturally occurring mermithid, *Agamermis unka* Kaburaki and Imamura, parasitized 50% and < 25% of BPH in rice paddies not treated and treated with insecticides, respectively (3). In the Philippines, 50% parasitism of BPH by an unidentified mermithid, probably *A. unka,* was recorded during the wet season in certain areas (10), but parasitism was low throughout the year and its impact as a natural control agent of BPH was negligible (6). In Japan, 30–40% parasitism of BPH by *A. unka* has been recorded, and Chiu (2) suggested that if this nematode can be reared artificially, it might be an important agent in BPH control.

Agamermis unka overwinters in Korean rice paddies and does not appear to disperse over long distances with its hosts (3,4). As very little is known of the impact of this mermithid on planthoppers in Korea, a number of studies were initiated to determine its role as a mortality factor in planthopper populations. Studies were conducted in Gyeongnam Province in 1988 on 1) mermithid parasitism according to the instar and sex of BPH and WBPH, 2) the effect of mermithid parasitism on egg production by BPH adults, and 3) the effect of tilling on nematode parasitism of BPH. In addition, prevalence of parasitoids in BPH and WBPH adults was recorded because they may be an alternative approach to biological control (6,12).

MATERIALS AND METHODS

Brown planthoppers and WBPH macropterous adults, that had immigrated into Korea, were collected at Namhae on 19, 23, and 26 July 1988. The adults were sexed and dissected, and the numbers of mermithids, hymenopterous parasitoids, and eggs per female were recorded.

The progeny of insects that had migrat-

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ed from China and F_1 adults of BPH were collected from rice paddies in Chinyang and Chinju on eight separate occasions between 10 August and 3 October. Similar populations of WBPH were collected at Chinju on 19, 25, and 28 August. BPH and WBPH were separated into groups of 1st–3rd, 4th, and 5th instars, and adults. Each instar group was placed on ten 10-day-old rice seedlings and covered with a test tube (14.5 × 2.5 cm d). There were no more than 30 planthoppers within a test tube; the insects were maintained at room temperature (27 ± 3 C). The planthoppers on the rice seedlings were dissected after becoming adults, and the number of mermithids per planthopper was determined. All planthoppers were collected with an aspirator.

In a separate study, BPH adults were collected from rice paddies in Chinyang and Chinju on a monthly basis from August to October. Adults were transported to the laboratory, sexed, dissected, and examined for mermithids and hymenopterous parasitoids. In addition, the number of eggs in the ovaries from a subsample of the BPH collected from Chinju was counted.

The effect of tilling on mermithid parasitism was studied in a rice paddy (soil 2.7% sand, 64% silt, 33.3% clay; organic matter 2.3%, pH 5.6) at Chinju. The rice paddy was divided into two tilled plots and one untilled plot, each 33 m^2. The tilled plots were plowed with a cultivator on 2 June and all plots were planted with rice (*Oryza sativa* L. cv. Congzin) on 5 June. Three screened cages, each 1.72 m^3, were placed in each tilled and untilled plot, and 30 pairs of insectary-reared BPH adults were placed in each cage on 3 July. The other tilled plot was allowed to have natural immigration of BPH. Adults of the F_1 generation were collected from each cage and from the uncaged tilled plot on 13, 17, 18, 25, and 28 August with an aspirator. Adults were dissected and examined for presence of mermithids. Percent parasitism was arcsine transformed, and analysis of variance was used to test for differences among treatments.

Results and Discussion

Brown planthopper (n = 83) and WBPH (n = 100) adults that had migrated from China to Korea and were collected at Namhae were not parasitized by mermithids. The majority of the BPH (90.4%) and WBPH (89%) adults were females. Of the females, 16 BPH (21.3%) and 2 WBPH (2.2%) contained eggs. Twelve BPH contained > 30 eggs, whereas the two WBPH contained <10 eggs. An unidentified hymenopteran parasitized 3.6% of the BPH and 2% of the WBPH. These data and those of Choo et al. (4) suggest that mermithid parasitism in insects that migrated into Korea does not occur or is a rare event; however, further studies are needed to establish this. The presence of hymenopteran parasitoids suggests that mermithids may be dispersed from China to Korea and may be storm dependent. That is, intense storms with strong winds such as would occur with a typhoon may aid in the dispersal of mermithid-parasitized planthoppers and collections of immigrating adults after such a storm may prove this hypothesis.

Mermithid parasitism was present in all segregated stages of the planthoppers (Table 1), but only females were parasitized. Males of BPH and WBPH are susceptible to parasitism by *A. unka* (8), so the lack of parasitism probably reflects the low number of males in this study.

The data clearly demonstrate that *A. unka* parasitizes young (1st–3rd) instars of BPH and WBPH. Superparasitism, defined as two or more parasitic stage nematodes of the same species occurring within the insect's hemocoel, was common in BPH in all segregated instars and in WBPH adults (Table 1). The maximum number of mermithids found in a BPH female adult was 14. Other BPH females had eight (n = 1), seven (n = 2), six (n = 2) and five mermithids (n = 3). The maximum number of mermithids found in a WBPH female adult was 12. Two other WBPH females had five mermithids each.

The population of WBPH was low in 1988, but *A. unka* was recovered from this

TABLE 1. Parasitism of the brown planthopper (BPH) and whitebacked planthopper (WBPH) within a given instar by *Agamermis unka*, August–October 1988.

Number of *Agamermis*/ host	Insects parasitized within instar, % (n)			
	1st–3rd	4th	5th	Adult
		BPH		
0	68.5 (491)	38.5 (74)	33.6 (43)	54.6 (232)
1	24.4 (175)	46.8 (90)	44.5 (57)	26.6 (113)
2	4.9 (35)	10.9 (21)	19.5 (25)	10.8 (46)
3	11.7 (12)	3.6 (7)	2.4 (3)	5.2 (22)
4	0.5 (4)	0 (0)	0 (0)	0.7 (3)
> 5	0 (0)	0 (0)	0 (0)	2.1 (9)
		WBPH		
0	50.0 (2)	50.0 (7)	0 (0)	9.3 (7)
1	50.0 (2)	42.9 (6)	69.2 (9)	56.0 (42)
2	0	7.1 (1)	30.8 (4)	25.4 (19)
3	0	0 (0)	0 (0)	5.3 (4)
4	0	0 (0)	0 (0)	0 (0)
> 5	0	0 (0)	0 (0)	4.0 (3)

insect; this is a new host record for Korea. This mermithid has been recovered from WBPH in other Far East countries (7,8,11,16). Moreover, *A. unka* has been recovered from planthoppers in the genera *Deltocephalus* (16), *Laodelphax* (16), *Nisia* (16), and *Nephotettix* (5,10). To date, *A. unka* has been recovered only from BPH and WBPH in Korea.

Multiple parasitism, in which two species of parasites invade the same insect host, was found in a few instances in Chinju and Chinyang (Table 2). It did not appear to play a significant role in the population dynamics of the hymenopterous parasitoid, *Pseudogonatopus* (Dryinidae), or *A. unka*. Multiple parasitism occurred in < 1% of the sample. Parasitism by the hymenopterous parasitoid alone occurred in < 1%, whereas parasitism by *A. unka* alone occurred in > 40% of the sample. These data suggest that the hymenopterous parasitoid is not a significant mortality factor. As only adult planthoppers were examined for parasitoids, however, their importance as mortality factors in other instars is unknown. In the Philippines when late instar and adult BPH were sampled, overall parasitism by dryinids was 9.7% in the wet season and 6.4% in the dry season (12). The continual presence of BPH in a tropical environment does not appear to enhance parasitism by hymenopterous parasitoids. Cook and Perfect (6) also observed low parasitism by hymenopterous parasitoids in late instar nymphs and adults of BPH.

TABLE 2. Occurrence of a hymenopterous parasitoid (*Pseudogonatopus* sp.) and *Agamermis unka* in the brown planthopper from two rice fields in Korea.

Site	Total dissected	Insects with parasites (%)		
		Agamermis	Parasitoid	*Agamermis* and parasitoid
Chinju	636	56.2	0.9	0.9
Chinyang	636	40.9	0.5	0.5

Agamermis unka significantly reduced the fecundity of BPH (Table 3). The majority (85.5%) of unparasitized BPH had eggs in their ovaries. In contrast, 4.2% of mermithid-parasitized adults had eggs in their ovaries. The data suggest that an increasing number of mermithids in a host further reduced fecundity. As with many other mermithids that parasitize adult insects, host castration is a common effect (13,14). Few males were collected from the field (n = 28) and they were not parasitized by *A. unka*. In contrast, 48.2% of the female BPH (n = 398) were parasitized.

Significantly ($F = 16.8, P < 0.05$) greater parasitism of BPH occurred in tilled than in untilled plots. Mermithids parasitized 39.3 ± 9.2% of BPH (n = 251) in the untilled caged plot and 77.8 ± 9.4% (n = 190) in the tilled one. Of the BPH collected from the tilled but uncaged plot 72.0 ± 3.7% (n = 436) were parasitized by *A. unka*. The difference in mermithid parasitism between tilled and untilled plots may be attributed to the redistribution of mermithids in the soil. Mermithids are normally found 1–5 cm below the soil surface in May (3), but tilling probably brought them nearer to the soil surface. Upon flooding, the parasitic stage would then be in the water or would not have to migrate far through soil. Many of the rice fields would

TABLE 3. Female brown planthoppers containing eggs† with and without *Agamermis unka.*

Number mermithids/ female	Total examined	Females with eggs (%)								
		0	1–10	11–20	21–30	31–40	41–50	51–60	61–70	> 71
0	206	14.5	0.5	1.9	0.5	6.8	3.9	56.3	3.9	11.7
1	113	94.7	3.5	0	0.9	0	0	0.9	0	0
2	46	97.8	2.2	0	0	0	0	0	0	0
3	22	95.5	0	4.5	0	0	0	0	0	0
4	11	100.0	0	0	0	0	0	0	0	0

† The numbers of eggs in the ovaries were grouped by increments of 10.

not have sufficient populations of BPH or WBPH during the early summer. Thus, by disturbing the soil, it became less compact and allowed greater numbers of the parasitic stage, which is synchronized with its hosts, to migrate through soil and parasitize hosts when they became established in the rice fields.

Agamermis unka is an important mortality factor in planthopper populations in Korea. It kills the adults and reduces the fecundity of the females. To affect planthopper populations, the mermithid must parasitize a high number of progeny of the migrating population. *A. unka* should be most effective when the migrating adult insects produce few progeny and the parasitic stage of the mermithid occurs in high numbers. A control strategy would be to reduce the number of progeny produced by the migrating adults. Perhaps this reduction could be accomplished through an integrated manner with chemical or biological insecticides, resistant cultivars, cultural methods, or a combination of these control tactics. The diminished fecundity of mermithid-parasitized planthoppers should reduce the F_2 generation of the planthoppers. Such a scenario requires monitoring of the planthoppers and the mermithid. Before an integrated pest management system can be incorporated in Korean rice fields, further studies on the biology of the mermithid and its compatibility with current control tactics are needed.

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