# EVALUATING DIFFERENT RELEASE STRATEGIES FOR THE CONTROL OF AMERICAN COCKROACHES USING THE EGG PARASITOID, *APROSTOCETUS HAGENOWII*

B. M. PAWSON & R. E. GOLD
Texas A&M University, College Station, TX 77843-2475, USA

**Abstract**—The ability of *Aprostocetus* (*Tetrastichus*) *hagenowii* (Ratzeburg) to find oothecae in plumbing chases infested with American cockroaches was evaluated using different release strategies for six weeks. This pilot study used forty-three plumbing chases. Chases were assigned one of four treatments (release strategy) which were: (1) weekly releases of 300 female *A. hagenowii* using parasitized oothecae, (2) bi-weekly releases of 300 female *A. hagenowii* using parasitized oothecae, (3) weekly releases of 50 female *A. hagenowii* using free-living adults and (4) no releases which served as controls.

Sentinel oothecae (laboratory-reared oothecae placed in 2 × 3 cm fibreglas-window screen bags) were placed in plumbing chases to monitor parasitoid releases. Sentinel bags were placed at five locations in release chases and at three locations in non-release chases. Sentinel locations (1, 2, 3, 4 and 5) were 4, 0.5, 4, 5 and 16 m from the release point, respectively. Locations 1, 2 and 3 were on the floor of the plumbing chase; locations 4 and 5 were 1 m above the floor. Sentinel locations in non- release chases corresponded to locations 1, 3 and 5 in release chases.

The overall parasitism levels of sentinel oothecae placed in plumbing chases were 30.6, 18.2, 20.6 and 0% for Treatments 1, 2, 3 and 4, respectively. Weekly releases of *A. hagenowii* using parasitized oothecae produced parasitism levels ranging from 23 to 39% throughout the six week study period. Releases of live females resulted in parasitism levels ranging from 13 to 35%. Bi-weekly releases of *A. hagenowii* showed the highest variation in parasitism levels. During weeks 2, 4 and 6 when releases were made, parasitism levels were 2, 40 and 44%, respectively. During weeks 1, 3 and 5 when no releases were made, parasitism levels were 0, 17 and 6%, respectively. Mean wasp emergence was highest for Treatment 3 averaging 60 wasps per parasitized oothecae followed by Treatment 2 (55 wasps) and Treatment 1 (53 wasps). *A. hagenowii* was capable of finding and parasitizing sentinel oothecae at all locations within the plumbing chase. Average parasitism levels for sentinel oothecae at locations 1, 2, 3, 4 and 5 were 21, 29, 24, 35 and 9%, respectively. These results indicate that the potential exists for using *A. hagenowii* to control American cockroaches.

## INTRODUCTION

Interest in using natural enemies to control pest populations in urban situations has increased in the past few years. Many urban pests, including cockroaches, are attacked by natural enemies. There are several families of parasitic Hymenoptera, including Eulophidae, Eupelmidae, Encyrtidae, Evaniidae and Pteromalidae, that use cockroach oothecae as hosts (Roth & Willis, 1960). Habits of these parasitic wasps are highly variable ranging from solitary developmental behavior to gregarious, and from attacking several species of hosts to being host specific.

Most of the research with the parasitic wasps that attack cockroaches has dealt with basic biology and field surveys. Through this research, several species have been identified as potential control agents and include the eupelmid, *Anastatus tenuipes* Bolivar y Pieltain (Manweiler, 1988), the encyrtid, *Comperia merceti* (Compere) (Coler et al., 1984, LeBeck, 1991) and the eulophid, *Aprostocetus* (*Tetrastichus*) *hagenowii* (Ratzeburg) (Roth and Willis, 1954, Hagenbuch et al., 1989). Both *A. tenuipes* and *C. merceti* attack only Brownbanded cockroach oothecae. *A. hagenowii* is known to attack nine species of cockroaches including: American cockroach, *Periplaneta americana* (L.); Smokybrown cockroach, *P. fuliginosa* (Serville); and the Oriental cockroach, *Blatta orientalis* (L.).

Because of the hosts attacked, *A. hagenowii* has been studied in far more detail than *A. tenuipes* and *C. merceti*. *A. hagenowii* is a small parasitic wasp ranging from 1 to 2 mm in length; its size is determined by the number of progeny developing within a host. Cameron (1955) found that the average number of progeny from American cockroach oothecae ranged between 30 to 40 with a 1:4 male:female sex ratio. As with size, developmental time of progeny is dependent on the number of progeny developing within a host; as the number of progeny per ootheca increases, the developmental time decreases (Fleet and Frankie, 1975). Maki (1937), Edmunds (1955), Narasimham (1984) and Hagenbuch et al. (1988) reported developmental times ranging from 29 to 60 days. Adult wasps are short lived with females living up to 10 days (Heitmans et al., 1992). Size of adult wasps



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influences their egg supply and the number of hosts they attack (Heitmans et al., 1992). Larger wasps (determined by length of forewing) have a larger egg supply and attack more hosts. Eggs are deposited into host(s) during the first couple days of adult life (Roth and Willis, 1954).

Release studies have been conducted to evaluate the potential of *A. hagenowii* to parasitize host(s). Roth and Willis (1954) achieved 85% parasitism by releasing 1000 female wasps in experimental rooms where cockroach oothecae were distributed. Releases of *A. hagenowii* resulted in parasitism rates over 90% in test kitchens (Hagenbuch et al., 1989). These studies showed the potential of *A. hagenowii*; however, releases under natural conditions are needed. This study was conducted to evaluate the potential of *A. hagenowii* to parasitize cockroach oothecae under natural conditions. Specific objectives of this pilot study were to evaluate different release strategies and to field test whether host preference between different *A. hagenowii* strains exist.

## MATERIALS AND METHODS

Three species of cockroaches and three strains of *A. hagenowii* were tested. All cockroach oothecae and strains of *A. hagenowii* were obtained from colonies maintained at the Center for Urban & Public Health Entomology, Texas A&M University. Colonies of American (*Periplaneta americana* (L.)) and smokybrown (*P. fuliginosa* (Serville)) cockroaches were originally established from field collections from College Station, TX during the summer of 1990. The colony of Oriental (*Blatta orientalis* L.) cockroaches was established from field collections from Midland, TX during the spring of 1991. The colony of *A. hagenowii* was originally established from collections of parasitized oothecae from College Station, TX during the spring of 1991. The American strain of *A. hagenowii* was obtained from parasitized American oothecae, whereas the smokybrown strain of *A. hagenowii* was obtained from parasitized Smokybrown oothecae. The Oriental strain of *A. hagenowii* was established in June 1991 and was obtained by exposing some of the American strain *A. hagenowii* to Oriental oothecae. All strains have been pure since establishment; females have been provided hosts only from their respective strains.

The ability of *A. hagenowii* to find cockroach oothecae was study in 43 plumbing chases infested with American cockroaches. All chases were assigned to one of four treatments (release strategy) which were: (1) weekly releases of 300 female *A. hagenowii* American strain using parasitized oothecae (12 chases), (2) biweekly releases of 300 female *A. hagenowii* American strain using parasitized oothecae (11 chases), (3) weekly releases of 50 female *A. hagenowii* of all strains using free-living adults (i.e., only one strain of *A. hagenowii* (50 females) was released/chase) (10 chases) and (4) no releases which served as controls (10 chases).

**Release preparations.** Releases of *A. hagenowii* were prepared by isolating groups of newly emerged wasps of each strain. After allowing them to mate for 24 h, individual females of each strain were placed in $1.5 \times 5.5$ diam. cm petri dishes along with one host (20–25 d old) of the respective strain. After 48 to 72 h, the females were removed and the oothecae were held for the emergence of cockroaches from unparasitized oothecae. To obtain the numbers needed for release, 60 American, 20 smokybrown and 20 Oriental oothecae were exposed to their respective strains three times per week. Environmental conditions for exposures and development of *A. hagenowii* and cockroach oothecae were 25°C, $40 \pm 10\%$ RH and a 14:10 L:D photoperiod.

**Releases.** Release bags and dishes were prepared the day before releases were made. Release bags were made by folding a piece of $4 \times 3$ cm fibreglass window screen in half and securing the sides with staples. Nine intact oothecae were selected from those oothecae exposed to *A. hagenowii* (American strain) females and placed in 2 or 3 bags. The number of bags used depended on the number of exposure dates used to obtain intact oothecae. The bags (2 or 3) were placed in pre-labelled petri dishes which designated releases locations. Release dishes were made by placing newly emerged males (5 to 10) and females (50) ($< 2$ h old) of a specific strain in pre-labelled petri dishes streaked with honey. Dishes for all three strains were prepared for release. All dishes were placed in their designated chases the following day. Dishes containing parasitized oothecae were left in the chases for two weeks and then returned to the laboratory. To estimate the number of females being released, pre-release samples were taken. These samples estimated the number and proportion of *A. hagenowii* females being released. Post-release counts (number of oothecae with emergence holes)

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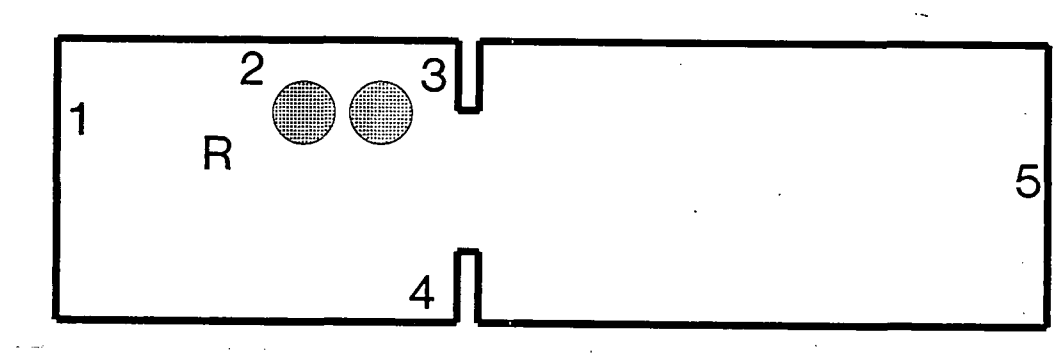


Fig. 1. Placement of sentinel oothecae used to monitor releases of *A. hagenowii* in plumbing chases and the release location. Numbers designate sentinel locations, R designates release point.

were made on the parasitized oothecae that were placed in the chases. Using the average number of females that emerged from the pre- release sample and the number of oothecae with emergence holes from the post-release counts, the number of female *A. hagenowii* was estimated per chase.

**Monitoring of releases.** Activity of released *A. hagenowii* was monitored using 14 to 17 d old, laboratory-reared oothecae of American, smokybrown and Oriental cockroaches. To facilitate placement in the field, oothecae were placed in sentinel bags. Bags were made by folding a piece of 4 × 3 cm fibreglass window screen in half and securing the sides by staples. Three different groups of sentinel bags were made. One group of bags contained two American oothecae and were placed in chases where releases were made using parasitized oothecae (Treatments 1 and 2). Another group of bags containing one American, one smokybrown and one Oriental oothecae were placed in chases where free-living adults were released (Treatment 3). The last group of bags contained only one American ootheca which were placed in non-treatment chases (Treatment 4).

During each week of the study, sentinel bags were placed at five locations in release chases and at three locations in non-release chases (Fig. 1). Sentinel locations (1, 2, 3, 4 and 5) were 4, 0.5, 4, 5 and 16 m from the release point, respectively. Locations 1, 2 and 3 were on the floor of the chase; locations 4 and 5 were 1 m above the floor. Sentinel locations in non-release chases corresponded to locations 1, 3 and 5 in the release chases, respectively. After one week in the plumbing chases, all sentinel bags were returned to the laboratory. Oothecae were removed from the bags, placed individually in gelatin capsules, and held in petri dishes. All petri dishes were placed in a growth chamber set at 25°C with a 40 ± 10% RH and a 14:10 L:D photoperiod for cockroach or wasp emergence.

This experiment was designed to be conducted for 16 weeks. Treatment 1 used the inundative release strategy where continued releases would be made. Treatment 2 used the inoculative approach where a few releases would be made early and then discontinued with the hopes that released *A. hagenowii* would become established. Treatment 3 tested the feasibility of adult releases and determined if strain preferences occurred. Due to a malfunction in the cockroach rearing chamber, the experiment was terminated after six weeks so the difference between the inundative and inoculative approaches was not fully realized.

## RESULTS

The average number of female *A. hagenowii* released per chase during the duration of the study ranged from 275 to 415 for Treatment 1 and from 229 to 355 for Treatment 2. The overall parasitism levels of sentinel oothecae placed in plumbing chases were 30.6, 18.2, 20.6 and 0% for Treatments 1, 2, 3 and 4, respectively (Fig 2.). Weekly releases of *A. hagenowii* using parasitized oothecae produced parasitism levels ranging from 23 to 39% throughout the six week study period. Releases of live females achieved parasitism levels ranging from 13 to 35%. Bi-weekly releases of *A. hagenowii* showed the highest variation in parasitism levels. During weeks 2, 4 and 6 when releases were made, parasitism levels were 2, 40 and 44%, respectively. During weeks 1, 3 and 5 when no releases were made parasitism levels were 0, 17 and 6%, respectively.

Mean wasp emergence from parasitized oothecae was 52.8, 54.6 and 59.7 for Treatments 1, 2 and 3, respectively (Fig. 3). The range of wasp emergence was similar for all three treatments. Emergence results for Treatments 1 and 2 were from only American oothecae, whereas results for Treatment 3 were from American, smokybrown and Oriental oothecae. The proportion of female progeny that emerged was higher for Treatments 1 (87%) and 2 (88%) than the proportion of females for Treatment 3 (76% females).

*A. hagenowii* was capable of finding and parasitizing sentinel oothecae placed at all locations within the plumbing chases (Fig. 4). Overall average parasitism levels for sentinel oothecae placed at locations 1, 2, 3, 4 and 5 were 21, 29, 24, 35 and 9%, respectively. Treatment 1 achieved the highest parasitism levels at the different sentinel locations; parasitism levels obtained by Treatments 2 and 3 were similar. During the 6 week study, locations 1 and 3 showed high variations in parasitism levels for Treatment 1. All locations showed high variations in parasitism levels for Treatment 2. Parasitism levels at locations 3 and 4 showed the highest variations for Treatment 3.

There was no host preference when releases of a particular strain of *A. hagenowii* were made in plumbing chases (Fig. 5). Although the American strain of *A. hagenowii* parasitized more American oothecae, they readily parasitized both smokybrown and Oriental oothecae. When either the

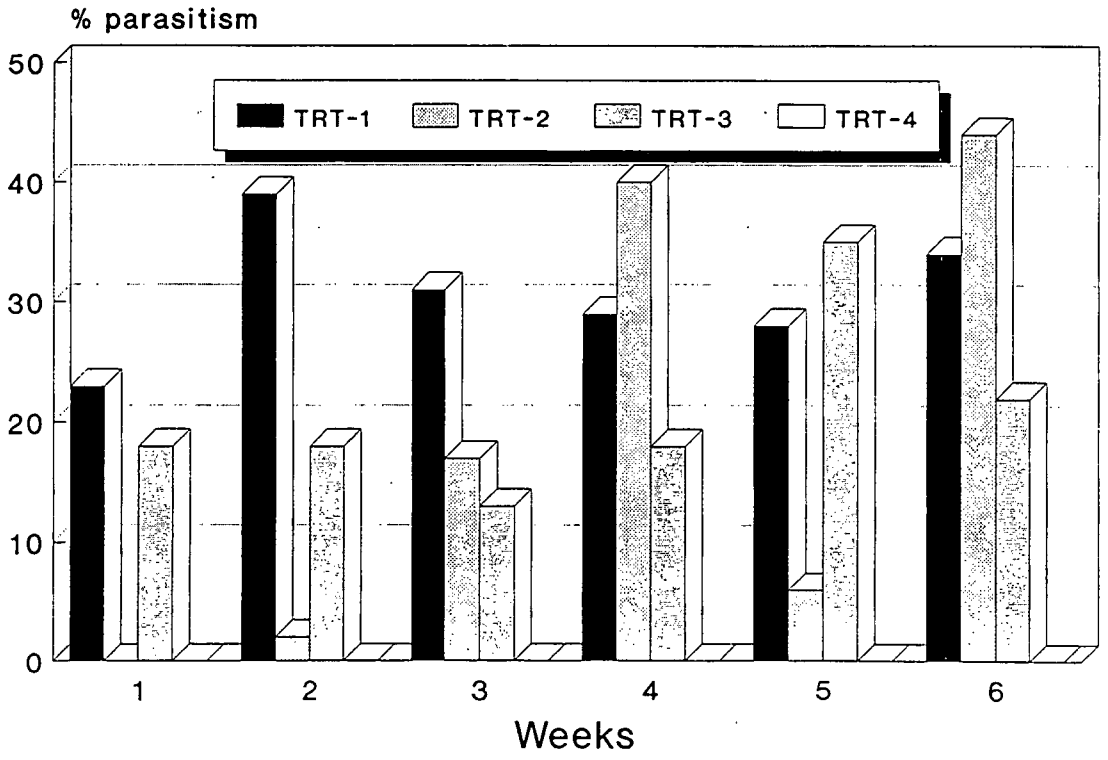


Fig. 2. Proportion of sentinel oothecae parasitized by *A. hagenowii* in plumbing chases using four release strategies. Release strategies were: Treatment 1 – ca. 300 females released weekly, Treatment 2 – ca. 300 females released biweekly, Treatment 3 – 50 females released weekly and Treatment 4 – no females released (controls).

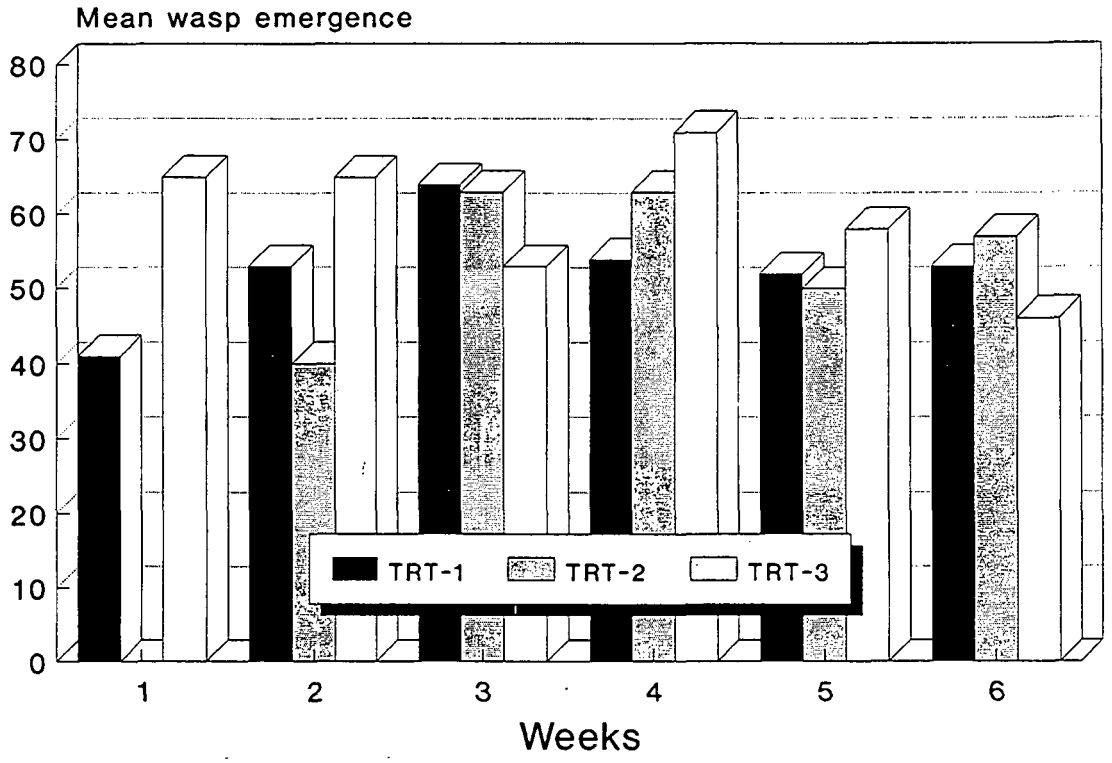


Fig. 3. Mean number of wasps to emerge/parasitized host from sentinel oothecae used to monitor different release strategies of *A. hagenowii*.

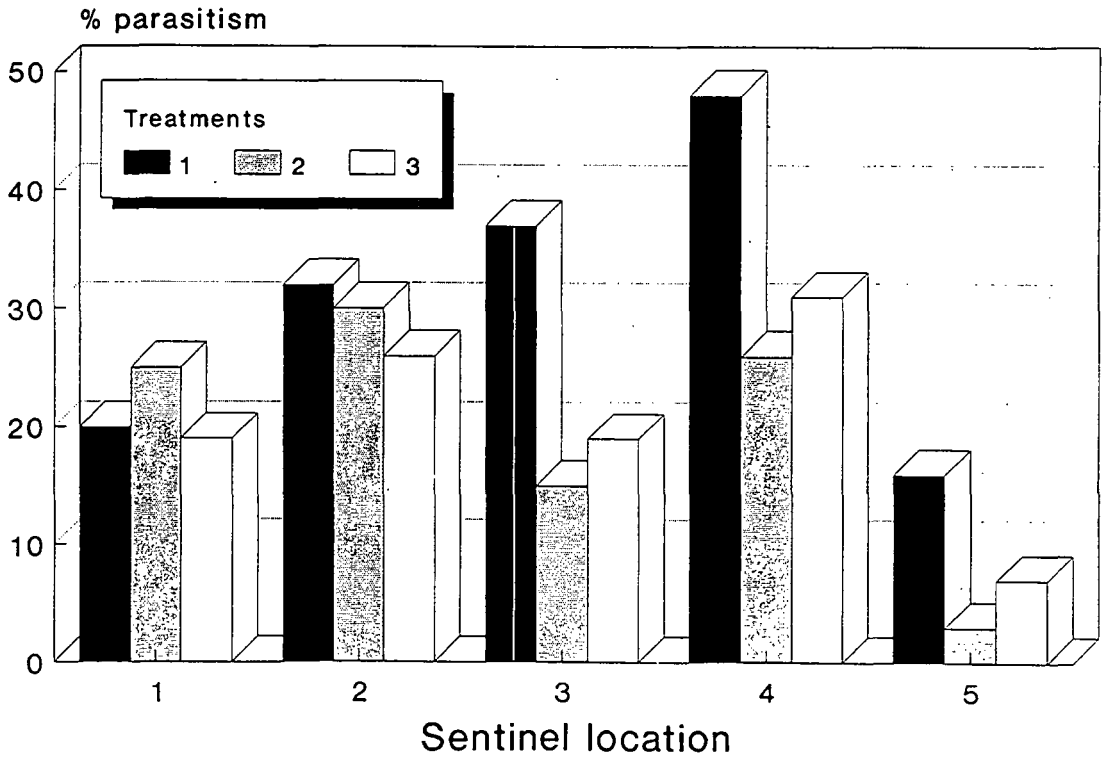


Fig. 4. Proportion of sentinel oothecae parasitized by *A. hagenowii* at five locations in plumbing chases using different release strategies.

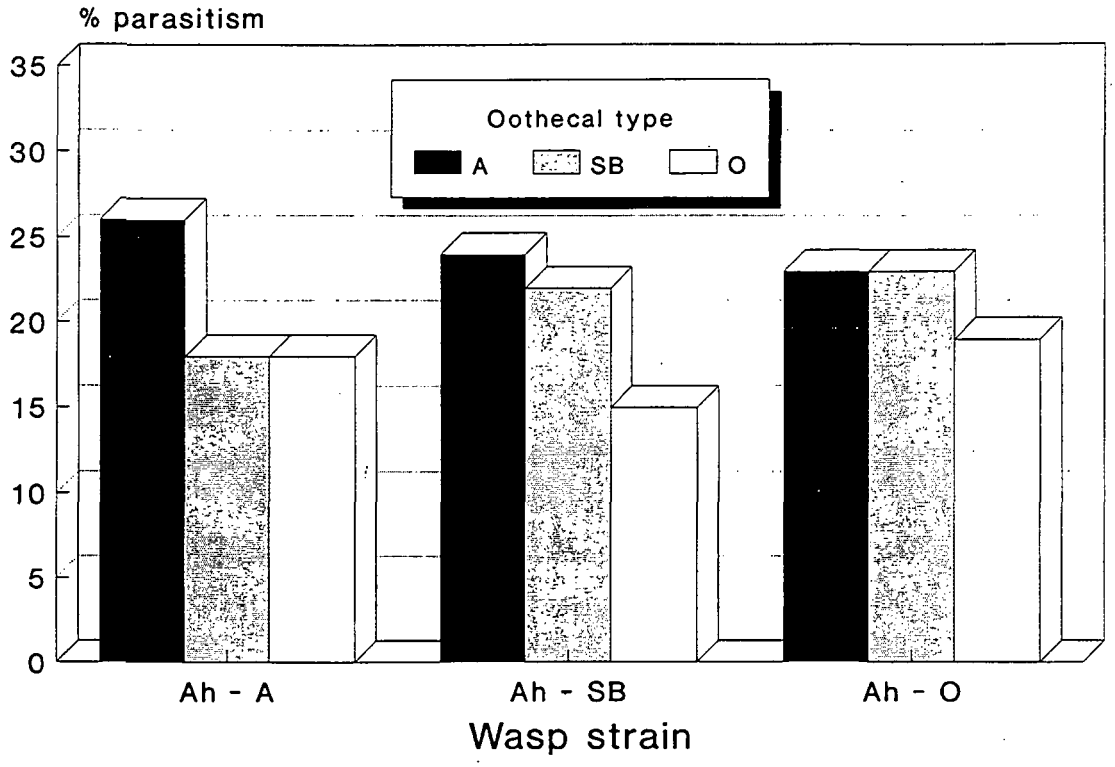


Fig. 5. Proportion of American, Smokybrown and Oriental cockroach oothecae parasitized by different *A. hagenowii* strain.

Smokybrown or Oriental strain of *A. hagenowii* were released, more American oothecae were parasitized than their respective host strain. The mean number of progeny per host was highest from Smokybrown oothecae averaging 68 progeny. The mean number of progeny from American (53) and Oriental (52) oothecae was similar.

## DISCUSSION

Due to the fact that this study was terminated earlier than planned, inundative and inoculative approaches could not be compared from this study. Inundative or weekly releases of *A. hagenowii* (as adults or parasitized oothecae) produced higher levels of parasitism in sentinel oothecae than did the biweekly releases. Parasitism levels achieved by *A. hagenowii* appeared low at first glance, but the results are encouraging because of the low numbers of females that were released. Other release studies obtained higher parasitism levels, but higher numbers of *A. hagenowii* were released and the rooms were smaller (Roth and Willis, 1954, Hagenbuch *et al.*, 1989). Therefore, higher levels of parasitism may be obtained if higher numbers of *A. hagenowii* are released.

The highest parasitism levels were obtained from oothecae placed at location 4 inside the plumbing chases. This is interesting because location 4 was farther away from the release point than locations 1, 2 and 3. Furthermore, location 4 was one metre off the floor, whereas locations 1, 2 and 3 were situated on the floor. Although Piper *et al.* (1978) indicated that parasitism is not influenced by height, the only noticeable difference between these four locations was height. More research may be needed to determine if height influences parasitism levels. The former study was a survey which possibly influenced their findings. Another encouraging aspect of this study was that *A. hagenowii* was capable of dispersing throughout the entire length of the plumbing chase which indicates that they are good searchers. It appears that the number of females being released may influence dispersal distance from the release site. Highest parasitism levels at location 5 which was 16 m from the release point, was obtained using Treatment 1.

Results from the host/strain preference portion of the study indicate that the various strains of *A.*

*hagenowii* do not prefer to parasitize their respective host strains. Different but similar results were obtained in a seasonal activity study when American and smokybrown oothecae were used to determine activity levels of *A. hagenowii* throughout the year (Pawson unpublished). Parasitism levels of American and smokybrown oothecae were similar when *A. hagenowii* had a choice between the two hosts. Although the "strain" of host was unknown, the study occurred outdoors where normally only Smokybrown cockroaches were present. The preference results obtained in this study allows the researcher some freedom in what host they use to rear *A. hagenowii*. Other factors such as number of progeny/host and ease of rearing become important.

To evaluate their true potential, it is important to release organisms of high quality. A mass rearing program has been developed for *A. hagenowii* by Hagenbuch *et al.* (1988), however a different procedure was used to obtain *A. hagenowii* for release in this study. Hagenbuch's method produced a mean of 56 wasps/ootheca with 53.6% (or 30) being females. In this study an average of 63 wasps emerged/ootheca with 82.5% (or 52) being females. The high proportion of male to female progeny in the former rearing method is a possible indication that the oothecae were being over-parasitized. In a seasonal activity study (Pawson unpublished), the mean number of progeny to emerge from American oothecae parasitized under nature field conditions was lower than these laboratory numbers (45), but 82.8% (or 37) were females (n = 120). Although isolating females with individual hosts requires more time, the benefits of the isolation rearing method appear to outweigh its drawbacks. Benefits include healthy, robust wasps, a more defined window for emergence, and a high proportion of females. Additionally, Heitmans *et al.* (1992) have shown that large wasps are more fecund and attack more hosts.

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