The Multicolored Asian Lady Beetle (Coleoptera: Coccinellidae): Orientation to Aggregation Sites[1]

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Abstract Several studies were conducted to determine the cues used by the lady beetle *Harmonia axyridis* (Pallas) when orienting to aggregation sites in autumn: (1) artificial shelters modeled after those commercially available in mail order catalogues were baited with live adults and hung on the outside of buildings known from past years to be aggregation sites, (2) differential arrival of the two sexes at overwintering sites was examined by collecting and sexing the beetles alighting on buildings at two points in time during the aggregation period, and (3) the distribution of overwintering *H. axyridis* among beehives was determined in ten apiaries. Results indicate no preference for the artificial shelters and no orientation to the conspecifics within them. Sex ratios of beetles arriving at aggregation sites were consistent over time in two of the three sites examined. During winter, adult *H. axyridis* were non-randomly distributed among physically similar beehives. We conclude that there is little evidence for volatile aggregation pheromones and suggest that the chemical cues that mediate the final stages of aggregation behavior in *H. axyridis* may be based on contact chemoreception with conspecifics or the feces and residues that persist in aggregation sites from previous years.

Key Words *Harmonia axyridis,* lady beetles, overwintering, beehives, pheromones, aggregation

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The multicolored Asian lady beetle, *Harmonia axyridis* (Pallas), is an effective predator of aphids and other soft-bodied insects in crops, orchards, gardens, meadows and trees. It can, however, be a nuisance to homeowners during autumn, when large numbers may alight on the exterior of buildings, then move into dark, protected fissures and recesses to overwinter. Like other coccinellids (Hodek 1973), they remain in groups within their shelters during the central, cold part of the dormant period. During warm spells, however, beetles may become active without breaking diapause (Anderson and Richards 1977), and in heated buildings activity may be relatively continuous throughout winter. Beetles emerge from wall voids, from behind baseboards, through vents, light fixtures, electrical outlet covers, and floor cracks, and may fly around rooms for hours at a time. Homeowners often object to sharing living quarters with *H. axyridis,* despite recognizing them as otherwise beneficial. Complaints include the staining of walls and furniture from reflex bleeding and fecal material, odor, and the general annoyance of the beetles flying around lights and encroaching on cooking, sleeping, bathing and recreational activities.

Harmonia axyridis is just one of many coccinellid species that aggregate during

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dormancy, but our knowledge of the factors mediating this behavior is limited (Majerus 1994). Until *H. axyridis* was introduced into the United States (Chapin and Brou 1991, Day et al. 1994, Tedders and Schaefer 1994), there was little economic incentive to explore the mechanisms responsible for coccinellid aggregation behavior. A working knowledge of the cues that trigger or regulate aggregation in *H. axyridis,* however, will be crucial in devising management strategies such as attracting aggregating beetles away from homes and toward artificial shelters or outbuildings. The initial choice of overwintering quarters by *H. axyridis* is known to be guided by their visual orientation to light-colored, conspicuous, often isolated features in the landscape (Hagen 1962, Obata 1986, Tedders and Schaefer 1994). Subsequently, a combination of other responses (e.g., geotaxis, hygrotaxis, phototaxis, thermotaxis, thigmotaxis, chemotaxis) influences the final choice of overwintering quarters (reviewed by Hodek 1967). These secondary cues are poorly understood and form the basis for the current study.

Here, we report the results of several exploratory studies of aggregation behavior in *H. axyridis,* using a variety of approaches. We tested the attractiveness of same-sex groups of live adults in artificial shelters to beetles arriving later at aggregation sites. We examined differential arrival of the two sexes at aggregation sites, to determine if there is a pioneering sex in this species, as in aggregating bark beetles (Turchin and Simmons 1997). We also tried to partition the relative influence of physical and chemical factors mediating aggregation by determining the distribution of overwintering *H. axyridis* among hives in ten apiaries. Because most overwintering beehives in North Carolina are of similar height, consisting of one hive body and one super, or two hive bodies, we hypothesized that if visual attraction to hives was the only factor mediating choice of aggregation site, the lady beetles would be randomly distributed among the hives in an apiary.

Materials and Methods

The shelters used in our study were modeled after those commercially available to homeowners through garden centers and mail order catalogues. They were constructed of sheets of luan 5 mm in thickness, and measured 8.5 × 20 × 25 cm with a hinged lid. External surfaces were painted with semi-gloss white paint, and internal surfaces were painted with flat black. Shelters were filled with styrofoam pellets to provide insulation and thigmotactic stimuli for the beetles. Holes (5 mm diam) were drilled in the bottom ($n = 20$), top front ($n = 9$), and around the entire box in a double row at the midpoint ($n = 42$) (Fig. 1) to provide insects access to the interior. We decided to drill holes instead of fashioning the slits used in commercial shelters after noting *H. axyridis* entering homes through the drainage holes in the lower frames of windows.

Sex specific attractiveness. Because *H. axyridis* begin aggregating in the western, mountainous part of North Carolina at least 1 wk earlier than in the piedmont (Kidd et al. 1995), beetles used as bait in the study were collected as they arrived at a single site in the mountains (Alleghany Co.) on 18 October 1995, then brought to the piedmont where the experiment was conducted (five sites in Wake Co., one site in Johnston Co.). Beetles were sexed, then chilled and placed in the center of a 22-cm diam circle of fiberglass screening, which was then formed into a pouch fastened with a length of paper-covered wire ($n = 42$ to 52 beetles per pouch). These pouches were placed on top of the styrofoam pellets in the shelters.

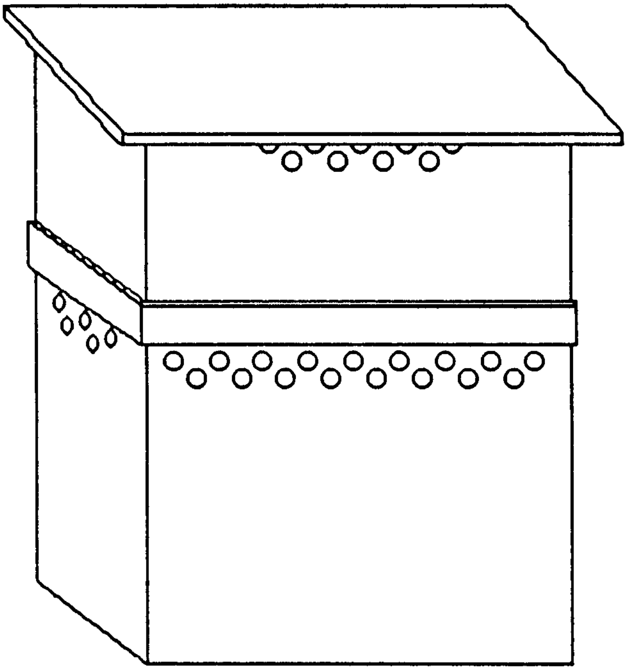

Fig. 1. Artificial shelter tested for attractiveness to *Harmonia axyridis*. Dimensions are given in the text.

The study consisted of six replicates (buildings) of three treatments each: artificial shelters with male beetles present, female beetles present, and no beetles present. Buildings used as replicates were known from previous years to be preferred aggregation sites. The three treatments at a site were each suspended, approximately 130 cm apart, on a single strip of wood. The entire apparatus was then hung on the building in a location reported as having the most beetle activity in previous years, usually near windows or under eaves. The position of treatments within a site was randomized. Shelters were hung at sites 24-30 October 1995; the first reports of the beetles flying in Wake Co. was on 19 November 1995 (at three sites). Shelters were checked for the presence of beetles twice; the first check was on 22 November 1995. The shelters were checked again and removed between 6 and 18 December 1995.

Differential arrival of the two sexes at aggregation sites. Two collections of beetles arriving at aggregation sites were made 4 to 8 d apart at each of three buildings known to be attractive to the coccinellids; the insects were then sexed using characteristics of the abdominal sternites. In two sites (Buncombe Co. and Wake Co.) the initial collection was made on the first day that beetles were reported flying in the area.

Distribution of *H. axyridis* in honey bee hives. Reports from apiary inspectors (North Carolina Department of Agriculture & Consumer Services) indicated that aggregations of *H. axyridis* were using beehives as winter shelter; clusters of the beetles were located between the inner and outer cover of Langstroth hives. Two apiaries in

Surry Co. were surveyed during the winter of 1995-96, and eight apiaries were surveyed in January of 1998 (Iredell, Surry, and Yadkin counties). We directed our search primarily to apiaries for which we had previous reports of activity. Hives were linearly arranged in each apiary, but apiaries differed in topography, exposure, and the degree to which they were sheltered. Outer covers were sequentially removed from each hive in an apiary and the number and location of *H. axyridis* in each were recorded (n = 10 apiaries, 197 hives).

Statistical analysis. The number of beehives housing beetles was compared to a Poisson distribution using Pearson goodness of fit test in SAS PROC GENMOD (SAS Institute 1993).

Results and Discussion

Large numbers of lady beetles were observed on and around the artificial shelters, and also inside the buildings on which the shelters were hung. Neither control shelters nor those baited with conspecifics, however, promoted settling of *H. axyridis* within them. Only 12 beetles were collected from 18 traps checked twice. No more than two beetles were collected from any one trap, and there was no pattern to the traps they inhabited. Serendipitously, we documented male vs. female survivorship of the "bait" beetles after approximately 6 wks outdoors in traps. Overall, 23.2% of the males (82 of 354) and 59.0% of the females (197 of 334) survived; this pattern may be due to the significantly larger size of the females (Nalepa et al. 1996).

The results of the sex specific arrival study were equivocal. At one aggregation site, the ratio of females to males was twice as great on the first date as on the second collection date (Table 1). Although this result is intriguing, there was no such trend in the other two sites, where the sex ratios were remarkably consistent between the two collection dates. We conclude that there was little evidence of differential arrival of the sexes at aggregation sites; a system in which one sex arrived first, then attracted the other would need to operate more consistently. It is notable, however, that half the collections were biased 2:1 in favor of females, and that these were collections from relatively early in the flight season.

Harmonia aggregations were found in 7 of the 10 apiaries surveyed. In apiaries that contained beetles, between 6.2 and 25.0% of the hives harbored *Harmonia* (Table 2). The number of beetles per hive ranged from 2 to 250 (Table 3). The number

Table 1. Sex ratios of *Harmonia axyridis* arriving at aggregation sites on two dates at each of three sites

County	Date	n	Sex ratio (F:M)
Buncombe	12 Oct 1995	113	1.8:1
	16–17 Oct 1995	28	1.8:1
Polk	22 Nov 1995	105	0.8:1
	8 Dec 1995	105	0.9:1
Wake	19 Nov 1995	75	1.8:1
	27 Nov 1995	89	0.9:1

Table 2. Number of hives harboring *Harmonia axyridis* in western North Carolina apiaries.

Apiary	No. hives	No. hives w/beetles	% hives w/beetles
1	22	2	9.1
2	16	1	6.2
3	8	2	25.0
4	30	7	23.3
5	31	7	22.6
6	22	4	18.2
7	28	3	10.7
8	29	0	0.0
9	6	0	0.0
10	5	0	0.0
Total	197	26	

Table 3. Frequency distribution of number of *Harmonia axyridis* within hives in occupied apiaries.

No. beetles	No. hives	% hives
0	131	86.8
2–10	10	5.1
11–20	5	2.5
21–30	2	1.0
31–40	2	1.0
41–50	4	2.0
51–60	2	1.0
250	1	0.5

of hives without beetles is significantly greater than the number of empty hives expected if a Poisson distribution is assumed (χ^2 = 7209.8, 1 df). Sequentially reanalyzing the data set after removing outlier apiaries (#1, where one of the hives had 250 beetles, and #8, with 29 hives, 0 beetles) did not affect the outcome. We can, therefore, reject the null hypothesis that beetles are randomly distributed among the hives in an apiary.

There is some indication that beetles redistribute themselves among hives on warm days. A few hives that housed beetles were empty when rechecked 2 wks later. Although Caron (1996) suggested that clusters of *Harmonia* may be detrimental to wintering hives by blocking ventilation holes in the inner cover, we found no beetles in the vicinity of ventilation holes. Groups of beetles were found primarily at the corners and edges, where the inner and outer covers meet.

There is currently no evidence that the insects rely on volatile chemicals as cues at the aggregation site; the presence of live *H. axyridis* in the artificial shelters used in this study had no influence on beetles arriving later at the site. Because the results were negative, however, we cannot conclude with confidence that long distance pheromones are not involved. The fact that *Harmonia* adults are distributed nonrandomly in physically similar beehives suggests that a chemical mechanism of some sort may be employed in locating conspecifics. Persistent pheromones, dead beetles or excreta from the previous year's inhabitants may serve as attractants, accounting at least in part for year-to-year site constancy (Hills 1969, Majerus 1994). Indeed, scientists have been able to attract several species of coccinellids to artificial sites containing dead conspecifics (Douglass 1930, Yakhontov 1938, Hodek 1960), but there are also reports that dead beetles act as a repellent (Hodek 1973). Majerus (1997) recently provided indirect evidence that pheromonal cues of long duration may be involved in winter aggregation of *Adalia bipunctata* (L.) in England. Repeatedly washing aggregation sites (window frames) with water during summer significantly decreased, but did not eliminate, the number of individuals in aggregations during the subsequent winter. Control buildings had aggregations that averaged 41 adult beetles, and treated sites had an average of 16. Power washing structures to control aggregating *H. axyridis,* however, is unlikely to be an effective management strategy. Most beetles and, thus, any chemical cues they exude, are in parts of buildings inaccessible to cleaning efforts. Additionally, their apparently heavy reliance on visual cues may overide homeowner efforts to eliminate chemical stimuli. Both *H. axyridis* and *H. conformis* are reported to return to the same sites year after year, provided the visual relief of the landscape remains the same (Obata 1986, Anderson and Richards 1977); aggregating coccinellids also readily mass on newly-erected conspicuous objects (Hagen 1962). Many homes in Raleigh (Wake Co.) reported beetle invasions for the first time in 1997, following significant loss of trees in the area during Hurricane Fran.

The occupation of an apiary by overwintering *Harmonia* depends on a number of factors, including topography, degree of shelter, and the proximity of aphid infestations in late summer. In North Carolina, *Harmonia* is rarely reported from hives in the coastal plain, while it is relatively common in the piedmont and mountains. This is due, at least in part, to the practice of shading hives by situating them beneath trees in the coastal plain. For example, apiary #8, with 29 hives and no beetles, was situated within a heavily-wooded site. This observation supports the primacy of visual cues to *Harmonia,* as trees mask hives from long distance orientation by flying beetles. Presence of the bees was not required for a hive to be attractive; empty hives, as well as a stack of outer covers in one apiary also sheltered beetles.

The accumulated evidence suggests to us that the presence of feces, residues or conspecifics may be involved in the final stages of aggregation in *H. axyridis,* as they are in *A. bipunctata.* Thus, like many other animals (Kavanaugh 1977), the assembly of *H. axyridis* into aggregations probably occurs in two sequential stages. First, individuals respond independently to environmental cues, leading to aggregation in an optimum location. Second, individuals respond to chemical and/or thigmotactic stimuli provided by other individuals, leading to aggregation in specific microhabitats within that location. The failure of aggregating *H. axyridis* to settle in the shelters we baited with live adult conspecifics may be due to their inability to establish contact with bait beetles through the mesh bag. Any chemical stimuli, then, may be detected by direct contact rather than as long distance airborne volatiles, and function as arrestants, rather than as attractants in mediating aggregation behavior.

We are at an early stage of determining management strategies for *Harmonia* aggregating on homes during the fall and winter. Because houses serve as visual superstimuli, any method of initially deflecting aggregating swarms from a home would involve installing surfaces that are taller, more reflective and possibly larger than the home in question. After beetles arrive at a site, it may be possible to direct their movement via secondary cues such as pheromones. Keeping the live insects in a chosen site, however, may be problematic, because of probable redistribution activities on warm days. Lights hung over glue traps or pans of soapy water in attics and false ceilings have been used to intercept beetles before they enter the living spaces of buildings (Hedges and Lacey 1996); these methods, however, kill an effective biocontrol agent.

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References Cited

Anderson, J. M. E. and A. M. Richards. 1977. First records of reproductive diapause and aggregation in Australian Coccinellidae (Coleoptera). Proc. Linn. Soc. New South Wales 102: 13-17.

Caron, D. M. 1996. Multicolored Asian lady beetles. A new honey bee pest. Amer. Bee Jour. 136: 728-729.

Chapin, J. B. and V. A. Brou. 1991. *Harmonia axyridis* (Pallas), the third species of the genus to be found in the United States (Coleoptera: Coccinellidae). Proc. Entomol. Soc. Wash. 93: 630-635.

Day, W. H., D. R. Prokym, D. R. Ellis and R. J. Chianese. 1994. The known distribution of the predator *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae) in the United States, and thoughts on the origin of this species and five other exotic lady beetles in eastern North America. Entomol. News 105: 244-256.

Douglass, J. R. 1930. Hibernation of the convergent lady beetle *Hippodamia convergens* Guer., on a mountain peak in New Mexico. J. Econ. Entomol. 23: 288.

Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Ann. Rev. Entomol. 7: 289-326.

Hedges, S. A. and M. S. Lacey. 1996. Field Guide for the Management of Structure-Infesting Beetles. Pest Control Technology Field Guide. Franzak & Foster Co., Cleveland, Ohio.

Hills, L. D. 1969. Biological Pest Control: Report 3. Henry Doubleday Research Assoc., Essex.

Hodek, I. 1960. Hibernation - bionomics in Coccinellidae. Cas. Cs. Spol. Entomol. 57: 1-20. (In Czech, English summary).

1967. Bionomics and ecology of predaceous Coccinellidae. Ann. Rev. Entomol. 12: 79-104.

1973. Biology of Coccinellidae. Prague & Dr. W. Junk, The Hague.

Kavanaugh, D. H. 1977. An example of aggregation in the *Scaphinotus* subgenus *Brennus* Motschulsky (Coleoptera: Carabidae: Cychrini). Pan-Pac. Entomol. 53: 27-31.

Kidd, K. A., C. A. Nalepa, E. R. Day and M. G. Waldvogel. 1995. Distribution of *Harmonia* *axyridis* (Pallas) (Coleoptera: Coccinellidae) in North Carolina and Virginia. Proc. Entomol. Soc. Wash. 97: 729-731.

Majerus, M. E. 1994. Ladybirds. Harper Collins, London.

1997. How is *Adalia bipunctata* (Linn.) (Coleoptera: Coccinellidae) attracted to overwintering sites? Entomologist 116: 211-217.

Nalepa, C. A., K. A. Kidd and K. R. Ahlstrom. 1996. Biology of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in winter aggregations. Ann. Entomol. Soc. Amer. 89: 681-685.

Obata, S. 1986. Determination of hibernation site in the ladybird beetle *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). Kontyu 54: 218-223.

SAS Institute. 1993. SAS/STAT software: The GENMOD Procedure, Release 6.09. SAS Institute, Cary, NC.

Tedders, W. L. and P. W. Schaefer. 1994. Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the southeastern United States. Entomol. News 105: 228-243.

Turchin, P. and G. Simmons. 1997. Movement of animals in congregations: an Eulerian analysis of bark beetle swarming, Pp. 113-125. *In* J. K. Parrish and W. M. Hamner [eds.], Animal groups in three dimensions. Cambridge Univ. Press, Cambridge.

Yakhontov, V. V. 1938. A biological method of controlling pests in lucerne and cotton. Rev. Appl. Entomol. 26: 238.