

## Aggregation of Coccinellidae throughout Winter Months

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Lady beetles will enter a period of diapause in winter months where many thousands will aggregate. There are two species of lady beetles that are typically associated with aggregations in the United States: *Hippodamia convergens* (convergent lady beetle) and *Harmonia axyridis* (multicolor Asian lady beetle.) Both of these species of lady beetles are commonly collected for the use of biological control. Collections occur in the winter when the beetles are localized in large numbers for diapause. During diapause, lady beetles will become dormant with very little activity or feeding. Low activity levels conserve stored energy allowing the beetle to remain dormant throughout the winter. Aggregations are found in protected areas where the lady beetles will receive shelter from exposure. *Hippodamia convergens* migrate from low elevations to higher elevation mountains in the Western United States. Upon aggregation *Hippodamia convergens* will seek out rocks, branches, and leaves for shelter. Similar to *Hippodamia convergens*, *Harmonia axyridis* will seek shelter during diapause. In its native range, *Harmonia axyridis*, migrates to cliffs and rock outcroppings for aggregation. In the United States, *Harmonia axyridis* have populated habitats that do not include cliffs or outcroppings. Instead *Harmonia axyridis* will move into or on the nearest prominent structure, which is typically a building or home. Lady beetle aggregations have become an important concern for home and landowners. As biological control agents, lady beetle aggregations mean that these insects are emigrating out of the field and into the mountains or a building. In essence lady beetles such as *Harmonia axyridis* and *Hippodamia convergens* will only be effective for a localized field for a single season.

Another aspect of importance is aggregation in buildings and homes. Home and structure aggregation concerns *Harmonia axyridis* primarily, since *Hippodamia convergens* migrates to the mountains. Recently research has focused upon repellants and deterrents to displace aggregations in man made structures. There is a fine line between removing nuisance beneficial insects and killing a pest species; therefore much of the research has focused around deterrents and repellants rather than insecticides.

### **Introduction**

Over the past century lady beetles (Coccinellidae) have been implemented for biological control with varying success. (Obrycki, 1996) The success of biological control can often be linked to the behavior of the insect such as the overwintering aggregation of Coccinellidae. Species such as *Harmonia axyridis* and *Hippodamia convergens* are effective biological control insects feeding on aphids and other pest insects until autumn when both of these species will migrate to localized areas for diapause. (Nalepa et al., 1999)(Lemana and Miller, 1996)(Micheals et al., 1997) Both *Harmonia axyridis* and *Hippodamia convergens* will aggregate in large localized populations but the habitat for diapause between these two species is dissimilar. *Harmonia axyridis* chooses to over winter in buildings and structures whereas *Hippodamia convergens* chooses mountains. (Nalepa et al., 1999)

Unlike the native species of Coccinillidae, *H. axyridis* has become a nuisance due to the tendency of indoor aggregations. (Nalepa et al., 1999) Indoor over wintering behavior has created problems for homeowners due to the large masses of lady beetles that enter homes in autumn. (Nalepa et al., 1999) There are many factors that contribute

to the indoor migrations such as temperature, light, visual cues, and chemical cues.

(Schaefer, 2004)(Nalepa et al., 1999)

*H. quinquesignata* aggregates in mountainous regions of the Western United States. Similar to *H. axyridis*, *H. quinquesignata* (a lady beetle native to the Northern United States and Canada) will use visual cues and temperature to locate aggregation sites. The behavior mechanisms that are used by Coccinellids to locate aggregation sites are visual cues, chemical cues, temperature, and light. (Nalepa et al., 1999) Through the use of these mechanisms Coccinellidae are able to locate aggregation sites for overwintering. Researches are studying various types of repellants to discourage the overwintering of the *H. axyridis* indoors. (Riddick et al., 2004) Repellants such as DEET and camphor have shown potential in early studies for repelling nuisance lady beetle.

### **Over wintering Habits**

Throughout winter Coccinellids go through a period of dormancy called diapause remaining inactive until spring. (Nalepa et al., 1999) The two species of lady beetles that are commonly associated with diapause in the United States are *Harmonia axyridis* and *Hippodamia convergens*, though the behavior of between the two species contrasts.

Over wintering survival in Coccinellids can be directly related to the cumulative exposure to both winds and temperature. (Schaefer, 2004) To avoid exposure Coccinellid beetles will migrate from lower elevations to sheltered higher elevation areas. Coccinellid beetles are considered freeze intolerant species meaning they must avoid extra cellular ice formation by super cooling. Super cooling is defined as the temperature at which body fluids spontaneously freeze when cooled below the melting point. (Koch et

al., 2004) The super cooling temperature represents the lower lethal temperature at which the Coccinellid can survive. Seeking shelter during the winter months allows Coccinellid species to avoid reaching a super cooling level thus allowing survival over the winter.

### ***H. convergens***

The behavior of *Harmonia axyridis* and *Hippodamia convergens* during winter aggregation is different. Both *Harmonia axyridis* and *Hippodamia convergens* seek shelter but in different locations. *Hippodamia convergens* or the convergent lady beetle is known for its winter migrations to the mountains. A similar species in behavior to *Hippodamia convergens*, *Hippodamia quinquesignata* immigrates to the mountains for diapause. (Harper and Lilly, 1982) The aggregation sites that *Hippodamia quinquesignata* concentrates on and around are rocks and debris such as logs and sticks on the sides of west facing slopes. (Harper and Lilly, 1982) This is due to the fact that the West facing slopes receive a great deal of sunlight. *Hippodamia quinquesignata* is not usually found on North, East, or South facing slopes. (Harper and Lilly, 1982)

The locations of the over wintering *H. quinquesignata* are on exposed slopes where the beetles can sun themselves. The West facing slopes that *H. quinquesignata* will over winter contains bushes, sticks, logs, loose rocks and other debris. (Harper and Lilly, 1982) These sites are also devoid of much other vegetation leaving them exposed to sunlight during the day. Warmer winter temperatures and Chinook winds create situations that *Hippodamia quinquesignata* will temporarily become active and move from their aggregation site to sun themselves. Upon cooler temperature of the evening, the lady beetles will return to their aggregation colonies for protection. (Harper and

Lilly, 1982)(Nalepa et al., 2004) In spring with warmer temperatures and snow melt *Hippodamia quinquesignata* will become more active exiting diapause and return from the mountains to the prairies to feed.

### ***H. axyridis***

*Harmonia axyridis* (multicolored Asian lady beetle) utilizes a different location for diapause. *Harmonia axyridis* originates from Korea, Japan, China, Siberia, and the Himalayas than *H. convergens*. (Acar et al., 2004) *H. axyridis* is known to over winter on prominent visual landmarks on the horizon. (Nalepa et al., 2004) In native range the visual landmarks are cracks and crevices of rock outcroppings. Much of the landscape in native Asia has small mountains and hills that are good visual landmarks for diapausing insects. (Riddick et al., 2000) In the United States, *H. axyridis* over winters in nearby prominent structures which are more often than not man-made buildings. Over the Midwest and Eastern regions of the United States buildings, homes, and man made structures may be the only visual landmarks that *H. axyridis* is able locate. Colonies have been known to reach tens of thousands in relatively small concentrated areas. (Riddick et al., 2000)

*H. axyridis* upon entering a structure or building has a tendency to diapause in areas with little to no light. (Schaefer, 2001) When observed in a man made structure such as a watchtower, *H. axyridis* would avoid the well lit entrance and move up to the second and third stories where there was less natural sunlight. (Schaefer, 2001)

Activity of *H. axyridis* during diapause is directly dependant on temperature. Throughout warm periods *H. axyridis* can be active and loosely aggregated. During time of relative activity *H. axyridis* has been noted to leave the unlit crevices and even fly

around. (Nalepa et al., 1999)(Schaefer, 2001)(Jean et al., 1990) Upon cooler temperatures aggregations become condensed and located deeper in crevices. Movement was sluggish or virtually non-existent throughout the cold spells. (Schaefer, 2001) Another temperature dependant phenomenon is coloration of *H. axyridis* relative to temperature. *H. axyridis* varies in color from yellow to brick red and may contain from one to ten spots on the elytra. (Nalepa et al., 1996) The spots on the elytra can be determined by the temperature of the winter. The colder temperature allows for slower the development which increases time to produce melanin creating more spots.

In spring with warmer temperatures *H. axyridis* emerges from diapause leaving the over wintering aggregation to feed and mate. Emergence is also the period of time when *H. axyridis* becomes the largest nuisance to homeowners.

Unlike Asia where there is little contact between *H. axyridis* and people in the United States *H. axyridis* often shares a home with humans for the winter. Once only considered a beneficial insect, lady beetles are now considered a pest species in much of the Eastern United States. (Nalepa et al., 1999) During the emergence period, beetles will literally appear out of every crack and void in a home for hours on end.

Congregating beetles have been known to stain walls, leave and odor, and become a nuisance flying around lights. Staining and odor come from reflex bleeding and fecal material. In buildings that are heated and do not reach low temperatures *H. axyridis* can remain active throughout the winter. (Nalepa et al., 1999) Throughout winter months it is often forgotten that *H. axyridis* is an important beneficial biological control agent.

## Mechanisms

Much speculation has been done on the mechanisms in which Coccinellids choose an over wintering location. Research has focused on an aggregation pheromone but to the best of my knowledge there has not been an aggregation pheromone isolated for any diapausing Coccinellids in the United States. In Europe however there is indirect evidence that *Adailia binpunctata* may use an aggregation pheromone. (Nalepa et al., 1999) Visual cues remain the strongest mechanism for aggregation site selection. (Nalepa et al., 1999) Visual cues come in the form of light abundance as well as visual appearance of the actual shelter. (Schaefer, 2004)(Nalepa et al., 1999) Inside or underneath a shelter Coccinellids will move to a dark location such as under a rock, under a bush, or inside an attic. (Riddick et al., 2000)(Harper and Lilly, 1982) It has also been shown that Coccinellids will avoid becoming overly clustered and avoiding covering ventilation holes. (Nalepa et al., 1999) Upon reaching the critical mass of overcrowding during the warmer portions of the day diapausing Coccinellids may redistribute into shelters with less individuals.

Another factor that may affect site selection for aggregation is chemical cues. Chemical cues may stem from either feces of individuals that are over wintering or previously over wintered in the same location or of dead Coccinellids. (Nalepa et al., 1999) Currently there is mixed evidence in research pertaining to dead Coccinellids as an attractant to an over wintering location. Studies have shown that dead Coccinellids can be used as an attractants as well as repellants. (Nalepa et al., 1999) Fecal material may also prove as an attractant to over wintering lady beetles. The residues of the feces may help

lady beetles in the vicinity of a nest site locate the colony of diapausing Coccinellids. (Nalepa et al., 1999)

Prior to the introduction of *H. axyridis* there was little economic incentive to discover the mechanisms involved in site location of Coccinellid over wintering. Importance of site selection for diapause has only recently been considered due to the nuisance problems of *H. axyridis*. (Nalepa et al., 1999) Studies now are beginning to focus on repellents for Coccinellids.

### **Repellants**

Chemicals such as DEET and camphor have been shown to deter lady beetle aggregations. Until recently Coccinellids have only been considered beneficial insects. Since the introduction of *H. axyridis*, Coccinellids have been considered pests. Many methods of removal have been used to rid homes of unwanted *H. axyridis*. The problem being is that most types of removal involve the killing of this biological control agent. One of the methods that is commonly used to remove *H. axyridis* is vacuuming the unwanted beetles. This will often lead to the death of many *H. axyridis*. Other methods that are used include using insecticides to remove the beetles. Both of these methods are not beneficial since they involve killing a beneficial insect.

Researchers now focus on using repellents to avoid the problem of killing the Coccinellids. DEET and camphor have shown potential in laboratory experiments to repel *H. axyridis*. (Riddick et al., 2000)(Riddick et al., 2004) DEET has shown in Y-tube olfactometer bioassay experiments that *H. axyridis* preferred the control (hexane blank) over DEET. (Riddick et al., 2004) In Petri dish experiments the same conclusion was found that *H. axyridis* would avoid the disks that contained DEET. The level of



avoidance varied with the concentration of DEET. The less concentrated the DEET solution the less avoidance there was to the experimental disk. (Riddick et al., 2004) Residual activity of DEET was also shown to repel Coccinellids over time showing potential for long term repellent.

Although proven effective in laboratory experiments, DEET has drawbacks when applied in field situations. Since DEET would be applied indoors to repel *H. axyridis*, it can only be applied to unpainted surfaces. (Riddick et al., 2004) DEET will dissolve paint and disrupt plastic surfaces that it is applied to. Solutions to the problem of using DEET indoors would be to spray the chemical only areas where invasion would occur for example cracks and crevices in a building. Another alternative would be to use a DEET strip which could be used around ventilation areas and other entry points. ( Riddick et al., 2004) Both of these solutions using repellents in a selective area.

Another effective repellent for lady beetles is camphor. Camphor is a monoterpene which are secondary plant compounds. Monoterpenes have been used to repel insects, kill bean weevils, protect stored grain, control mites in honey bee populations, and protect clothing. (Riddick et al., 2000)

When camphor was used in a Petri dish lab bioassay, *H. axyridis* avoided the treated strip 98% of the time. (Riddick et al., 2000) The next highest result of a monoterpene in the laboratory experiment was eugenol which had 91.7% avoidance *H. axyridis*. In field situations camphor proved to repel in a closed environment. (Riddick et al., 2000) Camphor did not repel as effectively in outdoor environment indicating that it may evaporate due to exposure. (Riddick et al., 2000)

Attractants too are also being studied for the removal of *H. axyridis*. Traps lined with attractants could prove effective in baiting *H. axyridis* out of homes where the Coccinellid could be relocated into an environment where they would be less of a nuisance. Using attractants and repellants to manage a pest is called the push-pull theory. (Riddick et al., 2000) The push-pull theory involves pushing a pest out of the undesired location and pulling the pest into a trap where they can be managed. Using repellants and attractants will allow for greater control and less eradication of a good biological control organism.

## **Conclusion**

Throughout winter month Coccinellid species undergo a period of dormancy called diapause. Species such as *Harmonia axyridis* and *Hippodamia convergens* have been emplaced as biological control insects feeding on aphids and other pest insects until autumn when both of these species migrate to a localized area for diapause.(Riddick et al., 2000) (Nalepa et al., 1999) Differences between *Harmonia axyridis* and *Hippodamia convergens* are in the locations of overwintering sites . *Harmonia axyridis* has a tendency to over winter in buildings and other man made structures whereas *Hippodamia convergens* migrates to the mountains. (Nalepa et al., 1999)

Unlike many other species of Coccinellidae, *H. axyridis* has become a nuisance due to the tendency of indoor aggregation. (Nalepa et al., 1999) Indoor over wintering behavior is a problem for building owners because the stain and odors that can be produced by the diapausing Coccinellids . (Nalepa et al., 1999) Factors that contribute to

the selection of nest sites include temperature, light, visual cues, and chemical cues.  
(Schaefer, 2004)(Nalepa et al., 1999)

*H. quinquesignata* aggregates in mountainous regions of the Western United States. Similar to *H. axyridis*, *H. quinquesignata* (a lady beetle native to the Northern United States and Canada) uses visual cues and temperature to locate aggregation sites.

Repellants and attractants are now becoming more researched as *Harmonia axyridis* is becoming more of a problem for home owners. As better techniques of repellent are discovered there will be less of a tendency to kill nuisance Coccinellids and push them away from houses and capture them with attractants. The push pull method will allow non harmful removal of beneficial biological control specie.

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