MIGRATORY PATTERNS AND DIAPAUSE OF *HIPPODAMIA CONVERGENS* (CONVERGENT LADYBUG)

SARA ELIZABETH GROSSETT – SARA.GROSSETT@GMAIL.COM
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ABSTRACT

Hippodamia convergens is among the most populous species of Coccinellidae found in North America and is commonly known as the convergent ladybug. As the beetles consume large quantities of aphids the *Hippodamia convergens* are often purchased by farmers and released on to the crop to help reduce aphid populations. The timing of the capture and release of these beetles must be carefully timed to fit within the beetle's natural breeding cycles for the beetles to be an effective form of pest management so that they are at the height of there feeding and not inclined to migrate immediately after release. The biggest problem facing using *Hippodamia convergens* as a pest management technique is the beetle's natural migration pattern which causes them to leave farm lands, travel a long distance and converge in mountain areas. Due to the beetle's popularity as a pest management technique, a large amount of research has been conducted on the migration and hibernation practices of the beetle. This research will help farmers understand how to use the beetles more effectively, and help companies ship them safely. Based on research it is evident that food supply, day length and temperature are important migration triggers for the *Hippodamia convergens.* Once the *Hippodamia convergens* reach the hibernation locations they cluster together and enter a state of diapause for approximately 9 months often under feet of snow in subzero temperatures. The *Hippodamia convergens* survive this long winter by carefully controlling their diet and water intake before aggregating with other beetles. The beetles also carefully control the position of

the cluster in relation to the sun in an effort to provide increased protection from the elements under leaf cover and rocks.

INTRODUCTION

Hippodamia convergens is among the most common species of Coccinellidae found in North America. Coccinellidae is a family of beetles frequently referred to as 'lady bugs' and they are often used for pest control in the United States. *Hippodamia convergens* is well known for its unusual migration patterns. Many other species of Coccinellidae also hibernate in winter months, but they do not travel as far to do so as the *Hippodamia convergens*. While the beetles are capable of surviving on nectar and pollen their diet consists primarily of aphids which are necessary for the reproductive cycle of the beetle. Aphids are one of the most destructive pests found in temperate regions, making *Hippodamia convergens* a popular insect in those areas and an excellent choice for natural control of aphid infestations. Due to the beetle's propensity to consume large numbers of aphids per day, they are favored for aphid control over riskier alternatives such as insecticides.

These beetles are often purchased by farmers and released on to the crop, however the timing of the capture and release of these beetles must be carefully timed to fit within the beetles feeding and breeding cycles for the beetles to be an effective form of pest management. If the release of the beetle is not within the feeding season of their natural life

Figure 1: *Hippodamia Convergens* in Colorado Springs. Photo by Drobin Corvette

cycle the beetles will simply fly off to begin their migration without consuming the aphid population and because of this tendency, the beetles are preferred for greenhouse use over field farming (Olkowski et al. 1995). Due to an increased desire for biologically friendly pest management in recent years, *Hippodamia convergens* has been studied extensively so we can learn more about using the beetle's natural behaviors to improve pest management techniques.

The biggest problem facing using *Hippodamia convergens* as a pest management technique is the beetle's natural migration pattern which causes them to leave farm lands and converge in mountain areas. Not much has been known about the beetle's aggregative migration patterns until recent years, but pest management specialists are hopeful that research into these unusual insects will help us to use the beetle more effectively in aphid control. For instance, if we know the factors that trigger these long distance migrations we can work within the insects natural behaviors to time the release of the *Hippodamia convergens* to maximize the effect of the pest control, or control the environment to encourage the beetles to stay longer.

DISCUSSION

LIFE CYCLE OF *HIPPODAMIA CONVERGENS*

Hippodamia convergens females search during the spring for areas of high aphid concentrations and lay 200-1000 eggs. There is potential for up to five generations per summer depending on available food quality, most of which will stay nearby the original field chosen by the beetles leaving hibernation (Michaud and Qureshi, 2006). The *Hippodamia convergens* hatch and spend their larval stage consuming aphids and other prey and after two to three

weeks are considered a fully grown adult. Some of these adults will reproduce and some of them will wait, enter hibernation and begin the generation of the next spring. Once the weather begins to grow colder the remaining *Hippodamia convergens* travel long distances, far away from potential prey, to mountain areas where they converge and hibernate for up to nine months and then return to areas with large aphid populations in the spring. (Hoffman and Frodsham, 1993). While in hibernation the beetles will mate during periods of warmer weather and then begin the spring season as soon as they are able.

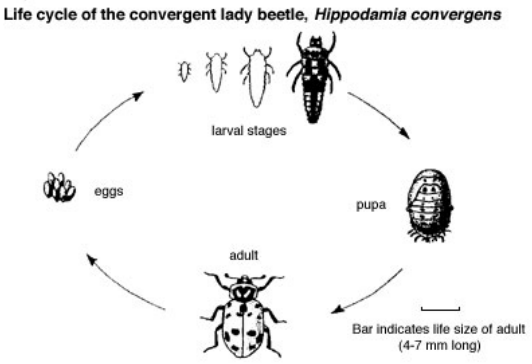

Figure 2: Life Cycle. (Hoffman and Frodsham, 1993)

FALL MIGRATION TRIGGERS

The *Hippodamia convergens* is an ideal candidate for migration experiments performed in a laboratory due to their natural tendency to walk rather then fly when travelling short distances. If these beetles are in flight for greater than 30 minutes, they almost always continue to fly for several hours, indicating migratory behavior (Rankin and Rankin, 1980). This allows researchers the ability to perform tethered flights in a laboratory to test what triggers seem to influence long, or migratory, flights.

Based on research it is evident that food supply is an important migration trigger for the *Hippodamia convergens.* In experiments preformed by Rankin and Rankin in 1980, the *Hippodamia convergens* were divided into two groups after adult emergence with group one

being offered fresh aphids, an optimal food source, and group two being offered frozen aphids, a tolerable but non-optimal food source. The flight times of the beetle were recorded for 12 days following the meal and flights lasting 30 minutes or longer were considered a migratory behavior. The study found that regardless of other factors such as amount of daylight, and ambient temperature, that *Hippodamia convergens* from group two, who fed on frozen aphids, began migration within 4 days of adult emergence and continued to have high levels of migration throughout the study. Group 1, who was fed on live aphids, tended to have a high level of migration after four days, but by day 6 showed very little migratory tendencies throughout the rest of the study. This shows that *Hippodamia convergens* with a supply of a high quality food, will chose to remain in that location rather than migrate, while *Hippodamia convergens* with a low quality diet will be triggered to migrate to winter hibernation.

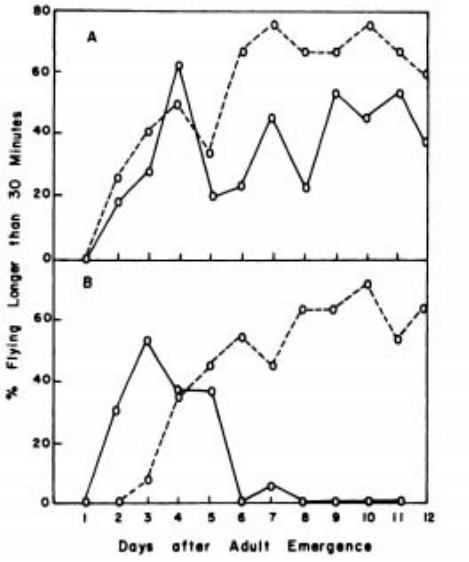

Figure 3: Flight Activity. Group A, Shorter days - Group B, Longer Days. Dashed Line, frozen fed - Solid Line, Fresh Fed (Rankin and Rankin, 1980)

A second study performed by Michaud and Quereshi in 2006 looked into the correlation between reproduction and food quality. Since the beetles have generational overlap the researchers were curious as to which females reproduced and which lived to hibernate. The theory was that high food quality would trigger lower egg release and low food quality would encourage hibernation, so if there were less aphids that year, the beetles would lay fewer eggs. They believed a strategy like this one would be beneficial to the species since in times of low amounts of food there would be less competition for the adult beetles and the few eggs which

hatched striking a balance between desire for reproductive success and self propagation. In the experiment they collected *Hippodamia convergens* from fields in Kansas and isolated mating pairs. The pairs were all given a constant supply of sunflower petioles with alternating access to the frozen eggs of a common prey and bee pollen, however some pairs were also given greenbug, a more desirable food source. The females who fed on greenbug produced nearly 5 times as many eggs as females on the maintenance diet, however as a result of the stress of reproduction they lived a considerably shorter amount of time, often the cause of death being related to egg laying. The females fed the maintenance diet did eventually reproduce but only after a long period of time. The researchers believe this is because the beetles reproductive success declines with age, so they will hold off on reproducing until they find an optimal food source or until their reproductive period is drawing to a close. One third of the females fed on a maintenance diet never reproduced however, and they all lived much longer than females who did reproduce. The researchers speculate that these females could be triggered to reproduce in a season with plentiful aphid prey, however in a normal season these are the females that will head to overwintering sites and begin the breeding season in the spring. The researchers concluded that reproductive flexibility is a large part of what makes these beetles so successful and therefore a good choice for biocontrol of pests.

Research shows that day length also has an influence on *Hippodamia convergens* migratory behavior. In the same study by Rankin and Rankin, a new supply of beetles was divided into two groups, group one with shorter exposure to light similar to what the beetles would experience as winter drew nearer and group two with longer exposure to light similar to what the beetles would experience in summer months. Group one's continued to have

migratory flights throughout the remainder of the experiment while group two's migratory behavior was almost non-existent after 6 days. This experiment shows that the length of the day helps the beetles to keep track of the time of year so that they can time there migration to hibernation locations with the onset of winter.

DIAPAUSE

Once the *Hippodamia convergens* reach the hibernation locations they cluster together and enter a state of diapause for approximately 9 months. Several studies have been done on the purpose of entering to to diapause and the beetles ability to survive these long, harsh winters. This is an area of particular interest because most companies that sell the beetles harvest them during periods of diapause while they are clustered on mountains and easy to collect and then bring them back down to farms and sell them as a pest management tool. Unfortunately most of these insects are improperly 'woken up' from diapause and therefore most of the insects sold through this trade die within a few days. With a better understanding of the triggers that let the insect know it is ready to begin the migration back to areas of aphid rich plant life, these harvesters would be able to bring the *Hippodamia convergens* out of diapause using a safer method and reduce the high mortality rate.

Research performed by Newton Hopp showed that there are many potential factors influencing hibernation in *Hippodamia convergens* but he believes the most important factor is temperature. He preformed a series of experiments in which he heated and cooled the beetles to various temperatures and then exposed them to different types of light and pheromones and then observed there aggregation behavior in response to these changes. Hopp concluded that temperature seems to be what triggers the beetles to aggregate and that they use light to

help them create more successfully packed aggregations. He found that at temperatures near freezing the beetles are still active but become very sluggish and that as a result the aggregations are always dynamic. When the temperature drops below 7 C he found that the beetles point the aggregation away from any sources of light and that at a temperature of about 15 C almost all of the beetles can be found in an aggregation and not dispersed. However during the long months of hibernation it is not uncommon for the beetles to disperse and mate during warmer days when there is no snow on the ground and reaggregate when the temperatures drop again. While Hopp is unsure what the direct benefit to the beetles is in forming these aggregations, it is clear that temperature plays a large role in signaling the beginning and end of diapause. Perhaps being in these clusters and able to mate on warmer days allow the reproductive season to begin immediately upon successfully migrating back to the farm lands, thereby allowing for more generations per reproductive season.

This amazing ability to survive under feet of snow for up to nine months sparked research into the mechanisms used by *Hippodamia convergens* to survive at below freezing temperatures. Strong-Gunderson et al. believed that the ability to survive may have something to do with the beetle's diet and investigated the effects of ingested bacteria on the beetles supercooling point. They fed the beetles different strains of bacteria and then placed them in glass tubes in a refrigerated bath. They then slowly lowered the temperature in the bath and recorded the beetle's temperature and the point at which the beetles froze. The research discovered that the type of bacteria ingested by the beetles could have a great effect on the beetle's ability to survive at below freezing temperatures. Beetles given only water were able to survive at temperatures as low as -16 C and beetles with ice-nucleating negative bacteria in

their stomachs could tolerate temperatures up to -14 C. However beetles given ice-nucleating positive bacteria could only tolerate temperatures of -4 C. This shows that something in the beetle's diet can have a profound effect on their ability to survive overwintering. Companies interested in harvesting and transporting *Hippodamia convergens* should keep this in mind when storing the beetles in refrigeration units. If they feed the beetles an unnatural diet, or the diet becomes contaminated there is a high risk of altering the beetle's ability to survive at low temperatures.

CONCLUSION

While the research has illuminated many aspects of *Hippodamia convergens* unusual lives, more research needs to be done to investigate these beetles in order to make them an effective alternative to insecticides in farming. As American culture is becoming increasingly more concerned with eco-friendly farming techniques and sustainable methods, more and more farmers are turning to these alternative methods. They offer a large variety of benefits since aphids cannot gain tolerance to beetles as then often do to insecticides. The beetles are also generally safer for the farm hands who would be exposed to dangerous insecticides while working on the fields. The largest danger *Hippodamia convergens* poses to farmers is in the form of allergic reactions and very few have been reported over the years, and when they are reported it is often during unusual seasons of beetle swarms.

If these beetles are going to be continued for pest management techniques however, the companies who collect and sell them need to invest more money into research to ensure the beetles safe transport and provide the customers with accurate information regarding

proper release for effective management. It is clear that the beetles are most effective when released in spring in an area with a large amount of aphids and allowed to reproduce throughout the summer. It is also clear that the best techniques for storage and transportation will require the beetles to be able to remain in aggregations and slowly returned to normal temperatures before release. However the exact mechanisms for these triggers are still unknown. Perhaps with further research these beetles could be encouraged to hibernate in simulated protected areas and for shorter periods of time, allowing for an almost year round natural control for aphids.

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