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Recognition of some lady beetles (Coleoptera: Coccinellidae) deadly sighted for insect and mite pests in agroecosystems

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Abstract
In the present article, an attempt is made to interpret the identification of ladybeetles (Coleoptera: Coccinellidae), their ecology, preys and inferences drawn by discussing the role they play in agroecosystems. Predaceous ladybeetles have largely fascinated to ecologists of the world over, because of their biocontrol potential against aphids, diaspids, coccids, aleyrodids and other soft-bodied insects and mites. Lady beetles are easily recognized by their shiny, convex, half-dome shape and short clubbed antennae. Most lady beetles species are predaceous as both larvae and adults, whereas the young larvae usually pierce and suck the contents from their prey. Older larvae and adults chew and consume their entire prey, and both prey on soft-bodied pests such as aphids, mites and scales. One larva can consume hundreds of prey during its development, and owing to their voracious appetites and ability to multiply rapidly, lady beetles can control even large infestations of pests. They are important predators of orchard pests, and the two most common species are the convergent and transverse lady beetles. Adults and larvae of both these beetles feed primarily on aphids and occasionally on whiteflies, other soft-bodied insects and insect eggs. Multicolored Asian lady beetle *Harmonia axyridis*, can establish itself extensively, and since it feeds on many species of soft-bodied insects, including aphids, scales and psyllids, this beneficial insect is considered to be a very good friend to gardeners. Both adults and larvae of *Harmonia convergens* feed primarily on aphids and occasionally on whiteflies, other soft-bodied insects and insect eggs, and a very few species eat fungal spores. A few lady beetles eat pollen; especially early in the spring when there are not so many aphids to eat. The beating tray is the most widely used method of monitoring lady beetle adults, but densities of larvae and pupae can be estimated while making visual counts of pest populations. Avoid using broad-spectrum insecticides on plants that are toxic to lady beetles. Supplies of adults can be bought for release in orchards but they often disperse when aphid populations are low. Releases of lady beetles in the orchard in mid or late summer are unlikely to be very beneficial.

Keywords: Agroecosystem, Coleoptera, Coccinellidae, Generalist predator, Predaceous beetle.

1. Introduction

Lady beetles, ladybugs, or ladybird beetles (Coleoptera: Coccinellidae) are among the most visible and best known beneficial predatory insects. Worldwide, some 4500 species of ladybirds are known, of which among the adventive species, some are introduced (introduced deliberately) and others are immigrants (having arrived by any means except deliberate introduction) from other countries. Most lady beetles are beneficial as adults and larvae, feed primarily on aphids and they also feed on mites, small insects, and insect eggs. The two exceptions are the introduced Mexican bean beetle, *Epilachna varivestis*, and the squash beetle, *Epilachna borealis*, wherein the adults and larvae of both species feed on plants. Adult lady beetles are round and small about 1-10 mm long. They are usually colored in some combination of black and red, orange, or yellow and often have spots on their wing covers. Some species always have the same pattern of colors and spots, but in some species individual beetles can have very different colors. Lady beetle's antennae are short, shorter than the front legs and are thicker at the ends than the middle. Lady beetle's larvae are very active and have rather rough or bumpy looking bodies that are longer than the adults. Lady beetle's pupae look somewhat like the adults. It is nearly impossible for anybody to tell about separation of male from female and even the experts sometimes cannot tell without dissecting the beetle. Lady beetles are found all around the world and there are hundreds of species of lady beetles that have been transported between continents by people hoping they would eat aphids and other pests better than the native beetles do. Lady beetles live where their preys live and this means on plants, mostly herbs and bushes, but sometimes on trees or even grass. Species that live in temperate climates with cold winters sometimes make short migrations to warmer habitats, and many spend the winter by hiding under bark or in a crack or crevice. Lady beetles have the same life stages as other beetles and their larvae are more active than many other kinds of beetles. Lady beetles spend the winter as adults and lay their eggs in the following summer. The hatched larvae eat a lot and grow fast, and emerge as adults in the late summer or fall. As long as there are prey insects to eat, the lady beetles will be there. They are active in the day if it is not too hot, and in fall and winter lady beetles hibernate, sometimes in large groups [1, 2, 3].

All adult lady beetles have reflex bleeding (hemolymph), this means that when they are attacked they automatically leak some of their blood out from joints in their legs and other parts of their body. Their blood has toxic chemicals in it, and tastes bad to predators. The bright colors of lady beetles are warnings to predators, because all lady beetles have toxic chemicals in their blood that makes them taste very bad. Lady beetle larvae often go away from their food supply and hide to pupate that may help them avoid other predators. Whether

people call them ladybird beetles or ladybugs, these insects are useful to whom growers definitely want to keep in their garden. Learning a little about these beneficial creatures can help to growers for properly identifying them and determining which plants to add to the yard if they want these good gangs to join the garden party for controlling of pests on farms and in gardens. It can be difficult to recognize a lady beetle without studying some of its minute morphological features, however, the majority of species are very small, drab and pubescent (furry). The charismatic red and black dappled members of the tribe Coccinellini are easily recognized by the layperson, but the family as a whole is somewhat difficult to characterize. Most species can be identified by the broadly rounded to elongate body form with convex dorsum and flattened venter, clubbed antennae and the presence of a postcoxal line on the first abdominal ventrite (lacking in *Paranaemia*, *Naemia* and *Coleomegilla*). The tarsal formula of most species is 4-4-4 with the third tarsomere minute and tucked within the broad triangular second (cryptotetramerous or pseudotrimerous), only a few have the tarsomeres more equal (truly tetramerous) and some have tarsi reduced to 3-3-3 (truly trimerous) [4, 5]. Here are some ladybird basics to help the growers for identifying these helpful garden visitors.

1.1. Seven-Spotted Lady Beetle *Coccinella septempunctata*

The adult seven-spotted lady beetle is relatively large (7-8 mm) and has an odd number of spots on its back, with one spot normally split right in half between its two wings. The body is oval and dome-shaped, and it has a white or pale spot on either side of the head. The black spot pattern on the body is usually 1-4-2, with either red or orange forewings. Lady beetle larva can grow up to 7-8 mm in length and are dark with three pairs of prominent legs. Eggs are about 1 mm long and are small and spindle shaped. The seven-spotted ladybird beetle is carnivorous and both the adult and larval stages feed on insects harmful to plants, such as aphids and scale insects. Adults can be known to eat up to 100 aphids a day. Rather than using any complicated methods for eating its prey, the ladybug kills its prey outright and then devours it. This European native can be repeatedly released in field as a biological control agent to feed on pest aphids and it may establish in an area. In the spring, overwintering adults first find food and then lay their eggs in clusters of 10 to 50 within aphid colonies. Eggs hatch in three to five days, and larvae feed on aphids or other insects for two to three weeks, and then pupate. Adults emerge in seven to ten days. Ladybugs are most commonly found from the beginning of spring until the cool sets in fall. When it starts to become cool outside, ladybugs look for sheltered places to live in order to hibernate. Ladybugs can't sting, but they probably do taste bad and produce a bad smelling odor, perhaps by way of a fluid from joints in the legs, which may help to protect them. They also will play dead when in danger since many predators will not eat an insect that does not move. The seven-spotted ladybug lives in a wide variety of habitats. Any place where there are plants and aphids may attract this species. Lady bugs, which eat aphids and other harmful pests such as scale insects, take care of the pest problems in gardens, orchards and farms [6, 7].

1.2. Multicolored Asian Lady Beetle *Harmonia axyridis* (Pallas)

The multicolored Asian lady beetle, *Harmonia axyridi*s, is a tree dwelling beetle of the family Coccinellidae and an important predator of aphids and scale insects. Multicolored Asian lady beetles are slightly larger than native lady beetles, with adults measuring 7 mm long and 5.5 mm wide. They are oval or convex in shape and yellow to red in color with or without black spots on the wing covers. The beetle's spots, which can vary in size and pattern, number from no spots to as many as nineteen. Multi-spotted individuals tend to be females while those with few or no spots tend to be males. The head is usually concealed beneath the disk-shaped pronotum, which is cream to yellow in color with a black 'M' design in the center on the whitish area behind the head. Asian lady beetle larvae are elongated, flattened and covered with minute tubercles or spines. The eggs which are laid upright in clusters of about twenty are oval and yellow. Life cycle from egg to adult to egg takes about three to four weeks depending on temperature and food abundance. The eggs are laid on the undersides of leaves of low-growing ornamentals, forest trees, roses, wheat, tobacco, soybean and numerous other plants. They take from three to five days to hatch. During the first twelve to fourteen days after hatching, the larvae use their chewing mouthparts to feed on aphids. The immatures (larvae) are often orange and black and shaped somewhat like tiny alligators. Larvae complete their development on plants where their primary food (aphids) is abundant. The non-mobile cocoon (pupal) stage remains attached to vegetation by its molted skin, but occasionally may be found clinging to exterior walls of buildings. Adults emerge several days after pupation and can live for more than one year. The beetles are apparently attracted to the sunlight reflecting off of the south or southwest-facing sides of the building. A similar behavior is seen in their native Japan where the beetles fly to south-facing rock cliffs and outcroppings. There they enter cracks and crevices to overwinter. Females overwinter (without mating) along with the aggregate population. Mating occurs later the next spring and there are multiple generations per year. The average time from egg to adult is about one month and there are multiple generations per year. Individual beetles can live up to three years. In nature, lady beetles eat other tiny insects and have chewing mouthparts. During spring and summer, the larvae and adults feed mainly on aphids, consuming hundreds per day [8, 9].

The Asian lady beetle is mainly tree-dwelling, living in forests and orchards, it is also abundant in soybean fields and the beetles inhabit ornamental and agricultural crops, including roses, corn, soybeans, alfalfa and tobacco. On beginning about the winter season, during a sunny, warm afternoon following a cold night, the multicolored Asian lady beetles congregate outside of houses, sheds, and other buildings in search of overwintering sites. Once inside to buildings, they crawl about on windows, walls, attics, etc., often emitting a noxious odor and yellowish staining fluid before dying. Adult multicolored Asian lady beetles in large numbers are also found congregating on doors and porch decks. At present, Asian lady beetles appear to have few natural enemies, a small percentage of beetles are parasitized by tiny wasps and flies, while up to 80% are infected by a fungus, which is only occasionally lethal. As a defense

against predators, the beetles secrete a foul smelling yellowish fluid (volatile compounds used in defense against bird and other vertebrate predators) from their leg joints when disturbed. Some mortality occurs at sub-freezing temperatures, although survival is enhanced within buildings and other protected locations if adequate moisture or humidity is available. Asian lady beetles generally do not injure humans and unlike some household pests (e.g., fleas and cockroaches), they do not reproduce indoors and do not attack wood, food or clothing. When large numbers of beetles are flying in the fall, they often land on clothing and occasionally will bite or pinch if in contact with skin, and the bite feels like a pinprick and is seldom serious. Nonetheless, although Asian lady beetles do not transmit diseases, but recent studies suggest that infestations can cause allergies in some individuals, ranging from eye irritation to asthma. People should avoid of touching their eyes after handling the beetles, and should consult a physician if they suspect they are having an allergic reaction [10, 11].

1.3. Two-spotted ladybird beetle *Adalia bipunctata* (Linnaeus)

These adult beetles have red wings with two black or brown spots, and their dome-shaped bodies are 4-5 millimeters (mm) long. They overwinter as adults and come out in early to mid-spring, and they can live for one or two years. Adults and larvae both feed on many soft-bodied pests in the garden, like aphids. The beetle can be cultured and is commercially available from insectaries, and *Adalia bipunctata* is a polyphagous species with a wide range of aphid prey. It uses coccids and diaspids as its alternative prey and also indulges inpollenvory, which supports survival in the absence of aphids. Female larvae consume more food and have a higher relative growth rate in the fourth instar than the male larvae. Adults of *A. bipunctata* feed continuously compared with the coccidophagous ladybird, *Cryptolaemus montrouzieri* Mulsant which does not feed continuously and spend lesser time on feeding because of its smaller gut capacity. They are effective just before flowering at a time when growers normally have to spray their trees. However, their effectiveness decreases on encountering the indigenous ants in the field [12].

1.4. Twice-stabbed ladybird beetle *Chilocorus stigma* (Say)

These cute little ladybugs are black with two red spots on their backs that is just to the opposite of the two-spotted ladybird beetle. They are small just about 3¾-5 mm, but they are very aggressive feeders. The *C. stigma* adults appear shiny black with a large red spot in the center of each elytron. The body is completely black except for the abdomen, which is yellow or red. Their diet is primarily scales, which can be nasty insect pests to control. These little ladybugs can often be found hunting for their next meal in trees. The *Chilocorus* species typically prefer arboreal habitats. They have been identified as beneficial natural enemies in orchards, tree plantations and forests. The genus *Chilocorus* consists mostly of armored scale insect predators. The *C. stigma* is an omnivorous predator of several scale insects, aphids and mealybugs. It has been reported often as a predator of the pine needle scale (*Chionaspis pinifoliae*) and also has been observed attacking on beech bark scale (*Cryptococcus fagisuga*) [13].

1.5. Pink spot ladybird beetle *Coleomegilla maculata* (Degeer)

These beetles can be pink to red and are 5-6 mm long, while the adult pinks are oval-shaped with six black spots on each elytron (wing cover). Pronotum (between head and wings) pink or yellowish with two large triangular black spots and head is black with pink or red triangular marking. Female lady beetles may lay from 200 to more than 1,000 eggs over a one to three month period commencing in spring or early summer. Eggs are usually deposited near prey such as aphids, often in small clusters in protected sites on leaves and stems. Larvae grow from about 1 mm to 9 mm in length and may wander up to 12 m in search of prey. The larva attaches itself by the abdomen to a leaf or other surface to pupate. The pupal stage may last from 3 to 12 days depending on temperature. As much as 50 percent of their diet can be pollen, so if growers want to attract these helpful insects to their garden, be sure to have lots of flowering plants. Adults and larvae are important aphid predators, but also prey on mites, insect eggs and small larvae. Reported prey include pea, green peach, melon, cotton, cabbage and potato aphids and green bug; and eggs of European corn borer, imported cabbageworm, fall webworm, and corn earworm; asparagus beetle, Mexican bean beetle; and Colorado potato beetle eggs and larvae. Unlike most of lady beetles, plant pollen may constitute up to 50% of its diet. This is the only lady beetle that can complete its life cycle on plant pollen, and common pollen food sources are dandelion, squash, corn and lily. Because pollen is an essential component of the diet of *Coleomegilla*, the planting or preservation of refuges, or interplantings, of early-flowering species with high pollen load may be beneficial especially to provide a food source during late spring before the buildup of aphids. Flowering dandelions, for example, have been recorded as a heavily used pollen source for dispersing adults in late spring potato fields [14, 15].

1.6. Mealybug destroyer *Cryptolaemus montrouzieri*

This beetle is a specialized feeder, it affections too much on mealybugs and other soft scales, and it can also control to citrus mealybug. This aggressive feeder is 3-4 mm long and has a dark brown body and orange head. Females have dark brown forelegs and male's forelegs are light brown. The larvae are white and fluffy and grow up to 1.3 cm long, and are covered with waxy white curls making and it is difficult to see their legs. Larvae resemble mealybugs except that they are larger and more active. The wax can be scraped off the larvae to reveal the pale, alligator-shaped beetle larvae. The *C. montrouzieri* eggs are yellow and are laid among the cottony egg sacks of mealybugs. Pupation occurs in sheltered places on stems or other substrate. Crypts, with their shiny black body and dull-orange head and thorax, definitely prefer to dine on mealybugs (especially young nymphs) to clean up large populations. These ladybugs are often purchased from commercial insectaries and released in lieu of using pesticides. When purchasing beetles, be sure to have an adequate ratio of females to males [16].

1.7. Spider mite destroyer *Stethorus punctillum*

This one is small beetle and only measures 1½ mm long, but that does not mean it cannot eat a lot. Tiny adults are oval shaped dark brown to black in color and are covered with tiny hairs, with brownish-yellow antennae, mouthparts and legs.

Larvae are slow moving, grey with conspicuous legs. They move from plant to plant on leaves. Eggs are yellowish ovals, laid singly in or near mite colonies. Adult beetles can fly, and have an unusually good ability to find small infestations of spider mites. This ladybug loves to feed on spider mites and the adults can consume 75 to 100 mites per day. Its target pests are two-spotted spider mite (*Tetranychus urticae*), European red mite (*Panonychus ulmi*), spruce spider mite (*Oligonychus ununguis*) and Southern red mite (*Oligonychus ilicis*). They can often be found feeding among high numbers of spider mites in landscapes and orchards. When combined with other biological control agents such as predatory mites, Stethorus can improve the management of a variety of pest mites in greenhouses, interior plants and nurseries. Optimum conditions for its activities are moderate to high temperatures of 67-90°F (16-35 °C), and they may remain active and feed, but will not fly at temperatures below 54°F [17].

1.8. Convergent lady beetle *Hippodamia convergens* Guerin-Meneville

This is predaceous on aphids and occasionally other soft-bodied homopterans, used for aphid control in roses and can be important in every crop with aphid pests. Adult convergent lady beetles measure 4-7 mm long and have orange to red forewings, with up to 13 black spots; however, many individuals have fewer spots and some have none. The thorax is black with two converging white lines inside and a white margin. Just in front of the forewings, or elytra, is the prothorax, which is black with two oblique (converging) white stripes and white edges. Its small head is almost covered by the front of the thorax. Legs and antennae are short. Eggs are oblong, yellow, measure about 1 mm in length and are laid on end in groups on leaves and stems near aphids. Eggs are laid in clusters, usually on the bark or leaves of tree infested with prey. The elongated larvae grow up to 7 mm long and are blackish with orange spots. The alligator-shaped larva is dark gray with two small, often indistinct, orange spots on the prothorax and four larger ones on the back, and develops through four instars. The pupa is orange and black and almost hemispherical, and it is most often found attached to the upper surface of a leaf. Pupation occurs in sheltered places on stems or other substrates. Convergent lady beetles undergo complete metamorphosis and have one or two generations per year and populations are higher in the first generation. Larvae and adults of *H. convergens* can feed on most small soft-bodied insects, but prefer aphids. They overwinter as hibernating adults, usually in mountainous regions. Large concentrations are often found in the same area each year. In spring, the beetles return the valleys. After mating, females seek out a good location for their offspring, usually a tree infested with aphids that ensures a plentiful food supply for the larvae. Eggs are laid only after adults have fed on prey. One female can lay between 200 and 500 eggs, depending upon the availability of prey. Eggs hatch in 5 to 7 days. The young larvae devour prey as fast as they can find them. The life cycle from egg laying to adult takes 4 to 7 weeks, depending on the temperature and amount of food available. Convergent lady beetles are effective predators in spring ad in late summer, adults migrate to mountain areas to hibernate [18, 19].

1.9. Transverse lady beetle *Coccinella transversoguttata richardsoni* Brown

The transverse lady beetle attacks aphids of apples and stone fruits and other soft-bodied insects such as pear psylla. The egg is yellowish orange and spindle shaped, similar in size and appearance to that of the convergent lady beetle. The larva is blue-black with orange markings and is alligator shaped. The adult is 6 to 7.5 mm long and t is more rounded in shape than the convergent lady beetle and has fewer spots on the elytra. While the body is black, the dominant color is the orange of the elytra which covers most of the body. The transverse lady beetle has 1 to 3 generations and it is one of the first predators to arrive in orchards in the spring. Overwintering adults may be observed as early as March. Eggs and larvae appear from mid-May to June, and new adults emerge in late June and July. Larvae can often be seen in orchards as late as mid-September [20].

1.10. Black lady beetle *Stethorus picipes* Casey

These small black lady beetles prey chiefly on mites and *Stethorus picipes* is usually found in orchards with heavy spider mite or rust mite populations and generally does not appear in orchards until mite populations are quite high. The egg of *Stethorus* is gray, tiny and spindle shaped and is laid singly in mite colonies. The larva is about 1 to 1.5 mm long and is dark brown or black with short spines. The pupa is mahogany colored and usually attached to a leaf surface. The adult is black and covered with silvery hairs and it is about 1 mm) long, which is much smaller than the transverse or convergent lady beetles. Distribution of black lady beetles is patchy, and they generally are not as closely associated with their mite prey as are predatory mites. Although they may be useful in reducing high mite populations, they cannot be relied upon to maintain phytophagous mites at a low level on a long-term basis [21].

1.11. *Scymnus louisianae* Chapin

The genus *Scymnus* includes many species of small black, brown, mottled or spotted beetles and adults are about 2 mm long. The larvae are usually covered with a white wax and are often mistaken for mealybugs. A field population of *Scymnus louisianae* is found attacking soybean aphids, *Apis glycines* Matsumura. Total time to develop from egg to adult for this beetle is about 20 d. About 70% of immatures survived to adulthood and they consumed approximately 100 aphid nymphs per beetle larva during the beetle's four larval instars. Adults lived for an average of 47 d (mated males) and 63 d (mated females), and during their total adult lifetime, mated males consumed an average of 665 nymphs while mated females consumed 1261 nymphs. They also feed on mealybugs, scale insects, aphids, red spiders, mites and insect eggs [22].

1.12. Mealybug destroyer *Cryptolaemus montrouzieri* Mulsant

The *Cryptolaemus montrouzieri* Mulsant lady beetle can be an effective predator of mealybugs and will also feed on soft scales and aphids. Both adults and larvae are predaceous. Adult beetles are black with orange markings on the head, thorax and tip of the elytra and are about 1 mm long. Larvae are covered with white waxy filaments giving them an appearance similar to their host. The small orange eggs are

laid within mealybug colonies. A single generation can be completed in as little as 30 days during the summer. The *Cryptolaemus* are raised primarily as a control agent for the citrus mealybug and they are generally released as adults in the early spring when mealybugs become active. The *Cryptolaemus montrouzieri* has been evaluated as a potential biological control for the grape mealybug in pear and apple orchards [23, 24].

All the species ladybird have this typical life, their eggs produce larvae that undergo four instars before pupating, metamorphosing, and giving rise to adults. Typically, ladybirds have several generations each year and reproduction is slowed or halted by cooler winter weather, when adults may hibernate. Adults and larvae of about 75 species feed on scale insects (in the broad sense, and only 13 feed primarily on aphids. As pointed out by Dixon [25], there are typical differences in behavior between these trophic groups. Those that feed on aphids develop faster, age faster, move faster, typically are larger, and lay their eggs in clusters. Those that feed on scale insects develop more slowly, live longer, move more slowly, typically are smaller, and lay their eggs singly.

2. Conclusion

Lady beetles are found all around the world and nearly all species eat insects that are pests of certain plants. Sometimes lady beetles can be very helpful in controlling of pests on farms and in gardens. Several hundred lady beetles are sufficient to rid a modest garden of insect pests and about 1,000 lady beetles can rid an infested acre of most soft-bodied insect pests. Releases of aggregation-collected *H. convergens* can significantly reduce populations of melon aphids on potted chrysanthemums and of rose aphids on potted roses. Lady beetle releases are effective to pest control, but most beetles left the plants with in 1or 2days of release. Allowing beetles to fly and feed before releasing them or releasing laboratory-reared beetles instead of aggregation-collected beetles from cold storage may reduce dispersal, but this is uncertain and requires more research, and the economic return of such treatments needs to be examined carefully. If lady beetle releases are made in conjunction with insecticide sprays for other pests, substantial care should be taken in the choice of material to avoid killing of released beetles. Unfortunately, lady beetles have the tendency to disperse once they are released, even if food is abundant. Although they are extremely important natural enemies of aphids, their propensity to disperse makes it difficult for them to be used in inoculative or inundative biological control programs.

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