A STUDY OF THE BIOLOGY OF TWO COCCINELLID BEETLES

FOUND ON MAIZE AND EGG-PLANTS.

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BY

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D. T. A. REPORT

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SECTION 1

Tropical agriculture is largely characterized by plantation crops. It is under such conditions, i.e., large areas of monoculture, that pest infestations build up at their fastest rate. Such infestations are further aided by the cooperatively uniform climate of these regions. Since World War II, the use of insecticides in tropical agriculture has increased considerably. This is due partly to the more efficient reliability of the insecticidal firms, but also because of the increasing resistance of the insects to the various insecticides, and therefore the increasing necessity of applying more of the insecticides per acre, for control to be effective. No applied entomologists can say that insecticides are not effective over a short period, for the increase in long yields that they produce is often staggering. They do have their drawbacks (e.g., killing beneficial insects, continued chemical residue, etc.,) and they do not answer the long term control problem. This problem must be answered by either cultural or biological control, and it is with the latter in view that this present work has been conducted.

The Coccineellidae are a family of some 5,000 species (June 1957), many of which are predatory insects feeding on aphids, scale insects, mealybugs, psyllids, etc., and are therefore of great significance in biological control problems. Tillyard (1929) considered that certain of the Coccineellidae are amongst the most beneficial of all insects. The species under examination in the present work, 

Sphenocmelus nasicus (L.) and Coccinella septempunctata (L.) are undoubtedly beneficial. An attempt to ascertain the degree of their importance has been undertaken, but due to shortage of time (i.e., the study was only carried out from October 1958 to March 1959 inclusive) their economic importance could not be examined as fully as desired.
A STUDY OF THE BIOLOGY OF TWO COCCINELLID BEETLES FOUND ON MAIZE AND EGG-PLANTS

INTRODUCTION

Tropical agriculture is largely characterized by plantation crops. It is under such conditions i.e. large areas of monoculture, that pest infestations build up at their fastest rate. Such infestations are further aided by the comparatively uniform climate of these regions. Since World War II, the use of insecticides in tropical countries has increased considerably. This is due partly to the more efficient salesmanship of the insecticidal firms, but also because of the increasing resistance of the insects to the various insecticides, and therefore the increasing necessity of applying more of the insecticide per acre, for control to be effective. No applied entomologists would say that chemicals are not effective over a short period, for the increase in crop yields that they produce is often staggering. They do however have harmful effects (e.g. killing beneficial insects, phytotoxicity, consumer toxicity, etc.), and they do not answer the long term control problem. This problem must be answered by either cultural or biological control, and it is with the latter in view that the present work has been conducted.

The Coccinellidae are a family of some 5,000 species (Imms 1957), most of which are predacious insects feeding on aphids, adelgids, scale insects, mites, etc., and are therefore of great significance in biological control problems. Tillyard (1926) considered that certain of the Coccinellidae are amongst the most beneficial of all insects. The species under examination in the present work, Cycloneda sanguinea (L.) and Ceratomegilla maculata (DeGeer) are undoubtedly beneficial. An attempt to ascertain the degree of their importance has been undertaken, but due to shortage of time (i.e. the study was only carried out from October 1958 to March 1959 inclusive) their economic importance could not be examined as fully as desired.
and it is hoped that the present work will form a basis for further study on this point.

The two species in question have come under extensive consideration during the past. Their beneficial importance has been noted on various crops throughout the Neotropics. However little work has been done on the biology or morphology of either species. Yet from the point of view of biological control measures, it is essential to know something of the biology and morphology of the species in question. This work is therefore an attempt to cover the first of these two neglected aspects.

A section of the project is being devoted to a study of the life history of the two species, another section to a description of their four stages (egg, larva, pupa and imago). The larvae have not been previously described, and owing to the remarkable resemblance between the larval forms of the two species a considerable amount of space has been allocated to a detailed description of them. The quantities of aphids which the several stadia are capable of eating are given, and there is a discussion on the parasites and predators of the two species of ladybirds.

EXPERIMENTAL PROCEDURE

1. Collection and Identification

All three stages (larva, pupa and adult) of Cycloneda sanguinea and Ceratomegilla maculata were collected between October 1958 and March 1959 inclusive. Collections were made throughout Trinidad, but in the main from the St. Augustine area, off maize (Zea mays L.) and egg-plants (Solanum melongena L.).

The imagines of Cycloneda sanguinea were identified by comparison with those determined by F.C. Camargo in the I.C.T.A. collection. The imagines of Ceratomegilla maculata were identified by comparison with those determined by G.E. Bryant in the I.C.T.A. collection. The larvae and pupae were identified after being bred from their respective adults.
The rapid dehydration, which would occur if they were transferred from the killing bottles directly into strong alcohol.

The ethyl alcohol was found to preserve the specimens quite satisfactorily, except that it darkened the tissues slightly.

4. **Drawing**

The figures were drawn with the aid of a "Carl Zeis" Camera Lucida, the details being filled in free hand. All shading was carried out by use of "Zip-A-Tone" (or "Plastitone") sheets. The Camera Lucida was used in conjunction with either a "Leitz Wetzlar" binocular or a "Baker" monocular microscope. The figures were measured by means of a "Beck" micrometer eyepiece and a graduated slide.
SECTION 2

SECTION 2

The freely deposited egg (Fig. 1 A) is somewhat long and by G.5 to
2.8 mm. oval to bright yellow and therefore rather striking. But on
embryonic development proceeds it becomes more of an ochre-yellow and
for less noticeable against the green background of the leaves on which
it is deposited. Finally within twelve hours of hatching the egg turns
grey due to the developing larva within it. The body is spindle-shaped
and when deposited their long axes are perpendicular to the leaf surfaces.
The spiracle end is blunter than the opposite pole.

(b) The Larva. (Fig. 2)

A detailed description of the larva of Cyclommatus sp. is given in the larvae of the two species under consideration are remarkably similar and could otherwise easily be mistaken. Also,
there is no record of a previous description of the larvae of this species.

The head of the larva is grey to black, the thorax in an
orange-red or grey colour except for a pair of large brown to black tubercles
on the dorsal surface of each thoracic segment. The tubercles are
characteristic of most cyclommatus larvae. The dorsal surface of the
headnoro is basically grey, except for a characteristic cross, the colour
of which varies from orange to grey. The long axes of the cross run
along the mid-dorsal line. The other are formed by segment four. Ex-
cluding segment nine, each segment bears six pairs of hairy tubercles;
the dorsal, one lateral and three central pairs (the two inner central
pairs are reduced to tufts of one, two or three hairs). Two dorsal and
lateral tubercles are brown or black in colour, with the following
exceptions. In segment four, only the inner ventral pair is black; the
others are orange or creamy in colour, in segment four all the tubercles
are orange, and in segment five the lateral pairs are orange. Segment
dine is grey and without tubercles. Ventrally the body and tubercules
are light in colour, the limbs however are grey to black.
DESCRIPTION OF THE STAGES OF THE TWO COCCINELLID SPECIES

1. CYCLONEDA SANGUINEA (L.)

(a) The Egg. (Fig. 1,A).

The freshly deposited egg (1.2 to 1.4 mm. long by 0.5 to 0.6 mm. wide) is bright yellow and therefore rather striking, but as embryonic development proceeds it becomes more of an ochre-yellow and far less noticeable against the green background of the leaves on which it is deposited. Finally within twelve hours of hatching the egg turns grey due to the developing larva within it. The eggs are spindle shaped and when deposited their long axes are perpendicular to the leaf surface. The micropylar end is blunter than the opposite pole.

(b) The Larva. (Fig. 2)

It is intended to give a fairly full description of the larvae of Cycloneda sanguinea, as the larvae of the two species under consideration are remarkably similar and could otherwise easily be mistaken. Also, there is no record of a previous description of the larvae of Cycloneda sanguinea. The head of the larva is grey to black, the thorax is an orange-creamy colour except for a pair of large brown to black tubercles on the dorsal surface of each thoracic segment. The tubercles are characteristic of most coccinellid larvae. The dorsal surface of the abdomen is basically grey, except for a characteristic cross, the colour of which varies from orange to cream. The long arm of the cross runs along the mid-dorsal line, the other arm is formed by segment four. Excluding segment nine, each segment bears six pairs of hairy tubercles, two dorsal, one lateral and three ventral pairs (the two inner ventral pairs are reduced to tufts of one, two or three hairs). The dorsal and lateral tubercles are brown or black in colour, with the following exceptions. In segment one, only the inner dorsal pair is black, the others are orange or creamy in colour, in segment four all the tubercles are orange, and in segment five the lateral pairs are orange. Segment nine is grey and without tubercles. Ventrally the body and tubercles are light in colour, the limbs however are grey to black.
There are four larval instars. In the first instar the tubercles are very pronounced, closely packed and hairy, but the dorsal cross is not clearly distinguished. By the second instar the larva is of a much lighter overall hue, which is more characteristic of the two older instars. The cross can now be distinguished due to the more open nature of the tubercles, and by the third instar the cross is the characteristic feature of the larva. There are however exceptions in that certain individuals develop the characteristic cross at an earlier instar than others. There is therefore only one certain way of distinguishing between the instars and that is by size:

<table>
<thead>
<tr>
<th>Instar</th>
<th>Measurement of Body Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1.4 - 2.2 mm.</td>
</tr>
<tr>
<td>Second</td>
<td>2.8 - 3.4 mm.</td>
</tr>
<tr>
<td>Third</td>
<td>3.8 - 4.6 mm.</td>
</tr>
<tr>
<td>Fourth</td>
<td>5.0 - 8.2 mm.</td>
</tr>
</tbody>
</table>

The measurements of the body length as given above, are seen to fluctuate considerably (twenty individuals from each instar were measured), but in no case do they approach the measurements of the instars above or below them. It was therefore considered unnecessary to measure head capsule width (Dyar's law) as is more normal when body measurements show excessive fluctuations. Measurement is therefore a more accurate means of determining the several instars than is colour. Colour and marking are however a satisfactory means of distinguishing between the larvae of *Cycloneda sanguinea* and *Ceratomegilla maculata*.

In common with many types of larvae, the larvae of coccinellids are capable of evacuating their rectums so that they act as a "sucking disc" (Gage 1920). Both the species under consideration make considerable use of this organ in locomotion.

(c) The Pupa (Fig. 4).

The Coccinellidae, unlike most other Coleoptera, have obtect adecticous pupae, that is the appendages of the pupa are firmly soldered down to the body wall by a secretion produced at the last larval moult (Imms 1957). The larval exuviae is pushed down to the anal extremity during the formation of the pupa.
The pupa (4.2 - 6.0 mm. in length) changes in colour during its development, from ochre-yellow to orange. On its dorsal wall and between the wing buds are a series of black spots. The number and position of these spots show considerable variation. There are always four black spots present, one pair on the third thoracic segment and a second pair on the third abdominal segment. Besides these there can be none to five pairs of secondary spots on segments two, three and four of the abdomen. These latter spots are smaller and less conspicuous than the former. The inner margins of the elytra are darkened by a thin deposition of black pigments.

(d) The Imagō (Fig. 6)

On emergence the adults are pale yellow in colour, and very soft. The hind wings hang extended beneath the elytra until they are dry, a matter of ten to fifteen minutes. They are hemispherical insects measuring 3.9 to 5.8 mm. long by 3.5 to 4.6 mm. wide. Full colour is reached only after the cuticle has completely hardened (approximately one day), the imagines then have red elytra, but the intensity of the red varies considerably. The pronotum is black except for some white markings mainly around the margins. These pronotal markings are however extremely variable, even among specimens taken from the same plant.

2. CERATOMEGILLA MACULATA (DEGEER)

(a) The Egg. (Fig. 1. B).

The egg of Ceratomegilla maculata is similar to that of Cycloneda sanguinea in both colour and colour changes. It is however considerably larger (i.e. 1.4 to 1.5 mm. long by 0.6 to 0.7 mm. wide) and there can also be a slight bulge on the basal pole of the egg, but this is not a constant characteristic.

(b) The Larva (Fig. 3.)

The head and pronotum of the larva are blackish, the pronotum bearing two very large tubercles, separated only by a thin light-coloured line. The anterior and lateral margins of the pronotum are white and there are also two small white spots on the front margin of both pronotal...
tubercles. The tubercles on the remaining thoracic segments are smaller, and there is a correspondingly larger area of white. There are nine abdominal segments each with six pairs of tubercles. Dorsally the segments are dark grey and the tubercles are brown to black, except for segments one and four. The lateral thirds of the first abdominal segment are white, and all segment four is white. There is no orange colour present as there is in Cycloneda sanguinea, and neither is there the mid-dorsal line down the abdomen. So the characteristic cross of Cycloneda sanguinea is absent in Ceratomegilla maculata, and as a general rule the latter coccinellid is much darker than the former.

There are three pairs of ventral tubercles per segment, the two inner pairs being more prominent than in Cycloneda sanguinea. The ventral sclerites are grey but for a mid ventral line of lighter hue stretching from the head to the tip of the abdomen. The limbs are black.

The first and second instar larvae are generally lighter but more hairy owing to the compact nature of the tubercles, each of which has a tuft of hairs arising from it. The instars are best separated by their size. The following measurements being the extremes of twenty sets of figures taken for each instar.

<table>
<thead>
<tr>
<th>Instar</th>
<th>Measurement of Body Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1.6 - 2.5 mm.</td>
</tr>
<tr>
<td>Second</td>
<td>3.0 - 4.0 mm.</td>
</tr>
<tr>
<td>Third</td>
<td>4.5 - 5.8 mm.</td>
</tr>
<tr>
<td>Fourth</td>
<td>6.9 - 9.6 mm.</td>
</tr>
</tbody>
</table>

On no occasion did the measurements for any instar approach the measurements of those above or below it.

(c) The Pupa (Fig. 5)

The pupa (4.3 - 6.1 mm. in length) is mainly orange in colour, although there are several black markings. The first thoracic segment has three pairs of black marks on it and the other two thoracic segments have a single pair of black marks each. Each wing cover has four black spots. A pair of black spots is also found on the dorsal surface of the second, third and fifth abdominal segment.
The Imago (Fig. 7)

Directly after eclosion the imagines are of a pale pinkish colour, which slowly darkens during the subsequent twenty-four hours. The final colour of the elytra on which there are thirteen large black spots is dark red. It is possible when discussing the elytral markings of coccinellids to simplify the description of the marks, by use of a formula which was first described by Donisthorpe (1930) "Taking the left elytron the spot on the scutellum is called half, and the remaining spots are numbered from left to right, transversely from the base to the apex. Cases in which any spots of the series are confluent are expressed by the sign +". In *Ceratomegilla maculata* the spots can be expressed according to the above formula as follows:

1 \( \frac{1}{2} \)

2 + 3

4 5+

6

The pronotum is normally black, except for white margins but there can also be a mid-dorsal white line on the pronotum. The head, limbs and ventral surface of the body are also black.

*Ceratomegilla maculata* is ovoid in shape (5.6 to 7.4 mm. long by 3.2 to 4.7 mm. wide) with its head projecting well beyond the pronotum. In most Coccinellidae the head is partly concealed by the pronotum.


SECTION 3

Egg deposition was found to begin outdoors during the period of late winter, but for older observation in the life history and feeding habits it was necessary to breed and rear a number of aphides elsewhere. Cultures of A. pismum were established on egg-plants as a source of food for the conchialidae. This arrangement proved very satisfactory. For a large abcdelilin population was soon built up, and a continual flow of specimens were provided for observation.

(a) Egg Deposition and Development.

The eggs are deposited on the undersides of leaves which have any debris heavily infested with aphids. On no occasion were eggs observed within an aphid colony, this is possibly a means of protecting the eggs from ants which were always found attending the aphids. The eggs are deposited with the long axis perpendicular to the leaf surface. The parasitoids, however, at the end of the month the selected pattern becomes irregular and on the occasion eggs were seen to have been deposited at an angle of the other.

The eggs are laid singly at intervals of 20-30 seconds, usually in the early morning or late evening. The number of eggs per batch varies between 12 and 29, with 20 as the more usual figure. One female laid 315 eggs during its life of 67 days.

Souchon (1932) reported that two females laid totals of 373 and 368 eggs each during survival periods of 79 and 109 days, respectively. The duration of the egg stage is three days.

It was observed that on any infested plant there were always more larvae and nymphs than there were adults. This suggests that the oviposition is accidental in order to breed on "fresh" material, a means whereby mortality from cannibalism and natural enemies can be reduced. Mortality when however occurs in both the egg and larval stages. Cannibalism is common in the second and third instar larvae which hatch first oit of the unhatched eggs next to them. If a larva and adult or egg it usually

We have been able to make a bare subcultural search for aphids. By nture prog

Density is. The cannibalism has a survival value for the individual stock (Zahn 1932). It is thought by suggested that each individual is an a

unusual amount of the western.
Cycloneda sanguinea was found to breed outdoors throughout the period of study, but for close observations on its life history and feeding habits it was necessary to breed and rear a number of specimens indoors. Cultures of A. gossypii were maintained on egg-plants as a source of food for the coccinellids. This arrangement proved very satisfactory, for a large coccinellid population was soon built up, and a continual "flow" of specimens were provided for observation.

(a) Egg Deposition and Development.

The eggs are deposited on the undersides of leaves, which have not become heavily infested with aphids. On no occasion were eggs observed within an aphid colony, this is possibly a means of protecting the eggs from ants which were always found attending the aphids. The eggs are deposited, with their long axis perpendicular to the leaf surface, in two parallel rows, although towards the end of the batch the deposition pattern becomes irregular and on one occasion eggs were seen to have been deposited one on top of the other. The eggs are laid singly at intervals of 30-60 seconds, usually in the early morning or late evening. The number of eggs per batch varies between 12 and 29, with 20 as the more usual figure. One female laid 315 eggs during its life of 87 days. Szumkowski (1956) reported that two females laid totals of 373 and 388 eggs each during survival periods of 75 and 109 days, respectively. The duration of the egg stage is three days.

It was observed that on any infested plant there were always more larvae and pupae than there were adults. This suggests that the adults dispersed in order to breed on "fresh" material, a means whereby mortality from cannibalism and natural enemies can be reduced. Mortality does however occur in both the egg and larval stages. Cannibalism is common in the species, and those larvae which hatch first often eat the unhatched eggs next to them. Once a larva has eaten an egg it benefits by being able to make a more prolonged search for aphids. So when prey density is low cannibalism has a survival value for the individual larva (Banks 1956). It is therefore suggested that such behaviour is in no way detrimental to the continued existence of the species.
Larval Development

The mature embryo emerges from the egg by pressing its pronotal egg burster through the chorion (Emden 1949), splitting it across the pole from one side to the other. The larva emerges slowly and rests on top of the egg-shell while its cuticle hardens and changes from a light to a dark colour. This cuticular hardening process lasts for nearly two hours, after which small movements are made in preparation for crawling down the egg-shell. The base of the egg-shell is then pierced and any fluid remaining within it is sucked out. The shell is also occasionally eaten.

Their first major feed comes from either a neighbouring unhatched egg or an aphid. The time taken by the newly hatched larva to leave the egg batch varies greatly, it may be four to five hours after eclosion, while at the other extreme it is as much as twenty-four hours. During this period mortality is high due to the attacks of older instars of their own and other coccinellid species. Certain neuropterous larvae and ants can also be troublesome at this early age, before the young larvae are capable of defending themselves. Those larvae which have eaten develop very rapidly, increasing their size by half as much again in twenty-four hours, e.g. newly hatched larvae measure 1.4 to 1.5 mm. long while larvae one day old measure 1.9 to 2.2 mm. in body length.

The limbs of the first larval instar are weak and incapable of retaining a hold of the plant tissue if this is suddenly moved. This inability is overcome by the larva retaining a strong hold of its substratum with its evaginated rectum (see page 7).

There are four larval instars, the duration of which is approximately as follows:

<table>
<thead>
<tr>
<th>Instar</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>2 days</td>
</tr>
<tr>
<td>Second</td>
<td>1 day</td>
</tr>
<tr>
<td>Third</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Fourth</td>
<td>3-5 days</td>
</tr>
</tbody>
</table>

The larvae feed predaciously on aphids throughout the four instars (8-11 days) except for the last 1-1½ days. Feeding ceases during this final period and the larva becomes very sluggish. The time is spent suspending themselves by their caudal extremity to the undersides of the leaves of the
host plant, with the aid of an adhesive substance which they secrete. This period is therefore to be considered as prepupal and it is terminated by the moult which reveals the true pupa.

(c) Pupal Development

The pupa can be found suspended by its caudal extremity to the lower surface of the leaf of an egg-plant. During its development, which lasts three to five days, the pupa undergoes various colour changes (see page 8). It is however, at all times, very conspicuous owing to its bright colours and the exposed nature of its site. This results in the pupa being rather vulnerable to the attacks of its enemies (see page 23).

Provided that an adequate supply of food is available during the larval period, then development from egg deposition to emergence of the imago, will take fifteen to nineteen days. If the aphid supply is restricted, and feeding limited, then this developmental period can be extended to twenty-eight days (see page 19).

(d) The Imago

The imagines emerged throughout the period of study, and there appears to be no seasonal effect on the life cycle. Some adults were observed to die when emerging, but the percentage mortality from this cause was not ascertained.

Adults were mainly collected from the St. Augustine area and the Aranguez Estates. It was observed that imagines collected at the Aranguez Estate had a much darker and more shiny red elytra than those caught elsewhere. No explanation can be offered for this.

The sex ratio (which was ascertained by dissection of over seventy individuals) of the species is about unity and pairing will occur within two days of emergence and continue intermittently throughout the females life. This suggests that there can be no adult diapause (for the physiological development of the ovaries and testes) as has been reported in several temperate region coccinellids (Dobizhanski 1922, and Rushton 1958). The pre-oviposition period is four to five days, and the life cycle, from pairing to pairing, can be completed in twenty-three days.
2. CERATOMEGILLA MACULATA (DEGEER)

Individuals of Ceratomegilla maculata were bred in a large greenhouse along with individuals of Cycloneda sanguinea. They also feed on A. gossypii on egg-plants, as does Cycloneda sanguinea. Specimens found pairing were placed on fresh egg-plants in special breeding cages, from where their life activities could be observed.

(a) Egg Deposition and Development

The eggs are deposited on the undersides of the leaves of egg-plants, and on either surface of maize leaves. This apparent inconsistency arises from the fact that maize leaves are often vertical, when neither surface can be considered as lower than the other. In egg-plants the leaves are always more or less horizontal, and if eggs were laid on the upper surface desiccation might occur. Oviposition on aphid infested leaves was not observed on either maize or egg-plant. The egg stage lasts for three days.

The eggs are laid in two or three parallel rows, but this pattern is even more likely to be irregular than it is in Cycloneda sanguinea. The number of eggs per batch varies between nine and twenty-eight, with an average of eighteen. Two females from the same batch were observed to lay 217 and 246 eggs in 85 days respectively. These figures are considerably lower than the figures for the same period in Cycloneda sanguinea.

Ceratomegilla maculata has a relatively low reproductive potential, in that there are always more adults in a given area than there are larvae or pupae. This is partly due to egg and larval mortality from cannibalism and other causes, but it is mainly due to the relatively low oviposition rate as mentioned above.

(b) Larval Development.

The mature embryo emerges from the egg-shell by using its pronotal egg bursters in a similar manner to Cycloneda sanguinea. Once the larva's cuticle has become hardened, the larva descends the egg shell and sucks any remaining fluid out of the base of the shell. Neighbouring unhatched eggs are next attacked, for cannibalism is just as common in
Ceratomegilla maculata as it is in Cycloneda sanguinea. Once the larvae have completed their first feed, they become much more capable of defending themselves, and the incidence of cannibalism decreases.

There are normally four larval instars in the family Coccinellidae (Imms 1957) and Ceratomegilla maculata is no exception to the rule. The duration of the four instars is as follows:

- First Instar - 1-2 days
- Second Instar - 2-3 days
- Third Instar - 2-3 days
- Fourth Instar - 5-7 days

There are therefore 10-15 days of actively predacious larval life, except for the final day when predacious activity is suspended and the larva is to be considered as prepupal. The predacious period is appreciably longer than the equivalent period in Cycloneda sanguinea, and there are correspondingly greater numbers of aphids eaten in this period (see page 18). This would suggest that larva for larva Ceratomegilla maculata is of a greater economic benefit to man than Cycloneda sanguinea. The rate of control of Ceratomegilla maculata is however slightly slower.

(c) Pupal Development.

The pupae are usually suspended away from an aphid colony on the under surfaces of leaves. The exuviae from the last larval moult can be seen stuck down between the anal extremity of the pupa and substratum.

Pupal development takes four to five days, and so the complete pre-imaginal developmental period lasts seventeen to twenty-three days. With restricted feeding the developmental period can be extended to thirty-one days (see page 19).

(d) The Imagio.

The imagines emerged throughout the study period, for as in Cycloneda sanguinea there appears to be no seasonal effect on the life cycle. Mortality at eclosion is fairly common.

The sex ratio shows a very pronounced difference between the numbers of males and females i.e. 17% males to 83% females. Sixty specimens were dissected to ascertain the above ratio, which is not
enough for the result to be significant, but the figures are divergent enough to show that there is a marked preponderance of females. There is no adult diapause and pairing continued throughout the period of study. The pre-oviposition period is approximately four days, and as pairing can occur within two days of emergence, the life cycle can be completed in twenty-two days. As a rule the life cycle is considerably larger.

FEEDING HABITS

Both species of Coccinellidae were observed to feed on three species of Aphididae, e.g.:

1. *Aphis gossypii* (Glover).
2. *Rhopalosiphum maidis* (Fitch).

There are also reports of the two species being predacious on members of the Pyrrhocoridae, Delphacidae and Coccidae in the Hemiptera. While in the Lepidoptera there are species in the Crambidae and Noctuidae which are attacked. (see Appendix I). The wide range of species which are attacked indicates that the host specificity of both coccinellids is but slight. An experiment was undertaken to ascertain whether either species of larva would eat *Corythaica planaria* (Uhler) (Heteroptera, Tingidae), a serious pest of egg-plants. All other forms of food were withheld, and under such conditions larvae of *Cycloneda sanguinea* did feed unwillingly on the tingids. This phenomenon was never witnessed in the field, where the tingid population would build up to enormous numbers regardless of the presence of ladybirds. Larvae of *Ceratomegilla maculata* would not eat the tingids, even under laboratory conditions.

For purposes of experimentation a colony of *A. gossypii* was maintained. This species readily bred on egg-plants, where it rapidly became overcrowded, with the result that starvation forms were produced. These are very small, light green aphids, as opposed to the more normal large dark green forms. Therefore it is as well to remember that in the following experiments on feeding, the figures are rather higher than those one might expect if normal forms of *A. gossypii* had been bred.
Four larvae of *Cycloneda sanguinea* were reared from first instar larvae to pupae in small one-inch glass-topped pill-boxes. Aphids were fed to them "ad lib" and on the average each larva ate 373 aphids in 10 days. The total number of aphids consumed by each instar, and the average numbers consumed per day by the respective instars, are given below:

<table>
<thead>
<tr>
<th>Instar</th>
<th>Total No. of Aphids</th>
<th>Average No. of Aphids per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>First (2 days)</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Second (1 day)</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Third (2-3 days)</td>
<td>84</td>
<td>28-42</td>
</tr>
<tr>
<td>Fourth (3-5 days)</td>
<td>228</td>
<td>46-76</td>
</tr>
</tbody>
</table>

Two adults which were reared in similar pill-boxes were found to destroy an average of 139 and 168 aphids per day with a maximum of 212 and 207 respectively.

A similar experiment was carried out with the larvae and adults of *Ceratomegilla maculata*. Three larvae were observed to eat an average of 484 aphids in 14 days. The average numbers of aphids per day, and the total numbers of aphids consumed by each instar are given below:

<table>
<thead>
<tr>
<th>Instar</th>
<th>Total No. of Aphids</th>
<th>Average No. of Aphids per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>First (1-2 days)</td>
<td>23</td>
<td>12-23</td>
</tr>
<tr>
<td>Second (2-3 days)</td>
<td>37</td>
<td>12-18</td>
</tr>
<tr>
<td>Third (2-3 days)</td>
<td>82</td>
<td>27-41</td>
</tr>
<tr>
<td>Fourth (5-7 days)</td>
<td>342</td>
<td>49-68</td>
</tr>
</tbody>
</table>

Two adults were observed to destroy an average of 178 and 181 aphids per day, with a maximum of 224 and 255, respectively.

Szumkowski (1956) undertook a similar experiment in Venezuela. His figures on the amounts eaten per *Ceratomegilla maculata* larva, correspond roughly to the present ones i.e. 449 aphids per larva. The figures on the amounts the adults eat do not however correspond. In Szumkowski’s experiment the adults ate an average of 82 aphids per day with a maximum of 120. The figures from the present experiments are far higher, this being due no doubt to the starvation forms of *A. gossypii* which were being fed to the coccinellids.
Szumkowski made no reference to the numbers of aphids eaten by the larvae of *Cycloneda sanguinea*. He did however show that the adults ate on the average 69 aphids per day, with a maximum of 145. These figures are far lower than those achieved in the present observations, and again this is probably due to the starvation forms of *A. gossypii* which were being fed.

So far both adults and larvae have been fed "ad lib"; if however the number of aphids fed per day, to the larvae are restricted then their developmental period can be prolonged. Over a number of experiments it was observed that larvae of *Cycloneda sanguinea* would complete their development in 28 days, if they were only fed a total of 131 aphids, or approximately 4.7 aphids per day. While the larvae of *Ceratomegilla maculata* would complete their development in 31 days if they were restricted to a total of 154 aphids or approximately 4.9 aphids per day. If the numbers of aphids being fed, were reduced below the above figures then the coccinellid would die in either one of the larval stages, or else the pupal stage.

The size of an aphid colony which one coccinellid larva is capable of controlling during its larval period, is of obvious interest from an economic point of view. Owing to shortage of time, experiments could only be carried out on one of the two species under consideration. Five newly hatched larvae of *Ceratomegilla maculata* were each placed on an aphid free egg-plant. Then on each egg-plant the following numbers of aphids were released:

<table>
<thead>
<tr>
<th>Egg-plant</th>
<th>A. gossypii (Glover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

It was observed that one larva could pass through its four larval instars if there were at least 40 aphids present to start with. If there were less, the rate of reproduction of the aphids was not fast enough to reach equilibrium with those being eaten by the coccinellid larva, and so
the larva died of starvation. If there were 50 or more aphids at the start, then their numbers built up regardless of the presence of the coccinellid. It may therefore be concluded that one larva of Ceratomegilla maculata can effectively control colonies of up to 40 or 45 aphids.

Ceratomegilla maculata has been reported eating the glumes of rice in British Guiana (F.D. Bennett, personal communication). This phytophagous habit has not been previously reported outside of British Guiana, but during the present work large numbers of adult Ceratomegilla maculata were noticed on Razor grass (Paspalum virgatum; Graminae) and on Soap Weed (Sphenoclea zeylanica; Campanulaceae) at the Government Experimental Farm, Centeno. On closer examination it was found that the seeds of Razor grass were being stripped of their testa. In consequence of this observation adults of Ceratomegilla maculata were placed in pill-boxes along with undamaged seeds of Razor grass. The seeds were re-examined a week later, and it was found that many of them had been partly stripped of their testa, which leaves little doubt that the ladybirds were doing the damage. The Soap Weed was in flower, and adults were seen entering the flowers and apparently imbibing nectar and eating pollen from the base of the corolla. The floral parts were not damaged. This phytophagous habit is of considerable economic interest, for the two plants attacked during the present observations are serious weeds, and the attack is therefore beneficial. If however rice is also attacked, as reported from British Guiana, then this habit is of very doubtful value.
SECTION 4

The two species of Cycloneda have a wide distribution, requiring warm low altitudes throughout South and Central America to the Southern States of the U.S.A. They can also be found in many of the West Indian Islands, and in Trinidad the two species have an island-wide distribution, Aphelinus having been taken in the Cedros, the Ellice, Chiribiquete and St. Augustine areas.

The two species are predacious on a number of different hosts, and very few studies of host relationship have been published. These hosts occur on several types of plants, the most important of which are citrus, coffee, cacao, banana, cotton, tobacco, sugar, yams, eggplants, etc. and have been observed in a few areas. In the present study only these two species occurring on two of the plants, eggplant and eggplant, were examined, and field studies were restricted to the St. Augustine area in Florida. In 1935 a number of eggplant and cotton suffer from a number of insects which were found economically on these plants. The present work of Cycloneda was carried out in the St. Augustine area from 1934 to 1938. On these two species occurring on eggplant Cycloneda examined is by far the most common, with

<table>
<thead>
<tr>
<th>Cycloneda wasulata</th>
<th>Cycloneda vasculina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Value</td>
</tr>
<tr>
<td>cotton</td>
<td>cotton</td>
</tr>
<tr>
<td>95%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Both species are taken from a total of over 6000 specimens caught, and only 2% of these records were found. There is little variation between the cotton and eggplant from March to October.

No attempt was made to maintain the actual number of specimens but the number of eggs, so that a natural balance with the population of the species is kept. The population of the latter appeared to increase with the increasing size of the plant.

In general, the population of the second species (Cycloneda vasculina) is decreasing considerably due to the increasing size of the eggplant and the presence of the two species.
The two species of Coccinellidae have a wide distribution, ranging from the Argentine throughout South and Central America to the Southern States of the U.S.A. They can also be found in many of the West Indian Islands, and in Trinidad the two species have an island-wide distribution; specimens having been taken in the Cedros, Rio Claro, Centeno and St. Augustine areas.

The coccinellids are predacious on a number of different insect species, but mostly on aphids or noctuids (see Appendix I). These hosts occur on several types of plants, the more important of which are cotton, citrus, sugar-cane, maize, wheat, barley, oats, egg-plants, okra and bamboo, as well as several ornamentals. In the present work only those coccinellids occurring on two of the plants, maize and egg-plant, were examined, and field studies were restricted to the St. Augustine area in Trinidad. In this district both egg-plant and maize suffer from a common pest, *A. gossypii*, which can be found abundantly on them.

The proportions of *Cycloneoda sanguinea* and *Ceratomegilla maculata* on the two plant species was ascertained by four monthly surveys from November, 1958, to February, 1959. On maize the two species occur in roughly equal proportions, on egg-plant *Cycloneoda sanguinea* is by far the most common, e.g.

<table>
<thead>
<tr>
<th>Plant</th>
<th><em>Ceratomegilla maculata</em></th>
<th><em>Cycloneoda sanguinea</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>Egg-plant</td>
<td>6%</td>
<td>94%</td>
</tr>
</tbody>
</table>

These percentages are taken from a total of over 400 ladybirds caught, roughly 100 being caught each month. There is little variation between the figures from month to month.

No attempt was made to ascertain the actual numbers of coccinellids per acre of crop, as this naturally varied with the population of *A. gossypii*. The population of the latter appeared to decrease with:

1. Increasing age of the plant.
2. Increasing population of flea beetles (*Epitrix parvula* F.).
3. Increasing population of lace bugs (*Corythaica planaris* Uhler)
4. Increasing populations of its own parasites and predators.
Two of the above are correlated with number one, and so any variation in the environment could affect one or all of the above factors in varying degrees. These interactions would cause considerable fluctuations in the coccinellid population, and no single set of data could therefore be considered as accurate.

**NATURAL ENEMIES**

Two insect species were recorded as enemies of *Ceratomegilla maculata* and *Cycloneda sanguinea* during the present study. The first is a predator which was identified as a member of the sub-family Zelinae (Heteroptera, Reduviidae), and is a large bug which was noticed to attack third and fourth stage larvae and also pupae. It sucked their body fluids out by piercing the mid-dorsal region of the abdomen.

The second enemy is *Homalotylus terminalis* (Say.) (Hymenoptera, Encyrtidae), a small parasitic wasp which has been recorded as a frequent parasite of both species of coccinellids (Timberlake 1919). The female wasp alights on the abdomen of third and fourth stage coccinellid larva, inserting her ovipositor through the intersegmental rings to oviposit within the larval abdomen. From egg deposition to the emergence of the adult wasps takes ten to twelve days, but seven to eight days before the wasps emerge the parasitized larva takes on a very characteristic appearance. It becomes blackened and mummified and is suspended by its caudal extremity to the lower surface of a leaf. Between three to eight wasps will complete their pre-imaginal development in one coccinellid larva, completely destroying the internal contents of the larva. Emergence from the parched larval skin is made by each adult wasp biting a neat round hole through the abdomen or thorax of the coccinellid larva. As each parasitized larva gives rise to an average of five wasps, it follows that the build up of the parasites can be very rapid in an area where the coccinellid population is high. A survey taken on two fields show this to be the case:

<table>
<thead>
<tr>
<th>Coccinellidae</th>
<th>Plant</th>
<th>Percentage larvae Parasitize</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cycloneda sanguinea</em></td>
<td>Egg-plant</td>
<td>73</td>
</tr>
<tr>
<td><em>Ceratomegilla maculata</em></td>
<td>Maize</td>
<td>60</td>
</tr>
</tbody>
</table>
The percentages were worked out from approximately one hundred larvae, both parasitized and non-parasitized taken from each crop.

Two mummified pupae which were observed in the field were found to be parasitized by *H. terminalis*. An experiment was therefore conducted to ascertain if the wasps would parasitize the pupae under laboratory conditions. Ten pupae were placed in separate pill-boxes, each with four wasps, but in no case did a pupa become parasitized. In a control experiment in which larvae instead of pupae were used, the larvae did become parasitized. It is therefore assumed that if a fourth stage larva is parasitized just before pupation, then it is still capable of pupating, and so the wasps now develop within the pupa, so that the latter takes on a mummified appearance. The pupa itself is not however parasitized.

d'Araujo e Silva (1947) has reported that *H. flaminius* (Dalm) is a parasite of *Cycloneda sanguinea* in the Argentine. This species was not identified amongst any of the parasites examined in the present work.

Finally one adult of *Cycloneda sanguinea* was found to be heavily infested with a fungus belonging to the order Laboulbeniales (Ascomycetes). The main bodies or receptacles of the fungus were found covering the ventral surface of the insect, but otherwise the insect appeared quite healthy. Although some people consider the fungus to be parasitic, others consider it as a commensal which is harmless to the host (Steinhaus, 1949) and the latter point of view appeared to be the correct one with regard to the present specimen.

**PROTECTIVE DEVICES**

Both species of ladybird show a common protective device, that of thanatoid (or "playing 'possum"). When disturbed they at once fall from their position on the plant and feign death, remaining so for one to two minutes. This device is effective for the insect usually escapes detection in a crack of the soil into which it falls.

Another protective device common to most Coccinellidae is reflex bleeding. This is the discharge of an oily, bitter, amber-coloured liquid through the pores in the membrane of the tibio-femoral joint, and the joints around the mouth-parts and at the base of the elytra. This fluid is
considered to be the blood of the insect (Kunath 1939 and Wigglesworth 1950) except in the genus *Epilachna* (Coccinellidae) where it is regarded as a product of the hypodermal gland-cells in the region of the "knee" (McIndoo 1916). The fluid is forced through the pores by a build up of blood pressure, brought about by strong contractions of the abdominal segments. The mechanism of reflex bleeding is however poorly developed in both *Ceratomegilla maculata* and *Cycloneda sanguinea*. Both species have to be roughly handled for any blood to appear, and it then only appears around the tibio-femoral joint. *Cycloneda sanguinea* bleeds more readily than *Ceratomegilla maculata*.

Reflex bleeding is universally regarded as defensive in action, for it is said to have an unpleasant bitter taste. Wigglesworth (1950) explained that it contains cantharidin and other caustic substances, which repel birds that might otherwise try and eat the coccinellids. Imms (1937) pointed out that several species of birds are known to eat coccinellids, although the bleeding probably serves as a protection against some. No birds were noticed eating the coccinellids during the present study.

**ECONOMIC IMPORTANCE**

*A. gossypii* is the major aphid pest of both maize and egg-plants in Trinidad. Its numbers are however kept down by direct and indirect mortality factors. The indirect mortality factors are:

1. Age of the plant
2. The presence of flea beetles (*E. parvula* F.)
3. The presence of lace bugs (*C. planaris* Uhler)

Factors (2) and (3) operate only on egg-plants. The direct mortality factors consist of several predacious and parasitic species, the more important predators being syrphids, lacewings and coccinellids. Neither the syrphids nor the lacewings were identified, but the numbers of their larvae observed were recorded, as also were the numbers of larval
Cycloneda sanguinea and Ceratomegilla maculata; e.g.:

<table>
<thead>
<tr>
<th>Total</th>
<th>Numbers Recorded</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larval Syrphidae</td>
<td>25</td>
<td>5%</td>
</tr>
<tr>
<td>Larval Neuroptera</td>
<td>36</td>
<td>7%</td>
</tr>
<tr>
<td>Larval Coccinellidae</td>
<td>441</td>
<td>88%</td>
</tr>
</tbody>
</table>

These figures leave little doubt as to the relative economic importance of the three groups.

The coccinellids observed on egg-plant and maize, were by no means confined to the two species mentioned above. Five other species were recorded from the two plants:

1. *Hyperaspis billoti* (Muls.)
2. *Curinus coeruleus* (Muls.)
3. *Hyperaspis donzelii* (Muls.)
4. *Cycloneda antillensis* (Crotch)
5. *Chilocorus cacti* (L.)

They are placed in order of their abundance, but the total numbers caught are less than 5% of Cycloneda sanguinea and Ceratomegilla maculata, i.e. 20 other Coccinellidae to at least 400 Cycloneda sanguinea and Ceratomegilla maculata. These figures show the greater importance of the two coccinellids under observation, in comparison to the rest of the aphid extermination complex.

Of the two species of Coccinellidae being discussed, Cycloneda sanguinea occurs in greater numbers than Ceratomegilla maculata on egg-plants, and there is only a slight numerical difference between the two on maize (see page 22). From the numerical point of view it would therefore appear that Cycloneda sanguinea is of greater beneficial importance than Ceratomegilla maculata. On the other hand it seems that Ceratomegilla maculata is of greater individual importance, for it exterminates more aphids in its larval period than does Cycloneda sanguinea in the corresponding period. The adults of the former will also eat 10-50 aphids a day more than adults of the latter species (see page 18).
Experiments were carried out which showed that a larva of *Ceratomegilla maculata* was capable of controlling (i.e. so that there was no increase in population) a colony of 40-45 aphids during its larval period. This however was under the stable conditions of the laboratory and it is doubtful if the size of the colony controlled would be the same under field conditions. As a general rule it was noticed that the aphids never increased to the extent of seriously damaging the plant in the field. How much of this is due to indirect mortality factors cannot be estimated. However from what has already been said the two coccinellids, *Ceratomegilla maculata* and *Cycloneda sanguinea*, are the most important causes of direct mortality. They can therefore be considered as of considerable importance in the control of *A. gossypii* on both maize and egg-plants. Of the two species *Cycloneda sanguinea* is considered the more beneficial, because it is more common and because the usefulness of *Ceratomegilla maculata* is somewhat impaired by its occasional phytophagous habit.
APPENDIX 1

The following is given as the literature ouipece of insect attacks by the two species of continental Aphidines: *Aphidinae* (Beehov) AND *Aphidinae* (Beehov). The data is taken from reports published over the last twenty years. If any incident has been reported as prey of one species of the continent in several countries, then only the most recent report has been referred to in the present work. All reports refer to the "Review of Applied Entomology".

Reports are as follows:

1. *Aphidinae* (Beehov, Faunoscece), Brusselowskii (W.) 1956.
4. *Aphidinae* (Beehov, Apulinae), The present author.

Reports are as follows:

1. *Aphidinae* (Beehov, Psocidae), Brusselowskii (W.) 1956.
3. *Aphidinae* (Beehov, Psocidae), The present author.

Reports are as follows:

1. *Aphidinae* (Beehov, Psocidae), Brusselowskii (W.) 1956.
A list is given of the different species of insects attacked by the two predacious coccinellids Ceratomegilla maculata (DeGeer) and Cycloneda sanguinea (L.). The list is taken from reports published over the last twenty years. If any insect has been reported as prey of one or other of the coccinellids on several occasions, then only the most recent report has been referred to in the present work. All reports refer to the "Review of Applied Entomology".

Both species are predacious on:

- **Dysdercus spp.** (Heteroptera, Pyrrhocoridae) - Szumkowski (W.) 1956.
- **Aphis gossypii** Glov. (Homoptera, Aphididae) - Szumkowski (W.) 1956.
- **Rhopalosiphum maidis** Fitch (Homoptera, Aphididae) - The present author.
- **Sipha flavia** Forbes (Homoptera, Aphididae) - Box (H.E.) 1952.
- **Toxoptera aurantii** Boy. (Homoptera Aphididae) - Wille (J.E.) 1944, reported it as prey of **C. sanguinea** L.; and the present author reported it as prey of **C. maculata** DeGeer.
- **Toxoptera graminum** Rond. (Homoptera, Aphididae) - Hayward (K.J.) 1941 reported it as prey of **C. sanguinea** L.; and Fenton (F.A.) and Fisher (E.H.) 1941 reported it as prey of **C. maculata** DeGeer.
- **Saccharosyndne saccharivora** Weetw. (Homoptera, Delphacidae) - Szumkowski (W.) 1956.
- **Agrotis repleta** Wlk. (Lepidoptera, Noctuidae) - Szumkowski (W.) 1956.
- **Alabama argillacea** Hb. (Lepidoptera Noctuidae) - Szumkowski (W.) 1956.
- **Feltia subterranea** F. (Lepidoptera, Noctuidae) - Szumkowski (W.) 1956.
Heliothio armigera Hb. (Lepidoptera, Noctuidae) - Newson (L.D.) and Smith (C.E.) 1950.

Laphygma frugiperda S.& A. (Lepidoptera, Noctuidae) - Szumkowski (W.) 1956.

Prodenia latifascia Wlk. (Lepidoptera, Noctuidae) - Szumkowski (W.) 1956.

Sacadodes pyralis Dyar. (Lepidoptera, Noctuidae) - Szumkowski (W.) 1954.

Diatrae lineolata Wlk. (Lepidoptera, Crambidae) - Szumkowski (W.) 1956.

C. sanguinea L. has also been reported as being predacious on:

Asterolecanium miliaris Boisd. (Homoptera, Coccidae) - Bartlett (K.A.) 1940.

Heliothis virescens F. (Lepidoptera, Noctuidae) - Wille (J.E.) 1951.

The present author found that if other forms of food were withheld, then larvae of C. sanguinea L. would prey on nymphaL forms of Corythaica planaria Uhler (Heteroptera, Tingidae).
APPENDIX 2

If any name is followed by an asterisk, then only the review in the "Review of Applied Entomology" has been used.


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Wille, J.E. (1951) - Biological Control of certain Cotton Insects and the Application of new organic Insecticides in Peru.


APPENDIX 3
LIST OF FIGURES

Fig. 1 - A. Egg of Cycloneda sanguinea.
        B. Egg of Ceratomegilla maculata.

Fig. 2 - Larva of Cycloneda sanguinea.

Fig. 3 - Larva of Ceratomegilla maculata.

Fig. 4 - Pupa of Cycloneda sanguinea.

Fig. 5 - Pupa of Ceratomegilla maculata.

Fig. 6 - Adult of Cycloneda sanguinea.

Fig. 7 - Adult of Ceratomegilla maculata.
FIG. 4.

3.0 MM.