

Parasitoids and Predators of the Sugarcane Soft Scale *Pulvinaria Tinuivalvata* (Newstead) and Their Role as Biological Control Agents

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Abstract: In the last years, the sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae) has become a major pest of sugarcane plants. Results of the present studies indicate that, the primary endoparasitoid *Coccophagus semicircularis* (Förster) (Hymenoptera : Aphelinidae) is the most important parasitoid and represent about 92.4 % of the emerging parasitoids. It is common and emerge during summer and autumn months, and normally one parasitoid emerge from one parasitized soft scale. In few cases more than one parasitoid emerge. The encyrtid primary endoparasitoid *Microterys flavus* (Howard) (Hymenoptera : Encyrtidae) represents about 7.6% of the total emerging parasitoids and only one parasitoid emerge from one single host. A key is given for distinguishing between them. Biological studies on *C. semicircularis* (Förster) indicate that, it has three larval instars, prepupal and pupal stages. The total duration of different stages including incubation period of eggs (2.6 ± 0.79 days) reached an average of 30.9 ± 2.87 days. The sex ratio in field samples was 9 ♀ : 1 ♂ and in laboratory rearing 9.9 ♀ : 0.1♂. The longevity of female parasitoid ranged between 5 and 25 days (13.4 ± 7.2) and that of male ranged between 2 and 12 days (5.08 ± 2.8) when both of them fed on bee honey. Parasitoid females prefer 3rd nymphal stage and full grown soft scales more than 2nd nymphal stage. Each soft scale host received one egg per insertion of ovipositor and normally one egg deposited per one host. The female deposited an average of 31.7 ± 4.3 eggs (25-38 eggs) throughout its life. Field studies at Mallawi, Minya Gov. and N. Hammadi, Qina Gov. indicate that, *P. tenuivalvata* (Newstead) is active during summer and autumn and all stages are found during periods of activity, which means overlapping of generations. The percentage of parasitism on *P. tenuivalvata* (Newstead) reached averages of 39.2 %, 19.1%, 6 % and 13.3% during the years 2003, 2004, 2005, 2006 respectively at Mallawi, and 36%, 18.6 % and 19.2% during the years 2003, 2004 and 2005 respectively at N. Hammadi, and it ranged between 1% - 10% during the years 2007, 2008, 2009 at N. Hammadi. The larvae of the polyphagous predator *Chrysoperla carnea* (Stephens) (Neuroptera : Chrysopidae) have been seen in few numbers feeding upon *P. tenuivalvata* (Newstead) in sugarcane fields. Under laboratory condition, high percentage of mortality (72.2 % and 51.6 %) had been found during 2nd and 3rd larval stages of *C. carnea* (Stephens), when it reared on *P. tenuivalvata* (Newstead). In spite of the Coccinellid beetle *Chilocorus bipustulatus* (L.) prey successfully upon *P. tenuivalvata* (Newstead) under laboratory conditions. Field experiments proved that, it can not be used as biological control agent under field conditions.

Keywords: *Pulvinaria tinuivalvata* (Newstead), *Coccophagus semicircularis* (Förster), *Microterys flavus* (Howard), *Chrysoperla carnea* (Stephens), *Chilocorus bipustulatus* (L.)

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is the most important crop grown in Egypt for sugar production, refining and distillation of alcohol and production of yeast and molasses. The total sugarcane cultivated area reached about 354 thousands feddan in middle and Upper Egypt. In the last years, the sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae) has become a major pest of sugarcane plants in Egypt (El-Serwy, 2001, Ali, *et al.*, 2000, Ghabbour, 2001, Shalaby, 2002, Abd El-Moniem, 2003, Azab *et al.*, 2003, Abd El-Samea, 2004, Khew, 2005) it attacks leaves causing a great reduction in yield and sugar production. In spite of wide application of insecticides in Middle and Upper Egypt to control it, its population increased annually and spread in most sugarcane fields. (Hamed, Naglaa (2009). Since the role of the parasitoids and predators have not been thoroughly studied before, the present work was initiated with the aim of Survey of the natural enemies (parasitoids and predators) of the soft scale insect *Pulvinaria tenuivalvata* (Newstead), morphological, biological and ecological studies on most efficient parasitoids *Coccophagus semicircularis* (Förster)

(Hymenoptera : Aphelinidae), and *Microterys flavus* (Howard) (Hymenoptera : Encyrtidae), role of parasitoids in regulating the population of *P. tenuivalvata* (Newstead) under field conditions in Minya and Qina Gov., assessment the role of *Chrysoperla carnea* (Stephens) (Neuroptera : Chrysopidae) as a predator of *P. tenuivalvata* (Newstead), and studying the possibility of using the Coccinellid beetle *Chilocorus bipustulatus* (L.) to control *P. tenuivalvata* (Newstead) on sugarcane plants under field conditions.

MATERIALS AND METHODS

Rearing of host insect:

The soft scale insect *P. tenuivalvata* (Newstead) was collected from sugarcane fields in Giza, Minya and Qina Gov. A stock culture of it was reared on sugarcane seedlings planted in plastic pots kept under laboratory condition of 22.2 ± 1.4 C° and 45 ± 5.6 RH. and 10 h.E. lighting. Another culture of *P. tenuivalvata* (Newstead) was reared on sugarcane seedling and Napier grass (*Pennisetum purpureum* Schumach.) in a glass house (Biological control Res. Department, ARC) under semi controlled conditions of 30.9 ± 2.2 C° and 62 ± 4.3 RH.

The fresh green leaves of the sugarcane seedling were covered with the heavily infested sugarcane leaves collected from the fields. On drying, the naturally infested leaves, the young crawlers of the soft scale move from the naturally infested leaves to the exposed sugarcane seedling and settle down on it.

Rearing of the parasitoid *C. semicircularis* (Förster):

When nymphs of soft scale insect *P. tenuivalvata* (Newstead) reached the appropriate stage for parasitization (2nd, 3rd and full-grown females), the artificially infested sugarcane seedlings were used for rearing the parasitoid by exposing it to a number of males and females of the parasitoid for oviposition.

Survey of parasitoids of *P. tenuivalvata*:

Samples of sugarcane leaves infested with *P. tenuivalvata* (Newstead) collected from sugarcane fields on different localities in Giza, Minya, Qina and Aswan Gov. these samples were kept in laboratory and confined in glass or plastic Jars 28 cm h. and 14cm Ø for securing and identifying of the emerging parasitoids. The emerged parasitoids were collected and identified in Biological control Res. Department, ARC by Prof. Dr. A. Raouf Hamed.

Biological studies:

Incubation period:

P. tenuivalvata (Newstead) soft scales reared on sugarcane seedling were exposed to the parasitoid *C. semicircularis* (Förster), under laboratory conditions of 22.2 ± 1.4 C° and 45 ± 5.6 RH. for two hours. After which the parasitoids were removed. A certain number of scales were removed from the plant and dissected daily for a period of one week to count the number of hatched eggs

Number of eggs per one insertion of ovipositor:

When a single insertion took place, the host was immediately removed and dissected.

Number of eggs per host:

A large number of the soft scale *P. tenuivalvata* (Newstead) were exposed to females of *C. semicircularis* (Förster) for a period of 24 hours. The soft scales were removed one day after exposure and dissected. The number of eggs found in each individual host was recorded.

Effect of stage of host on parasitism:

A large equal numbers of different stages of *P. tenuivalvata* (Newstead) were simultaneously exposed to adequate number of *C. semicircularis* (Förster) females for a period of 24 hours. Percentage of parasitism was determined for each stage

Fecundity:

Since mating was not observed at laboratory conditions. Fecundity of *C. semicircularis* (Förster) was studied for virgin females only. Virgin females were confined individually in glass tubes (2.5x12cm) provided with fine droplets of honey and part of sugarcane leaf infested artificially with 2nd, 3rd nymphal stage and full grown females of *P. tenuivalvata* (Newstead). The part of the infested sugarcane leaf was removed daily and another new part was provided into

the tube. The soft scale insects, were dissected to determine the number of eggs deposited by the parasitoid female daily and throughout its life.

Sex ratio:

The sex ratio of *C. semicircularis* (Förster) was estimated in samples of parasitoids collected from the field and in some individuals obtained from laboratory rearing

Longevity:

The newly emerged parasitoids had been isolated singly in glass vials 2.5x12cm.. Longevity of females and males was estimated, when they left without food and when they fed on bee honey till the death of the tested parasitoids.

Number of parasitoids emerging from one host under laboratory rearing and under natural conditions:

A randomized sample of parasitized *P. tenuivalvata* (Newstead) soft scales were taken from a laboratory rearing of the parasitoid *C. semicircularis* (Förster) and kept singly in glass tubes (6x1cm.) till emergence of parasitoids. The number of parasitoids emerged from each soft scale was recorded. A randomized sample of 50 parasitized soft scales had been collected from sugarcane fields at Minya Gov. during August 2003, and kept singly in glass tubes (6x1cm.) till emergence of parasitoids (the parasitoid pupal stage can be seen easily inside the soft scales). The number of parasitoids emerged from each soft scale was counted.

Morphology of immature stages:

The morphology of immature stages had been studied from fresh material of laboratory rearing of the parasitoid *C. semicircularis* (Förster)

Sampling and counting for estimation of population density of *P. tenuivalvata* on sugarcane plants:

Once every month a sample of 50 leaves of sugarcane plants were taken at random. Sampling began from August 2003 to the end of 2005 at Minya Gov. and from September 2003 to August 2005 at Qina Gov. Leaves were taken from different parts of the field and from middle and Upper strata of sugarcane plants which are the preferred parts of the plant for infestation. The soft scales found on these leaves were counted in the laboratory and classified into the following groups:

- a) Full grown females.
- b) Middle grown female nymphs (2nd and 3rd nymphal stages)

The obtained result were recorded.

Sampling for estimating percentage of parasitism:

After counting of the soft scale insects *P. tenuivalvata* (Newstead) on the above mentioned at random sample of 50 leaves of sugarcane plants collected from the two fields of study, at random samples consist of 50 soft scale insects were taken from these leaves. The soft scales were dissected and classified into the following groups:

- a) Alive unparasitized soft scales.
- b) Parasitized soft scales having larvae of parasitoids.
- c) Parasitized soft scales having pupae of parasitoids.

It is be noted that, soft scales having emerging holes indicating previous emergence of adult parasitoids may be occurred during a period before date of sampling and did not represent actual parasitism during sampling. Therefore this category was negligible. The percentage of parasitism was estimated for every sample according to the following formula

$$\text{Percentage of parasitism} = \frac{\text{No. of parasitized soft scales}}{\text{Total No. of soft scales of the sample}} \times 100$$

Rearing of the predator *Chrysoperla carnea* (Stephens) :

For rearing of the predator larvae, adults of *C. carnea* (Stephens). were collected from the fields and confined for oviposition in plastic jars 12 cm (Ø) x12cm. H., covered with a piece of muslin and tightly held by a rubber band. The jars are covered from inside with fine paper as site for oviposition. The eggs of the predator were collected daily and transferred to other jars. The newly hatched larvae were provided with aphids which maintained on Faba beans seedlings, as food till pupation. The needed larval stages for experiments were obtained any time from such culture.

Studying the possibility of using the Coccinellid beetle *Chilocorus bipustulatus* (L.) to control *P. tenuivalvata* under field conditions:

A wooden cage 1m. (W) x1m. (L) x 2.5(H.) was used for releasing the predatory beetle in the field. All sides of the cage are covered with muslin except of the bottom. About 25-30 sugarcane plants infested with the soft scale *P. tenuivalvata* (Newstead) were found inside the cage Fig. (31). Before releasing of the predatory beetle inside the cage the total number of nymphal and adult stages of *P. tenuivalvata* (Newstead) / 50 at random leaves of sugarcane had been recorded. Field observations had been done for about 4 weeks. On the 4th week after release, the number of all stages of *P. tenuivalvata* (Newstead) found on 50 leaves was again recorded to know if the population of the soft scale insect decreased after releasing of the predatory beetles or not. In addition the number of eggs, larvae and pupae of the predatory beetles were recorded also if it had been found on the sugarcane plants inside the cage.

RESULTS AND DISCUSSION

The following are the parasitoids and predators secured from different localities of Middle and Upper Egypt during the course of the present work:

Parasitoids:

1- *Coccophagus semicircularis* (Förster) (Order: Hymenoptera, Fam.: Aphelinidae):

A primary endoparasitoid of *P. tenuivalvata* (Newstead). Represent about 92.4% of the emerging parasitoids (Table 1). It is the most important parasitoid of *P. tenuivalvata* (Newstead) in Egypt. It emerged during summer and autumn months, specially during July, August and September. It is common in middle and upper of Egypt. Normally one parasitoid emerge from one single host. In few cases more than one parasitoid emerge.

2- *Microterys flavus* (Howard) (Order: Hymenoptera, Fam.: Encyrtidae):

An encyrtid primary endoparasitoid of *P. tenuivalvata* (Newstead), it represent about 7.6% (Table1) of the total number of emerging parasitoids. Only one parasitoid emerge from a single host. It emerged in few numbers during summer and autumn months. It is less common than *C. semicircularis* (Förster)

Form literature, it was found that, some research workers mentioned about 13 species of parasitoids and predators as biological control agents for *P. tenuivalvata* (Newstead) in Egypt (El- Serwy 2001) and some others mentioned few species. Some of the mentioned species are not known as parasitoids of *P. tenuivalvata* (Newstead) and some other species are not belong to Egypt or Africa. If the soft scale insect *P. tenuivalvata* (Newstead) has so large number of parasitoids and predators in Egypt, why it spread then in all sugarcane fields all over the country in short time, and we were forced to use chemical insecticide intensively to stop its spreading.

Predators

Chrysoperla carnea (Stephens), (Order : Neuroptera, Fam. : Chrysopidae) :

The larvae of this predator have been seen in few numbers feeding upon the soft scale insect *P. tenuivalvata* (Newstead) in sugarcane fields in Minya, Qina and Aswan Gov. during summer and autumn months. It is well known that, *C. carnea* is polyphagous predator and prey upon *Aphis spp.*, nymphs of armored and soft scale insect. Ali, (2001) indicated that *C. carnea* (Stephens) larvae in case of feeding on the soft scale insect *P. tenuivalvata* (Newstead), the larvae can complete their duration till adult stage, but percentage of mortality during larval stage was very high (64.7%). Therefore an assessment of the role of larvae of *C. carnea* (Stephens) as predator for *P. tenuivalvata* (Newstead) will mentioned later.

Key to distinguish between *Coccophagus semicircularis* (Förster) and *Microterys flavus* (Howard) :

The following key is given to distinguish between *C. semicircularis* (Förster) (Aphelinidae) and *M. flavus* (Howard) (Encyrtidae). The key based on distinguishing characters of females and males which are easily to found.

1. The body is black with the larger part of the scutellum striking yellow. The scutellum is densely covered with setae and has one large pair of blackish setae. Male colour black as in female except for the scutellum. Which is not yellow (2)

1'. Body and head largely yellowish brown, some what shiny, but without a metallic luster (2')

2. Antenna brownish with eight segments, the funicle and club both with three segments each (Fig.4) (3)

2'. Antenna 11 segments, with scape, pedicel and first three funicle segments brownish, the distal three funicle segments snow-white. The club blackish in contrast (3')

3. Legs yellow whitish, except for the fore, middle and hind coxae and hind femur which are dark (4)

3'. Legs yellowish, a little paler than the body, without any dark markings (4')

4. Female and male wings hyaline *Coccophagus semicircularis* (Förster) (Fig.1)

4. Fore wing of female with a characteristic pattern of two hairy cross bands. *Microterys flavus* (Howard) (Fig.2,5).

Distinguishing between *Coccophagus semicircularis* (Förster) and other species of *Coccophagus* associated with soft scale insects:

The genus *Coccophagus* is one of the known groups of the family Aphelinidae and comprises a large number of species, about 60 of which occur in Africa (Prinsloo, (1984), Annecke (1964), Annecke *et al.* (1974).

The species of genus *Coccophagus* can be distinguished by their medium size, usually about 1 mm. in length, fairly strongly sclerotized. Colour yellow or black, or black with some parts marked with yellow. Legs pale or marked with blackish, wings hyaline without a pattern of darker colour. Male and female similar in structure. Antenna with eight segments, the funicle and club both with three segments each. The scutellum with three pairs of long strong setae or less, tarsi five segments (Prinsloo, 1984). The species, which are dealt with here (Fig. 3) are *C. semicircularis* (Förster), *C. cowperi* Girault, *C. pulvinariae* Compere, *C. basalis* Compere, *C. catherinae*. Annecke.

Table (1): Number of the parasitoids, *Coccophagus semicircularis* (Förster) and *Microterys flavus* (Howard) emerged from some field samples of *P. tenuivalvata* (Newstead) on sugarcane plants.

Sampling date	Locality	Number of emerged parasitoids			% of <i>C. semicircularis</i>
		<i>C. semicircularis</i>	<i>M. flavus</i>	Other spp.	
2003-2009	Giza, Minya, Qina	559	46	0	92.4%

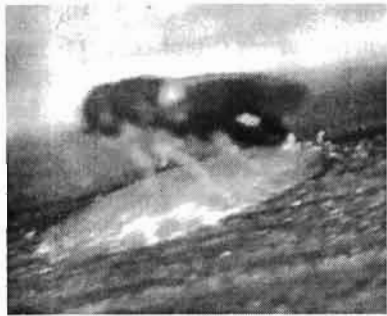


Fig (1): *Coccophagus semicircularis* (Förster)

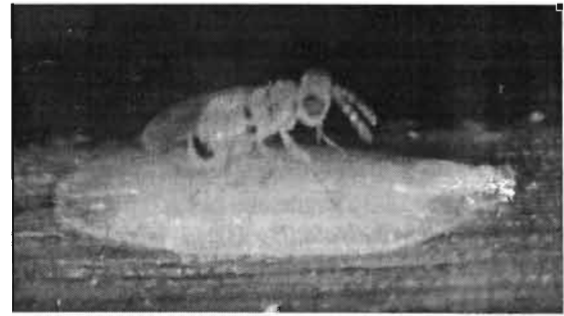


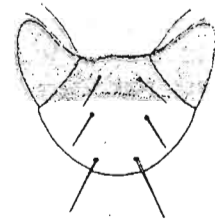
Fig (2): *Microterys flavus* (Howard)



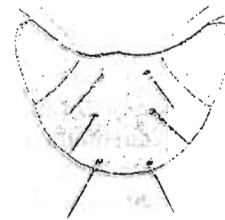
1 a- *C. semicircularis* (Förster)



1 b- *Coccophagus semicircularis* (Förster)



2 - *C. basalis* Compere



3- *C. Pulvinariae* compere
C. catherinae Annecke
C. cowperi Girault

Fig (3): Female sutellum of different *Coccophagus* spp.
1a,2,3 after Prinsloo (1984)

1b- female scutellum of *C. semicircularis* (Förster) emerged from *P. tenuivalvata* (Newstead) obtained from infested sugarcane fields in Minya, Qina, Aswan Gov. (Egypt) during the course of this study.

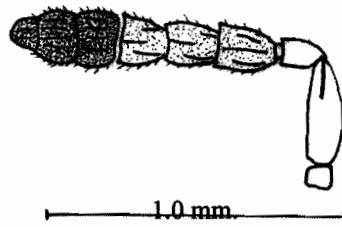


Fig. (4): Antenna of *C. semicircularis* (Förster)

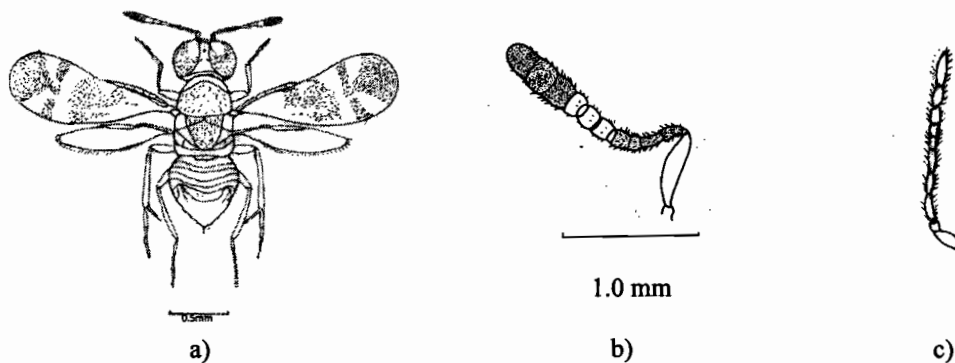


Fig. (5): a) The encyrtid endoparasitoid *M. flavus* (Howard) (Female)
b) Antenna of female. c) Antenna of male

Biological studies on *Coccophagus semicircularis* (Förster):

Oviposition:

From observation made during the studies, it was found that, the female of *C. semicircularis* (Förster) walks among the hosts at random and the host is perceived at a very short distance. The female parasitoid first examines the host *P. tenuivalvata* (Newstead) carefully with the antenna. Then it mounts upon the soft scale and another examination is made by tapping the soft scale body with the antenna. Then it bends the end of the abdomen and insert the ovipositor through the wax of the dorsal of the soft scale and an egg is deposited inside the body of the soft scale.

Number of eggs per insertion of ovipositor:

It was found that only one egg was deposited per insertion. On dissection of about 27 hosts, it is proved that each host received one egg per insertion of ovipositor.

Number of eggs deposited per one host:

Date obtained (Table 2), show that, under the condition of the laboratory experiment, the female parasitoid of *C. semicircularis* (Förster) deposited normally one egg per one host of *P. tenuivalvata* (Newstead). The soft scale insects, which exposed to the parasitoid females, represent different developmental stages (2nd, 3rd nymphal stages and full grown females). All exposed stages were accepted by the parasitoid as hosts for depositing their eggs.

Effect of stage of host on parasitism:

The obtained results (Table 3) show that, females of the parasitoid seem to prefer 3rd nymphal stage and full grown female soft scales more than 2nd nymphal stage. The percentage of parasitism reached 80 % and 76 % in 3rd nymphal stage and full grown females respectively, while it reached 24 % in case of 2nd nymphal stage.

Morphology of immature forms:

Deposited egg (Fig.6):

The deposited egg is of hymenopterous form, yellowish white in colour. The egg is about 4-5 times as long as broad, with an average of 0.21 ± 0.02 mm. in length and 0.05 ± 0.01 mm. in width. The deposited egg lies free in the body cavity of the host near the body wall

First instar larva (Fig.6):

The first instar larva measures about 0.34 ± 0.07 mm. in length and 0.07 ± 0.004 in width. The larva lies free in the body cavity. The stomach is a dilated blind sac, which attains the colour of fluids of the host insect. The mandibles (Fig7) are very small and slightly arched.

The second instar larva (Fig.6):

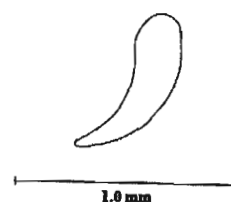
The second instar larva measures in the average about 0.62 ± 0.18 mm. in length and 0.20 ± 0.03 mm. in width. The stomach still closed as a blind sac. Trachea and spiracles are not visible. The distal ends of the mandibles (Fig.7) are slightly darker in colour.

Table (2): Number of eggs deposited by female of *Coccophagus semicircularis* (Förster) in one soft scale of *Pulvinaria tenuivalvata* (Newstead)

Stage and number of host exposed		Number of dissected parasitized hosts	Number of eggs per one host			Total number of deposited eggs
Stage	Number		One egg	Two eggs	Three eggs	
2 nd nymphs	152	31	31	0	0	31
3 rd nymphs	58	45	44	1	0	45
Full grown females	29	25	25	0	0	25
Total	239	101	100	1	0	101

Table (3): Effect of stage of the soft scale *Pulvinaria tenuivalvata* (Newstead) on parasitism by *Coccophagus semicircularis* (Förster)

Stage of soft scale	Number of soft scale	Number of dissected soft scales		% parasitism
		Unparasitized	Parasitized	
2 nd nymphs	50	38	12	24
3 rd nymphs	50	10	40	80
Full grown females	50	12	38	76

deposited egg of *C. semicircularis* (Förster)The first instar larva of *C. semicircularis* (Förster)X10
X4The second instar larva of *C. semicircularis* (Förster)X10
X4The third instar larva of *C. semicircularis* (Förster)**Fig. (6):** Immature forms of *C. semicircularis* (Förster)**The third instar larva (Fig. 6):**

The larva of 3rd instar measures about 1.15 ± 0.38 mm. in length and 0.55 ± 0.14 mm. in width. The stomach is a blind sac till the end of this larval instar and before prepupal stage, the stomach be opened from the posterior end. The spiracles and trachea are not visible. The distal ends of the mandibles (Fig.7) are more darker in colour.

The third instar larva (Fig. 6):

The larva of 3rd instar measures about 1.15 ± 0.38 mm. in length and 0.55 ± 0.14 mm. in width. The stomach is a blind sac till the end of this larval instar and before prepupal stage, the stomach be opened from the posterior end. The spiracles and trachea are not visible. The distal ends of the mandibles (Fig.7) are more darker in colour.

Prepupa:

The prepupa is yellow in colour, about 1.20 ± 0.15

mm. in length and 1.12 ± 0.3 mm. in width. The prepupa lies in the empty body of the host with the ventral side directed towards the dorsal surface of the host. It is spindle in shape. Stomach is opened. The imagend eyes faint developed.

Pupa (Fig. 8):

The newly formed pupa is yellow in colour, with the compound eyes faint brownish in colour. The pupa becomes gradually brown black in colour. Head, thorax, abdominal segments legs and antenna become clear and distinct, days prior to emergence. The pupa measures about 1.36 ± 0.16 mm. in length and about 0.63 ± 0.11 mm. in width.

Duration of different larval instars, prepupa and pupal stages of *C. semicircularis* (Förster):

The parasitoid *C. semicircularis* (Förster) has 3 larval instara. Duration of different stages is given in Table (4).

The results indicate that, under the conditions of the experiment, the incubation period ranged between 4 days and one day with an average of 2.58 ± 0.79 days. The first larval instar lasted a period of 4 days to 8 days with an average of 6.08 ± 1.24 days. The second larval instar lasted a period of 5 to 9 days with an average of 6.75 ± 1.42 days. The third larval instar takes a period ranged between 3 and 7 days with an average of 5 ± 1.2 days. The prepupal period ranged between 1 and 2 days with an average of 1.16 ± 0.38 days. The pupal stage lasted a minimum of 6 days and a maximum of 11 days with an average of 8.8 ± 1.4 days. The total duration of

different stages of *C. semicircularis* (Förster) including incubation period reached an average of 30.4 ± 2.87 days.

Number of parasitoids emerging from one host under laboratory rearing and under natural conditions:

One parasitoid pupa is always found in one soft scale *P. tenuivalvata* (Newstead) and only one adult parasitoid emerges from each soft scale reared under laboratory conditions.

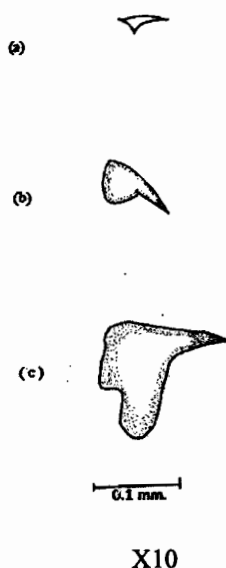


Fig. (7): Mandibles of larval instars of *C. semicircularis* (Förster) [(a) 1st, (b) 2nd, and (c) 3rd]



Fig. (8): Pupa of *C. semicircularis* (Förster) dorsal view

Table (4): Duration of *C. semicircularis* (Förster) on *P. tenuivalvata* (Newstead) in days under laboratory condition of 22.2 ± 1.4 C° and 45 ± 5.6 % RH.

	Duration (days)		
	Minimum	Maximum	Average + Sd.
Incubation period	1	4	2.58 ± 0.79
1 st larval instar	4	8	6.08 ± 1.24
2 nd larval instar	5	9	6.75 ± 1.42
3 rd larval instar	3	7	5 ± 1.2
Perpupa	1	2	1.16 ± 0.38
Pupa	6	11	8.8 ± 1.4
Total			30.4 ± 2.87

Table (5): No. of parasitoids emerged from one soft scale insect *Pulvinaria tenuivalvata* (Newstead) (field samples).

No. of emerged parasitoids	% of cases in collected samples (n = 50)
1	76%
2	10%
3	10%
4	2%
5	2%

Under natural conditions, as shown in table (5), it was found that, 76% of the parasitized soft scales give only one parasitoid, 10 % of them give 2 parasitoids and 10 % give three parasitoids. In only 2% of the collected sample, 4 or 5 parasitoids are emerged from one single host insect. In another field sample collected at random from sugarcane field at Qina Gov. during September 2003, a total number of 8 parasitoids are emerged from one soft scale (rare case) as a result of super parasitism.

Sex ratio of *C. semicircularis* (Förster):

The total number of the parasitoids obtained from some at random field samples collected during summer and autumn months reached 331 parasitoids. 297 of them were females representing about 89.7 %, 34 were Males representing 10.3 %. The sex ratio of *C. semicircularis* (Förster) in the field was about 9♀ : 1♂. From a laboratory rearing under glass house conditions (30.9 C° ± 2.2 and 62 RH. ±4.3) 86 parasitoids were females and only one of them was male. The sex ratio was (9.9 ♀: 0.1 ♂).

Differentiation between female and male of *C. semicircularis* (Förster):

The scutellum of female is densely covered with fine setae and has one pair of black long setae and it is yellow. The scutellum of male is not yellow. Ovipositor of female at most slightly protruding at the apex of the gaster, and easily distinguished on the ventral side of the sub-triangular abdomen. Male genitalia can be distinguished and distinct on the ventral side of the sub-oval abdomen.

Longevity of *C. semicircularis* (Förster) under different conditions:

Both males and females have a short longevity under starvation condition. The longevity of females ranged between 3 and 5 days with an average of 4±1 days. Longevity of males ranged between 2 and 3 days with an average of 2.25 ± 0.5 days.

The longevity of female parasitoid ranged between 5 and 25 days with an average of 13.4 ± 7.2 days when it feeds on bee honey, while longevity of male ranged between 2 and 12 days with an average of 5.08 ± 2.8 days.

Fecundity of *C. semicircularis* (Förster):

Since mating was not observed under laboratory conditions and numbers of male parasitoid were very low, fecundity of *C. semicircularis* (Förster) virgin females has been studied under laboratory conditions of 22.2 ± 1.4 C° and 45 ± 5.6 RH. The obtained results Table (6) show that, the female deposited an average of 31.7 ± 4.3 eggs with a minimum of 25 eggs and a maximum of 38 eggs throughout its life which extended to 13.4 days in the average. The daily number of eggs deposited per female ranged between 0 and 5 eggs with an average of 2.4 ± 0.3 eggs. No preoviposition period was found. The oviposition period ranged between 11 and 14 days with an average of 12.7 ± 0.9 days. Intervals of rest days was not found. The postoviposition

period was not found in most cases except in two cases, it was one day each.

Host range of *C. semicircularis* (Förster):

Some soft scale species had been recorded as host insects for the aphelinid endoparasitoid *C. semicircularis* (Förster); the soft brown scale, *Coccus hesperidum* L. on citrus in R. S. Africa (Prinsloo, 1984), the red striped sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) (El Serwey, 2001), the horse chestnut scale *Pulvinaria regalis* Canard on ornamental trees in Germany (Arnold *et al.*, 2003).

During the course of the present study (2003- 2010) *C. semicircularis* (Förster) was found to be the most important parasitoid on *Pulvinaria tenuivalvata* (Newstead) in Middle and Upper Egypt in all investigated infested sugarcane fields.

Fluctuations of population density of the sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) under field conditions:

The studies on fluctuations of population density began early during 2003, 2004 and 2005. Two localities were used for sampling. The first locality was an infested sugarcane field at Hafez village, Mallawi, Minya Gov. to represent Middle of Egypt. Sampling began from August 2003 and continued to the end of 2005. The second locality was an infested sugarcane field at Nag Hammadi, Qina Gov. about 400 km. south of Minya Gov. to represent Upper Egypt. Sampling began from September 2003 and continued to the end of 2005.

The obtained results indicate that, the soft scale *P. tenuivalvata* (Newstead) is active during summer and autumn months. All stages of the soft scale are found during all periods of activity and abundance which means an overlapping of generations. In general the population density of the sugarcane soft scale during 2004 and 2005 was less than that of 2003.

The obtained data at Mallawi, Minya Gov., (Fig. 9) show that, during the first year of study (2003), the number of 2nd nymphal stage increased gradually from 300/50 leaves during 1st week of August to reach a peak of 1138/50 leaves on 2nd week of September, then it dropped down sharply to reach bottoms of 34 and 120/50 leaves on last week of Oct. and 2nd week of November respectively. The same trend was found in case of 3rd nymphal stage. (435/50 leaves) and that of full grown females (101/50 leaves), which occurred on the 2nd week of September. It is to be noted that 3rd and full grown females are preferred for parasitisation by females of *C. semicircularis* (Förster).

In the second and 3rd years of investigation, the same pattern of fluctuations occurred during summer and autumn. The total number of all stages reached its maximum of 920 and 160 soft scales /50 leaves on 2nd W. of September in both of them. The population density reached its lowest level in winter and late autumn.

Table (6) Fecundity of *Coccophagus semicircularis* (Förster)

	Total No. of deposited eggs/fem.	Daily No. of deposited eggs per one female			Pre-oviposition period	Oviposition period	Post-oviposition period	Longevity (days)
		Min.	Max.	Average				
Min.	25	0	4	2.0	0	11	0	11
Max.	38	1	5	2.9	0	14	1	14
Average	31.7±4.3	0.8±0.4	2.4±0.5	2.4±0.3	0	12.7±0.9	0.8±0.4	13.0±1.1

The second locality (Qina Gov.) represent the changes of population density of *P. tenuivalvata* (Newstead) in sugarcane fields in Upper Egypt (Fig. 10). In the first year of investigations (2003), the peak of total number of different stages of the soft scale (831/50 leaves) occurred on the 3rd week of October. The numbers decreased to its minimum during the end of the year. In the second year of investigation (2004), The total number of different stages reached its highest peak (605 /50 leaves) on the second week of September. In the third year of investigation (2005), the total number of different stages of soft scale reached its maximum of 317 /50 leaves on the 3rd week of August. In general population density of *P. tenuivalvata* (Newstead) was lower during the years 2004 and 2005 than that of the year 2003, the population density at Mallawi, Minya Gov. was higher than that of N. Hammadi, Qina Gov.

Role of parasitoids in controlling the sugarcane soft scale *P. tenuivalvata* (Newstead) under field conditions:

During the course of this work, an evaluation of the role of parasitoids as a mortality factor of the sugarcane soft scale insect has been done. Monthly field samples were taken from infested sugarcane fields at Mallawi, Minya Gov. to estimate percentage of parasitism and N. Hammadi, Qina Gov. during the years 2003, 2004 and 2005, in addition to some check up samples, which were taken from 2006-2009.

No single case of multiple parasitism has been found during studying parasitism on *P. tenuivalvata* (Newstead) under field conditions. The female of the primary endoparasitoid *C. semicircularis* (Förster) accept soft scales, which previously parasitized by females from its own species. In spite of the fact that, female of *C. semicircularis* (Förster) deposit normally one egg per host, 73 and 62 cases of super parasitism are found by dissecting of parasitized soft scales, which collected from the fields at Mallawi, and N. Hammadi, respectively. No secondary parasitoids were found on the primary parasitoid *C. semicircularis* (Förster) during the course of the present work.

Percentage of parasitism on *P. tenuivalvata* (Newstead) under field conditions:

In the first year of investigations (2003) at Mallawi, Minya Gov. (Fig. 11), the percentage of parasitism on *P. tenuivalvata* (Newstead) ranged between 30 % and 50%, with an average of 39.2 %. The percentage of parasitism was high during summer and autumn months and reached its highest peak of 50 % on 20th of Oct. 2003. In the second year of investigations (2004), the percentage of parasitism was lower than that of the first year. It ranged between 2 % and 30 % with an average

of 19.1 %. The highest peak of 30 % occurred on the 4th week of August.

In the third year of investigations (2005), the percentage of parasitism ranged between 2 % on 1st week of June and 12 % on 2nd week of Oct, with an average of 6 %.

In general the high percentages of parasitism were coincided with the periods of high populations of the host insect. It is also clear that, the percentage of parasitism deceased year after year. This may be attributed to the successive use of insecticides in large areas year after year

In the first year of investigation at N. Hammadi, (Fig. 12) the percentage of parasitism on *P. tenuivalvata* (Newstead) from August till December 2003 ranged between 16% and 56%, with an average of 36%. The peak of parasitism occurred on the third week of Oct.

In the second year of investigations (2004), at N. Hammadi, almost the same trend of parasitism fluctuations was found with minor changes. The percentage of parasitism ranged between 6% on the third week of June and 30% on the second week of November, with an average of 18.6 %. In the third year of investigations (2005), the percentage of parasitism ranged between 4% and 40%, with an average of 19.2 %. The lowest percentage occurred on first week of June, then it increased again to reach its highest peak of 40% on the last week of September. It has to be noted that, the parasitized soft scales, which harboring living larvae and pupae of the primary endoparasitoid *C. semicircularis* (Förster) were found during all summer and autumn months. That indicate overlaping of generations of the parasitoid.

The results of check up samples show that, the percentage of parasitism on *P. tenuivalvata* (Newstead) by *C. semicircularis* (Förster) at Mallawi during (July, August and Sept.) 2006 ranged between 2% and 24% with an average of 13.3% and at N. Hammadi during the years 2007, 2008, and 2009 ranged between 1% and 10%. It is clear that, the percentages of parasitism on *P. tenuivalvata* (Newstead) in sugarcane fields in Mallawi, and N. Hammadi, decreased gradually year after year. This may be attributed to wide use of insecticides in large areas as has been mentioned before.

Suitability of *P. tenuivalvata* (Newstead) as prey for larvae of the predator *Chrysoperla carnea* (Stephens):

Few numbers of *Chrysoperla carnea* (Stephens) larvae were observed feeding upon nymphs of *P. tenuivalvata* (Newstead) in infested sugarcane fields in Middle and Upper Egypt, during summer and autumn months. The larvae of *C. carnea* (Stephens) were almost of 3rd larval instar and found in the peripheral zones of

the fields. During the course of the present work, 2nd instar and 3rd instar larvae of *C. carnea* (Stephens) were used in some experiments to assess the suitability of *P. tenuivalvata* nymphs as prey for *C. carnea* (Stephens). The high percentages of mortality 72.2% and 51.6%, which occurred during rearing of 2nd and 3rd instar larvae of *C. carnea* (Stephens) on nymphs of the

sugarcane soft scale means that, the nymphs of *P. tenuivalvata* alone are not suitable prey for *C. carnea* (Stephens) larvae. (Table 7). *C. carnea* (Stephens) is well known as aphids predator and as polyphag predator. The field bend weed, *Convolvulus arvensis* L. was found highly infested with aphids in sugarcane fields during conducting the researches.

Fig. (9) Total number of different stages of *Pulvinaria tenuivalvata* (Newstead) / 50 at random leaves of sugarcane Mallawi, Minya Gov. , 2003-2005

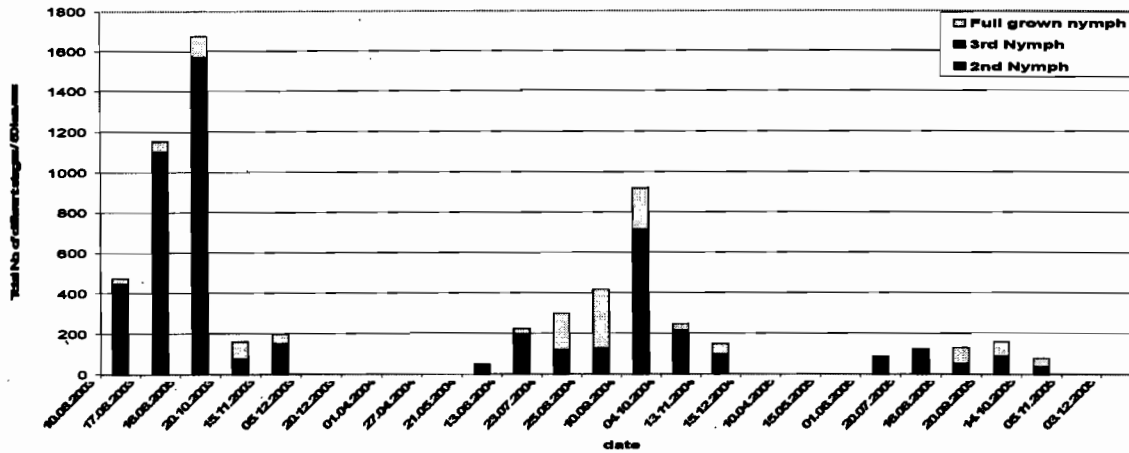


Fig. (10) Total number of different stages of *Pulvinaria tenuivalvata* (Newstead) / 50 at random leaves of sugarcane N. Hammadi, Qena Gov. , 2003-2005

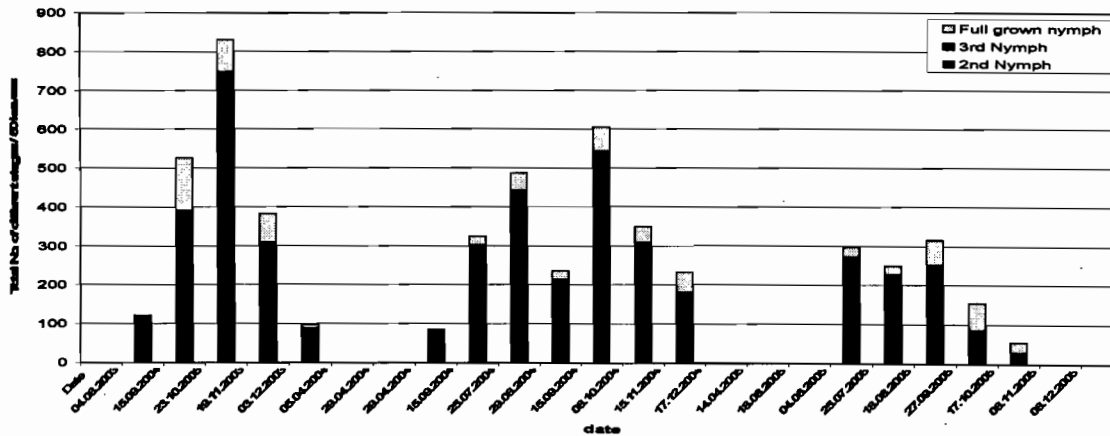


Fig (11) Percentage of parasitized soft scale *Pulvinaria tenuivalvata* (Newstead) with larvae and pupae of the parasitoid *Coccophagus semicircularis* (Förster), Mallawi, Minya Gov. August 2003- Dec. 2005 (n=50 soft scales)

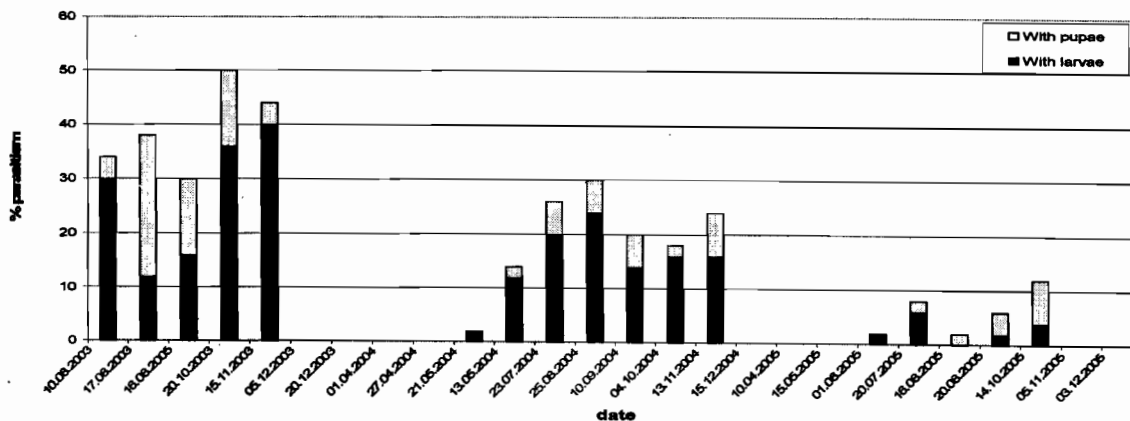


Fig (12) Percentage of parasitized soft scale *Pulvinaria tenuivalvata* (Newstead) with larvae and pupae of the parasitoid *Coccophagus semicircularis* (Förster), N. Hammadi Qina Gov. August 2003- Dec. 2005 (n=50 soft scales)

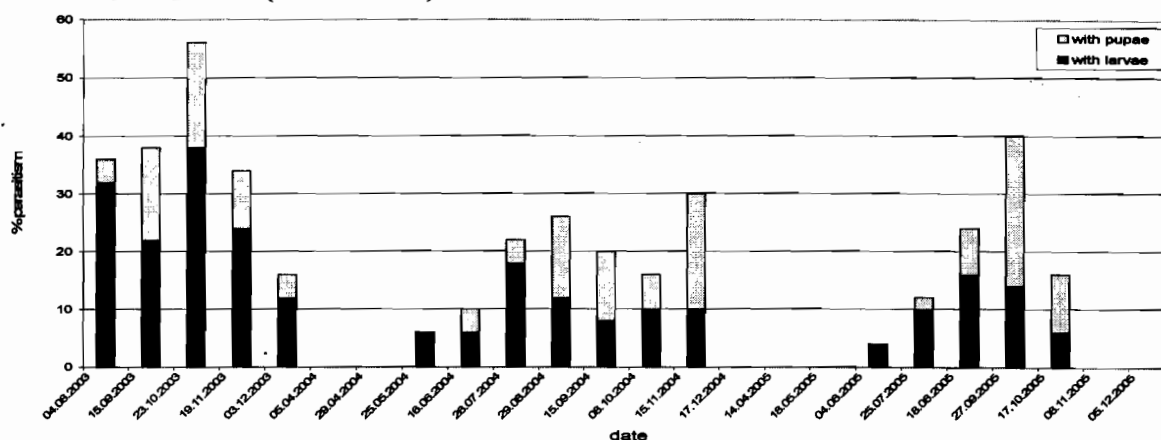


Table (7): Suitability of sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) nymphs as prey for *Chrysoperla carnea* (Stephens) larvae

Larval instar	No. of used larvae	Total No. of dead larvae till pupation	Total No. of nymphs consumed till pupation	No. of formed pupae	No. of emerged <i>C. carnea</i> adults	Total % of mortality
2 nd L.	54	36	2436	18	15	72.2
3 rd L.	60	29	2014	31	29	51.6

The possibility of using the coccinellid beetle *Chilocorus bipustulatus* (L.) to control the sugarcane soft scale *Pulvinaria tenuivalvata* (Newstead) under field conditions:

Since *C. bipustulatus* (L.) prey successfully on the sugarcane soft scale insect *P. tenuivalvata* (Newstead), under laboratory conditions (Ali, 2001), two field experiments had been conducted in sugarcane fields infested with *P. tenuivalvata* (Newstead), at N. Hammadi, and Mallawi, during Sep. / Oct. 2003 and August / Sep. 2004 respectively, to study the possibility of using *C. bipustulatus* (L.) to control *P. tenuivalvata* (Newstead). The obtained results show that, the predatory beetle *C. bipustulatus* (L.) has no effect under field conditions. The numbers of 2nd, 3rd, and full grown soft scales / 50 sugarcane leaves increased greatly 4 weeks after releasing of large numbers of the predator (22 and 41 beetles / 1m²) in large cages. No eggs or larvae or pupae of the predator had been found on the plants inside the cages. No adult beetles had been also found, or seen feeding on the soft scales on 1st, 2nd, and 3rd week of field observation.

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