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Research Article

Coccophagus scutellaris (Hymenoptera: Aphelinidae): A Highly Effective Biological Control Agent of Soft Scale Insects (Hemiptera: Coccidae) in Egypt

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About 953000 individuals of the cosmopolitan parasitoid, *Coccophagus scutellaris* (Dalman) (Hymenoptera: Aphelinidae), were released and evaluated during 2009-2010 for the control of the following soft scale insects (Hemiptera: Coccidae) infesting the following economic crops in Egypt: *Ceroplastes rusci* on citrus in Beni Seuf, *Ceroplastes floridensis* Comstock on citrus in Gharbiya, *Coccus hesperidum* L. on guava in Giza, *Pulvinaria floccifera* (Westwood) on mango in Sharqiya, *Pulvinaria psidii* Maskell on mango in Ismailia, *Saissetia coffeae* (Walker) on olive in Marsa Matruh, and *Saissetia oleae* (Oliver) on olive in the Northern Coast. The population of *C. scutellaris* showed a significant correlation with the build up of the population of the soft scale insects population in all of the release sites studied. The maximum rate of parasitism of the other species of parasitoids associated with soft scale insects at the release sites decreased after the release of *C. scutellaris*.

1. Introduction

Soft scale insects (Hemiptera: Coccidae) constitute one of the most important groups of pests in agriculture. Many species are destructive especially to fruit trees and ornamentals plants. Organophosphorus insecticides have been used in an effort to control these pests; however, these products have often been ineffective, costly and have resulted in the contamination of the soil, water, and environment in the areas of Egypt that were previously unpolluted. Whereas biological control of soft scale species has been very effective, with relatively low costs and with little or no negative effects on the environment.

The genus *Coccophagus* Westwood (Hymenoptera: Aphelinidae) is cosmopolitan in distribution and is comprised of many of the most frequently encountered parasitoids of soft scales, several of which have been used in biological control programs [1]. *Coccophagus scutellaris* (Dalman) is a cosmopolitan parasitoid of various soft scale species [2] including *Coccus longulus* (Douglas) [3], *Parasaissetia nigra* (Nietner) and *Parthenolecanium corni* (Bouché) [4], *Saissetia oleae* (Oliver) and *Ceroplastes floridensis* (Comstock) [5] among other species. In Egypt, Priesner and Hosny [6] recorded this species associated with *Coccus hesperidum* L. and *Pulvinaria floccifera* (Westwood). Later, Abd-Rabou [7] added *Pulvinaria mesembryanthemi* (Vallot) and *Saissetia coffeae* (Walker) as coccid hosts of this species in Egypt. Bodenheimer [8] and Abd-Rabou et al. [9] recorded *C. scutellaris* as a common parasitoid of *Coccus hesperidum* and *Ceroplastes floridensis.*

Coccophagus scutellaris is considered to be an effective parasitoid of *Saissetia coffeae* and *S. oleae* with maximum parasitism rates of 26 and 22% during November and August 1999, respectively [10]. Currently, it is known to attack six species of soft scales insects in Egypt and is considered to be an effective parasitoid of some of these pests. It is an autoparasitoid; the female is a primary parasitoid of soft scales and the male is a hyperparasitoid of primary parasitoids of soft scales including its own species [4]. During 2009-2010, it was reared and released in different locations in Upper Egypt [11] to control various species of soft scale insects on economic crops. The release, and establishment of

this biological control agent in Egypt allows future studies to be conducted on its effects on the survival of soft scale insects at low population densities.

The aim of this work is to clarify the importance of rearing, release and establishment of *Coccophagus scutellaris* for the control of the soft scale insects and to evaluate its efficacy and the role it plays in controlling of soft scales on economic crops in Egypt.

2. Materials and Methods

2.1. Laboratory Rearing. The parasitoid was reared in three glasshouses. In the first glasshouse, green potato sprouts and tubers were sown in shallow trays, the bottoms of which were perforated with many holes for drainage. The trays were filled with a mixture of equal quantities of loam, sand, and peat moss and irrigated every 1-2 days. When the sprouts reached approximately 10–12 cm in height, eggs and crawlers of *Saissetia coffeae* were individually scattered on the potato sprouts in the second glasshouse conditioned at $25 \pm 2^{\circ}$C, 65% of relative humidity, and 14 hours of light per day. A colony of *Coccophagus scutellaris* was initiated in the third glasshouse with specimens that had emerged *S. coffeae* in the field and released on a culture of *S. coffeae* (5-6 weeks old). The procedures followed in the treatment experiments were also applied to the control experiment. The development from egg deposition to adult under the above mentioned thermic conditions required 34–36 days. Parasitoids emerging from field and from laboratory rearing were utilized for field releases.

2.2. Field Releases. About 963,000 adult *C. scutellaris* individuals were released during the period 2009-2010 on the following crops and locations: (1) citrus in Beni Seuf infested with *Ceroplastes rusci*, (2) citrus in Gharbiya infested with *Ceroplastes floridensis* Comstock, (3) guava in Giza infested with *Coccus hesperidum* L., (4) mango in Sharqiya infested with *Pulvinaria floccifera* (Westwood), (5) mango in Ismailia infested with *Pulvinaria psidii* Maskell, (6) olive in Marsa Matruh infested with *Saissetia coffeae* (Walker), and (7) olive in Northern Coast infested with *Saissetia oleae* (Oliver). Parasitoids were released as adults by fixing vials or cups containing these parasitoids on stems of the various hosts and allowing the adults to exit.

2.3. Assessment of Efficacy. The efficacy of released parasitoids was assessed by parasitoid emergence or dissection of their hosts. Rearing of soft scale stages was achieved by holding a total of 30 leaves each of citrus, guava, and mango and 60 olive leaves from each site in 0.5 liter cardboard containers with ventilated tops at $25 \pm 2^{\circ}$C for two weeks. During 2009-2010, soft scales obtained from 7 locations in Egypt were dissected to detect prepupa and pupa of parasitoids. Samples were collected every month from October 2009 through October 2010. Three replicates of the study were performed on 14 feddan (about 0.1 hectares) of each crop. Each leaf was stored in a well-ventilated emergence glass tube and monitored daily for parasitism which was calculated as follows:

$$\text{Percentage} = \frac{\text{No. parasitized}}{\text{No. parasitized}} + \text{No. unparasitized.} \quad (1)$$

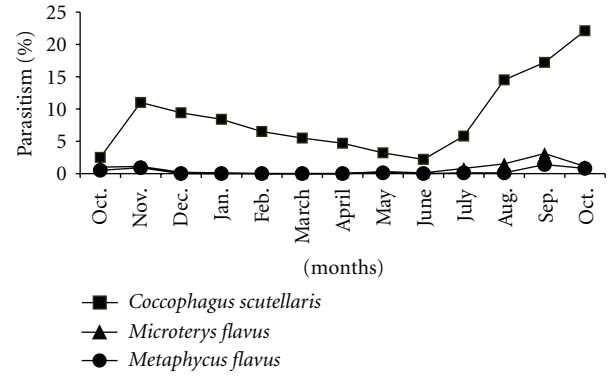

Figure 1: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Ceroplastes floridensis* on citrus in Gharbiya governorate after releasing during 2009-2010.

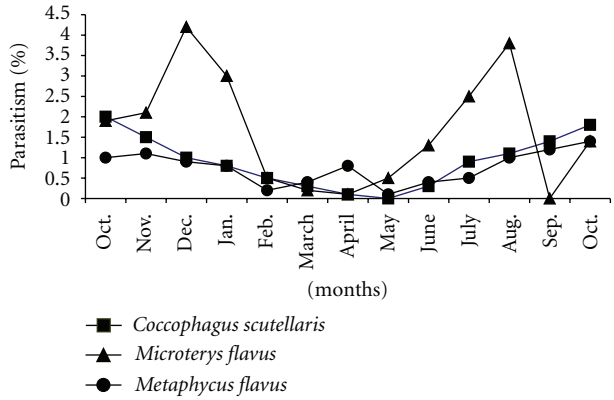

Figure 2: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Ceroplastes floridensis* on citrus in Gharbiya governorate before releasing during 2009-2010.

2.4. Statistical Analysis. Simple correlation and regression [12] origin were performed on data to determine the relationship between the populations of *C. scutellaris* and populations of the various species of soft scales.

3. Results and Discussion

The efficacy of the release of the individuals of *C. scutellaris* in controlling different species of soft scales on different crops and locations in Egypt was evaluated .

3.1. Ceroplastes floridensis on Citrus in Gharbiya. About 136,000 adults of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 1). The buildup of the population of *C. scutellaris* in the Gharbiya governorate on citrus correlated with that of *C. floridensis* ($r = 0.973$) with

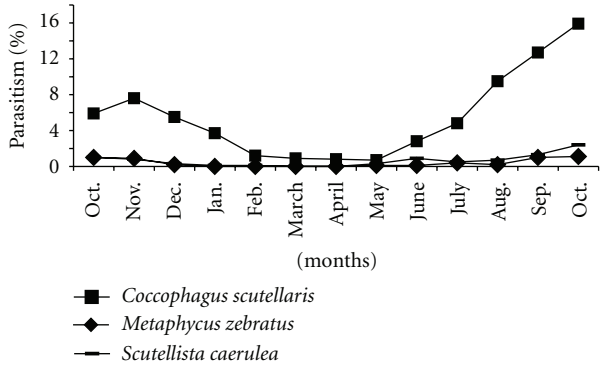

Figure 3: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Ceroplastes rusci* on citrus in Beni Seuf governorate after releasing during 2009-2010.

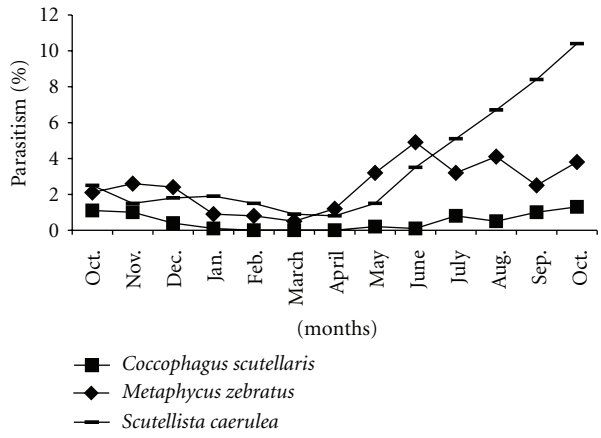

Figure 4: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Ceroplastes rusci* on citrus in Beni Seuf governorate before releasing during 2009-2010.

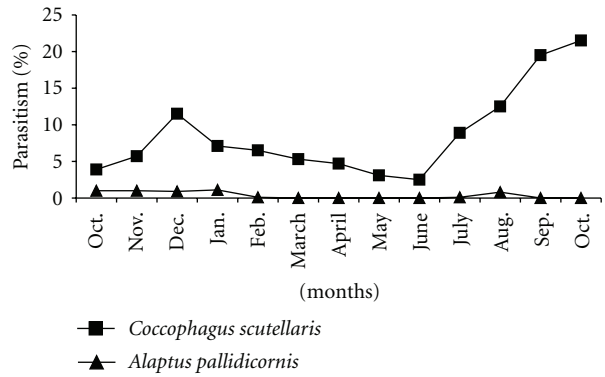

Figure 5: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoid of *Coccus hesperidum* on guava in Giza governorate after releasing during 2009-2010.

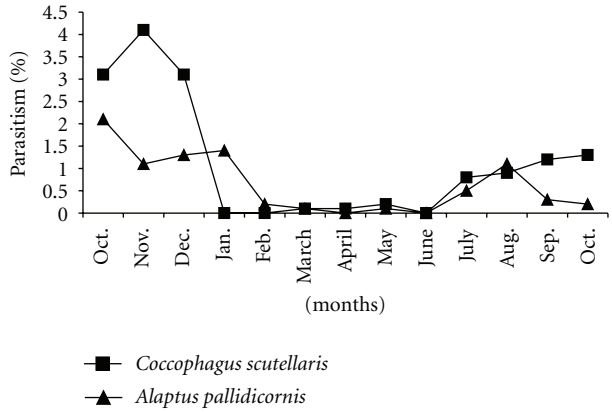

Figure 6: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoid of *Coccus hesperidum* on guava in Giza governorate before releasing during 2009-2010.

simple regression values of $b = 0.311$, $R^2 = 0.951$, and $P < .01$. Parasitism reached a maximum of 22.1% during October 2010 in the treatment plot (after release) while a maximum of 1.8% was reached during October 2009 in the control plot (before release). Parasitism by the other associated primary parasitoids *Microterys flavus* (Howard) and *Metaphycus flavus* (Howard) decreased from 1.4 to 1.1% and from 1.4 to 0.8%, respectively, after the release of *C. scutellaris* (Figures 1 and 2).

3.2. Ceroplastes rusci on Citrus in Beni Seuf. About 137,000 adult of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 3). The buildup of the population of *C. scutellaris* in the Beni Seuf governorate on citrus correlated with that of *C. rusci* ($r = 0.813$) with simple regression to these revealed values of $b = 0.311$, $R^2 = 0.804$, and $P < .01$. Parasitism reached a maximum of 15.9% during Oct. 2010 in the treatment plot (after the release), while parasitism reached a maximum 1.3% during Oct. 2010 in the control plot (before the release). Parasitism by the primary parasitoid *Metaphycus zebratus* (Mercet) and the egg predator, *Sutellista caerulea* (Boyer de Fonscolombe), decreased from 3.8 to 1.1% and from 10.4 to 2.4%, respectively, after the release of *C. scutellaris* (Figures 3 and 4).

3.3. Coccus hesperidum on Guava in Giza. About 138,000 adult of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 5). The buildup of the population *C. scutellaris* in the Giza governorate on guava correlated with that of *C. hesperidum* population buildup ($r = 0.870$) with simple regression values of $b = 0.301$, $R^2 = 0.842$, and $P < .01$. Maximum parasitism reached 21.5% during Oct. 2010 in the treatment plot (after release), while maximum parasitism reached 1.3% during November 2009 in the control plot (before release). Parasitism by the egg parasitoid, *Alaptus pallidicornis* Förster, decreased from 1.4 to 1.1% after the release (Figures 5 and 6).

3.4. Pulvinaria floccifera on Mango in Sharqiya. About 127,000 adult of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 7). The buildup *of the* population

Table 1: Total numbers of the adult parasitoid *Coccophagus scutellaris* released in different fields of citrus, guava, mango, olive in Beni Seuf, Gharbiya, Giza, Ismailia, Marsa Matruh, Northern Coast, and Sharqiya governorates in Egypt during each year from 2009/2010.

Month	No. of released parasitoids by scale insect species						
	Ceroplastes floridensis	*Ceroplastes rusci*	*Coccus hesperidum*	*Pulvinaria floccifera*	*Pulvinaria psidii*	*Saissetia coffeae*	*Saissetia oleae*
Oct.	10000	11000	9000	11000	9000	12000	10000
Nov.	10000	11000	8000	10000	11000	11000	10000
Dec.	12000	10000	11000	11000	11000	11000	9000
Jan.	11000	10000	10000	11000	10000	10000	11000
Feb.	12000	10000	11000	11000	11000	11000	9000
March	10000	11000	11000	10000	12000	11000	10000
April	9000	10000	10000	11000	10000	10000	9000
May	11000	10000	12000	11000	10000	10000	11000
June	10000	11000	12000	10000	11000	12000	10000
July	10000	9000	11000	10000	11000	11000	12000
Aug.	10000	11000	11000	10000	12000	11000	10000
Sept.	11000	12000	10000	11000	12000	10000	10000
Oct.	10000	11000	12000	10000	11000	10000	13000
Total	136000	137000	138000	127000	141000	140000	134000

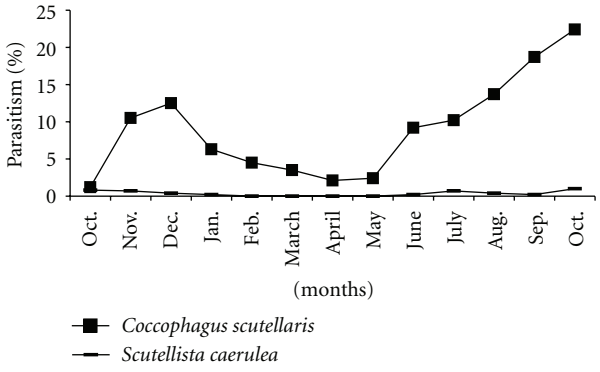

Figure 7: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoid of *Pulvinaria floccifera* on mango in Sharqiya governorate after releasing during 2009-2010.

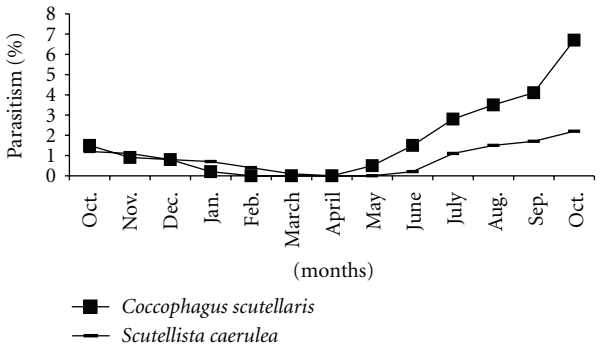

Figure 8: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoid of *Pulvinaria floccifera* on mango in Sharqiya governorate before releasing during 2009-2010.

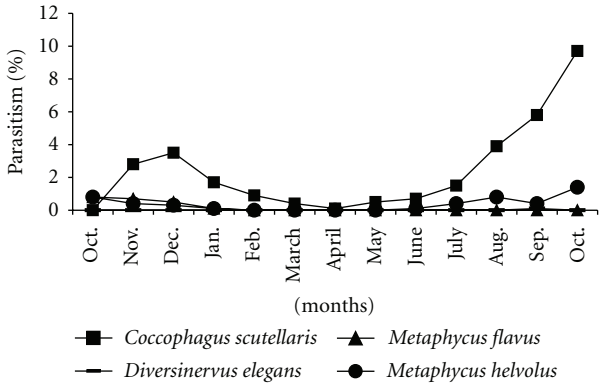

Figure 9: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Pulvinaria psidii* on mango in Ismailia governorate after releasing during 2009-2010.

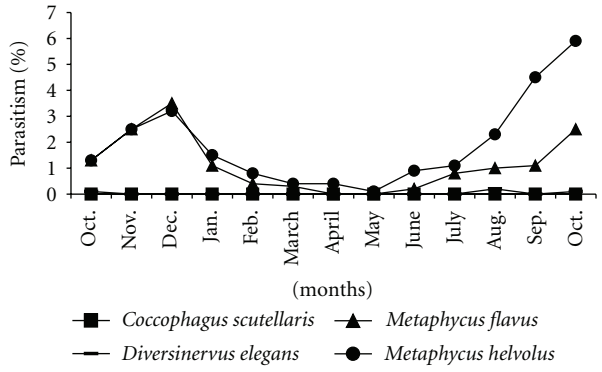

Figure 10: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Pulvinaria psidii* on mango in Ismailia governorate before releasing during 2009-2010.

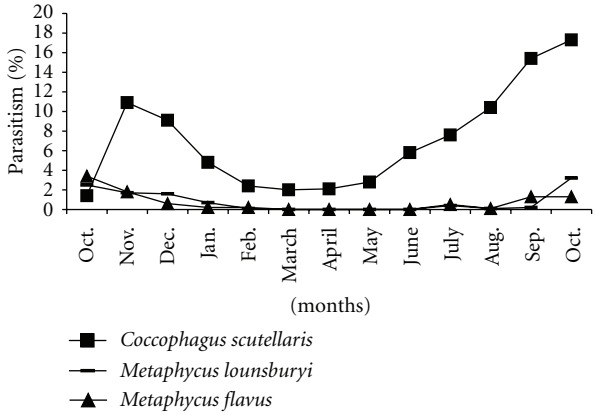

Figure 11: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Saissetia coffeae* on olive in Marsa Matruh governorate after releasing during 2009-2010.

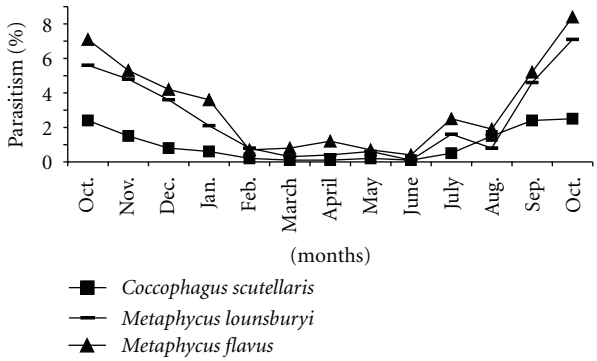

Figure 12: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Saissetia coffeae* on olive in Marsa Matruh governorate before releasing during 2009-2010.

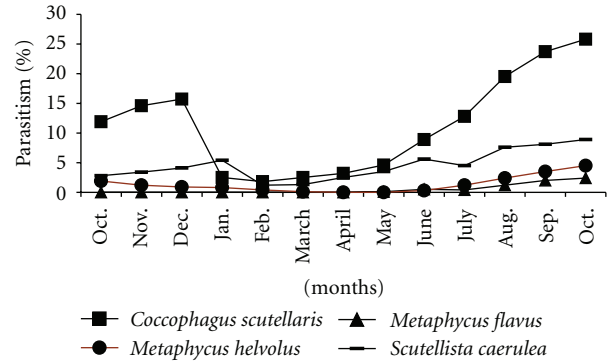

Figure 13: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Saissetia oleae* on olive in Northern Coast governorate after releasing during 2009-2010.

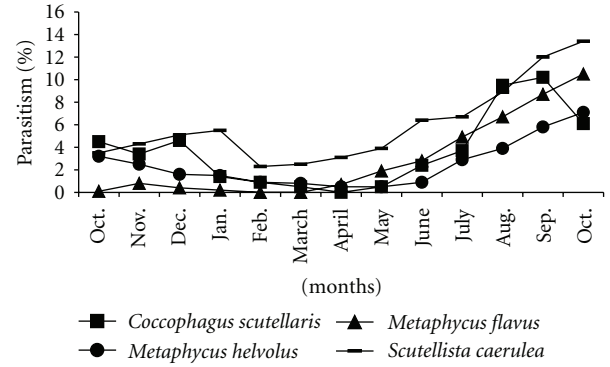

Figure 14: Percent parasitism of *Coccophagus scutellaris* and other associated parasitoids of *Saissetia oleae* on olive in Northern Coast governorate before releasing during 2009-2010.

of *C. scutellaris* in the Sharqiya governorate on mango correlated with that of *P. floccifera* ($r = 0.798$) with simple regression values of $b = 0.295$, $R^2 = 0.788$, and $P < .01$. Maximum parasitism reached 22.4% during Oct. 2010 in the treatment plot (after the release), while maximum parasitism reached 6.7% during Oct. 2010 in the control plot (before the release). Parasitism by the primary parasitoid *S. caerulea* decreased from 2.2 to 1.0% after the release (Figures 7 and 8).

3.5. Pulvinaria psidii on Mango in Ismailia. About 141,000 adults of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 9). The buildup of the population of *C. scutellaris* in the Ismailia governorate on mango correlated with that of *P. psidii* ($r = 0.934$) with simple regression values of $b = 0.324$, $R^2 = 0.903$, and $P < .01$. Maximum parasitism reached 9.7% during Oct. 2010 in the treatment plot (after release), while no parasitism was observed during Oct. 2010 in the control plot (before release). Parasitism by the primary parasitoids *Metaphycus flavus* (Howard), *M. helvolus* (Compere), and *Diversinervus elegans* Silvestri decreased from 3.5 to 0%, from 5.9 to 1.4%, and from 0.2 to 0%, respectively, after release (Figures 9 and 10).

3.6. Saissetia coffeae on Olive in Marsa Matruh. About 140,000 adult of *C. scutellaris* individuals were released during the period 2009-2010 (Table 1). Parasitism increased after the release (Figure 11). The buildup of the population of *C. scutellaris* in the Marsa Matruh governorate on olive correlated with that of *S. coffeae* ($r = 0.798$) with simple regression values of $b = 0.299$, $R^2 = 0.787$, and $P < .01$. Maximum parasitism reached 17.3% during Oct. 2010 in the treatment plot (after release), while maximum parasitism reached 2.5% during Oct. 2010 in the control plot (before release). Parasitism by the primary parasitoids *Metaphycus lounsburyi* (Howard) and *M. flavus* decreased from 7.1 to 3.2% and from 8.4 to 1.3%, respectively, after the release (Figures 11 and 12).

3.7. Saissetia oleae on Olive in Northern Coast. About 134,000 adult of *C. scutellaris* individuals were released during the period of 2009-2010 (Table 1). Parasitism increased after the release (Figure 13). The buildup in the population of *C. scutellaris* in the Northern Coast region on olive correlated with that of *S. oleae* population buildup ($r = 0.855$) with simple regression values of $b = 0.301$, $R^2 = 0.846$, and $P < .01$. Maximum parasitism reached 25.8% during Oct. 2010 in the treatment plot (after the release), while maximum

parasitism reached 6.1% during Oct. 2010 in the control plot (before the release). Parasitism by the primary parasitoids *Metaphycus flavus* (Howard), *M. helvolus* (Compere), and the egg predator *Scutellista caerulea* (Boyer de Fonscolombe), decreased from 10.5 to 2.4%, from 7.1 to 4.5%, and from 13.4 to 8.9%, respectively, after the release (Figures 13 and 14).

Results of the mass rearing showed that large numbers of this parasitoid species can be obtained by mass rearing. Parasitoids collected in areas where they are abundant and those reared in the laboratory can be transferred, distributed, and released in locations where the parasitoid is rare or not known to occur. Monthly collections of scale hosts and parasitoids were made in the release sites to monitor the population of the parasitoid where it was not previously known to exist.

The seven sites in Egypt where the parasitoids were released distinctive in their locations as well as their environmental conditions. Prior to its release, *Coccophagus scutellaris* was not found in Ismailia but was found in the other locations with parasitism rates ranging from 1.3 to 6.7% in control plot and from 15.9 to 25.8% in the treatment plot. After its release, *Coccophagus scutellaris,* was found to be established in Ismailia, with maximum parasitism rate of 9.7% during Oct. 2010. The egg parasitoid, *Alaptus pallidicornis* was collected only in Giza, located south of Nile Delta, an area characterized as having high humidity. Also the parasitoid, *Diversinervus elegans,* was only collected in Ismailia, located on Suez Canal and Temsah Lake, which is characterized as having low humidity.

This work is an important step towards replacing the chemical insecticides currently used for controlling these soft scale species with environmentally friendly biological control agents. The control of these serious pests on economic crops in Egypt is especially important for products exported to other countries.

4. Conclusion

The methodology developed in amassing large numbers of the parasitoid, *C. scutellaris*, in the laboratory, reared or collected in the field and distributed them in areas where they are not known to occur is an effective way of establishing the parasitoid in areas where the parasitoid is needed to control soft scale species. The percentage of parasitism was satisfactory, and the population of soft scales decreased to a satisfactory level at the sites studied.

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