Ecology, Behavior, and Biocontrol Studies on the Scarab Beetle, *Maladera castanea* (Coleoptera: Scarabaeidae) Infesting Strawberry Plants in Egypt

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Abstract: Seasonal fluctuations of the scarab beetle, *Maladera castanea* that infest strawberry plants in the field, were conducted during the 2019/2020 season. The obtained results revealed that the highest population of scarabs was recorded in October, April, with averages of (61.2, 57.0, beetle/trap) under field conditions, the behavior of the adult scarabs to the preferred color and the activity periods was studied. The results showed that the white color was the most preferred one for the beetles, recording 37.0±2.6 adults/hour. The adults were assumed to be night activity during the period from 06:00 pm to 12.00 midnight, where the average number of *M. castanea* scarabs was recorded as 226.2± 8.1 adults/trap. Drying process for three weeks showed a 100% decrease in the population, while starvation process recorded a 90% decrease, after all, 100% decrease was recorded after four weeks. Entomopathogenic Nematodes (EPNs) were used on *M. castanea* at the laboratory, but its results showed that the third stage larvae have strong resistance to (EPNs). Under field conditions, the soil drench application of 24 cm^3 of Lambda-Cyhalothrin 10% + 24 cm^3 Abamectin 1.8% + 24 cm^3 Emamectin 5% per feddan (4200 m^2) decreased 60% of *M. castanea* larvae**,** 3 days after treatment raised to 75 % 10 days after treatment. The hypopus of *Caloglyphus audemansi* mite was associated on *M. castanea.*

Keywords: White grubs, scarab beetles, strawberry, color preference, EPNs, drying

INTRODUCTION

Strawberry in Egypt is one of the most important crops that grow rapidly. Egypt strawberry exports equals 20% of the global exports and ranks the first among top producing strawberry countries worldwide (UN/ITC, 2020); (GOEIC, 2020). One of the important constraints of the production of strawberry is the grub beetles (Cross et al., 2001); (Shehata *et al.,* 2020). The family Scarabaeidae includes 40 thousand species (Erwin, 1991). One of these species is the scarab beetle *Maladera castanea* (Fig. 1 a, b), the subject of the present investigation, the adult causes damage to strawberry leaves (Fig. 1 c), larva infests routs leading to dead plants (Fig. 1 d).

Light traps (Robinson type) as a glass jar with a fatal agent placed in the bottom of each trap were effectively used for monitoring scarab beetles (Morsi and El- Gharabawy, 2006, Maharjan and Khanal, 2016).

Mites are commonly phoretic on insects, especially upon the Coleopteran. (Welbourn, 1983; Zaki *et al*., 1987). Phoretic mites on insects are reported in different mite orders (Athias-Binche, 1994). Astigmata (hypopi) adapted phoronts because of its complicated suckers (Evans *et al*., 1961; Negm and Alatawi, 2011). Phoretic mites are common with Scarabaeid beetles (Lindquist, 1975). *Caloglyphus* sp. is reported as a Phoretic mite on *Pentodon bispinosus* (Ibrahim *et al.,* 1992).

MATERIALS AND METHODS

1. Ecology and behavior of the scarab beetle, *Maladera castanea* infesting strawberry plants:

1.1. Seasonal fluctuation of the adult of the scarab beetle, *M. castanea*

An ecological study in Badr center, El Beheira Governorate, Egypt was conducted under field conditions to study the seasonal fluctuations of the scarab beetle, *Maladera castanea* adults infesting strawberry plants in the field along the period from May2019 to April 2020. Three Robinson light traps (Robinson and Robinson, 1950) dispersed along the study period in specific places at the field of the experiment and the numbers of insects were weekly recorded. Moreover, the mean of air temperature and relative humidity were measured.

1.2. Effect of color attractiveness on *M. castanea* adults:

The behavior of the adults was studied under field conditions to clarify which color the adults of the insect under the study preferred. Three colored stickers (white, yellow, and red) were tested for its attractiveness to the adults of *M. castanea*, where the number of insects visited each sticker was recorded by the hour.

1.3. The activity time of *M. castanea* adults:

As well as the most activity time of *M. castanea* was also observed using traps along day hours, where the day was divided into 4 periods, each period was 6 hours, each period has a trap and the numbers of attracted beetles in each trap was recorded and the averages were calculated.

1.4. Drying and starvation in the control of white grub, *M. castanea*:

Drying and starvation were used to control the white grub, *M. castanea*. The larvae of *M. castanea* and the sand soil were obtained from the experimental farms mentioned previously, transferred to the laboratory to conduct a semi field experiment, where one larva was put in glass jars 250 ml in sand soil with strawberry roots without irrigation and food to study the effect of dryness and starvation on the life of these larvae, the jars were put under laboratory conditions 25±2°C and 60±5% RH and checked daily for whole month.

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2. Control of white grub, *M. castanea*:

2.1. by Entomopathogenic nematodes:

Control experiments were conducted at the laboratory using Entomopathogenic Nematodes (EPNs). The strains of EPNs, *Heterorhabditis indica*, and *Steinernema glaseri* were isolated from soil samples of Menoufia Governorate. The late instar larvae of the wax moth, *Galleria mellonella* were used as host to increase the numbers of the (EPNs) in the laboratory at 25°C (Woodring and Kaya, 1988). The emerged IJs from wax moth, *G. mellonella* larvae, were collected by modified White traps and stored in darkness at 15°C in deionized water (Kaya and Stock, 1997), before application, the IJs putfor one hour at room temperature to adapt their capability were checked by observation of movements under a stereomicroscope. One larva was put in glass jars 250 ml in sand soil with strawberry roots. Nematodes in 0.5 ml of deionized water were added to the water in concentrations of 25, and 50 IJs/larva, each concentration has three replicates. Untreated control jars had the same irrigation except for IJs. Larvae were checked every day for up to 7 days.

2.2. Chemical control:

Under field conditions, 24 cm^3 of Lambda-Cyhalothrin 10%+24 cm^3 Abamectin 1.8%+24 cm^3Emamectin 5% per feddan (4200 m^2) were soil drenched with irrigation water 2 months after planting.

3. The mite *C. audemansi* identification:

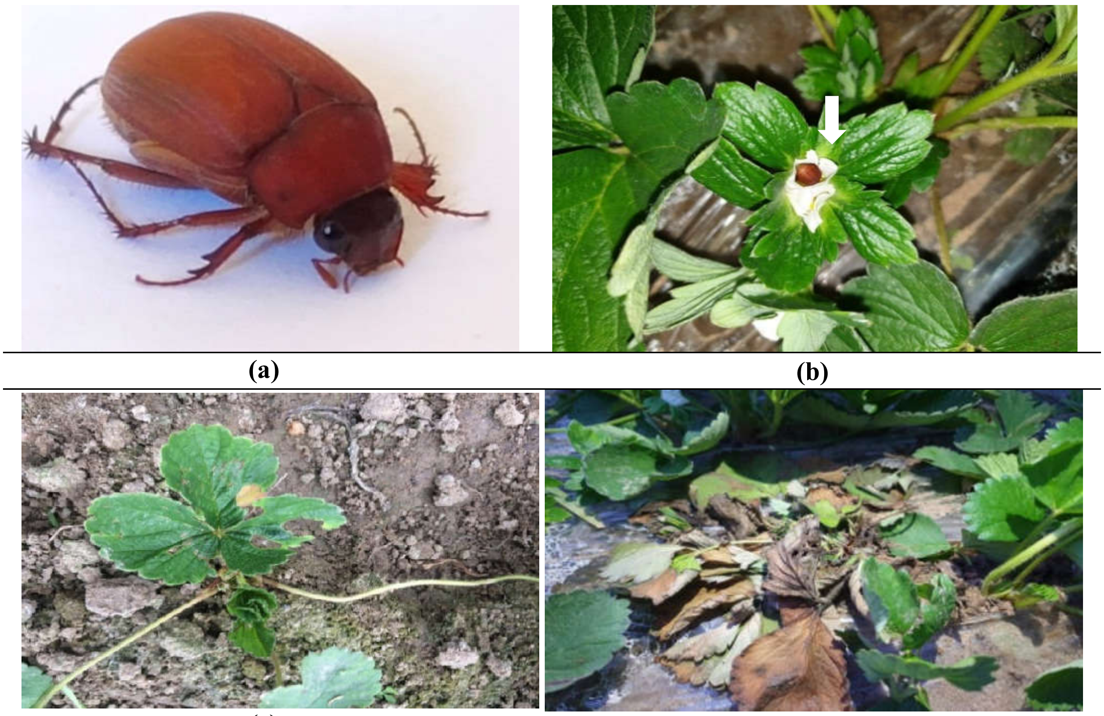
The Phoretic mite, *Caloglyphus audemansi* Zachvatkid, (Acaridae) was recorded for the first time at Menoufia governorate with the aid of a dissecting stereomicroscope under 100 x magnification. Hypopus of mite were mounted on glass slides with cover, and then classified by the identification key of Krantz (1978, 2009).

4. Statistical analysis:

All obtained data were subjected to ANOVA test using a computer program (Costat, 2008) to determine Duncan's multiple range test and the LSD 5% (least significant difference). In addition, Abbott's formula was used to determine the increase percentages of vegetative characters.

Reduction percentages were counted according to Abbott's formula (1925).

$$\text{Corrected mortality \%} = \left(1 - \frac{\text{No in Treatment after treatment}}{\text{No in Control after treatment}} \times\right) 100$$



(a) (b) (c) (d)

Figure (1): (a) *Maladera castanea* adults, (b) adult of *M. castanea* on a flower, (c) damage caused by the adult on strawberry leaves, (d) dead plant as a result of infestation of *M. castanea* larvae to roots

RESULTS AND DISCUSSION

1. The ecology and behavior of the scarab beetle, *M. castanea* infesting strawberry plants:

1.1. Seasonal fluctuation in the field along 2019-2020 season:

The numbers of adult scarab beetle were weekly recorded. The data obtained from (Table1) showed that the adults were recorded its highest levels of infestation in the months (October, April, May, March, September, and November) with respective averages of (61.2, 57.0,40.7, 24.1, 22.0, and 17.87). However, the months of Jul., December, and January did not record any infection.

1.2. Effect of color attractiveness on *M. castanea* adults:

Behavioral study was conducted to determine the adult preferred color under field conditions, where the number of the adults of *M. castanea* visited each sticker was recorded by the hour. The obtained data (Table 2) revealed that the most preferable sticker color was the white, (37± 2.6adults/ hour), followed by the yellow color (26.67± 2.4 adults/ hour), and lastly the red color (8.33± 0.3 adults/ hour).

Table (1): Average numbers of the scarab beetle, *M. castanea* infesting strawberry plant along the season

Month	2019									2020		
	May	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
	average numbers of beetles/ light trap											
Rep. 1	37.6	2.0	0.0	0.0	17.6	51.2	11.8	0.0	0.0	1.8	20.2	63.0
Rep. 2	36.2	0.0	0.0	2.8	22.2	60.2	23.6	0.0	0.0	0	13.8	47.0
Rep. 3	48.2	0.0	0.0	3.0	26.2	72.2	18.2	0.0	0.0	0	38.2	61.0
Mean	40.7b	0.7 d	0.0d	1.9 d	22.0 c	61.2a	17.9c	0.0 d	0.0 d	0.6 d	24.1 c	57.0a
LSD5%	**10.31**											

Mean values followed by the same letter are not significantly different by (P=0.05)

Table (2): Average numbers of the scarab beetle, *Maladera castanea* visited colored stickers per hour

Color	Average numbers of beetles/ colored sticker/ hour			Mean	± S. E.
	replicate 1	replicate2	replicate3		
White	36	42	33	37.00	2.6
Yellow	30	28	22	26.67	2.4
Red	09	08	08	08.33	0.3

1.3. The activity time of *M. castanea* adults:

The time of activity for the adults of *M. castanea* was studied by using traps along the four periods of the day and the numbers of the beetles fouled by each trap was recorded and the averages were calculated (Table 3). Data showed that the period from 06:00 pm to the mid night has the most activity for the adults of *M. castanea,* the average recorded was 226.2±8.1 adults/ trap, followed by the period from mid night to 06:00 am with 158.6 ± 8.0 adults/ trap, while the periods from 06:00 am till 06:00 pm have intangible records (1.2± 0.7 and 0.0 ± 0.0) adults/ trap, respectively.

1.4. Effect of drying and starvation on *M. castanea* population:

As shown in (Table 4) drying process caused 30% reduction after 14 days, and 70% reduction after 21 days recording 100% reduction as accumulative reduction of the population.

Meanwhile, starvation process caused 30% reduction after 7 days, in addition to 30% after 14 days, and other 30% after 21 days recording 90 % reduction as accumulative reduction of the population increasing to 100% reduction at the end of the experimental period (28 days).

Table (3): Average numbers of the scarab beetle, *Maladera castanea* fouled/trap

Periods	Average numbers of beetles/ trap			Mean	± S. E
	Replicate 1	**R. 2**	**R. 3**		
18:00- 00:00	220.2	242.2	216.2	226.2	8.1
00:00- 06:00	162.6	143.2	170.0	158.6	8.0
06:00- 12:00	1.2	2.4	0.0	1.2	0.7
12.00-18:00	0.0	0.0	0.0	0.0	0.0

Table (4): Reduction % of the white grub, *Maladera castanea* after drying and starvation

Days after application	Reduction % of drying		Reduction % of starvation	
	Mean	**± S. E**	**Mean**	**± S.E**
1 day	0.0	0.0	0.0	0.0
3 days	0.0	0.0	0.0	0.0
7 days	0.0	0.0	30.0	0.0
14 days	30.0	0.0	30.0	0.0
21 days	70.0	0.0	30.0	0.0
28 days	0.0	0.0	10.0	0.0

2. Control of white grub, *M. castanea*

2.1. by Entomopathogenic nematodes:

The efficacy of the EPNs, *Heterorhabditis indica*, and *Steinernema glaseri*, against the last instar larvae of *M. castanea*, were evaluated according to the doses of their infective juveniles as well as the exposure period. Negative results were found after application along one week in both (EPNs) species. The results of (EPNs) against the larvae of *M. castanea*are agree with (Laznik and Trdan, 2014) mentioned that EPNs (*Heterorhabditis bacteriophora*) and bacteri-insecticides (*Beauveria brongniartii, B. bassiana, Bacillus thuringiensis* var. *kurstaki, B. th.* var. *tenebrionis*) were effective against first and second instar larvae of the white grubs and declined against the third instar larvae.

2.2. by chemical control:

Under field conditions, 24 cm^3 of Lambda-Cyhalothrin 10% + 24 cm^3 Abamectin 1.8% + 24 cm^3Emamectin 5% per feddan (4200 m^2) were soil drenched with irrigation water 2 months after planting. This treatment decreased 60% of *M. castanea* larvae**,** 3 days after treatment raised to 75 % 10 days after treatment**.**

Table (5): Reduction % of the white grub, *Maladera castanea*after the (EPNs) application

Days after application	Reduction % of *H. indica*		Control	Reduction % of *S. glaseri*	
	25 IJs/ larva	**50 IJs/ larva**		**25 IJs/ larva**	**50 IJs/ larva**
1 day	0	0	0	0	0
3 days	0	0	0	0	0
7 days	0	0	0	0	0

4. The Phoretic mite, *Caloglyphus audemansi* associated with *M. castanea*:

The Phoretic mite, *C. audemansi* Zachvatkid, (Acaridae) was recorded for the first time at Menoufia governorate. The hypopus of *C. audemansi* as a phoretic mite was seen associated with different developmental stages of *Maladera castanea* on all parts of the insect body with the average of 25 individual/insect stage.

The adults of *C. audemansi* were accidently found after the death of some larvae of *M. castanea*, the mite was classified by the keys identification of (Krantz, 1978; Krantz and Walter, 2009).

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دراسات بيئية وسلوكية ومكافحة حيوية على خنفساء *Maladera castanea* التي تصيب نباتات الفراولة في مصر

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أجريت تجربة لدراسة التقلبات الموسمية لخنفساء *Maladera castanea* التي تصيب نباتات الفراولة في الحقل خلال موسم ٢٠٢٠ وأظهرت النتائج أن شهر أكتوبر سجل أكبر أعداد الخنفساء بمتوسط ٦١.٢ حشرة تلاه شهر ابريل بمتوسط ٥٧ حشرة، ثم شهر مايو بمتوسط ٤٠.٧ حشرة ثم شهر مارس ٢٤.١ حشرة، ثم شهر سبتمبر بمتوسط ٢٢ حشرة، ثم نوفمبر بمتوسط ١٧.٩ حشرة، ولم يسجل تواجد للحشرات الكاملة خلال شهور يوليو وديسمبر ويناير، بينما سجل شهري فبراير ويونيو ٠.٦ ، ٠.٧ حشرة. تمت دراسة سلوك الحشرات الكاملة في الحقل من حيث تفضيلها للألوان، وأظهرت النتائج أن اللون الأبيض هو الأكثر تفضيلاً للخنافس وكذلك دراسة فترات نشاط الحشرات خلال اليوم وأوضحت النتائج أن الحشرات ليلية النشاط حيث سجلت أكبر أعداد في الفترة من ٦ مساء حتى منتصف الليل وهي ٢٢٦.٢ ± ٨.١ حشرة تلاها الفترة من منتصف الليل حتى السادسة صباحاً حيث سجلت ١٥٨.٦ ±٨.٠ حشرة. كذلك أجريت التجارب المعملية لدراسة تأثير كلاً من الجفاف والتجويع، ولكن جميع نتائجها أظهرت أن اليرقات لديها مقاومة قوية للجفاف لمدة أسبوع وسجل التجويع ٣٠٪ فقد في الأعداد، بعد أسبوعين سجل الجفاف ٣٠٪ وسجل التجويع إجمالي ٦٠٪ من المجموع وبعد ثلاثة أسابيع سجل الجفاف ١٠٠٪ موت للمجموع تحت التجربة بينما التجويع تسبب في فقد ٩٠ ٪ وسجل التجويع ١٠٠٪ موت للمجموع بعد أربعة أسابيع. أثبتت النيماتودا الممرضة للحشرات عدم فعاليتها ضد يرقات *M. castanea*. كذلك أجريت تجربة مكافحة في الحقل باستخدام المبيدات الحديثة، وكانت الطريقة الأكثر فاعلية هي حقن التربة مع ماء الري ب ٢٤ سم٣ من اللمبادا - سيالو ثيرين ١٠٪ + ٢٤ سم٣ أبامكتين ١.٨٪ + ٢٤ سم إيمامكتين ٥٪ الفدان، حيث أبادت ٦٠٪ من اليرقات بعد ٣ أيام من المعاملة ارتفعت إلى ٧٥ ٪بعد ١٠ أيام من المعاملة. كما تم تسجيل أكاروس *Caloglyhus audimansi* متعايشا على حشرة خنفساء *M. castanea* لأول مرة.

الكلمات المفتاحية: الجعال - الديدان البيضاء - الفراولة - التفضيل اللوني - الجفاف