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Biocontrol of the Carob Moth *Ectomyelois Ceratoniae* (Lepidoptera, Pyralidae) in Pomegranate and *Citrus* Orchards in Tunisia

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***Abstract* – *Ectomyelois ceratoniae* is a major pest in pomegranate and orange (« Thomson » variety) in Tunisia causing highly economic losses. This study was performed in order to obtain a suitable control method for this species. Field trials were conducted in two types of orchards: two *Citrus* orchards and two pomegranate orchards (organic and conventional). In field, the use of *Trichogramma* releases (300 eggs/tree) mass trapping (10 traps/ha), and mating disruption using SPLAT EC (350g/ha), seemed promising. Results showed that mating disruption with SPLAT EC was the most effective treatment in reducing the rate of infestation by *E. ceratoniae* in the *Citrus* orchards. In fact, after 13 days of the treatment with SPLAT EC (350g/ha), the reduction of the infestation rate reached 100%. In pomegranate orchards, the most effective treatment was the releases of *Trichogramma*. Indeed, after 8 days of the second *Trichogramma* release, the infestation level in the organic pomegranate orchard decreased from 82% to 22%.**

***Keywords* – *Ectomyelois Ceratoniae*, Attract and Kill, *Trichogramma* Releases, Mass-trapping, SPLAT EC.**

I. INTRODUCTION

The carob moth, *Ectomyelois ceratoniae* (Zeller, 1839) (Lepidoptera: Pyralidae) (**Fig.1**), is an important pest of pomegranate (*Punica granatum*) in Tunisia [21]-[5].

It is also known as a pest of *Citrus* (« Thomson» variety) (**Fig.2**) were damages can reach 16% [1].

Fig. 1. Carob moth *Ectomyelois ceratoniae*

Fig. 2. Carob moth damage on Orange (“Thomson” variety)

In Tunisia, we can find *E. ceratoniae* in the north as well as in the south of the country, especially in Saharan areas where infestations can reach 90% of pomegranate fruits [7].

Carob moth rarely attacks healthy pomegranate fruits. In fact, females prefer to lay eggs on damaged fruits, where two calyx petals touch. Larvae typically enter through cracks, rotten spots, or wounds caused by other pests. However, if numbers are high, damage can be serious and it can highly affect fruit quality.

To reduce this damage, several control methods have been experimented [2]-[4]-[5]-[8]-[9]-[10]-[11]-[12]-[13]-[22]-[23]. Chemical control is effective against the carob moth. However, it is not satisfactory in field due to the endophytic behavior of the pest. In fact, the larvae feed and develop inside the fruit, where they are protected from the chemicals [6]-[14]- [15]-[16]-[17]-[18]-[19]-[20]. In addition, a public awareness has arisen with the negative impacts of chemicals on human health and their harmful influence on the environment. Consequently, there is now a high demand for non-chemical disinfestation treatments while at the same time maintaining a high degree of control efficacy to satisfy International regulations and standards necessary for export [24]-[25]-[3].

This study evaluates the efficacy of some treatment methods, in order to substitute the chemical control and to strengthen the integrated control. In fact we tested: *Trichogramma* releases, mass-trapping, SPLAT EC product and Attract and kill method, in two types of orchards: *Citrus* orchards and pomegranate orchards (biological and conventional orchard).

II. MATERIALS AND METHODS

2.1. *Citrus* treatments

2.1.1. Experimental fields

In 2013, we started field treatments in two *Citrus* orchards located in two different regions.

- *First Orchard (El Khlidia)*

The first series of fields trials were conducted in a *Citrus* orchard (2,25 ha) in the region of El Khlidia (in the governorate of Ben Arous). The grown variety of orange in this orchard is « Thomson ».

This orchard was divided into four plots: one control plot (0,5 ha) and four plots to receive various different treatments (**Table.1**).

We put two pheromones traps/ha in the orchard for detecting and monitoring the pest.

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Table. 1. Characteristic of the different plots in the first citrus orchard (El Khlidia)

Plot	Number of trees	Treatment	Dose of the used product
P_1	156	(untreated)	_
P_2	203	SPLAT EC	350g / ha (2 drops/selected tree)
P_3	260	Mass trapping	10 traps/ha
P_4	156	Fortune AZA (3,2% Azaderachtin)	0.25l/hl
P_5	156	*Trichogramma* cacociae	300eggs/tree, 1card/tree, 12 trees

- *Second Orchard (Mornag)*

The second series of treatment were done in a 0, 5 ha orchard (169 *Citrus* trees) in the region of Mornag (governorate of Ben Arous) (**Table.2**). The grown variety in this orchard is "Thomson".

Table.2. Characteristic of the different plots of the second citrus orchard (Mornag)

Plot	Number of trees	Treatment	Dose of the used product
P'_1	39	(untreated)	_
P'_2	31	SPLAT EC	350g / ha (2 drops/selected tree)
P'_3	36	Mass trapping	10 Delta traps/ha
P'_4	30	Fortune AZA (Azaderachtin3,2%)	0.25l/hl
P'_5	34	*Trichogramma cacociae*	300eggs/tree, 1card/tree, 10 trees

2.1.2. *Control of the Treatments Efficacy*

For the orchard of El Khlidia, the effectiveness of every treatment is determined marking a certain number of trees (5 trees) in each elementary plot and counting all healthy and attacked fruits before treatment, then, after 3, 7, 15, 21 and 30 days of the treatment.

We followed the same experimental protocol for the second orchard (of Mornag), except that the examination of the fruits was done before treatment and after 4, 7, 13, 21, 28 and 35 days of the treatment.

The randomly selected fruits were examined in the laboratory under binocular microscope in order to determine the percentage and the evolution of the infestation by the Carob Moth.

In addition, a delta trap was placed in each plot to follow the development of the population structure of the insect (**Fig.3**).

Statistical analysis was performed through the STATISTICA (6,0). The comparisons of the averages were performed through the NEWMEN Keuls test at the 5% threshold.

Fig. 3. Carob moth larva inside orange fruit

2.2. *Pomegranate treatments*

2.2.1. *Experimental fields*

In 2015, other field trials were carried out in two pomegranate orchards: an organic orchard (0,576 ha) and a conventional one (0,599 ha), in the region of Kettana (governorate of Gabes). The distance between the two orchards is 1,5Km.

- *Conventional Orchard*

This orchard was also divided into four elementary plots: a control plot and three other plots that were chosen to receive different treatments (**Table.3**).

Three series of treatments were done:

-1st series of treatments: 05/28/2015.
-2nd series of treatments: 07/14/2015.
-3rd series of treatments: 08/11/2015.

Table 3. Characteristic of the different plots in the conventional orchard

Plot	Area of the plot (ha)	Number of trees	Treatment	Dose of the used product
C_1	0,19	80	(untreated)	_
C_2	0,175	78	SPLAT EC	350g / ha
C_3	0,124	76	*Trichogramma* cacoeciae releases	25000 insects / ha (5 trees)
C_4	0,11	70	Attract and Kill method	400 drops/ ha

- *Organic Orchard*

The orchard was divided into four plots: three plots were intended to receive different treatments and the third one was used as a control plot (**Table.4**).

Two series of treatments were done in this orchard:

-1st series of treatments: 07/14/2015.
-2nd series of treatments: 08/11//2015.

Table 4. Characteristic of the different plots in the organic orchard

Plot	Area of the plot (ha)	Number of trees	Treatment	Dose of the used product
O_1	0.182	400	(untreated)	_
O_2	0.169	300	SPLAT EC	350g / ha
O_3	0.12	250	*Trichogramma* cacoeciae releases	25000 parasitoids/ ha (5 trees)
O_4	0.105	200	Attract and Kill method	400 drops/ ha

2.2.2. *Control of the Treatment Efficacy*

In December, we put two traps per plot in the conventional orchard, and in June, we put only one trap per plot in the organic orchard.

On May 20, we started fruit sampling (50 fruits were collected randomly) from the different plots of the two orchards (organic and conventional) .Then, we brought these samples to the laboratory and we examined them using a binocular microscope.

In early July, we detected the presence of *E. ceratoniae* in the pomegranate orchards, so, we marked trees

randomly (with paint) in every elementary plot of the two orchards and we started counting all healthy, attacked and fallen fruits per tree (**Fig.4**).

Fig. 4. Carob moth damage on pomegranate

2.3. *The Different Treatments*

- *Trichogramma Cacoeciae Releases*

The species used is *Trichogramma cacoeciae.* The success of this method is based on the coincidence between the time of release and the pest oviposition period. So, we had to take fruit samples and to examine the population structure of *Ectomyelois ceratoniae* in the two orchards (organic and conventional orchard). In general 25000 *Trichogramma*/ha were used (**Fig.5** and **Fig.6**).

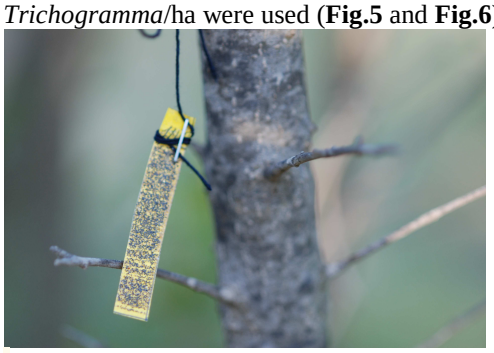

Fig. 5. Trichogramma card placed in the field (stapled to a trunk)

Fig. 6. Trichogramma card with nominal 100,000 parasitized eggs (of Ephestia kuehniella) placed in test tubes.

- *Pheromone-Mediated Mating Disruption Using SPLAT EC*

Splat EC is Z, E 7, 9, 11 dodecatrienyl formate, analogue of Z, E, 9, 11,13 tetradecatrienal which is more stable and gives better results.

SPLAT EC was applied as discrete point sources to minimize its relative surface area in order to increase the product longevity. We applied 350g/ha of SPLAT EC on a branch of trees throughout the selected plots (**Fig.7**).

Fig. 7. A drop of SPLAT EC placed on a branch

- *Attract and Kill Method*

This control method is based on a combination between a carob moth sex pheromone (0, 08%) and an insecticide (Permethrin: 6%) and 93.93% of inert ingredients.

In field, we put drops of the product on a branch of every selected tree with a gun (400 drops/ ha). This product attracts the males of *E. ceratoniae*, and with their contact with the product, the insecticide kills them.

In the conventional plot selected for this treatment (C_4), we applied 6 drops of the product on every selected tree. But, in the organic plot (O_4) we applied only 2 drops/selected tree.

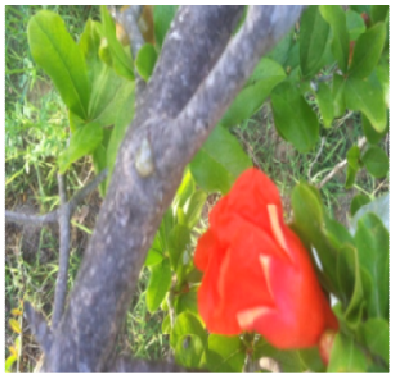

Fig. 8. A drop of Attract and Kill product placed on a tree

- *3, 2% Azaderachtin (Fortune AZA)*

Fortune Aza 3, 2% EC is a 3,2% Azadirachtin (32 g/l) formulated Insect Growth Regulator (IGR). Azadirachtin, a chemical compound belonging to the limonoid group, is a secondary metabolite present in neem seeds.

Fortune Aza 3,2% prevents molting between larval, pupal and nymphal stages, reducing insect infestations. We used Fortune AZA in the selected plot (P_3 and P'_3) with the dose 0,25l/hl.

- *Mass Trapping*

These traps attract the maximum number of *E. ceratoniae* males and it reduces consequently the population level of the pest.

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Mass trapping was conducted in two plots of (P_3 and P'_3), using 10 pheromone traps/ha. Traps were placed evenly through the plots (P_3 and P'_3), and hung to trees at a height of 1,5 m. They were checked weekly and the sticky cards were replaced (**Fig.9** and **Fig.10**).

Fig. 9. A delta trap used for mass trapping

Fig. 10. A sticky card (used in a delta trap) that captured some *E. ceratoniae* adults

III. Results and Discussion

3.1. *Results of Treatments Conducted in Citrus Orchards*

3.1.1. *Evolution of the Number of Males of E. Ceratoniae*

- *First orchard (El Khlidia)*

The first peak (corresponding to the maximum of the captured males) was reached on October 12, 2013 with an average of 16 males/trap corresponding to the last generation of the pest before overwintering. This peak coincides with oranges ripening period. Later, another pic was observed on April 15, 2014 with an average of 8 males/trap. This pic is the result of the emergence of adults from overwintering pupae in fallen fruits left on the ground.

- *Second Orchard (Mornag)*

The first pic of captured males was observed on October 31 with an average of 4 males/trap. Another generation was observed on April 20, 2014 with an average of only 2 males/trap.

Although the average of captured males per trap was not very important for the months of September and October, the attack of the pest led to fruit drop.

With the approach of winter, the insect starts overwinter as an old instar. The insect activity and the population rate depends on the region. Indeed, in the orchard of El-Khlidia, the rate of the captured insect was higher than the one recorded in the orchard of Mornag.

I.1.2. *Evolution of the Population Structure of E. Ceratoniae*

- *First Orchard (El Khlidia)*

The examination of the fallen fruits showed that 30-60% of the insect populations consisted of young larvae, which proves that the fruit generally falls at the beginning of the attack and thus, at the time of penetration of the L_1 larva. The larva continues then, its development cycle in the fallen fruit.

In late October, we didn't detect any infestation by the insect in fallen fruits, because, the insect started overwintering.

Fallen fruits were not 100% attacked by *E. ceratoniae*. This is explained by pre-harvested drop which is related to several orchard and climatic factors including tree mineral nutrition, summer pruning, and water availability and growing season temperature.

We noticed that some fruits were damaged while the larvae were absent. The percentage of these fruits is ≈ 10%. This can be explained as follows: the larva needs more than one fruit to complete its development cycle especially as the fruit can become rotten after its fall, or that pupation occurs outside of the fruit.

The examination of the fruits samples taken from orange trees showed that 58-85% of the insect population was composed of eggs and young instars (L_1, L_2 and L_3).

We noticed that young instars number is higher in the fruits taken from trees than in fallen fruits. So, without treatment, the majority of the fruits on the tree will fall because of the infestation.

- *Second Orchard (Mornag)*

When we started the treatments in this orchard, half of the population (50 %) was composed of young instars (L_1 and L_2) and the other half of the population consisted in old instars (L_3 and L_4) and eggs. L_5 stages and pupae were absent.

I.1.3. *Treatments Efficacy*

- *First Orchard (El Khlidia)*

From September until harvest of the oranges, we evaluated the effect of different treatments on the evolution of the infestation level by examining samples of falling fruits and fruits on trees.

After 7 days of the treatment by SPLAT EC (350g/ha), the infestation level by *E. ceratoniae* decreased to reach 10% compared to 60% in the control plot (**Fig.11**).

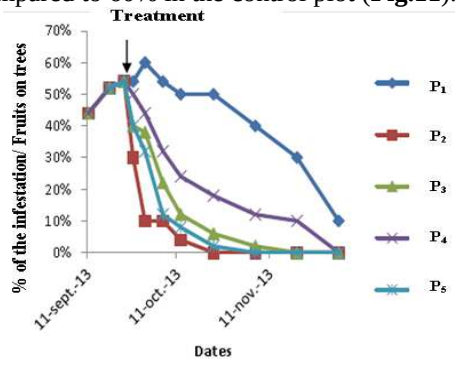

Fig. 11. Evolution of infestation of the fruits on trees for the different treatments (El Khlidia orchard)

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P_1: Control plot, **P_2**: Plot treated with SPLAT EC (350g/ha),**P_3**: Plot selected for mass trapping (10 traps/ha),**P_4**: Plot treated with Fortune AZA (250cc/hl). **P_5**: Plot selected for *Trichogramma* releases (300 eggs/tree).

The examination of the dropped fruits showed that the infestation level in the plot treated with SPLAT EC decreased from 53% (September 26, 2013) to 5% (October 23, 2013) (**Fig.12**).

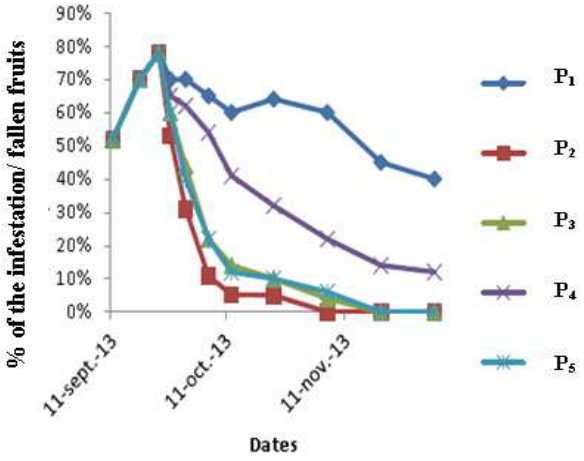

Fig. 12. Evolution of infestation of the fallen fruits for different treatments

P_1: Control plot, **P_2**: Plot treated with SPLAT EC (350g/ha),**P_3**: Plot selected for *Trichogramma* releases (300eggs/tree),**P_4**: Plot treated with Fortune AZA (250cc/hl),**P_5**: Plot selected for mass trapping (10 traps/ha).

The release of *Trichogramma* (300 eggs/tree) lowered the infestation level to ≈ 8% (October 12, 2013). However, there was no statistically significant difference between the infestation rate in the plot used for mass trapping and the plot receiving *Trichogramma cacoeciae* releases ($p< 0,05$).

Treatment with Fortune AZA (3,2%) has no effect on reducing the populations of the pest. This can be explained by the endophytic behavior of the pest.

Statistical analysis showed a significant difference between the infestation rate in the plot treated with SPLAT EC and the plot treated with Fortune AZA ($p<0,05$).

Table. 5 shows that SPLAT EC (T_1) was the most effective treatment against *E. ceratoniae* compared to other treatments (on 10/23/2013 (D5), the reduction of the infestation rate in the plot treated with SPLAT EC, reached 100%).

- *Second Orchard (Mornag)*

Examination of the fruits taken from trees in the control plot showed that the infestation rate increased in October to reach the maximum (≈40%) on mid-October. This indicates the importance of the damage caused by the last generation of the insect (before overwintering). Later, on November 4, 2013, the infestation level decreased to reach only 10% at the end of the month (overwintering period) (**Fig.13**).

Table. 5. The reduction of the infestation rate (of each treatment) (%) in the first orchard (El Khlidia)

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8
T_1	44	83	81	92	100	100	100	100
T_2	26	37	59	76	88	95	100	100
T_3	7	27	41	52	64	70	67	100
T_4	26	47	78	84	96	100	100	100

T_1: Plot treated with SPLAT EC (350g/ha).**T_2:** Plot used for mass trapping (10traps/ha),**T_3:** Plot treated with Fortune AZA (3,2%),**T_4:** Plot used for *Trichogramma* releases (300eggs/tree), **D_1**: 9/26/2013, **D_2**: 9/30/2013, **D_3**: 10/6/2013, **D_4**: 10/12/2013, **D_5**: 10/23/2013,**D_6**: 10/6/2013, **D_7**: 11/20/2013, **D_8**: 12/4/2013.

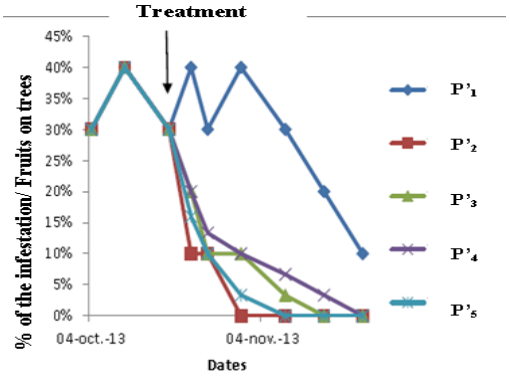

Fig. 13. Evolution of infestation of the fruits on trees for different treatments (Mornag orchard)

P'_1: Control plot,**P'_2:** Plot treated with SPLAT EC (350g/ha),**P'_3:** Plot used for mass trapping,**P'_4:** Plot treated with Fortune AZA (3.2%),**P'_5:** Plot used for *Trichogramma* releases (300 eggs/tree).

Examination of fallen fruits in the control plot showed a similar evolution of the infestation. Indeed, on the middle of October, the infestation rate started to increase to reach its maximum on November 4 (≈60%). Then, it decreased to reach ≈ 20% by the end of the month (**Fig.8**).

Fig.8 shows that treatment with SPLAT EC and mass trapping reduce the rate of infection after a week of their application from ≈50% in the control plot to ≈30% (in the treated plots). In the plot used for *Trichogramma cacoeciae* releases, the infestation level was lower than the one in the plot treated with Fortune AZA (3.2%) even after three weeks of the application. This significant difference was verified by statistical analysis.

The examination of the fallen fruits indicated that some of the fruits (5% of the examined fruits) were damaged while the larvae were absent. In addition, most of the larvae penetrate through the navel of the fruit, except the cases where they penetrate from injuries or by the peduncle of the fruit (1%).

Most of the examined fallen fruits contain a single larval stage except in 1% of cases where they can contain 2 (in the case of a heavy infestation). 2% of the fruits contained empty cocoons, suggesting that the pest has achieved all its cycle inside the fruit until the emergence of the adult.

Fallen fruits were not 100% attacked by *E. ceratoniae.* In fact, 15% of the fruits fell due to the attack of other pests or to other orchard and climatic factors.

Fig. 8 shows that after 7 days of the application of the different treatments, infestation rate in the plot treated with Fortune AZA (3,2%) stayed higher than in the other treated plots.

The results shown in **Fig. 14** indicate also that treatment with SPLAT EC was the most effective in lowering the rate of infestation of *E. ceratoniae.* Indeed, the difference between the efficacy of this treatment and the rest of the treatments is statistically significant (P>0, 05).

The results shown in **Table.6** confirm that the treatment with SPLAT Ec ($\mathbf{T_1}$) is the most effective against *E. ceratoniae.* In fact, after 13 days of the treatment ($\mathbf{D'_3}$**:**10/31/2013), the reduction of the infestation rate reached 100% (**Table. 6**).

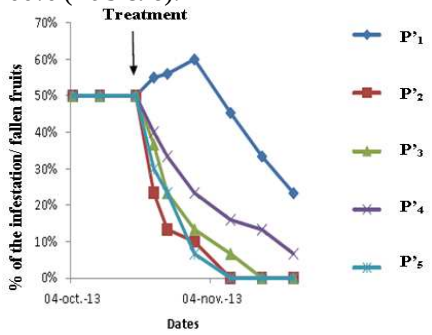

Fig. 14. Evolution of infestation of the fallen fruits for different treatments (Mornag orchard)

$\mathbf{P'_1}$**:** Control plot, $\mathbf{P'_2}$**:** Plot treated with SPLAT EC (350g/ha), $\mathbf{P'_3}$**:** Plot used for mass trapping,$\mathbf{P'_4}$**:** Plot treated with Fortune AZA (3.2%), $\mathbf{P'_5}$**:** Plot used for *Trichogramma* releases (300 eggs/tree).

Table. 6. The reduction of the infestation rate (of each treatment) (%) in the second orchard (Mornag).

	$\mathbf{D'_1}$	$\mathbf{D'_2}$	$\mathbf{D'_3}$	$\mathbf{D'_4}$	$\mathbf{D'_5}$	$\mathbf{D'_6}$
$\mathbf{T_1}$	75	67	100	100	100	100
$\mathbf{T_2}$	50	67	75	89	100	100
$\mathbf{T_3}$	50	56	75	78	83	100
$\mathbf{T_4}$	60	67	92	100	100	100

$\mathbf{T_1}$**:** Plot treated with SPLAT EC (350g/ha),$\mathbf{T_2}$**:** Plot used for mass trapping,$\mathbf{T_3}$**:** Plot treated wit Fortune AZA (3.2%),$\mathbf{T_4}$**:** Plot used for *Trichogramma* releases (300 eggs/tree),$\mathbf{D'_1}$**:** 10/22/2013, $\mathbf{D'_2}$**:** 10/25/2013**,** $\mathbf{D'_3}$**:** 10/31/2013**,** $\mathbf{D'_4}$**:** 11/08/2013**,** $\mathbf{D'_5}$**:** 11/15/2013**,** $\mathbf{D'_6}$**:** 11/22/2013.

I.2. *Results of Treatments Conducted in Pomegranate's Orchards*

The traps installed inside the two pomegranate orchards, allowed us to have an idea about the time in which the insect starts its development cycle.

3.2.1. Evolution of the Number of Males of E. Ceratoniae

- *Conventional Orchard*

After a period of diapause (from January until March), adults of *E. ceratoniae* appeared (towards the end of April) with an average of 4 males per trap (**Fig.5**). This first detection of the pest coincides with the pomegranate's blooming period.

The first peak of captured adults was reached on May 26 with an average of 4 males/trap corresponding to the first generation of the pest. The maximum of captured males was recorded on June 26 with an average of 9 males/trap. The second generation appeared on July 26 with an average of 6 males/trap and the third and final generation appeared on August 26 with an average of 8 males/trap (**Fig.15**).

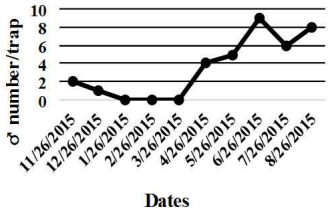

Fig. 15. Evolution in the number of males captured with pheromone traps installed in the conventional orchard (♂: males)

- *Organic Irchard*

The pest monitoring in the organic orchard started a little late, so, we missed the first generation (**Fig.16**). However, maximum of males trapped was recorded on June 23 with an average of 24 males per trap. Later, this number has begun to decrease to reach: 6 males/trap on 7 August, which corresponds to the second generation of the pest. On August 25, we caught 10 males/trap which corresponds to the third and final generation (**Fig. 16**).

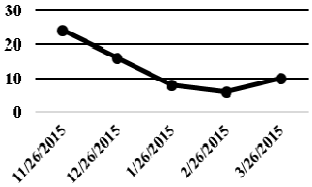

Fig. 16. Evolution in the number of males captured with pheromone traps installed in the organic orchard, ♂ : males

I.2.2. *Evolution of the Population Structure of E. Ceratoniae*

- *Conventional Orchard*

The examination of the fruits samples in the laboratory allowed us to determine the evolution of the insect population's structure during the treatment period in the conventional orchard.

For the first three weeks of May, the majority of the insect populations found in harvested fruits consists in eggs and young instars (L_1, L_2 and L_3) (**Fig.11**). Towards the end of May, nymphs and old instars of *E. ceratoniae* appeared and their number increased to reach almost 20 % of the populations in April. These stages (Nymphs, L_4 and L_5) appeared and disappeared throughout the generations but their number has not exceeded 20 %.

The majority of the populations (<65%) found in the fallen fruits were also formed of young instars, which can be explained by the fact that the fruit attack by the larvae is the main reason of fruit drop process.

- *Organic Orchard*

In the organic orchard, examination of fruit samples in the laboratory showed that the population of *E. ceratoniae* was formed mainly of young instars and eggs (>65 %). While old instars and pupae appeared and disappeared over the different generations. But, they did not exceed 20 % of the population.

I.2.3. *Treatments Efficacy*

- *Conventional Orchard*

The maximum of infestation was reached on July 24 (60%), which corresponds to the attack of the insect's third generation. After 13 days from the first treatments (05/28/2015), the infestation level in all the treated plots decreased.

The most effective treatment was the releases of *Trichogramma*. In fact, the infestation in the plot selected for these releases decreased from 30% (control plot) to 12%.

The second series of treatments (07/14/2015) were more effective against the pest. In fact, after 10 days (07/24/2015), the infestation level in the plot used for *Trichogramma* releases decreased to only 10% compared to 60% in the control plot. In the plot treated with SPLAT EC, the infestation rate decreased to 14%. Finally, the infestation level in the plot treated with Attract and Kill product reached 16% (**Fig.17**).

Based on the statistical analysis (p<0, 05), no significant difference was found between the infestation rate in the different elementary plots of the conventional orchard, whether it was treated by the release of *Trichogramma*, or SPLAT EC or Attract and Kill product.

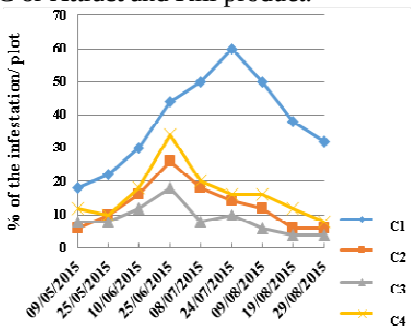

Fig. 17. Evolution of infestation percentage in each treated plot (conventional orchard)

C1: untreated plot, **C2:** plot treated with SPLAT EC (350g/ha),**C3:** plot that received *Trichogramma* releases (300 eggs/tree),**C4:** plot treated with Attract and Kill product (400 drops/ ha).

- *Organic Orchard*

The maximum of infestation in the organic orchard (86%) was recorded on August 9. After 10 days of the first series of treatments (July 24), releasing *Trichogramma* (1,400 individuals/card) reduced the infestation level from 80% in the control plot to 50% in the treated plot. In the plot treated with SPLAT EC, the infestation level declined to reach 56%. Finally, the infestation level in the plot treated with Attract and Kill (400 drops/ ha) decreased to reach 60%.

As to the second series of treatments, after 8 days of the application (August 19), the infestation level in the plot selected for *Trichogramma* releases, decreased from 82% in the control plot to reach 22% in the treated plot. The infestation rate in the plot treated with SPLAT declined to reach 30% on August 19. Finally, in the plot treated with Attract and Kill product, the infestation level decreased to 40% (August 19) (**Fig.18**).

Based on the statistical analysis (p<0,05), no significant difference was found between the infestation rate in the different elementary plots of biological orchard too.

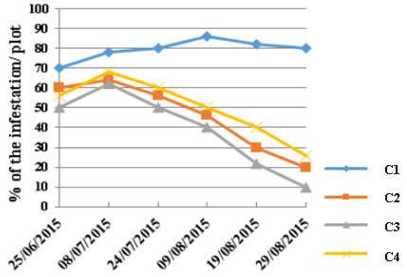

Fig. 18. Evolution of infestation rate in each treated plot (The organic orchard) **C1:** untreated plot, **C2:** plot treated with SPLAT EC (350g/ha),**C3:** plot that received *Trichogramma* releases (300eggs/tree),**C4:** plot treated with Attract and Kill product (400 drops/ ha).

IV. Conclusion

In the two *Citrus* orchards, we detected two important peaks of *E. ceratoniae* males. The first peak is in April (orchard of El Khlidia: 8 males/trap, orchard of Mornag: 2 males/trap) and its the result of the emergence of adults from overwintering pupae in fallen fruits left on the ground. This peak coincides with pomegranate's blooming period. The second peak is in October and its the most important peak. It corresponds to the last generation of the pest before overwintering (orchard of El Khlidia: 16 males/trap, orchard of Mornag: 4 males/trap). This peak coincides with orange's ripening period. All these results confirm that *E. ceratoniae* attacks only fruits.

In the pomegranate orchards, the most important number of captured males was detected in June (conventional orchard: 9 males/trap, organic orchard: 24 males/trap). Another important peak was recorded on late August (conventional orchard: 8 males/trap, organic orchard: 10 males/trap) and it corresponds to the third and final generation.

Mating disruption using SPLAT EC was the most effective treatment in reducing the rate of infestation by *E. ceratoniae* in the *Citrus* orchards. In fact, in the two plots treated with SPLAT EC, after only one week of the treatment, results showed a significant reduction in the infestation level by *E. ceratoniae* (from 60% to 10% in the first orchard, from 50% to 30% in the second orchard). The releases of *Trichogramma* (3000 eggs/tree) and Mass trapping (10 delta traps/ha) had signicantly lowered the level of infestation. However, treatment with Fortune AZA 3,2% (250cc/hl) had no effects on reducing the populations of the pest in the two orchards. This can be explained by the endophytic behavior of the pest.

In the pomegranate orchards, a significant reduction in the infestation level was recorded in all the treated plots (SPLAT EC (350g/ha), *Trichogramma* releases (300 eggs/tree) and Attract and Kill product (400 drops/ha)). The most effective treatment was the releases of *Trichogramma*. But, no significant difference was found between the infestation levels in the different elementary plots of the two pomegranate orchards.

Our results proved that *Trichogramma* releases (300 eggs/tree) mass trapping (10 traps/ha), and mating disruption using SPLAT EC (350g/ha) are promising tools for controlling *E. ceratoniae* populations. Nevertheless, in order to pursue and to optimize such control methods, more field trials are needed.

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