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# Population dynamics of the citrus leaf miner *Phyllocnistis citrella* (Lepidoptera: Gracillaridae) on four citrus crops in the Surman region, Libya

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**Abstract**

The present study aimed to investigate the population abundance of the citrus leaf miner (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillaridae), and determine the number of mines/leaflets on the studied host plants in the Surman region. Four citrus species were selected as host plants, and 100 infected leaves were collected from each host plant. Samples were kept in plastic bags and transferred for examination in the laboratory. The results showed that *P. citrella* larvae recorded four peaks of abundance on lemon occurred on the 21st of July, the 18th of August, the 17th of November, and the 1st of December, and five peaks of abundance on Washington navel occurred on the 14th of July, the 25th of August, 8th of September, 22nd of September and 6th of October respectively, while recorded five peaks of abundance on Tarocco, occurred on the 30th of June, the 21st of July, the 1st of September, the 15th of September, and the 10th of November. Moreover four peaks of abundance recorded on Hasna occurred on the 14th of July, the 11th of August, the 25th of August, and the 1st of September, and *P. citrella* prepupa recorded four peaks of abundance on citrus lemon that occurred on the 7th of July, the 25th of August, the 27th of October, and the 1st of December, and three peaks of abundance on Washington's navel occurred on the 7th of July, 14th of July, and 20th of October and recorded three peaks of abundance on Tarocco occurred on the 30th of June, the 7th of July, and the 20th of October, while recorded on Hasna three peaks of abundance occurred on the 7th of July, the 11th of September, and the 20th of October. While *P. citrella* Pupa recorded five peaks of abundance on citrus lemon occurred on the 16th of June, 30th of June, 10th of January, 17th of January, and 8th of March, and recorded five peaks of abundance on Washington's navel occurred on the 22nd of May, 9th of June, 16th of June, 30th of June and 7th of July and recorded four peaks of abundance on Tarocco occurred on the 9th of June, the 30th of June, the 20th of October, and the 27th of October while recorded three peaks of abundance on Hasna occurred on the 30th of June, the 7th of July, and the 20th of October respectively, further, recorded an increase in the number of mines in autumn and summer in all host plants in the study, while decreasing the number of mines during the winter for both Abusora, Washington Navel, and Tarocco. and at the beginning of spring in lemon and the late autumn for Hasna blood orange.

## Introduction

Citrus is infested with many pests that cause severe damage to trees as well as have a significant impact on production. The main pests are the Mediterranean fruit fly, the red mite, the California louse, aphids, and the citrus leaf miner *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillaridae). The latter is the most important pest that attacks citrus and other species of the Rutaceae family and some related ornamental plants (Abbas *et al*., 2013).

*P. citrella* is native to and originates from East and South Asia (Japan, Thailand, China, India, Malaysia, and Taiwan). It is also present in Australia, Africa, the Mediterranean region, and the Americas (Urbaneja *et al*., 2000). It was discovered in Algeria in 1994 when it was recorded in the coastal districts of the cities of Mostaganem and Oran (Berkani, 1995). Since then, this citrus pest has infiltrated all of the country's citrus-growing districts, including Tipaza, Skikda, and Annaba, before spreading to the country's interior, including Blida, Chlef, and Tizi-Ouzou (Dridi and Berkani, 1996).

In 1994, citrus leaf miner was found in Tunisia. Since then, it has spread to all the citrus trees in Tunisia and become an economic pest of citrus (Jerraya *et al*., 1997 and Chermiti *et al*., 1998). In Libya, the citrus leaf miner was first recorded in 1995 since that time the insect spread rapidly throughout the citrus-growing areas in Libya (EPPO, 2014 and CABI, 2021).

*P. citrella* is a pest that mostly affects plants in the Rutaceaea family and also feeds on plants from different botanical families, including jasmine, mistletoe, willow, and several legumes, where it cannot complete its life cycle. Therefore, its preferred hosts are all members of the citrus genus, including orange, lemon, lime, tangerine, etc. (Knapp *et al*., 1995; Bermúdez *et al*., 2004; Nagamine and Heu, 2002; Godfrey and Grafton-Cardwell, 2002).

The citrus leaf miner is an important factor affecting the production of citrus and causes serious damage to citrus yield because the larvae feed on the leaves and make serpentine mines, which affect plant photosynthesis as the larvae consume between 1 and 7 cm2. Then the edge of the leaf curls upward, followed by chlorosis and later by necrotic spots causing leaf drop (Knapp *et al*., 1995). Additionally, it makes citrus canker disease worse by giving the bacterium *Xanthomonas axonopodis pv. citri* a point of entrance (Gottwald *et al*., 1997). According to Jesus *et al*. (2006), an increase in the number of CLM mines on the leaf surface causes an increase in the severity of the citrus canker disease.

Several control measurements have been developed in response to the enormous damage that this insect has recently caused. Biological control remains the most popular method for controlling the *P. citrella* increase in population. The purpose of any biological control, according to Amalin *et al*. (2002), is to reduce the amount of pest infestations by using natural enemies. Over 40 Hymenoptera species exist, including 25 in Near East countries, attacking citrus leaf miner larvae. No parasitoids have been recorded on leaf miner eggs (Munir, 1996). Moreover, several studies on the population dynamics of *P. citrella* have been conducted on several citrus cultivars in the Mediterranean Basin region (Salhi and Doumandji-Mitiche,2009; Ali and Ali, 2018 and Gharib *et al*., 2019).

But rarely in Libya, so the present investigation aimed to evaluate the population dynamics of *P. citrella* and determine the number of mines/leaflets on the studied host plants.

## Materials and methods

### 1. Area of the study:

To estimate the population fluctuation of citrus leaf miner *P. citrella* and the incidence of its parasitoids, weekly samplings were conducted in a citrus orchard in the Surman region (Location: Latitude 32.7562 Longitude 12.5693).

### 2. Host plants:

In this investigation, four citrus varieties were targeted: lemon (*Citrus limon*), Hasna or blood orange (*Citrus sinensis*), Abusora, Washington navel (*Citrus sinensis* (*Osbeck*) and Tarocco orange (*Citrus sinensis*).

### 3. Sampling:

No insecticide sprays were applied during the period of the study. In each sample, five trees were randomly selected from each citrus species. The canopy of each tree was divided into two sides (north and south), two layers (one and two meters above the ground), and one flush, where 20 young leaves were collected from each tree. Therefore, a total of 100 young leaves per citrus species were collected in each sample; 400 leaves per week from each citrus species were collected and placed into plastic bags.

### 4. Examination:

Leaves were examined under a binocular stereomicroscope for the presence of mines (Either occupied or abandoned), larvae (First to fourth instar based on their morphology), and pupae of the citrus leaf miner, live and dead, as well as parasitoid immature stages (eggs, larvae, and pupa). The results were recorded in weekly tables for each month. Leaves containing parasitized individuals of *P. citrella* were placed in Petri dishes with water-soaked cotton. Until the adult emergence of parasitoids. Adult parasitoids were collected in plastic vials and kept for systematic taxonomy.

### 5. Statistical analysis:

The arithmetic average, standard deviation, coefficient correlation values, and regressions were estimated using Microsoft Excel software 2016.

## Results and discussion

### 1. Seasonal abundance of *Phyllocnistis citrella*:

#### 1.1. On lemon *Citrus Limon* (L) *Osbeck*:

##### 1.1.1. *Phyllocnistis citrella* larval stage:

As presented in Figure (1), *P. citrella* larvae recorded low numbers at the beginning of the season in early June then the population increased recording four peaks of abundance (185, 206, 212, and 288 individuals/100 infested leaves) occurred on the 21st of July the 18th of August,17th of November and 1st of December, while dead larvae recorded five peaks of abundance ( 82, 64, 97, 119, and 92 individuals/100 infested leaves ) occurred on the 8th of September, the 27th of October, the 24th of November, the 1st of December, and the 8th of December. On the other hand, the total of living larvae and dead *P. citrella* in Lemon recorded six peaks of abundance (203, 255, 236, 230, 312, and 407 individuals/100 infested leaves) occurred on the 21st of July, the 18th of August, the 1st of September, the 27th of October, the 24th of November, and the 1st of December.

##### 1.1.2. *Phyllocnistis citrella* prepupal stage:

As shown in Figure (2), the living prepupa of *P. citrella* on Limon recorded four peaks of abundance (49, 19, 12, and 14 individuals/100 infested leaves) that occurred on the 7th of July, the 25th of August, the 27th of October, and the 1st of December, while the dead prepupa recorded two peaks of abundance (16 and 17 individuals/100 infested leaves) that occurred on the 27th of October and the 9th of March. On the other hand, the

total of prepupa of *P. citrella* recorded four peaks of abundance (49, 21, 28, and 26) that occurred on the 7th of July, the 25th of August, the 27th of October, and the 9th of March.

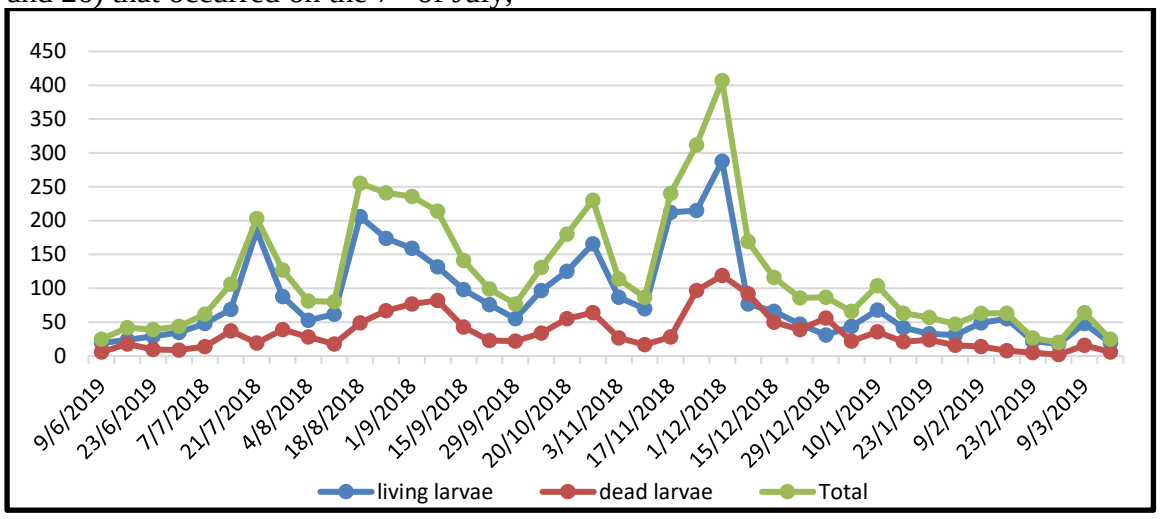


**Figure (1): Population abundance of living larvae, dead larvae and the total of *Phyllocnistis citrella* on Lemon during season 2018-2019.**

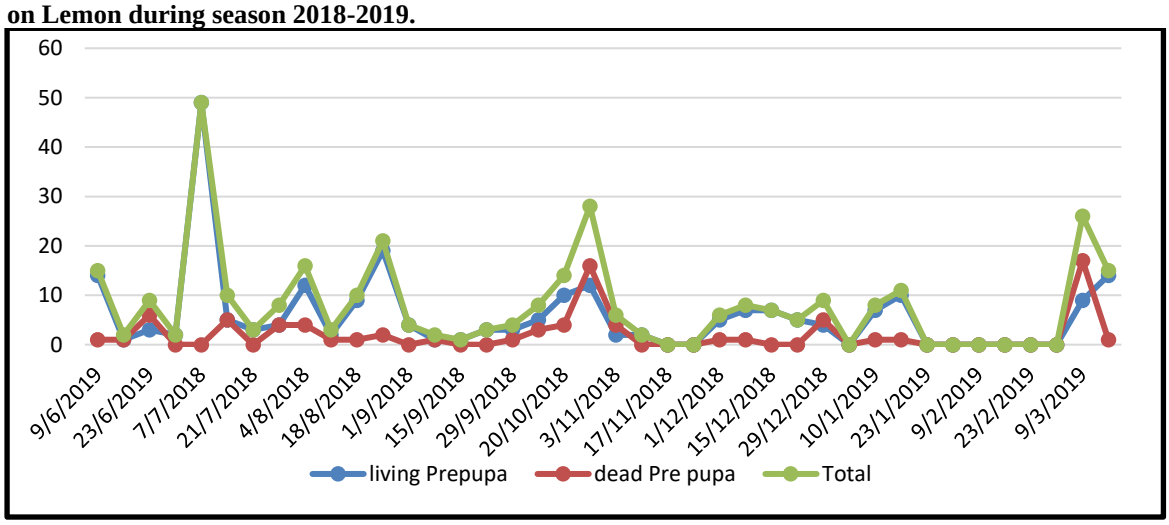


**Figure (2): Population abundance of living prepupa, dead Prepupa and the total of *Phyllocnistis citrella* on lemon during season 2018-2019.**

### 1.1.3. *Phyllocnistis citrella* pupal stage:

As presented in Figure (3), *P. citrella* Pupa recorded five peaks of abundance (23, 29, 66, 47, and 24 Individuals/100 infested leaves) occurring on the 16th of June, 30th of June, 10th of January, 17th of January, and 8th of March, while the dead Pupa recorded two peaks of abundance (14 and 14 individuals/100 infested leaves) occurred on the 9th of June and the 16th of March. As for as the total number of pupae of *P. citrella* recorded five peaks of abundance (29, 22, 71, 51 and 31 individuals/100 infested leaves) on the 30th of June, the 27th of October, the 10th of January, the 17th of January, and the 9th of March.

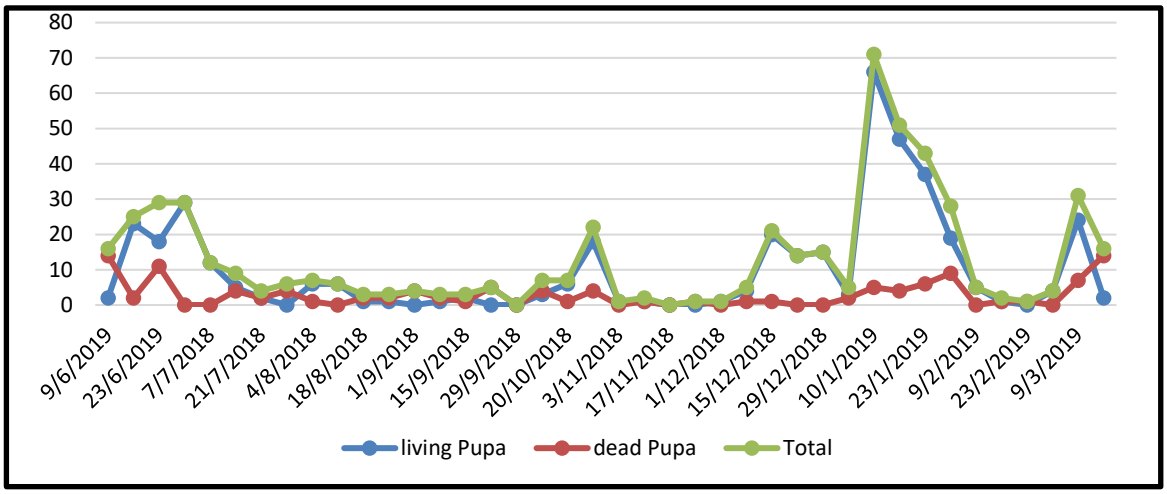


**Figure (3): Population abundance of living pupa, dead pupa and the total of *Phyllocnistis citrella* on lemon during season 2018-2019.**

As shown in Table (1), *P. citrella* stages on lemon showed their highest monthly average numbers in November (188.25 ± 106.08 individuals /100 infested leaflets) for larvae and (17.5±21.21 individuals/ 100 infested leaflets) in July for prepupa and (39.6±24.80 individuals/ 100 infested leaflets) in January for pupal stage. On the other hand, *P. citrella* stages on lemon showed their lowest monthly average numbers occurred in March (36.33±24.091ndividuals/100 infested leaflets) for larvae and (0 individuals/100 infested leaflets) in February for prepupa and (1±0.82 individuals/100 infested leaflets) in November for pupal stage.

**Table (1): Total average numbers ± SD of CLM stages and Infested leaflets during the period of the study on *Citrus limon* (L) *Osbeck*.**

| Months | CLM Larvae Mean ± S.d | CLM PrePupa Mean ± S.d | CLM Pupae Mean ± S.d |
|---|---|---|---|
| **June** | 37.5 ± 8.58 | 7.0 ± 6.27 | 24.75 ± 6.13 |
| **July** | 124.75 ± 95.37 | 17.5 ± 21.21 | 7.75 ± 3.5 |
| **August** | 164.25 ± 96.88 | 12.5 ± 7.77 | 4.5 ± 2.06 |
| **September** | 153.4 ± 69.72 | 2.8 ± 1.30 | 3.0 ± 1.87 |
| **October** | 180.33 ± 49.50 | 16.67 ± 10.26 | 12.0 ± 8.66 |
| **November** | 188.25 ± 106.08 | 2.0 ± 2.83 | 1.0 ± 0.82 |
| **December** | 173.0 ± 135.08 | 7.0 ± 1.58 | 11.2 ± 8.08 |
| **January** | 67.4 ± 21.71 | 3.8 ± 5.31 | 39.6 ± 24.80 |
| **February** | 51.0 ± 20.78 | - | 2.67 ± 2.08 |
| **March** | 36.33 ± 24.09 | 13.67 ± 13.05 | 17.0 ± 13.53 |
| **Mean ± S.d** | 117.62 ± 59.18 | 8.29 3± 6.96 | 12.37167 ± 7.15 |

### 1.2. On Abusora, Washington navel (*Citrus sinensis osbeck*):

### 1. 2.1. *Phyllocnistis citrella* larval stage:

As presented in Figure (4), *P. citrella* larvae on Abu Sora Washington navel recorded five peaks of abundance (184, 313, 279, 255 and 189 individuals/100 infested leaves) that occurred on the 14$^{th}$ of July, 25$^{th}$ of August, 8$^{th}$ of September, 22$^{nd}$ of September and 6$^{th}$ of October, respectively, while dead larvae recorded three peaks of abundance (113, 102, and 104 individuals/100 infested leaves) on the 1$^{st}$ of September, the 22$^{nd}$ of September, and 6$^{th}$ of October. On the other hand, the total number of *P. citrella* larvae recorded six peaks of abundance (232, 224, 369,

365, 357, and 293 individuals/100 infested leaves) on the 14th of July, the 11th of August, the 25th of August, the 8th of September, the 22nd of September and the 6th of October.

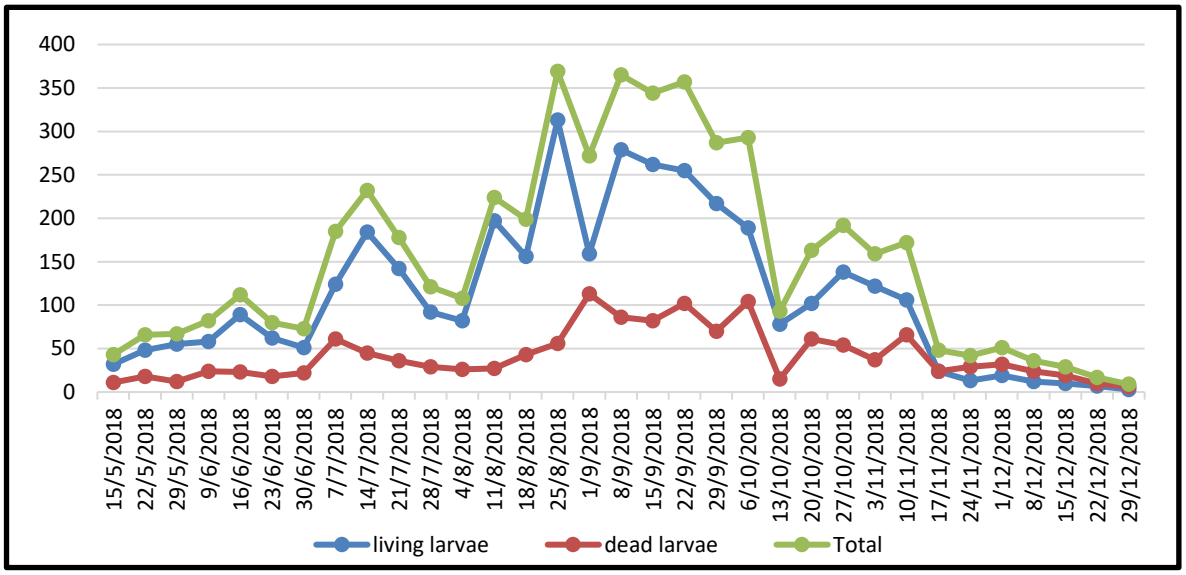


**Figure (4): Population abundance of living larvae, dead larvae, and the total of *Phyllocnistis citrella* on Abu Sora Washington navel during season 2018-2019.**

### 1.2.2. *Phyllocnistis citrella* prepupal stage:

As presented in Figure (5), The population of living *P. citrella* prepupa recorded three peaks of abundance (23, 11, and 11 individual/ 100 infested leaves) on the 7th of July, 14th of July, and 20th of October, while dead prepupa recorded three peaks of abundance (12, 6, and 33 individuals/100 infested leaves) on the 22nd of May, the 4th of August, and the 27th of October. As for the total number of *P. citrella* prepupa recorded, three peaks of abundance (15, 28, and 33 individuals/100 infested leaves) occurred on the 22nd of May, the 7th of July, and the 27th of October.

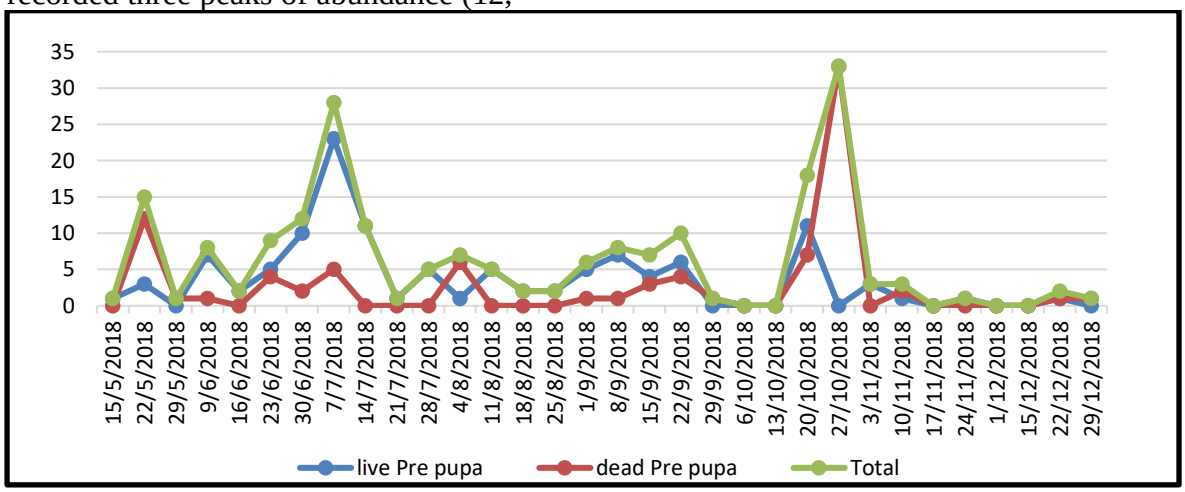


**Figure (5): Population abundance of prepupa, dead Pre pupa and the total of *Phyllocnistis citrella* on Abu Sora Washington navel during season 2018-2019.**

### 1.2.3. *Phyllocnistis citrella* pupal stage:

As presented in Figure (6), *P. citrella* pupa recorded the highest number at the beginning of the season, where five peaks of abundance (20, 34, 38, 62, and 22 individual/ 100 infested leaves) on the 22nd of May, 9th of June, 16th of June, 30th of June and 7th of July respectively, while the dead pupa

recorded one peak of abundance (18 individuals /100 infested leaves) on the 27th of October. As for the total of *P. citrella* Pupa recorded five peaks of abundance (25, 37, 39, 62, and 28 individuals/100 infested leaves) occurred on the 22nd of May, the 8th of May, the 16th of May, the 30th of May, and the 27th of October.

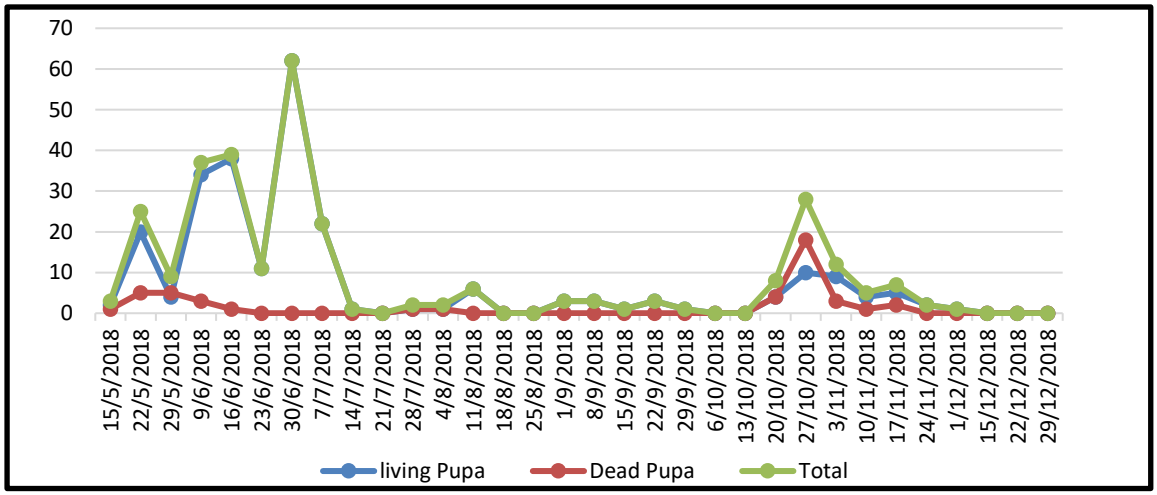


**Figure (6): Population abundance of living pupae, dead pupae and the total of *Phyllocnistis citrella* on Abusora Washington navel during season 2018-2019.**

As shown in Table (2), *P. citrella* stages on Washington navel (*Citrus sinensis Osbeck*) showed their highest monthly average numbers in September (325±42.54 individuals/ 100 infested leaflets) for larvae and (12.75±15.95 individuals/100 infested leaflets) in October for prepupa and (37.25±20.86 individuals/ 100 infested leaflets) in June for pupae stage. On the other hand, as shown in Table (2), *P. citrella* stages on Washington navel (*Citrus sinensis Osbeck*) showed their lowest monthly average numbers in December (28.4±16.40 individuals/100 infested leaflets) for larvae and (0.8±0.84 individuals)/100 infested leaflets) in December for prepupa and (0.2±0.45 individuals/100 infested leaflets) in December for pupae stage.

**Table (2): Total average numbers ± SD of CLM stages and Infested leaflets during the period of the study on Washington navel (*Citrus sinensis osbeck*).**

| Months | CLM Larvae Mean ± S.d | CLM PrePupa Mean ± S.d | CLM Pupae Mean ± S.d |
|---|---|---|---|
| **May** | 58.67 ± 13.58 | 5.67 ± 8.08 | 12.33 ± 11.37 |
| **June** | 86.75 ± 17.27 | 7.75 ± 4.19 | 37.25 ± 20.86 |
| **July** | 179.0 ± 45.50 | 11.25 ± 11.90 | 6.25 ± 10.53 |
| **August** | 225.0 ± 108.17 | 4.0 ± 2.45 | 2.0 ± 2.83 |
| **September** | 325.0 ± 42.54 | 4.6 ± 3.36 | 2.2 ± 1.10 |
| **October** | 185.25 ± 82.90 | 12.75 ± 15.95 | 9.0 ± 13.22 |
| **November** | 105.25 ± 69.82 | 1.75 ± 1.5 | 6.5 ± 4.20 |
| **December** | 28.4 ± 16.40 | 0.8 ± 0.84 | 0.2 ± 0.45 |
| **Mean ± S.d** | 149.17 ± 49.53 | 6.30 ± 6.03 | 9.47 ± 8.07 |

### 1.3. On Tarocco orange (*Citrus sinensis*):

#### 1.3.1. *Phyllocnistis citrella* larval stage:

As presented in Figure (7), *P. citrella* larvae recorded high seasonal abundance during most of the study period and recorded five peaks of abundance (87, 139, 259, 212, and 107 individuals/100 infested leaves) occurred on the 30th of June, the 21st of July, the 1st of September, the 15th of

September, and the 10th of November, while the dead larvae recorded four peaks of abundance (66, 98, 87, and 145 individuals/100 infested leaves) on the 21st of July, the 25th of August, the 8th of September, and the 15th of September. On the other hand, the total number of *P. citrella* larvae recorded seven peaks of abundance (126, 205, 244, 316, 326, 357, and 154 individuals/100 infested leaves) that occurred on the 30th of June, the 21st of July, the 18th of August, the 25th of August, the 1st of September, the 15th of September, and the 10th of November, respectively.

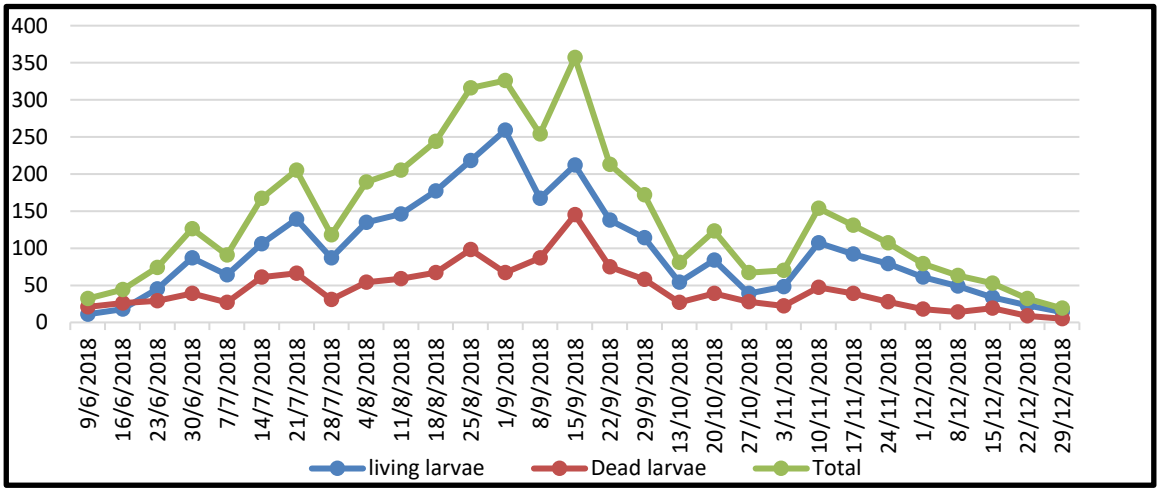


**Figure (7): Population abundance of living larvae, dead larvae and the total of *Phyllocnistis citrella* on Tarocco orange during season 2018-2019.**

### 3.2. *Phyllocnistis citrella* prepupal stage:

The prepupal stage population as presented in Figure (8), recorded three peaks (10, 19, and 16 individuals/100 infested leaves) occurring on the 30th of June, the 7th of July, and the 20th of October, while the dead prepupa recorded one peak (9 individual/100 infested leaves) on the 20th of October. On the other hand, the total number of *P. citrella* prepupa recorded two peaks of abundance (19, and 25 individuals/100 infested leaves) occurred on the 7th of July and the 20th of October.

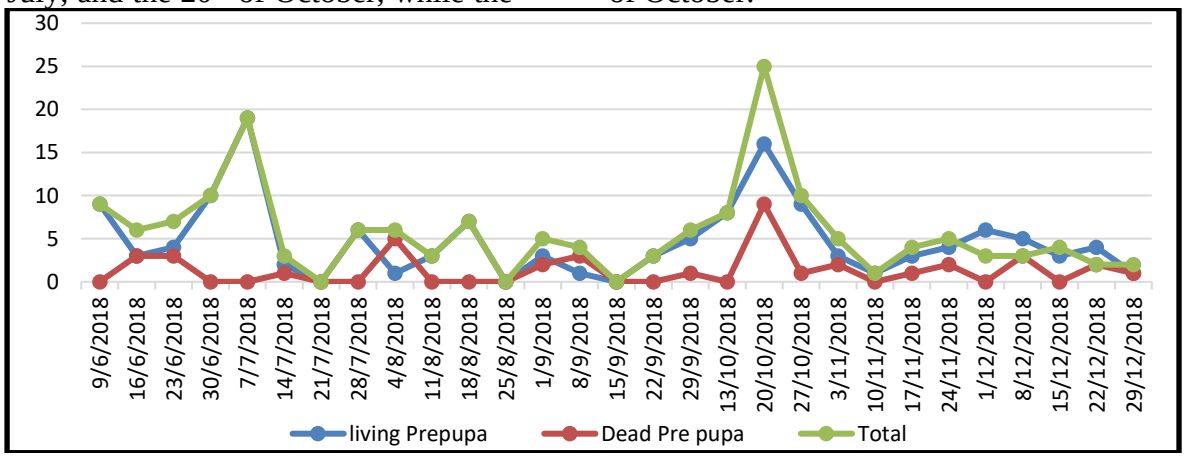


**Figure (8): Population abundance of living pre pupa, dead, and the total of *Phyllocnistis citrella* on Tarocco orange during season 2018-2019.**

### 1.3.3. *Phyllocnistis citrella* pupal stage:

As presented in Figure (9), The *P. citrella* pupae living population, however, recorded four peaks of abundance (47, 33, 16, and 25 individual/100 infested leaves) occurring on the 9th of June, the 30th of

June, the 20th of October and the 27th of October, respectively, while the dead pupa didn't have any peaks of abundance; however, the total of *P. citrella* pupa recorded four peaks of abundance (52, 47, 30, and 30 individuals/100 infested leaves) that occurred on the 9th of June, the 16th of June, the 30th of June, and the 27th of October.

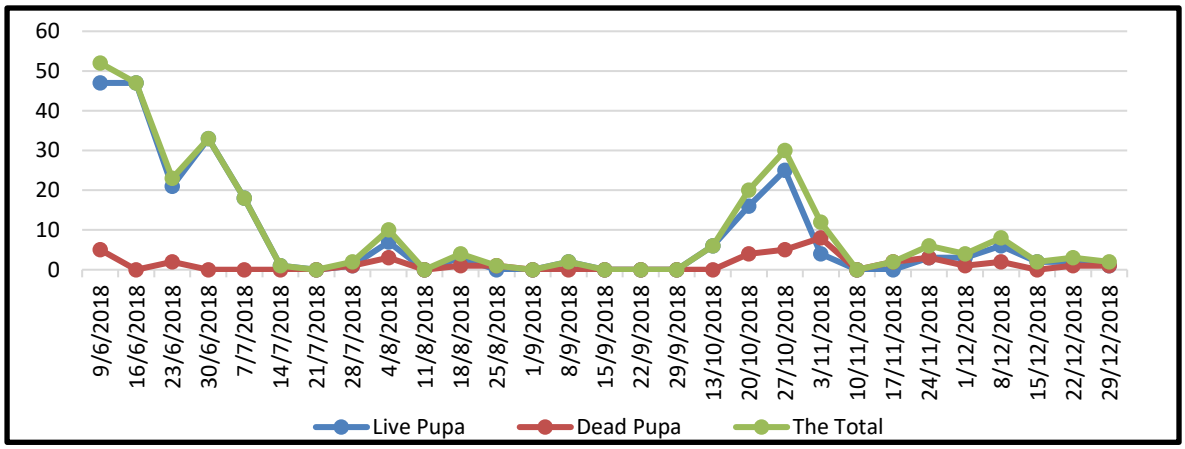


**Figure (9): Population abundance of living pupa, dead pupa and the total of *Phyllocnistis citrella* on Tarocco orange during season 2018-2019.**

As shown in Table (3), *P. citrella* stages on Tarocco orange (*Citrus sinensis*) showed their highest monthly average numbers in September (264.4±76.91 individuals/100 infested leaflets) for larvae and (14.33±9.29 individuals/100 infested leaflets) in October for pre pupae and (38.75±13.23 individuals/100 infested leaflets) in June for pupae stage. On the other hand, *P. citrella* stages showed their lowest monthly average numbers in December (49.2±23.98 individuals/100 infested leaflets) for larvae. (2.8±0.84 individuals/100 infested leaflets) in December for prepupae and (0.4±0.89 individuals/100 infested leaflets) in September for pupal stage.

**Table (3): Total average numbers ± SD of CLM stages and Infested leaflets during the period of the study on Tarocco orange.**

| Months | CLM Larvae Mean ± S.d | CLM Pre Pupa Mean ± S.d | CLM Pupae Mean ± S.d |
|---|---|---|---|
| **June** | 96.0 ± 41.91 | 8.0 ± 1.83 | 38.75 ± 13.23 |
| **July** | 145.25 ± 50.76 | 7.0 ± 8.37 | 5.25 ± 8.54 |
| **August** | 238.5 ± 56.60 | 4.0 ± 3.16 | 3.75±4.5 |
| **September** | 264.4 ± 76.91 | 3.6 ± 2.30 | 0.4 ± 0.89 |
| **October** | 90.33 ± 29.14 | 14.33 ± 9.29 | 18.67 ± 12.06 |
| **November** | 115.5 ± 35.90 | 3.75 ± 1.89 | 5.0 ± 5.29 |
| **December** | 49.2 ± 23.98 | 2.8 ± 0.84 | 3.8 ± 2.49 |
| **Mean ± S.d** | 138.88 ± 45.03 | 6.213 ± 3.95 | 10.80 ± 6.71 |

### 1.4. On Hasna (*Citrus sinensis*):

#### 1.4.1. *Phyllocnistis citrella* larval stage:

As shown in Figure (10), Living *P. citrella* larvae recorded four peaks of abundance (137, 156, 194, and 180 individuals/100 infested leaves) occurring on the 14th of July, the 11th of August, the 25th of August, and the 1st of September. While the dead larvae recorded three peaks of abundance (63, 52, and 67 individuals/100 infested

leaves), occurring on the 14th of July, the 11th of August, and the 1st of September, respectively. As for the total number of *P. citrella* larvae recorded, there were four peaks of abundance (200, 208, 233, and 247 individuals/100 infested leaves), occurring on the 14th of July, the 11th of August, the 25th of August, and the 1st of September.

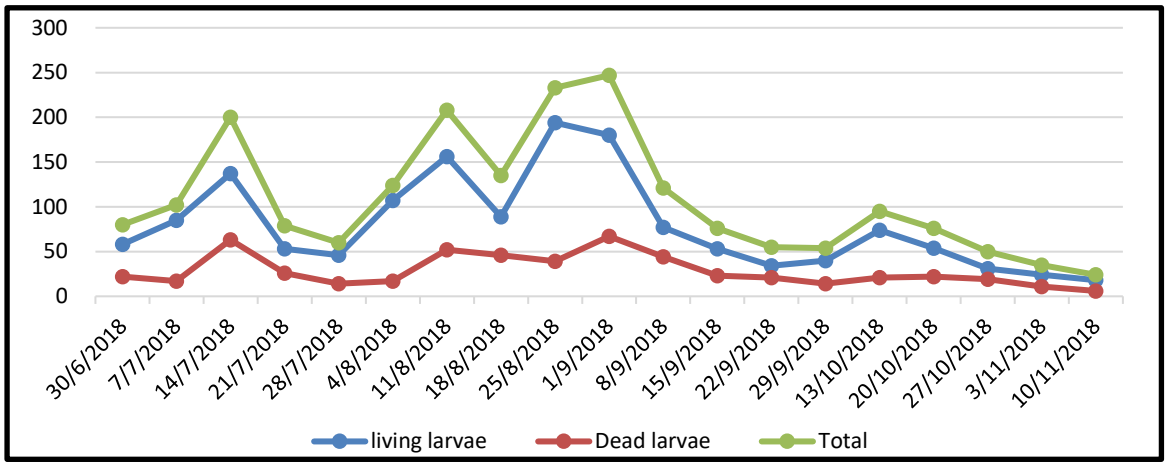


**Figure (10): Population abundance of living larvae, dead larvae, and the total of *Phyllocnistis citrella* on Hasna (*Citrus sinensis*) during season 2018-2019.**

### 1.4.2. *Phyllocnistis citrella* prepupal stage:

As presented in Figure (11), living prepupa of *P. citrella* recorded three peaks of abundance (20, 11, and 12 individuals/100 infested leaves) occurring on the 7th of July, the 11th of September, and the 20th of October, while dead prepupa recorded one peak of abundance (3 individuals/100 infested leaves) occurring on the 8th of September. As for the total number of *P. citrella* prepupa recorded three peaks of abundance (21, 11, and 13 individuals/100 infested leaves) occurred on the 7th of July, the 11th of August, and the 20th of October.

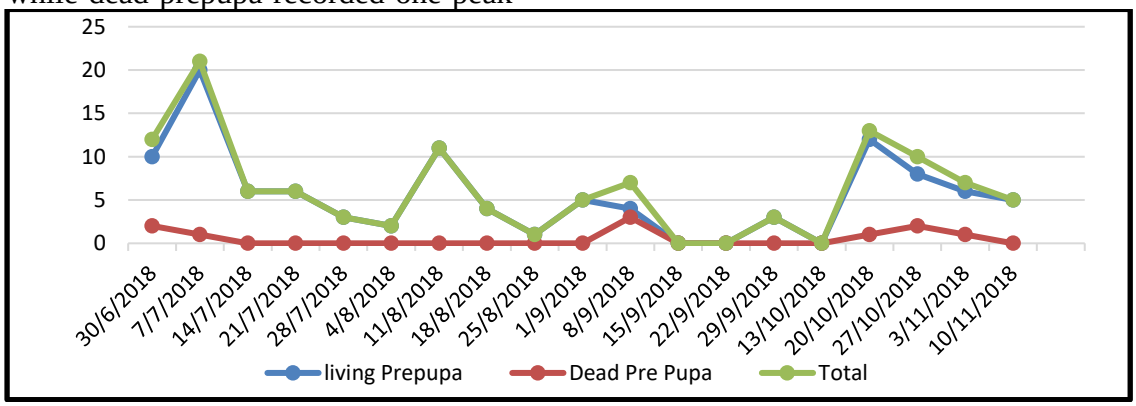


**Figure (11): Population abundance of living prepupa, and dead prepupa and the total of *Phyllocnistis citrella* on Hasna (*Citrus sinensis*) during season 2018-2019.**

### 1.4.3. *Phyllocnistis citrella* pupal stage:

As presented in Figure (12), living pupae of *P. citrella* recorded three peaks of abundance (12, 19, and 9 individuals/100 infested leaves) occurring on the 30th of June, the 7th of July, and the 20th of October, while the dead pupa didn't record any peaks of abundance. On the other hand, for the total number of them recorded, three peaks of abundance (12, 19, and 11 individuals/100 infested leaves) occurred on the 30th of June, the 7th of July, and the 20th of October, respectively.

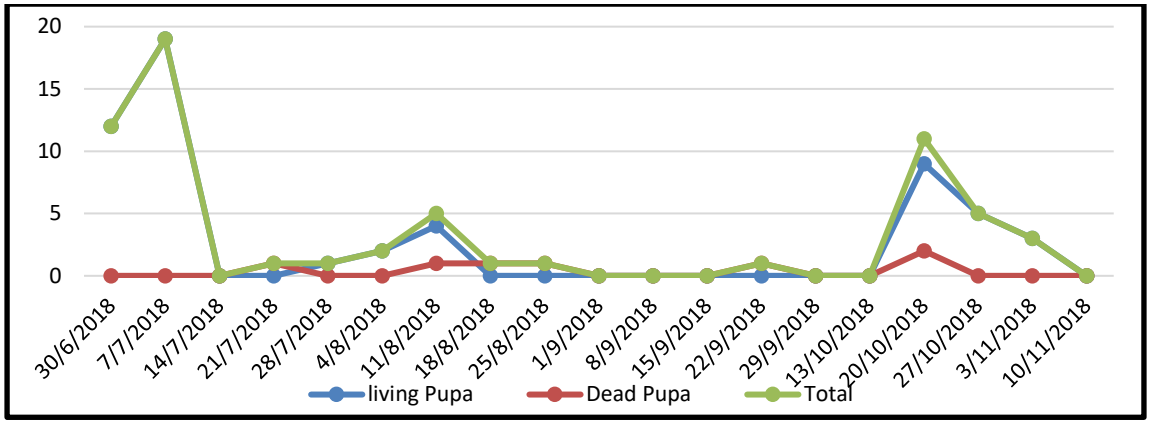


**Figure (12): Population abundance of living pupa, dead pupa, and the total pupa of *Phyllocnistis citrella* on Hasna (*Citrus sinensis*) during season 2018-2019.**

As shown in Table (4), *P. citrella* stages on Hasna (*Citrus sinensis*) showed their highest monthly average numbers in August (175±53.71 individuals/100 infested leaflets) for larvae and (9±8.12 individuals/100 infested leaflets) in July for prepupa and (8.75±3.59 individuals/100 infested leaflets) in June for pupa stage. On the other hand, in Table (4), *P. citrella* stages on Hasna, or blood orange (*C. sinensis*), showed their lowest monthly average numbers in November (29.5±7.78 individuals/100 infested leaflets) for larvae and (3±3.08 individuals/100 infested leaflets) in September for prepupa and (0.2±0.45 individuals/100 infested leaflets) in September for pupae stage.

**Table (4): Total average numbers ± SD of CLM stages and infested leaflets during the period of the study on Hasna (*Citrus sinensis*).**

| Months | CLM Larvae Mean ± S.d | CLM Pre Pupa Mean ± S.d | CLM Pupa Mean ± S.d |
|---|---|---|---|
| **June** | 127.5 ± 41.56 | 7.0 ± 5.23 | 8.75 ± 3.59 |
| **July** | 110.25 ± 62.25 | 9.0 ± 8.12 | 5.25 ± 9.18 |
| **August** | 175.0 ± 53.71 | 4.5 ± 4.51 | 2.25 ± 1.89 |
| **September** | 110.6 ± 80.94 | 3.0 ± 3.08 | 2.0 ± 0.45 |
| **October** | 73.67 ± 22.59 | 7.67 ± 6.81 | 5.33 ± 5.51 |
| **November** | 29.5 ± 7.78 | 6.0 ± 1.41 | 1.5 ± 2.12 |
| **Mean ± S.d** | 104.42 ± 44.80 | 6.19 ± 4.86 | 3.88 ± 3.79 |

**2. Number of mines/leaflets**:

**2.1. On *Citrus limon (Citrus sinensis* (L.) *Osbeck*):**

As shown in Figure (13), the lowest number of mines/leaflets recorded (0.6) mines/leaflets occurred on the 2nd of March of the year 2019 while the highest number recorded (3.7) mines/leaflets occurred on the 17th of November 2018.

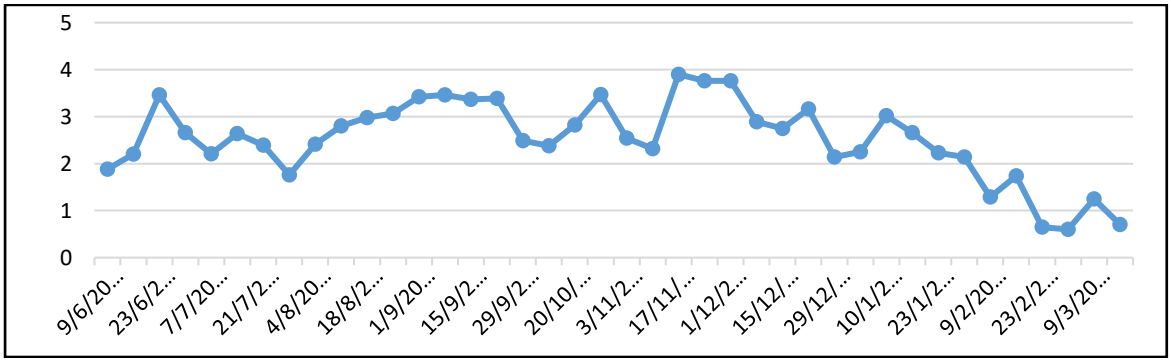


**Figure (13): Number of mines/leaflets in lemon.**

**2.2. On Abusora, Washington navel (*Citrus sinensis osbeck*):**

As shown in Figure (14), the lowest number of mines/leaflets recorded (1) mines/leaflets occurred on the 29th of December 2018, while the highest number recorded (4.68) mines/leaflets occurred on the 15th of September 2018.

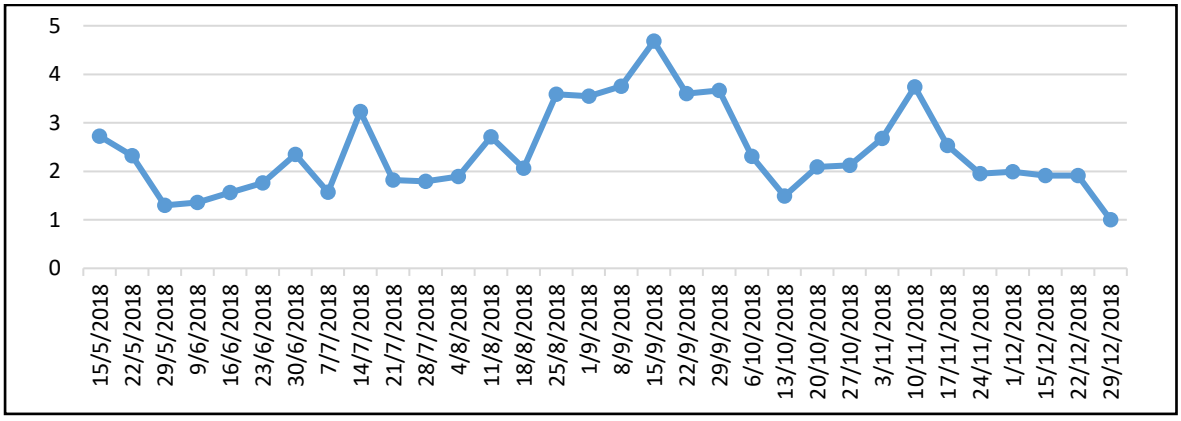


**Figure (14): Number of mines/leaflets in Abusora Washington navel.**

**2.3. On Tarocco orange (*Citrus sinensis*):**

As shown in Figure (15), the lowest number of mines/leaflets recorded (0.55) occurred on the 29th of December 2018, while the highest number recorded (5.15) of mines/100 leaflets occurred on the 15th of September 2018.

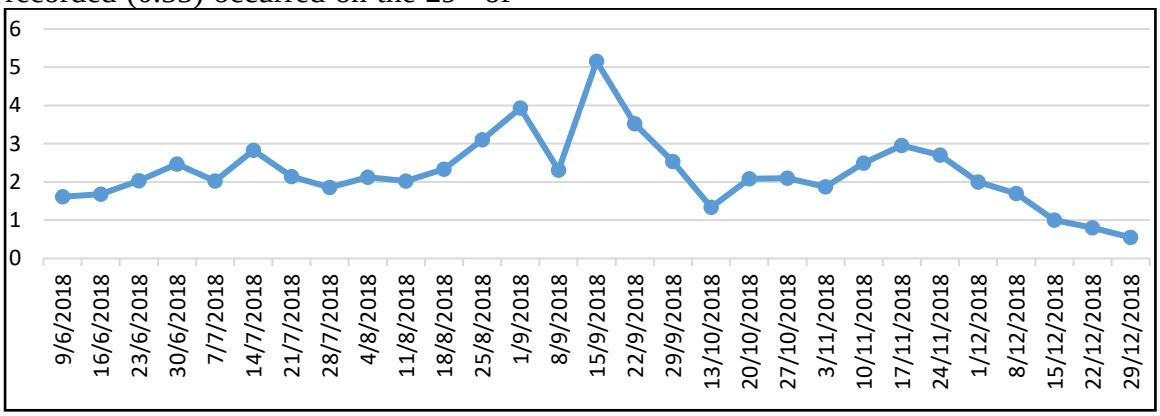


**Figure (15): Number of mines/leaflets in Tarocco orange.**

**2.4. On Hasna, blood orange:**

As shown in Figure (16), the lowest number of mines/leaflets recorded (0.4) occurred on the 10th of November 2018, while the highest number recorded (4.03) occurred on the 1st of September 2018.

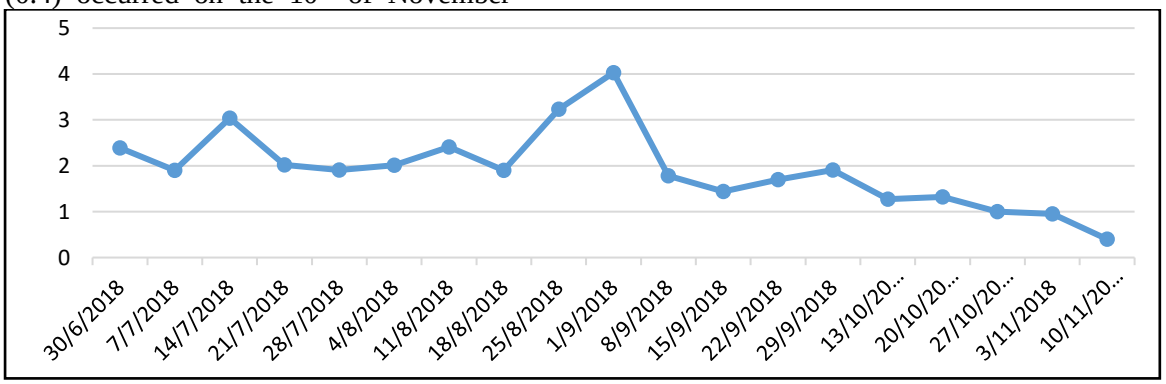


**Figure (16): Number of mines/leaflets in Hasna blood orange.**

Data presented in Table (5), shows the total monthly average number of mines ± SD of *P. citrella* Larvae in all host plants in the study. The highest monthly average number of mines for lemon, *C. limon*, occurred in November (3.13 ± 0.82 mines/100 infested leaflets). While the lowest monthly average numbers occurred in March (0.85 ± 0.35 mines/100 infested leaflets). The highest monthly average number of mines for Abusora Washington navel (*C. sinensis Osbeck*) was recorded in September (3.85 ± 0.47 mines/100 infested leaflets), and the lowest monthly average numbers occurred in December (1.74 ± 0.42 mines/100 infested leaflets), In Tarocco (*C. sinensis*), the highest monthly average numbers of mines were in September (3.49 ± 1.15 mines/100 infested leaflets), and the lowest monthly average numbers were in December (1.21 ± 0.62 mines/100 infested leaflets), while the highest monthly average numbers of mines for Hasna or Blood Orange (*C. sinensis*) were in August (2.39 ± 0.60 mines/100 infested leaflets), and the lowest monthly average numbers were in November (0.68 ± 0.39 mines/100 infested leaflets).

**Table (5): Total monthly average number of mines ± SD of *Phyllocnistis citrella* Larvae in all host plants during the period of the study.**

| Months | Lemon Mean ± S.d | Abusora Mean ± S.d | Tarocco Mean ± S.d | Hasna Mean ± S.d |
|---|---|---|---|---|
| **May** | - | 2.11 ± 0.73 | - | - |
| **June** | 2.55 ± 0.69 | 1.75 ± 0.43 | 1.95 ± 0.39 | - |
| **July** | 2.25 ± 0.37 | 2.10± 0.76 | 2.21 ± 0.43 | 2.22 ± 0.55 |
| **August** | 2.82 ± 0.29 | 2.56 ± 0.77 | 2.39 ± 0.49 | 2.39 ± 0.60 |
| **September** | 2.23 ± 0.41 | 3.85 ± 0.47 | 3.49 ± 1.15 | 2.17 ± 1.05 |
| **October** | 2.89 ± 0.55 | 2.00 ± 0.36 | 1.84 ± 0.43 | 1.20 ± 0.17 |
| **November** | 3.13 ± 0.82 | 2.73 ± 0.75 | 2.50 ± 0.46 | 0.68 ± 0.39 |
| **December** | 2.94 ± 0.59 | 1.74 ± 0.42 | 1.21 ± 0.62 | - |
| **January** | 2.46 ± 0.37 | - | - | - |
| **February** | 1.23 ± 0.55 | - | - | - |
| **March** | 0.85 ± 0.35 | - | - | - |

As presented in Tables (1-4) and Figures (1-12), it is clear that the CLM population displayed 3–7 peaks of abundance on all targeted host plants, where a low number was recorded during the winter months and the beginning of spring. This can be justified by the fall in temperatures and the scarcity of young leaves. Then it recorded its highest levels in summer and autumn, coinciding with new citrus flushes and favorable temperatures for *P. citrella* development. Similar results were obtained by Peña *et al*. (1996), who found that the high peaks of the CLM population were observed during the summer (June–July) and fall (Sept–October) in Florida. These results also agree with those of Mafi and Ohbayashi (2004), who discovered two *P. citrella* infection maxima in July and October, which were closely associated with temperatures that were ideal for growth and constant flushing of new shoots. These results are also online with those of Elkhouly, 2024 and Elkhouly *et al.*, 2017 and 2018. In Sicily (Italy), Caleca and Lo Verde (1997) report that the spring outbreak is spared from infestations of *P. citrella*, with contamination only beginning in the second half of June. Likewise, Pinto and Fucarino (2000) report that in Sicily, summer and fall are CLM's most

active periods. These results also agree with the results of Alkhateeb *et al*. (1999) and Jafari *et al.* (2000) in that the highest density of the pest was during the summer growth period, specifically in July and August, and differs from them in the decrease in infection on the autumn growths. Through the results, it is shown that the CLM population fluctuations are affected by the high rate of a new flush as well as weather factors such as temperature and humidity. According to Sétamou *et al*. (2010), the new flashes, which increase with increasing temperatures and sunlight activity, are the most important biological factors for CLM. Hassina et al. (2017) established that two separate phases determine the miners. The first Summer-Autumn, when the weather is ideal, and the leaves are tender. The second phase is the Winter-Spring season, when there is little to no activity from miners. The drop in temperature and scarcity of the young leaves justify this.

A total of 100 leaves per host plant were examined for mines caused by leaf miners. The mean number of mines was estimated by using Microsoft Excel, and the results in Figures (13,14 ,15 and16), and Table (5) showed an increase in the number of mines in autumn and summer in all host plants in the study. The number of mines decreased during the winter for both Abusora, Washington Navel, and Tarocco, at the beginning of spring in lemon, and in late autumn for Hasna blood orange. The number of mines reflects the extent of the infection, as they are caused by feeding the larvae. Due to this, the number of mines increases in the autumn and decreases in the winter, with increasing population density. According to Malausa (1997), the reason for this insect's inactivity during this time is that the adult density is low throughout the winter. In addition, the indirect effects of climate-caused stressed leaves would harm the larvae. Mingdo *et al*. (1989) and Huang *et al*. (1989) reported that the primary cause of death in winter and early spring of CLM generations was the lack of water in the leaves. But, according to Deng and Garrido (1999), the amount of water in the leaves did not affect how many CLM larvae died.

They also argued that the cold winter weather and the fact that there weren't any new leaves growing were the main reasons why the CLM disappeared during that time. Where the number of mines reflects the extent of the infection, caused by feeding the larvae. Due to this, the number of mines increases in the autumn and decreases in the winter, with increasing population density. These results agree with the study of Liu *et al.* (2008), where the results showed the mean number of mines per tree per month was very low during the cooler months (November through March), while large numbers of mines were detected in May through July, and the numbers of mines were significantly higher in June. This is also consistent with the results of Rahman *et al.* (2005) finding that an area of leaf infestation was observed in April, but it was reduced to the minimum in July. An increase in the area of leaf infestation was again observed in August, which reached a peak in September. These results are in agreement with those of Legaspi *et al*. (2001) and Ahmed *et al*. (2013). Who stated that the percentage of harm caused by CLM peaked in September and then decreased between January and March. Powell *et al.* (2007) reported that May through July saw the discovery of a large number of mines, which seriously damaged the young leaves where they were found. The mean number of mines per tree per month was very low during the cooler months (November through March) in all study years. Also, Kumar *et al.*

(2023), found that there were 1.81 to 9.59 live mines per shoot in the citrus leaf miner population. The months of August, December, and January saw the pest's highest activity. April and May were the months with the lowest incidence. The results of the present study showed differences in the monthly mean number of mines between selected citrus cultivars. Variations in leaf thickness and specific anatomical changes could be the cause of the damage level variation (Mathews *et al*., 2007). These results agree with the study of Arshad *et al*. (2019), where the results showed the mine area generated by CLM larvae was significantly different on citrus cultivars.

Based on the obtained results, it can be concluded that the population dynamics of *P. citrella* throughout the study in the Surman region were higher in the summer and autumn seasons than in the winter and spring seasons. It started in July, and reached a population peak in September and October, and then started to decline in the winter and spring months. In addition, the results showed an increase in the number of mines in autumn and summer in all host plants in the study.

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