**International Journal of Entomology Research**
**www.entomologyjournals.com**
**ISSN: 2455-4758**
**Received: 10-11-2022, Accepted: 28-11-2022, Published: 13-12-2022**
**Volume 7, Issue 12, 2022, Page No. 70-77**

# Host preference and distribution within the tree's canopy of some insect pests infesting citrus species with response to certain weather factors

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**Abstract**
The purple scale, *Lepidsaphes beckii* (Newman), California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) and the citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) are of the most important and serious pests infesting citrus orchards. The present study was carried out during the period from the 2nd of June till the 17th of November 2021 in an orchard cultivated navel orange, mandarin and lemon located in the Experimental Farm of Faculty of Agriculture, Mansoura University, Egypt to study some ecological aspects of the tested pests. The obtained data showed that *L. beckii* and *P. citrella* preferred navel orange followed by lemon and mandarin; while, *A. aurantii* was recorded on lemon leaves only. *L. beckii* showed two peaks of activity in navel orange and one peak in mandarin and lemon orchards; also, *A. aurantii* showed only one peak of activity in lemon orchard. *P. citrella* showed three, one and two peaks in navel orange lemon and mandarin orchards, respectively. The diaspidids *L. beckii* and *A. aurantii* in lemon and mandarin trees preferred east direction followed by north; while, on navel orange trees, *L. beckii* was higher in middle followed by west direction. Also, *P. citrella* preferred middle and east direction of its host trees. Statistical analysis showed that temperature degrees had a positively significant effect on *L. beckii* population (especially in navel orange orchard); while, this effect was insignificant on *A. aurantii* population. In contrary, *P. citrella* population showed negative response to the increase of temperature degrees and showed mostly positive responses to the increase of relative humidity during the present study. Chemical analysis showed that navel orange leaves had relatively high content percentages of nitrogen and carbohydrates coincided with the low content of humidity.

**Keywords:** host preference, distribution, purple scale, California red scale, citrus leafminer, citrus orchards and weather factors

## Introduction
Citrus (Family: Rutaceae) crops are among the world's most significant horticultural industries with the highest foreign trade value (Manner *et al*. 2006) [35]. Nutritionally, fruits of citrus contain carbohydrates, fructose, sucrose, citric acid, fibers, vitamins, minerals, carotenoids and flavonoids (Liu *et al*. 2012) [34]. In Egypt, citrus is considered as the major fruit crops, due to its tremendous economic impact in local market and exportation; whereas, Egypt ranking the sixth biggest producer of orange throughout the world after Brazil, China, US, EU, and Mexico (Abobatta, 2018) [2]. The area of cultivated citrus crops in Egypt reached 530,415 feddans and producing 4,402,180 tons of fruits with an average yield of 9.4 tons/feddan (Anonymous, 2015). Citrus orchards are subject to many insect pests; some of these pests cause serious damage and cause economic loss in the crop (Moustafa, 1999; Ghanim, 2003 and Moustafa, 2004) [41].

The purple scale, *Lepidsaphes beckii* (Newman) (Hemiptera: Diaspididae) is one of the most important and serious species of scale insects in tropical and subtropical regions (Danzig & Pellizari, 1998; Claps *et al*., 2001; Foldi, 2001 and Aly, 2011) [4]. It is a polyphagous attacking 176 genera, belonging to 83 families of plants (Davidson & Miller, 1990; Aly, 2011 and Garcia *et al*., 2016) [4]. It attacks leaves, young shoots, old branches and fruits of citrus trees, causing dieback of the young leaves and twigs in the heavy infestations; so, the infested area looks like a fire burn, and often a sheet of purple scales is covered on the fruits (Gill, 1997, Moghaddam, 2013 and Damavandian, 2020) [27]. *L. beckii* usually has up to four generations per year according to environmental conditions (Zuniga, 1971; Bénassy *et al*., 1975; Davidson & Miller, 1990 and Gill, 1997) [27].

The California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) attacks many host plants belonging to at least 80 plant families (El-Minshawy *et al.*, 1974 and Moursi, 1991) [40]. It is one of the most important insect pests of citrus orchards worldwide damaging all parts of the citrus tree, leaves, twigs and fruits (Onder, 1982; Batra *et al*., 1987; Bozan & Yldrm, 1992; Longo *et al*.1994; Karaca, 1998; Claps *et al*., 2001; Abd-Rabou, 2009 and Pekas, 2011) [44]. The infested leaves have yellow spot under and around each female scale. Prolonged infestation may cause leaf drop and dieback of twigs and eventually large branches. Prominent pits appear on young fruit which are still evident when the fruit matures, and maturing fruit can become completely encrusted with scales. Such fruit tend to dry out and fall off (Bedford, 1998) [12].

The citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) is among the serious pests attacking citrus trees in Egypt and worldwide. Whereas, it is one of the most serious pests of nursery and young plantations as well as new flushes of citrus orchards causing severe damage to them (Heppner and Dixon, 1995; Smith and Hoy, 1995; Moustafa, 1999 and 2004) [30]. It attacks more than half of the new leaves produced on citrus trees (Wilson, 1991). Female of *P. citrella* deposits its eggs singly on the young leaves (Knapp *et al.*, 1995) [32]. The hatched larvae cause damage to citrus through feeding, mining and habiting in the parenchymatous tissues of the leaves producing silvery mines and reducing photosynthetic area of the leaf which eventually reduces the quantity of production (Abdalla *et al*., 2004 and Belasque *et al*., 2005) [13]. *P. citrella* attacks succulent stems and fruits in some citrus varieties which become deformed, yield poor fruits and reduces the marketability of the infested fruit (Giorbelidze, 1979 and Argov & Rossler, 1998) [7]. Other insect pests such as aphids and mealybugs often continue feeding on the damaged leaves after the *P. citrella* have finished feeding (Michaud and Grand, 2003) [38]. Also, the citrus canker, *Xanthomonas citri* Dowson and other fungus pathogens such as *Alternaria* can be augmented on damaged leaf plants by *P. citrella* (Sohi and Sandhu, 1968, Guerout, 1994, Achor *et al.*, 1997 and Bautista-Martinez *et al*., 1998) [11]. *P. citrella* had eleven generations annually (Knapp *et al.*, 1995 and Abdel-Rahman, 1998) [32].

To building-up an efficient integrated pest management for any pest, ecological studies should be done to understand the interactions between the target pest and the elements of the surrounding environment. So, the present work aimed to study some ecological points (*i.e.* host preference, distribution within the tree's canopy and response to certain weather factors) of *L. beckii*, *A. aurantii* and *P. citrella* on certain citrus orchards (navel orange, mandarin and lemon).

## Materials and Methods

The present study was carried out in citrus orchard cultivated with three citrus species [navel orange (*Citrus sinensis* L.), mandarin (*Citrus reticulata* L.), and lemon (*Citrus limon* (L.))]. This orchard located in the Experimental Farm of Faculty of Agriculture, Mansoura University, Egypt.

Five trees of each host plant species homogenous in size and age were selected and marked for the present study. Samples were collected every two weeks during the period from the 2nd of June till the 17th of November 2021. For each host plant, sample consisted of 250 leaves (50 leaves/tree) collected randomly from the cardinal directions (north, south, east and west) and middle of the trees (10 leaves/direction). For each direction, leaves were covered with paper bag on the tree, then pulled up and transferred to the laboratory for investigation by the aid of stereomicroscope. Number of insect pests were counted and recorded.

To represent the effect of certain weather factors (*i.e.* temperature degrees and relative humidity) on the recorded insect populations, daily records of temperature degrees and relative humidity for Mansoura district were obtained from the Central Laboratory of Climatic Research. The daily records of each weather factor were grouped into biweekly means according to the sampling dates.

Data were analyzed by using one-way ANOVA followed by least significant difference (LSD) at probability level of 0.05. Correlation analysis was also performed to represent the effect of weather factors on the recorded insect pests. All analyses were performed using CoHort Software (2004).

Certain components (*i.e.* nitrogen, carbohydrates, fats and humidity) of navel orange, mandarin and lemon leaves were determined. Nitrogen, fats and humidity were determined in Lab of Soil Fertility Tests and Fertilizers Quality Control. Carbohydrates were determined in Seed and Tissue Pathology Lab. The two laboratories are affiliated with the Faculty of Agriculture, Mansoura University, Egypt.

## Results

### 1. Host preference

The obtained data showed that *L. beckii* significantly preferred navel orange leaves followed by mandarin and lemon leaves (with no significant differences between the last two host plants). Where, the mean number of insects/10 leaves reached 249.49±9.20, 197.40±39.59 and 178.69±62.15 on navel orange, mandarin and lemon, respectively. With respect to *A. aurantii*, it preferred lemon leaves only (with a mean of 19.59±4.34 larvae/10 leaves), but it was not recorded on navel orange or mandarin leaves during the tested period. In the case of *C. floridensis*, it was recorded with few numbers (0.02±0.03 and 0.04±0.13 insects/10 leaves) on navel orange and lemon, but it was not recorded on mandarin leaves during the tested period with no significant differences between the three host plant species. *P. citrella* mostly preferred navel orange (10.97±1.31 larvae/10 leaves) followed by lemon leaves (6.24±1.04 larvae) and mandarin leaves (1.33±0.25 larvae) with significant differences between them (Fig., 1).

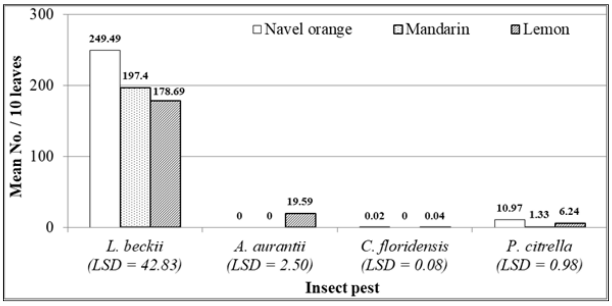


**Fig 1:** Mean numbers of the recorded insect pests infesting navel orange, mandarin and lemon orchards at Manoura district, Egypt.

Data illustrated in Fig. (2) showed that number of *L. beckii* / 10 leaves of navel orange was significantly higher during seven samples; while, on mandarin this pest was significantly higher during three samples. With respect to lemon leaves, *L. beckii* was significantly higher during two samples only.

On another hand, *L. beckii* showed two peaks of activity in navel orange orchard during the tested period. Theses peaks were recorded on the 2nd of July (366.80 insects/10 leaves) and 11th of August (348.33 insects/10 leaves). While, in mandarin orchard, population of *L. beckii* was approximately stable (ranged between 162.60 and 248.66 insects/10 leaves) showing a slight increase on the 14th of July (248.66 insects/10 leaves). In lemon orchard, *L. beckii* was the lowest during most of the tested period, but it showed a distinct peak (518.13 insects/10 leaves) on the 3rd of November (Fig., 2).

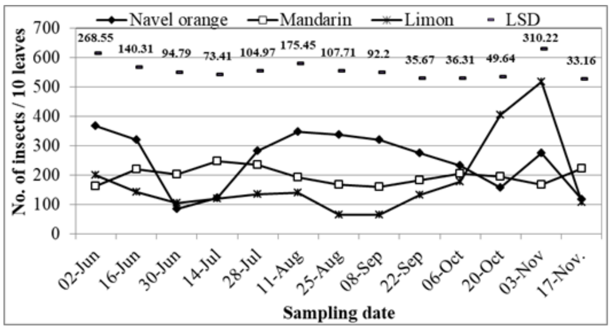


**Fig 2:** Activity of *L. beckii* on navel orange, mandarin and lemon orchards during the period from 2nd of June till 17th of November 2021.

The red scale, *Aonidiella aurantii* (Maskell) was recorded on leaves of lemon only, but it was not recorded on navel orange or mandarin leaves during the tested period (Fig., 3). So, it could be concluded that *A. aurantii* preferred lemon obviously more than navel orange and mandarin leaves.

On another hand, *A. aurantii* showed only one distinct peak of activity in lemon orchard during the tested period. This peak was recorded on the 20$^{th}$ of October (126.86 insects/10 leaves) (Fig., 3).

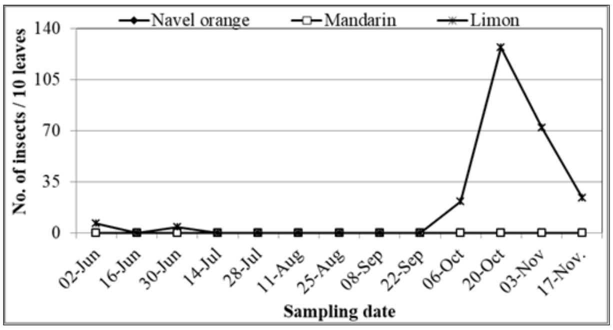


**Fig 3:** Activity of *A. aurantii* on navel orange, mandarin and lemon orchards during the period from 2$^{nd}$ of June till 17$^{th}$ of November 2021.

The citrus leaf miner (CLM), *P. citrella* preferred obviously leaves of navel orange more than lemon; while, mandarin was the lowest preferred host plant. Where, the number of *P. citrella* larvae / 10 leaves of navel orange was significantly higher during ten samples; in contrary, on mandarin this pest was significantly lower during eleven samples. With respect to lemon leaves (the moderate host plant), *P. citrella* was significantly higher than mandarin during ten samples, statistically equal to navel orange during four samples and equal to mandarin during two samples (Fig., 4).

Figure (4) indicated that *P. citrella* showed three peaks of activity in navel orange orchard during the tested period. Theses peaks were recorded on the 30$^{th}$ of June (13.20 larvae/10 leaves), 6$^{th}$ of October (18.40 larvae/10 leaves) and 17$^{th}$ of November (15.53 larvae/10 leaves). While, in lemon orchard, population of *P. citrella* showed two peaks of activity; the first peak (10.13 larvae/10 leaves) was recorded on the 30$^{th}$ of June and the second peak (6.73 larvae/10 leaves) was recorded on the 17$^{th}$ of November. In mandarin orchard, *P. citrella* was the lowest during most of the tested period, but it showed a peak (5.80 larvae/10 leaves) on the 20$^{th}$ of October.

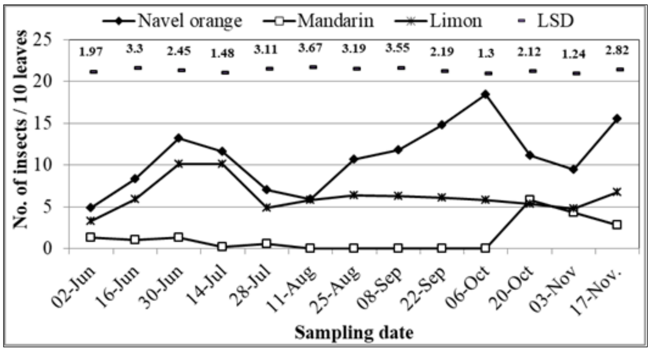


**Fig 4:** Activity of *P. citrella* on navel orange, mandarin and lemon orchards during the period from 2$^{nd}$ of June till 17$^{th}$ of November 2021.

***2. Distribution within the tree's canopy***

Distribution of the purple scale, *L. beckii* in different cardinal directions (north, south, east & west) and middle of tested host plant trees is illustrated in Fig. (5). On navel orange trees, *L. beckii* was higher in middle (with a mean of 339.28±53.6 insects / 10 leaves) followed by west (285.82±35.2 insects), north (246.54±27.2 insects), east (216.95±38.8 insects) and south (154.21±23.1 insects), respectively. Statistical analysis showed that numbers of *L. beckii* in middle of trees were significantly higher than that in south direction, and there were no significant differences between the rest directions. On mandarin trees, there were no significant differences between the tested directions; where, the mean numbers of insects / 10 leaves reached 209.97±15.4, 206.59±12.6, 200.28±15.3, 191.79±15.0 and 180.54±10.7 insects in middle, west, north, east and south, respectively. With respect to lemon trees, *L. beckii* was higher in east direction followed by west, south, middle and north, respectively (with means of 227.26±38.6, 169.64±42.6, 148.95±32.8, 120.54±31.2 and 115.77±26.9 insects / 10 leaves, respectively). Statistical analysis showed that numbers of *L. beckii* in east direction of trees were significantly higher than those in north and middle directions, and there were no significant differences between the rest directions.

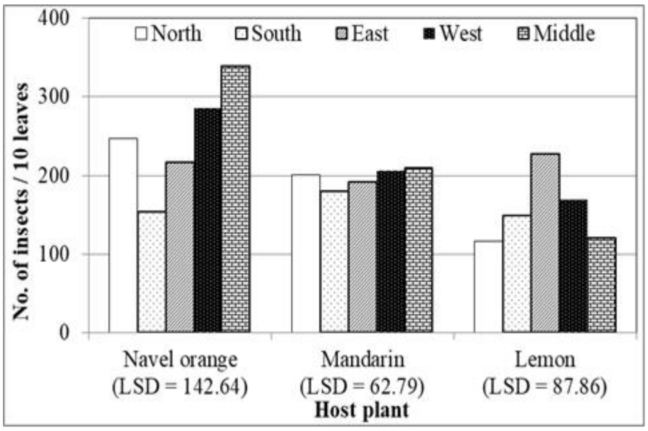


**Fig 5:** Distribution of *L. beckii* on the different cardinal directions and middle of navel orange, mandarin and lemon trees during the period from 2$^{nd}$ of June till 17$^{th}$ of November 2021.

The red scale, *A. aurantii* was recorded on lemon trees only during the tested period. Its distribution in different cardinal directions (north, south, east & west) and middle of the host trees is illustrated in Fig. (6). *A. aurantii* was higher in east direction (with a mean of 33.15±15.3 insects / 10 leaves) followed by north (21.59±11.6 insects), west (15.49±11.7 insects), south (14.61±8.8 insects) and middle (13.13±8.1 insects), respectively. Statistical analysis showed that there were significant differences between numbers of *A. aurantii* in the directions of east, north, west and middle of the trees, and there were no significant difference between south and each of west and middle (where LSD were 2.18).

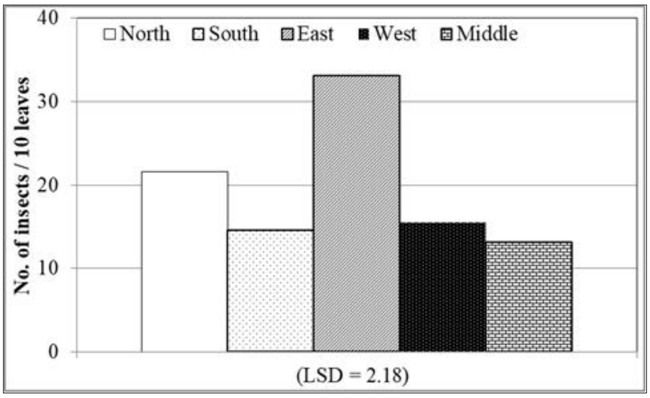


**Fig 6:** Distribution of *A. aurantii* on the different cardinal directions and middle of lemon trees during the period from 2nd of June till 17th of November 2021.

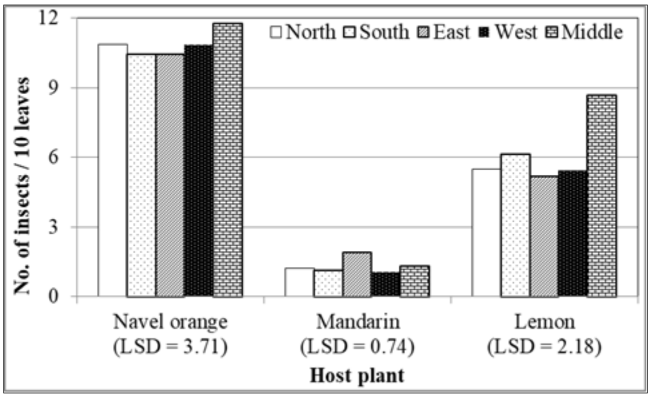


**Fig 7:** Distribution of *P. citrella* on the different cardinal directions and middle of navel orange, mandarin and lemon trees during the period from 2nd of June till 17th of November 2021.

As shown in Fig. (7), distribution of *P. citrella* in different cardinal directions (north, south, east & west) and middle of navel orange trees did not differ significantly. Where, mean numbers of *P. citrella* larvae / 10 leaves reached 11.79±1.38 (in middle), 10.87±1.46 (in north & west) and 10.46±1.38 (in south & east). On mandarin trees, east direction had the highest numbers of *P. citrella* larvae (1.92±0.80 larvae / 10 leaves) followed by middle (1.31±0.50 larvae), north (1.23±0.47 larvae), south (1.13±0.46 larvae) and west (1.08±0.49 larvae), respectively. Statistical analysis showed that numbers of *P. citrella* in east direction of the trees were significantly higher than that in south and west directions, and there were no significant differences between the rest directions. With respect to lemon trees, *P. citrella* was significantly higher in middle of the trees than the four cardinal directions which did not differ significantly. The mean larvae / 10 leaves was recorded as 8.69±0.80, 6.15±0.50, 5.49±0.45, 5.46±0.60 and 5.18±0.50 larvae in middle, south, north, west and east directions, respectively.

### 3. Effect of temperature degrees and relative humidity

Correlation co-efficient values between the tested insect pests (*L. beckii*, *P. citrella* & *A. aurantii*) and certain weather factors (temperature degrees & relative humidity) is represented in Table (1).

As shown in Table (1), effect of temperature degrees was significantly positive on *L. beckii* population in navel orange trees in the north direction (r = 0.63*) and middle (r = 0.63*) of the trees as well as the general mean of population (r = 0.65*). The lowest effect of temperature degrees was recorded in the south direction (r = 0.28$^{ns}$). In contrary, the effect of relative humidity on *L. beckii* on navel orange orchard was insignificantly negative (its highest effect was recorded in south direction (r = 0.54$^{ns}$)). The effects of temperature degrees and relative humidity were generally insignificant in mandarin and lemon orchards.

**Table 1:** Correlation co-efficient values between the tested insects (*L. beckii*, *P. citrella* & *A. aurantii*) populations and certain weather factors (temperature degrees (T.) & relative humidity (R.H.)) on navel orange, mandarin and lemon orchards during the period from 2nd of June till 17th of November 2021.

| | **Navel orange** | | **Mandarin** | | **Lemon** | |
|---|---|---|---|---|---|---|
| | **T.** | **R.H.** | **T.** | **R.H.** | **T.** | **R.H.** |
| ***L. beckii*** | | | | | | |
| North | 0.63* | -0.02 | 0.07 | -0.002 | -0.17 | 0.10 |
| South | 0.28 | -0.54 | 0.01 | -0.15 | -0.01 | -0.20 |
| East | 0.40 | -0.08 | 0.01 | 0.29 | -0.30 | 0.07 |
| West | 0.38 | -0.08 | -0.27 | -0.12 | -0.24 | -0.004 |
| Middle | 0.63* | -0.24 | -0.48 | 0.04 | -0.24 | 0.14 |
| General mean | 0.65* | -0.26 | -0.21 | 0.03 | -0.30 | 0.11 |
| *A. aurantii* | | | | | | |
| North | --- | --- | --- | --- | -0.40 | 0.27 |
| South | --- | --- | --- | --- | -0.39 | 0.32 |
| East | --- | --- | --- | --- | -0.47 | 0.47 |
| West | --- | --- | --- | --- | -0.30 | 0.27 |
| Middle | --- | --- | --- | --- | -0.41 | 0.35 |
| General mean | --- | --- | --- | --- | -0.42 | 0.36 |
| *P. citrella* | | | | | | |
| North | -0.46 | 0.07 | -0.50 | 0.27 | -0.62* | 0.14 |
| South | -0.06 | 0.39 | -0.47 | 0.44 | -0.08 | 0.19 |
| East | -0.58* | 0.76** | -0.60* | 0.31 | -0.27 | -0.01 |
| West | -0.75** | 0.61* | -0.43 | 0.39 | -0.46 | -0.06 |
| Middle | -0.53 | 0.57* | -0.36 | 0.14 | -0.04 | 0.11 |
| General mean | -0.60* | 0.59* | -0.52 | 0.33 | -0.31 | -0.05 |

The effect of temperature degrees on *A. aurantii* population was insignificantly negative in lemon orchard; while, the effect of relative humidity on this pest was insignificantly positive. The highest effects of temperature degrees and relative humidity in lemon orchard were recorded in east direction (r = -0.47$^{ns}$ and 0.47$^{ns}$, respectively). In contrary, the lowest effects of these weather factors (r = -0.30$^{ns}$ and 0.27$^{ns}$, respectively) were recorded in west direction (Table, 1).

The effect of temperature degrees on *P. citrella* population was negative in navel orange, mandarin and lemon orchards. The highest and lowest effects in navel orange orchard were recorded in west (r = -0.75**) and south (r = -0.06$^{ns}$) directions, respectively; while, the highest and lowest effects in mandarin orchard were recorded in east direction (r = -0.60*) and middle (r = -0.36$^{ns}$). The highest (r = -0.62**) and lowest (r = -0.04$^{ns}$) effects of temperature degrees on *P. citrella* population in lemon orchard was recorded in north and middle of the trees, respectively. In contrary, the effect of relative humidity on *P. citrella* population was positive in navel orange, mandarin and mostly in lemon orchards. The highest and lowest effects in navel orchard were recorded in east (r = 0.76**) and north (r = 0.07$^{ns}$) directions, respectively; while, the highest and lowest effects in mandarin orchard were recorded in south direction (r = 0.44$^{ns}$) and middle (r = 0.14$^{ns}$). The highest (r = 0.19$^{ns}$) and lowest (r = -0.01$^{ns}$) effects of relative humidity on *P. citrella* population in lemon orchard was recorded in south and east directions of the trees, respectively (Table, 1).

**Discussion**

According to Price (1992), resource use by herbivore insect populations is a result of complex interactions between detailed requirements of individual herbivores and biotic & abiotic variables affecting resource availability. The present study indicated that *L. beckii* and *P. citrella* preferred navel orange leaves more mandarin and lemon. This preference may be attributed to the relatively high content percentages of protein (nitrogen) and carbohydrates coincided with the low content of humidity. Where, the percentages of nitrogen and carbohydrates in navel orange leaves were obviously high (1.50 and 4.42%, respectively) in comparison with mandarin (1.40 and 3.64%) and lemon (1.26 and 2.60%) leaves; while, the percentages of humidity reached 55.64, 57.43 and 62.63% in navel orange, mandarin and lemon leaves, respectively (Table, 2). The present suggestion is supported by EL Afify *et al.* (2018a); they reported that navel orange has highly content of nitrogen and carbohydrates, in addition to its relatively lowest content of humidity in comparison with mandarin. Also, Nabil *et al.* (2019) recorded significant positive correlations between the population of the black parlatoria scale, *Parlatoria ziziphi* (Lucas) and chemical contents of carbohydrates & protein in navel orange leaves. Salem *et al*. (2006) reported that protein and carbohydrates are the main sources for energy and amino acids for insects. In the present study, the effect of fat contents did not show a clear trend with preference of the tested insect pests to host plant species; where, the percentage of fats in navel orange, mandarin and lemon leaves reached 1.44, 2.35 and 1.47%, respectively. These results are supported by Nabil *et al.* (2019); they reported no significant correlation between *P. ziziphi* and the contents of fats.

With respect to *A. aurantii*, the present results indicated that it preferred lemon leaves only with no record on navel orange or mandarin leaves. This may be attributed to the high content of humidity percentage; which was recorded in lemon leaves (Table, 2). Also, Abd-Elghaffar *et al*. (2018) reported that navel orange and mandarin were obviously less preferred to *A. aurantii* in comparison with sweet orange. The same authors explained that because the effect of epidermal cell thickness; where, the epidermal cell thickness was high in navel orange and mandarin leaves in comparison with sweet orange. According to Alsabte *et al*. (2022), the differences between lemon and orange trees in containing a certain volatile organic compounds may be the cause of *A. aurantii* preference to lemon more than orange. Khalaf *et al.* (2008) (in Iraq) reported that lemon was the most susceptible to the infestation by *Aonidiella orientalis* in comparison with mandarin and orange. In addition, Badary and Abd-Rabou (2010) reported that citrus trees were preferred to *A. aurantii* in comparison with the other tested host plants (*i.e. Ficus nitida* and mango).

**Table 2:** Estimation of certain components (as hundred percentages) in leaves of navel orange, mandarin and lemon trees collected from Dakahlia governorate during November 2021.

| Plant content of | Navel orange | Mandarin | Lemon |
|---|---|---|---|
| Nitrogen | 1.50 | 1.40 | 1.26 |
| Carbohydrates | 4.42 | 3.64 | 2.60 |
| Fats | 1.44 | 2.35 | 1.47 |
| Humidity | 55.64 | 57.43 | 62.63 |

The results of EL Afify *et al.* (2018a) are in agreement with the present study (*P. citrella* preferred navel orange leaves more mandarin and lemon); however, they reported that *P. citrella* preferred navel orange followed by lemon; while, mandarin was the lowest preferred host plants to this pest. Also, Elkady (2005) and Abd-Elghaffar *et al*. (2018) reported that navel orange was more susceptible to *P. citrella* infestation in comparison with mandarin; while, lemon was the most preferred host plant to this pest. El-Dessouki *et al*. (2005) found that mandarin represented the least preferred host plant to *P. citrella*. With regard to Wilson (1991), Knapp *et al.* (1995) [32] and Bermudez *et al.* (2004), higher infestation levels on orange and grapefruit than on other citrus species. Elkady (2005) studied the effect of volatile oils leaf content on *P. citrella* host preference and found that navel orange had high percentages of linalool and β-pinene; while, mandarin had a low percentage of eugenol. Steinbauer *et al.* (1998) and Kursar *et al.* (2006) mentioned that the availability or predictability of suitable age class foliage can be even more important than physical or chemical differences among host species in determining preferences of phytophagous insects. Citrus species show different flushing patterns throughout the year; thus, interspecific differences in temporal availability of young leaves could greatly affect host use by *P. citrella* (Jacas *et al.*, 1997; Goane *et al.*, 2008). So, Goane *et al.* (2008) mentioned that oviposition behavior and performance of *P. citrella* could be determined by ecological conditions or resource availability rather than by physiological adaptation of larvae to each citrus species. Moreover, the inconsistent preferences shown by *P. citrella* females suggest an evolutionarily labile host order of preference (Carrie´re, 1998; Smyth *et al.*, 2003).

Gotthard *et al.* (2004) reported that there was an evidence of geographic variations in oviposition preferences of phytophagous insects. Messina (2004) added that labiality of host preference has been shown to vary among populations, which precludes generalization at the species level. Finally, different preference performance patterns might be detected if other citrus species were considered, because host ranking might vary depending on the options available (Martin *et al.*, 2005). These findings could explain the variations between the present results and others.

During the present study, the activity peaks of *L. beckii* were recorded on July and August in navel orange and mandarin orchards during the tested period; while, in lemon orchard, *L. beckii* showed a distinct peak during November. These findings approximately agreed with those obtained by Esmaeili *et al.* (2022) (in Iran); they found that the highest activities if *L. beckii* were recorded during June, August and October. Also, Draz *et al*. (2011) recorded the highest peaks of *L. beckii* in El-Behaira governorate during April-May, August-September and November. Aly (2011) [4] found that the highest activity of *L. beckii* all over the year on mango orchards in Giza governorate were recorded during the period from July till November. Also, in Giza governorate, El-Amir *et al.* (2012) recorded the highest activity peaks of *L. beckii* on sour orange during May, July, September and February. According to Castaño *et al*. (2008) (in Spain), initial infestation of growing citrus fruits by *A. aurantii* occurs in early June and increases steadily through the summer, reaching its maximum level in October which was similar to the obtained data on this pest (*A. aurantii* showed only one distinct peak of activity during October). In Sicily, Conti and Fisicaro (2008) reported that the highest activities of *A. aurantii* were recorded during July, September and November. In Sharkia governorate, Abd-Elghaffar *et al*. (2018) reported that the highest activities of *A. aurantii* infesting citrus orchards were recorded during February, June and September-October. The variations between the present results and any other study may be attributed to the variation of weather factors, agricultural conditions and/or the tested host plants. With respect to *P. citrella*, it showed its peaks of activity in navel orange, mandarin and lemon orchards during June, October and November of the tested period. These results are approximately in agreement with those obtained by EL Afify *et al.* (2018b); they reported that *P. citrella* showed its peaks during August, September, October and November. Also, Moustafa (2004) [41] reported that the highest activities of *P. citrella* on navel orange trees were recorded during September and October. In Qalubia governorate, Elkady (2005) found that the highest activity of *P. citrella* on six varieties of citrus was recorded during August and September; while, El-Dessouki *et al*. (2005) found that the highest activities of this pest on sour orange trees were recorded during July.

Distribution of the diaspidid scale insects (*L. beckii* and *A. aurantii*) in different cardinal directions (north, south, east & west) and middle of lemon and mandarin trees revealed that both of them preferred east direction followed by north; while, on navel orange trees, *L. beckii* was higher in middle followed by west direction. These results came in the same line of El-Amir *et al.* (2012) (in Giza governorate); they reported that north and east directions of sour orange trees harbored the heaviest infestation levels by *L. beckii* in comparison with other directions. Also, Esmaeili *et al.* (2022) (in Iran) reported that the highest population of *L. beckii* was recorded in north direction followed by east, south and west directions, respectively. In addition, the diaspidid species (*Hemiberlesia latania* (Signort), *Pseudaulacaspis pentagona* (Targioni–Tozzeti), *Parlatoria oleae* (Colvee) and *Chrysomphalus aonidum* (L.)) in Ismailia, Qalubyia and Giza governorates on olive and peach trees preferred north and west directions more than east or south ones (Mohamed, 1999, El-Amir, 2002 and Abdel-Ghaffar *et al.*, 2008). Damavandian (1994) added that the diaspidid, *Chrysomphalus dictyospermi* (Morgan) prefers shady areas of the tree and they can not activate in sunny areas of the tree. In contrary, Draz *et al*. (2011) (in El-Behaira governorate) stated that the highest average population of *L. beckii* was counted in the south and west directions, while the lowest was in the east and north directions; the authors explained that distribution due to the direction of the wind from north to south, which carries newly hatched crawlers. With respect to the diaspidid, *Aulacaspis tubercularis* Newstead, El-Metwally *et al*. (2011) reported that it preferred south direction of mango trees; while, Bakr *et al.,* (2009) mentioned that it preferred east and west direction during cooler and summer weather, respectively. In Iraq, Khalaf *et al.* (2008) reported that the inner part of citrus canopy was found to be nearly similarly susceptible to *A. orientalis*. In the present study, distribution of *P. citrella* in different directions of host trees revealed that it preferred middle and east direction of the host trees. While, EL Afify *et al.* (2018a) reported that *P. citrella* was higher in west direction in comparison with the other cardinal directions and middle of citrus trees. The same authors explained this behavior that the females may search for a moderate shaded side of its host tree which will be suitable for its offspring during spring season (time of the experiments). This explanation may explain the present findings because the most of the present study was done during summer season (with relatively high temperature degrees). Also, these findings are supported by the statistical analysis in the present study; which revealed that *P. citrella* was negatively correlated with the changes of temperature degrees. Amara (2017) found that the citrus flower moth, *Prays citri* (Mill.) population was significantly higher at the south direction than the other cardinal directions and middle of the canopies. According to Southwood (1978), Wratten & Fry (1980) and Amara (2017), the causes of aggregation in these species might be due to their inherent active aggregative behavioral response such as in a situation where the presence of one individual attracts the others, and also due to some heterogeneity of the environment such as microclimate and preferred part of the plant. The differences between the above studies and the present one can be due to the geographical location which influenced on the directions of sunlight, shadow and wind in addition to the temperature degrees.

Statistical analysis showed that temperature degrees had a positively significant effect on *L. beckii* population (especially in navel orange orchard); while, this effect was insignificant on *A. aurantii* population. The effect of relative humidity on *L. beckii* and *A. aurantii* populations was insignificant. These results are in agreement with Aly (2011) [4] and Draz *et al*. (2011); they found that the activity of *L. beckii* was significantly affected by temperature degrees; while the effect of relative humidity on this pest was insignificant on mango orchard in Giza governorate. On another hand, Bakr *et al.*, (2009) and El-Metwally *et al*.

(2011) reported that there were negatively correlations between the fluctuations of *A. tubercularis* population and temperature degrees. Karaca (1998), Claps *et al*. (2001) and Badary & Abd-Rabou (2010) found that the temperatures greatly influenced the development of *A. aurantii*. With respect to *P. citrella* population, it showed negative response to the increase of temperature degrees and showed mostly positive responses to the increase of relative humidity during the present study. These results are supported by those obtained by Aymen and Ali (2018); they explained that temperature degrees had consistent negative correlation with *P. citrella* abundance and incidence, whereas, relative humidity had a positive correlation with insect infestation. Also, Nguvu (2015) reported that the activity of *P. citrella* decreased with the increase of temperature degrees. In contrary, El-Dessouki *et al.* (2005), Singh (2014), Farghaly *et al*. (2016) and EL Afify *et al.* (2018b) reported that the activity of *P. citrella* had positive correlation with temperature degrees and negative with relative humidity. The differences between the present results and others may be attributed to the variation between some weather factors and /or agro-ecosystem.

**Conclusion**

*Lepidsaphes beckii* and *P. citrella* preferred navel orange; while, *A. aurantii* preferred lemon leaves. The diaspidids *L. beckii* and *A. aurantii* preferred east and north directions; while, *P. citrella* preferred middle and east direction of its host trees. Temperature degrees had a positively effect on *L. beckii* population and had negative effects on *A. aurantii* and *P. citrella* populations. Navel orange leaves had relatively high content percentages of nitrogen and carbohydrates coincided with the low content of humidity which was high in lemon leavs.

**References**


1. Abd-Elghaffar AM, Selem GS, Kelany IM, Omara SM. Seasonal abundance and host preference of most insect pests and predators associated with certain citrus trees. Middle East J. Appl. Sci.,2018:8(2):567-576.
2. Abobatta W. Challenges for citrus production in Egypt. Acta Scientific Agriculture,2018:2:40-41.
3. Alsabte A, Ahmed QH, Kayahan A, Karaca I. Effects of volatile organic compounds (VOCs) emitted by citrus infested with *Aonidiella aurantii* on the predator *Rhyzobius lophanthae* attraction. Phytoparasitica,2022:50:645–653.
4. Aly N. Population dynamics of the purple scale, *Lepidosaphes beckii* (Hemiptera: Diaspididae) and its parasitoid *Aphytis lepidosaphes* (Hymenoptera: Aphelinidae) as a new threat pest on mango trees in Egypt. Egypt. Acad. J. biolog. Sci.,2011:4(1):1-12.
5. Amara TMME. The relation between some insect pests and certain environmental factors on citrus trees. Unpublished M. Sc. Thesis, Fac. Agric., Mansoura Univ., 2017, 115.
6. Anonymous. Maroc citrus 2015. Protocole experimental de traitement au froid de la ceratite Maroc citrus. http://2fois11.com/citrus/?p=198
7. Argov Y, Y Rossler. Rearing methods for the citrus leaf miner *Phyllocnistis citrella* Stainton and its parasitoids in Israel.Biological control,1998:11:18-21.
8. Aymen EA, AE Ali. Population dynamics of citrus leaf miner, *Phyllocnistis citrella* (Stainton) on some citrus species and its relation to important weather factors at River Nile State, Sudan. Journal of Agricultural Research,2018:6(7):205-212.
9. Badary H, Abd-Rabou S. Biological studies of the California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) under different host plants and temperatures with an annotated list of natural enemies of this pest in Egypt. Egypt. Acad. J. biolog. Sci.,2010:3(1):235–242.
10. Bakr FA, Badawy RM SF, Mousa SL, Hamooda SA Atteia. Ecological and taxonomic studies on the scale insects that infest mango trees at Qaliobiya Governorate. Egypt. Acad. J. biolog. Sci.,2009:2(2):69-89.
11. Bautista-Martinez N, JL Carrillo-Sanchez H.Bravo-Mojica, S D Koch. Natural parasitism of *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) at Cuitlahuac, Veracruz, Mexico. Florida Ent.,1998:8(1):30-73.
12. Bedford ECG. Red scale *Aonidiella auranii* (Maskell). In: E.C.G. Bedford, M.A. Van den Berg and E.A. De Villiers (eds.), Citrus pests in the Republic of South Africa. Dynamic Ad., Nelspruit, South Africa, 1998, 132-134.
13. Belasque J, JR Parra-Pedrazzoli, Rodrigues AL, J Neto PT, Yamamoto MCM Chagas, et al. Adult citrus leaf miners (*Phyllocnistis citrella*) are not efficient vectors for *Xanthomonas axonopodis* pv. *citri*. Plant Diseases,2005:89:590–594. Citrus crop production in Sudan 2016.
14. Castaño AB, Escrig M, Guillén O, López M, Llopis AB, Martínez A, *et al*. Seasonal trend of California Red Scale (*Aonidiella aurantii*) populations in eastern Spain 2005-2007. Integrated Control in Citrus Fruit Crops IOBC/wprs Bulletin,2008:38:25.
15. Cohort Software. CoStat. www.cohort.com Montery, California, USA, 2004.
16. Conti F, Fisicaro R. Population dynamics of *Aonidiella aurantii* (Homoptera: Diaspididae) on citrus nursery trees in North and Eastern Sicily in the period 1997 – 2006. Integrated Control in Citrus Fruit Crops IOBC/wprs Bulletin,2008:38:19-24.
17. Damavandian MR. Biology of citrus brown scale, *Chrysomphalus dictyospermi* (Morgan) (Hom. Diaspididae) in Mazandaran northern province of Iran. M.Sc Thesis, Shahid Chamran University of Ahvaz, Ahvaz, Iran, 1994.
18. Damavandian MR. Citrus pests, biological control and considering the conditions of Mazandaran. Sari Agricultural Sciences and Natural Resources University Press, Sari, Iran, 2020.
19. Draz KAA, GB El-Saadany, Mansour MA, Hashem AG, Darwish AAE. Ecological studies on the purple scale insect, *Lepidosaphes beckii* (Hemiptera: Diaspididae) on navel orange trees at Elbehaira governorate, Egypt in 2009 and 2010 seasons. J. Agric. & Env. Sci. Dam. Univ., Egypt,2011:10(1):25-43.
20. EL Afify AH, Shreef RM, Ghanim NM, Hendawy MA. Host preference, spatial distribution and chemical control of the citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae). Zagazig Journal of Plant Protection and Pathology Research,2018a:45(1):151-164.
21. EL Afify AH, Shreef RM, Ghanim NM, Hendawy MA. Seasonal activity of the citrus leafminer, *Phyllocnistis*

*citrella* Stainton in navel orange orchards during autumn season. IOSR Journal of Agriculture and Veterinary Science,2018b:11(1 Ver. I):16-21.
22. El-Amir SM, Abou-Setta MM, Abd El-Ghaffar MM, Ibrahim IL, Mahmoud GH. Abundance and generation determination of *Lepidosaphes beckii* (Hemiptera: Diaspididae) on sour orange at Qalubyia Governorate. Egyptian Academic Journal of Biological Sciences,2012:5(3):79-87.
23. El-Dessouki SA, AS El-Khouly MW, El-Kordy, LE Abdel-Rhman. Host Preference and Seasonal fluctuation of citrus leaf miner, *phyllocnistis citrella* stainton , population on the preferred host in relation to ITS parasitoids and weather factors. Annals of agric.Sc.,moshtohor,2005:43(2):895-901.
24. Elkady HA. Host preference and chemical control of *phyllocnistis citrella* stilton (lepidoptera : gracilarlldae) in qalubla governorate. Annals of Agric. Sc., Moshtohor,2005:43(2):885-894.
25. El-Metwally MM, Moussa SF, Ghanim NM. Studies on the population fluctuations and distribution of the white mango scale insect, *Aulacaspis tubercularis* Newstead within the canopy of the mango trees in eastern of Delta region at the north of Egypt. Egypt. Acad. J. biolog. Sci.,2011:4(1):123-130.
26. Esmaeili S, Damavandian MR, Ahadiyat A, Faez R. A field study on the biology of the purple scale, *Lepidosaphes beckii* (Newman) (Hemiptera: Diaspididae) on citrus trees in Mazandaran, Iran. Arthropods,2022:11(2):81-96.
27. Gill RJ. The scale insects of California. Part 3. The armored scales (Homoptera: Coccoidea: Coccidae). Technical Series in Agricultural Biosystematics and Plant Pathology No. 3. California Department of Food and Agriculture, Sacramento, California, USA, 1997.
28. Goane L, G Valladares, E Willink. Preference and performance of *Phyllocnistis citrella* Stainton (Lepidoptera : Gracillariidae) on three Citrus Hosts: Laboratory and Field Assessment. Environ. Entomol,2008:37(4):1025-1034.
29. Gotthard K, Margac raf N, Rahier M. Geographic variation in oviposition choice of a leaf beetle: the relationship between host plant ranking, specificity and motivation. Entomol. Exp. Appl.,2004:110:217-224.
30. Heppner JB, Dixon WN. Potential spread of *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) in the United States. Am. Entomol,1995:41:110-113.
31. Khalaf MZ, Abed AK, Alrubaie HM, Okaily RA, Minshed AK. Host preference of *Aonidiella orientalis* on citrus in South Baghdad (Homoptera: Coccidae). Integrated Control in Citrus Fruit Crops IOBC/wprs Bulletin,2008:38:76.
32. Knapp JL, Albrigo LG, Browning HW, Bullock RC, Heppner JB, Hall DG et al. Citrus leafminer, *phyllocnistis citrella* Stainton: Current status in Florida. Florida Cooperative Extension Services,Institute of Food and Agricultural Services, University of Florida, Gainesville, 1995, 35.
33. Kursar TA, BT Wolfe, MJ Epps PD, Coley. Food quality, competition and parasitism influence feeding preference in a neotropical lepidopteran. Ecology,2006:87:3058-3069.
34. Liu YQ, Heying E, Tanumihardjo SA. History, global distribution, and nutritional importance of citrus fruits. Comprehensive Reviews in Food Science and Food Safety,2012:11:530–545.
35. Manner HI, Buker RS, Smith VE, Ward D, Elevitch CR. Citrus (Citrus) and Fortunella (Kumquat). Species Profile for Pacific Island Agroforestry,2006:2:1-35.
36. Martin AD, Stanley-Horn D, Hallett RH. Adult host preference and larval performance of Liriomyza huidobrensis (Diptera: Agromyzidae) on selected hosts. Environ. Entomol,2005:34:1170-1177.
37. Messina FJ. How labile are the egg-laying preferences of seed beetles. Ecol. Entomol,2004:29:318-326.
38. Michaud JP, A K Grant. IPM-compatibility of foliar insecticides for citrus: Indices derived from toxicity to beneficial insects from four orders. Journal of Insect Science,2003:3:1-8.
39. Mohamed GH. Studies on scale insects infesting olive trees. Ph. D. Thesis, Fac. Agric. Al-Azhar Univ., Egypt, 1999, 234.
40. Moursi KS. Preliminary studies on Mediterranean fig scale, *Lepidosaphes ficus* (Sign.) (Homoptera: Diaspididae) at Hammam area (Egyptian Western Desert). J. Agri. Sci., Mansoura Univ,1991:16(9):2174-2178.
41. Moustafa SA. Studies on some natural enemies associated with the citrus leafminer, Phyllocnistis citrella Stainton. Unpublished Ph. D. Thesis, Fac. Agric., Mansoura Univ., 2004, 178.
42. Nabil HA, OIM Hegab, MAM Hegab. Seasonal occurrence of *Parlatoria ziziphi* (Lucas) and its parasitoid in relation with some climatic factors and chemical components on navel orange trees. J. Plant Prot. and Path., Mansoura Univ.,2019:10(8):407-413.
43. Nguvu G. Aspects of biology and ecology of citrus leafminer (Lepidoptera: Gracillaridae) in major citrus growing regions of Tanzania. M.Sc. Thesis, Morogoro-Tanzania, 2015, 73.
44. Pekas A. Factors affecting the biological control of California red scale, *Aonidiella aurantii* (Hemiptera: Diaspididae) by *Aphytis* (Hymenoptera: Aphelinidae) in eastern Spain citrus: host size, ant activity, and adult parasitoid food sources. (Doctoral dissertation), 2011. doi:https:// doi.org/ 10. 4995/ Thesis/ 10251/ 10293.
45. Price PW. Plant resources as the mechanistic basis for insect herbivore population dynamics. In M. Hunter, T. Ohgushi, and P. Price (eds.), Effects of resource distribution on animal plant interactions. Academic, New York, 1992, 139-172.
46. Salem MS, Maha I El-Said, Abd El-GHany AM, MM Abd El-Rahman. Susceptibility of five mango cultivars to *Icerya seychellarum* (Westwood) (Homoptera: Margarodidae) in relation to leaf quality, nutrients and inhibitors. Egypt. J. Agric. Res.,2006:84(3):697-711.
47. Smyth RR, Hoffman MP, Shelton AM. Larval performance in relation to labile oviposition preference of Crocidolomia pavonana (F.) (Lepidoptera: Pyralidae) among phenological stages of cabbage. Environ. Entomol,2003:32:765-770.
48. Wilson CG. Notes on *Phyllocnistis citrella* Stainton (Lepidoptera: Phllocnistidae) attacking four citrus varieties in Darwin. J. of the Australian Ent.Soc.,1991:30(1):77-78.
49. Wratten SD, GL Fry. Field and laboratory exercises in ecology. Edward Arnold, London, 1980, 227.