Research Paper

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

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ABSTRACT

This study was conducted throughout the years 2015 and 2016 to quantify the seasonal population dynamics of the citrus leaf miner (CLM), *Phyllocnistis citrella* (Stainton) (Lepidoptera: Gracillariidae), on grapefruit (*Citrus paradisi* Macf), orange (*C. sinesis* L.Osb.), local lime (*C. aurantifolia* L.) and mandarin (*C. reticulata* Blanco) trees in the existing orchard in the River Nile State (Sudan), and also determine the effect of the important weather factors viz. maximum and minimum temperatures and relative humidity on the population dynamics of the pest throughout the year. The experiments were laid out in a randomized complete block design with three replicates. The seasonal abundance was investigated by half-monthly on different citrus species from January to December in both years. The results of the seasonal population dynamic of the *P. citrella* throughout the two years showed that the peaked population reached in December up to February coincided with the availability of new vegetative flush leaves. The seasonal population dynamic of *P. citrella* was attributed to the availability of new vegetative flush leaves and to ambient weather conditions. Grapefruit was ranked the most susceptible to citrus leaf miner, followed by orange and the least infestation was recorded on mandarin. Our results indicated that the population of *P. citrella* was found to be negatively correlated with maximum and minimum temperatures and had positive correlation with relative humidity (%).

Key words: Citrus species, *Phyllocnistis citrella*, population dynamics, weather factors, seasonal abundance.

INTRODUCTION

Citrus is one of the most important fruit crop in tropical and subtropical regions and is one of the major sources of vitamins, especially vitamin C (Bedri, 1984). Most of the citrus production in Sudan is for local consumption. Recently, citrus production in Sudan has attracted the attention of policy makers and growers due to its positive economic contributions. Accordingly, citrus crops have been included in most of the newly developed public schemes. However, many reigns with their fairly high temperatures during most of the year and the mild winters give Sudan a great potential of citrus production. Citrus species, such as orange, has been cultivated in Sudan since 1904 in the Northern State. Since then, both cultivated area and production have been consistently increasing to meet the domestic and potential foreign market demands (Fatima and Dawoud, 2017).

The estimated cultivated area and production of citrus crops in Sudan is 642.550 thousand tons from 71.568 thousand hectares (FAOSTAT, 2016).

However, there are numerous constraints facing citrus
production in the country: lack of improved seedlings and free from viral diseases, complicated factors, such as irrigation system and fertilization, low awareness by farmers to apply the technologies as recommended by the Agricultural Research Corporation, and insect pests and diseases.

The crop is attacked by many insects through its life, particularly Mediterranean fruit fly, *Ceratitis capitata* (Wied); citrus mealy bug, *Planococcus citri* (Risso); lemon butter fly, *Papilio demodocus* and citrus leaf miner, *Phyllocnistis citrella* (Stanton). These insects are considered as the major insect pests that limits production of crop in Sudan (Badawi, 1967; Schmutterer, 1969 and Khair, 2004).

The citrus leaf miner (*CLM*), *P. citrella* Stainton, is a key pest that limits the production of citrus in Sudan. It causes damage to citrus through feeding, mining and habiting in the parenchymatous tissues of the youngest tender leaves. *P. citrella* produces silvery mines on the surface of fruits, leaf and stem and reduce the quality of fruits, and photosynthetic area of the leaf which eventually reduces the quantity of production (Abdalla et al., 2004; Belasque et al, 2005). Moreover, CLM has also been associated with transmission of the citrus canker disease caused by *Xanthomonas axonopodis* pv. *citri* (Jesus et al., 2006; Atiq et al., 2007). Numerous studies on seasonal variations of the population of *P. citrella* have been conducted in India (Batra and Sandhu, 1981), Mexico (Bautista-Martinez et al., 1998), USA (Legaspi et al., 2001), Europe (Urbaneja et al., 2000) and Brazil (Greeve and Redaelli, 2006). Studies on the seasonal population dynamics and its relationship with important weather factors, susceptibility of different species of citrus and efficacies of different insecticides for the control of citrus leaf miner are either scanty or lacking.

Therefore, the objective of this study was to quantify seasonal population dynamics of the citrus leaf miner on some citrus species and the effects of the important weather factors viz. maximum and minimum temperatures and relative humidity on population dynamics of the *P. citrella* in the River Nile State.

**MATERIALS AND METHODS**

Population dynamic of *Phyllocnistis citrella* on citrus species

Estimation of the population dynamics and seasonal abundance of *P. citrella* were carried out for the two years, extending from January, 2015 to December, 2016. Citrus species of 5 years old that was selected for this study, located in Elgabarab area (River Nile State), contained an area of 5 feddans infested by the *P. citrella*. In this orchard, no chemical treatments were applied throughout the two years prior to investigation during the study period. The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replicates. The seasonal abundance was investigated by half-monthly intervals throughout the two years. Ten trees of each species (grapefruit, orange, local lime and mandarin) were selected randomly from different directions of the orchard and marked. Then ten flush leaves represented from the different sides, top, lower and middle strata of the tree. The larvae of *P. citrella* were detected and counted.

**Determination of weather conditions (temperature and humidity)**

Environmental factors, mainly maximum and minimum temperatures, as well as percentages of relative humidity (R.H. %) for the two years (2015 and 2016) were recorded by monthly means, to represent the prevailing conditions in the location. These records were obtained from the nearest Meteorological Station at Hudeiba Research Station, River Nile State which is about 5 km away from the experimental area.

A statistical analysis of variance (AOVA) for significant differences and Duncan’s Multiple Range Test (DMRT) for means separation among treatments were done using the MSTAT computer software program. Simple correlation, regression and partial regression values between the mean numbers of larvae of *P. citrella*/10 flush leaves and the mean records of some weather factors (maximum and minimum temperatures and relative humidity (%)) were calculated to obtain information about the relationship between them. The half-monthly mean numbers of larvae of *P. citrella*/10 flush leaves and the mean records of mean counts of *P. citrella* larvae and leaves infested were considered as the dependent variable (y), while the corresponding mean weather factors represented the independent variable (x). The general equation of multiple linear regression models is as follows:

\[ Y = B_0 + B_1X_1 + E_i \]

Where,

- **Y:** The dependant variable
- **B_0:** A constant of regression model
- **B_1:** Regression coefficient
- **X_1:** The observation of independent variables
- **E_i:** The value of the random error

**RESULTS AND DISCUSSION**

Seasonal population dynamic of *Phyllocnistis citrella* on citrus species

Figure 1 shows the fluctuation in infestation of *P. citrella* as...
indicated by the total half-monthly numbers of larvae /10 flush leaves on four citrus species during different months in relation to temperature (°C) and relative humidity in the River Nile State throughout the year of the study 2015. The fluctuation in infestation showed relatively high levels throughout the year of the study; at mean of infestation annually 0-57% /10 flush leaves.

The seasonal population dynamics of *P. citrella* during the summer season gave the lowest count in the year of the study. The population dynamic fluctuated to give a synchronized one major peak during January-March and December throughout the year of investigation. In the first year infestation of *P. citrella* fluctuating forming variable numbers and showed up to 57% /10 flush leaves throughout the period of study. The population disappeared in fall of 2015 from July at Max. Temp. (43.2°C), Min. Temp. (27.0°C) and R.H (32.0 %), to Oct. at Max. Temp. (40.3°C), Min. Temp. (26.0°C) and R.H (41.0%).

It gradually started to build up in November and reached high level (50.3%/10 flush leaves) during winter in December 2015 at Max. Temp. (29.9°C), Min. Temp. (14.1) and R.H (47%) and declined in summer from April at Max. Temp. (38.3°C), Min. Temp. (22.3°C) and R.H (24.0%), to May at Max. Temp (43.2°C), Min. Temp. (27.0°C) and R.H (21%).

In the second years 2016, the population dynamic of *P. citrella* ranged from 0-30%/10 flush leaves and showed the lowest density zero from the beginning of summer to the end of autumn in 2016 from April at Max. T. (39.7°C), Min. T. (22.4°C) and R.H. (31%), to Oct. at Max. Temp. (40.1°C), Min. Temp.(25.3°C) and R.H (35%). It reached high level (30%/10 flush leaves) in winter during 15th January 2016 at Max. Temp (28.1°C), Min. Temp (12.9°C) and R.H.(44%). The result showed that in the population dynamic of *P. citrella* throughout the second year of investigation, this pest had one peak during winter of 2016. The peak occurred on 15th January recorded 30.2%/10 flush leaves at Max. Temp(29.2°C), Min. Temp. (13.2°C), and R.H (53.78%) (Figure 2).

The results of the findings are in line with those of Diez et al. (2006) who reported the highest population levels of *P. citrella* during January and March. Also, these results are similar to the findings reported by Patricia et al. (2006) who observed four population peaks first registered in January, February, and March of 2000, the second population peak was recorded in the first week of January 2001, third was observed in January and December 2002 in Argentina. According to Khanna and Pandey (1966), the peak period of this pest was recorded from February-March and then declined gradually with the commencement of summer. The most likely reason for the increase and decrease in population was related to both the development of new flush leaves and decrease in temperatures for the pest's development. During the first season of investigation, a peak occurred during the winter season.

The results shown in Figures 3 and 4, indicated that there was a highly significant difference among citrus species tested against CLM infestation. Cultivars such as grapefruits, orange, and local lime were most susceptible to CLM infestation in both years, whereas the least susceptibility was recorded on Mandarin. These findings
are in agreement with the Atiq (2013) who observed the highest CLM population on the variety C. paradise. Overall, C. reticulata was the most unprofitable variety tested, while C. paradise, C. sinensis and C. aurantifolia were the most susceptible varieties. Similar results have been reported by El-Dessouki (2001), Xiao et al. (2007) and Muhammad Mustafa et al (2014). As regards the range of susceptibility, the present observations indicated that the grapefruit ranked the most susceptible to CLM, while Mandarin recorded the least infestation. This may be due to denser growth of foliage and shoots of grapefruit as compared with mandarin trees which may probably help in creating a favorable microclimate for the insect.

**Correlation of citrus leaf miner infestation with important weather factors on four citrus species**

The results presented in Figure 5 showed that the percent of citrus leaf miner infestation correlated with weather factors during January, 2015 to December, 2016 in the River Nile State. Among the four citrus species, the highest
infestation throughout the two years 2015 and 2016 was recorded on grapefruit.

As shown in Table 1, there was highly significant interaction of CLM infestation with weather factors x cultivars.

Maximum and minimum temperatures were found to be significantly negative on the incidence of citrus leaf miner on grapefruit, followed by orange and local lime.

Relative humidity favored the growth of new flush leaves irrespective of citrus species as indicated by positive correlation coefficient and significant effect only on grapefruit.

**Population dynamics of *P. citrella* relation to important weather factors on grapefruit**

The data of the effect of maximum and minimum temperatures (°C) and Relative Humidity (%) on the population of *P. citrella* throughout the two successive
Table 1: Correlation between *P. citrella* infestation on four citrus species and weather factors throughout the two years 2015 and 2016 in the River Nile State.

<table>
<thead>
<tr>
<th>Citrus species</th>
<th>Correlation coefficient</th>
<th>Maximum temperature (°C)</th>
<th>Minimum temperature (°C)</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape fruit</td>
<td>-0.77**</td>
<td>-0.78**</td>
<td>0.50*</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>-0.71**</td>
<td>-0.74**</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>-0.57*</td>
<td>-0.61*</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>Mandarin</td>
<td>-0.41</td>
<td>-0.46</td>
<td>0.07</td>
<td></td>
</tr>
</tbody>
</table>

* and **Significant at 0.05 and 0.001, respectively.

Table 2: Infestation of *P. citrella* per 10 flush leaves as affected by maximum & minimum temperature °C and relative humidity on grapefruit throughout the two years 2015 and 2016 in the River Nile State.

<table>
<thead>
<tr>
<th>Year</th>
<th>A biotic factors</th>
<th>Simple correlation and regression</th>
<th>Partial regression</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>b</td>
<td>t-value</td>
</tr>
<tr>
<td>2015</td>
<td>Max. Temp. °C</td>
<td>0.88</td>
<td>-3.27</td>
<td>-4.59</td>
</tr>
<tr>
<td></td>
<td>Min. Temp. °C</td>
<td>0.91</td>
<td>-3.64</td>
<td>-5.30</td>
</tr>
<tr>
<td></td>
<td>R.H (%)</td>
<td>0.81</td>
<td>1.44</td>
<td>3.35</td>
</tr>
<tr>
<td>2016</td>
<td>Max. Temp. °C</td>
<td>0.91</td>
<td>-1.86</td>
<td>-5.31</td>
</tr>
<tr>
<td></td>
<td>Min. Temp. °C</td>
<td>0.89</td>
<td>-1.81</td>
<td>-4.90</td>
</tr>
<tr>
<td></td>
<td>R.H (%)</td>
<td>0.67</td>
<td>0.73</td>
<td>2.20</td>
</tr>
</tbody>
</table>

Max. Temp. °C = Maximum Temperature; Min. Temp. °C = Minimum Temperature; R.H (%) = Relative Humidity; (r) = simple correlations, (b) = simple regressions.

** Significant (at probability level 0.01), n.s = non significant

Table 3: Infestation of *P. citrella* per 10 flush leaves as affected by maximum & minimum temperature °C and relative humidity throughout the two years 2015 and 2016 in the River Nile State.

<table>
<thead>
<tr>
<th>Year</th>
<th>A biotic factors</th>
<th>Partial regression</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>p. reg.</td>
</tr>
<tr>
<td>2015</td>
<td>Max. Temp. °C</td>
<td>-1.05</td>
<td>-0.33</td>
</tr>
<tr>
<td></td>
<td>Min. Temp. °C</td>
<td>-4.36</td>
<td>-1.26</td>
</tr>
<tr>
<td></td>
<td>R.H (%)</td>
<td>-0.82</td>
<td>-0.70</td>
</tr>
<tr>
<td>2016</td>
<td>Max. Temp. °C</td>
<td>-1.98</td>
<td>-1.17</td>
</tr>
<tr>
<td></td>
<td>Min. Temp. °C</td>
<td>0.44</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>R.H (%)</td>
<td>0.32</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Max. Temp. °C = Maximum Temperature; Min. Temp. °C = Minimum Temperature; R.H (%) = Relative Humidity; (R) = partial correlations, (p) = partial regressions; (T) = t-value.

* Significant (at probability level 0.05).

years 2015 and 2016 in the River Nile State are presented in Tables 2 and 3.

The results indicated that the influences of maximum and minimum temperatures on the population of *P. citrella* was highly significant in the two years of the study, while the influence of the relative humidity was highly
significant in the first year only. That is to say that the activity of *P. citrella* was generally influenced by maximum and minimum temperatures in the two years of the study, and the relative humidity during the first year of the study.

As shown in Table 1, statistical analysis of maximum temperature in the two years indicated that the simple correlation and regression coefficient were negative and significant. The simple regression equations of (YP) with maximum temperature (X1) and minimum temperature (X2) are given as:

\[ Y_a = 141.14 - 3.27 X_{1a} \text{ for the first year (a)} \]
\[ Y_b = 79.88 - 1.86 X_{1b} \text{ for the second year (b)} \]

The population dynamics of the larvae decreased to -3.37 and -1.86 when maximum temperature increased for the two years, respectively. The correlation coefficient values were 0.88 and 0.91 for the two years, respectively. Whereas the regression coefficient values were equivalent (-3.27 and -1.86) for the two years, respectively. The minimum temperature showed negative influence and highly significant effect on the population of *P. citrella* in the two years. Therefore, the simple regression equations of (YP) with minimum temperature (X2) are given as:

\[ Y_a = 96.69 - 3.64 X_{1a} \text{ for the first year (a)} \]
\[ Y_b = 48.82 - 1.81 X_{2b} \text{ for the second year (b)} \]

The population density of the larvae decreased to -3.64 and -1.81 when minimum temperature increased for the two years, respectively. The correlation coefficient values were 0.91 and 0.89 for the two years, respectively, whereas the regression coefficient values were equivalent (-3.64 and -1.81) for the two years, respectively. As for the relative humidity, the results showed positive correlation and regression and high significant effect in the first year only, so the regression equation infestation of *P. citrella* (YP) with the relative humidity factor (X3) in the first year (a) is:

\[ Y_a = 1.44 X_{3b} - 27.82. \]

That means the population density of the insect decreased to 1.44 when relative humidity decreased to a certain limit. The correlation coefficient values were 0.81 and 0.67, whereas the regression coefficient values were equivalent (-1.44 and 0.73) for the two years, respectively.

Results presented in Table 3 showed that maximum and minimum temperature (°C) and Relative Humidity (%) had great effect on the activity of the pest under investigation. The statistical analyses of data indicated that, the partial correlation and regression coefficient were highly significant at probability level 0.05 in the two years of investigation. The correlation coefficient values were 0.92 and 0.94 for the two years respectively, in case of the population of larvae. The regression equations of the total population of *P. citrella* (YP) with all factors under study (X) are given as:

\[ Y_a = 179 -1.05 X_{1a} - 4.36 X_{2a} - 0.82 X_{3a} \text{ for the first year (a)} \]
\[ Y_b = 62 -1.98 X_{1b} + 0.44 X_{2b} + 0.32 X_{3b} \text{ for the second year (b)} \]

The population of *P. citrella* larvae decreased to -1.05 when maximum temperature increased by 1°C and -4.36 as minimum temperature increased by 1°C and -0.82 when the relative humidity decreased to 1% in air in the first season, respectively and decreased to -1.98 when maximum temperature increased to 1°C, and 0.44 and 0.32 as minimum temperature increased to 1°C and increased to 0.28 when relative humidity decreased to 1% in air in the second season, respectively.

Based on the results obtained in the present study, the abiotic factors showed the strongest influence on the population dynamic of *P. citrella* throughout the two years in the river Nile State. Maximum and minimum temperature had consistent negative correlation with *P. citrella* abundance and incidence, whereas, relative humidity had a positive correlation with insect infestation. These findings are in agreement with those of Nguvu (2015) who reported that the activity of *P. citrella* decreased with the increasing temperatures. Similar results have been obtained by Singh (2014) who reported that the infestation of citrus leaf miner was negatively correlated with relative humidity. According to Doaa et al. (2016) who found that the population dynamics of *P. citrella* had positive correlation and regression with maximum and minimum temperature and negative with relative humidity.

**Conclusion**

Based on the obtained results, it can be concluded that the population dynamics of *P. citrella* throughout the two years in the River Nile State was higher in winter season than that in summer and autumn seasons. It started on November and reached population peak on December and January and then started to decline in summer months.

Climatic conditions were found to be the important factors in determining the intensity of *P. citrella* incidence. There was negative correlation between maximum and minimum temperatures and population of *P. citrella*, but positive correlation between relative humidity and population dynamic of the pest and as such, further investigation are required.

Therefore, it is suggested that the chemical control of this pest should begin in mid November and early December, where the pest incidence is highest and there is
need to protect the new flush leaves from the infestation.

REFERENCES


Citrus crop production in Sudan 2016.


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