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Population dynamics of citrus leaf miner, *Phyllocnistis citrella* on acid lime in relation to abiotic factors

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Abstract
The present investigation was conducted at All India Co-ordinated Research Project on fruit crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra State during 2018 and 2019 on acid lime. The data revealed that during 2018-2019, maximum larval population (14.26 larvae per twigs) along with the highest leaf infestation (42.36 %) were recorded in the second week of July, 2018 (28th SMW). The lowest larval population (0.01 larvae per twigs) along with the lowest leaf infestation (1.84 %) were noticed in the third week of March, 2018 (12th SMW). During the successive year (2019-2020), maximum larval population (14.19 larvae per twigs) along with the highest leaf infestation (46.13 %) were recorded in the first week of August, 2019 (31th SMW). The lowest larval population (0.01 larvae per twigs) along with the lowest leaf infestation (1.24 %) were noticed in the last week of May, 2019 (22th SMW). The data on correlation of the larval population and per cent leaf infestation with the abiotic factors revealed that amongst nine factors, six factors *viz*., minimum temperature, morning relative humidity, evening relative humidity, Bright sunshine, wind velocity and rainfall were found positively correlated; remaining three factors *viz*. with maximum temperature, number of rainy days and evaporation were found negatively correlated. More or less negligible pest incidence was found during summer months.

Keywords: Acid lime, Citrus leaf miner, *Phyllocnistis citrella* Maharashtra

1. Introduction
Citrus is a globally cultivated important fruit crop, which includes orange, sweet orange, acid lime, pomelo, grape fruit and other related species of citrus. Citrus species are native of tropical and sub-tropical regions of south-east Asia and Malayan Archipelago (Webber, 1967) [15] and acid lime (*Citrus aurantifolia*) belongs to family Rutaceae, originated in India and it is the third most important citrus species, after Mandarin and Sweet orange (Yadlod *et al*., 2018) [16]. Citriculture is the third largest fruit industry after mango and banana in India. Citrus belongs to family Rutaceae. Citrus is not only delicious and refreshing fruit to eat, but also it provides vitamins, minerals and many other essential elements which are essential for human health. Citrus is the main source of vitamin "C" (citric acid). Citrus fruits also have sufficient amounts of vitamins and minerals that your body needs to function properly, including B vitamins, phosphorous, potassium, magnesium and copper. Also, they are rich in plant compounds that have various health benefits, including anti-inflammatory and antioxidant effects. The fruit has valued not only for its nutritional and medicinal uses but also extensively used for the preparation of value added products, like squashes, syrup, cordials, pickles, manufacture of citric acid and for culinary uses in the daily diet of Indians (Tetens, 2013) [14].
In India, leading kagzi lime producing states are Andhra Pradesh, Gujarat, Tamil Nadu, Karnataka, Maharashtra, Assam and Rajasthan. In India, acid lime covers about 2.83 lac hectares area and about 32.21 lac metric tonnes production during 2018-19. In Maharashtra Nagpur, Akola, Amravati and Wardha are the major citrus growing districts which cover about 27.27 thousands hectares area of acid lime with 2.50 lac metric tonnes production during 2018-19 (Anonymous, 2018) [2].
About 250 different species of insects and mites have been found in India which are infesting different species of citrus crop (Butani, 1979) [3]. In Maharashtra state, 14 species are reported out of these 8 species have most significant importance (Lad *et al.*, 2010). Citrus leaf miner is the most destructive pest and mostly attacks nurseries, tender flushes and young plantations which completed about 16 overlapping generations in a year (Sandhu, 1964) [9]. Kalidas and Shivankar (1994) [7] stated that, more than 80 per cent citrus nurseries were infested by this

The total damage caused by the various pest of citrus, 30 per cent damae caudes by *P. citrella* alone. The average infestation rate caused by citrus leaf miner varied from 17 to 57 per cent (Boughdad *et al.,* 1999) [4].

Larval mines are seen throughout the year on new flush. It is found that almost all the citrus orchards were affected by this pest attack to a greater or lesser extent. Sometimes the indirect damage of citrus leaf miner is very important. Mining of immature foliage by the larvae can lead to reduced growth rates; yield and mined surfaces serve as foci for the establishment of diseases such as citrus canker, *Xanthomonas citri*. Economic losses caused by citrus leaf miner include increased costs for protecting nursery trees and young non-bearing citrus plants, increased orchard production costs and reduced sales to home gardeners, either directly, through the use of pesticides which are largely ineffective, or indirectly, through treatments that disrupt biological control and Integrated Pest Management Programs (Sarda *et al*., 2014) [12].

Information concerning the seasonal incidence and population dynamics is an important tool for developing the pest management strategies against citrus leaf miner. Periods of no incidence, initiation of incidence, low incidence, peak incidence etc. have important meaning for deciding the time for adoption of management practices. Incidence of citrus leaf miner is affected by temperature and short periods of rains. Weather factors also play an important role in population build up of *P. citrella* and to have a close relationship between abiotic factors and the pest (Katole *et al.,* 1997) [8]. This has indicated that the incidence of leaf miner is influenced by the ecological factors. If so, information would be of significant importance in predicting the period of expected incidence which would also serve as prediction model. With this view, correlations between pest incidence and the weather parameters *i.e.* temperature, humidity, rainfall and rainy days, have been worked out. This information would also be useful to inform the citrus growers for the expected incidence based on the ecological conditions and to adopt the management practices in time (Lad *et al*., 2010) [9]. So, considering the importance of its problem and to get a comprehensive idea, present investigation was carried out to study the role of abiotic factors on the population build up of *Phyllocnistics citrella*.

2. Materials and Methods

The present investigation was conducted at All India Co-ordinated Research Project on fruit crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra State during 2018 and 2019 on acid lime. For recording seasonal incidence and population dynamics of citrus leaf miner, *P. citrella* weekly observations were recorded throughout the year from February, 2018 to January, 2019 and February, 2019 to January, 2020 on the randomly selected ten trees of acid lime, whereas on each tree, ten twigs of 15 cm length were selected randomly, covering the whole canopy of each plant. The selected plants were kept unsprayed during the entire studies on investigations. The *P. citrella* larvae along with total and damaged leaves by *P. citrella* recorded from ten randomly selected fresh tender twigs of each plant. The data recorded were pooled for the average incidence and the mean per cent leaves infested were completed. . The population of was then correlated with the prevailing meteorological weather parameters *viz*., maximum temperature (^{0}C), minimum temperature (^{0}C), rainfall (mm), morning relative humidity (%), evening relative humidity (%), bright sunshine hours, wind velocity (km/hr) and evapo-transpiration (mm) using standard statistical procedure as suggested by Steel and Torrie (1980) [13] to find out the specific impact of the weather parameters on citrus leaf miner, *P. citrella* on acid lime plant.

3. Results and Discussion

3.1 Observations on population dynamics (2018-2019)

The data on larval population and leaf infestation are tabulated in Table 1 and depicted in Fig 1 and 2, respectively. The data reveals that the maximum larval population (14.26 larvae per twigs) along with the highest leaf infestation (42.36 %) were recorded in the second week of July, 2018 (28th SMW). The lowest larval population (0.01 larvae per twigs) along with the lowest leaf infestation (1.84 %) were noticed in the third week of March, 2018 (12th SMW). More or less the negligible pest incidence was found during the summer months of 2018.

Overall five peaks of the pest incidence were recorded during the year 2018-2019. The first, second, third, fourth and fifth peaks of leaf infestation were occurred during 6th, 10th, 28th, 38th and 52th standard meteorological week with 24.32, 16.12, 42.36, 34.58 and 28.69 per cent, respectively. Similarly, in all the five peaks of larval population were occurred during 6th, 28th 38th, 46th and 52th standard meteorological week with 8.87, 14.26, 6.79, 4.79 and 6.18 larva per twigs respectively.

The data on per cent leaf infestation and larval population were correlated with the abiotic factors are presented in Table 2. The data on leaf infestation reveals that the maximum temperature (r = -0.7304), sunshine (r = -0.6450) and evaporation (r = -0.7445) were found to be highly significant negatively correlated with leaf infestation whereas, the minimum temperature (r = 0.0198) was correlated as non significantly positive. The morning relative humidity (r = 0.7882), evening relative humidity (r = 0.7508), rainfall (r = 0.2814) and number of rainy days (r = 0.4783) were observed to be highly significant positive correlation with leaf infestation whereas, the wind velocity (r = 0.3279) was correlated as significantly positive.

The data on larval population reveals that the maximum temperature (r = -0.5988), sunshine (r = -0.6223) and evaporation (r = -0.6513) were found to be highly significant negative correlated whereas minimum temperature (r = 0.1046) was correlated as non significantly positive. The morning relative humidity (r = 0.6878), evening relative humidity (r = 0.6646), rainfall (r = 0.3635), number of rainy days (r = 0.54.60) and wind velocity (r = 0.3777) exhibited as highly significant positive correlation.

Table 1: Population dynamics of citrus leaf miner, *P. citrella* infesting acid lime during 2019-2020

Standard Meteorogical Week	Month	Average No. of Larvae/10 twig *		Leaf infestation (%) *	
		2018-2019	2019-2020	2018-2019	2019-2020
5	February	5.96	5.23	15.59	18.63
6	February	8.87	2.63	24.32	12.56
7	February	3.56	8.96	22.14	36.32
8	February	3.48	5.78	13.25	26.3
9	March	3.12	4.84	10.26	14.37
10	March	4.16	3.47	16.12	12.32
11	March	3.84	2.94	9.52	9.65
12	March	0.01	0.29	1.84	6.4
13	April	0	0	0	0
14	April	0	0	0	0
15	April	0	0	0	0
16	April	0	0	0	0
17	April	0	0	0	0
18	May	0	0	0	0
19	May	0	0	0	0
20	May	0	0	0	0
21	May	0	0	0	0
22	June	0.03	0.04	2.86	1.24
23	June	7.16	2.53	20.92	2.33
24	June	6.14	4.61	18.56	5.12
25	June	5.76	7.2	24.32	17.53
26	July	7.54	8.61	26.84	20.71
27	July	9.77	6.29	32.66	19.26
28	July	14.26	8.49	42.36	28.19
29	July	6.78	6.25	24.33	24.15
30	July	8.26	7.16	29.58	34.22
31	August	5.21	14.19	28.66	46.13
32	August	3.86	11.74	21.98	26.13
33	August	6.78	4.61	19.12	17.23
34	August	7.67	5.19	24.37	19.65
35	September	4.86	8.63	26.86	22.63
36	September	3.26	9.21	24.53	24.87
37	September	2.18	8.33	16.98	26.42
38	September	6.79	4.06	34.58	13.11
39	September	3.14	7.41	12.64	15.63
40	October	4.16	5.55	16.31	24.53
41	October	4.89	9.5	14.89	32.55
42	October	3.71	6.22	13.94	14.56
43	October	2.46	6.13	8.1	16.3
44	November	4.26	7.19	10.16	13.85
45	November	1.12	6.22	7.82	11.64
46	November	4.79	5.61	12.58	10.32
47	November	1.86	3.46	13.12	8.23
48	December	2.03	4.86	14.63	9.11
49	December	1.96	6.34	11.46	12.19
50	December	3.46	12.46	11.98	37.56
51	December	2.98	4.07	12.84	19.22
52	December	6.18	5.36	28.69	15.41
1	January	3.12	3.51	18.1	10.36
2	January	4.12	6.73	17.54	16.5
3	January	3.15	4.94	15.81	16.39
4	January	2.23	4.75	21.34	12.23

* Mean of Observations from 10 plants

Table 2: Correlation co-efficient of citrus leaf miner, *P. citrella* population with respect to abiotic factors during 2018-2019

Sr. No.	Weather parameters	Correlation coefficient value			
		Average No. of Larvae/10 twig		Leaf Infestation (%)	
		2018-2019	2019-2020	2018-2019	2019-2020
1.	Max. Temperature (^{0}C)	-0.5988 **	-0.6786 **	-0.7304 **	-0.6225**
2.	Min. Temperature (^{0}C)	0.1046	0.0918	0.0198	0.0170
3.	Morning RH (%)	0.6878 **	0.7465 **	0.7882 **	0.6302 **
4.	Evening RH (%)	0.6646 **	0.7523 **	0.7508 **	0.6475 **
5.	Bright Sunshine (hrs)	0.3635 **	0.2984 *	0.2814 **	0.2267
6.	Wind velocity (Km/hr)	0.5460 **	0.4187 **	0.4783 **	0.3703*
7.	No. of rainy days	-0.6223 **	-0.6931 **	-0.6450 **	-0.6211 **
8.	Rainfall (mm)	0.3777 **	0.0697	0.3279 *	0.0447
9.	Evaporation (mm)	-0.6513 **	-0.6979 **	-0.7445 **	-0.6905**

* 5 % level of significance df 50=0.273

** 1 % level of significance df 50 =0.354

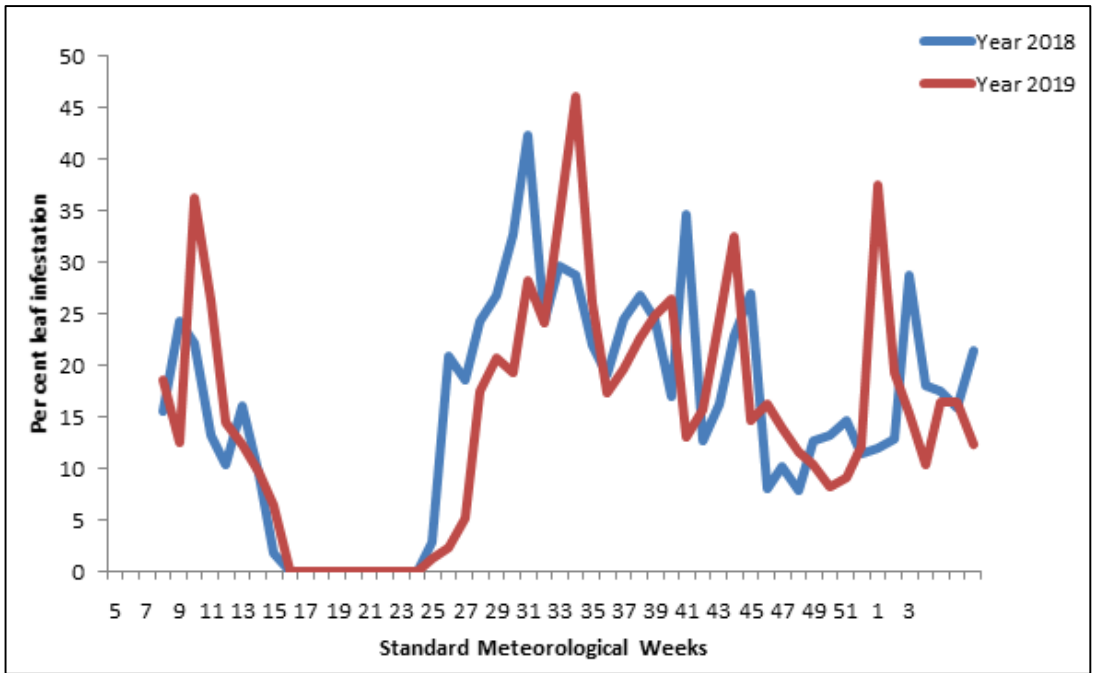

Fig 1: Leaf damage by citrus leaf miner, *P. citrella* on acid lime during 2018-2019

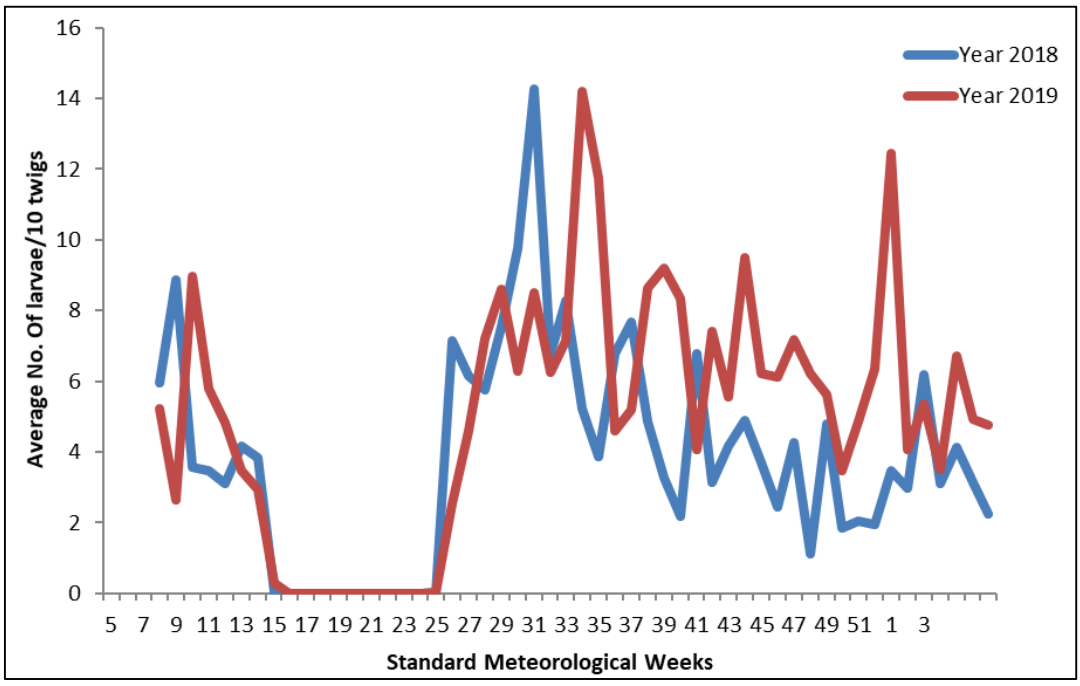

Fig 2: Population dynamics of citrus laf miner, *P. citrella* on acid lime during 2018-2019

3.2 Observations on population dynamics (2019-2020)

The data on larval population and leaf infestation are tabulated in Table 1 and depicted in Fig 1 and 2, respectively. The data reveals that the maximum larval population (14.19 larvae per twigs) along with the highest leaf infestation (46.13 %) were recorded in the first week of August, 2019 (31th SMW). The lowest larval population (0.01 larvae per twigs) along with the lowest leaf infestation (1.24 %) were noticed in the last week of May, 2019 (22th SMW). The lowest count of the larval pest population was found in the summer months of 2019.

Overall four peaks of the pest incidence were recorded during the year 2019-2020. The first, second, third, fourth and fifth peaks of leaf infestation were occurred during 7th, 31th, 41th and 50th standard meteorological week with 36.32, 46.13, 32.55 and 37.56 per cent, respectively. Similarly, in all four peaks of larval population were occured during 7th, 31th, 41th and 50th standard meteorological week with 8.96, 14.19, 9.5 and 12.46 larva per twigs respectively.

The data on per cent leaf infestation and larval population were correlated with the abiotic factors are presented in Table 2.The data on leaf infestation reveals that maximum temperature (r = -0.6225), sunshine (r = -0.6211) and evaporation (r = -0.6905) were found to be highly significant negatively correlated with leaf infestation whereas, the minimum temperature (r = 0.0170), wind velocity (r = 0.0447) and rainfall (r = 0.2267) were correlated as non significantly positive. The morning relative humidity (r = 0.6302), evening relative humidity (r = 0.6475) were observed to be highly significant positive correlated with leaf infestation and number of rainy days (r = 0.3703) was correlated as significantly positive.

The data on larval population reveals that maximum temperature (r = -0.6786), sunshine (r = -0.6931) and evaporation (r = -0.6979) were found to be highly significant negatively correlated whereas, the minimum temperature (r = 0.0918) and wind velocity (r = 0.0697) were correlated as non significantly positive. The morning relative humidity (r = 0.7465), evening relative humidity (r = 0.7523) and number of rainy days (r = 0.4187) were observed to be highly significant positive and rainfall (r = 0.2984) was correlated as significantly positive.

In the present investigations, during 2018-2019 in all five peaks of leaf infestation were recorded during the month of February, March, July, September and December. However, during 2019-2020 in all four peaks were observed during the month of February, August, October and December. Mafi and Ohbayashi (2004) [10] reported two peaks in the month of July and October. Lad *et al*. (2010) [9] also found two peaks during the month of March and October.

The studies carried out on larval population during 2018-2019 indicates that there were five peaks recorded in the month of February, July, September, November and December. However, during 2019-2020 in all four peaks were noticed during the month of February, August, October and December. Chetry *et al*. (2012) [5] reported three peaks of larval population during the months of April, July and September.

It appears that all the abiotic factors under the studies excepting maximum temperature and evaporation were found to be congenial for the pest development and increased the incidence there by; obviously, the increase in development relates with the availability of new flush. More or less similar observations have been reported by Jamir *et al*. (2015) [6] and Ali and Ali (2018) [1].

4. Conclusion

The pest occurs throughout year excepting summer months. The abiotic factors *viz*. minimum temperature, morning relative humidity, evening relative humidity, bright sunshine, wind velocity and rainfall were found positively correlated indicating that the increase in the larval population was synchronized with these factors. The remaining factors *viz*. maximum temperature, number of rainy days and evaporation were found negatively correlated indicating that the decrease in the larval population was influenced by these factors. There is a close relationship exists between the aforesaid factors and the new flush for the occurrence of the pest which may be useful for developing the prediction model.

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