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Seasonal incidence of citrus leaf miner, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillaridae) in the hilly region of Chikkamagaluru district

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Abstract
The study was undertaken at the College of Horticulture, Mudigere, during Kharif, Rabi and summer season from July 2019 till June 2020 to understand the seasonality of citrus leaf miner on Coorg mandarin. Seasonal incidence revealed the prevalence of citrus leaf miner activity around the year. Roughly three broad peaks could be noticed during the IV week of July 2019, III week of October 2019 and II week of April 2020. The leaf miner activity was predominant from September to December 2019 and less during January and February 2020. Further, the correlation of weather parameters with citrus leaf miner incidence indicated that rainfall, minimum and maximum temperature and minimum relative humidity had a non-significant effect. In contrast, maximum relative humidity had a positive and significant impact (r=0.301).

Keywords: Citrus leaf miner (CLM), Coorg mandarin, seasonal incidence, correlation coefficient (r)

1. Introduction
Citrus belongs to the family Rutaceae. In India, citrus is grown in an area of about 10.03 lakh ha with production and productivity of 12,546 t and 40.60 MT/ha, respectively. In India, Andhra Pradesh and Maharashtra lead the country in citrus production (39.46 and 15.79%, respectively) (Anon., 2018) [5]. While Maharashtra and Madhya Pradesh lead the nation in citrus productivity. In Karnataka, the prominent citrus growing districts are Vijayapura, Kodagu, Chikkamagaluru and Kalaburgi, with an area, production and productivity of 0.18 lakh ha. 41,105 MT and 61.96 MT/ha, respectively (Anon., 2018) [5]. Citrus is highly nutritious and refreshing, rich in vitamin C, minerals and alkaline salt having anti-cancer and cholesterol-lowering ability. It is a good source of vitamin A and B, fruit acid, fruit sugar, calcium, phosphorus, iron and various phytochemicals (Singh, 1969) [21]. The mandarins are the most important among citrus fruits grown in India. There are three distinct ecotypes of mandarin in India, the Nagpur mandarin, the Coorg mandarin and the Khasi mandarin.
Coorg mandarin is a famous ecotype grown over a century in South India. The Coorg mandarin is conferred with a geographical indicator tag in 2005-06 because of the unique characteristics, subtle pulp texture, pleasant distinct flavour, sugar and acid blend. It is grown in Karnataka (Kodagu, Hassan and Chikkamagaluru district), Tamil Nadu and Kerala. In Karnataka, it is cultivated as a mixed crop with coffee. The monoculture of this crop is virtually non-existent. The area under mandarin cultivation in Karnataka is 3,650 ha with an annual production of 79,070 MT and productivity of 21.64 MT/ha (Anon., 2018) [5].
A high incidence of pests plagues citrus cultivation in India, and 250 species of insects and mites have been reported infesting different species of citrus in India **(**Wadhi and Batra 1964) [24] and about 165 species cause a yield loss of up to 30 per cent at all stages of crop growth, *i.e.*, from nursery stage to bearing trees (Bhutani, 1979) [7]. The major pests are citrus leaf miner, soft green scale, citrus butterfly, mites, orange shoot borer, aphids and psylla. Aphids and psylla are vectors transmitting Tristeza and greening disease, respectively (Tripathi and Karunakaran, 2016) [23], which caused a rapid decline in mandarin production since the 1960s.
The citrus leaf miner (CLM), *Phyllocnistis citrella* Stainton, is a potentially serious pest of citrus, related Rutaceae and ornamental plants almost worldwide (Kalshoven, 1981; Beattie

et al., 1995 and Achor *et al*., 1996) [12, 6, 1]. The CLM can cause leaf damage ranging from two to 85 per cent (Lara *et al*., 1998 and Zeb *et al*., 2001) [14, 26] in citrus. The growth is slowed down in young trees, and yield is reduced in mature trees.

Leaf miners have a short developmental time. The total generation period of CLM fluctuates between 13 to 52 days (Pandey and Pandey, 1964) [18]. Depending on foliage flushing cycles and weather conditions, six to 13 generations per year can be expected (Sarada *et al*., 2014) [20]. With the above facts, the research was conducted to know the CLM peak population and decide the best time for management either by prophylactic way or by curative control method.

2. Materials and Methods

The experiment was conducted at the College of Horticulture, Mudigere, Chikkamagaluru district, Karnataka. Previously planted Coorg mandarin citrus block was utilized for the present study, and all the recommended practices were followed to raise the citrus crop. The Coorg mandarin citrus block was divided into four equal blocks, and five plants were randomly selected from each block. Observations on the number of live mines were taken on the top five leaves of fresh twigs in all four directions (North, South, East and West) of the citrus plant. The percentage of infestation by citrus leaf miner was assessed by considering the total number of damaged leaves, *i.e*., leaves infected with leaf miner were counted and divided with the total number of leaves per twig on a citrus plant and multiplied by a hundred (Elanchezhyan, 2015) [10]. Per cent leaf miner infestation was computed to draw an inference.

During the study, meteorological data on the minimum and maximum temperature, maximum and minimum relative humidity and rainfall obtained from ZAHRS, Mudigere (Figure 1) was utilized for correlating with the seasonal incidence of citrus leaf miner. The weekly averages of minimum and maximum temperature, minimum and maximum relative humidity and total precipitation of the particular week were calculated. and correlated with the citrus leaf miner per cent infestation. The data were subjected to a partial correlation analysis using SPSS software to calculate r values.

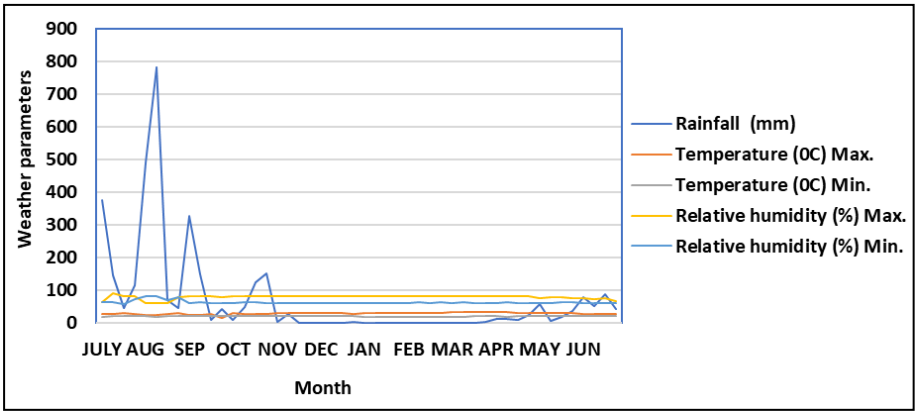

Fig 1: Fluctuations in weather parameters recorded during 2019-20 at Zonal Agricultural and Horticultural Research Station, Mudigere

3. Results and Discussion

3.1 Seasonal incidence of citrus leaf miner on Coorg mandarin

3.1.1 Larval population of citrus leaf miner

The observations recorded weekly on leaves infested by larva revealed the prevalence of CLM around the year, where the number of live mines recorded from twenty plants ranged from 0.8 (Jan 2020 III week) to 3.75 (III and IV weeks of Oct 2019). The four sample means were used to determine the seasonal pattern of CLM in Mudigere. Roughly three broad peaks could be observed during the IV week of July 2019, III week of October 2019 and II week of April 2020. However, the activity of CLM was predominant from September till December 2019 and was less during January and February 2020 (Figure 2). Elekcioglu and Uygun (2013) [11] and Legaspi *et al*. (1999) [15] reported similar findings of high incidence during July and October.

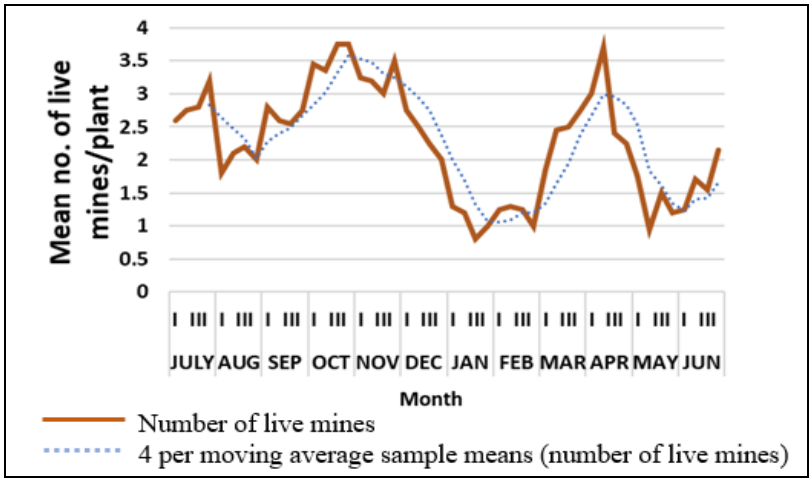

Fig 2: Seasonal fluctuation of citrus leaf miner population on Coorg mandarin from July 2019 to June 2020

However, the findings of Deepan *et al*. (2019) [9] were contradictory. The leaf miner incidence was less (< 1mine per twig) during April. Further during 2020, the minimum incidence recorded during the third week of January 2020 with the mean value of 0.8 larvae per plant (Figure 2) was in concurrence with the research findings of Powell *et al.* (2007) [19], who reported that fewer than one mine per tree was detected over the five years in January from 2000 to 2003 in a Florida citrus grove.

3.1.2 Per cent population of citrus leaf miner

Similarly, when the per cent leaf infestation by CLM was observed, it was found that CLM damage was seen around the year, where the per cent infestation ranged from 16 (III week of Jan 2020) to 75 per cent (III and IV week of October 2019).

Application of four sample means indicated a seasonal pattern with three peak infestation (IV week of July 2019, III week of October 2019 and II week of April 2020) during the study period (Figure 3). The first peak recorded during the fourth week of July 2019 (64%) is in accordance with the reports of Mafi and Ohbayashi (2004) [16]. They noticed two *P. citrella* infestation peaks, one in July (68%) and another in October (80%) from June 2001 through May 2002.

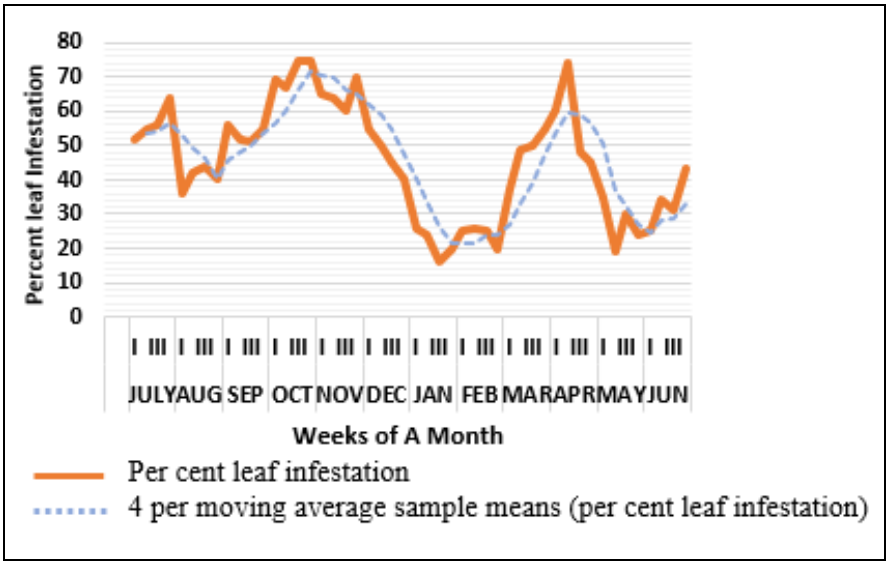

Fig 3: Seasonal fluctuation of citrus leaf miner (per cent population) on Coorg mandarin from July 2019 to June 2020

Similarly, it is in agreement with Wagh (2016) [25] (citrus leaf miner incidence gradually increased up to the third week of July and reached its peak (68%)).

Also, Lad *et al.* (2010) [13] said a peak incidence of citrus leaf miner during the second week of October (19.00%), and this result is also in corroboration with Mafi and Ohbayashi (2004) [16]. Similarly, Ali and Ali (2018) [4] and Deepan *et al.* (2019) [9] reported that the seasonality was attributed to the availability of new flush and ambient weather conditions.

The minimum incidence of *P. citrella* was noticed during the third week of January 2020, followed by February 2020 in the present study. The low incidence agrees with the study's outcome conducted by Powell *et al.* (2007) [19]. The predominant activity of CLM from September till December 2019 agrees with Sreedevi (2010) [22] report, where citrus leaf miner incidence was severe (16-30%) during November and December. Further, Alexander *et al.* (2014) [3] reported two citrus leaf miner infestation peaks, one during September with 60.90 per cent infestation.

3.2 Correlation between the seasonal incidence and weather parameters

3.2.1 Larval population of citrus leaf miner

A non-significant positive correlation of rainfall, minimum temperature and maximum relative humidity with the number of live mines (r=0.077, 0.091 and 0.180, respectively) was recorded in the present study (Table 1). Mustafa *et al*. (2010)[17] reported similar findings with rainfall and CLM population in the Sargodha district of Punjab. Ahmed *et al.* (2013) [2] reported that minimum temperature (r=0.63) and average weekly temperatures (r=0.66) had consistent positive relations with CLM abundance and incidence in Sargodha. Chhetry *et al*. (2012) [8] reported a non-significant and positive (r=0.14) correlation of relative humidity and CLM on sweet oranges in Jammu.

Further, the correlation between leaf miner incidence and weather parameters revealed a non-significant negative correlation of CLM with maximum temperature and minimum relative humidity (r= -0.120 and -0.024, respectively). Lad *et al.* (2010) [13] also reported a negative correlation (r=-0.715) between temperature and CLM pest incidence at Akola. Similar findings were noticed by Ahmed *et al.* (2013) [2], with relative humidity negatively influencing the CLM pest infestation.

3.2.2 Per cent infestation by citrus leaf miner

A significant positive correlation between CLM incidence and maximum relative humidity (r=0.301) noticed during the present study (Table 1) is in corroboration with the results of Mustafa *et al.* (2010)[17] and Wagh (2016)[25], where maximum relative humidity significantly and positively influenced citrus leaf miner infestation (r=0.167). Contrastingly, Chhetry *et al.* (2012)[8] reported that the influence of average relative humidity on CLM was not significant (r=0.14). Ahmed *et al.* (2013)[2] also noted similar findings of negative or no correlation of maximum relative humidity with CLM pest infestation.

However, a non-significant positive correlation with rainfall

(r=0.194) obtained during the study at Mudigere (Table 1) is in agreement with Mustafa *et al.* (2010) [17], where rainfall positively (r=0.567) impacted CLM larval population. Likewise, Chhetry *et al.* (2012) [8] also reported a positive correlation of citrus leaf miner population with average rainfall (r=0.36). Contrastingly, Lad *et al.* (2010) [13] reported a non-significant negative correlation between leaf miner incidence and rainfall (r=-0.137), which did not substantially influence pest incidence. Similarly, Ahmed *et al.* (2013) [2] reported that rainfall (r=-0.49) had either a negative or no correlation to pest infestation.

Table 1: Correlation between leaf miner incidence and weather parameters during 2019-20

Weather Parameters / Leaf miner incidence	Rainfall (mm)	Temperature (°C)		Relative humidity (%)	
		Maximum	Minimum	Maximum	Minimum
No. of live mines per plant	0.077	-0.120	0.091	0.180	-0.024
Per cent leaf miner infestation	0.194	-0.148	-0.090	0.301*	-0.049

Note: * $p \leq 0.05$ is considered significant

Further, in the present study, maximum and minimum temperature, as well as minimum relative humidity, negatively influenced the CLM infestation, and it was non-significant (r= -0.148, -0.090 and -0.049, respectively; Table 1). Lad *et al.* (2010) [13] reported similar findings of negative correlation (r=-0.715) with temperature and CLM pest incidence. Likewise, Mustafa *et al.* (2010) [17] also reported that temperature was negatively correlated (r=-0.100) with the leaf miner larval population. The correlation of CLM with maximum temperature also matches Ali and Ali (2018) [4]. Contrastingly, Ahmed *et al.* (2013) [2] and Wagh (2016) [25] reported a significant positive correlation of citrus leaf miner infestation with minimum temperature. Further, Ahmed *et al.* (2013) [2] noticed relative humidity negatively influencing (r=-0.15) CLM infestation. While Wagh (2016) [25] reported a significant positive correlation of citrus leaf miner infestation with minimum relative humidity (r=0.551).

4. Conclusion

Seasonal incidence revealed the prevalence of citrus leaf miner activity around the year. Roughly three broad peaks could be noticed during the IV week of July 2019, III week of October 2019 and II week of April 2020. Management of citrus leaf miner could be taken up during or before these peaks to avoid the damage. The leaf miner activity was predominant from September till December 2019 and less during January and February 2020. Further, the correlation of weather parameters with citrus leaf miner incidence indicated that rainfall, minimum and maximum temperature and minimum relative humidity had a non-significant effect. In contrast, maximum relative humidity had a positive and significant impact (r=0.301).

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