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Research Paper

Population prediction model of citrus psylla, *Diaphorina citri* Kuwayama on Kinnow Mandarin using weather data in Punjab, India

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ABSTRACT

Field experiments were carried out to study the population dynamics of citrus psylla, *Diaphorina citri* Kuwayama on Kinnow Mandarin for twelve years (2007-08 to 2019-20) in relation to different weather parameters and to develop population prediction model. Adult psyllids were observed throughout the year but the population was very low during November-January. Two population peaks were observed during March and September. Highest mean population (80.8 nymphs/25 twigs) was observed during second fortnight of September which varied in different years. Psyllid population showed significant and positive correlation with maximum and minimum temperature, vapour pressure, wind speed, sunshine hours, rainfall and negative correlation with relative humidity and number of rainy days. A weather-based model was developed to predict psylla population seven days in advance. The validation of the model carried out using various indices viz, root mean square error, coefficient of determination, Nash-Sutcliffe efficiency and mean bias error suggested that, the model predicted the population of citrus psylla quite satisfactorily. Thus, the developed model can be used satisfactorily for weather-based prediction of citrus psylla in Punjab, seven days in advance.

Keywords: *Diaphorina citri*, Correlation, Temperature-humidity index (THI), Prediction model, Psylla population, Kinnow Mandarin

Citrus is an important fruit crop of India, being grown over an area of 1003 thousand ha with a total production of 12546 thousand metric tonnes. Among citrus, mandarins are grown over an area of 428 thousand ha with production of 5101 thousand metric tonnes (Anonymous, 2023). Kinnow is reported to be attacked by about 45 insect and mite pests in Punjab (Singh *et al.,* 2016). One of the major constraints that limit productivity of Kinnow is the damage caused by Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae). *Diaphorina citri* has emerged as the most important sap-feeding insect pest of citrus throughout the world (Hall *et al.,* 2013). Both the nymphs and adults of citrus psylla cause damage by sucking plant sap from young twigs, leaves, flower buds and fruits resulting into heavy drop of young flush and fruits. More importantly, ACP vectors a phloem-limited bacterium, *Candidatus liberibacter asiaticus* (*C*Las), a causative agent of Huanglongbing (HLB), also known as 'citrus greening disease' (Pelz-Stelinski *et al.,* 2010).

Generally, Kinnow growers adopt chemical control of citrus psylla once they notice the incidence of the pest. There is a considerable lag period of 10-12 days between the start of insect attack, its build up and finally its detection by the farmers. Till the insect population becomes noticeable, considerable damage might have already occurred through the buildup of insect population. To avoid such instances of unnoticed damage, some prophylactic application of insecticides can be helpful which is generally not done by the farmers, but the prophylactic application is required in this

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case to manage the buildup of the population. However, prophylactic application of insecticides without any prior information on chances of occurrence of insect-pest may be environmentally damaging as well as uneconomical by unnecessarily increasing the use of insecticides. As monitoring is often constrained in time and space, it is important to have a model or decision support system capable of estimating the population of insect in advance. Weather based prediction models have been successfully developed for *Helicoverpa armigera* Hubner in chickpea (Sagar *et al.,* 2017) and *Zeugodacus* (*Bactrocera*) *cucurbitae* (Coquillett) (Halder *et al.,* 2022). These studies/works highlight the importance of weather-based pest population prediction models but development and application of pest and disease models to analyze and predict occurrence of insect is still a challenge for the scientific community. The present study was therefore carried out with an objective to develop a weather-based population prediction model for citrus psylla.

MATERIALS AND METHODS

Data collection

The citrus psyllid population data were collected from experimental fields continuously for twelve years (2007 to 2019 except during 2012) at Fruit Research Farm, Punjab Agricultural University (PAU), (30°54'01.9"N, 75°47'40.2), Ludhiana (Punjab), India. The experimental field (0.4 ha area) consisted of about 111 Kinnow trees planted at a spacing of 6 x 3 meters. Observations on the population of psylla adults were recorded throughout the year at 15-day intervals by visual observation from 25 shoots/ plant and 10 randomly selected plants were marked for the study. The mean number of psylla adults was calculated. The data on weather parameters recorded at Agrometeorological Observatory, PAU, Ludhiana were obtained from the data records maintained at Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana. To predict the impact of weather parameters on citrus psylla population, correlation studies were carried out between psylla population and meteorological variables. In the development of the psylla prediction model, the weekly meteorological data of the seven days preceding to the day of citrus psylla observation was used (if insect data was recorded on 15^{th}, then the weather data was from 1^{st} to 7^{th} day of the month).

In case of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and bright sunshine hours, seven days average was used while in case of rainfall, total rainfall of seven days was used. The weather and pest data for eight years from 2007 to 2015 were used for the development of citrus psylla population prediction model and four-year data from 2016 to 2019 was used for validation of the developed model.

Identifying the significant weather parameters

In order to identify the weather parameters having significant influence on psylla population, the coefficient of determination (R^2) was worked out**.** The weekly (seven days preceding to the day on which psylla data was recorded) weather data from 2007 to 2015 and corresponding psylla data at 15 days interval was used for calculation of R^2. The values of R^2 greatly increased after applying the log transformation to the psylla count. Log transformation was applied as Gomez and Gomez (1976) suggested that insect count data having wide range of variations should be log transformed before further analysis.

Development of psylla population prediction model

Based on the statistically significant values of R^2, maximum and minimum temperatures, duration of bright sunshine, morning relative humidity and THI were selected for the development of the citrus psylla population prediction model. Log transformed {Log (x+10)} data were used to develop relationship between insect count and the selected meteorological variables. Weather parameters having only statistically significant impact on psylla population were selected based on significant R^2 values.

Validation and error analysis

The output of any model needs to be validated before the application of the model to different set of environmental conditions under which the model was developed. The multiple regression model between Log transformed citrus psylla population data (dependent variable) and weather parameters along with THI (as independent variables) was validated by using four years (2016 to 2019) data., which was not used in the development of the model. The validation was done by using the index of agreement (Willmott, 1981), co-efficient of residual mass (Loague and Green, 1991), Nash-Sutcliffe efficiency (Nash and Sutcliffe, 1970), root mean square error (RMSE) and the mean bias error.

RESULTS AND DISCUSSION

Seasonal dynamics of citrus psylla

The present study on seasonal dynamics of citrus psylla revealed that the adults of citrus psylla started to build up from the first week of March and maximum population was recorded during two months i.e. March (61.6 adults /25 twigs) and September (80.8 adults / 25 twigs) (Table 1). Thereafter, the population declined. The lowest population of adults was observed during winter months from November to February. The variation in the population during different years was due to the effect of weather parameters. The gradual rise in daily minimum and maximum temperature from late February with decrease in relative humidity proved conducive for the build-up of population. High population of psylla has been reported from July to August with peak during April and again in August in Punjab (Sharma, 2008) and Gujarat (Bhut *et al*., 2013). The population of *D. citri* attained its first peak during 1^{st} week of May in Tamil Nadu as observed by Poovizhiraja *et al.,* (2019). Only adult psyllids were reported to survive during December-February months in Punjab due to extremely low temperature (Devi and Sharma, 2014). Mild winter followed by a favourable spring and pre-monsoon rains during April provides suitable conditions for build-up of population of citrus psylla (Table 1).

Apart from these direct data on meteorological parameters, a temperature-humidity index (THI) was also calculated as THI has been used widely (West *et al.,* 2003, Dikmen and Peter, 2009) to study the combined effect of temperature and humidity. The weekly temperature and humidity data of the seven days preceding to the day of citrus psylla observation was used for calculation of THI as

Table 1: Population of *Diaphorina citri* and weather parameters of Ludhiana, Punjab during study period (2007-2015)

Month	Insect count	Min. temp. (°C)	Max. temp. (°C)	Vapour pressure (mm)	Sunshine (h)	Rainfall (mm)	Relative humidity (%)	Wind speed (Km/h)	Rainy days (No.)
January	3.3	6.8	16.9	8.1	5.1	29.1	81.5	3.8	2.8
February	39.8	10.0	21.0	9.1	7.6	39.7	74.1	4.6	3.5
March	61.6	15.0	27.3	12.8	8.8	19.2	66.0	4.0	2.4
April	25.2	20.7	33.8	11.5	9.9	18.9	44.3	5.1	2.0
May	28.8	25.2	36.8	13.8	9.4	22.1	42.8	6.0	1.8
June	42.7	27.5	36.6	20.6	7.2	88.0	57.6	6.8	5.8
July	47.3	27.5	33.3	24.3	6.8	222.7	76.9	5.5	7.8
August	61.6	27.0	32.8	24.8	6.9	198.8	80.8	4.3	8.6
September	80.8	24.7	31.9	21.7	8.1	77.9	77.1	3.4	3.3
October	17.7	18.8	30.1	14.3	8.0	14.2	67.2	2.7	1.1
November	1.0	13.2	24.8	9.7	6.3	3.3	65.5	2.4	0.6
December	0.2	8.6	18.3	9.0	5.4	7.3	76.0	3.1	1.0

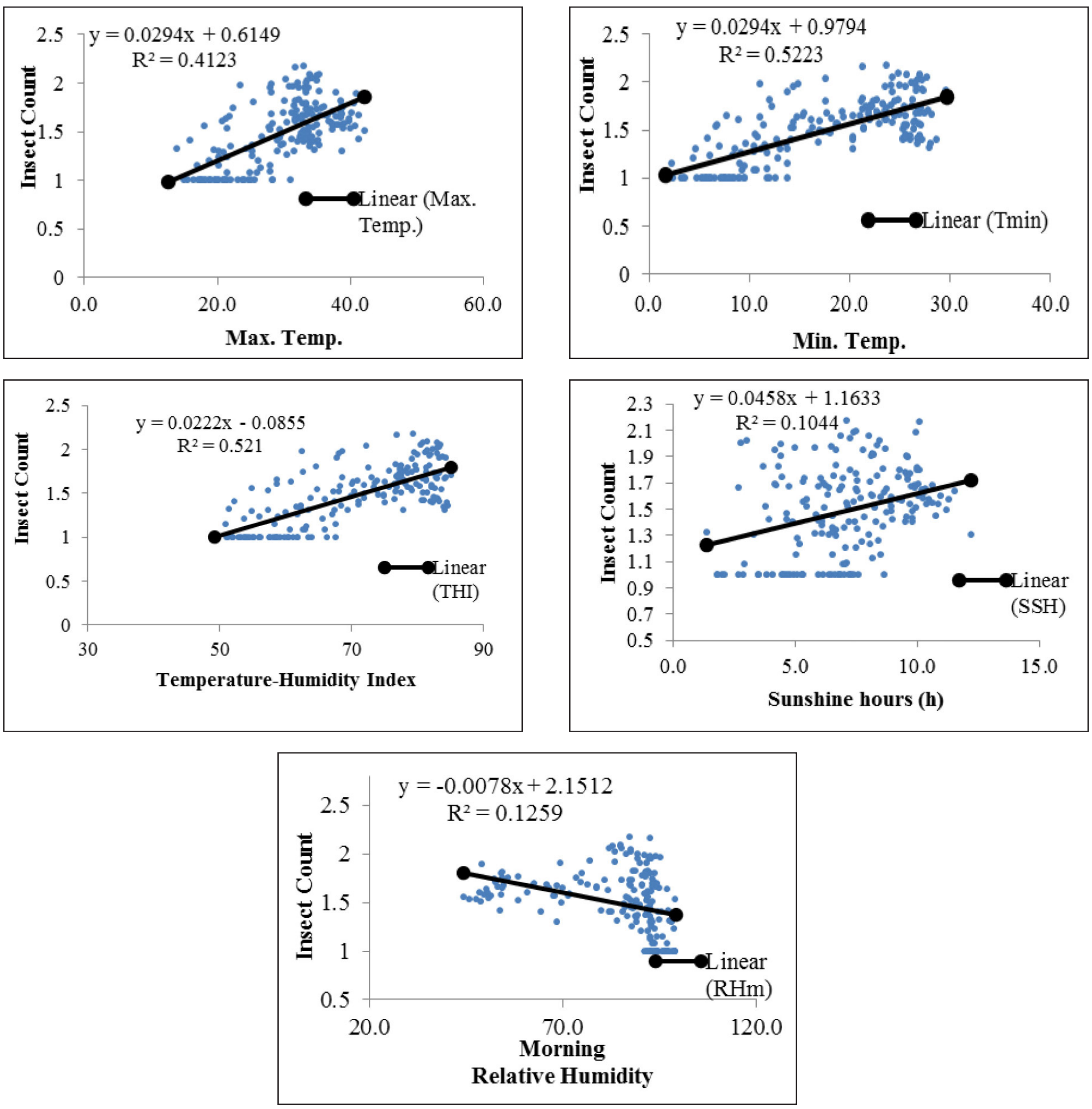

Fig. 1: Relationship between weather parameters and citrus psylla population (log transformed data)

Table 2: Correlation between population of *Diaphorina citri* and weather parameters during study period (2007-2020).

Weather parameters	Correlation coefficient
Maximum temperature	0.52
Minimum temperature	0.62
Mean temperature	0.61
Morning RH	-0.09
Evening RH	0.38
Vapour pressure	0.73
Wind speed	0.31
Sunshine	0.43
Rainfall	0.55
No. of rainy days	-0.05

explained previously. The temperature-humidity index (THI) was calculated following Mader *et al.,* (2006).

$$THI = (0.8 \times T°C) + [(RH/100) \times (T°C - 14.4)] + 46.4$$

where T = average daily temperature and RH = average daily relative humidity.

Correlation coefficients of the relationship between adult population of citrus psylla during study period and weather parameters are presented in Table 2. The correlation coefficient indicated that maximum, minimum and mean temperatures, wind speed, sunshine and evaporation had high positive correlation whereas relative humidity and number of rainy days had negative impact on the psylla population. In the log transformed data, influence of temperature (both maximum and minimum), bright sunshine hours and morning relative humidity on psylla count was found to be statistically significant (Fig. 1). Positive correlation of psylla population with maximum, minimum temperature, sunshine, rainfall, evaporation, wind speed and negative with bright sunshine, morning and evening relative humidity and vapour pressure was reported by various workers in India (Patel and Patel, 2006; Sharma, 2008; Bhut *et al*., 2013; Poovizhiraja *et al.,* 2019). Maximum and minimum temperatures were found to have significant positive correlation with guava fruit fly, *B. zonata* (Saunders) (Sharma *et al*., 2015).

Table 3: Validation of the citrus psylla population prediction model

Statistics	Year			
	2016	2017	2018	2019
Observed mean	38.42	32.91	34.88	33.59
Predicted mean	36.28	38.57	34.92	33.93
Percent deviation	-5.56	17.20	0.13	1.02
Standard deviation (SD)	31.90	29.80	33.80	32.90
Half of SD	15.95	14.90	16.90	16.45
RMSE	9.91	10.60	10.84	7.97
R^2	0.52	0.38	0.52	0.85
F value	11.38	6.43	11.38	59.50
Probability level	P≤0.01	P≤0.01	P≤0.01	P≤0.01
Index of agreement (IA)	0.78	0.75	0.74	0.87
CRM	0.06	-0.17	0.00	-0.01
Nash Sutcliffe efficiency	0.00	-0.04	0.00	0.01
MBE	-0.43	1.13	0.01	0.07

Number of observations=24

Development of psylla population prediction model

The multiple regression analysis between Log transformed citrus psylla population data (as dependent variable) and maximum and minimum temperatures, duration of bright sunshine, morning relative humidity and THI (as independent variables) resulted into the following model with R^2=0.564:

Y=0.02892-0.03304*Tmax+0.00797*Tmin+0.03791*SSH-0.0028625*RHm+0.03203*THI

Where Y: psylla count, Tmax: maximum temperature, Tmin: minimum temperature, SSH: duration of bright sunshine, RHm: morning relative humidity and THI: thermal humidity index.

The model was developed by using 192 observations on psylla population and selected meteorological parameters. The R square, adjusted R square and F values of 0.5636, 0.5519 and 48.0429 indicated a good agreement of the model to the observed data.

Validation of the developed model

The model was validated by using various indices (Table 3), among them the four-year average of observed and predicted population was almost similar. On average basis, the model over predicted the population by 2.8 per cent only. The value of RMSE also suggested that the model predicted the psylla population quite satisfactorily. Even the highest value of RMSE for 2018 was lower than the half of standard deviation of the observed data; therefore, it was also categorized as low. Singh *et al.,* (2004) suggested that

RMSE values less than half of the standard deviation of the measured data may be considered as low. The coefficient of determination (R^2) was statistically highly significant as evident from high values of F and very low probability levels. The index of agreement (IA) also indicated that the developed model predicted the population of citrus psylla quite satisfactorily as a computed value of 1 indicates a perfect agreement between the measured and predicted values (Willmott, 1981) and in the present case all values were greater than 0.74. The coefficients of residual mass (CRM) also depicted that the developed model predicted the population quite accurately as its value was near to zero and zero value of CRM represents a perfect fit. The Nash-Sutcliffe efficiency also represented that the model was able to predict the psylla population satisfactorily as in all cases its value was above zero. The mean bias error (MBE) values were near zero which means the model prediction was close to the observed values (Table 3).

The overall results of validation suggested that the performance of the model according to different indices was satisfactorily to excellent during different years under study. Thus, the developed model will be helpful in forewarning the farmers to manage the pest as it predicts the incidence of psylla attack seven days in advance so that the farmers can timely adopt control measures.

CONCLUSION

Two population peaks of citrus psylla, *Diaphorina citri* Kuwayama on Kinnow Mandarin were observed during March and September months. Highest population (80 nymphs/25 twigs) was observed during second fortnight of September. Psyllid population showed significant and positive correlation with maximum and minimum temperature, vapour pressure, wind speed, sunshine hours, total rainfall and negative correlation with relative humidity and number of rainy days. A weather based psylla population prediction model was developed to predict psylla population seven days in advance. The model was validated satisfactorily by using Root mean square error (RMSE), Coefficient of determination, Nash- Sutcliffe efficiency and Mean Bias Error. Thus, the developed model can be used satisfactorily for weather-based prediction of citrus psylla in Punjab, seven days in advance.

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Data availability : Data can be provided on reasonable request.

***Author's contribution*: S. Singh:** Carried out the implementation of experiments and wrote the manuscript; **R. K. Sandhu:** Analysed the data and wrote the manuscript; **S. S. Sandhu:** Designed the model and analysed the data; **K. K. Gill:** Designed the model and analysed the data; **M. Siraj:** Helped in improving the manuscript and in data analysis; **P. V. R. Reddy:** Conceived the study and improved the manuscript; **P. Patil:** Conceived the study

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REFERENCES

Anonymous. (2023). *Horticultural Statistics at A Glance*. Government of India. 490 pp.

Bhut, G.D., Borad, P.K. and Gadhiya, V.C. (2013). Effect of weather parameters on activity of psylla and leaf miner on Kagzi Lime. *AGRES- An Intern. e-J.,* 2: 101-107.

Devi, H.S. and Sharma, D.R. (2014). Impact of abiotic factors on build-up of citrus psylla, *Diaphorina citri* Kuwayama population in Punjab, India. *J. Appl. Nat. Sci.,* 6: 371-376.

Dikmen, S. and Peter, H. (2009). Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? *J. Dairy. Sci.,* 92: 109-116. https://doi.org/10.3168/jds.2008-1370.

Gomez, K.A. and Gomez, A.A. (1976). Statistical Procedures for Agricultural Workers. An International Rice Research Institute Book, John Wiley and Sons, Singapore.

Halder, J., Rai, A.B. and Deb, D. (2022). Distribution and abundance of cucurbit fruit fly, *Zeugodacus* (*Bactrocera*) *cucurbitae* in relation to weather parameters. *J. Agrometeorol.,* 24(2): 220-222. https://doi.org/10.54386/jam.v24i2.1643.

Hall, D.G., Richardson, M.L., Ammar, E.D. and Halbert, S.E. (2013). Asian citrus psyllid, *Diaphorina citri*, vector of citrus huanglongbing disease. *Entomol. Experim. Appl.,* 146: 207-223.

Loague, K. and Green, R.E. (1991). Statistical and graphical methods for evaluating solute transport models: Overview and application. *J. Contamin. Hydrol.,* 7: 51-73.

Mader, T.L., Davis, M.S. and Brown-Brandl, T. (2006). Environmental factors influencing heat stress in feedlot cattle. *J. Anim. Sci.,* ٨٤: 712-719. https://doi.org/10.2527/2006.843712x

Nash, J.E. and Sutcliffe, J.V. (1970). River flow forecasting through conceptual models: Part I. A discussion of principles. *J. Hydrol.,* 10: 282–290. http://dx.doi.org/10.1016/0022-1694: 90255-6.

Pelz-Stelinski, K.S., Brlansky, R.H., Ebert, T.A. and Rogers, M.E. (2010). Transmission parameters for *Candidatus Liberibacter asiaticus* by Asian citrus psyllid (Hemiptera: Psyllidae). *J. Econ Ent.,* 103: 1531-1541.

Patel, P.S. and Patel, G.M. (2006). Population dynamics of important pests of citrus, *Citrus aurantifolia* Swingle. *Indian J. Ent.,* 68: 255-259.

Poovizhiraja, B., Chinniah, C., Murugan, M., Irulandi, S., Aiyanathan, K.E.A. and Balamohan, T.N. (2019). Population dynamics and seasonal incidence of major sucking pests of acid lime, *Citrus aurantifolia* Swingle. *Int. J. Curr. Microbiol. App. Sci.,* 8: 386-393.

Sagar, D., Nebapure, S.M. and Chander, S. (2017). Development and validation of weather based prediction model for *Helicoverpa armigera* in chickpea. *J. Agrometeorol.,* 19(4): 328-333. https://doi.org/10.54386/jam.v19i4.600.

Sharma, D.R. (2008). Population dynamics in relation to abiotic factors and management of citrus psylla in Punjab. *Indian J. Hort.,* 65: 417-422.

Sharma, K., Sharma, R.K., Chander, S. and Jilu, V. (2015). Effects of weather parameters on Guava fruit fly (*Bactrocera zonata*) population at IARI, New Delhi. *J. Agrometeorol.*, 17(2):227-229. https://doi.org/10.54386/jam.v17i2.1012.

Singh, J., Knapp, H. V. and Demissie, M. (2004). Hydrologic modeling of the Iroquois River watershed using HSPF and SWAT. ISWS CR 2004-08. Champaign, Ill.: Illinois State Water Survey. Available at: www.sws.uiuc.edu/pubdoc/CR/.

Singh, Sandeep., Rao, C.N., Deka, S., Sonalkar, V., Datkhile, R., Kadam, U.K., Rani, U., Sarada, G., Kaur, G. and Patil, P. (2016). Insect and mite pests of Citrus in India-Monograph. ICAR-AICRP on Fruits, IIHR, Bengaluru (March), 114 pp.

West, J.W., Mullinix, B.G. and Bernard, J.K. (2003). Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. *J. Dairy. Sci.,* 86, 232-242.

Willmott, C.J. (1981). On the validation of models. *Phys. Geograph.,* 2: 184-194.