Role of climatic factors on citrus psylla, *Diaphorina citri* Kuwayama (Psyllidae :Hemiptera) in Coorg mandarin, *Citrus reticulata* Blanco

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ABSTRACT

The decision tree analysis was carried out to study the role of biotic and abiotic factors in relation to citrus psylla incidence on Coorg mandarin (*Citrus reticulata*). The citrus psylla population was recorded HIGH if min temperature ranged between 18.71-19.42^{0}C, maximum temperature ranged between 30.57-32.28^{0}C and Max. relative humidity 87.1-95.6%. If minimum temperature ranged between 19.5-29.33^{0}C with minimum relative humidity 64.6-81.0% then psylla population was high. The correlation analysis with weather parameters showed positive significant correlation with maximum temperature (r = 0.23) at $P < .01$ level and negative significant correlation with minimum temperature (r = -0.21) and rainfall (r = -0.18) at $P < 0.05$ level.

KEY WORDS: *Citrus reticulata,* decision tree, *Diaphorina citri,* mandarin

INTRODUCTION

The Asian citrus psylla, *Diaphorina citri* Kuwayana, is widely distributed in southern Asia. It is an important pest of citrus in several countries as it is a vector of a serious citrus disease called greening disease or Huanglongbing. This disease is responsible for the destruction of several citrus industries in Asia and Africa (Manjunath, 2008). Coorg mandarin, *Citrus reticulata* Blanco is an important fruit crop of Kodagu, Haasan and Chickamagalur districts of Karnataka state. In Kodagu, mandarins are raised as rainfed, under multi-storied coffee based cropping system. The area covered under mandarin cultivation in the country is 1.68 lakh ha with annual production of 14.14 lakh tonnes. The climatic conditions in Coorg mandarin growing areas are characterized by mild temperature and high humidity, which favours the pests and disease incidence. In the past few decades the growers are facing, the Coorg mandarin decline as the health of the plants deteriorated. This problem is broadly referred to as “decline” or “die-back” and a number of factors are attributed to this problem. In recent years, the ‘Citrus greening disease’ caused by a fastidious phloem limited endocellular bacterium, *Candidatus liberibacter asiaticus* has assumed a devastating role in Coorg mandarin decline.

Citurs psylla, *Diaphorina citrii* Kuwayana (Homoptera: psylliade) is becoming a serious threat to citrus industry. Chung and Brlansky 2009 reported Citrus greening bacterium (CGB) or Huanglongbing (HLB) is caused by a phloem-limited bacterium that has a true cell wall. There are at least three forms or species: *Candidatus* L. africanus causing African HLB; *Candidatus* L. asiaticus causing Asian HLB; and a new varient found in Brazil, tentatively called *Candidatus* L. americanus. Asian HLB is the bacterium found in Florida. Cirtus psylla is known to vector this citrus greening disease. The nymphs that inhabit new growth and adults suck the sap causing curling of leaves, defoliation, heavy flower drop affecting the fruit set severely and even causing death of the branches from tip to downwards, *i.e.,* die-back. It secretes some toxins, whitish crystalline honey dew that covers the shoots and leaves giving the appearance of having been dusted on which the sooty mold grows (Parvatha Reddy, 2009). This disease can also be transmitted through tissue grafts. Capoor *et al.* revealed that the adult psyllids were able to transmit greening in a minimum infection feeding time of 15 minutes but the transmission percentage will be low. They found that 4^{th} and 5^{th} instar nymphs and adults are effective transmitters of vectors of this disease. The vectors will retain the pathogen throughout their life time following short access feeding period (15-30 minutes) and requires an incubation period of about 21 days. One hour or more feeding period gave 100 per cent infection by psyllids. The peak activity of this pest generally synchronises with the emergence of new flushes in citrus during January-February and July-August (Dharmaraju and Reddy, 1975). The low densities of psylla are sufficient enough to incur huge damage, hence it is necessary to understand the dynamics of the population build-up of this vector for effective management practices. So, a study has been carried out gathering historical data of psylla incidence and relate it with weather parameters to arrive at suitable weather models under the National Initiative of Climate Resilient Agriculture (NICRA, ICAR) as the weather parameters influences the population build-up of citrus psylla on Coorg mandarin.

MATERIALS AND METHODS

The citrus psylla incidence data set from the year 2003 to 2013 from Central Horticultural Experiment Station (CHES), Chettalli (Latitude:12.380N ; Longitude: 75.640E; Altitude: 609 MSL), a Regional Station of Indian Institute of Horticultural Research, Bangalore, Karnataka was used for prediction analysis. Weekly observations on mean number of psylla/flush present on 5 flush per 20 trees (total 100 flush) were recorded for the period of 10 years and maintained in the station's register. Weekly means of weather parameters like maximum temperature (Maxt), minimum temperature (Mint), maximum relative humidity (RHmax), minimum relative humidity (RHmin), average rainfall (RF) and number of rainy days in a week have collected from the meteorological department. Weekly observations of pest incidence data corresponded with standard week data of weather parameters. The pest incidence data with previous week weather parameters have taken for decision tree analysis.

Table 1: Sample records/tuples from the database

Tuples S.No.	Variables/Attributes							Class/ Target (PI)
	MaxT (^{0}C)	MinT (^{0}C)	RHmax (%)	RHmin (%)	RF (mm)	RFD	Average Psylla/flush	
1	31.28	19.14	81.85	46.42	6.7	2	1.4	Low
2	24.33	19	98	79.16	17.65	6	0.32	Low
3	32.85	9.35	90.28	35.4	0	0	6.4	Medium
4	32.85	13.78	90.42	47.71	0	0	32.4	High
5	32.21	18.71	93	57	10.27	5	21.7	High

Pest incidence (PI) was the dependent variable (Also referred to as class or target variable) and it was predicted based on several independent variables which are weather parameters (also referred to as features or attributes).

The pest incidence was grouped into three classes based on their numbers namely, low, medium and high. Pest incidence (PI) was considered as high if PI≥ 10/ new flush, medium if PI≥ 5-10/new flush, and low if PI≥0-5/new flush. The Shannon information theory is used for the attribute selection measure. The expected information needed to classify a tuple/record in D is given by

$$\text{Info (D)} = \sum_{i=1}^{m} p_i \log_2(p_i)$$

where p_i is the probability that an arbitrary tuple in D belongs to class C_i and is estimated by $n(C_i,D)$ / n(D). Info(D) is also known as the entropy of D. *ie*., total information value. Let $n(C_i,D)$ denotes total number of tuples or records in class C_i and n(D) denotes total number of tuples or records in Drespectively. Entropy of attribute A with values $\{A_1,A_2,...,A_v\}$ is used to split D into v subsets where v varies from 1to 5 (total number of bins) and $\text{Info}_A(D)$ is calculated based on the total number of label A1 to A5 values in a particular class values of PI and it can be represented as:

$$\text{Info}_A\text{ (D)} = \sum_{j=1}^{v} \frac{n(D_j)}{n(D)} x Info(D_j)$$

Info_A is denoted as the information value for the attribute A.
$\text{Info}_A(D)$ is the expected information required to classify a tuple from D based on the partitioning by A. Information is gained by branching an attribute A, and gain value for an attribute A is calculated as

$$\text{Gain (A)} = \text{Info(D)} - \text{Info}_A\text{(D)}$$

The attribute A with the highest information gain, (Gain (A)), is chosen as the splitting attribute at node N (Gupta, 2006).

Table 2: Gain value based on Shannon Information Theory

Name of the variable	Gain value
MinT	0.13
RHmax	0.11
MaxT	0.1
RF	0.09
RHmin	0.06
RFD (no. of rainy days)	0.06

Information gain is a measure of how good an attribute is for predicting the class of each of the training data. The attribute with the highest information gain was selected as the next split attribute according to the standard procedure (Gupta, 2006).

The attribute selection measure based on Shannon information theory was used in the decision tree analysis. According to this, the maximum gain value attribute was chosen as the splitting attribute and based on the attribute subsets were evaluated. Information measure was used recursively for each subset until the gain value or the entrophy reached zero for the attribute and this was used as a stopping criterion. The process continued until the search was completed and the attributes and labels stored in the table for tree generation. The model used the filter method as it selecting the features/attributes before applying an induction algorithm. The subsets had been generated automatically based on the information theory. The decision tree is a non-backtracking algorithm and hence it was constructed in a top-down pattern. The constructed binary tree had decision node as the condition and output/result of that condition derived as the yes or no options. The yes option always grows as left child and no option as right child in the tree. The node ended when the condition was not able to proceed further in the no option as right child. The end of the leaf node denoted the class label of pest incidence.

RESULTS AND DISCUSSION

Gain value was calculated recursively for each subset evaluation (decision space) and the stopping criterion until the gain value reaches zero has been used. The gain values for all the attributes at iteration 1 (level 1) are given in Table 2. The root of the decision tree was fixed as PI and it was at level 0. The maximum gain value of the attribute was Mint (Table.2). Hence tree generation started from the Mint when ranges from 18.71^{0}C to 19.42^{0}C and 19.5^{0}C to 29.33^{0}C.

From the figures 1 & 2, the IF-THEN rule were derived for the minimum temperature ranges from 18.71°C to 19.42°C and 19.5^{0}C to 29.33^{0}C respectively. When the minimum temperature ranges from 18.71^{0}C to 19.42^{0}C and maximum temperature ranged from 18.8^{0}C to 25.8^{0}C, pest incidence was LOW (Table.3). But, when Mint ranged from 18.71^{0}C to 19.42^{0}C, Maxt 25.83-27.60^{0}C and the rainfall was in the range of 1-7mm and 20-103mm, then the pest incidence was LOW. Similarly the same Mint (18.71^{0}C to 19.42^{0}C), and Maxt (25.83-27.60^{0}C) with the average rainfall ranges from 7-20mm, the pest incidence was MEDIUM (Table 3). But when the Mint ranged from 18.71^{0}C to 19.42^{0}C, the Maxt ranged from 27.60-32.28^{0}C with the RHmax ranged from 52.5-95.6 per cent, pest incidence was LOW. If the Mint is 18.71^{0}C to 19.42^{0}C and Maxt is 27.60-30.28 with the RHmax of 95.7-98.5 per cent, pest incidence was MEDIUM. But, the minimum temperature 18.71^{0}C to 19.42^{0}C and Maxt ranged from 30.57-32.28^{0}C with 87.1-95.6 per cent RHmax, the pest incidence was HIGH. Similarly, when the Mint 18.71^{0}C to 19.42^{0}C with the Maxt 32.46-39.07^{0}C, pest incidence was LOW.

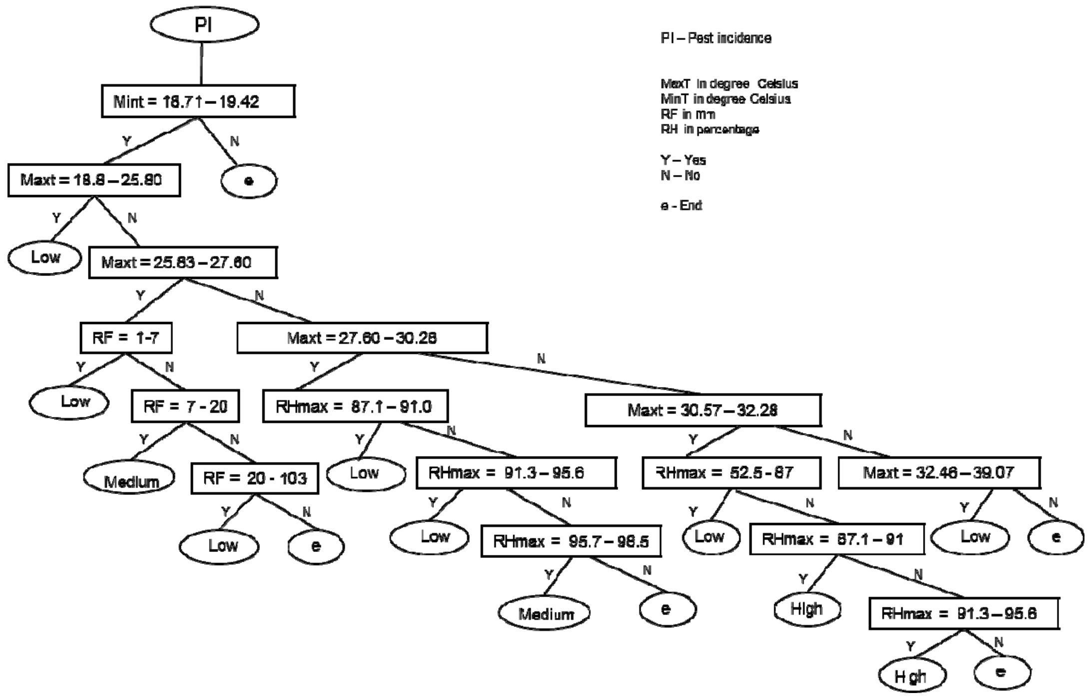


Fig.1: Decision Tree based on Mint (minimum temperature) ranges from 18.71°C to 19.42°C

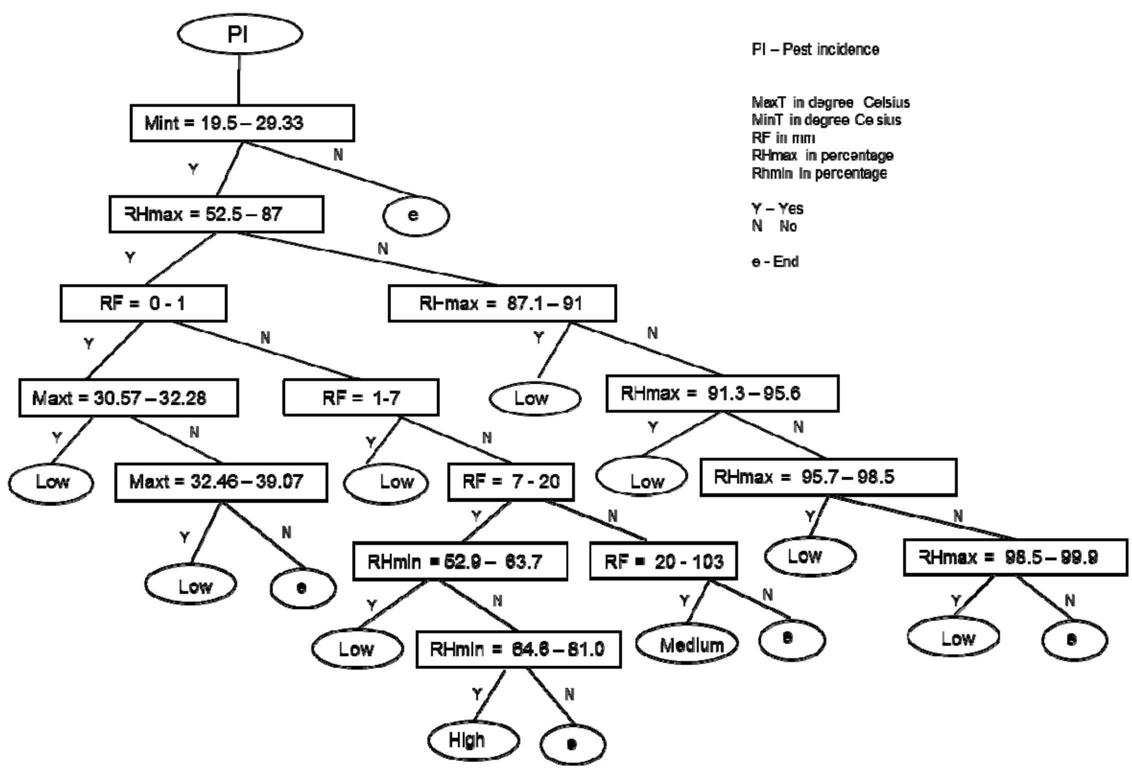


Fig.2: Decision Tree based on Mint (minimum temperature) ranges from 19.5°C to 29.33°C

Table 3: IF-THEN rules for minimum temperature 18.71^{0}C to 19.42^{0}C

	Condition		Class
IF	Min.T= 18.71-19.42^{0}C, Max.T= 18.8-25.80^{0}C	THEN	Low
IF	Min.T= 18.7 -19.42^{0}C, Max.T =25.83-27.60^{0}C, RF=1-7mm	THEN	Low
IF	Min.T= 18.71 -19.42^{0}C, Max.T =25.83-27.60^{0}C, RF=7-20mm	THEN	Medium
IF	Min.T= 18.71-19.42^{0}C, Max.T =25.83-27.60^{0}C, RF=20-103mm	THEN	Low
IF	Min.T= 18.7 -19.42^{0}C, Max.T=27.60-30.28^{0}C, Max RH=87.1-95.6%	THEN	Low
IF	Min.T= 18.71-19.42^{0}C, Max.T=27.60-30.28^{0}C, Max RH=95.7-98.5%	THEN	Medium
IF	Min.T= 18.7 -19.42^{0}C, Max.T=30.57-32.28^{0}C, Max RH=52.5-87%	THEN	Low
IF	Min.T= 18.71-19.42^{0}C, Max.T=30.57-32.28^{0}C, Max RH=87.1-95.6%	THEN	High
IF	Min.T= 18.71-19.42^{0}C, Max.T=32.46-39.07^{0}C	THEN	Low

Table 4: IF-THEN rules for minimum temperature 19.5^{0}C to 29.33^{0}C

	Condition		Class
IF	Min. T= 19.5-29.33^{0}C, Max RH =52.5-87%, RF=0-1mm,Max T=30.57-39.07	THEN	Low
IF	Min. T= 19.5-29.33^{0}C, Min RH =52.9-63.7%, RF=1-20mm	THEN	Low
IF	Min. T= 19.5-29.33^{0}C, Min RH =64.6-81.0%	THEN	High
IF	Min. T= 19.5-29.33^{0}C, Max RH =87.1-99.9%	THEN	Low
IF	Min. T= 19.5-29.33^{0}C, , Max RH =52.5-87%,RF=20-103mm	THEN	Medium

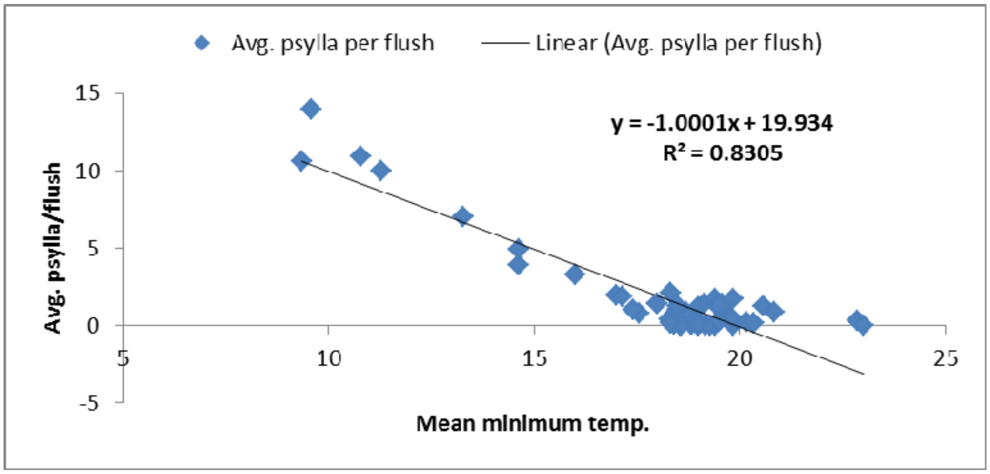
Based on table 4. when the Mint ranges from 19.5-29.33^{0}C and RHmax ranges from 52.5-87 per cent with <1mm rainfall and Mint ranged from 30.57-39.07^{0}C, pest incidence was LOW. But, Mint ranges from 19.5-29.33^{0}C and RHmax ranges from 52.5-87 per cent with 20-103mm RF, the pest incidence was MEDIUM. When the RHmin ranged from 52.9-63.7 per cent with 1-20mm RF, pest incidence was LOW but, Mint 19.5-29.33^{0}C and RHmax ranged from 87.1-99.9 per cent, the pest incidence was LOW. The pest incidence was HIGH when the Mint ranged from 19.5-29.33^{0}C and RHmin ranged from 64.6-81.0 per cent.

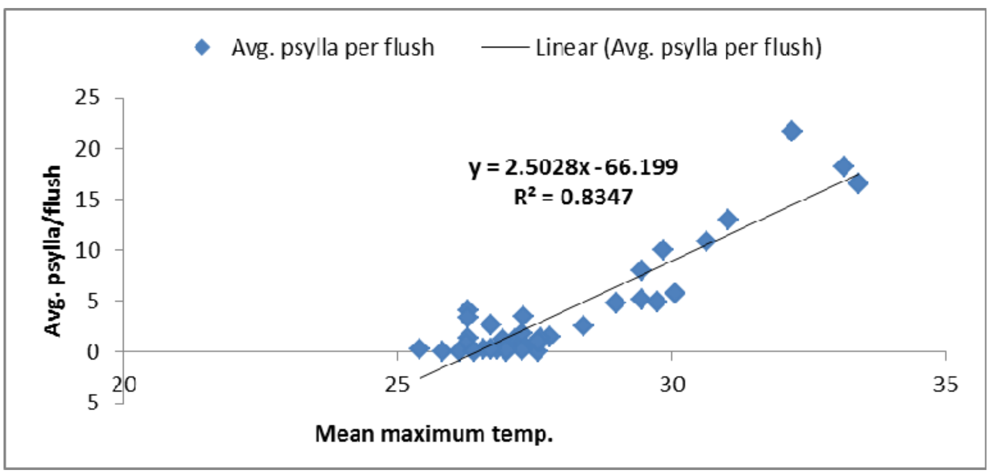
Table 5: Comparison between information gain values, correlation values and regression analysis

Name of the variable	Information gain value	Correlation value ('r')	Regression analysis
Max.Temp.	0.1	0.234**	Y=2.502x-66.19 R^2=0.83
Min.Temp.	0.13	-0.215*	Y=1.00x+19.93 R^2=0.83
RH max.	0.11	-0.158	
RH min.	0.06	-0.125	
Rainfall	0.09	-0.189*	
No. of rainy days	0.06	-0.151	

r values with * are significant at $P < 0.05$ level and with ** are significant at $P < 0.01$ level

When the data was subjected to correlation analysis, the maximum temperature, minimum temperature and rainfall played a major role in the psylla population. The variability in the psylla population is explained to the tune of 83% each by maximum temperature, minimum temperature and rainfall after eliminating the outliers (Table.5). The variability in the psylla population by all these factors are explained to the tune of 8% (Y= -0.052+0.24 Max. Temp -0.022 Min. Temp-0.026 RF; R^2=0.05). The variability in the psylla population is explained to the tune of 5 the maximum temperature alone (Y= -6.70+0.33 Max. T; R^2=0.05). The correlation analysis of PI with abiotic factors is coincided with information gain table (Table 2). Hence, Shannon information theory can be used for finding the significance of abiotic factors in cause of pest Incidence. Similar studies on population dynamics of citrus psylla was conducted at Central Horticultural Experiment Station (CHES), Chettalli, karnataka by Bhumannavar & S. P. Singh, 1985 reports that the psylla was high from January to March, and in the month of May. The reports of Jamesh H. Tsai *et al.*2002, reveal that the psylla population peaks on orange jasmine in South Florida was positively related to the availability of new flush which in turn related to weekly minimum temperature and rainfall. The high nymphal population observed during August when the weather factors viz. minimum temperature (26.0-27.2^{0}C), maximum temperature (33.5-34.9^{0}C), mean temperature (30^0C), relative humidity (74-84%), sunshine hours (6.3-9.3 hrs), and rainfall (24.5-29.7 mm). The correlation analysis of nymphal and adult population show positive relationship with minimum, maximum, mean temperatures, relative humidity and vapour pressure, whereas wind velocity had very low impact on adult population (Sharma D. R., 2008).





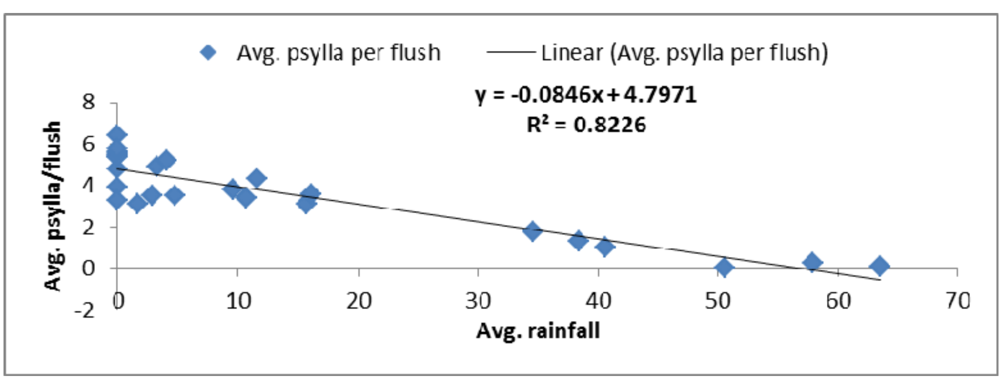


Fig. 3: Relationship between psylla number with mean minimum temperature, mean maximum temperature and average rainfall

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