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Weather based forewarning models for coffee berry borer and shot hole borer in Wayanad, Kerala

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सार – 1977 से 2007 (30 वर्ष) के दौरान की समयावधि में क्षेत्रीय कॉफी अनुसंधान केन्द्र, चुंडेल में कॉफी प्लांटेशन में कॉफी बैरी बोरर और शॉट होल बोरर की वजह से पेस्ट से नुकसान ओर मौसम प्राचलों के आँकड़ों को रिकार्ड किया गया है। कीटों से नुकसान और मौसम प्राचलों के दीर्घकालिक आँकड़ों का उपयोग करते हुए कॉफी बैरी और शॉट होल बोरर घटना पर मौसम परिवर्तनशीलता का प्रभाव वायनाड में कॉफी बैरी बोरर और शॉट होल बोरर से होने वाले नुकसान के बारे में मौसम के आधार पर पहले से चेतावनी देने वाले मॉडलों को विकसित करने के उद्देश्य से अध्ययन किया गया है। कॉफी बैरी बोरर (CBB) का नुकसान विशेष रूप से जनवरी से मार्च के दौरान देखा गया है जबकि शॉट होल बोरर (SHB) का नुकसान जनवरी से अप्रैल और अक्तूबर से दिसंबर के दौरान फैलता हुआ देखा गया है। कॉफी बैरी बोरर और शॉट होल बोरर से सबसे अधिक नुकसान जनवरी के पहले पूर्वाद्ध में देखा गया है। कॉफी बैरी बोरर की वजह से सबसे अधिक नुकसान 1982 के दौरान देखा गया और शॉट होल बोरर की वजह से सबसे अधिक नुकसान 1994 में हुआ। जनवरी के पहले पंद्रह दिनों में अधिक तापमान रिकार्ड जो मौसम परिवर्तनशीलता से प्रबल था। जनवरी के पहले पंद्रह दिनों के दौरान शॉट होल बोरर के प्रबल मौसम परिवर्तनशीलता इनफेस्टेशन को निर्धारित करती है। फसल की उपज और नवोदित अवस्थाओं को कॉफी बैरी बोरर ओर शॉट होल बोरर ने भारी नुकसान पहुंचाया है।

ABSTRACT. Pest damage due to coffee berry borer and shot hole borer in coffee plantations in Regional Coffee Research Station, Chundale and data on weather parameters were recorded during 1977 to 2007 (30 years). These long-term data on the pest damage and weather parameters were utilized to study the influence of weather variables on coffee berry and shot hole borer incidence with a view to develop weather based forewarning models for coffee berry borer and shot hole borer damage in Wayanad. The damage of coffee berry borer (CBB) was observed to be significant during January to March while the damage of shot hole borer (SHB) was spread during January to April and October to December. Highest percent damage of coffee berry borer and shot hole borer was observed during first fortnight of January. Maximum damage due to coffee berry borer was observed during 1982 and maximum damage due to shot hole borer was observed in 1994. Maximum temperature recorded during the first fortnight of January is predominant weather variable determining infestation of shot hole borer during first fortnight of January. Harvest and budding stages of the crop suffered heavy incidence of coffee berry borer and shot hole borer, respectively.

Key words – Coffee berry borer, Shot hole borer, Weather, Pest forewarning model.

1. Introduction

Coffee is one of the world's most popular beverages (Fujioka and Shibamoto, 2008) cultivated by 20 millions farmers in more than 50 countries in Africa, Asia and America. It generates an industry that surpasses USD 70 billion, annually. Coffee cultivars are planted in a very wide range of ecological and social conditions. Both Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*) coffee varieties are extensively cultivated in India. It was introduced in India and Sri Lanka towards the end of the 17th century. Coffee is cultivated commercially in the four Southern States of Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. It is also grown on limited scale in some non-traditional areas of Orissa, West Bengal, Assam and Madhya Pradesh.

Coffee production suffers from numerous insect pests such as coffee berry borer, white stem borer, leaf miners and mealy bugs which can cause up to 20% yield loss and also reduce value of coffee by 30 to 40%. These coffee pests could be managed to remain below economic threshold levels by adoption of integrated pest management (IPM) strategies which include continuous monitoring and anticipation of pest outbreaks, optimum shade management, pruning of coffee bushes, good

harvesting, conservation and augmentation of indigenous natural enemies, introduction of exotic natural enemies and timely use of need based bio insecticides or chemicals.

Coffee Berry Borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae: Scolytinae) is the most serious insect pest of coffee worldwide (Vega *et al.*, 2009) with its origin from Africa. Coffee berry borer causes direct damage to the coffee beans. The attacked green, ripe and dry fruits or berries usually show a hole located at the center or ring of the berry's ostiole. Characteristic damage includes the drop of young berries due to attack, and the loss of bean weight due to insect feeding. All the commercial coffee varieties and species are attacked by this insect. However, it shows preference for *Coffea canephora*, and its multiplication is also higher on beans of this coffee species. Recently it was suggested that *H. hampei* serves as a vector for *Aspergillus ochraceus* Wilh., which produces ochratoxin-A, a potent toxin that sometimes contaminates green coffee beans, roasted coffee, and coffee brews, including instant coffee.

Adult females initiate the infestation. In general, a berry is infested by a single female. If the coffee bean is watery or milky, the insect tends to abandon it and the bean usually rots. But if the bean consistency is hard enough, the female constructs a gallery where it lays the eggs. The eggs are oviposited one by one, forming small groups within the coffee bean. The female lays from 1 to 3 eggs per day during the first 15-20 days; afterwards, the egg laying diminishes gradually. Both the founding female and the larvae build tunnels in the bean, where they also feed. Pupation takes place within the coffee bean where the larva hatched. The duration of the biological cycle, from egg to adult, varies according to the temperature : 21 days at 27 °C, 32 days at 22 °C and 63 days at 19.2 °C. As the first adult offspring appear, the population inside an infested bean typically consists of 25-30 individuals in all stages of development, of which there are approximately 10 females for each male. Mating is conducted between siblings inside the bean. The mated females leave the bean where they developed to look for another where they will oviposit. Several generations occur while berries are available. After coffee harvest, the borer continues to reproduce in the non-harvested berries located on the plant and on the ground. In locations with low rainfall, where there is a clearly defined period between harvests, the adults find refuge in the black, dry berries. Adult females emerge massively from these old berries with first rainfall, initiating the infestation by attacking berries from the earliest flowerings of the new harvest. The use of insecticides to control the coffee berry borer should be carried out only when technically needed, that is when levels of borer infestation surpasses 2% during the critical period of the attack of the coffee berry borer, and at the moment that more than 50% of the flying females are still outside the coffee berries (Benavides *et al.*, 2012).

Shot hole borer, *Xylosandrus compactus* is also a serious pest of Robusta coffee which attack on tertiary twigs, young primaries and suckers. The adult female bores a hole of the size of a pin head on the lower side of a twig in the internode region and damage the shoot of the plant. Presence of shot hole is the symptom in the plants. Drooping of leaves is the initial symptom followed by withered (faster in young branches and delayed in older twigs) or dried branches. Attacked leaves fall prematurely and terminal leaves wilt, droop and dry up. In severe infestation, there is loss of considerable number of productive branches. Adult beetles are brown to black with a short, sub cylindrical body and covered with fine hairs. Females are darker and larger (1.5 to 1.8 mm), males are dull and small (0.8 to 1.0 mm).

An attempt has been made in this paper to investigate the influence of weather on coffee berry borer and shot hole borer infestation and also to develop forewarning models for predicting the damage of these pests.

2. Data and methodology

The study was conducted at Chundale, Wayanad district in Kerala, to assess the seasonal incidence and influence of weather on coffee berry borer and shot hole borer from 1977 to 2012 in Robusta coffee plantations (variety S 274) planted in 1971 at Regional Coffee Research Station, Chundale. Wayanad is a conventional coffee growing district of Kerala State. Wayanad lies between North latitude 11° 27′ and 15° 58′ and East longitude 75° 47′ and 70° 27′. The experimental field at Regional Coffee Research Station, Chundale, Wayanad is located at an altitude of 840 m above mean sea level. The annual rainfall of this area ranges between 2000-3000 mm of which 80% is the contribution of southwest monsoon and the rest from northeast monsoon. Blossom showers are received during February/March and supporting backing showers are received during March/April. This area experiences a dry spell for a period of three months from December to February with occasional rains in between. It has an average relative humidity of 88.9% and an average maximum and minimum temperature of 27.3 °C and 17.6 °C. The soil type of this station is generally lateritic to laterite. The soil structure varies from sandy to clayey loams with the soil pH varying from 5.2 to 6.3. Organic carbon content is medium and phosphorous and potassium status in soil is low to medium.

The experimental plots consist of one acre plantation and 20 plants were selected for recording pest data at fortnightly interval. Observations were made from 20 randomly selected coffee plants and in each plot. Three branches at top, middle and bottom were chosen to record the pest data. The damaged berries by coffee berry borer were collected and per cent damage was worked out. The damaged shoots were counted to workout percent damage of shot hole borer. The data on weather parameters, maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) were recorded from Agromet observatory installed in the station during the study period. The fortnightly mean of percent damage were correlated with weather parameters of corresponding fortnight and six fortnights prior to the reported infestation for 1977 to 2007.

Simple correlation coefficient (CC) between pest damage and weather parameters was worked out for fortnight when maximum infestation was observed. Student's '*t*' test (Fisher and Yates, 1938) was applied to test the significance of correlation coefficient. The fortnight's individual weather parameters having highest correlation coefficients which are statistically significant were selected. All these statistically significant parameters were subjected to multiple correlations and stepwise regression combining all the selected parameters using SPSS software, Version 15.0 (IBM, Bangalore, India) and '*F*' test was performed for testing its significance. Regression equations were developed for the fortnight with maximum infestation using the significant weather parameters having highest correlation coefficients. Statistical regression equations to predict the pest damage were developed using selected weather parameters. The regression model developed was validated for 2008, 2009, 2010, 2011 and 2012. Graphical analysis between significant weather parameters and pest damage was made.

3. Results and discussion

3.1. *Monthly/annual variation of pest damage*

The pest data for the years under study revealed that coffee berry borer attack was mainly occurred between first fortnight of January and second fortnight of March. The damage was above 1% during these months. The peak damage was observed during first and second fortnight of January which corresponds to harvest stage of coffee in Wayanad. The maximum attack was observed at first fortnight of January (Fig. 1). This insect is also found in the remaining coffee berries left on the coffee plants after harvesting and in berries fallen to the ground during the dry season. At the starting of the rainy season, the female adults initiate the flight activity and the infestation

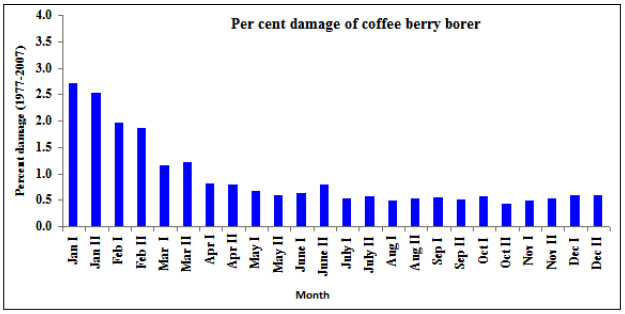


Fig. 1. Per cent damage of coffee berry border (1977-2007)

of new berries begins. When rain events occur during the dry season, coffee berry borer adults may activate its flight and die because of the lack of suitable coffee berries to be infested. On the other hand, the rain favours all those living organisms present in the soil that may affect the CBB, either eggs, larvae, pupa, or adults. Torres *et al.* (2012) reported that rain events occurred during the dry season is capable of reducing the adult female population that wait for the new harvesting season, either by stimulating the flight activity before the berries are ripen enough to be infested or by increasing the natural mortality factors due to the biological activity in the humid soil. These results may help coffee growers to foresight the population of just by knowing the precipitation charts or rainfall occurred in their area during the dry season and, entomologists may refine their strategies for controlling this pest based on IPM programs. The coffee growing areas of Niligiri District of Tamil Nadu, Wayanad District of Kerala and Kodagu District of Karnataka together form a contiguous coffee growing tract. The CBB infestation in this region had spread from the Nilgiris towards Wayanad and South Kodagu over a period of four to five years. An analysis of the nature and spread of the coffee berry borer incidence in the affected areas revealed that the build up and spread are faster in Robusta areas when compared to Arabica areas. The pest problem is acute in Wayanad and southern parts of Kodagu where Robusta is predominantly cultivated. Harvesting of Arabica coffee is generally completed by December/January. The growers bestow more care on a timely harvest of Arabica as most Arabica coffee is prepared as washed coffee. On the other hand, Robusta takes more time for ripening and so harvesting generally extends up to February/March. Since Robusta coffee is processed by drying the fruits to prepare cherry coffee, there is a general tendency to prolong the harvesting due to various reasons, especially if there is a labour shortage. This offers the berry borer a better chance to multiply faster as the berries at this stage are best suited for their multiplication. If berries are left on the plants after ripening, the number of berries falling during harvest would be more. This leads to increased residual

TABLE 1

Correlation coefficient (C.C.) between percent damage of coffee berry borer and weather parameters at RCRS, Chundale

Month	Weather parameters			
	*T*max	*T*min	RH	Rainfall
January 1st fortnight	-0.03	0.36	0.25	-0.11
December 2nd fortnight - January 1st fortnight*	0.12	0.49**	0.27	-0.01
December 1st fortnight - January 1st fortnight	0.20	0.31	0.07	0.03
November 2nd fortnight- January 1st fortnight	0.09	0.46*	0.09	0.31
November 1st fortnight - January 1st fortnight	0.31	0.34	0.14	-0.11
October 2nd fortnight- January 1st fortnight	0.06	0.29	-0.01	0.03
October 1st fortnight - January 1st fortnight	-0.02	0.34	-0.01	-0.48*

CCs significant at 5 % level*, CCs significant at 1% level**
* December 2nd fortnight - January 1st fortnight indicates that pest damage of January 1st fortnight and based on weather parameters of December 2nd fortnight

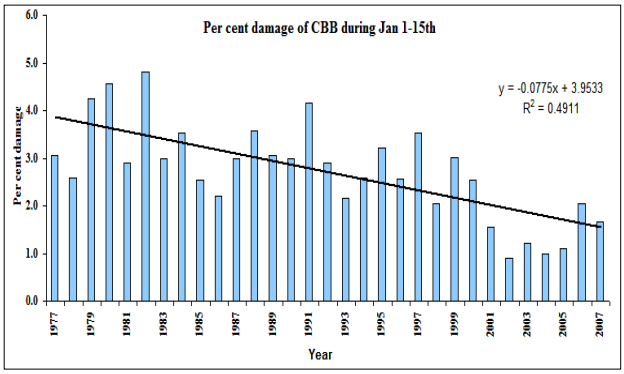


Fig. 2. Year wise damage of coffee berry border during January 1st fortnight

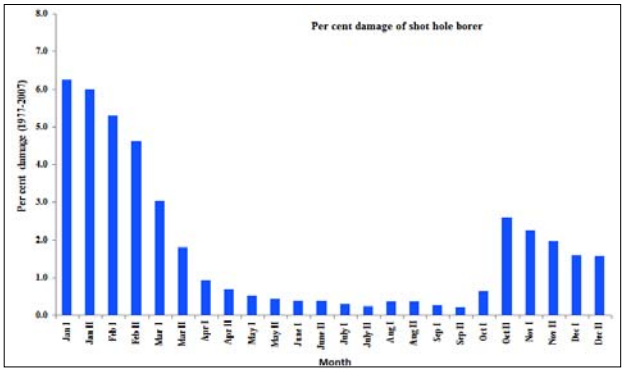


Fig. 3. Per cent damage of shot hole border (1977-2007)

populations of the pest in the fallen berries (gleanings). Furthermore, berries leftover on tall branches of big Robusta bushes can also provide a refuge for the CBB. Maximum pest damage during individual years showed

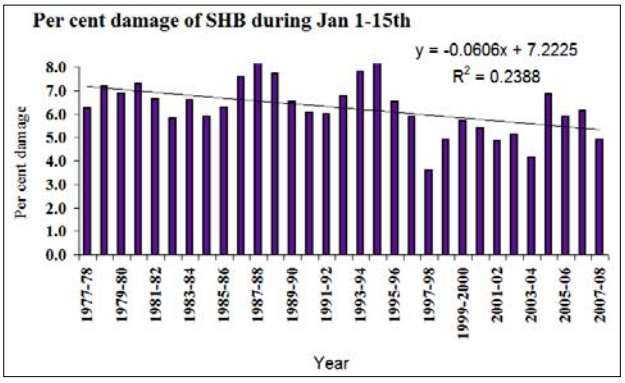
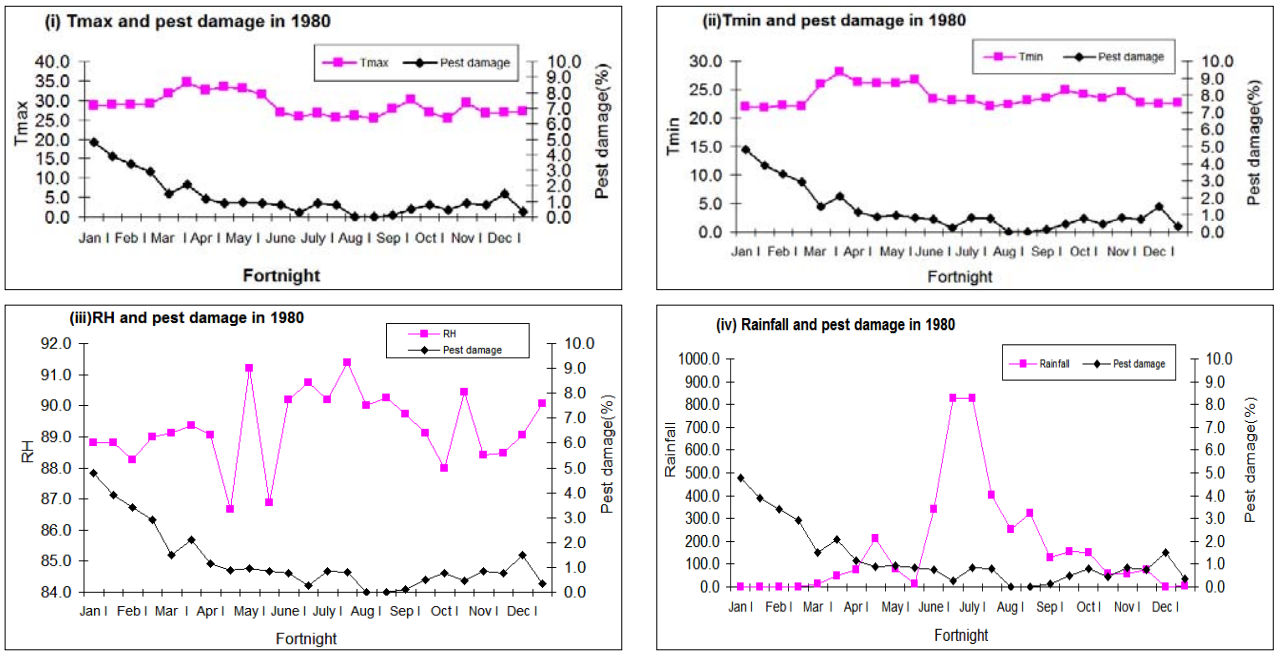


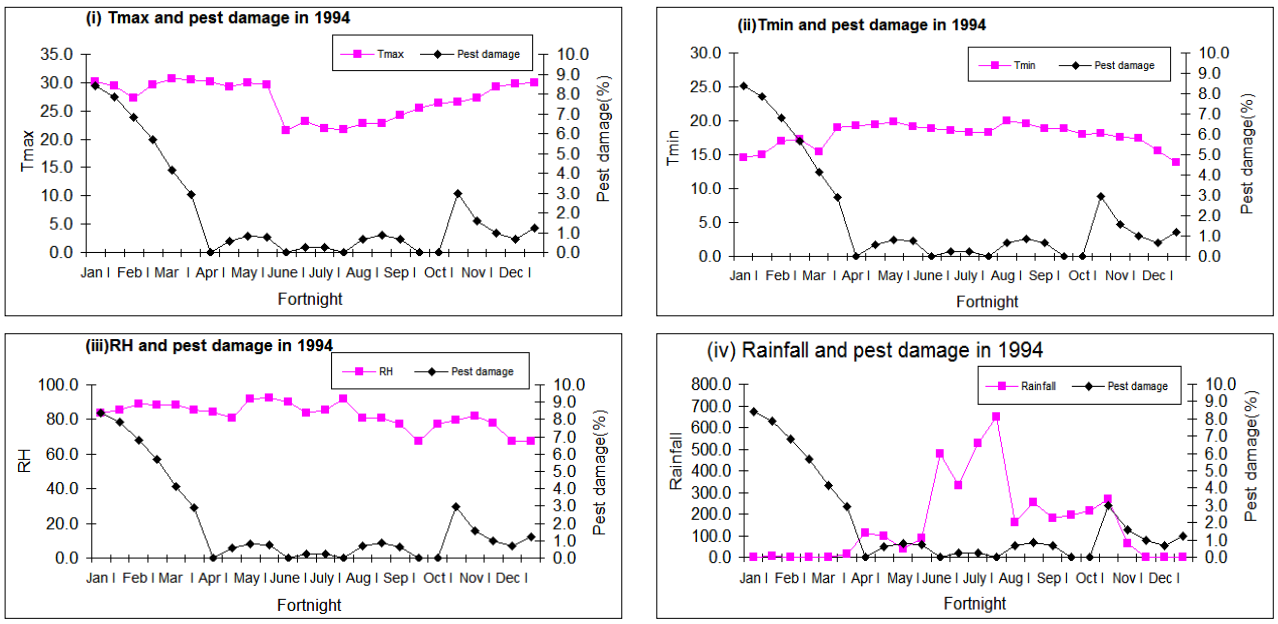
Fig. 4. Year wise damage of shot hole border during January 1st fortnight

considerable variations (Fig. 2) as a result of weather variations / aberrations. In all the years, the damage was below 5%. Maximum damage of CBB (4.8%) was recorded in 1982 followed by 4.56% in 1980, 4.25% in 1979 and 4.16% in 1991. Minimum damage was recorded in 2002 (0.9%). Graphical analysis of weather parameters and CBB during 2nd maximum damage year (1980) was made due to missing weather data during maximum damage year (1982).

Damage of shot hole borer was observed during January to April and October to December and peak damage of the pest was observed during first fortnight of January. The maximum attack was observed during first fortnight of January followed by 2nd fortnight of January (Fig. 3) which corresponds to budding stage of coffee in Wayanad. Maximum damage of SHB during first fortnight of January was 8.4% recorded in 1994 followed by 8.25% in 1986, 7.8% in 1993 and minimum population of 3.6% was recorded in 1997 (Fig. 4).



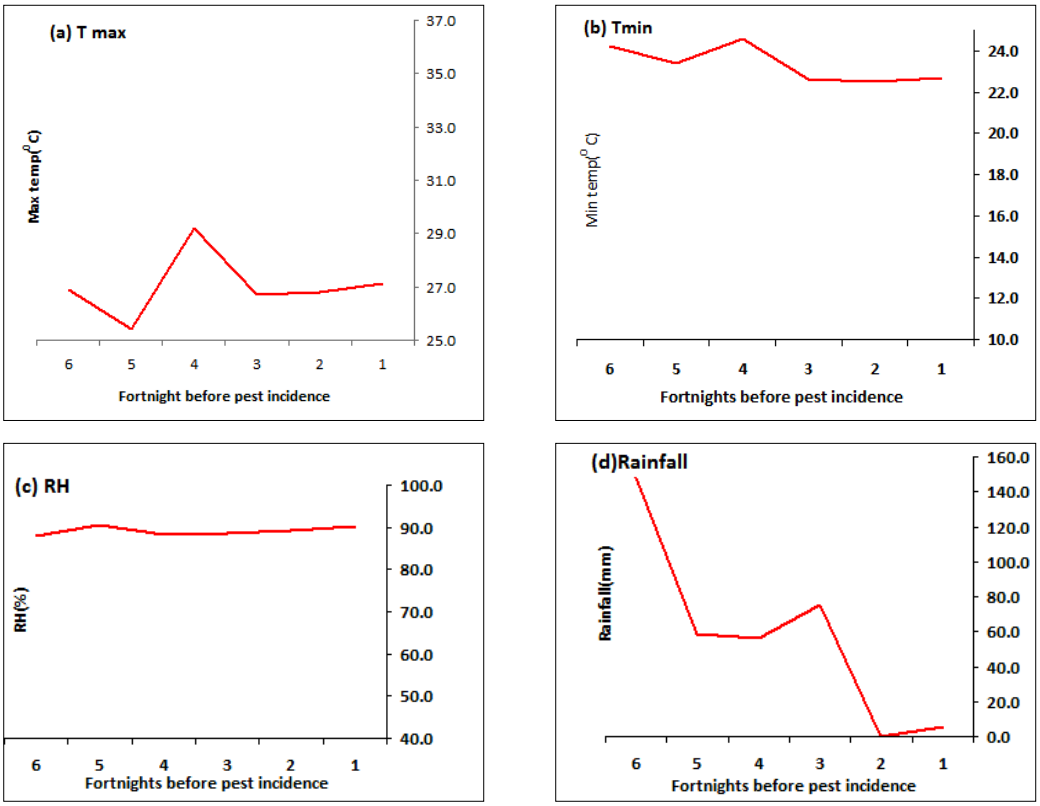
Figs. 5a(i-iv). Variation of weather parameters and coffee berry border damage during 1980 (year of 2nd maximum damage)



Figs. 5b(i-iv). Variation of weather parameters and shot hole border damage during 1994 (year of maximum damage)

3.2. *Correlation with weather parameters*

Correlation coefficients were worked out between fortnightly damage of CBB and different weather parameters (Table 1). Correlation studies indicated that different weather parameters influenced the pest damage differently. In the present study, damage of CBB during first fortnight of January was found to have highest significant positive correlation with minimum temperature during 2nd fortnight of December. Rainfall during first fortnight of October had highest significant negative correlation with pest damage during first fortnight of January. Maximum temperature and relative humidity was not significantly correlated with CBB incidence.



Figs. 6(a-d). Variation of different weather parameters in the fortnights before incidence of coffee berry border and shot hole borer

Maximum temperature during first fortnight of January had highest positive correlation with shot hole borer damage of the same fortnight.

3.2.1. *Correlation with maximum temperature (Tmax)*

Maximum temperature (*T*max) was not significantly correlated with CBB incidence. *T*max during first fortnight of November had highest correlation with CBB damage of first fortnight of January but the correlation was not statistically significant. Positive correlation of CBB with temperature was observed with climatic data from Colombia, Kenya, Tanzania, and Ethiopia by Jaramillo *et al.* (2009). Maximum temperature during first fortnight of January and 2nd fortnight of December had significant correlation with SHB damage with correlation coefficients of 0.71 and 0.42 respectively.

3.2.2. *Correlation with minimum temperature (Tmin)*

During all the six fortnights, *i.e.*, first fortnight of October to first fortnight of January, minimum temperature (*T*min) showed positive correlation with CBB damage of first fortnight of January. Significant correlations were noticed for minimum temperature of 2nd fortnight of November (0.46) and 2nd fortnight of December (0.49). Rising minimum temperature has significantly increased infestation of coffee berry borer in the sun-grown coffee plantation (Jaramillo *et al.*, 2013). Minimum temperature has no significant correlation with shot hole borer damage during first fortnight of January. Relative humidity (RH) was not significantly correlated with CBB incidence but the highest correlation was found between RH during 2nd fortnight of December and pest damage during first fortnight of January. RH has no significant correlation with shot hole borer damage of first fortnight of January.

3.2.3. *Correlation with rainfall (RF)*

Rainfall during first fortnight of October showed highest negative correlation (-0.48) with pest damage of CBB at first fortnight of January. Rehiman and Vijayalakshmi (1998) have reported that rains cause mortality of the beetle. Further, Vijayalakshmi (2000) reported that the coffee berry borer infestation had a significant negative correlation with rainfall. Irulandi *et al.* (2007) also reported negative ccorrelation between rainfall

TABLE 2

Correlation coefficient (C.C.) between per cent damage of shot hole borer and weather parameters at RCRS, Chundale

Month	Weather parameters			
	*T*max	*T*min	RH	Rainfall
January 1st fortnight	0.71**	0.24	0.17	-0.25
December 2nd fortnight - January 1st fortnight *	0.42	0.19	-0.26	0.02
December 1st fortnight - January 1st fortnight	0.32	0.25	-0.32	0.05
November 2nd fortnight- January 1st fortnight	0.33	0.30	0.02	-0.04
November 1st fortnight - January 1st fortnight	-0.06	0.25	0.22	0.16
October 2nd fortnight- January 1st fortnight	0.10	0.25	-0.09	-0.02
October 1st fortnight - January 1st fortnight	0.05	0.21	-0.16	-0.12

CCs significant at 5% level*, CCs significant at 1% level**
* December 2nd fortnight - January 1st fortnight indicates that pest damage of January 1st fortnight and based on weather parameters of December 2nd fortnight.

and infestation of coffee berry borer. Rainfall has no significant correlation with shot hole borer damage of first fortnight of January.

3.3. *Favourable weather for development of pests*

A critical examination of various weather parameters during previous fortnights [Figs. 5(a) & Figs. 6 (a-d)] showed that CBB damage increases substantially when the maximum temperature was above 27.1 °C and minimum temperature was above 22.7 °C and rainfall below 5.6 mm. Jaramillo *et al.* (2009) reported lower threshold values of temperature, lower optimal temperature, upper optimal temperature and upper threshold temperature for population growth of CBB are 14.9 °C, 23 °C, 30 °C and 32 °C, respectively. These critical limits of weather variables were mostly prevailed in 2nd maximum damage year 1980 [Fig. 5(a)]. The maximum temperature and minimum temperature during previous four fortnights showed increasing trend towards the 2nd maximum infestation week during first fortnight of January in 1980. Rainfall showed decreasing trend towards the first fortnight of January during 1980. Shot hole borer damage increases substantially when maximum temperature was above 27.1°C and minimum temperature above 22.7 °C [Figs. 5(b) & Figs. 6(a-d)]. These critical limits of weather variables were mostly prevailed in maximum population year 1994 [Figs. 6(a-d)].

3.4. *Forewarning model*

The highest correlation coefficient between the CBB damage at first fortnight of January and fortnightly mean of weather parameters were noticed with minimum temperature during 2nd fortnight of December and rainfall during first fortnight of October. Maximum temperature during first fortnight of January was highly correlated with shot hole borer incidence of first fortnight of January.

The values of the correlation coefficients for different weather parameters along with their significance at different levels are given in Table 1. The multiple regression equation which describes the average relationship between the CBB damage and significant weather parameters obtained by step wise regression is expressed below:

$$Y = -0.011 + 0.151\ T\text{min\_Dec.II}\ (R^2 = 0.24)$$

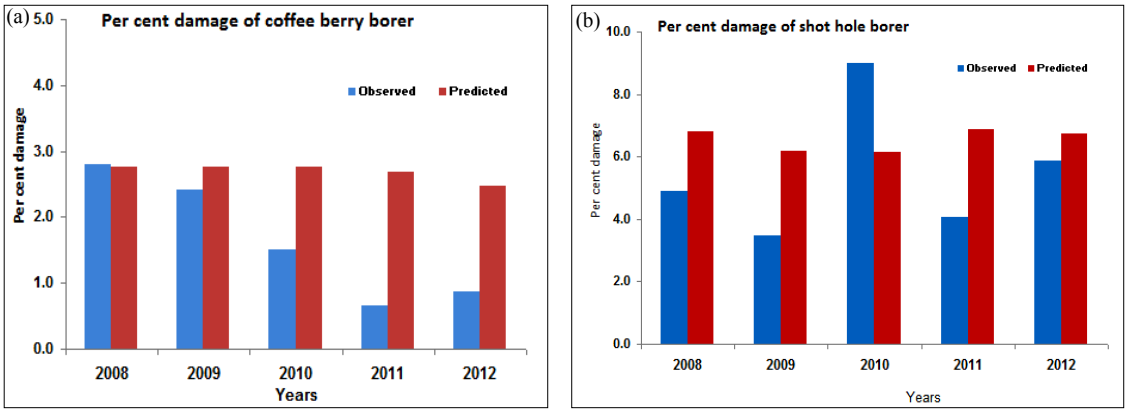
Y = CBB damage (%) during first fortnight of January. The multiple correlation coefficient was 0.48 which was significant.

The multiple regression equation which describes the average relationship between the SHB damage and significant weather parameters obtained by stepwise regression is expressed below:

$$Y = -7.624 + 0.479\ T\text{max\_Jan.I}\ (R^2 = 0.52)$$

Y = SHB damage (%) during first fortnight of January. The multiple correlation coefficient was 0.72 which was significant.

The multiple regression models developed for predicting the damage of coffee at Chundale were validated using real time weather parameters



Figs. 7(a&b). Observed and predicted damage of (a) CBB and (b) shot hole borer

for 2008, 2009, 2010, 2011 and 2012. Observed and predicted values of percent damage coffee are presented in Figs. 7(a&b). Validated results showed that less than 10% deviation during 2008 in coffee berry borer. During 2009 to 2012, deviation is more than 10% due to exceptionally low per cent damage during these years and trend analysis (Fig. 2) also showed decreasing trend of damage due to coffee berry borer.

4. Conclusions

(*i*) The maximum activity and damage due to high population of coffee berry borer and shot hole borer at Chundale was observed during first fortnight of January.

(*ii*) Minimum temperature was positively correlated with coffee berry borer incidence and rainfall was negatively correlated. Minimum temperature above 22.7 °C were found favourable for high incidence at Chundale in Wayanad coffee region of Kerala.

(*iii*) Maximum temperature was positively correlated with shot hole borer incidence. Maximum temperature above 27.1 °C were found congenial for development of high incidence of shot hole borer.

References

Benavides, P., Góngora, C. and Bustillo, A., 2012, "IPM program to control coffee berry borer *Hypothenemus hampei*, with emphasis on highly pathogenic mixed strains of *Beauveria bassiana*, to overcome insecticide resistance in Colombia", Insecticides - Advances in Integrated Pest Management, Perveen, F. (Ed.), ISBN: 978-953-307-780-2

Fisher, R. A. and Yates, F., 1938, "Statistical tables for biological, agricultural and medical research", Oliver and Boyd, London, W.C.

Fujioka, K. and Shibamoto, T., 2008, "Chlorogenic acid and caffeine contents in various commercial brewed coffees", *Food Chemistry*, **106**, 217-221.

Irulandi, S., Rajendran, R., Chinniah, C. and Samuel, S. D., 2007, "Influence of weather factors on the incidence of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Scolytidae: Coleoptera) in Pulney hills, Tamil Nadu", *The Madras Agricultural Journal*, **94**, 218-231.

Jaramillo, J., Chabi-Olaye, A., Kamonjo, C., Jaramillo, A., Poehling, V. H. F. E. and Borgemeister, C., 2009, "Thermal tolerance of the coffee berry borer *Hypothenemus hampei*: Predictions of climate change impact on a tropical insect pest", *PLoS ONE*, **4**, 8, e6487, doi:10.1371/journal.pone.0006487.

Jaramillo, J., Setamou, M., Muchugu, E., Chabi-Olaye, A., Jaramillo, A., Mukabana, J., Maina, J., Gathara, S. and Borgemeister, C., 2013, "Climate Change or Urbanization? Impacts on a traditional coffee production system in East Africa over the last 80 Years", *PLoS One*, **8**: e51815.

Rehiman, P. A. and Vijayalakshmi, C. K., 1998, "Effect of hot and cold water treatment on the mortality of coffee berry borer, *Hypothenemus hampei* (F)", *Planters Chronicle*, **93**, p87.

Torres, A. N., Lozada, B., Acevedo, Y., Zambrano, M.E., Bautista, I., Camacho, W. and España, S., 2012, "Rain effect on coffee berry borer mortality present in berries fallen to the ground at the Bramón Experimental Station in Táchira, Venezuela", Programme and abstracts, 24th International conference on coffee science, November 11-16, 2012, ASIC Costa rica, p300.

Vega, F. E., Infante, F., Castillo, A. and Jaramillo, J., 2009, "The coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae): A short review, with recent findings and future research directions", *Terrestrial Arthropod Review*, **2**, 129-147.

Vijayalakshmi, C. K., 2000, "Bioecology and control of the coffee berry borer, *Hypothenemus hampei* F. (Coleoptera: Scolytidae) in India", Ph.D. Thesis, Mysore University, Mysore, p162.