Original Research Article

Emergence and incidence of coffee white stemborer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae), under different rainfall regimes across the coffee-growing regions of Karnataka, India

ABSTRACT

. The coffee white stem borer (CWSB), *Xyloterchus quadripes* (Chevrolat) (Coleoptera: Cerambycidae) is one of the most destructive pests of arabica coffee in India. As coffee cultivation in India is mostly confined to the hilly tracts of the Western Ghats of the southern states and it is mainly grown in Kodagu, Chikmagalur and Hassan districts of Karnataka with varying rainfall patterns ranging from more than 3000 mm to less than 1000 mm. The study of the incidence of WSB and emergence of adults in relation to local weather conditions in the estates at different rainfall patterns in Karnataka [High(<2500mm), Medium(2000 to 1000mm) and low(<1000mm) rainfall areas] for two years (2016 and 2017). The emergence data and local weather parameters viz rainfall, relative humidity and temperature were correlated with adult emergence. The results indicated that the emergence of CWSB during the years 2016 and 2017 exhibited a significant positive correlation with maximum temperature and minimum temperature. While beetle emergence was negatively correlated with the quantity of rainfall and relative humidity across the six locations. From these observations, it is evident that the beetles required a higher temperature for their emergence and peak beetle emergence occurred during the middle of November in the winter flight season and during the end of April and the first fortnight of May in the summer flight periods. The coffee plantations were surveyed in all the rainfall regimes to know the effect of rainfall. During the year 2017-18 The per cent incidence was 10.81 at rainfall <1000, 7.67 at medium rainfall and 6.16 at high rainfall areas and was non-significant across rainfall regimes.

Keywords: White Stem Borer, *Xyloterchus quadripes,* Emergence pattern, flight period, Climate change

1. Introduction :

Coffee is an introduced crop into India from Africa. Arabica (*Coffea arabica*) and Robusta (*Coffea canefora*) are the two commercially grown coffee species in India. As coffee cultivation in India is mostly confined to the hilly tracts of the Western Ghats of the southern states viz., Karnataka, Kerala and Tamil Nadu. It is also grown to a small extent in Andrapradesh and some North Eastern states. Whereas 70 per cent of coffee is produced in Karnataka state. Coffee belt of Karnataka includes parts of three districts - Kodagu, Chickmagalore and Hassan (1).

The coffee white stem borer (CWSB), *Xyloterchus quadripes* (Chevrolat) (Coleoptera: Cerambycidae) is one of the most destructive pests of arabica coffee plants in all coffee growing areas of India. While robusta coffee is free from CWSB attack (4). The coffee white stem borer (CWSB), is a major pest in Arabica coffee plantations in India, Thailand, Sri Lanka, Vietnam and China (6, 9, 16).

Studies on the emergence (flight) pattern of *X. quadripes* have shown that the adult beetles have two flight periods in a year *viz*., April to May and October to November (10,14). There is also mention that the premonsoon flight begins in April and extends to the end of May and the post-monsoon flights begin by the end of September and extend to the end of December or the middle of January (5, 11). Whereas in Vietnam recorded the greatest number of beetles emergence in May, June and July when the temperature was highest but smaller numbers also appeared in February to March and November to December (2). With the change in weather conditions in recent years, the emergence pattern has been varying but limited information is available on the influence of weather factors on adult emergence from different regions of coffee growing tracts in India (15). By considering the above views, the present study on the emergence pattern of *X. quadripes* in relation to weather in different climatic regions was carried out.

2. Materials and methods:

2.1 Emergence pattern under different rainfall regimes

The study on the emergence of CWSB at the different rainfall patterns in coffee growing regions in Karnataka *viz.*, High (> 2000 mm), Medium (1000-2000 mm) and low rainfall areas (< 1000 mm) was done for two years *i.e*., 2016 and 2017. Two estates for each rainfall

regime were selected with a total of six Arabica coffee estates. The details of estates selected for the study of emergence patterns was provided in table 1. In each location, 50 coffee plants that are infested by *X. quadripes* were identified and covered with nylon mesh to trap adult beetles that emerged in the field (Plate 1). The infested plants are identified based on visible symptoms on the plants with bulged rings on the stem, and small and yellow leaves, such infested plants are checked for emergence holes and confirmed that the beetle was not emerged out from the plant without exit holes. Then the infested plants without emergence holes were caged well before the start of the flight period *i.e.*, during summer first week of March retained up to August and during winter during the first week of September and retained up to February or until complete cessation of adult emergence and after infested plants are exhausted after each flight season the fresh infested plant was searched and such plants are newly caged in next season as mentioned above. Observations on the number of beetles emerged in each caged plant at each location at weekly intervals for two years. Along with the adult emergence weather parameters *viz.*, maximum and minimum temperature (° C), morning and evening relative humidity (%), total rainfall (mm), and sunshine hours (hrs) were collected from the nearest weather stations and these weather parameters were correlated with adult emergence of specific location and season (3).

Plate 1. Caging of borer-infested plants in fields for monitoring adult emergence

2.2 Survey of *Xylotrechus quadripes* incidence on Arabica coffee at different rainfall regimes:

A random survey was carried out to know the level of infestation and incidence of CWSB in different rainfall regimes in coffee-growing areas of Chikmagalur, Hassan and Kodagu districts from 2016 to 2017. Randomly 10 estates were selected for each rainfall regime low *viz*., (<1000mm), medium (1000 to 2000mm) and high rainfall areas (>2000mm). The data

was collected on the number of infested plants and total number of plants per acre and incidence of borer before flight season and per cent incidence was worked out (3).

Table 1: Details of the estates selected for studying the emergence pattern of CWSB.

Sl no.	Rainfall Regimes	Estate name	Place, Taluk and District	Avg. Annual Rainfall (mm)
1	High rainfall coffee growing region (>2000mm)	CCRI, farm	Balehonnur,Koppa, Chikamagalur	2600
		Glibert Estate	Javali, Kalasa, Chikamagalur	2800
2	Medium rainfall region (1000-2000mm)	CRSS, Farm	Chettalii,Somavarpete, Kodagu	1600
		Brudhavan Estate	Mudigere, Chikamagalur	1500
3	Low Rainfall region (<1000)	Koppagodu Estate	Beluru, Hassan	800
		Mansinamakki Eatate, Blupete	Balupet, Salkespura,Hassan	800-1000

3. RESULTS AND DISCUSSION

Comment [Tm1]: Always separate results and discussion

Adult emergence for a specific location is correlated with the respective weather parameters. The weather parameters are correlated in correspondence to the summer and winter flight of beetle, (table 2), the emergence showed significant correlation in several variables. In high rainfall regime of >2000mm, maximum temperature and the minimum temperature had a significant positive correlation with adult emergence (r = 0.48 and r = 0.69 respectively). During the winter flight, maximum temperature and sunshine hours had a significant positive correlation with adult emergence (r = 0.60 and r= 0.80, respectively), whereas, rainfall, morning relative humidity, evening relative humidity and the minimum

temperature had a significant negative correlation with the emergence (r = -0.82, r = -0.82, r=-0.75 and r = -0.48, respectively).

The multiple linear regression analysis between abiotic factors and the emergence of adult beetles (Table 3) indicated that all the weather parameters together influenced the adult emergence to the extent of 71 per cent during the summer and 89 per cent (R^2 values) during the winter for locations of high rainfall regions (average annual rainfall >2000mm).

In medium rainfall regions (1000 to 2000mm) annual rainfall was correlated with maximum temperature, minimum temperature had significant positive correlation (r = 0.70 and r = 0.73 respectively). Whereas the other parameters *Viz.*, sunshine hours, rainfall, morning relative humidity and evening relative humidity were non-significant. However, during winter flights, the emergence of adults had a significant positive correlation with maximum temperature (r=0.83) and sunshine hours (r=0.62). The beetle emergence was significantly negatively correlated between rainfall (r =-0.749), morning relative humidity (r=-0.594) and evening relative humidity. The multiple linear regression analysis between abiotic factors and the emergence of adult beetles (Table 3) indicated that all the weather parameters together influenced the adult emergence to the extent of 72 per cent during the summer season and 92 per cent (R^2 values) during the winter season for locations of medium rainfall regions of (1000 to 2000mm).

In low rainfall regions (<1000mm), maximum temperature (r=0.342) and minimum temperature (r=0.58) correlated significantly positive while others had a non-significant influence on adult emergence. With respect to the winter season, minimum temperature had a significant positive correlation with adult emergence (r =0.471), whereas, rainfall, morning relative humidity, evening relative humidity and the maximum temperature had a non-significant negative correlation with the emergence (r= -0.402, r = -0.19, r=-0.217 and r = -0.258 respectively). The multiple linear regression analysis between abiotic factors and the emergence of adult beetles (Table 3) indicated that all the weather parameters together influenced the adult emergence to the extent of 66 per cent during the summer season and 68 per cent (R^2 values) during the winter season for locations in low rainfall regions (<1000mm).

Similar findings were also reported by Sylesh (12) that, When the emergence of beetle was correlated with weather parameters prevailing during the particular season revealed a

positive significant correlation with minimum temperature, humidity and sunshine hours. The result indicated that sunshine hours and temperature may have an intrinsic influence on the growth and emergence of CWSB beetles. Reddy (7) showed that the emergence of CWSB during the summer flight exhibited a significant positive correlation with maximum temperature and sunshine hours. While, during winter flight in contrast there was a significant negative correlation between beetle emergence and rainfall and minimum relative humidity and Reddy and Bhat (8) reported that, the beetles required bright sunshine for the emergence.

3.1 Incidence of coffee white stemborer

The incidence of CWSB ranged from 1.50 to 16.00 per cent among the coffee plantations surveyed in all the rainfall regimes. During the year 2017-18 the lowest incidence (5.12 %) was recorded in high rainfall estates were on par with the medium rainfall estates (7.12 %) while, the highest incidence was recorded in low rainfall estates (10.42%). Similarly during 2018 per cent infestation was 7.2, 8.23 and 10.81 levels in low, medium and high rainfall areas, respectively, and were non-significant with each other. The per cent incidence was 10.81 at rainfall <1000, 7.67 at medium rainfall and 6.16 at high rainfall areas and was non-significant across rainfall regimes (Table 4). In the survey conducted on the incidence of CWSB, all rainfall regimes ranged from 1.50 to 16.00 per. The mean per cent incidence was highest at rainfall <1000mm coffee growing regions, whereas in the estates of high and medium rainfall areas per cent incidence was found moderate.

Similarly, the survey done by Reddy (7) recorded the incidence of CWSB ranged from 1.50 to 8.00 per cent and the mean per cent incidence was 4.39 among the coffee plantations surveyed in Mudigere taluk of Chikmagalur, District. In case of variation in the range of infestation in all three regimes found low to very high which was mainly because of the management practices adopted and the level of shade maintained in the estate. YouSheng et al (17) reported the percentage of affected trees is usually 2% to 5%, and in some years may be high as 10% to 25% depending on weather factors. Measures of integrated management of the pest are suggested and have proved effective, the percentage of local affected trees reduced from 5% to 10.5% to 1.5% to 3.3%. However, Sreedharan and Vinod Kumar (13) mentioned the key issues and reasons for the variation in CWSB infestation between different plantations, *Viz*., the expertise availability for borer tracing, uprooting and burning in different plantations varies due to non-availability of labour and most of the growers do not

have irrigation facilities during summer months which cause severe water stress and coffee plants become weak and later become susceptible for CWSB infestation, as beetle lays more eggs on stressed plants. Hence, the variation in the infestation levels was observed between plantations and also in different rainfall regimes.

Table 2: Correlation analysis between weather parameters and the emergence of CWSB adults from infested plants during different flight seasons 2017 -18

Sl no.	Rainfall Region	Year /Flight season	Rainfall (mm)	RH (%)Morning	RH (%) Evening	Temp. Max. (°C)	Temp Min. (°C)	Sunshine (hrs)
1	> 2000mm	2016-17	-0.28	--	0.004	0.250	0.260	0.302*
	1000-2000mm		-0.182	-0.0009	-0.006	0.385*	0.027	0.16
	<1000mm		-0.154	-0.396*	-0.052	-0.109	-0.183	-0.15
2	> 2000mm	Summer	-0.187	-0.175	-0.201	0.480*	0.695*	0.178
		Winter	-0.829*	-0.82*	-0.752*	0.604*	-0.48*	0.80*
	1000-2000mm	Summer	-0.229	-0.215	-0.183	0.704*	0.735*	0.284
		Winter	-0.749*	-0.594*	-0.786*	0.83*	-0.19	0.62*
	<1000mm	Summer	-0.189	-0.409*	0.047	0.342	0.58*	-
		Winter	-0.402	-0.19	-0.217	-0.258	0.471*	-

* Significant at 5%,

Table 3: Multiple regression analysis between weather parameters and the emergence of CWSB adults from infested plants during different flight periods 2016-17

Sl No.	Rainfall Region	Flight season	Regression Equation	R^2
1	> 2000mm	Summer	y= -63.67-0.011RF+0.159RH+1.059Tmax+1.40Tmin -0.745SS	0.71
		Winter	y =27.08-0.03RF-0.25RHmorng-0.03RHevn-0.45Tmax+0.53Tmin+1.89SS	0.89
2	1000-2000mm	Summer	y = -73.13-0.002RFmm+ 0.0.044RH max + 1.84T Max + 1.06Tmin-0.609SS	0.72
		Winter	y= 27.73+0.35RF-0.32RHmorng-0.76RHeveng+3.11Tmax-1.18Tmin-0.17SS	0.92
3	<1000mm	Summer	y = -20.2067- 0.013RF - 0.404RH max + 0.194RH min + 1.01Tmax + 1.10Tmin	0.66
		Winter	y = 35.87-0.06RF-0.50RHmorng-0.07RHmin-0.77Tmax+2.16Tmin	0.68

Comment [Tm2]: Replace summer, winter by the universal terms, rainy season, dry season or put the months of the year(June-July)

Table 4: Analysis of CWSB infestation level in estates of the coffee growing region under different rainfall regimes

Comment [Tm3]: Theses informations would be interesting by presenting them in graphs

Annual Rainfall (mm)	Average infestation of CWSB per ha				Rainfall Correlation
	2017	2018	Mean	Range	
<1000	10.42 (18.48)^{bc}	11.19 (19.17)^{a}	10.81 (18.83)^{a}	2.5-16.00	-0.42
1000-	7.12 (15.44)^{ab}	8.23 (16.67)^{a}	7.67 (16.08)^{a}	2-14.5	

2000					
>2000	5.12 (10.33)[a]	7.20 (13.02)[a]	6.16 (14.37)[a]	1.5 -15	
SEm±	1.36	1.50	1.48		
CD	3.93	NS	NS		

(n=30)

Note: Means followed by the same letter do not differ significantly at *P = 0.05* according to DMRT.

Figures in the parentheses are arc sine transformed values

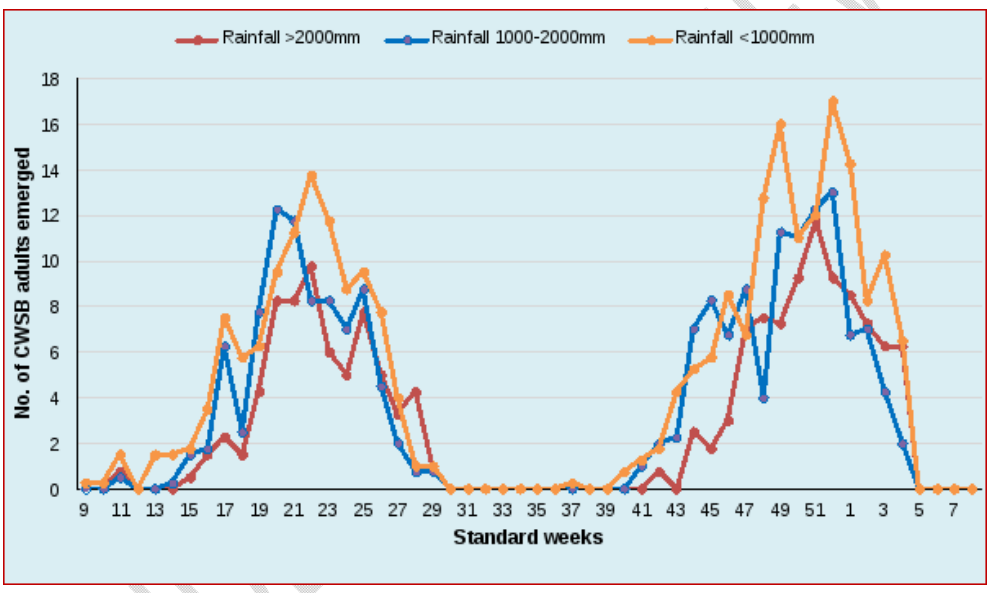

Fig. 1: Emergence of CWSB adult beetles from infested caged plants in different rainfall regions of coffee growing areas of Karnataka locations 2017 -18

Comment [Tm4]: Please add the trend for the insect studied and not put rainfall only, please add two graphs for rainfall, temperature, relative humidity, number of rainy days against the emergency of the borer insect

4. Conclusion

The emergence pattern over the three different rainfall regimes of coffee growing regions of Karnataka for two years indicated that irrespective of rainfall regimes there is a presence of two distinct flight periods in a year ie., one during April - May (summer flight) and another during October to November (winter flight) (fig-1). The total number of beetles and number of beetles that emerged per plant at locations was comparatively higher in low rainfall regions than that medium and high rainfall. The relationship between CWSB adult

emergence and weather conditions that prevailed during the study indicated that at all the different rainfall regimes the adult emergence showed a significant positive correlation with sunshine hours, maximum and minimum temperature and negatively correlated with rainfall and relative humidity. The observations made on CWSB incidence during the survey indicated maximum incidence in low rainfall areas as compared to other medium and high rainfall areas and the incidence of CWSB in all rainfall regimes ranged from 1.50 to 16.00 per cent among the coffee plantations surveyed in all the rainfall regimes.

Comment [Tm5]: Add in the discussion information about climate change, climate variability and phenology of coffee flowering, climate change impacts on coffee pollination services at different altitude, climate change effect on biocontrol of different pests and diseases in various regions in the tropics

COMPETING INTERESTS

This is to declare that the authors have no conflict of interest in the publication of this manuscript or research data. Hence, this paper may be considered for possible publication in your esteemed journal.

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Comment [Tm6]: Please add recent papers(2010-2022), they are many

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