Short Communication

Influence of abiotic factors on coffee leaf rust disease caused by the fungus *Hemileia vastatrix* Berk. & Br. under changing climate

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Coffee being a perennial crop, harbours pathogens on all parts of the plant continuously and the intensity of diseases increase under favourable conditions. Coffee leaf rust (CLR) caused by the fungus *Hemileia vastatrix* Berk. & Br. is one among the most important diseases affecting coffee all over the world. *Coffea arabica* L. is well known to be highly susceptible to leaf rust (Wellman, 1953; Waller, 1982). The infection leads to foliage and berries loss up to up to 50 and 70% respectively (Sudhakar *et al.,* 2014). Under favourable conditions, the disease appears after the blossom showers in March/April. Foliage present at that period is mostly of the previous season and the fungus remains dormant on these infected leaves during the dry weather from December to February and sporulates to form fresh uredospores after the blossom showers (Muthappa et al., 1989). After the receipt of blossom showers, a new cycle of vegetative growth starts. If the younger flush (young leaves) is not protected during the month of May, the disease makes a steady progress and infects 50% or more foliage by September. Abiotic factors play a key role in determining the incidence and severity of the disease. Cloudy and continuous South-West monsoon weather (from June to September) favours the spread and development of *H. vastatrix*.

Weather factors influence all stages of host and pathogen life cycles as well as the development of diseases (Ghini *et al.,* 2008, Gupta *et al.,* 2017)). Relationships between weather variables and disease are routinely used for forecasting and managing epidemics and disease severity over a number of years and can fluctuate according to weather fluctuations (Lopez *et al.,* 2012). The weather elements *viz.,* temperature, rainfall and relative humidity influence on the incidence of CLR. The intermittent rainfall and duration of leaf wetness play important role in growth and infection of the CLR fungus. Intensity of CLR epidemics is on the increase in recent years at many coffee growing countries like Colombia, Central America, Mexico, Peru and Ecuador (Avelino *et al.,* 2015).

To understand the influence of weather variables on CLR incidence, the present study was conducted at Central Coffee Research Institute (CCRI), Coffee Research Station, Chikkamagaluru District, Karnataka, India. The leaf rust susceptible arabica coffee selection Sln.3 was used as control over interspecific *arabica* hybrid Sln.5B and *robusta* cultivar C×R. The observations on the incidence of CLR were recorded at regular fortnight intervals from *Coffea arabica* L cultivars Sln.3 & Sln.5B and *C. canephora* cultivar C×R at CCRI farm during 2015-16, 2016-17, 2017-18 and 2018-19 seasons (Table 1). The weather data *viz.*, maximum temperature, minimum temperature, relative humidity and quantum of rainfall received were recorded from meteorological observatory located at CCRI (Table 2). The data on incidence of leaf rust was correlated with the weather parameters and subjected to regression analysis by using MS-Excel software (Table 3).

Behaviour of CLR pathogen during 2015-16

From the Table 3, it is evident that in *arabica* cultivar Sln.3 the CLR incidence is positively correlated with minimum temperature and relative humidity and is negatively correlated with maximum temperature and cumulative rainfall. Whereas, CLR incidence of Sln.5B is negatively correlated with maximum temperature, minimum temperature and relative humidity and is positively correlated with cumulative rainfall. However, CLR incidence of C×R is positively correlated with maximum temperature, minimum temperature and cumulative rainfall and is negatively correlated with relative humidity.

The coefficient of determinative value (R^2) was found to be 84 per cent in Sln.5B. There was variation in the leaf rust incidence which was accounted by the linear functions of the independent variables such as maximum & minimum temperature, relative humidity & cumulative rainfall and CLR incidence.

$Y = -9.48-0.51X_1-0.22X_2-0.03X_3+0.00X_4$

Where,

Y: Dependent variable coffee leaf rust incidence; X_1 : Maximum temperature; X_2 : Minimum temperature; X_3: Relative humidity; X_4: Cumulative rainfall

Behaviour of CLR pathogen during 2016-17

In *arabica* cultivar Sln.3 the CLR incidence was positively correlated with maximum temperature and negatively correlated with minimum temperature, relative humidity and cumulative rainfall. Whereas, CLR incidence of Sln. 5B positively correlated with maximum temperature and cumulative rainfall, negatively correlated with minimum temperature and relative humidity. However, CLR incidence of CxR is negatively correlated with maximum temperature and minimum temperature and is positively correlated with relative humidity and cumulative rain fall. The coefficient of determinative value (R^2) was found to be 93 per cent in Sln.3. The regression equation is

$Y = 233.56-0.57X_1-6.69X_2-0.88X_3-0.06X_4$

Behaviour of CLR pathogen during 2017-18

From the Table 3 it is clear that, in arabica cultivar Sln.3 the CLR incidence is negatively correlated with maximum temperature, minimum temperature, relative humidity and is positively correlated with cumulative rainfall. Whereas, in Sln. 5B the rust incidence is positively correlated with maximum temperature, relative humidity, rainfall and negatively correlated with minimum temperature. However, in CxR CLR incidence is negatively correlated with maximum temperature and minimum temperature and is positively correlated with relative humidity and cumulative rain fall.

The coefficient of determinative value (R^2) was found to be 91 per cent in Sln. 5B. The regression equation is

$Y= 45.12+1.03X_1-4.13X_2+0.06X_3+0.00X_4$

Behaviour of CLR pathogen during 2018-19

From the Table 3 it is clear that in arabica cultivars Sln.3 and Sln.5B, the coffee leaf rust incidence is negatively correlated with minimum temperature and relative humidity and is positively correlated with maximum temperature and cumulative rainfall. The coefficient of determinative value (R^2) was found to be 90 per cent in Sln.3 and 87 per cent in Sln. 5B.

$Y= 117.92-0.82X_1-0.09X_2-1.11X_3+0.00X_4$ Sln.3

$Y= 89.84-0.68X_1-0.88X_2-0.62X_3+0.00X_4$ Sln.5B

CLR epidemics were almost always associated with rainy seasons. The higher intensity and frequency of rains results in rapid progress of the disease. Rainfall plays a major role in spread and development of the disease. Because, it provides free water on the leaf surface which is must for germination of uredospores and further infection on the coffee leaves (Daivasikamani *et al*., 2011; Suresh *et al.,* 2012 and Groenen, 2018). In the present investigation, during the month of May 2016-17 seasons, it was found that the overall CLR incidence was very low compared to 2015-16 season of the corresponding month. Because, during this month the frequency (nine rainy days) and quantum (112.2 mm) of rainfall was low compared to 2015-16 season (12 rainy days and 124.6 mm) and also the mean maximum temperature during May 2016-17 season recorded more than 32°C in majority of the days. The present study upholds the results of Nutman and Roberts (1963) that the optimum temperature for leaf rust uredospore germination and penetration is 22°C and maximum temperature is 28°C. If, temperature is more than 28°C then the germination and penetration will not take place.

The CLR incidence was recorded high in 2017-18 season during the peak period (September) even though the cumulative rainfall was lesser (1972 mm) with uniform distribution as compared to 2018-19 (3657.6 mm) season. The earlier studies indicated that, the increase in the cumulative rainfall increases the leaf wetness period which in turn increases the CLR incidence. According to Kushalappa (1989) free water period of less than 6 hours at optimum temperature (22 to 23°C), the infection process becomes unsuccessful. The meteorological data collected revealed that, the number of rainy days during the season 2017-18 was sixteen which was evenly distributed with intermittent bright sunny days. While in 2018-19 season, the number of rainy days recorded was only eight. The intermittent rainfall received during the month of September 2017 might have increased the duration of leaf surface wetness. This might have enhanced the germination and penetration of uredospores which finally resulted in the high incidence of CLR even though the cumulative rainfall was less during that period. In case of 2018-19 season, the data pertaining to the CLR incidence revealed that there was a lesser spread and development of disease, this may be due to heavy rainfall received during the monsoon period might of washed off the uredospores, which in turn reduced the inoculum

Table 1: Coffee leaf rust incidence on Sln.3, Sln.5B and C×R from 2015-16 to 2018-19

Month	Fortnight	Per cent leaf rust incidence											
		Sln.3				Sln.5B				C×R			
		2015-16	2016-17	2017-18	2018-19	2015-16	2016-17	2017-18	2018-19	2015-16	2016-17	2017-18	2018-19
April	1st	1.91	2.28	4.93	0.0	0.11	0.00	0.00	0.67	3.94	0.00	0.076	0.00
	2nd	4.96	2.50	5.50	0.09	0.36	0.00	0.00	0.00	2.11	0.32	0.15	0.52
May	1st	5.52	0.41	4.00	0.55	0.56	0.27	0.06	1.37	3.85	0.64	0.63	0.58
	2nd	10.26	0.13	7.56	1.16	0.58	0.04	0.22	1.13	3.35	1.41	1.10	1.00
June	1st	22.88	0.44	8.39	2.25	0.88	0.19	0.13	1.36	4.32	0.04	0.16	0.14
	2nd	24.97	0.82	8.94	4.92	1.34	0.00	0.41	2.56	2.27	0.86	0.32	0.39
July	1st	58.66	0.44	42.00	5.46	2.88	0.24	1.80	1.35	2.81	41.00	1.38	1.48
	2nd	64.61	0.56	44.61	5.67	4.39	0.05	2.80	0.81	7.32	0.04	1.77	1.97
Aug	1st	49.05	2.02	47.87	5.60	5.28	0.22	2.04	0.80	7.67	0.50	1.912	1.72
	2nd	48.50	2.03	48.02	5.50	4.70	0.22	2.80	0.78	8.14	0.50	2.36	2.29
Sept.	1st	22.65	2.03	62.88	5.58	7.73	0.20	5.33	0.22	13.55	0.50	2.80	2.30
	2nd	20.90	4.69	68.72	11.91	6.93	0.55	8.04	1.04	14.70	2.19	10.49	2.32
Oct.	1st	8.26	9.05	61.84	16.43	8.35	0.13	15.45	4.20	11.56	3.68	12.48	5.24
	2nd	8.27	12.28	51.73	17.83	7.74	0.73	21.96	6.20	11.93	2.92	13.28	6.80
Nov.	1st	8.32	13.80	72.31	18.92	8.40	1.84	27.87	9.12	11.57	2.21	6.57	10.19
	2nd	8.40	14.00	75.3	25.82	14.28	2.40	35.4	10.0	10.69	2.32	4.23	8.09
Dec.	1st	5.35	33.72	72.31	31.70	12.37	2.49	27.87	6.10	8.98	3.84	6.57	8.20
	2nd	3.80	38.53	71.51	46.22	9.29	9.60	35.91	4.80	6.48	7.87	5.82	8.00
Jan.	1st	10.74	58.25	68.82	45.77	11.49	4.00	27.87	8.54	10.55	6.80	6.57	3.34
	2nd	15.97	61.69	46.01	59.87	18.56	3.17	37.27	10.87	6.84	2.40	4.29	3.34
Feb.	1st	13.02	67.52	18.00	13.59	18.75	4.30	31.60	5.67	4.23	6.20	4.52	3.83
	2nd	8.31	79.69	14.06	12.69	11.29	1.31	24.10	7.20	4.93	6.90	4.69	0.89
March	1st	6.8	70.02	11.08	8.11	9.02	1.23	18.76	3.68	2.98	5.80	3.09	0.00
	2nd	4.9	62.00	8.00	4.99	7.23	0.91	11.02	0.56	2.23	5.20	2.21	0.00

Table 2: Meteorological data recorded at CCRI from 2015-16 to 2018-19

Month	Fort night	2015-16				2016-17				2017-18				2018-19			
		Tmax (°C)	Tmin (°C)	RH (%)	RF (mm)	Tmax (°C)	Tmin (°C)	RH (%)	RF (mm)	Tmax (°C)	Tmin (°C)	RH (%)	RF (mm)	Tmax (°C)	Tmin (°C)	RH (%)	RF (mm)
April	1st	29.88	19.07	82.07	76.1	33.56	20.58	83.07	27.6	33.23	20.43	78.67	42.1	33.18	17.97	80.00	82.0
	2nd	29.67	18.97	83.47	193.7	34.67	20.87	83.07	39.6	33.67	20.13	68.80	60.7	32.36	20.00	77.53	134.4
May	1st	29.67	18.93	84.20	288.7	33.83	20.49	83.67	58.0	32.09	19.53	71.80	126.1	31.10	18.70	82.33	286.8
	2nd	29.50	19.47	85.94	318.3	30.39	20.59	91.38	158.5	29.00	20.34	79.19	225.4	29.12	19.18	82.68	490.0
June	1st	28.80	19.40	83.87	321.1	28.10	20.07	88.53	216.7	26.33	20.00	83.60	321.3	26.23	19.93	88.60	939.0
	2nd	24.97	19.27	90.33	886.3	24.33	19.18	91.93	359.5	25.40	19.60	86.53	530.9	25.00	18.90	89.40	1182.2
July	1st	25.99	20.07	87.40	1000.1	23.21	19.77	91.33	870.9	24.95	19.60	87.27	748.6	25.50	19.34	89.20	1899.0
	2nd	24.44	19.44	90.63	1281.3	25.06	19.28	91.69	1125.5	24.44	19.69	88.63	1096.7	22.93	19.25	91.75	2360.8
Aug	1st	24.37	19.20	91.53	1584.5	24.03	19.20	92.20	1359.2	25.72	19.60	81.27	1323.6	23.53	19.06	92.33	3054.4
	2nd	26.09	19.96	88.19	1687.5	24.92	19.44	92.00	1538.7	25.24	19.22	88.75	1590.4	23.68	19.12	93.37	3530.0
Sept.	1st	23.33	21.93	85.07	1818.7	24.27	19.01	85.73	1620.9	28.15	20.10	94.10	1844.5	27.53	17.66	89.73	3555.4
	2nd	22.90	22.05	87.93	1914.5	24.85	19.22	92.13	1731.2	28.05	19.27	86.87	1972.0	28.43	18.56	90.73	3657.6
Oct.	1st	23.80	23.14	84.00	2005.5	27.08	17.87	85.07	1808.6	27.55	19.53	86.40	2086.8	29.33	19.00	84.93	3725.2
	2nd	24.31	23.78	76.94	2036.1	28.04	17.22	86.69	1832.3	28.29	19.14	87.56	3349.3	29.15	17.62	83.43	3807.2
Nov.	1st	26.93	18.62	80.07	2161.1	29.23	17.11	85.60	1858.4	28.84	16.61	80.60	2147.3	29.36	16.33	80.33	3815.6
	2nd	27.97	18.27	79.60	2188.7	29.71	16.20	78.87	1865.2	29.27	17.13	83.53	2154.0	28.70	16.86	77.33	3835.0
Dec.	1st	28.51	18.00	80.13	2201.7	26.99	16.97	80.20	1866.1	29.23	15.47	67.87	2156.2	28.99	16.40	80.13	3851.0
	2nd	29.91	16.19	82.38	2201.7	29.45	15.16	75.81	1871.0	28.98	13.97	69.50	2157.2	28.75	14.88	86.15	3859.8
Jan.	1st	28.38	14.89	62.93	2201.7	28.69	14.13	76.33	1871.0	29.90	18.69	77.87	2157.2	28.93	12.56	86.13	3859.8
	2nd	29.39	15.76	70.06	2201.7	29.30	15.34	58.75	1871.0	29.24	14.56	83.38	2157.2	29.03	13.50	85.50	3859.8
Feb.	1st	30.31	17.02	89.33	2201.7	31.17	16.00	67.13	1871.0	30.03	16.76	78.07	2157.2	31.30	16.23	67.46	3859.8
	2nd	32.00	18.34	85.33	2201.7	32.71	16.65	57.79	1871.0	31.65	16.20	80.00	2157.2	32.07	15.26	72.69	3859.8
Mar.	1st	33.34	19.32	87.86	2201.7	33.45	17.2	56.93	1871.0	33.74	19.43	80.20	2157.2	33.30	16.73	87.60	3859.8
	2nd	34.12	19.41	87.12	2203.7	33.38	18.9	71.62	1875.8	33.10	18.53	82.69	2179.3	33.40	18.75	77.06	3884.2

T. Max. – Maximum Temperature; T. Min. – Minimum Temperature; RH – Relative Humidity; RF – Rainfall

Table 3: Correlation coefficient (r) of CLR incidence with weather parameters .

Weather		2015-16			2016-17			2017-18 2018-19				
parameters	Sln.3	Sln.5B	C×R	Sln.3	Sln.5B	C×R	Sln.3	Sln.5B	C×R	Sln.3	Sln.5B	C×R
Max. temp.	-0.54	-0.05	+0.61	+0.13	+0.14	-0.31	-0.30	+0.22	-0.02	+0.01	+0.16	+0.08
Min. temp.	+0.15	-0.38	+0.34	-0.87	-0.76	-0.04	-0.41	-0.87	-0.29	-0.69	-0.76	-0.77
RH	+0.41	-0.45	-0.31	-0.85	-0.60	+0.07	-0.12	+0.0	+0.14	-0.24	-0.50	-0.35
Rainfall	-0.13	+0.70	+0.56	-0.06	+0.22	+0.02	+0.73	+0.78	+0.81	+0.79	+0.52	+0.72

load. Added to this, the less number of rainy days with erratic distribution and long dry spell might have affected the uredospore germination and penetration which in turn resulted in the less incidence of CLR compared to the previous season (2017-18).

The present investigation indicated that apart from the quantum of rainfall received during the period September to November, the distribution of rainfall during that particular period and temperature plays a crucial role in the development and spread of coffee leaf rust disease.

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