International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Online International Journal Available at http://www.cibtech.org/jfav.htm
2012 Vol. 2 (2) May- August, pp.50-55/Suresh et al.
Research Article

COFFEE LEAF RUST (CLR) AND DISEASE TRIANGLE: A CASE STUDY

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ABSTRACT
Leaf rust in coffee is the major fungal disease caused by *Hemileia vastatrix* that devastates the coffee plantations at its peak incidence levels. Present study reveals the relationship of the three components of disease triangle viz. host, environment and pathogen involved in coffee-leaf rust disease complex. Results indicated that, in the case of coffee; the host disease resistance is more influencing than the other two factors i.e. pathogen and environmental variables. This is clearly elucidated by the fact that with the prevalence of almost 37 races in Indian coffee tracts the evolution one predominant race is not observed, i.e. races I and II that were prevalent in 1930s continue to be predominant even now. With the changing climatic conditions shifts in patterns are observed in the factors that influence the climate but not much effect on disease development as disease develops whenever favourable conditions occur, i.e. spore germination that requires lower temperatures (15-20^{o}C) and diffuse light. Therefore, the ability of the host plant to tolerate the pathogen attack should be given prime importance in breeding approaches for sustainable coffee production.

***Key Words**: Disease Triangle, Arabica Coffee, Coffee Leaf Rust*

INTRODUCTION
Coffee belongs to the genus *Coffea* of the family Rubiaceae (Bridson and Verdcourt, 1988). Commercial production of coffee comes from two species namely, *Coffea Arabica* L. and *Coffea canephora* Pierre ex Froehner, popularly known as `arabica coffee' and `robusta coffee' respectively. Arabica coffee is in much demand in the international market for its excellent inherent cup quality. In India, during the year 2008-09 the total planted area of arabica coffee was 1,89,511 ha with an average productivity of 624 kg ha^{-1}. In Karnataka state, arabica coffee is cultivated in Chikmaglur, Kodagu and Hassan districts spread over an area of 1,10,298 ha with a production of 61,135 MT (Anonymous, 2010).
Coffee being a perennial crop harbours pathogens continuously and the degree of infection increases under favourable conditions. Arabica coffee is known to be highly susceptible to the deadly disease "leaf rust" or "orange rust" (Wellman, 1953; Waller, 1982). This disease was considered to be the most severe of foliar diseases known to date (Large, 1940) and is a major disease of arabica coffee reported from over fifty coffee growing countries (Kushalappa and Eskes, 1989). This foliar disease was first found on cultivated coffee in India during 1869 (Anonymous, 2003). A little earlier, this disease caused the abandonment of plantations in Sri Lanka and Indonesia where arabica coffee was replaced with robusta coffee (Cramer, 1957).
The fungus (*Hemileia vastatrix* Berk. et Br.) is host specific and infects only the foliage. The pathogen can cause foliage loss up to 50% and berries up to 70% (Muthappa, 1975; Vallega and Chiarappa, 1964; Bhat *et al*., 2000). Leaf rust pathogen occurs in different forms called physiological races capable of infecting specific genotypes of the host and the coffee plants also exist in genetically different host types called coffee physiologic groups (Mayne, 1932). Effective management of this major disease is important for profitable cultivation of arabica coffee. In this context, the three important components of the disease complex of coffee leaf rust, the coffee plant, its environment and the genetically different pathogen races have to be understood well. Considerable variations in weather during the recent past have been observed and were thought to be a part of the climate change that is happening all over the world. Present study was undertaken with the aim of understanding the abiotic factors influencing the dynamics of leaf rust

disease manifestation using three different varieties of coffee. For the first time, an attempt is made to apply the disease triangle model to elucidate the disease incidence. Disease triangle is a conceptual model that explains the interactions between the environment, the host and the pathogen (McNew, 1960).

MATERIALS AND METHODS

The field experiment was conducted at the Central Coffee Research Institute (CCRI), Balehonnur, Chikmaglur district, Karnataka State, India. The leaf rust susceptible arabica coffee cultivar S.795 was used as susceptible control over two interspecific hybrids derived by spontaneous and artificial hybridization of *C. arabica* and *C. canephora* viz. Sln.5A and Sln.6 respectively. Observations were recorded on the seasonal incidence and progression of coffee leaf rust at monthly intervals for a period of two years from July 2008 to June 2010. Coffee leaf rust (CLR) incidence was assessed by recording the total number of healthy and diseased leaves in three selected branches per plant and from a total of ten marked plants. Percentage of rust infected leaves was calculated and the disease index was expressed as percentage rust incidence (Muthappa, 1974).

The abiotic factors such as temperature (minimum and maximum), relative humidity, sunshine hours and quantum of rainfall were recorded using the Indian Meteorological Department (IMD) approved weather station installed at CCRI. The weather data was collected on a daily basis during the entire experiment period. The data were tabulated and average values for monthly intervals were calculated to match with the periodicity of coffee leaf rust infection. The data on incidence of leaf rust on S.795, Sln.5A and sln.6 were correlated with the weather parameters using regression analysis. The percentage values were subjected to square root transformation. The treatment means were compared using Duncan's multiple range test (DMRT) for their significance (Gomez and Gomez, 1984).

RESULTS

The leaf rust incidence values recorded on all the three varieties at monthly intervals for two consecutive years are depicted in Figure 1.

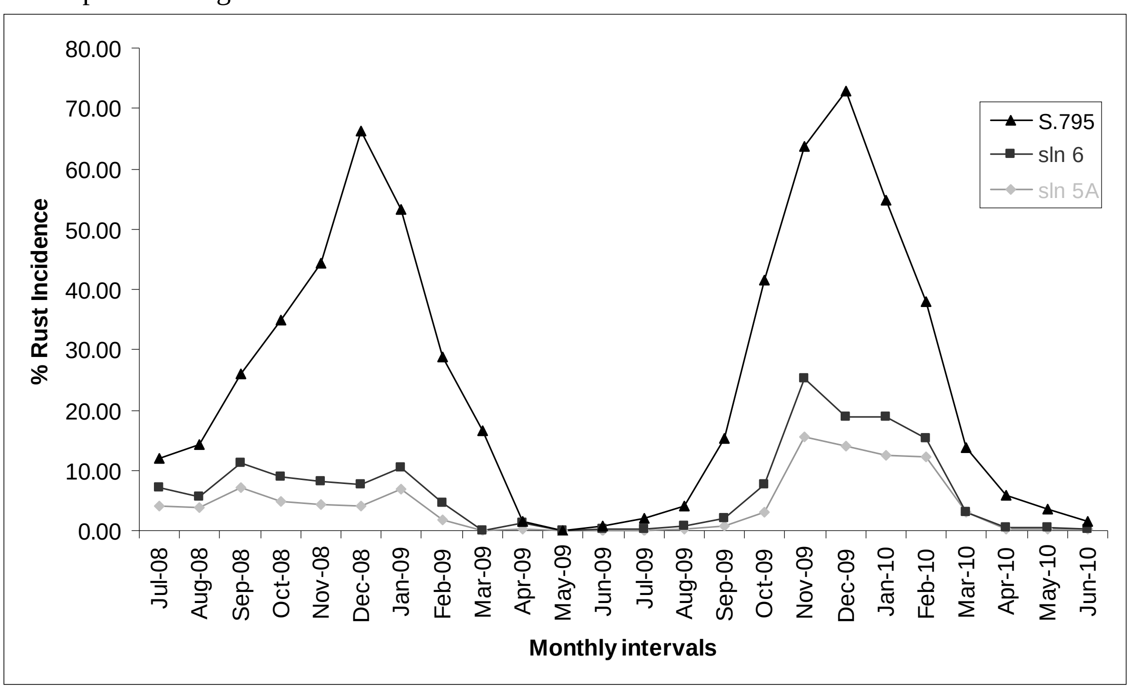

Figure 1: Graph showing the disease incidence levels during monthly intervals in three different genotypes for the years 2008-09 and 2009-10

During the experiment period from 2008-09 to 2009-10, the rainfall varied from 1930 mm to 2906 mm. The maximum temperature ranged from 24.5 to 33.5^{o}C, minimum temperature from 13.6 to 23.03^{o}C, relative humidity from 71.46 to 93.35% and sunshine hours from 2.3 to 7.2 h. The leaf rust incidence had a peak period during September to December. The incidence was lower during April to June period and increased from July onwards and peaked during November/December. Using the weather data and leaf rust incidence, the correlation coefficients were derived and the details are presented in Table 1.

Table 1: Table showing the details of meteorological data for a period of two years and disease incidence levels in three different varieties

MONTH	Min. Temp.	Max. Temp.	SS hours	RH (%)	RF (mm)	% RI (Sln.5A)	% RI (Sln.6)	% RI (S.795)
Jul-08	19.16	25.20	0.00	92.23	0559.60	04.20	2.90	05.00
Aug-08	18.87	24.70	0.00	93.35	0517.40	03.70	1.80	08.70
Sep-08	18.42	27.10	5.30	86.57	0070.20	07.15	3.98	14.80
Oct-08	18.50	28.70	5.20	88.77	0205.40	04.81	4.17	25.90
Nov-08	15.98	28.00	6.40	86.07	0012.00	04.27	3.87	36.20
Dec-08	13.60	29.50	6.30	81.87	0000.00	04.07	3.56	58.60
Jan-09	17.22	30.60	6.70	84.77	0000.00	06.88	3.47	42.80
Feb-09	20.01	32.50	7.20	71.46	0000.00	01.83	2.74	24.30
Mar-09	20.98	32.50	5.80	84.39	0034.90	00.00	0.06	16.50
Apr-09	23.03	32.00	6.00	86.20	0028.60	00.26	1.08	00.09
May-09	18.87	30.90	7.00	84.90	0214.40	00.00	0.05	00.00
Jun-09	18.42	27.50	3.50	87.97	0287.80	00.05	0.09	00.55
Jul-09	19.30	24.50	0.00	92.20	1296.20	00.05	0.14	01.97
Aug-09	19.40	25.90	0.00	91.00	0259.20	00.13	0.62	03.28
Sep-09	19.30	26.50	3.30	91.30	0481.40	00.65	1.39	13.34
Oct-09	18.30	27.50	5.50	81.60	0234.20	03.13	4.40	34.05
Nov-09	18.10	28.00	4.50	84.50	0119.10	15.42	9.86	38.32
Dec-09	16.80	28.30	2.30	85.80	0039.40	14.00	4.87	54.04
Jan-10	16.50	28.60	4.50	84.50	0021.80	12.61	6.30	35.81
Feb-10	16.50	31.60	5.00	81.10	0000.00	12.13	3.28	22.50
Mar-10	19.00	33.50	6.80	82.00	0013.00	02.93	0.10	10.62
Apr-10	20.20	33.00	6.00	84.30	0150.20	00.28	0.19	05.40
May-10	20.80	30.60	6.00	83.00	0068.40	00.18	0.26	03.25
Jun-10	20.10	27.90	4.00	86.10	0224.00	00.13	0.11	01.20

Table 2: Correlation matrix of weather parameters and rust incidence on three arabica coffee varieties

Factors	Sln.5A	Sln.6	S.795
Minimum Temperature (°C)	y = -1.437x + 30.905 R^2 = 0.3248 r=0.570 **	y = -0.6773x + 15.095 R^2 = 0.2797 r=0.529 **	y = -7.0912x + 151.23 R^2 = 0.5799 r=0.762 **
Maximum Temperature (°C)	y = -0.1113x + 7.3417 R^2 = 0.0038 r=0.062 ^{NS}	y = -0.1637x + 7.2125 R^2 = 0.0319 r=0.179 ^{NS}	y = 0.3993x + 7.4853 R^2 = 0.0036 r=0.060 ^{NS}
Relative Humidity (%)	y = -0.1468x + 16.697 R^2 = 0.02 r=0.141 ^{NS}	y = -0.0876x + 9.9778 R^2 = 0.0276 r=0.166 ^{NS}	y = -1.364x + 135.9 R^2 = 0.1265 r=0.356 ^{NS}
Rain Fall (mm)	y = -0.0053x + 5.1912 R^2 = 0.0996 r=0.316 ^{NS}	y = -0.0024x + 2.9476 R^2 = 0.0765 r=0.277 ^{NS}	y = -0.0265x + 24.386 R^2 = 0.181 r=0.425 ^{NS}
Sun Shine (hours)	y = -0.0274x + 4.2416 R^2 = 0.0002 r=0.014 ^{NS}	y = 0.0639x + 2.1848 R^2 = 0.0038 r=0.062 ^{NS}	y = 2.0046x + 10.088 R^2 = 0.0705 r=0.266 ^{NS}

*** Significance at 1% & 5%, NS - Non Significant*

The mean minimum temperature had significant (P=0.01 and 0.05) negative correlation with disease incidence on all the three varieties studied, whose 'r' values are 0.570 for Sln.5A, 0.529 for Sln.6 and 0.762 for S.795 (Table 2). The 'r' values indicated the susceptible control (S.795) was more influenced than the two interspecific hybrid varieties. Other factors did not show any significant relationship to disease incidence. Some earlier reports on *in-vitro* studies (Daivasikamani and Rajanaika, 2009) suggested that minimum relative humidity of 70% was required for maximum urediospore germination. Another recent study (Daivasikamani *et al.*, 2011) reported that coffee leaf rust disease was also influenced by the amount of rainfall received during the infection process, which enhances relative humidity.

DISCUSSION

The disease incidence and severity in any living system varies with variations in the three components of the disease triangle i.e. host, pathogen and environment (McNew, 1960; Scholthof, 2007). The relation between theses three components should be understood well to define epidemiology of any disease and its management. As of now the disease epidemics in coffee were not explained with this model.

Experimental host materials are three varieties of coffee with different resistance to the leaf rust pathogen. However, it is observed that the initiation of disease on all three varieties is more or less at the same time. Thus, leaf rust pustules with spores become visible on all three varieties in the month of July but the proportion of infected leaves is less at about 1.5% in Sln.6 and 2% in Sln.5A on average and is slightly more on S.795 of about 3.5%. With the passage of time there is an increase of in the proportion of infected leaves to over 50% in S.795, to about 4% in Sln.6 and 9% in Sln.5A on an average in the months of November and December. The monsoon period promotes the disease progression as noted in the earlier studies (Daivasikhamani and Rajanaika, 2009; Daivasikhamani *et al*., 2011). The disease incidence and progression trend indicates that host resistance is a significantly important factor in determining disease incidence and progression in coffee.

Leaf rust is known to exist in physiological forms with the ability to infect specific genotypes of coffee (Mayne, 1932). At least 37 different physiological races are reported from Indian coffee fields (Prakash *et al*., 2005). This is a significant increase in pathogen variability as only 13 physiological races of CLR were known until 1980s (Roudrigues *et al*., 1975). From the present study it is evident that physiological specialization has no influence on the phonological development of the leaf rust. In spite of this capability of the pathogen, the level of incidence of disease on the three tested varieties is considerably variable (Table 1) as discussed above. This also indicates that host resistance is a major factor having larger influence than the virulence of the pathogen races. Possibly, the races capable of specifically infecting the resistant materials may be at lower prevalence under field conditions, indicating that acquisition of more virulence genes by the pathogen may be imposing a fitness penalty (Leach *et al,* 2001; Casjana *et al*., 2000).

When considering the environmental context, the averages of observations in the study years on all the parameters like maximum temperatures, sunshine hours and relative humidity are remarkably constant, even though there are fluctuations within each year varying from month to month. Rainfall however manifested large variation between years as well as within years. Thus, these parameters are unlikely to be influencing the initiation and progression of CLR disease. Interestingly, the minimum temperatures observed manifested variation within a narrow range (Table 1) with variation between months in the order of $0.29^{o}C$ to $2.5\,^{o}C$ with an occasional high of upto $4\,^{o}C$ in the course of two years. Thus, this appears to be the critical environmental condition that determines not only initiation but also the progression of CLR disease. This conclusion draws support from the study of Daivasikamani and Rajanaika, (2009).

From the foregoing discourse it can be concluded that changing weather and increased variability of the pathogen could not significantly influence the initiation and progression of disease on genetically resistant interspecific hybrid derived varieties of coffee. Thus, the breeding approaches to increase the durability of resistance to coffee leaf rust have been given prime importance in India even though the variability in rust races was observed since a long period. MAS based breeding approaches (Prakash *et al*., 2011) may enhance the efficiency of conventional strategies to obtain durable resistance in coffee cultivars.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. Jayarama, Director of Research and Dr. N. Suryaprakash Rao, Head Division, Plant Breeding and Genetics, CCRI, CRS; for their kind cooperation in carrying out the following work.

REFERENCES

Anonymous (2003). Board Research Department, Central Coffee Research Institute. *Coffee Guide* Coffee (Chikmagalur, Karnataka, India) 200**.**

Anonymous (2010). Economic and Market Intelligence Unit. *Database on Coffee – March, 2010* (Coffee Board, Bangalore, India) **101** .

Bhat S S, NaiduR, Daivasikamani S and Nirmala Kannan (2000). Integrated disease management in coffee. **In:** *IPM system in Agriculture – Cash crops.* Volume 6, edited by Upadhyay RK, Mukerji KG and Dubey OP, Aditya Books Private Limited (New Delhi, India) 65-82.

Bridson DM and Verdcourt B (1988). Flora of tropical Africa. Rubiaceae (Part 2), edited by Polhell RM **227**.

Casjana MVC, Jinafa Bai, Isabelita Ona, Hei Leung, Rebecca JN, Twng-Wah M and Leach EJ (2000). Predicting durability of a disease resistance gene based on assessment of the fitness loss and epidemiological consequences of avirulence gene mutation. *PNAS* **97**(25) 13500-13505.

Cramer PJS (1957). Inter-American Institute of Agricultural Scinces. *A Review of Literature of Coffee Research in Indonesia* (Turrialba).

Daivasikamani S and Rajanaika (2009). Effect of some abiotic factors on germination of urediospore of the coffee leaf rust fungus, *Hemileia vastatrix* (Berkeley & Broome). *Journal of Biopesticides* **2**(1) 15–17.

Daivasikamani S, Rajanaika, Vinod kumar PK, Sudhakar S Bhat and Jayarama (2011). Influence of weather parameters on leaf rust incidence of arabica coffee c.v. S.795. *Journal of plantation Crops* **39**(1) 190-192.

Gomez KA and Gomez AA (1984). Statistical procedures for agricultural research. John Wiley and Sons, Inc. New York **680.**

Kushalappa AC and Eskes AB (1989). Coffee rust: Epidemiology, Resistance and Management. CRC Press, Florida **345.**

Large EC 1940. *The Advance of fungi.* Johathan Cape. London. 196-207

Leach EJ, Casiana MVC, Jinafa Bai And Hei Leung (2001). Pathogen Fitness Penalty as a Predictor of Durability of Disease Resistance Genes. *Annu. Rev. Phytopathol* **39** 187-224.

Mayne BWW (1932). Physiological specialization of Hemeliea vastatrix B and Br Nature (London) 129-510.

McNew GL (1960). The nature, origin and evolution of parasitism. In Plant Pathology: An advanced treatise, edited by Horsfall JG and Dimond AE (Acedemic press, New York) 19-69.

Muthappa BN (1974). A method for estimating the field incidence of coffee leaf rust. *Journal of Coffee Research* **4**(2) 40-45.

Muthappa BN (1975). Progress and status of coffee disease research in India. *Pesticides Annual* 115-121.

Prakash NS, Ganesh D and Bhat SS (2005). Durable Resistance to Coffee Leaf Rust, edited by L Zambolin, EM Zambolin and VMP Varzea. Federal University of Vicosa (UFV) 411-442.

Prakash NS, Muniswamy B, Hanumantha BT, Sreenath HL, Sundaresha Kumar Deepak, Suresh N, Santhosh P, Soumya P, Asha Bhat M, Bhat SS and Jayarama (2011). Marker assisted selection and breeding for leaf rust resistance in coffee (Coffea arabica L.) - some recent leads. *Indian Journal of Genetics & Plant Breeding* **71**(2) 185-189.

Roudrigues Jr, CJ, Bettencourt AJ and Rijo L (1975). Races of the pathogen and resistance to coffee rust. *Annual Review of Phytopathology* **13** 49-70.

Scholthof KG (2007). The disease triangle: pathogens, the environment and society. *Nature Reviews (Microbiology)* **5**(2) 152-156.

Vallega J and Chiarappa, L (1964). Plant disease losses as they occur world wide. *Phytopathology* **54**(11)1305-1308.

Waller JM (1982). Coffee rust-epidemiology and control. *Crop Protection* **1**(4) 385-404.

Wellman FL (1953). The Americas face up to threat of coffee rust. *Foreign Agriculture* **27**(3) 1-7.