Hemileia vastatrix

Introduction

Coffee rust was first reported in 1861 on wild coffee near Lake Victoria in East Africa. In 1867 growers in Ceylon, the largest producer in the world, noted the appearance of a leaf disease. By 1879 the disease was causing such damage that the Ceylon government appealed to the British to send someone to investigate the disease and suggest a cure. However, the plantations had declined to a point of being economically non-viable. The British planters changed to growing tea, which eventually replaced coffee as the national beverage. Within a few years rust had devastated the extensive coffee plantations in Java and Sumatra. As a result the world's centre for coffee production shifted to the Americas, where the rust did not exist. Brazil soon became the largest producer.

In 1970, coffee rust was first discovered in the Americas near Itabuna in the State of Bahia, Brazil and by 1983 it had spread to all the important coffee producing areas of South and Central America (Schieber and Zentmyer, 1984).

Identity

Authority : Berkeley & Broome
Classification : Alexopoulos et al., 1996
- Kingdom : Fungi
- Phylum : Basidiomycota
- Order : Uredinales
- Family : Pucciniaceae
- Genus : *Hemileia*
- Species : *vastatrix*
- Common names: Orange rust, oriental rust, common rust, coffee leaf disease, Roya del cafeto
- Role : Pest

Signs & Symptoms

The first observable symptoms (on young or old leaves) are small, translucent, pale yellow spots 1-3mm in diameter. Within a few days the spots increase in size, sometimes coalescing to form large patches, and produce masses of yellow-orange urediniospores (uredospores) on the undersurface of the leaf (Fig.1.). The opposite side of the lesion (the upper surface) is visible as a chlorotic area. Old pustules sometimes become necrotic while sporulation continues from circular bands of sori at the edges of the lesion (Schieber & Zentmeyer, 1984). The fungus sporulates through the stomata, unlike most rusts whose pustules rupture the epidermis. The colour of the spore mass varies from one location to another, but is not due to differences in race characteristics. Occasional infection of berries has been reported. Early spotting frequently occurs around the margins or tips of leaves (the most susceptible tissue), where dew and raindrops tend to linger and create opportunities for the germination and penetration of fungal spores (Fig. 2). Subsequent infection of other areas on a leaf results from splash or wind dispersal of spores. The first lesions generally appear on the lower leaves and infection gradually progresses upward into the tree. In certain locations new foliage at the tops of young coffee trees may show infection. Also, pustules can develop on the first leaves of seedlings germinating under established trees. The infected leaves drop prematurely and the ensuing defoliation leads to yield reduction, die-back and debilitation of trees, which, if not arrested, will terminate in the death of trees. In the field, defoliated trees (Fig. 3) are scattered, indicating that they are not all affected at the same time.

Morphology

The fungus occurs in nature primarily in the uredinial stage, which repeats the disease on coffee. A single uredopustule produces as many as 150,000 uredospores (urediniospores). The latter are borne on thickened, colourless hyphal stalks each of which gives rise to several of the kidney-shaped uredospores attached asymmetrically on short sterigmata. The hyaline spores (30-40 x 27-30μm) are smooth on the concave, inner surface and rough on the outer, convex surface.
Teliospores are turnip-shaped, 20-25 μm in diameter and infrequently produced within the uredia on short pedicels. They germinate to produce four basidiospores whose fate is unknown.

Biology & Epidemiology

H. vastatrix produces only the uredinial, telial and basidial stages in nature; the pycnial and aecial stages have not been discovered (Fig. 4). The pathogen propagates itself by urediniospores, but the function of teliospores and basidiospores has not been elucidated. The basidiospore does not infect *Coffea spp.* and no alternate host has been found to date. The urediniospore germinates optimally at 22-24C (range, 15.5 to 28C) only in the presence of free water. Two to three germ tubes are produced and these directly, or after some branching, produce appressoria on stomata, penetrating into the substomatal chamber by means of infection hyphae. High RH in the absence of water is insufficient to induce germination. Urediniospores can survive under dry conditions for 6 weeks but, once germination commences, loss of moisture for about 2 hours completely inhibits the process. Germination percentage is highest on young leaves.
Within the leaf, growth is intercellular and cells are penetrated by haustoria. Colonization is influenced by temperature, which affects the rate of disease development rather than survival. The optimal temperature for development of disease is 21-25C, the range being 15-30C. The degree of host resistance also influences the process. In Brazil, studies have shown that rust epiphytotics are delayed when temperatures rise above 30C, due to a cessation of fungal colonization at the stage before the development of protosori - a type of heat dormancy. The mycelium retains viability for up to 60 days, during which period sporulation can recommence if the temperature decreases (Becker - Raterink, 1984). Under favourable conditions urediniospore germination and penetration into the host occur within 72 hr, early symptoms appear 12-15 days later and urediniospores are produced from lesions in another 18-22 days.
Only a few of the 32 known races of *H. vastatrix* are isolated regularly, race II being by far the most prevalent (Rodrigues Jr., 1984). Much of the world's coffee, based as it is on *C. arabica*, is susceptible to rust. This is especially the case in Latin America where the warm

conditions and genetic uniformity of the varieties are a prescription for destructive epiphytotics and severe economic hardship particularly for small growers. Accurate knowledge of the races present in any country is critically important in developing management strategies and in planning the deployment of resistance genes in breeding programmes.

Dispersal / vectors

Detailed studies in Kenya and Brazil have determined that wind is the primary disseminating agent of coffee rust. Although it may never be proved, the consensus is that *H. vastatrix* urediniospores, borne on the winds that blow from the West Coast of Africa to South America, introduced rust to Brazil. Spore numbers, trapped in the air above coffee fields, have been shown to be linearly related to disease severity. Continuous spore trapping located between, above and outside infected plantations showed that spores were continually windborne. Densities decreased with increasing height and distance from infected fields, but spores were trapped up to 1000 m above plantations. The failure to arrest the advance of rust by eradicating very large areas of the crop shortly after its discovery in Brazil was further evidence for the importance of wind as an agent of dissemination.

Rain is also important in dispersal of urediniospores and plays the additional role in the disease cycle of providing the free water necessary for spore germination. During the wet season rain combines with wind (sometimes of high speed) and in such conditions the highest numbers of spores have been trapped. However, no specific relationship between the amount of rainfall and the number of intercepted spores has been found. Rainsplash is known to function in dissemination by washing spores within plants and from one plant to another.

Coffee rust is disseminated by man in a number of ways:

- on infested nursery plants, as occurred between Brazil and Bolivia
- as a contaminant on other plant species from countries where *H. vastatrix* exists
- on the clothing and skin of individuals who have been in contact with diseased plants.

Insects are recognized as having a minor role in disseminating spores within and among trees.

Management

Quarantine

In its march into coffee- growing countries all over the world, *H. vastatrix* has been aided by man as a major disseminator. Although the pathogen now exists worldwide the distribution of its 32 (so far) races is limited. It is a worthwhile objective to maintain the *status quo* of race distribution.

An effective quarantine, which requires a comprehensive public education programme, is an essential first line of defence against coffee rust. Agronomically acceptable varieties are now available with resistance to Races I and II, the two most prevalent races of rust. Limiting the intrusion of new races into a country or region (e.g., Latin America) would serve to extend the productive life of existing resistant varieties and provide time for breeding programmes to generate superior varieties.

Cultural Practices

Cultural techniques: The necessity to manage coffee rust imposes the need to provide adequate spacing, primarily between rows, to facilitate the application of fungicides as well as to reduce humidity. Pruning and training of trees assist in maintaining vigour that enhance resistance to infection. In addition, pruning controls overcropping which increases the level of disease in the current growing season and reduces vigour that impacts negatively on yields in subsequent seasons. All of these methods improve fungicide deposition, by exposing the foliage during application. Adequate fertilization to rejuvenate coffee plants under stress from overproduction in a particular season ensures against the increased occurrence of rust in the future.

Proper weed control is important in maintaining vigour in a crop that is known for its sensitivity to weed competition. Weed management serves to reduce the humidity around the "skirts" of the trees, the area where the fungus usually first invades.

A considerable amount of the world's coffee is produced by small farmers, many of whom grow the crop under shade in preference to the unshaded system used by large-scale producers. Faced with the need to institute a fungicide programme, many have abandoned coffee production due to a lack of financial resources. Those who have been able to stay in production have found that rust incidence is lower under shade. Opinions differ on whether this is caused by lower dew formation under shade or by the reduced susceptibility of coffee as a result of lower yields. On the other hand, the leaves of coffee grown without shade dry faster and are less vulnerable to urediniospore infection, despite the higher yielding plants.

Fungicide application

A great deal of research has been conducted with the objective of achieving greater precision in the application of fungicides for the management of coffee rust.

The essential information is:

1) Coffee trees are conical in shape, with all the foliage on the outer part of the cone
2) On each expanding leaf the youngest tissue is on the margin and the oldest near the midrib.
3) Urediniospore germination near leaf margins is 30% higher than towards the midrib
4) Leaf flushing coincides with the early rains, in the spring or start of the rainy season, and continues through the season, producing a new pair of terminal leaves every 21-25 days
5) Inoculum levels are at their lowest during and at the end of the dry season, but vary significantly from year to year
6) Early wet season (or spring) rains and warm temperatures are accompanied by growth flushes and gradual increase in rust development
7) As the rainy season peaks and trees attain full canopy the disease reaches epiphytotic proportions; leaf abscission depletes plant reserves, flower bud potential and, consequently, crop yield in the following year(s)
8) The threshold concentration for leaf infection to be achieved is 16-20 urediniospores per cm^2 and this occurs or is exceeded in a direct linear relationship with rainfall intensity,
9) Assessment keys for rust on coffee (Eskes and Toma-Braghini, 1981) have revealed good correlation between lesions per leaf and percentage of diseased leaves; the best indicator of rust incidence in the field was the number of lesions per leaf.

Forecasting modules have been developed, incorporating the range of factors that influence rust development (Kushalappa and Eskes, 1989). The most precise model uses regression analysis to predict the rate of rust development from the net survival ratio for the monocyclic process of *H. vastatrix*.

The following are some recommendations based on the forecast model:

1 Low dosages of copper fungicides (1-1.5 kg a.i./ha) control rust when disease pressures are lower; under higher disease levels rates of 3-3.5 kg a.i./ha are suggested
2 When predicted and initial disease levels are very high, systemic fungicides (mainly triadimefon or pyracarbolid) should be employed
3 One application, timed for the period of first rain showers, can substantially reduce disease incidence for several months
4 Having low inoculum levels toward the end of a rainy season helps in reducing infection at the start of the following rainy season.

An important advantage of a forecasting system to the farmer is that it clearly indicates the most appropriate spray option.

Fungicides

The established copper-based fungicides, cuprous oxides, copper oxychloride and cupric hydroxide are the most effective protectants and form the backbone of a chemical programme. Extensive use can lead to increased numbers of leaf miners, spider mites and, sometimes, a flare-up of coffee berry disease. Dithiocarbamates will effectively reduce rust levels, but do not weather as well as copper-based compounds. For this reason they are sometimes used in mixes with copper fungicides.

The more expensive and eradicative systemic fungicides, triadimefon and pyracarbolid, are normally reserved for situations of higher rust incidence (> 20% of leaves with lesions). The systemics are often used either in mixtures or in alternate cycles with the copper-based chemicals. These strategies are used to avoid the development of resistance to the systemics in *H. vastatrix* populations.

Resistant varieties

Efforts at developing varieties of coffee resistant to rust have been constrained by the limited resistance available in *C. arabica*. There is the further constraint of serious losses of the genetic diversity in wild *Coffea spp.* caused by depredations in Ethiopian forests where most of the diversity exists. The Ethiopian government has prohibited the export of coffee plants and seed (APS, 2000).

Current breeding programmes have the prime objective of selecting for resistance from inter-specific hybrid populations containing resistance genes from *C. canephora* and *C. liberica*. Another source of high resistance is the natural hybrid between *C. arabica* and *C. canephora*, named Híbrido de Timor (HDT), from East Timor that possesses dominant resistance factors. Hybrids of *C. arabica* and HDT carrying resistance from HDT have had commercial success in Latin America, demonstrating resistance to all known races of *H. vastatrix*. The resistance genes are different from those found in *C. arabica* and confer a complete vertical resistance that is durable. Horizontal resistance is thought to occur and would contribute to the stability exhibited by the hybrids against the many races of the pathogen in nature.

The search for horizontal resistance and for methods to reduce the inherently long selection cycle in coffee has led to the use of novel techniques. Anther culture, *in vitro* propagation, genetic male sterility, protoplast fusion and spontaneous haploids will more effectively utilize the varied rust resistance factors present in *Coffea spp*.

Host notes

The experience of Sri Lanka is indicative of the destructive potential of coffee rust. A Rockefeller Report of 1970 stated that a fall of one cent per pound in the price of coffee would signify a loss of US$55 million in foreign exchange for the 14 coffee- producing countries in the Western Hemisphere. The most important disease of one of the leading commodities in international trade is a very significant problem. *Coffea spp., Gardenia spp* are hosts of the disease.

Distribution

The disease is found in the Indian sub-continent, all former production areas in south-east Asia, (many of which have been converted to rubber), all coffee-growing regions of east, south, central and west Africa and Madagascar. Since its first discovery in Brazil, it is now well established in 12 countries in the Americas, from Argentina to Mexico, Cuba, Dominican Republic, and Jamaica.

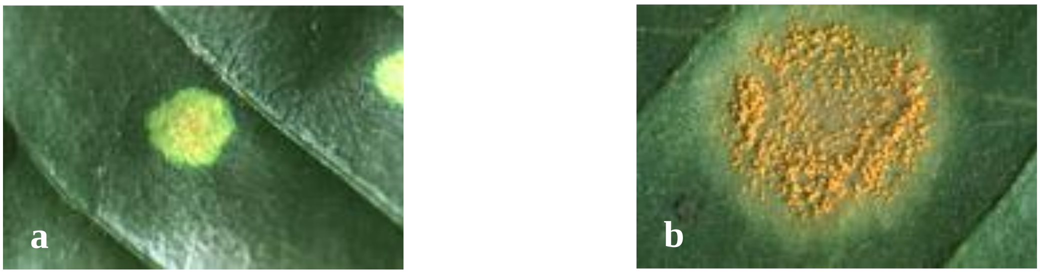

Fig. 1: Early **(a)** and sporulating **(b)** lesions of ***H. vastatrix*** on coffee leaves.

Fig. 2: Coffee leaf lesions caused by ***H. vastatrix*** showing higher level of infection on leaf margins

Fig. 3: Coffee plant showing extensive defoliation caused by **coffee rust.**

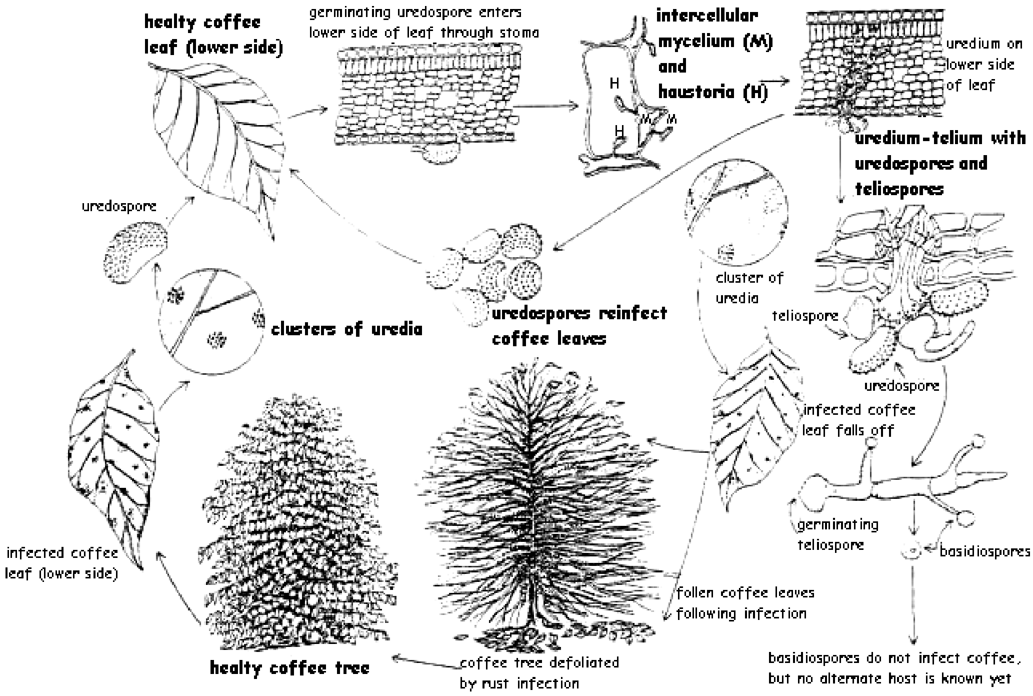

Fig. 4 Life cycle of *H. vastatrix*

Bibliography

Agrios, G.N. (1997). Plant pathology. 4th ed. Academic Press. New York. 635 p.

Alexopoulos, C.J., Mims, C.W. and Blackwell, M. (1996). Introductory mycology. 4th ed. John Wiley & Sons Inc. New York. 869 p.

American Phytopathological Society, (2000). Coffee rust: Management of coffee rust. PlantPath/Coffeerust/text/MNGMNT.HTM

Becker-Raterink, S.M. (1984). Epidemiology and spread of *Hemileia vastatrix*, p. 35-40. *In* R.H. Fulton (ed.) Coffee rust in the Americas. APS. St. Paul.

Eskes, A.B. and Toma-Braghini, M. (1981). Assessment methods for resistance to coffee leaf rust (*Hemileia vastatrix)*. Plant Prot. Bull. FAO 29:56-66.

Fulton, R.H. (1984). Chemical control of coffee leaf rust, p. 75-83. *In* R.H. Fulton (ed.) Coffee rust in the Americas. APS. St. Paul.

Kushalappa, A.C. and Eskes, A.B. (1989). Coffee rust. Epidemiology, Resistance and Management. CRC Press.

Rodrigues Jr., C.J. (1984). Coffee rust races and resistance. *In* R. H. Fulton (ed.) Coffee rust in the Americas. APS. St. Paul.

Schieber, E. and Zentmyer, G.A. (1984). Coffee rust in the Western Hemisphere. Plant Dis. 68: 89-93.

Silva-Acuña, R. (1990). Control químico de la roya del cafeto (*Hemiliea vastatrix*) con el uso de un fungicida sistémico y uno protector. Fitopatol. Venez. 3:22-26.

Web Resources -

http://www.apsnet.org/education/Lessons