A rust epidemic of the coffee shade tree

(Paraserianthes falcataria) in East Timor

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Abstract

During the past two years a very damaging disease has affected Paraserianthes falcataria (formerly Albizia falcataria), the tree most commonly grown in East Timor to provide shade for coffee plantations. A taskforce established by the Department of Agriculture and Forestry of East Timor in 2001 found that 67% of the total coffee plantations, across all eight districts where the crop is grown, were affected. The district of Ermera, which accounts for more than half of the total coffee-producing area of the country, was one of the most severely affected regions.

The disease is caused by Uromycladium tepperianum, a rust disease known to affect only acacias and Paraserianthes/Albizia spp., resulting in the formation of galls on foliage and branches. So far it appears that the strain of the fungus causing damage is restricted to Paraserianthes. The pathogen attacks all above-ground parts of susceptible hosts, however damage is most severe when shoots and branches are affected, as these are girdled by the rust and secondary invading insects and saprophytes which invade galls. As shoots are partially girdled and come under severe stress, massive defoliation of the tree crowns occurs and, eventually, large trees can be killed.

The loss of shade is expected to result in significant reduction in coffee yield and is promoting weed invasion on an unacceptable scale. Shade-tree crown components and, eventually, whole trees are dying and falling branches and wind-thrown trees will damage the coffee. Falling branches will create very dangerous conditions within the plantations and along sections of highways, which are overhung by heavy limbs.

No practicable remedial measures can be recommended to restore the health of standing trees. The likely solution will be to remove severely affected shade trees from plantations, replant with alternative shade species or rust resistant selections of P. falcataria and probably replant the coffee. Expert opinion quoted in a recent survey of the coffee sector in East Timor has indicated that virtually all the coffee plantations in East Timor would benefit from replanting. In the longer term, therefore, some positive benefits will flow to the farmers and the industry by the provision of an opportunity to replace coffee plantations with improved cultivars.

Background

Coffee is East Timor’s major export and the approximately 45,000 ha of plantations provide partial support for an estimated 45,000 families. It is by far the main source of cash income for these families and the decentralised nature of the industry makes it a mainstay of the rural economy of five of the western districts of East Timor. A coffee survey was conducted in May 2001 with World Bank support (Braz and Cristovao, 2001). Results indicate that an average family, participating in coffee growing, earns about US$200 per year from coffee sales (about 90% of its cash income). The current world commodity price of coffee is depressed, the farmgate price for dried Arabica beans has fallen from 8600 Indonesian Rupiah/kg in 1988 to Rps 4300 in 2000. Even allowing for currency fluctuations this fall has had a negative impact on coffee growers although there is a trend for premiums to be attached to quality and organically grown coffee is set to have a valuable market niche.

Coffee is grown using a shade tree system often on very steep sloping terrain. The main shade trees...
being used are *Paraserianthes falcataria* (formerly *Albizia falcataria*), commonly called madre de cacau, and *Casuarina junghuhniana*. In the principal coffee growing districts of Ermera and Liquica visited during this consultancy, *P. falcataria* was the only shade tree being used on any significant scale (Fig.1).

![Figure 1. Coffee growing under *Paraserianthes falcataria.*](image1)

During 1998–2001, *P. falcataria* has become widely infected by a rust disease that has attacked shade tree plantations, especially in the Liquica and Ermera districts (Figs 2 and 3). The time of the initial outbreak has not been recorded but the condition of the worst-affected plantations suggests that the fungus has been present for at least five years. A taskforce report prepared by the Forestry and Plantations Division, Ministry of Agriculture and Fisheries (Anon., 2001) provides a very good summary of the status of the disease, an indication of the levels of impact in coffee-growing districts and a list of recommendations. The report estimated that 67% of coffee plantations in East Timor were affected by the disease. Both the distribution of the disease and its severity can be confidently expected to have increased since that time.

![Figure 2. Lightly infected crown showing spreading canopy.](image2)

![Figure 3. Tree with total defoliation and many galls.](image3)

Photographer: Ken Old

The pathogen

A preliminary identification of the causal agent of the disease as *Uromycladium tepperianum* in the taskforce report (Anon., 2001) has been confirmed by microscopic examination of fruiting bodies collected in the three localities visited during the consultancy. Only two *Uromycladium* species are known to result in massive gall formation on woody shoots and other affected plant parts of acacias and *Albizia/Paraserianthes* spp., namely *U. notabile* and *U. tepperianum* (Figs 4 and 5), (Old et al., 2000). These fungi can be distinguished by the morphology of their sexually produced teliospores, the teliospores of *U. tepperianum* having radially oriented ridges (Fig. 6). In addition, no asexual urediniospores have been reported for *U. tepperianum*, whereas these are produced early in the fruiting season by *U. notabile*. So far all reports of *Uromycladium* sp. on *Paraserianthes* appear to have been attributed to *U. tepperianum*. 

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**Potential remedial measures for standing trees**

Despite the value of standing trees to coffee growers, no remedial measures can be recommended. The current level of inoculum is very high and all trees will be exposed to infection. Each of the possible remedial measures is considered in turn.

**Eradicate the disease from infected plantations and other locations by topping branches from lightly infected trees**

This will not be practical. *P. falcataria* shade trees are often very tall and spreading in habit and such operations would be very dangerous and expensive. The species is also common in the landscape arising from seed cast by plantation trees or planted around dwellings. Also, the disease has a latent period from infection to symptom development so it would not be possible to remove all affected branches. Eradication of the disease, therefore, will not be possible, as further trees will succumb to infection. As felling and tree removal are very expensive, this could only be envisaged in coffee plantations leaving roadside trees and volunteer trees in other sites as a source of infection.

**Remove dead and dying trees**

This may have to be done in the long term due to safety concerns and to replant new shade trees and coffee plantations. Costs will be great and erosion damage will be severe on steep slopes, which are characteristic of many coffee plantations.

**Systemic fungicides to kill the pathogen**

Even if a suitable chemical could be identified, a major R&D program would be needed to develop such a control measure. As this is a systemic disease persisting in woody stem tissue, complete control would not be possible. Chemical control would be very expensive, would carry risks of polluting the environment, affect non-target fungi and resistant strains of the target pathogen could arise. East Timor coffee would lose its market niche as an organic product.

**Biocontrol using antagonistic fungi such as Penicillium or Acremonium spp.**

This was suggested by the taskforce team as a possible means of control. Although such an approach may be possible for some crops and pathogens it would be neither practical nor reliable for the *Paraserianthes* rust epidemic in East Timor. Such an approach would require a major program to find possible agents and develop delivery systems to treat the crowns of 20–30 m high trees. The chances of failure would be high. The colonisation of older galls by insects and fungi is already going on and is probably already reducing the inoculum load on trees to some extent. Such naturally occurring biocontrol may increase over the next few years and exert some beneficial effect without any attempt at manipulation.
Let the disease take its course

The rust outbreak may subside to some extent over the next decade due to insects and fungi naturally colonising the galls, however the level of damage to existing trees will be very high. The incidence levels in the plantations, e.g. 90% plus of trees affected in older outbreaks in Liquica, suggests that the *Paraserianthes* currently being grown in East Timor has a very limited level of resistance to rust with very limited opportunities for natural selection to operate.

Impacts on plantations

*Uromycladium tepperianum* has the potential to severely damage plantations of susceptible hosts. An outbreak in Sabah (Anon., 1993) has been partially responsible for reduced interest in planting of *P. falcata*, similarly, incursion into New Zealand by the closely related *U. notabile* resulted in plans to establish *Acacia* plantations as the basis for a tannin extraction industry being abandoned (Dick, 1985). In South Africa, *U. tepperianum* has been successfully introduced as a biocontrol agent for *A. saligna*, an introduced Australian species that has become a major weed problem (De Selincourt, 1992).

In East Timor, the level of damage to *P. falcata* at both stand and individual tree levels is very high. In the taskforce report, the three districts of Ermera, Liquica and Manufahi were the most badly affected and percentage crown infection on a tree basis was between 57 and 90%.

Almost all the fine branches in many tree crowns bore galls and have died, shedding leaves from the canopy (Figs 2 and 3). In badly affected stands the disease appears to have already gone through one or more cycles of crown recovery with epicormic shoots in some trees constituting the total leaf biomass. The epicormic shoots, in turn, are likely to become infected, resulting in carbon deprivation, extreme stress and death of trees.

Other trees may survive but with reduced crown area and may not provide enough shade to maintain coffee yields. More information is needed on the rate of disease development in individual trees and stands and the onset of secondary invasion by fungal pathogens and boring insects that will hasten the death of large trees. A secondary effect of crown thinning and tree death is to allow the invasion of coffee plantations by weeds, especially vines and other woody species, which compete with the coffee and must be hand-removed.

Despite the very high level of defoliation, limited sampling of trees with severe crown symptoms in April 2002 indicated that they were alive with functional phloem and sapwood and some capacity for recovery. Indeed, it is possible that some trees will recover and the outbreak may remain worse in some areas than others but the outlook for the future of existing trees appears poor. There are several examples of newly introduced diseases virtually wiping out tree populations, even including native stands (for example chestnut blight and white pine blister rust in North America). *P. falcata* currently growing in East Timor seems to be very susceptible to rust and the prognosis must be for widespread tree death.

Sources of inoculum

The severity of damage, the absence of reports of this conspicuous disease prior to a few years ago and the high disease impacts in a wide range of age classes, including trees more than 50 years old and 30–35 m high, are very strong indicators that *U. tepperianum* has only recently been introduced into East Timor. Reports of the fungus in the literature are most commonly on *Acacia* spp., however there are reports of the pathogen on *Albizia/Paraserianthes* from Sabah (Anon., 1993), Papua New Guinea (Shaw, 1984) and the Philippines (Braza, 1997).

At the outset of this consultancy it was considered possible that the pathogen could be the same as that on acacias, in which case Australia would be the most likely source of inoculum. However, inspection of roadside acacias at several locations, e.g. Liquica, Armada and Ailue, failed to find any rust infections on *A. auriculiformis* and *A. mangium*. At the latter location very heavily infected *P. falcata* was nearby. The taskforce team also reported that the rust was found only on *P. falcata*.

The likelihood is therefore that race specialisation exists in the pathogen with some strains infecting only *P. falcata* and others specialised on acacias. Detailed DNA studies of populations of the fungus from a wide range of localities and hosts could throw some light on the possible origins of the incursion. Cross-species susceptibility between *Paraserianthes* and some acacia species is still a possibility, but this genus appears to be poorly represented in the landscape, compared to Australia. Cross-species infection to other genera is highly unlikely.

For the foreseeable future, the widespread use of *P. falcata* as the ‘madre cacau’ will ensure the continued availability of inoculum to sustain the epidemic. Also, the common presence of the species elsewhere in the landscape will assure the disease as a major problem for the cultivation of *P. falcata*.
Alternative shade tree species and selection of resistant *P. falcataria*

There are many and varied cropping systems that incorporate coffee worldwide. These systems vary according to the presence of shade, management and planting densities and many other factors. It may be grown in monocultures or mixed cropping systems in which coffee is but one component of a shrub layer. Among the conclusions of the Task Force report (Anon., 2001) are recommendations to seek alternative shade species and to select and propagate resistant *P. falcataria*.

The choice of shade also varies, temporary shade being provided by a variety of species and permanent shade, where this is used, by a range of tree species of which *P. falcataria* is but one. The taskforce suggested several alternative species including *Erythrina submarbrans*, *Casuarina equisetifolia*, *Leucaena leucocephala*, *Giricidia sepium* and *Samanea saman*.

Selection of rust-resistant *P. falcataria* is another option, although this does not seem to have been attempted before. Two factors may be taken to indicate potential for this being a viable alternative.

Firstly, the impact of rust on *P. falcataria* in East Timor has been very severe and widespread in many stands. Within these stands, little between-tree variation in impacts could be discerned. In contrast, where this pathogen occurs in native acacia stands in Australia, there is typically considerable between-tree variability in the numbers of galls present. Some trees are very heavily infected and may be killed. Others bear many galls but carry reasonably heavy crowns, and yet others show little evidence of infection despite being close to heavily infected individuals. This suggests that genes for resistance to the rust exist in the host trees and their presence is a major factor in determining disease impact. Such genes occur in other rust–tree combinations, for example western gall rust of radiata pine caused by *Endocronartium harknessii* (Old et al., 1986), and phylloide rust of acacias caused by *Atelocauda digitata* (Old et al., 1999) In studies of these host–pathogen systems we have found variation in resistance at the provenance, family and clonal level and this may well exist in *Paraserianthes* with respect to *U. tepperianum*.

The second factor, consistent with the uniformly susceptible reaction to rust infection, is that the genetic base of the *P. falcataria* grown in East Timor may be very narrow. *Paraserianthes falcataria* is not indigenous to East Timor, the several sub species being native to the Moluccas, Papua New Guinea, the Bismark Archipeligo and the Solomon Islands. Furthermore, the species has been cultivated extensively for many years, without catastrophic disease outbreaks, for example as a timber production species around Yogyakarta, Indonesia. It seems likely that the original introduction of the species by the Portuguese colonists may have consisted of a small quantity of seed, possibly from very few mother trees. From such an introduction, the rest of the trees grown in East Timor have probably been derived. Although the above is speculation, molecular technologies can test such a hypothesis.

It would be possible to import a structured sample of *P. falcataria* germplasm from the species’ native range in the Solomon Islands, Papua New Guinea and eastern Indonesia for field testing in one or more high disease impact sites in coffee areas, to determine whether there are disease-resistant genotypes.

Management strategies to reduce rust impacts

As indicated above, and in broad agreement with the findings of the taskforce, management strategies fall into three categories:

1. Assessment of the impacts and progress of the rust epidemic, especially in regard to crown damage and tree mortality so that, where necessary, salvage logging can be carried out. Decisions can then be made on those coffee plantations that can be rehabilitated and those that will need to be replanted.

2. Selection of alternative tree species that can be planted during rehabilitation or replanting of affected plantations.

3. Selection of resistant *Paraserianthes falcataria*.

Impact assessment

Where the disease has already resulted in significant numbers of dead trees, felling shade trees and replanting with alternative shade tree species is clearly a priority. It is, however, essential to systematically assess the current condition of selected plantations in each of the main affected coffee-growing areas and to derive baseline data on which the progress of the epidemic can be assessed. Plots need to be established and assessed at three-monthly intervals for at least two years with records being kept of crown condition, evidence of crown recovery, crown dieback and tree mortality.

Records would be kept on a stand and individual tree basis by trained observers using agreed criteria. Such data could then give a means for estimating the likely impacts of the disease across the whole East Timor coffee estate and for planning rehabilitation or replanting of individual plantations with both coffee and shade trees.
Where salvage logging is to be carried out, advice will be needed on minimising disturbance and erosion on difficult steep sites. Only simple equipment, such as axes and perhaps chainsaws, will be available, unless a large investment in specialised equipment in the hands of contractors is made. As the removal of trees will be expensive, any possible value-adding through wood utilisation must be sought. Trees close to roads could be felled and logs extracted for local sawmilling. The species has very light, soft wood that is not suitable for outdoor or structural applications. In Indonesia, the timber is used for making rough furniture, and internal cores of plywood doors. Defect-free sawn timber can only be obtained if trees can be harvested alive. Standing dead trees are rapidly invaded by saprophytic fungi and stem-boring insects. Even if large stems are removed from the site of salvage operations, large volumes of branch wood will remain to interfere with subsequent planting operations and it may be necessary to burn this coarse woody debris on the site.

An adaptive management approach is needed whereby information, on the severity of the epidemic, rate of mortality and improved knowledge of site clearing and rehabilitation methods, can be rapidly incorporated into practice.

**Alternative species**

Currently the only species, apart from *P. falcata*aria, used to provide shade for coffee plantations in East Timor is the native *Casuarina junghuhniana*. Of the several species recommended by the taskforce, *C. junghuhniana*, *Leucaena leucocephala* and *Sesbania sesban* seem to be prime candidates. Although *C. equisetifolia* was recommended by the taskforce, experience suggests that it is unlikely to perform well above 700 m. It would be important to obtain cultivars of *L. leucocephala* resistant to the leucaena psyllid, *Heteropsylla cubana*. An example is the advanced-generation hybrid KX2 between *L. leucocephala* and *L. pallida* (Hughes, 1998).

Other potentially useful shade species include *Casuarina oligodon* and *Grevillea robusta* (both suitable for high elevation sites at altitudes greater than 1000 m above sea level). Ideally, several alternative tree species will prove to be useful and can be matched to site and environmental parameters, thereby avoiding future reliance on one or two species to provide shade for coffee plantations.

Seed of the different species for evaluation in East Timor, and guidelines for raising the different species and establishing field trials could be provided by CSIRO’s Australian Tree Seed Centre via the ‘Domestication of Australian Trees’ project (http://www.ffp.csiro.au/tigr/atscmain/whatwedo/projects/dat/index.htm).

**Selection of rust resistant *P. falcata*aria**

The suggested approach would be to assemble a range-wide collection of seed from the natural populations of *P. falcata*aria. From each natural population a number of unrelated mother trees would be collected. This would provide a comprehensive sample of the gene pool of the species, likely to encompass any genetic variation in disease resistance. If resources do not permit a comprehensive collection from natural stands, then attempts should be made to obtain, through networking with other institutions in Indonesia, Malaysia, Papua New Guinea and the Solomon Islands, representative samples of seed with as much information as possible attached as to their origin.

Selection for rust resistance would be done concurrently with selection for other required traits (vigorous growth and good survival under East Timorese conditions) by planting seed in two or more replicated provenance trials. Each trial would occupy about 2 ha of land. With the cooperation of farmers, it may be possible to establish trials over existing coffee plantations where the cover of *P. falcata*aria has been lost to disease. It would be essential to have a reliable source of inoculum to ‘challenge’ the newly introduced material. Mature *P. falcata*aria trees with large numbers of viable galls in their crowns would be retained in the immediate vicinity of the trials to provide inoculum. Differences in disease resistance would become apparent very soon after planting the trials, possibly within one year and reliably within two years from establishment of the trials.

Depending on the characteristics of the germplasm included in the design, the trials would provide information on provenance variation in rust susceptibility, as follows: whether significant differences in rust resistance occur in the species and what form this takes, e.g. fewer, smaller galls or no disease; and whether some provenances contain more rust-resistant individuals than others.

By culling out highly susceptible individuals and retaining resistant individuals, such a field trial could be converted to a seed production area and provide seed with good rust resistance and other silvicultural qualities for decades to come.

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References