Final Technical Report
Sandragon Wilt Disease, Seychelles

February 2004

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Contents

Summary

Activities and outcomes of a joint visit from the 23 November to 2 December 2003 are described. We examined trees at field sites established previously in Mahé and Praslin and visited Fregate for the first time. Discussions and field visits were made with representatives from the Ministry for Agriculture and Marine Resources and the Ministry for Environment. A final workshop was held at which the results and conclusions of the technical aspects of the TCP were presented. This covered previous inputs by Dr Boa and Ms Nash in April and September 2002.

Sandragon wilt is a fungal disease that has existed in Malaysia and Singapore for many years. There it is known as angsana wilt. We also note mukwa wilt, a clearly related disease of *Pterocarpus angolensis* known for over forty years from Zambia and Zimbabwe. It is not clear how sandragon wilt disease got to the Seychelles or indeed if it was introduced in the first place. One theory is that the fungus was already present on the islands in a non-pathogenic form prior to the current disease outbreak in 1998. We do not know why it may have become pathogenic though stress is one suggested trigger. Much attention has focused on the increased abstraction of water on Mahé, for example, and consequent adverse effects on sandragon trees in water catchments.

A number of ambrosia beetles have been identified from sandragon trees affected or killed by the wilt disease. Of these, only the timber borer (*Euplatypus parallelus*), a confirmed vector of the wilt disease in Singapore, attacks healthy or recently infected trees. Until proven otherwise, it is safe to assume that it has assisted in the within and between islands spread of the disease. This timber borer was first recorded in 1985 and *P. indicus* (sandragon) was one of several exotic tree hosts.

The leafminer on sandragon has attracted much attention on Mahé. It causes notable visual damage but it is not killing the trees. We expect these attacks to decline in time as natural control mechanisms begin to take hold. The benefits of training people in tree health are clearly apparent. Extremely useful data has been obtained from observing selected trees at marked sites. The ability to identify trees under threat is an important aspect of planning an effective strategy for disease damage limitation.

There are more grounds for optimism about the survival of sandragon trees on Praslin for example, though the disease is widespread Mahé and other islands (e.g. Fregate and Round Island). Although significant numbers of sandragon trees continue to die it is also apparent that a confusion in distinguishing seasonal leaf drop on healthy trees has exaggerated the impact of the disease. The mature trees in the centre of Victoria had healthy crowns and lacked the wilting foliage and weedy regrowth seen clearly for the first time on diseased trees declining in nearby areas. The discovery of the disease has prompted a much closer examination of sandragon trees. As a result of this TCP we are able to assess more accurately which ones are diseased. This highlights the importance of observing trees over an extended period of time to avoid precipitate action. There is a need to continue observations of selected trees, as recommended in this report.

Experimental fungicide treatments based on the successful methods used against takamaka wilt have recently been started on Fregate and are a useful option for protecting high value sandragon trees. These trials need to be carefully monitored and protocols agreed for treating selected trees.

We delivered two keynote presentations at a final workshop held in Beau Vallon and Dr Boa gave television, radio and press interviews to state the above conclusions and to acknowledge the collaboration and support of staff in the Seychelles with regards to this TCP.

We would urge all officials to closely examine these conclusions and the evidence on which they are based. Significant progress has been made in understanding a complex problem and in identifying the means of dealing with it, and similar problems, more effectively in the future.

Previous work and reports

Dr Boa visited the islands in April 2002 and September 2002, when he was accompanied by Ms Paula Nash, also of CABI *Bioscience*. Here is a list of previous reports and other relevant documents:

- **First Mission Report, May 2002**
Author: Eric Boa

1. TERMS OF REFERENCE FOR FIRST VISIT
2. CONSULTANCY VISITS
3. MEETINGS AND CONTACTS
4. LOCAL COORDINATION AND PROJECT MANAGEMENT
5. SANDRAGON DISEASE: STATUS AND SYMPTOMS
6. SAMPLING AND DISPATCH OF SPECIMENS
7. MONITORING SANDRAGON DISEASE
8. EQUIPMENT
9. TRAINING COURSE, SEPTEMBER 2002
10. SUMMARY OF PROGRESS

- **Second Mission Report, September 2002**
Authors: Eric Boa and Paula Nash

1. TERMS OF REFERENCE FOR SECOND VISIT
2. SCHEDULE AND STAFF INPUTS
3. TRAINING COURSES
4. MEETINGS AND CONTACTS
5. LOCAL COORDINATION AND PROJECT MANAGEMENT
6. STATUS OF SANDRAGON DISEASE
7. MONITORING SANDRAGON DISEASE
8. EQUIPMENT
9. SUMMARY OF PROGRESS

APPENDED DOCUMENTS

Tree Health Courses: general report and outline of courses

Course feedback

Participant Details

- **Tree Health Courses 'manual'. November 2002.** An expanded and standalone report with copies of presentations. *Authors*: Eric Boa and Paula Nash

- **Sandragon Disease: Update of Current Knowledge. November 2002.** Written for a general audience. *Author*: Eric Boa

This was the first and only visit on the TCP by Dr Kirkendall. A previous report on insects collected from sandragon has been updated and included as Annex 5.

- **Report on bark beetles and timber borers (Curculionidae, Scolytinae and Platypodinae) collected from the Seychelles. Updated January 2004.** *(original version August 2003)*

Early history and origins of disease

It is now six years since three sandragon trees died 'suddenly' at La Plain (St Andre) in the south of Mahé. This and the subsequent death of almost 40 trees from 1998 until 2000 at nine locations throughout the island, signalled the arrival of disease not recorded previously in the Seychelles. Angsana wilt, from the local name of *Pterocarpus indicus* in Malaysia, has been recognized, however, for more that 130 years. All the available evidence clearly indicates that the same disease is affecting sandragon in the Seychelles.

Although angsana wilt has been known for many years it was not until research by Drs Pim Sanderson and Fong Yok King and colleagues, working in response to a serious outbreak in Singapore in the 1990s, that the real nature of the disease and how it spread first became clear. Their research has proved invaluable in our much more limited investigations of sandragon wilt. It must be remembered that tree diseases in particular require lengthy periods of time before key features can be established.

There is another disease related to angsana and therefore sandragon wilt, occurring on *Pterocarpus angolensis*, a native species of woodlands in southern Africa. Mukwa wilt has been observed in Zambia and Zimbabwe, and although this has been less well studied in comparison to the Singapore research programme, there are useful accounts of the symptoms and the history of the disease. Mukwa wilt has been known for at least 40 years. One notable feature of mukwa wilt is the failure to note any observed timber borer or bark beetle activity in the two papers we have seen on this disease.

There has been much speculation about the origin of sandragon disease and most appear to favour the theory that it is an introduced disease. This idea is supported by the regular shipment of goods from Singapore, including timber which may have been infected with *Fusarium oxysporum*, the fungus that causes angsana wilt. Furthermore, timber borers carrying the fungus could have been carried in containers, wood crating or pallets. There no strong evidence to support the introduction of the fungus from the African mainland, though *Pterocarpus angolensis* is a valuable timber and it is possible that artefacts and handicrafts made from this wood could have been brought to the Seychelles.

Much less attention has been given to another theory, that the disease has been present in the Seychelles for many years but without causing any noticeable damage. There have been unconfirmed reports of sandragon trees dieing before 1998 though exact details are vague. We note from other research that non-pathogenic forms of *Fusarium oxysporum* can co-exist peacefully (as endophytes) with both woody and herbaceous plants. The obvious question to ask is both how and why such forms would become pathogenic.

The 'how' is more difficult to answer, though clearly mutations and genetic changes would have to be involved. The 'why' is more easy to speculate on, though equally difficult to investigate and confirm or reject possible explanations. The speculation concerns the vastly increased abstraction of water on Mahé, where demand has soared in recent years. Sandragon is an important tree for water catchment areas and there have been repeated suggestions that trees have become stressed as groundwater resources have diminished. It is this stress that may have triggered the

Although the scope for research on *Fusarium oxysporum* and sandragon disease is limited, Dr Boa and CABI *Bioscience* are working with a colleague in the USA to determine the relatedness between isolates from the Seychelles and pathogenic strains from Singapore. We expect the results to show whether these are two distinct populations or whether it is possible that the fungus could have been introduced from Malaysia or Singapore.

Resolving the origin of sandragon disease might appear to have little consequence now that it is so widely distributed in the Seychelles, but it will emphasise both the need for effective quarantine and the need for regular surveillance and vigilance. The present TCP has tackled all three key topics and achieved important progress through training and other support.

Status and Symptomatology

Our detailed observations are contained in Annexes 3 and 4. A separate report on timber borers and bark beetles appears in Annex 5. Important points to note based on the findings and activities of this TCP are as follows:

STATUS

- the disease continues to kill trees and have a serious impact on tree populations
- it is present and causing serious damage on Mahé and Fregate
- trees on Praslin are largely healthy though we believe the disease is present; there are few indications, however, that damage will increase in future
- the disease is also present on La Digue, Round Island and Moyenne
- mature individual trees in and around Victoria now appear healthy and are growing vigorously; previous fears that they were about to succumb to sandragon disease have so far proven unfounded
- although the long-term impact of heavy leafminer infestations is still unclear, leafminers are not killing trees

SYMPTOMS

- there has been initial confusion concerning which trees are unhealthy and those which are temporarily without leaves because of seasonal growth fluctuations; the key symptoms of sandragon wilt are most clearly seen when trees are actively growing
- local capacity in symptom recognition and interpretation has been substantially improved following a training course held in September 2002
- the early and distinctive features of sandragon disease include a yellowing and wilting of foliage; these symptoms can be difficult to see at the best of times (during active growth and leaf flush) and absent at other times of year when leaves are not being produced
- vascular streaking is a widespread and common symptom of trees which exhibit both the distinctive yellowing and wilting and those that do not; we have not seen extensive staining in trunks in the small numbers of trees that were examined
- damage by leafminers has been confused with sandragon disease and misinterpreted generally; heavy attacks do lead to a yellowing of crowns but this is an overall effect and different from the more localised wilting and yellowing that occurs in diseased trees

An extensive library of digital photographs is available which illustrates these distinctive features and will help distinguish symptoms that superficially might appear to have the same origin or cause.

The data from the sample or monitoring plots have proved most useful in clarifying the early confusion about symptoms and impact of sandragon disease. It is essential that these data are studied carefully so as to design an effective plan for mitigating the impact of the disease. Some monitoring should continue and does not require major resources. Trees have only been assessed over a 12 month period and it would be beneficial to keep track of key trees, as suggested in Annex 3.

We are most grateful to Mr Randy Stravens and colleagues for summarising observations in an earlier report. This formed the basis for the table presented in Annex 4.

Cause and spread of disease

The widespread public concern about sandragon wilt has been reflected in a keen desire to know its implications for an important tree on the Seychelles. A number of theories concerning the origins and causes of the problem have emerged. These briefly are as follows:

- trees are stressed by adverse environmental conditions, particularly drought
- introduced timber borers are spreading a fungus and also causing damage to trees
- leafminer attack weaken trees and hasten their death
- a fungus introduced from Asia in or around 1998 became well established and spread throughout the islands

When diagnosing a disease of a tree it is often easier to state what is less important. We do not dismiss the potentially debilitating effects of repeated leafminer attacks, but the balance of the evidence suggests that such attacks are unlikely to have any major effect on the health of trees.

All the available evidence from our investigations in the Seychelles and from published work on *Pterocarpus* disease, strongly supports the theory that sandragon wilt is a fungal disease and that the most likely cause is *Fusarium oxysporum*.

It is vital that we perform pathogenicity trials which unfortunately could not be undertaken during this TCP. CABI *Bioscience* is making efforts to organise such trials and we also hope to gain useful evidence from a comparative study of *F. oxysporum* isolates by a US colleague.

We have speculated elsewhere in this report about the role of *E. parallelus* as a vector of the fungus and the possibility of fungus transfer via root contact. *Fusarium* is a soil-borne pathogen and requires active movement by some physical means, either by vector, in plant material or in soil. We have no doubt that ambrosia beetles and principally *E. parallelus* are spreading sandragon wilt in the Seychelles, as they do in Singapore, though we lack physical proof. That should not be difficult to obtain once the long delayed new plant pathology laboratory is up and running.

To summarise what we believe is happening in the fungus-tree-timber borer triangle, here are some key questions and answers based on what we know about the beetles (Annex 5):

- Do they vector sandragon wilt disease? PROBABLY
- Is there confirmed evidence they can vector the fungus? YES
- Are beetle attacks always found on diseased trees? NO
- Do they (the beetles) kill the tree? NO
- Will heavy attack preclude tree recovery from sandragon disease? PROBABLY YES

There is an important related question of whether it is useful to control *E. parallelus*. The short answer is that this would be impossible given that no specific attractants are known and the beetle feeds on other hosts. It is not a sandragon-specific timber borer. Since the disease is now established and may in any case spread locally by root contact, efforts to mitigate its effects should concentrate on a strategy of identifying high value trees and applying suitable fungicide treatments.

Final Workshop

A successful workshop was held towards the end of this visit. Drs Boa and Kirkendall presented their findings, taking particular attention to address various theories about the cause of sandragon disease and the role of the beetles. Dr Boa gave a series of media interviews, for television, radio and newspaper. See Annex 6 for copies of both presentations.

Future work

Key points are listed under three major headings.

Disease management

- confirm protocol for fungicide treatments, taking account of preliminary results from trials established on Fregate and noting general results of similar treatments on takamaka
- identify key trees that would benefit from treatment, for example those in Mission
- select trees and plots where assessment of tree health can be continued for at least one year, preferably two

Capacity building

- re-establish plant pathology laboratory
- examine ways in which training on tree health might be continued or incorporated into schools (for example – as proposed by one participant who was a teacher)

Further investigations

- pathogenicity trials with *Fusarium oxysporum* (currently attempting in UK, but should also pursue in the Seychelles)
- compare range of *Fusarium* isolates (in hand)

Acknowledgements

We are grateful to Mr Antoine Moustache and his colleagues for their support and organisation and for the effective collaboration of both MAMR and MOE. Many individuals have taken part in this TCP, as noted in previous reports. We want to particularly note the contributions of Helda Antoine, Randy Stravens, Samuel Brutus and for Andy Roucou's assistance with trips to Fregate and Round Island. We thank Beate Sachse and Steve Hill for their kind help with visiting Fregate and visits to sites.

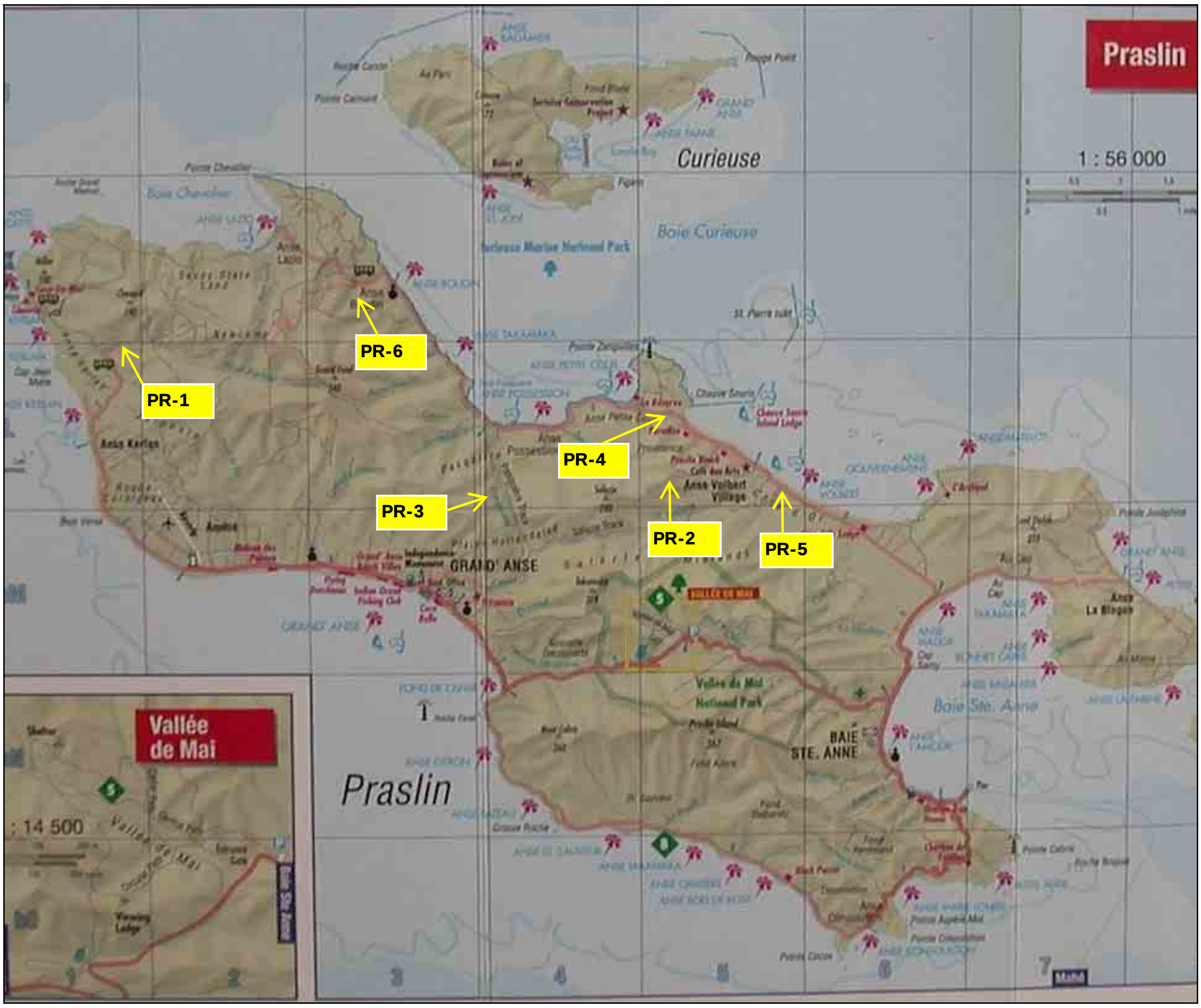
Mr Ravi Subramaniam provided expert support in arranging visits and ensuring that the final workshop went smoothly. We hope that we can continue to make progress in learning more about this disease.

ANNEX 1
MAHE: observation sites

See separate sheet for more details. Codes are given by Eric Boa and are used to identify photographs taken at various times between April 2002 and November 2003

PRASLIN: observation sites for sandragon disease

See separate sheet for more details. Codes are given by Eric Boa and are used to identify photographs taken at various times between April 2002 and November 2003



ANNEX 2

Site information, including codes, where diseased sandragon trees were observed

Mahé

MH4 was originally given to a site described as 'first site going up Sans Souci road (from Victoria), on the left, next to parking place for view over Victoria'. This is not a sandragon site, and MH4 has been reallocated to note the house owned by the chairman of the Seychelles Marketing Board.

CODE	SITE	DETAILS
MH01	MISSION	*Oldest trees in Seychelles, avenue leads to view over sea. Historic site.*
MH02	SANS SOUCI, UPPER	*Charcoal burner site, trees both sides of road that bisects this site; now more or less cleared on the eastern side with apparently diseased trees above.*
MH03	SANS SOUCI, MIDDLE	*Reached first on the way up from Victoria; plot defined on the sloping side by corner of road. We first talked about permanent plots here in April 2002 when there was no obvious sign of disease; all trees felled by November 2003. However, diseased trees occur on the periphery of the cleared area. Some more or less dead trees are still standing.*
MH04	PORT GLAUD	*Going up the hill, towards Mission, there is a sweeping curve with a large house in a guarded compound on the right. Currently occupied by the Seychelles Marketing Board chairman. Within the sweeping curve lemon grass is being grown. Single tree at gates not noted until November 2003*
MH05	FAIRYLAND	*On slope that goes past new house being built.*
MH06	MAISON ROUSSEAU	*Mr Rousseau's house, north of Victoria*
MH07	MT SIMPSON	*Mt Simpson, bottom of road on way to Mr Rousseau's house. N of Victoria*
MH08	PORT GLAUD	*Foret noir road; sample plot visited first with Pierre and Cliff*
MH09	MORNE BLANC	*Further up hill, beyond MH8, on corner where lots of dead trees exist. (east of MH4)*
MH10	NEAR PGR	*South on way to La Misere road (**not**, as noted before, the 'Sans Souci road' – this goes via Mission to Port Glaud).*
MH11	LA MISERE ROAD	*Hairpin bend as you descend towards Plant Genetic Resources building. There are three distinct populations: one in the river bed (mostly dead); trees further up the river valley below the low stone wall; and a third population on the left of the road that you encounter before you descend into this hairpin.*
MH12	LENIOL WATER CATCHMENT AREA	*[Check with Sam that this is the correct site.] First site visited on Tuesday, 25 Nov 03. Big cut trees, viewed trees slightly up the river bed, house on left approaching the depression, metal barrier discarded in water. We took pictures of trees with regrowth (very clumpy). First visited November 2003*
MH13	LA RETRAIT	*Big tree by Vaithi store. Road going up the hill. Schoolchildren were waiting to catch a bus when we first visited in November 2003*
MH14	MANRESA	*Big single tree on east side of road, heading north from La Retrait. Could be further along. We think there was a ?church beside the tree – well at least a hall with corrugated roof.*
MH15	BEL AIR	*Large single tree in residential home, heading downtown Victoria, first seen on way to final workshop in November 2003. Excellent mixture of classic wilt symptoms.*
MH16	PROVIDENCE, CHURCH BY AIRPORT	*Red roofed church at end of old road leading from Victoria to airport. Granite rock in background with trees going up the slope.*

Praslin

CODE	SITE	DETAILS
PR01	Mont Plaisir	*End of road, bunch of old trees, close to airport, north. Originally labelled 'New come'. Where the buses turn.*
PR02	Salazire	*Site at end of cul de sac. Houses on one side and small stream present below. Up steep road to get there first. East side of island. (Check spelling ? Salazie)*
PR03	Zimbabwe	*First ever site I went to; all healthy trees. This name does not appear on maps ERB or LK have seen. It is a hilltop site*
PR04	Petit La Cour	*On way to beach, the site where we found the first 'wilted' branches. On corner of small side road with gate on right.*
PR05	Vallé La Reserve	*First viewed in April 2003 and by November 2003 house had been constructed. Big, mature trees.*
PR06	Anse Boudin	*Site of oldest tree (if I remember correctly from Mason) in Praslin. Short drive up to cul de sac; had a wall painted red with 'music' daubed.*

La Digue

CODE	SITE	DETAILS
LD01	Giant Rock	*Past takeaway lunch spot and Giant Rock. Stop at base of hill and climb for 20 minutes or so. Group of trees growing amongst rocks.*
LD02	Near Quay	*Unreachable site (path closed) to left as you come off quay. Up side of hill.*

Ile Rônde

CODE	SITE	DETAILS
IR01	That's it	*Only one site since this is a tiny island*

Fregate

CODE	SITE	DETAILS
FR01	'inland stand'	*Large area of sandragon trees. First site that ERB and LK visited in Nov 03; area of dead or almost dead trees next to still healthy ones. The latter included six injected trees, the result of an initial and emergency step taken by 'forestry' and managed by Andy.*
FR02	Au Salon	*Monospecific stand; major problem started in Jan 03 when 20 – 30 trees died, but initial death of one tree occurred as early as 2001. Site visited by LK.*
FR03	South side, along road	*Patch of four trees, two dead. Site visited by LK*

See Annex 1 for locations of sites on Mahé and Praslin.

ANNEX 3

Observations of diseased trees, November 2003

These notes were prepared by ERB with later comments added by LK. They include sites on Mahé, Praslin, Fregate, Round Island + Moyenne (LK only). See previous reports by ERB for earlier information about disease status on the islands. This was the first visit by ERB and LK to Fregate. ERB has previously visited sites on Mahé, Praslin and Round Island as well as La Digue.

LK: Larry Kirkendall. V1 – visit one in April 2002. V2 – visit two in Sept. 2002. V3 – visit three in Nov./Dec. 2003.

Monday, 24 November

MH3 *Sans Souci*

All looked healthy at VI but by V3 most trees (ca 20) had been cut down because of danger to passing motorists. Sandragon sheds its branches quickly once they've died or are weakened. We saw old but still active borer tunnelling in the big cut trunks near to the road. Across the far side of the plot (downhill, away from the road), huge amounts of frass could be seen on vegetation adjacent to some big trees. This frass was coming from active borer tunnels in the lower part of the trunk, on one or two buttresses per tree. From a distance, the trees appeared healthy, but on careful examination we could find some dead and dying patches of foliage and could see streaking under the bark of several small branches. Foliage symptoms (especially colour change) are often difficult to discern and even more difficult to photograph, especially against the light, as was the case here. A few lower branches were removed and photographs taken.

All borers extracted from these live and dead trees were *Euplatypus parallelus*, though one *Xyleborus* was found walking on dead cut wood (vouchers collected).

MH2 *Sans Souci*

This site has attracted much public attention because it is next to a busy road and many trees died early on.

One of the first sites where the disease was observed, but little of scientific value has come from examining these trees. By V3 this plot was more or less devoid of trees towards the west side of the road's main direction (i.e. to the right as you go towards Mission). Further up the slope, sandragon trees could be seen with apparently dead branches. Some care must be taken in deciding whether bare branches are dead or simply dormant; in this case other parts of the affected crowns, as well as other trees, were actively flushing. More conclusively, we could see unhealthy patches of foliage. These 'wilted' leaves are in truth difficult to locate, even more so when all observations are being made through binoculars. Trees to the east of the road (i.e. down the slope) are still standing but also dead.

MH1 *Mission*

This site of high historical importance has a magnificent avenue of sandragon trees leading up to a small covered area overlooking the ocean. The trees have been hacked at their base to show visitors the rapid bleeding that is characteristic of sandragon. When examined at V1 there was no obvious sign of underlying staining in the trunks, which might indicate that trees were being attacked by the disease. Cursory examinations did not reveal any beetle attack. The crowns were sparse and had large areas without leaves yet there was no other indication that disease processes were taking place. At V2 we found vascular streaking in several trees, revealed by stripping back the green bark tissues of small stems. As we have witnessed in many other trees, this distinctive red, sometimes much darker streaks, did not extend into the sapwood.

While we were concerned about the vigour and general health of trees at V1 and V2, there was no conclusive proof that the trees were in any immediate danger or decline. Following this most recent visit we now confirm that sandragon wilt symptoms are present and that timber borers are active. Photographs taken from a distance clearly show that the wilt has begun to seriously affect trees towards the car park end of the avenue. There remains a remote possibility that crowns may still flush but this seems unlikely given that trees nearly to the covered area have green and healthy crowns. We also saw characteristic yellowing of foliage and shrivelling of leaves on one tree with a serious infestation of beetles along one buttress. Always remember that yellowing of foliage *without* noticeable dieback or browning and shrivelling of leaves could be due to severe leafminer attack.

It is essential that EACH tree is carefully monitored and its health assessed using damage scales applied to other sample plots. Given the importance of these trees they are an obvious priority for fungicide treatment.

MH11 *Grand Anse, hairpin bend*

Previously (V1 and V2) there was confusion about the health status of these trees. Trees with open crowns have since been seen to produce leaves and this has helped to establish a much clearer pattern of diseased trees at this site. Differences emerge between those more or less dead trees in the river bed below the road, the heavily leaf-mined trees further up the slope next to the road (but otherwise healthy), and the distinct patch of dead and almost dead trees further up. It is not clear why the trees sandwiched between the two obviously diseased groups are still apparently healthy, though there is one tree with diagnostic wilting on the lower section of road and vascular streaking is present in trees with symptomless (re. the wilt disease) crowns.

We speculate that disease spread may have been facilitated by root contact in the damper river bed, conditions which could be more conducive to disease development. LK checked the trunks of trees along the road and could not find any signs of borers, further evidence of their importance in disease transfer within tree populations. The middle group of 'healthy' trees had a distinct yellow tinge to the crowns which are almost certainly due to heavy leafminer attack. Note that the leaves still stay on the tree.

NB We re-visited the site on the 28 November when better light conditions existed for taking photos.

Tuesday, 25 November

MH12 *Leniol Water Catchment*

First visit to this site. We viewed a number of trees with regrowth or delayed leaf flush in the crown but would hesitate to call these 'recovered' since their overall appearance suggested trees in an advanced stage of decline. The large tree numbered PL6 (64 cm dbh) was recorded in September by the technicians as "maybe dead"; it now has a full crown (photographed), but also has heavy active attacks of *E. parallelus* on three quarters of the circumference of the lower trunk. We saw signs of typical leaf-clumping and sprouting of heavily leaved branches from the trunk, both of which we came to associate with unhealthy trees.

The trees at this site present an excellent opportunity for determining whether heavy borer attack of trees with full crowns is a predictor of ultimate tree death. PL7 is the nearest tree to PL6, only 2 m away, and was recorded as 'dead' in September. We confirmed this. There was no evidence of 'recovery'. Another affected tree (PL#?) had been more or less cut down by the small bridge that went over the river. Driving back towards Victoria we stopped to take pictures looking back to MH12 and saw patches of dead trees, providing further food for thought on the importance of root contact for disease spread within groups of trees.

MH13 *La Retrait*

Big tree next to Vaithi store, and first time we had observed it. Borer activity in the main trunk and heavy leafmining. No obvious wilting on this tree but we became more confident in assessing the shape of crowns, gaps in branch architecture at the crown periphery and the notion of 'weedy growth' – so called because the new leaves occur on branches with few leaves, low vigour, sometimes with dieback. Other parts of the crown are green and healthy.

Interpreting the history of disease development through crown appearance is far from easy, though often the only available means of assessing health status. Through experience of observing other trees and careful on-site checks with healthy neighbour trees, it is possible to build up a picture of what may have happened in previous months or even years. The crown in this tree had a distinctly lop-sided and uneven appearance, which when combined with the 'weedy growth' feature suggests that there is disease present but without any indication of the future fate of this large tree.

MH14 *North of La Retrait in small residential area (Manrese)*

Big, mature tree with similar features to that seen at MH13. First visit.

MH15 *Bel Air*

First observation and not seen until Friday, 28 November. Very distinctive symptoms of the disease– distinct wilt, browning of leaves in a mature tree, weedy growth: perhaps a hint that this could eventually die. This is the tree that most closely resembles the two pictures of a mature angsana tree with wilt in the Sanderson et al paper. MH15 otherwise still looking in reasonable shape providing some evidence for the moment that mature trees may be able to withstand a disease attack.

AND

ERB photographed trees along a route from Mont Fleuri (including the large one by the teacher training college) towards the centre of town. These are intended for future reference purposes. These haven't been coded but all are easy to locate. All looked well apart from a miserable, young tree in the car park opposite the Pizzeria, probably suffering from physical or physiological stress.

Wednesday, 26 November (Fregate Is.) and Sunday, 30 November (LK)

FR1 *Healthy and diseased inland stand (EB, LK)*

Medium sized patch of dead trees. Very distinct border between those clearly dead, through transition zone of those with some regrowth or delayed sprouting and finally those still healthy. Six experimental trees are being injected by Andy from MoE and monitored. Noted the abnormal (for this time of year) abundance of fallen leaves just within the living portion of the patch, not all of which are yellow. Could definitely see wilted and shrivelling leaves higher up and very distinct patterns of last-gasp sprouting from these trees.

The unusual pattern tells all: trees in their last throws and struggling gamely to survive. If we remember correctly, we also saw some evidence of heavier flowering and fruiting, though the significance of this and trees that are diseased is still somewhat vague. Could be that sandragons flower more intensely in some parts of the crown according to the aspect of the tree (exposure to sun, wind?), though we both favour the 'I'm about to die therefore I will flower more' theory.

FR2 *Fregate Island, Au Salon, almost completely dead monospecific stand on south side (LK visit)*

The first sandragon death in this patch took place in 2001; the tree was cut and burned, as were two nearby sick trees. In January 2003 one tree in the corner of the patch died, then 20-30 were noticed to be dead, and the epidemic snowballed until several hundred trees (over 90%) on both slopes are now dead, with a thin belt on the ridge having trees with leaves but which appear unhealthy (LK has photos of the patch).

Some of this latter group of trees do have borers, as do all of the dead trees. Those trees directly bordering the dead trees often had clumped foliage (the so-called 'recovery phase', but more commonly associated in other trees with a jerky response to severe damage) and a few "bleeding" borer entrances. *E. parallelus* was collected from the tunnels. The early stage trees here (those with original leaves but some dead twigs or branches and some wilting leaves) have no or few visible beetle attacks; re-foliated trees usually do have beetles and can have small patches of beetles, and trees with only a few foliated branches are heavily colonized and producing lots of frass (boring dust). The tree killing here definitely spread uphill on both slopes (also true at MH11?), suggesting that water transport is not necessary for spread of the disease. LK has an aerial photograph of this L-shaped patch; Beate Sachse, the resident ecologist, has an earlier aerial photo.

FR3 *Fregate Island, along road to south side (LK)*

We stopped briefly to examine four isolated trees where two were clearly dead and had borers, one was sick but had no obvious borers, and the fourth, nearby tree had some active borer tunnels. Both long-distance spread by the beetles and local spread by root contact would seem to be indicated here.

No code *Fregate, isolated tree 200 m down road going back towards villas.*

Patch of 300-400 dead trees, many dead branches on ground, lots of seedling regrowth, a mixture of native and exotic trees (have photos of patch). Beate Sachse first spotted symptoms and apparent disease in January. Every tree died here. Large, spreading tree in the open, with no central trunk (had been killed at an early age). Some fruiting on outermost branch. Basically, it looked 'normal'. On closer inspection, though, the following possible symptoms were noted. Some outer branches wilting, a few have partially to totally yellow leaves and dark streaking in the vascular tissue. There were a few dead branches, and these had *E. parallelus* (judging from hole size, no vouchers). Fairly heavily leafmined. **This tree should be monitored and carefully assessed**.

No code *Fregate, sandragon patch of dead and dying trees: S 4^{o} 35.164', E 55^{o} 56.503'*

A cluster of dead and dying trees. Examined one side of patch, where one tree has a nestbox numbered 31. Here, there are two trees with overlapping crowns (photographed), with leaves but both with some symptoms, 2.5 m apart. Both trees have some bare twigs. The smaller is 1 m from a small dead tree (with many borer entrances) but itself has no beetle attacks. The larger ("#31") is 45 cm dbh and has *E. parallelus* tunnels on about 50% of the circumference (the colonized side of the tree is 2m from a dead tree). Much frass from these tunnels, and the wood on the colonized part of the circumference is dead. The first branch on the "dead" side has yellowing (but not wilting) leaves. The next branch up has fewer than normal leaves and some slight wilting. There is some flowering at the top of the tree (difficult to see though, very tall tree with large crown).

Thursday, 27 November (Praslin Is.)

PR2 *Salazire*

Big tree (>1 m dbh) visited V1 and V2, when it looked a lot worse. In September, this tree had had perhaps only half of its leaves. At V3 we see luxurious crown with good growth, but tell-tale signs of bare branches around the periphery. Not enough to even suggest that further loss of leaves will occur-- are isolated, mature trees less likely to succumb? Some beetle damage in a 30 cm diameter fallen branch and in a few exposed, ca 10 cm diameter roots, but nowhere on the trunk as far as we could tell. (Exposed roots up to eight to ten metres away from the trunk were the source of the beetles identified from previous collections.) Trees up the slope also look good.

PR5 *Vallé La Reserve*

Leafminer damage seen before but no evidence of disease at this visit (V3). Big, mature and impressive trees. Note that there has been considerable site disturbance (mostly removal of non-sandragons) yet no evidence that this has affected the remaining trees.

PR6 *Anse Boudin*

Heavy leafminer damage at V1, now looking very healthy. But beginning to notice these patches at the edge of crowns: weedy growth, almost dead branches (one assumes; should also be cautious that no leaves indicates dead branch). No borers seen.

PR1 *Mont Plaisir*

Similar to PR6.Large mature trees here. Hints that the disease could be present as revealed by the patchiness of some crowns and other signs that I'm suggesting are indicative of wilt disease – yet unlikely to take hold and kill such trees. Saw some suggestion of increased flowering and seeding though all these trees looked in good condition. No borers seen.

PR3 Zimbabwe

Seen at V1 with Mason. Bit confusing because trees were in 'dormant' phase. At V3 they were growing well, good crowns and therefore all the more convincing when I saw not only weedy growth but distinct patches of yellow leaves. (No borers found here.) Difficult to photograph because of poor light conditions.

Monday, 1 December (LK)

Round Island

This tiny island has one path which circles the island, along which sandragons are the primary planted tree. The sandragons were apparently planted at 10 m intervals along the sea side of the path. There are (or were) other large sandragons on the island, many of which are now dead. From what we have seen of visible roots elsewhere (especially PR2), and given that these are relatively large trees, LK thinks it very likely that roots are in contact between trees only 10 m apart; this remains to be proven. Previous visits by ERB and Andy Roucou (MoE) to carry out a census of the sandragon trees did not notice any borer activity. ERB saw sparse crowns in September 2002 but no signs of wilting or clear indication that trees were diseased. There was some vascular streaking in small stems.

It is possible that timber borers (i.e. *E. parallelus*) were genuinely absent or that low numbers made them difficult to find. Most of the trees along the path are now dead or clearly diseased, the latter exhibiting such symptoms as some branches bare, some branches with wilting or yellowing leaves, some branches with very clumped foliage, and slow "bleeding". LK recorded symptoms and presence/absence of borers for the sandragons along the path,. starting at the visitor's centre and walking counterclockwise. Most of the trees which still have leaves have heavy infestations of leaf miners.

Only the sandragon trees are numbered; occasionally, the tree 10 m from a sandragon is a different species. Tree 1: dead, much frass (had leaves one month ago, *fide* Andy Roucou). Tree 2: no leaves, many *E. parallelus*, sapwood still alive (weak bleeding). Tree 3: some dieback, no borers. Tree 4: one side of tree with wilted or dead leaves and a few live leaves. some bare branches, some foliage clumping. No beetle tunnels found. Tree 5: Dense leaf cover lower in crown but upper branches are bare or are losing leaves, including some of the largest branches. Found only 2 borer tunnels, both failed. The next two sandragons are dead (have beetles). The large tree off of the trail on the point has moderate beetle attacks, clumped green wilting leaves or dead, dry leaves (on a few branches). In a counterclockwise direction from that tree is one which has been mostly chopped down and which has much accumulated frass on the ground. Finally, by the buildings, a tree with no leaves and much accumulated frass.

In summary, the trees examined varied from sick to dead. Some of the trees with the earliest symptoms did not seem to have borer attacks, but all of these are within 10 m of another sick tree. Trees with advanced symptoms invariably have borers (primarily, *E. parallelus*, which can be distinguished by their larger tunnel diameters; the bark beetles *Xyleborus similis* and *X. affinis* were also collected).

These trees will be monitored by Andy Roucou to see if symptomatic trees invariably die, even if not attacked by beetles (or if all are eventually attacked).

Moyenne Island

Another small granitic island, Moyenne has had around 15,000 trees planted post 1973. There are about ten large sandragons (which predate the plantings) close to the short on the Mahé side of the island, below the path circling the island. These trees seem to be healthy but only if the occasional branch with wilting or yellow leaves is attributed to salt spray. We carefully examined all the crowns and LK climbed down to examine the bases of several. No borer tunnels were seen but I did find a large dead fallen branch with old *E. parallelus* tunnels (judging from the size, no beetles were found), so the beetles are at least occasionally if not permanently present on the island (note that these borers are not host specific).

ANNEX 4

Change in health of trees in monitoring plots (PSPs): June 2002 – May 2003

From an original report by Randy Stravens, 15 May 2003. The results are based on the diligent work of MAMR and MOE and demonstrate the successful collaboration that has taken place.

H – healthy; NS – not sure ('borderline' – possibly diseased or could be recovering); DP – disease and progressing; DD – dead or almost dead.

< indicates an increase in numbers in the healthier categories (H and NS)
> indicates an increase in numbers of diseased or dead trees.

	observation period 1 JUN-DEC 2002 (# TREES)				***observation period 2*** JAN-MAY 2003 (# TREES)				
SITE	**H**	**NS**	**DP**	**DD**	**H**	**NS**	**DP**	**DD**	**SUMMARY**
PL Le Niole (10 trees)	0	9	1	0	0	0	>6	>4	Borderline trees are now showing signs of disease; four have died. Diseased site under threat.
PB La Batie (9 trees)	9	0	0	0	0	>3	>2	>4	Healthy trees rapidly showing decline though three still borderline. Diseased site under threat
PRC Roche Caiman (11 trees)	0	10	0	1	10<	0	0	1	Still healthy site. Demonstrates the difficulty of interpreting tree appearance at one point in time.
PV Sans Souci: Val Riche (11 trees)	0	10	1	0	0	11<	0	0	Trees still borderline. Note that the tree with symptoms has now be reclassified borderline.
GB Grande Anse: G. Bois (15 trees)	0	0	10	5	4<	0	4<	>7	Even though several trees have died still four trees have reverted to the healthy category.
PM Sans Souci: Mission (11 trees)	0	9	2	0	6<	>4	0	>1	Slightly confusing picture but overall trend is towards recovery.
VP Baie Lazare (10 trees)	0	10	0	0	6<	2<	0	>2	Six trees are no longer borderline. Two dead trees indicates a diseased site though trees broadly healthy
KTP Sans Souci: Kamp Tobruk: (11 trees)	(11)	0	0	0	0	0	0	>11	Trees appeared 'healthy or recovering' in 2002. Their rapid demise suggests that symptoms may have been missed earlier.
TOTALS	**20**	**48**	**14**	**6**	**26**	**20**	**12**	**30**	

Two sites were assessed at the beginning (PLP – 10 trees; PP – 11 trees, but there is not later data of what happened.

When observations began in June 2002, 20 out of 109 trees in the 10 sample plots showed definite disease symptoms. Relatively few had died (6). Of the remaining 68 trees, a majority were in the borderline category. Three sites were healthy, lacking definite signs of the wilt disease.

By May 2003, there had been a rapid and dramatic change, though note that two sites and 21 trees were not re-assessed. Final conclusions for the observation periods are therefore based on only eight sites and 88 trees. Of these, one site remained healthy (PV) while two sites (PL and PB) showed a significant decline.

The number of dead trees increased from 6 to 30. Perhaps of more importance, however, is the confirmation of the fuzzy border between those trees which are diseased and those that are either healthy or still borderline. The proportion of trees broadly classified as healthy (categories H and NS) shows a slight decrease though it is interesting to note that the proportion of trees without any signs of ill-health (H) has increased from 20/109 to 26/88, or from 18% to 30%.

There are genuine difficulties in assessing the health of a tree based on a visual examination. While this is not the preferred method for confirming the presence of the wilt disease it remains the most common (and pragmatic) method. Even if observers are skilled in identifying the distinctive yellowing and wilting symptoms of the disease, these are only briefly displayed. There is the additional confusion caused by yellowing induced by leafminer damage, and of course seasonal leaf fall. When is a branch high in a crown dead or simply dormant? It is not easy to say.

We are much more aware of why trees change their appearance and have the information and photographs to help people interpret tree health. This is an important achievement of the project that is essential for accurate and timely responses.

ANNEX 5

Report on bark beetles and timber borers (CURCULIONIDAE, SCOLYTINAE and PLATYPODINAE) collected from the Seychelles (2003)[1]

Prepared by L. Kirkendall

Collections from PTEROCARPUS INDICUS (sandragon)

In 2003, two sets of collections of wood borers were made, during the investigation of the sandragon wilt epidemic on the granitic islands of the Seychelles. The first collections were conducted by the Ministry of Agriculture and Marine Resources (MAMR) and Ministry of the Environment (MOE) in May and July, and included material from Mahé, Fregate and Praslin. In Nov.-Dec. 2003, Drs. Eric Boa and Lawrence Kirkendall along with staff members of MAMR and MOE collected again from these three islands as well as (LK) Round Island and Moyenne Island. Kirkendall identified the bark beetle and timber borer species, and his determinations were verified by Dr. Roger A. Beaver, a retired expert on these beetles who had collected on Mahé for two months in 1985 (Beaver 1987, 1988**).** Voucher specimens are in the collections of R. A. Beaver, L. Kirkendall.

The primary conclusion is that only one species, the invasive New World timber borer *Euplatypus parallelus*, attacks healthy or recently infected trees, though other ambrosia beetles (*Xyleborus* spp.) attack later. Given that *E. parallelus* has been shown to vector sandragon-killing *Fusarium oxysporum* in Singapore, we should assume unless proven otherwise that long-distance and some short-distance vectoring of the sandragon wilt disease on the Seychelles is by *E. parallelus.*

Summer 2003 collections

Four species of ambrosia beetles were collected by MAMR and MOE from 14 sandragon trees in the summer of 2003. Besides ten trees from Mahé, three from Fregate and one from Praslin were sampled. All but two samples were from the lower or middle trunk areas and buttresses of trees which ranged from 15 to 150 cm dbh. All trees were reported to have symptoms indicative of sandragon wilt disease; two had regenerated leaves (Mahé C1, D1) three (Mahé B3, B4 and E1) were dead when sampled.

The ambrosia beetles collected were *Euplatypus parallelus* (Fabricius) (Curculionidae, Platypodinae), *Xyleborus affinis* Eichhoff, *X. perforans* (Wollaston), and *X. similis* (Ferrari) (Curculionidae, Scolytinae) (see tables). The three xyleborines have not previously been recorded from this host plant. Platypodines such as the *Euplatypus* tunnel much deeper than xyleborines, but *X. affinis* also tunnels rather deeply.

Of the 14 samples, one (Mahé B1) did not have bark beetles or timber beetles, only a beetle which is probably a usurper of ambrosia beetle tunnels, *Shoguna* sp. (Monotomidae, Rhizophaginae). Ten of 14 had *E. parallelus*, so there were three trees which had *Xyleborus* species but not *Euplatypus*; the xyleborines in these three trees were primarily *X. affinis.* We can conclude from these observations that there are primarily two ambrosia beetle species which are regularly colonizing diseased trees, *Euplatypus parallelus* and *Xyleborus affinis.*

All the scolytines and platypodines in these *Pterocarpus* samples are ambrosia beetles: females inoculate farm fungi in the tunnel systems, which are the sole source of food for both parents and larvae.

[1] *Dr Kirkendall has added new observations and modified some of the text from a previous report issued in August 2003. The same title has been used for the updated version.*

Nov.-Dec. 2003 observations and collections

Given the limited number of taxa present (as established by the summer sampling and the first sampling in November) and the size differences among them, it is relatively simple for a specialist to distinguish the entrance holes of *E. parallelus* from those of *Xyleborus* species. Consequently, relatively few collections were made during this trip. In general, vouchers were collected from each location visited where the borers were present, but not from every tree examined. Since these two groups could be distinguished by size, many trees and much bark area could be rapidly scanned visually.

These collections and observations clarified the role played by xyleborines versus the platypodine. The platypodine was virtually always present when borers were present in standing trees, and was the only species present in trees with relatively healthy sapwood. The xyleborines were normally found where the sapwood was dead (brown). Often, a symptomatic tree had one or several narrow patches of dead sapwood but most of the circumference of the tree would still have living sapwood (capable of producing red sap when injured). The living sapwood in such trees had only *E. parallelus*, and usually in much lower densities than would have in dead patches.

The platypodines are present on every island I was able to visit. However, we found no obviously sick trees on Praslin, nor did I find any on Moyenne.

One new taxonomic observation was made, for beetles in sandragon. In the dead outer bark on live trees on Round Island, I discovered large numbers of tunneling ***Cryphalus*** sp. They are very similar to, and might be the same as, the *Cryphalus scabricollis* from takamaka; elsewhere in the range of that species, several other legumes are used as hosts. The tiny entrances are impossible to see, but I had been noticing patches of tiny holes (exit holes) in bark on trunks and larger branches, holes which didn't go all the way to the cambium. I finally figured out how to find the adult beetles, by carefully tearing apart samples of the outer and inner bark. Interestingly, these seem to be doing fine in living trees, because they do not tunnel far enough inwards to trigger the bleeding defense. Because I discovered this so late (the day before I left), I am not sure how widespread they are or if they can be in trees which are not sick. I had found the same holes in sandragon on Fregate, but there I was not able to find any beetles after an hour of searching. I will have to send samples to Roger Beaver, to find out if they are the same as the takamaka beetles. If they are not, they are probably new to the Seychelles, possibly new to science. If they are the same species, then this is a new host genus for them.

The ambrosia beetles

The outbreeding, monogamous ***Euplatypus parallelus*** is one of the commonest platypodines in Central and South America, where it is native; it was introduced to Africa in the late 1800s, where it is now fairly widespread and common, and more recently to southeast Asia, from where it is spreading rapidly. It is one of the few platypodines which can breed in standing live trees, though it is normally associated with trees stressed by drought, disease, or other factors. This species is associated in Bangladesh with massive die-off of *Dalbergia sissoo*[2]. It was virtually the only ambrosia beetle I collected from these dying trees. This timber borer probably does not vector the disease (or at least is not the only way in which the disease is spread), but it kills trees which might otherwise have recovered from the wilt disease (Kirkendall and Islam, unpublished manuscript).

The first record of *E. parallelus* for the Seychelles was in Beaver's 1988 ambrosia beetle paper. He reports that it commonly comes to lights at night, on Mahé, but was only collected from exotic trees there (including P. *indicus* but not *C. inophyllum*). It is a host generalist but selective with regard to host size; on Mahé (as elsewhere), it only colonizes trees 15 cm diameter or larger (which agrees with the data collected in 2003). He states that it does not

[2] A study in India in the 1950s concluded that the dieback was due to the fungus *Fusarium solani*. More recent investigations of the latest outbreak have made little progress in confirming the involvement of *F. solani* though there is little doubt that this is a fungal wilt disease (note added by ERB).

normally attack healthy trees (also my experience, though I did see a few unsuccessful tunnel starts on apparently healthy sandragon trees during my visit).

The three generally similar ***Xyleborus*** species are very widespread, host-generalist tropical species, though, interestingly, none were recorded from *P. indicus* in Beaver's paper. These data suggest that ***X. affinis*** is the most aggressive, in this situation in the Seychelles. Prior to these collections, there were two older literature records plus Beaver's record of one individual taken at light. The species is extremely polyphagous, with over 300 recorded host species. It is not usually associated with tree killing, but where it occurs, it is often one of the most abundant species. *Xyleborus perforans* and *X. similis* are also widespread and polyphagous, and have been recorded more frequently than *X. affinis* as attacking wounded or unhealthy trees. Beaver encountered the former in many hosts, but had only one specimen of the latter, from light.

Collection from *Calophyllum inophyllum* (takamaka), summer 2003

Twenty-nine scolytines were collected from under the bark of one branch from one wilting tree on Mahé. All are the same species, ***Cryphalus scabricollis*** Eichhoff (=*C. discretus* Eichhoff in Beaver 1987). This biology of this bark beetle has been studied recently by Wainhouse et al. (1998) with reference to its possible role as a vector in the wilting disease of *C. inophyllum*. They identified it as *C. trypanus* Sampson, a species known previously from higher elevations and from a totally unrelated host (*Northea*). However, how they reached this conclusion is not documented. *Cryphalus* is one of the most species-rich genera in the Scolytinae, and one of the most difficult bark beetle genera in which to identify species. There are few keys or illustrations, and many poorly known and undescribed species in this genus. *C. trypanus* is endemic to the Seychelles, but has been collected previously from higher elevations and from a different host family than Clusiaceae (from Sapotaceae). For confirmation, I sent specimens to Roger Beaver in Thailand, who has specimens of the *Cryphalus* species collected previously from the Seychelles, and he reports that the beetle from takamaka is *C. scabricollis*, a relatively widespread species known from takamaka on the Seychelles but from 4 other plant families elsewhere.

Conclusions

Pterocarpus indicus is being killed by *F. oxysporum* in Singapore, where the fungus is quite possibly vectored by *E. parallelus*. Extensive research led Sanderson et al. (1997) to hypothesize that these ambrosia beetles attacked lightning-struck trees, inoculating them with the fungus. The fungus was also spreading locally through the soil. The authors summarize the literature on vectoring of tree pathogens by scolytine and platypodine beetles.

If sandragon trees on the Seychelles are under stress (drought, for example, or possibly heavy leaf-miner infestations), then the Singapore scenario could apply here as well. Otherwise, the attacks by ambrosia beetles on the Seychelles may be secondary; even if they are secondary, dense colonizations by ambrosia beetles will kill trees or portions of trees which might otherwise have survived the attack by the fungus.

One should also keep in mind the possibility of the fungus being vectored by ambrosia beetles which colonize small branches and twigs. Three such species have been recorded from both sandragon trees (and also from takamaka; these remarks apply to both host trees). All three breed in small branches, and two (*Xylosandrus crassiusculus* and *X. morigerus*) are known to breed in relatively healthy saplings or branches; the former kills nursery plants and transplants, and the latter has been considered a pest of coffee, certain shade trees in coffee plantations, orchids, and tree seedlings. The third species, *Apoxyleborus mancus*, has once been recorded as attacking healthy cocoa trees, in Sri Lanka, but is otherwise considered relatively harmless. Given that the *Xylosandrus* are often aggressive, especially in plantations or with stressed trees, and thus will frequently try to breed in fresh tissue of small branches, it would be interesting to investigate whether they attack branches of nondiseased *Pterocarpus*, as well as breed in dying trees (which it is very likely that they do). That would be a scenario for vectoring the *Pterocarpus* disease from sick to nondiseased (but maybe stressed) trees. Finding evidence of colonization by these tiny beetles in the immense crowns of mature sandragon is a hopeless task. A better strategy would be using molecular methods to see whether or not disease-inducing fungi are present on or in the beetles.

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For more on the biology of the beetle taxa reported here, see the pair of articles by Beaver and references therein.

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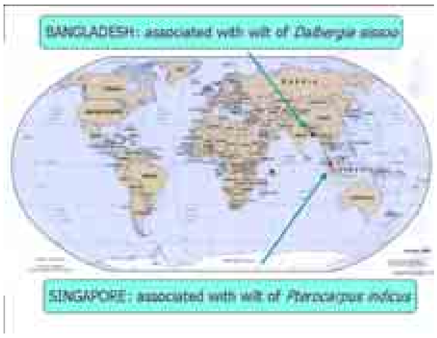
A N N E X 6

Presentations at final workshop, 28 November 2004.

Held at the Berjaya Beau Vallon Bay Hotel. The first presentation was by Dr Boa and covered general issues surrounding the disease. Dr Kirkendall addressed the broad topic of beetles associated with trees.

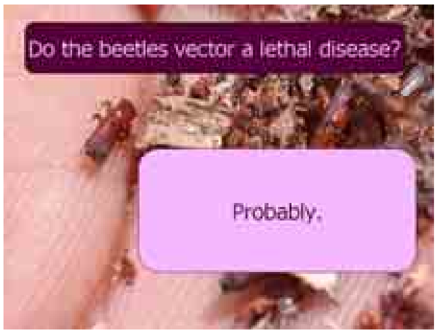
Presentation by Dr Kirkendall.


still hanging on


BANGLADESH: associated with wilt of *Dalbergia sissoo*
SINGAPORE: associated with wilt of *Pterocarpus indicus*


The beetles attack
the tree fights back


Do the beetles kill the trees?
No.


Do the beetles vector a lethal disease?
Probably.


Do the beetles vector a lethal disease?
The same species *does* vector *Fusarium oxysporum*, in Singapore.


Do the beetles vector a lethal disease?
Ambrosia beetles have evolved to transport fungi, vector can "hitch-hike".


Are the beetles necessary, for tree-killing?
Probably not.


Are the beetles necessary, for tree-killing?
Infected trees can be found which apparently do *not* have beetles.


Are the beetles necessary, for tree-killing?
Fungi like *F. oxysporum* can move to neighboring trees.


Are the beetles necessary, for tree-killing?
BUT!
Heavy ambrosia beetle attack
may preclude tree recovery.