Appendix B: African Mahogany (*Khaya senegalensis*) - Kiln Drying Schedule Development Trials

Scope

The following document is an account of experimental scale drying trials fro the development of a drying schedule to dry 25mm thick (nominal) *Khaya senegalensis* boards.

Equipment

Trials were conducted in the DPI&F Salisbury Research Centre 0.2 m^3 experimental conventional kiln. The kiln is controlled by an 'in-house' kiln control program. Heat is controlled by a series of electrical elements. Humidity is controlled by an electrical powered boiler and variable venting. Variable speed fans are used to provide airflow. The moisture content of the kiln load is measured using a load cell underneath the stack. In the case of these trials the kiln conditions were controlled automatically based on the moisture content of the timber.

Literature Review of Published Schedules

The following is a review of current available drying schedules for Khaya senegalensis. In the case where the schedules obtained specified temperature settings to the nearest 0.1ºC, these settings were rounded to the nearest 0.5ºC.

Reference 1

Boone et al. (1993) suggests the following schedules for 4/4, 5/4, and 6/4 inch dimension stock.

U.S. Schedule (T2-D4)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 50	37.5	34	15	79
50-40	37.5	32	12	68
40-30	37.5	32	12	68
30-25	43.5	32	8	45
25-20	49	32	6	31
20-15	54.5	32	4.5	21.5
15 to final	65.5	37.5	4	18

British Schedule (A)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 60	35	30.5	13	72.5
60-40	35	28.5	10.5	61.5
40-30	40	31	9	53
30-20	45	32.5	7	42.5
20-15	50	35	6	37.5
15 to final	60	30	2.5	11.5

The following U.S. schedule is suggested for wider 8/4 inch dimension stock.

U.S. Schedule (T2-D3)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 50	37.5	35	18.5	84.5
50-40	37.5	34	15	79
40-30	37.5	32	12	68
30-25	43.5	32	8	45
25-20	49	32	6	31
20-15	54.5	32	4.5	21.5
15 to final	65.5	37.5	4	18

Reference 2

The following schedules were developed based on the specific gravity of the timber as suggested by Simpson and Verill (1997). The average specific gravity can be used to produce a drying schedule using the program supplied by Simpson and Verill at the following internet address: http://www1.fpl.fs.fed.us/drying.html. The program itself has a database of species included whereby the specific gravity for each species is fixed from published data.

Alternatively if the exact average specific gravity of the material to be dried is known a schedule can be generated solely dependant on this value. The program generates two schedules based on both regression and classification approaches from published data. Simpson and Verill (1997) suggest that the classification approach schedule is generally considered to be more accurate.

Khaya senegalensis is one of the species included in the computer program database. The recommended schedule in this case is:

Schedule T2-D2 (25-38mm)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 50	38	36	18.5	87.5
50-40	38	35.5	17	85
40-35	38	34.5	15	79
35-30	38	32	11.5	66
30-25	43.5	32	7.5	45
25-20	49	32	5.5	31
20-15	54.5	32	4	21.5
15 to final	65.5	38	3.5	19

From recent trials, the average specific gravity of the said material is approximately 0.636. Using this value the program produced the following recommended schedules:

Schedule T5-D3 (25-38mm) –regression approach

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 50	49	46	16	84.5
50-40	49	45	14.5	79.5
40-35	49	43	11.5	70.5
35-30	49	38.5	8.5	52.5
30-25	54.5	35	5	28.5
25-20	60	32	3	15
20-15	65.5	38	3.5	19
15 to final	71	43.5	3.5	22

Schedule T6-D2 (25-38mm) –classification approach

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 50	49	46.5	17	87
50-40	49	46	16	84.5
40-35	49	44.5	13.5	77
35-30	49	41	10	62
30-25	54.5	38	6	36
25-20	60	32	3	15
20-15	65.5	38	3.5	19
15 to final	82	54.5	3.5	27

Reference 3

Farmer (1972) recommends the following schedule:

Schedule F (25-38mm)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 60	48.5	44	13.5	77
60-40	48.5	43	12.5	72.5
40-30	51.5	43	9.5	61
30-25	54.5	43	8	51.5
25-20	60	46	7	46.5
20-15	68	51	6	42
15 to final	76.5	58	5.5	42

Reference 4

Rozsa and Mills (1991) recommend a schedule for 25mm *Khaya spp*. It doesn't specifically stipulate *Khaya senegalensis* but it does state that this species is an exotic either imported directly into Australia or is an introduced species now growing in plantations. The schedule follows:

Schedule CW (25mm)

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 60	50	45	13	75
60-40	50	42	10	62.5
40-35	55	45	8.5	57
35-30	55	40	6.5	41
30-25	60	40	5	30.5
25-20	65	45	5	33.5
20-15	70	50	5	35.5
15 to final	70	50	5	35.5

Trial Methodology

The following methodology was used fro both trials 1 and 2. Note that end matched samples were used for each trial.

Initial Measurements

- Twenty 1000mm length boards (wrapped) were obtained from the fridge at DPI&F Indooroopilly and transport to DPI&F Salisbury.
- Each board was previously individually numbered.
- 75mm was removed from the end of each board and discarded.
- A further 25mm was removed from the freshly cut end of each board and labelled with the board original number. The pieces were wrapped in impermeable plastic until moisture content/basic density testing.
- The remaining 900mm sections were end coated.
- In accordance with AS/NZS 4787 – Timber – Assessment of drying quality, collapse, surface checking, end checking and end split was measured on the 900mm boards. Note: There was no point measuring distortion, as the pieces were too short to be representative and the stack too small to provide representative restraint.
- The weight of the 900mm sections was recorded. This is required to measure the total kiln load mass and hence moisture content for kiln control.
- The 900mm sections were wrapped in impermeable plastic until drying was ready to proceed.
- The average moisture content and basic density of the 25mm samples was measured as soon as practicably possible in accordance with AS/NZS 1080.1 and AS/NZS 1080.3 respectively.

Racking and drying

- Once the average MC of each 900mm section was calculated drying could commence.
- The material was racked into the kiln and the kiln started using the recommended schedule with an airflow of approximately 1.5 m/s. A 4 hour warm-up from ambient temperature to the initial kiln conditions (holding the same initial depression) was employed. The kiln was controlled based on the average MC of the boards via the kiln load cell.
- Following the recommended schedule, the material was dried to an average MC of 9%.
- The material was equalised to 10% MC for 24 hours under the following conditions: Dry Bulb Temp = last dry bulb temperature condition of the schedule and Wet Bulb Temp = wet bulb temperature to provide a 10% equilibrium MC in the kiln.

Final Measurements

- Each board was dressed to a thickness of 19mm (evenly planed on both wide faces).
- Surface checking on each face, end checking, collapse and end split were measured and classified in accordance with AS/NZS 4787.
- 100mm was cut from the end of each board and discarded.
- Two 25mm and one 50mm length sections were cut from the end of the freshly sawn end of each board and labelled with the same board number appended with ’a’, ‘b’ and ‘c’ respectively.

- The 25mm ‘a’ sections were used to measure average MC using the oven dry method in accordance with AS/NZS 1080.1. The 25 mm ‘b’ sections were ripped into three equally sized thicknesses to measure the MC gradient using the oven dry method in accordance with AS/NZS 1080.1. In accordance with AS/NZS 4787, the average MC and MC gradient values from the 20 boards were rated to give a quality rating for each property.
- In accordance with AS/NZS 4787 the residual drying stress was measured and rated using the 50mm ‘c’ sections.

Trial 1 Schedule Development

Initially a schedule was chosen based on the harshest conditions of the above listed schedules. The schedules pertaining to reference 1 have been discounted as they are for 4 inch thick stock and are considered inapplicable. The other schedules presented are specifically designed for 25-38mm thick material.

Schedule T6-D2 (from reference 2) has the harshest final conditions below the fibre saturation point (25% moisture content) while the schedule CW presented in reference 4 has harsher initial conditions above FSP. Therefore the initial schedule is a combination of the harshest parts of each schedule and is presented below.

Initial Schedule Trial 1

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 60	50	45	13	75
60-40	50	42	10	62.5
40-35	55	45	8.5	57
35-30	55	40	6.5	41
30-25	60	40	5	30.5
25-20	60	32	3	15
20-15	65.5	38	3.5	19
15 to final	82	54.5	3.5	27

Trial 1 Results

Initial moisture content = 47.4%

Drying Time = 70.5 hrs (excluding 24 hour equalising period)

Final moisture content = 9% before equalising

Final moisture content = 10.5% after equalising

After boards dressed/dried:

boards collapsed = 0

boards checked = 0 (except 1 board – heart check – not drying degrade)

boards end split = 0

Dried quality results (AS 4787) – see following table

Average MC grade = fail

MC gradient grade = fail

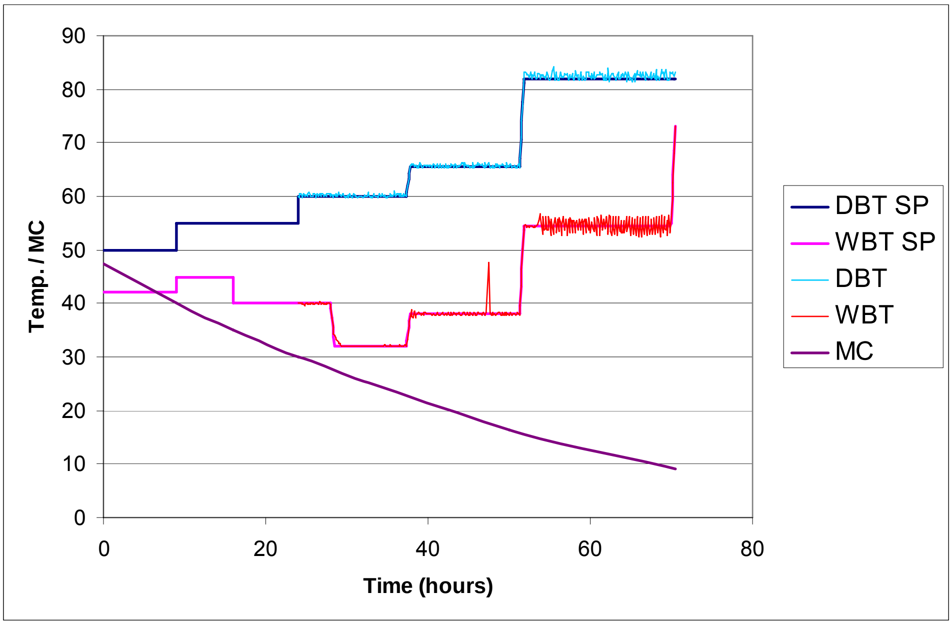
Drying stress grade = pass

Results from Trial 1

	Average MC %		MC Gradient %				Drying Stress		
Sample #	MC (%)	Grade	MC Sides (%)	MC Centre (%)	MC difference	MC Gradient Grade	Width (mm)	Gap (mm)	Drying Stress Grade
11-2	11.0	A	11.0	11.7	0.7	A	96.35	0.46	A
15?-2	20.3	Fail	15.1	21.9	6.8	Fail	102.1	0	A
15-2	10.8	A	11.4	11.6	0.3	A	101	0.41	A
153-2	11.9	A	12.0	12.7	0.7	A	102.8	1.11	C
154-2	10.3	A	10.9	11.6	0.8	A	101.7	0.43	A
157-2	8.3	B	9.5	9.3	-0.2	A	98.19	0.12	A
25-2	23.7	Fail	16.4	27.1	10.7	Fail	104.2	0	A
7H-2	11.4	A	11.0	11.6	0.6	A	99.56	0.47	A
86-2	19.8	Fail	14.0	19.6	5.6	Fail	102.7	0	A
H10-2	10.8	A	10.7	11.2	0.5	A	100.8	0.83	B
H13-2	9.0	A	10.0	10.1	0.1	A	100.9	0.67	B
H2-2	11.3	A	11.4	12.0	0.5	A	99.69	0.67	B
H8-2	20.7	Fail	16.2	21.7	5.5	Fail	102.3	0	A
T135-2	10.2	A	11.2	11.7	0.6	A	95.15	0.52	B
T138-2	8.2	B	8.9	9.0	0.1	A	100.5	0.61	B
T154-2	8.9	B	9.4	8.8	-0.6	A	102.3	0.47	A
T229-2	10.8	A	11.5	11.8	0.3	A	100.6	0.73	B
T275-2	9.9	A	10.2	10.1	-0.1	A	101.5	0	A
T922-2	11.1	A	11.9	11.9	0.0	A	101.8	0.47	A
T929-2	11.0	A	11.8	12.4	0.6	A	101.7	0.36	A

Total Grade	Fail		Fail			B

Drying Conditions during Trial 1



Trial 1 Discussion

If only the visual appearance grade results are taken into account then this trial would be considered a success. However, due to the failed average final moisture content and moisture content gradient results the overall dried quality is dismal.

Standard AS 4787 gives a quality class from A to E for a range of dried quality criteria. It does this by quantifying quality bandwidths for each class dependent on target values. The standard work *K. Senegalensis* such that each board is individually classified and then a total classification or grade is given based on 90% of boards falling into the highest class category. Obviously quality class A is the best or preferred class followed by class B and so on. Generally in industry class B is the cut off for appearance grade products.

From the data above 4 out of 20 sample boards completely failed to fall into any class for average moisture content and moisture content gradient. Therefore as this represents 20% of the sample size 90% of the boards do not fall into any class and therefore fail completely for these quality criteria. The B rating for residual drying stress is passable.

Obviously the reason that these boards failed was because of their extremely high moisture contents compared with the other sample boards. This shows convincing evidence that these boards have suffered from case hardening. This will generally occur if boards have been dried too quickly after the fibre saturation point (approx. 25% MC). Basically when a board's average MC is around the fibre saturation point (approx. 25% MC) stress reversal occurs whereby the outside of the board goes into compression and the inside of the board into tension (as opposed to early drying). If the drying rate after fibre saturation point is too great the compressive surface stress can cause the surface of the board to permanently 'set' and effectively stop/considerably reduce the water transport through the wood surface. Obviously as wood is an inhomogeneous material not all boards will case harden under the same conditions.

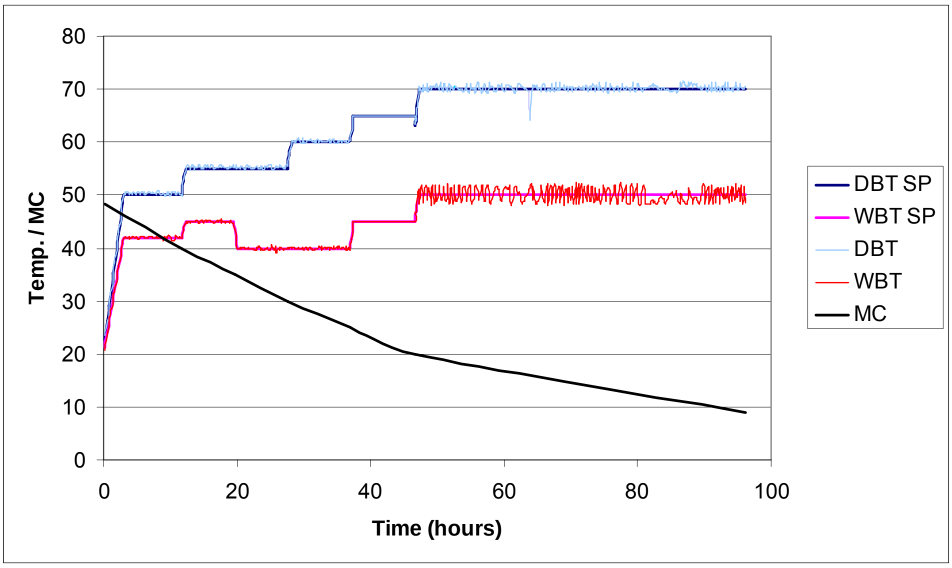
Trial 2 Schedule Development

From the results given from trial 1 the following schedule was proposed. It has the same conditions above the fibre saturation point as the first trial but is considerably less harsh than the first schedule during the later part of drying. It is the same schedule (CW) suggested by Rosza and Mills (1991) for 25mm thick material.

Initial schedule Trial 2

Moisture Content Change Point %	Dry Bulb Temp. (°C)	Wet Bulb Temp. (°C)	EMC (%)	Relative Humidity %
Above 60	50	45	13	75
60-40	50	42	10	62.5
40-35	55	45	8.5	57
35-30	55	40	6.5	41
30-25	60	40	5	30.5
25-20	65	45	5	33.5
20-15	70	50	5	35.5
15 to final	70	50	5	35.5

Drying condition during Trial 2



Trial 2 Results

Initial moisture content = 48.3%

Drying Time = 96.2 hrs (excluding 24 hour equalising period)

Final moisture content = 9% before equalising

Final moisture content = 10.6% after equalising

After boards dressed/dried:

- # boards collapsed = 0
- # boards checked = 0 (except 2 boards – slight heart check – not drying degrade)
- # boards end split = 0
- Dried quality results (AS 4787) – see following table for details
  - Average MC grade = B
  - MC gradient grade = B
- Drying stress grade = C

Results from Trial 2

	Average MC %		MC Gradient %				Drying Stress		
Sample #	MC (%)	Grade	MC Sides (%)	MC Centre (%)	MC difference	MC Gradient Grade	Width (mm)	Gap (mm)	Drying Stress Grade
11-3	9.7	A	9.5	10.0	0.5	A	97.37	0	A
156-3	11.0	A	10.5	10.9	0.4	A	99.88	0.81	B
15-3	11.8	A	11.3	12.0	0.7	A	98.83	1.15	C
153-3	8.6	B	8.5	8.3	-0.2	A	100.5	1.12	C
154-3	11.1	A	11.2	11.5	0.3	A	102.5	0	A
157-3	8.7	B	8.4	8.6	0.1	A	97.92	1.29	C
25-3	10.8	A	10.2	11.2	1.0	A	102.9	0	A
7H-3	12.4	A	11.6	12.7	1.0	A	97.81	0.44	A
86-3	12.7	A	12.4	13.2	0.7	A	104.2	0	A
H10-3	13.0	B	12.6	14.2	1.7	B	99	0	A
H13-3	8.3	B	8.5	8.4	-0.1	A	99.82	0.91	B
H2-3	11.3	A	11.3	11.5	0.3	A	92.6	0.62	B
H8-3	11.1	A	10.7	11.8	1.1	B	102.7	0.63	B
T135-3	9.3	A	8.6	9.6	1.0	A	99.5	0.74	B
T138-3	10.0	A	9.9	10.4	0.4	A	100.9	0.62	B
T229-3	11.6	A	11.8	12.7	0.8	A	102.6	0	A
T275-3	8.3	B	8.1	7.8	-0.3	A	98.96	1.38	C
T922-3	11.3	A	10.9	11.5	0.6	A	99.95	0.7	A
T929-3	10.8	A	10.6	10.8	0.3	A	99.22	0.6	A
Total Grade		B				B			C

Trial 2 Discussion

There was no drying induced collapse, surface checking, or end split measured in this trial. Dried quality in regards to final moisture content and moisture content gradient (both class B) was good. The residual drying stress grade (class C) may be considered a little high but is still satisfactory. Generally the drying stress can be improved by increasing the equalisation period.

Conclusions

Both schedules proved to be adequate at drying the material free of visual degrade. The schedule used in trial 1 however was too harsh below fibre saturation point resulting in a number of boards exhibiting 'wet wood' properties. This is most likely attributed to the phenomena of case hardening.

This was remedied in trial 2 whereby the initial schedule was altered to provide less harsh conditions below the fibre saturation point (25% MC). This did result in an increase in drying time (excluding equalising time) of 36% (96.2 hrs cf. 70.5 hrs).

Due to better results in dried quality the schedule used in trial 2 is recommended for drying this material.

References

Boone, R. S., C. J. Kozlik, et al. (1993). Dry kiln schedules for commercial woods - Temperate and tropical., Forest Products Society.

Farmer, R. H. (1972). Handbook of Hardwoods. London, Ebenezer Baylis & Son Ltd., The Trinity Press.

Rosza, A. and R. G. Mills (1991). Index of Kiln Seasoning Schedules. Melbourne, CSIRO.

Simpson, W. T. and S. P. Verill (1997). "Estimating kiln schedules for tropical and temperate hardwoods using specific gravity." Forest Products Journal **47**(7/8): 64-68.

Appendix C: Accelerated Decay Bioassay

BACKGROUND

The following report presents findings from an accelerated decay bioassay of mature plantation grown *Khaya senegalensis* (African mahogany). Accelerated decay bioassay is a rapid laboratory method that may be used to gain an indication of a timber's relative decay resistance.

Natural durability is defined in Australian Standard AS 5604-2003: Timber-Natural Durability Ratings, as the inherent resistance of a timber species to decay and insect attack. Wood properties within a species and even within an individual tree can vary (AWPA 1999; Standards_Australia 2003). Consequently, the classification of a species' durability cannot be done with absolute sensitivity, and instead durability ratings reflect a range of expected service life values. A species performance is also influenced by the hazard to which it will be exposed. Decay hazard influences include the climate and microbial ecology where the timber is to be used, whether or not it will be used in contact with the ground, as well as its' level of exposure to the elements.

In the context of the Standard, natural durability ratings are assigned according to a species performance both in contact with the ground and above ground when exposed to average environmental conditions (Table 1). AS 5604-2003 classifies natural durability into four groups, with species assigned to durability class 1 being most durable, while species assigned to durability class 4 are the least durable.

Table 1. Natural durability - probable life expectancy for average environmental conditions (AS 5604-2003)

Durability Class	Probable in-ground life expectancy (years)	Probable above-ground life expectancy (years)
1	Greater than 25	Greater than 40
2	15 to 25	15 to 40
3	5 to 15	7 to 15
4	0 to 5	0 to 7

NOTES:

1. As further reliable evidence becomes available, these ratings may require amending.
2. The heartwood of an individual piece of timber may vary from the species' nominated classification. Above-ground conditions equate to outside above-ground subject to periodic moderate wetting when ventilation and drainage are adequate.
3. The ratings in table one are based on expert opinions and on the performance of the following test specimens: (a) In-ground: 50 × 50 mm test specimens at five sites around Australia; and (b) Above-ground: 35 × 35 mm test specimens at eleven sites around Australia (this project continues, and specimens have now been exposed for 16 years). (Standards_Australia 2003)

The in-ground classification (Table 1) is widely accepted as a general guide, and is essentially a rating of the durability of the species heartwood when in ground contact and exposed to attack by decay and termites. Because of this combined assessment, the classification may not truly reflect the special qualities of some species (for example, brush box is very resistant to termites but much less so to decay) (Standards_Australia 2003). General species resistance is largely determined by the extractives formed when sapwood changes into heartwood. Termites are less easily deterred by these extractives than fungi and will attack most species, though slowly in the case of the very durable species. It is generally accepted that the performance of untreated heartwood above ground will be better than its performance in the ground, and untreated sapwood is considered to have poor resistance to biological attack. (Smith et al. 1991; Standards_Australia 2003)

African mahogany heartwood is currently classified as a durability class three timber. Durability class three timbers have a probable in-ground life expectancy of five to 15 years and a probable above-ground life expectancy of seven to 15 years (Standards_Australia 2003). The aim of this study was to compare the decay resistance of *K. senegalensis* samples with reference timber species representing each of the four durability classes.

This study was undertaken as part of a comprehensive *K. senegalensis* processing project. As the focus of the project was processing, samples were selected on the basis of suitability for processing studies. After the material was distributed for the processing study a small amount was available for accelerated durability testing. Therefore a relatively small qualitative bioassay was completed.

METHOD

The agar-plate accelerated decay (APAD) bioassay method utilised for this study is a qualitative method designed to provide a reproducible means of establishing the relative decay resistance between various species of wood. APAD combines aspects of European Standard EN113, agar jar technique (EN_113 1996) and American Standard D2017-81, soil jar technique (ASTM_D2017-81 1986) and involves the short-term exposure of small timber samples to pure cultures of decay fungi.

Sample selection

K. senegalensis samples, along with samples from various reference species were selected for separate exposure to three decay fungi (Table 2). All samples consisted of heartwood, except for *Eucalyptus grandis*, spotted gum and *Eucalyptus dunnii* where juvenile wood was used. Spotted gum sapwood was also included for comparison as it is considered to have low durability (Standards_Australia 2003). The reference samples represent a range from low to high durability and all reference timber samples were free of knots and excessive amounts of resin or gums, and had no visible evidence of fungal infection. Eighty-eight separate *K. senegalensis* samples were included. These samples were obtained from 42 *K. senegalensis* logs that were harvested from 42 separate trees (Appendix Two). The length of the logs ranged from approximately one to three metres, and there were four logs that were about eight meters long. Discs were cut from the bottom and top of each log, and a small sample from the middle region of heartwood from each disc was retained for accelerated decay testing (i.e. section from mid way along the radius of each heartwood disc). Three logs also had a mid-log disc cut, from which a sample was taken for accelerated decay testing. Given the small amount of material available, some *K. senegalensis* samples were irregular in size or appearance; however none had any visible signs of fungal infection.

Sample Preparation

Timber samples were sawn into slices approximately 15 mm (radial) x 25 mm (tangential) x 2-3 mm (longitudinal). These slices were labelled with a waterproof marker promptly after sawing. In most cases *K. senegalensis* timber slices were smaller as there was limited sample material available, samples that were exceedingly small or irregular in appearance were noted (Appendix One). Accelerated weathering of slices was then undertaken according to a modified version of European Standard EN 84 (Accelerated Ageing of Treated Wood Prior to Biological Testing – Leaching Procedure) (EN_84 1984). For each timber sample, replicates were transferred to 500ml flask *K. senegalensis* and immersed in sterile deionised water so that the volume of water was approximately ten times the volume of the specimens. Samples in flask of *K. senegalensis* were then placed on an orbital shaker for five days and the water was changed daily.

Following weathering, samples were oven-dried for approximately 24 hours at 103^{O}C then weighed (constant mass was measured to ensure the samples were completely dry). Samples were then sealed in airtight plastic bags and sent for sterilisation by gamma-irradiation (25 kilograys, ie approx. 3.25 hours @ 8 kGy/hr) at the University of Queensland Irradiation Facility.

Table 2: Timber samples (sample from one timber board unless otherwise indicated).

Reference Samples	Source	Details
Radiata pine *Pinus radiata*	Commercially available timber	Durability class 4 - low durability
Dunn's white gum **Eucalyptus dunnii**	?Young plantation	Juvenile wood (durability class 4 - low durability) Separate samples from four different trees 3,6, 9, 10
Rose gum **Eucalyptus grandis**	Young plantation	Juvenile wood
Rose gum **Eucalyptus grandis**	Mature native	Durability class 3 – moderate durability
Spotted gum Sapwood *Corymbia spp.*	Mature native	Low durability
Spotted gum *Corymbia spp.*	Young plantation	Juvenile wood
Spotted gum *Corymbia spp.*	Mature plantation	Durability class 2 – high durability
Spotted gum *Corymbia spp.*	Mature native	Durability class 2 – high durability
Grey ironbark ***Eucalyptus* spp.**	Mature native	Durability class 1 - highest durability
Cypress *Callitris glaucophylla*	Commercially available timber	Durability class 1 - highest durability
African mahogany (*Khaya senegalensis*)		
African mahogany *Khaya senegalensis*	? Mature native	88 samples from 42 individual trees

Exposure to Decay Fungi

One set of weathered and sterilised timber samples (consisting of five replicates from each timber sample) were separately exposed to the white rot decay fungus, *Coriolus versicolor*, and the brown rot decay fungus, *Fomitopsis lilacino-gilva*. These species of decay fungi were selected because they are among those recommended for use in conventional soil jar accelerated decay bioassays (AWPC 1997), and they had also best differentiated timbers of different durability in previous accelerated decay bioassays carried out at Horticulture and Forestry Science (H&FS) (Catesby and Powell 1999; Francis and Armstrong 2004; Meldrum and Powell 2002).

To prepare cultures to inoculate test timbers, each of the fungi were aseptically sub-cultured from the H&FS Wood Pathology Culture Collection onto fresh sawdust agar plates consisting of 15mL of Technical Agar No 2 (Oxoid™) with 1g of gamma-sterilised *Pinus carribea* sapwood sawdust and 1g of gamma-sterilised *E. grandis* sawdust, each spread over half of the plate. Revitalised cultures were then transferred onto 1% malt extract agar, then sub-cultured onto 1% malt extract agar plates (15 mL) ready to be used to inoculate timber samples. These inoculum cultures were incubated at 26^{O}C with no light for seven to ten days, depending on the speed of mycelial growth.

Sterile culture vessels were prepared for each fungus, each consisting of a glass slide support on the surface of a 1% malt extract agar plate (10mL) (Oxoid™ Technical Agar No 2 and Oxoid™ Malt Extract). Each of the five replicates from each timber specimen was individually added to separate culture vessels. Approximately 1 mL of sterilised de-ionised water was placed on top of each timber sample after it had been aseptically placed on top of a slide in its culture vessel to ensure adequate moisture for the fungi to colonise the sections.

Culture vessels were then inoculated with plugs of mycelium (3 mm diameter) that were aseptically transferred from the advancing edge inoculum cultures described above. Two mycelial plugs of inoculum were added to each culture vessel, one either side of the timber sample supported by the glass slide. Vessels were enclosed in paraffin tape and incubated at 26^{O}C with no light. Ideally, exposure is continued until pine or hardwood sapwood reference samples have undergone at least 20% mass loss, so samples exposed to *Fomitopsis lilacino-gilva* were incubated for 11 wee*K. senegalensis*while samples exposed to *Coriolus versicolor* were exposed for eight wee*K. senegalensis*to maximise decay. After the allotted exposure times, all sections were removed from their culture vessels, oven dried overnight (at 103°C) and then weighed. The relative decay resistance of timber samples was then determined by comparing losses in sample weights.

Data analysis was undertaken using GenStat (V6.1). Mean mass lost to decay was calculated for each group of five replicate samples. Box and whisker plots were generated for each set of samples exposed to a particular decay fungus, followed by one tailed analysis of variance (ANOVA) of sample means. Pair-wise multiple comparisons (using Fishers protected least significant difference analysis) were then undertaken if appropriate. In other accelerated decay bioassays such as soil jars and agar jars, timber specimens are often classified according to their mean percent mass loss. This approach however, is of limited statistical significance for APAD bioassay, but it can be used as a general guide (see Appendix 4).

RESULTS

The relative mass losses of timber samples following exposure to each of the decay fungi are listed in Appendix One and are illustrated in the 'box and whisker' plots below (Figures 1 & 2). In the plots, each 'box' spans the inter-quartile range for that species, so that the middle 50% of the data lay within the box, while the line in each box indicates the median. The 'whiskers' extend to the minimum and maximum values.

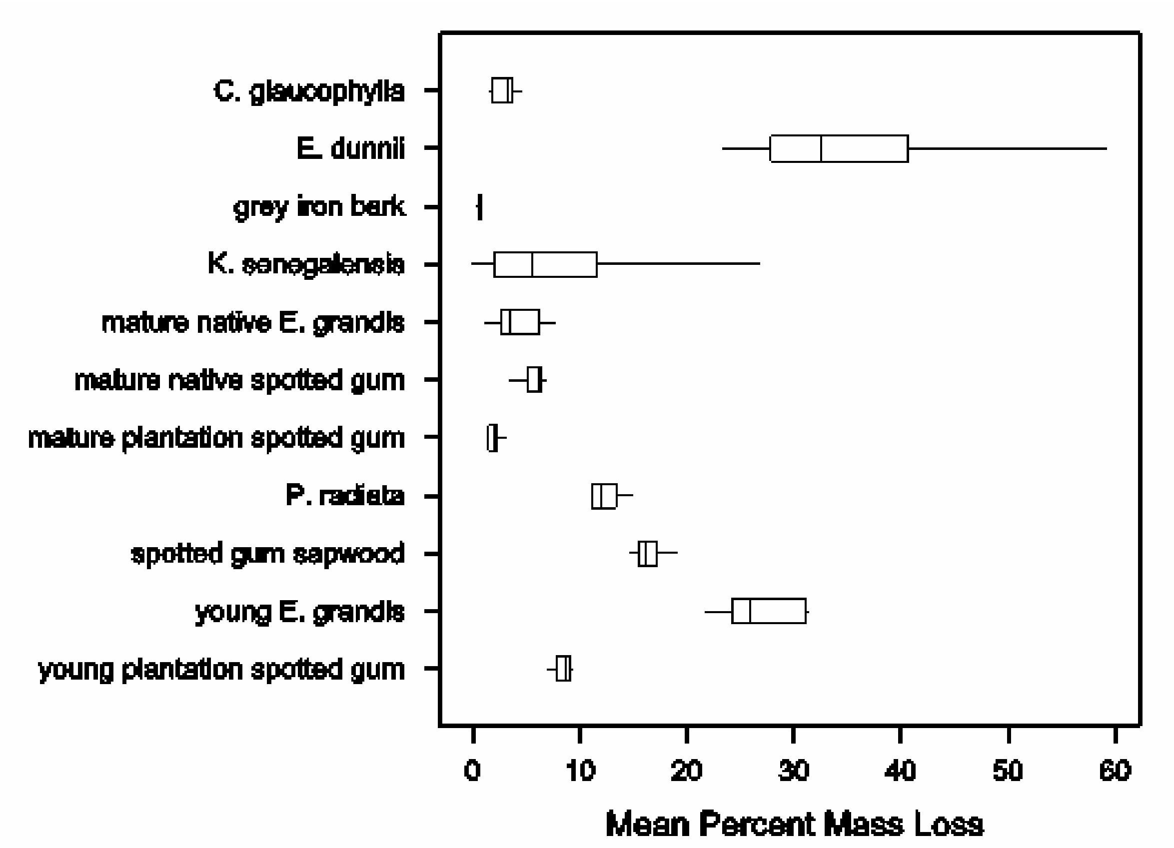


Figure 1: Relative decay susceptibility of K. senegalensisand reference samples represented as mean percent mass loss following exposure to the white rot fungus Coriolus versicolor.

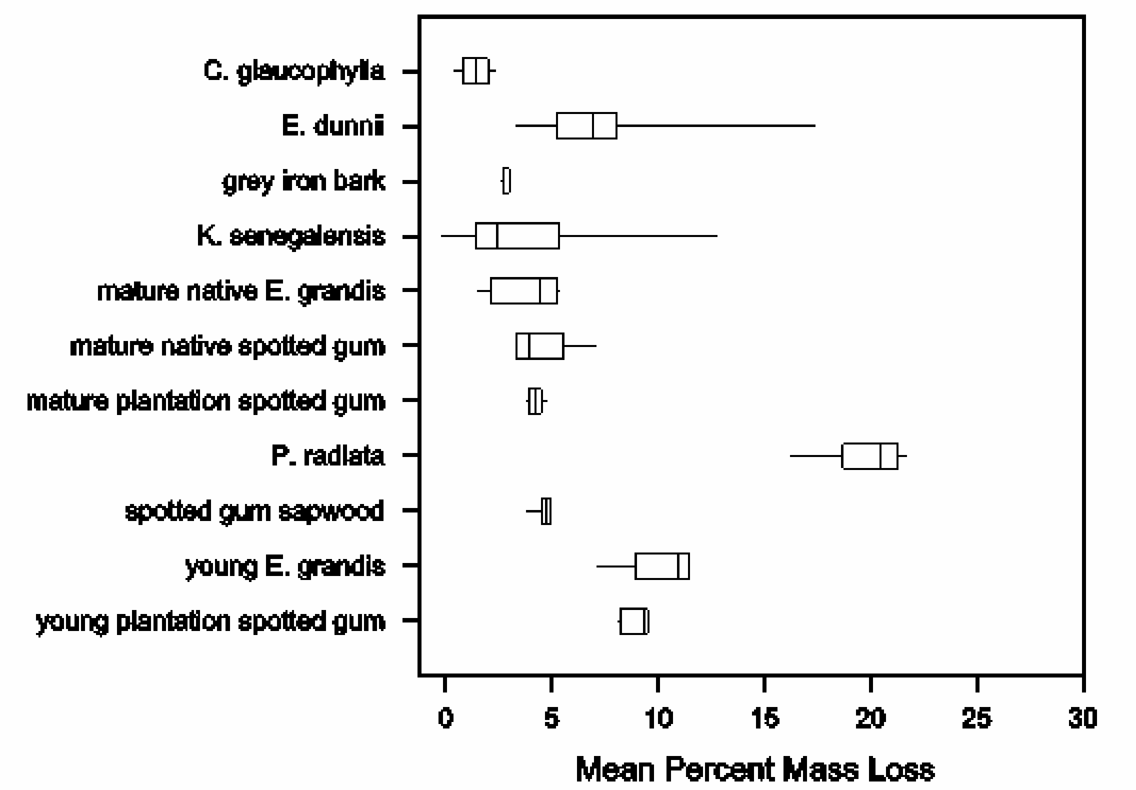


Figure 2: Relative decay susceptibility of *K. senegalensis* and reference samples represented as mean percent mass loss following exposure to the brown rot fungus Fomitopsis lilacino-gilva.

The relative mass losses observed for the reference samples were generally consistent with results from previous accelerated durability bioassays carried out by H&FS (Catesby and Powell 1999; Francis and Armstrong 2004; Meldrum and Powell 2002). In contrast to previous bioassays however, the mature plantation spotted gum had less mass loss than the mature native spotted gum sample, particularly after exposure to the white rot *C. versicolor*. The mature native spotted gum samples were prepared from a large stock and less durable inner heartwood (Clark and Scheffer 1983; Ocloo 1975) may have been used in this bioassay inadvertently. The mature native *E. grandis* sample however, had not been previously tested. Results suggest that this particular mature native grown sample is more resistant to decay by basidiomycete decay fungi than is common for that species (mass loss has been higher for other samples of mature *E. grandis* used in previous bioassays). Reference samples are included as a general guide, and it should be noted that reference samples were each obtained from one timber sample only.

The ranked order of mean mass loss for the replicate samples exposed to the brown rot fungus was somewhat different to that for the white rot (see Appendices One & Three). For example, juvenile *E. dunnii* and *E. grandis* were most susceptible to decay by the white rot fungus *C. versicolor*. Alternatively, *P. radiata* was most susceptible to decay by the brown rot fungus, *F. lilacino-gilva*.

While the mean decay resistance of the *K. senegalensis* samples was moderately high, considerable variability was observed (see Figures 1 & 2, Appendices). To identify which samples had mean mass loss results that were significantly different statistically, pair-wise multiple comparisons were performed. As shown in Appendix Three, the results provide a continuum of significant differences.

After exposure to *C. versicolor*, *K. senegalensis* samples from 86% (36/42) of trees showed bottom-sample mass losses to be greater than the top-sample mass loss. Of the six trees whose top-sample mass losses were greater than the bottom-sample mass loss, three were ‘b’ samples (8m in length). For samples exposed to *C. versicolor*, the bottom-samples’ mass losses ranged from 1.23 to 22.23% while the top-samples’ mass losses ranged from 0 to 14.27%. The mean mass loss from bottom-samples was 9.4% while the mean mass loss for the top-samples was 3.9%.

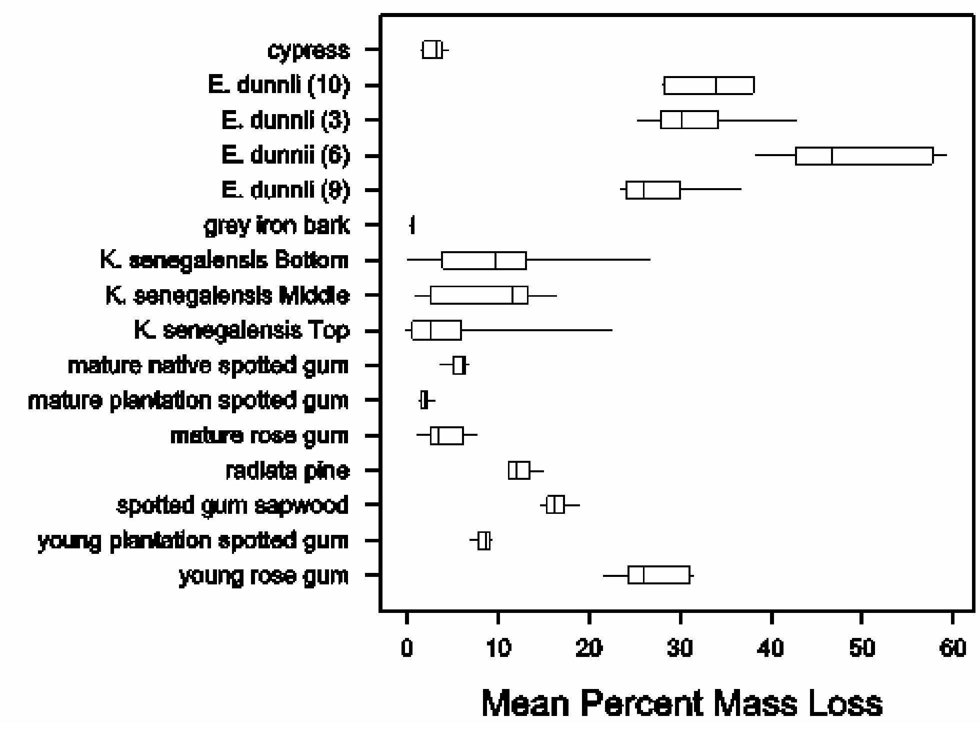


Figure 3 Relative decay susceptibility of *K. senegalensis* samples from different sample locations. With reference samples, represented as mean percent mass loss following exposure to the white rot fungus Coriolus versicolor.

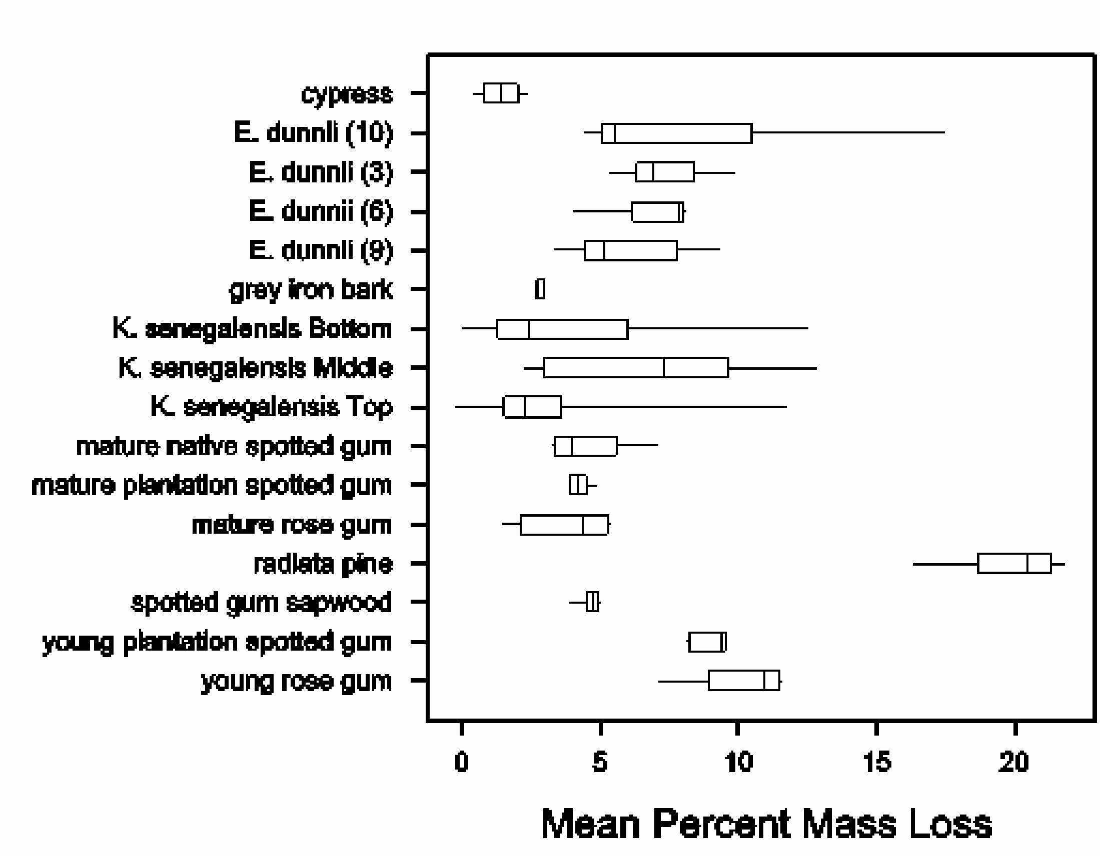


Figure 4 Relative decay susceptibility of *K. senegalensis* samples from different sample locations. With reference samples, represented as mean percent mass loss following exposure to the white rot fungus Fomitopsis lilacino-gilva.

After exposure to *F. lilacino-gilva*, *K. senegalensis* samples from 76% (32/42) of trees showed bottom-sample mass losses to be greater than the top-sample mass loss. Of the ten trees whose top-sample mass losses were greater than the bottom-sample mass loss, three were 'b' samples (8m in length). For samples exposed to *F. lilacino-gilva,* the bottom-samples' mass losses ranged from 0.41 to 10.48% while the top-samples' mass losses ranged from 0 to 10.33%. The mean mass loss from bottom-samples was 3.8% while the mean mass loss for the top-samples was 3.2%.

DISCUSSION AND CONCLUSIONS

Many variables affect a timber's performance in service. These include the climate and microbial ecology of the local area, along with the purpose, design and maintenance of the timber product. These factors are in addition to the relatively mild variations that occur naturally between timbers from different trees of the same species. Field exposure trials that are designed to simulate field conditions similar to those for the perceived end use of the timber in question are an ideal method for determining the natural durability of a timber species. However, these field trials can take decades to complete, and the expense involved in setting up field trials with sufficient replication is often prohibitive.

Agar plate accelerated decay bioassay was used to determine the ability of *K. senegalensis* (African mahogany) to resist attack by pure cultures of *Coriolus versicolor* and *Fomitopsis lilacino-gilva*. Conventionally, soil jar or agar jar techniques have been used for accelerated decay testing. The jar techniques require larger samples (which were not available for this study), more support substrate (soil or agar) and their preparation and incubation are more time consuming and therefore costly. The jar techniques however, still provide qualitative data regarding the relative decay susceptibility of timbers that are tested.

Considering results for both decay fungi, the samples can be more or less divided into two groups according to their relative mass losses. *Callitris glaucophylla* and grey ironbark were found to be most resistant to decay by pure cultures of decay fungi, followed closely by mature native spotted gum, mature plantation spotted gum and mature native *Eucalyptus grandis*. Conversely, *Pinus radiata* had poor decay resistance, as did *E. dunnii* and *E. grandis* juvenile woods.

While the results for *K. senegalensis* varied considerably, it is important to note that mean *K. senegalensis* result represents 88 separate samples (from 42 separate trees of different ages). Given that the logs were obtained from trees of a range of ages, and that samples were taken from the each end of a log, a degree of variation was expected. In addition, some of the observed variability could have been influenced by differences in sample size (some samples were quite small due to limited sample material being available). In contrast, the mean for each of the reference species represents only one timber sample (apart for *E. dunnii*, where four separate samples were used).

Approximately half of the *K. senegalensis* samples were taken from the bottom of the harvested logs and the other half from the tops. Interestingly, in most cases, the *K. senegalensis* sample from the bottom end of any particular log was less durable than sample from the top end. This result is in contrast to durability studies of several other timber species which have revealed that the outer heartwood of the butt log is commonly more durable than the outer heartwood from further up the tree (Clark and Scheffer 1983). After exposure to *C. versicolor*, paired (top and bottom) *K. senegalensis* samples from 86% of trees (36/42) had bottom-sample mass losses that were greater than the top-sample mass loss. Of the six trees that were exceptions, three were ‘b’ samples (8m in length) and one had grater mass loss for the bottom sample than the top after exposure to the other fungus. After exposure to *F. lilacino-gilva*, paired *K. senegalensis* samples from 76% (32/42) of trees showed bottom-sample mass losses to be greater than the top-sample mass loss. Of the ten trees that were exceptions, three were ‘b’ samples (8m in length) and five had grater mass loss for the bottom sample than the top after exposure to the other fungus.

Four of the logs selected for testing were very much longer than the others (Appendix Two, shaded grey with ‘b’ following tree number), and their diameter at the top end was considerably less than at their bottom end. Consequently, heartwood from the top of these logs may still have been quite young. Results are consistent with this possibility. For three out of the four logs, the sample from the bottom of the log was more durable than the sample from the top. When the bottom sections of the taller ‘b’ logs are compared with the results for the bottom sections of all logs, the bottom of the taller ones (‘b’ samples) were among the most durable (those with least mass loss). Furthermore, comparison of the results for the top sections of all trees, the top of the taller ones were among the least durable (those with most mass loss).

Even though many of the variables that impact a timber species performance in service are absent during accelerated decay bioassay, this method still provides valuable information regarding a timber’s resistance to attack by basidiomycete decay fungi. Given the length of field trials, accelerated decay data information can be utilised in the interim for instance during selection of trees for breeding. For example, *K. senegalensis* sample 595 was amongst the most resistant to decay by each of the three decay fungi. If this sample also had good results for other characteristics such as timber strength or growth habit, it may be useful for breeding.

The results of this study support anecdotal evidence suggesting that *K. senegalensis* may be more durable than is commonly thought (Armstrong 2005, pers. com.) particularly for above-ground applications. Placement of *K. senegalensis* samples at H&FS field exposure sites is recommended. Furthermore, it would be desirable for replicate samples

ACKNOWLEDGEMENTS

The assistance of Dr Lyel Carrington with the use of the University of Queensland's irradiation facility is gratefully acknowledged.

APPENDIX ONE – Mean mass loss for each timber sample

Table 3. Ranked mean mass loss data for **Coriolus versicolor**: Numbered *K. senegalensis* samples with reference species.

Timber	Mean percent mass loss
595	0.00
627	0.00
227	0.00
315	0.06
411	0.10
427	0.15
179	0.19
283	0.21
379	0.23
459	0.50
643	0.59
grey iron bark	0.68
347	0.89
271	1.09
499	1.23
43*^	1.56
195	1.72
59	1.80
11	1.86
mature plantation spotted gum	2.01
419^	2.07
163	2.11
683	2.18
147	2.22
211	2.30
363	2.57
19	2.71
659	2.77
67	2.77
403	2.84
475	2.85
83*	2.88
691	2.91
C. glaucophylla	2.96
491	2.99
299^	3.06
443	3.30
235	3.62
635	3.84
435	4.00
mature native *E. grandis*	4.22
571*^	4.27
291	4.56
507	4.58

Timber	**Mean percent mass loss**
467	4.73
563	5.02
123	5.15
323	5.24
187*+	5.34
339	5.48
75*	5.50
331	5.51
603	5.59
mature native spotted gum	5.66
667	6.20
355	6.74
611^	7.05
579	8.29
young plantation spotted gum	8.46
3^	8.63
395	8.73
619	9.21
651	9.33
699	9.41
307	9.92
114	10.06
451*	10.17
107	10.53
531*^	11.31
219*	11.57
251	11.58
243	11.61
387*^	11.65
515	11.77
131+	12.18
P. radiata	12.45
275*^	12.49
99	12.87
483	12.92
371+	13.02
155	13.30
259	13.43
539	13.50
523	13.60
587	13.65
203+	13.85
675	14.03
91	14.13

Timber	**Mean percent mass loss**
547*^	14.27
555+	14.45
171	14.81
27+	15.12
35^	16.30
spotted gum sapwood	16.45
139*^	18.69
51+	22.23
young *E. grandis*	27.01
E. dunnii (9)	27.65
E. dunnii (3)	31.69
E. dunnii (10)	33.30
E. dunnii (6)	49.11

Notes

*	Very small or irregularly–shaped samples
+	Light-coloured samples
^	Patchy colour or density

Table 4 Ranked mean mass loss data for **Fomitopsis lilacino-gilva**: Numbered K. senegalensissamples with reference species.

Timber	Mean percent mass loss
611^	0.41
435	0.42
419^	0.58
459	0.81
219*	0.81
3^	0.92
683	1.01
315	1.04
667	1.10
363	1.25
19	1.28
427	1.32
467	1.34
627	1.41
C. glaucophylla	1.41
163	1.53
691	1.53
403	1.59
187*+	1.60
339	1.64
595	1.66
347	1.77
603	1.81
211	1.90
227	1.94
411	1.95
355	1.95
283	1.97
659	1.98
475	1.99
147	2.00
123	2.02
67	2.04
171	2.04
443	2.18
114	2.19
699	2.26
107	2.47
59	2.49
271	2.51
235	2.58
643	2.71
635	2.77

Timber	Mean percent mass loss
grey iron bark	2.83
299^	3.14
331	3.22
195	3.29
83*	3.31
11	3.33
mature native *E. grandis*	3.78
395	3.82
451*	4.09
mature plantation spotted gum	4.25
563	4.31
mature native spotted gum	4.55
307	4.57
spotted gum sapwood	4.66
243	4.86
651	5.06
675	5.43
571*^	5.67
E. dunnii (9)	5.96
371+	6.09
387*^	6.11
579	6.45
587	6.57
507	6.78
E. dunnii (6)	6.97
91	7.01
515	7.10
E. dunnii (3)	7.36
523	7.52
259	8.13
E. dunnii (10)	8.18
155	8.71
483	8.96
young plantation spotted gum	8.97
619	9.30
young *E. grandis*	10.12
531*^	10.18
99	10.33
51+	10.48
27+	10.48
P. radiata	19.84

Notes

*	Very small or irregularly–shaped samples
+	Light-coloured samples
^	Patchy colour or density

APPENDIX TWO – Results with Sample Information

Key to abbreviations below

LC	light coloured sample
RC	cracking radial
GC	cracking along growth rings
IS	irregularly sized sample
ss	small sample
Black text	bottom mass loss > top mass loss
Blue text	top mass loss > bottom mass loss
Red Text	top mass loss >>> bottom mass loss
Shaded	Long logs (~8m) top samples from very top of tree

Table 5 All data in order of source (*continued next page)*

Source	Tree Number	Disc position	Segment Number	Mass Loss *C.versicolor*	Mass Loss *F.lilacino-gilva*
Central Af Rep D391	84	Bottom	155	13.30	8.71
Central Af Rep D391	84	Top	147	2.22	2.00
Ghana d500	3	Bottom	107	10.53	2.47
Ghana d500	3	Top	114	10.06	2.19
Ghana d500	4	Bottom	699	9.41	2.26
Ghana d500	4	Top	691	2.91	1.53
Ghana d500	12	Bottom	75	5.50	
Ghana d500	12	Top	83	2.88	3.31
Ghana d500	15	Bottom	483	12.92	8.96
Ghana d500	15	Top	475	2.85	1.99
Ghana d500	4b	Bottom	611	7.05	0.41
Ghana d500	4b	Top	619	9.21	9.30
New Caledonia D487	18	Bottom	635	3.84	2.77
New Caledonia D487	18	Top	627	0.00	1.41
New Caledonia D487	19	Bottom	243	11.61	4.86
New Caledonia D487	19	Mid	235	3.62	2.58
New Caledonia D487	19	Top	227	0.00	1.94
New Caledonia D487	151	Bottom	435	4.00	0.42
New Caledonia D487	151	Top	427	0.15	1.32
New Caledonia D488	152	Bottom	67	2.77	2.04
New Caledonia D488	152	Top	59	1.80	2.49
New Caledonia D522	11	Bottom	403	2.84	1.59
New Caledonia D522	11	Top	395	8.73	3.82
Nigeria D486	153	Bottom	355	6.74	1.95
Nigeria D486	153	Top	347	0.89	1.77
Senegal D417	70	Bottom	603	5.59	1.81
Senegal D417	70	Top	595	0.00	1.66
Senegal D417	155	Bottom	187	5.34	1.60
Senegal D417	155	Top	179	0.19	
Senegal D417	156	Bottom	387	11.65	6.11
Senegal D417	156	Top	379	0.23	
Senegal D417	157	Bottom	219	11.57	0.81
Senegal D417	157	Top	211	2.30	1.90
Senegal D417	a122	Bottom	451	10.17	4.09
Senegal D417	a122	Top	443	3.30	2.18
Senegal D417	b122	Bottom	259	13.43	8.13
Senegal D417	b122	Top	251	11.58	
Senegal D417	h1	Bottom	555	14.45	
Senegal D417	h1	Top	547	14.27	

APPENDIX TWO – Results with Sample Information

Table 5 All data in order of source *(continued from previous page)*

Source	Tree Number	Disc position	Segment Number	Mass Loss *C.versicolor*	Mass Loss *F.lilacino-gilva*
Senegal D417	h10	Bottom	203	13.85	
Senegal D417	h10	Top	195	1.72	3.29
Senegal D417	h11	Bottom	307	9.92	4.57
Senegal D417	h11	Top	299	3.06	3.14
Senegal D417	h12	Bottom	419	2.07	0.58
Senegal D417	h12	Top	411	0.10	1.95
Senegal D417	h12b	Bottom	499	1.23	
Senegal D417	h12b	Top	491	2.99	
Senegal D417	h2	Bottom	371	13.02	6.09
Senegal D417	h2	Top	363	2.57	1.25
Senegal D417	h5	Bottom	91	14.13	7.01
Senegal D417	h5	Top	99	12.87	10.33
Senegal D417	h6	Bottom	35	16.30	
Senegal D417	h6	Mid	27	15.12	10.48
Senegal D417	h6	Top	19	2.71	1.28
Senegal D417	h7	Bottom	171	14.81	2.04
Senegal D417	h7	Top	163	2.11	1.53
Senegal D417	h8	Bottom	3	8.63	0.92
Senegal D417	h8	Top	11	1.86	3.33
Senegal D417	h9	Bottom	275	12.49	
Senegal D417	h9	Top	271	1.09	2.51
Senegal S10066	14	Bottom	523	13.60	7.52
Senegal S10066	14	Mid	515	11.77	7.10
Senegal S10066	14	Top	507	4.58	6.78
Senegal S10066	150	Bottom	539	13.50	
Senegal S10066	150	Top	531	11.31	10.18
Senegal S9392	77	Bottom	467	4.73	1.34
Senegal S9392	77	Top	459	0.50	0.81
Senegal S9392	96	Bottom	291	4.56	
Senegal S9392	96	Top	283	0.21	1.97
Sudan S9687	25	Bottom	323	5.24	
Sudan S9687	25	Top	315	0.06	1.04
Sudan S9687	154	Bottom	571	4.27	5.67
Sudan S9687	154	Top	563	5.02	4.31
Togo D411	80	Bottom	667	6.20	1.10
Togo D411	80	Top	659	2.77	1.98
Uganda S10053	16	Bottom	339	5.48	1.64
Uganda S10053	16	Top	331	5.51	3.22
Uganda S10053	16b	Bottom	683	2.18	1.01
Uganda S10053	16b	Top	675	14.03	5.43
Unknown	h13	Bottom	587	13.65	6.57
Unknown	h13	Top	579	8.29	6.45
Unknown	h14	Bottom	139	18.69	
Unknown	h14	Mid	131	12.18	
Unknown	h14	Top	123	5.15	2.02
Upper Volta D415	86	Bottom	651	9.33	5.06
Upper Volta D415	86	Top	643	0.59	2.71
Upper Volta D416	158	Bottom	51	22.23	10.48
Upper Volta D416	158	Top	43	1.56	

APPENDIX THREE – Results of pair-wise multiple comparisons

Testing was undertaken using Fischer's Least Significant Difference Analysis after analysis of variance revealed that at least one of the means was significantly different to the others.

Table 6. Results of pair-wise multiple comparisons for Coriolus versicolor

Timber	**Mean % Mass Lost to Decay by *C. versicolor***	**Result for Fischers PLSD (Genstat v6.1)**	Timber	**Mean % Mass Lost to Decay by *C. versicolor***	**Result for Fischers PLSD (Genstat v6.1)**	Timber	**Mean % Mass Lost to Decay by *C. versicolor***	**Result for Fischers PLSD (Genstat v6.1)**
K 595	0.00	a	K 443	3.30	cdefghijklmn	K 387	11.65	vwxyzABCD
K 627	0.00	ab	K 235	3.62	defghijklmn	K 515	11.77	wxyzABCD
K 227	0.00	ab	K 635	3.84	efghijklmno	K 131	12.18	xyzABCDE
K 315	0.06	abc	K 435	4.00	fghijklmno	*P. radiata*	12.45	yzABCDE
K 411	0.10	ab	mature native *E. grandis*	4.22	fghijklmno	K 275	12.49	yzABCDE
K 427	0.15	abc	K 571	4.27	fghijklmno	K 99	12.87	yzABCDE
K 179	0.19	abc	K 291	4.56	ghijklmno	K 483	12.92	yzABCDE
K 283	0.21	ab	K 507	4.58	ghijklmno	K 371	13.02	zABCDE
K 379	0.23	ab	K 467	4.73	ghijklmno	K 155	13.30	ABCDEF
K 459	0.50	abc	K 563	5.02	hijklmno	K 259	13.43	BCDEF
K 643	0.59	abcd	K 123	5.15	ijklmno	K 539	13.50	BCDEFG
grey iron bark	0.68	abcd	K 323	5.24	ijklmno	K 523	13.60	BCDEFG
K 347	0.89	abcde	K 187	5.34	klmonp	K 587	13.65	CDEFG
K 271	1.09	abcdef	K 339	5.48	lmonpq	K 203	13.85	CDEFG
K 499	1.23	abcdef	K 75	5.50	lmonpq	K 675	14.03	CDEFG
K 43	1.56	abcdefg	K 331	5.51	lmonpq	K 91	14.13	CDEFG
K 195	1.72	abcdefg	K 603	5.59	jmonpqr	K 547	14.27	CDEFG
K 59	1.80	abcdefg	mature native spotted gum	5.66	mnopq	K 555	14.45	CDEFG
K 11	1.86	abcdefg	K 667	6.20	nopqr	K 171	14.81	DEFG
mature plantation spotted gum	2.01	abcdefgh	K 355	6.74	nopqr	K 27	15.12	EFG
K 419	2.07	abcdefghij	K 611	7.05	opqrs	K 35	16.30	FGH
K 163	2.11	abcdefghj	K 579	8.29	pqrst	spotted gum sapwood	16.45	GH
K 683	2.18	abcdefghijk	young plantation spotted gum	8.46	qrstu	K 139	18.69	H
K 147	2.22	abcdefghij	K 3	8.63	qrstuvw	K 51	22.23	I
K 211	2.30	abcdefghij	K 395	8.73	rstuv	young *E. grandis*	27.01	J
K 363	2.57	abcdefghijkl	K 619	9.21	rstuvwx	*E. dunnii* (9)	27.65	J
K 19	2.71	abcdefghijklm	K 651	9.33	stuvwx	*E. dunnii* (3)	31.69	K
K 659	2.77	abcdefghijklm	K 699	9.41	stuvwx	*E. dunnii* (10)	33.30	K
K 67	2.77	abcdefghijklm	K 307	9.92	stuvwxy	*E. dunnii* (6)	49.11	L
K 403	2.84	abcdefghijklm	K 114	10.06	stuvwxyz			
K 475	2.85	abcdefghijklm	K 451	10.17	stuvwxyzA			
K 83	2.88	abcdefghijklm	K 107	10.53	tuvwxyzAB			
K 691	2.91	abcdefghijklm	K 531	11.31	tuvwxyzABC			
C. glaucophylla	2.96	abcdefghijklm	K 219	11.57	uvwxyzABCD			
K 491	2.99	abcdefghijklm	K 251	11.58	vwxyzABC			
K 299	3.06	bcdefghijklm	K 243	11.61	uvwxyzABCD			

APPENDIX THREE – Results of pair-wise multiple comparisons

Testing was undertaken using Fischer's Least Significant Difference Analysis after analysis of variance revealed that at least one of the means was significantly different to the others.

Table 7. Results of pair-wise multiple comparisons for ***Fomitopsis lilacino-gilva***

Timber	**Mean % Mass Lost to Decay by *F. lilacino-gilva***	**Result for Fischers PLSD (Genstat v6.1))**	Timber	**Mean % Mass Lost to Decay by *F. lilacino-gilva***	**Result for Fischers PLSD (Genstat v6.1))**
K 611	0.41	a	K 299	3.14	ghijklmnopqr
K 435	0.42	a	K 331	3.22	hijklmnopqr
K 419	0.58	ab	K 195	3.29	ijklmnopqrs
K 459	0.81	abc	K 83	3.31	ijklmnopqrs
K 219	0.81	abcd	K 11	3.33	ijklmnopqrs
K 3	0.92	abcd	mature native *E. grandis*	3.78	klmnopqrst
K 683	1.01	abcde	K 395	3.82	lmnopqrst
K 315	1.04	abcdef	K 451	4.09	lmnopqrst
K 667	1.10	abcdef	mature plantation spotted gum	4.25	nopqrstu
K 363	1.25	abcdef	K 563	4.31	opqrstuv
K 19	1.28	abcdef	mature native spotted gum	4.55	pqrstuv
K 427	1.32	abcdef	K 307	4.57	qrstuv
K 467	1.34	abcdefgh	spotted gum sapwood	4.66	rstuv
K 627	1.41	abcdefghi	K 243	4.86	rstuvw
C. glaucophylla	1.41	abcdefg	K 651	5.06	stuvw
K 163	1.53	abcdefghi	K 675	5.43	tuvwx
K 691	1.53	abcdefghi	K 571	5.67	tuvwxy
K 403	1.59	abcdefghij	*E. dunnii* (9)	5.96	uvwxy
K 187	1.60	abcdefghij	K 371	6.09	vwxy
K 339	1.64	abcdefghij	K 387	6.11	uvwxy
K 595	1.66	abcdefghij	K 579	6.45	wxyz
K 347	1.77	abcdefghij	K 587	6.57	wxyz
K 603	1.81	abcdefghijkl	K 507	6.78	wxyz
K 211	1.90	abcdefghij	*E. dunnii* (6)	6.97	wxyzA
K 227	1.94	abcdefghijkl	K 91	7.01	xyzAB
K 411	1.95	abcdefghij	K 515	7.10	yzABC
K 355	1.95	abcdefghijkl	*E. dunnii* (3)	7.36	yzABCD
K 283	1.97	abcdefghij	K 523	7.52	yzABCD
K 659	1.98	abcdefghij	K 259	8.13	zABCD
K 475	1.99	abcdefghijk	*E. dunnii* (10)	8.18	zABCD
K 147	2.00	abcdefghijk	K 155	8.71	ABCDE
K 123	2.02	abcdefghijkl	K 483	8.96	BCDE
K 67	2.04	abcdefghijkl	young plantation spotted gum	8.97	CDE
K 171	2.04	abcdefghijkl	K 619	9.30	DE
K 443	2.18	abcdefghijkl	young *E. grandis*	10.12	E
K 114	2.19	abcdefghijkl	K 531	10.18	E
K 699	2.26	abcdefghijklm	K 99	10.33	E
K 107	2.47	bcdefghijklmn	K 51	10.48	E
K 59	2.49	cdefghijklmn	K 27	10.48	E
K 271	2.51	cdefghijklmn	P. *radiata*	19.84	F
K 235	2.58	cdefghijklmno			
K 643	2.71	defghijklmno			
K 635	2.77	efghijklmnop			
grey iron bark	2.83	fghijklmnopq			

APPENDIX FOUR – Approximate classification

Although it is not statistically sound to impose discrete cut-offs to categorise the performance of a timber after APAD bioassay, to aid interpretation and provide a general indication of performance, timbers can be categorised into resistance groups based on the mass loss criteria used in the American standard method of accelerated laboratory testing of the natural decay resistance of woods used to interpret soil jar data (ASTM_D2017-81 1986) (Table 9).

To account for greater mass loss when using soil rather than agar (Van Acker et al. 1998) and because the incubation time for agar plate bioassay is less than that for soil jars, the mean mass loss cut off criteria were reduced (in proportion to the soil jar criteria) for interpretation of agar plate data.

Table 8. General classification of results based on mean % mass loss

Soil Jar data interpretation (ASTM_D2017-81 1986)		***Agar Plate Accelerated Decay Bioassay data interpretation***	
Indicated class of resistance to a specified fungus	*Mean mass loss (%)*	*Indicated class of resistance to a specified fungus*	*Mean mass loss (%)*
[1] Highly resistant	*0 to 10*	*[1] Highly resistant*	*0 to 3*
[2] Resistant	*11 to 24*	*[2] Resistant*	*3.1 to 7.4*
[3] Moderately resistant	*25 to 44*	*[3] Moderately resistant*	*7.5 to 13.4*
[4] Slightly / non-resistant	*45 or more*	*[4] Slightly / non-resistant*	*13.5 or more*

(ASTM_D2017-81 1986) states that considerable background data indicate that there is relatively good agreement between weight losses for soil jars and service experience with the tested woods. Examples discussed include:

Highly resistant / Resistant – redwood, black locust and white oak, western red cedar;

Moderately resistant – Douglas fir, western larch;

Slightly resistant or non-resistant – true firs, spruce, beech, birch and hemlock.

Loose association, for the sake of comprehension, can be made with durability classes.

Using the cut-offs above, *K. senegalensis* samples can be separated into four groups according to mass loss criteria, with samples belonging to group one having good potential for above average decay resistance.

Table 9. *Example of approximate classification for* Coriolus versicolor *(white rot, 8 week K. Senegalensis* incubation)

Timber	**Mean % Mass Lost to Decay**
grey iron bark	0.68
***K. senegalensis*group 1** (0 – 3% mass loss)	1.56
mature plantation spotted gum	2.01
C. glaucophylla	2.96
mature native *E. grandis*	4.22
***K. senegalensis*group 2** (3.1 – 7.4% mass loss)	5.04
mature native spotted gum	5.66
young plantation spotted gum	8.46
***K. senegalensis*group 3** (7.5 – 13.4% mass loss)	11.0
P. radiata	12.45
***K. senegalensis*group 4** (> 13.5% mass loss)	15.28
spotted gum sapwood	16.45
Young plantation *E. grandis*	27.01
E. dunnii	35.44

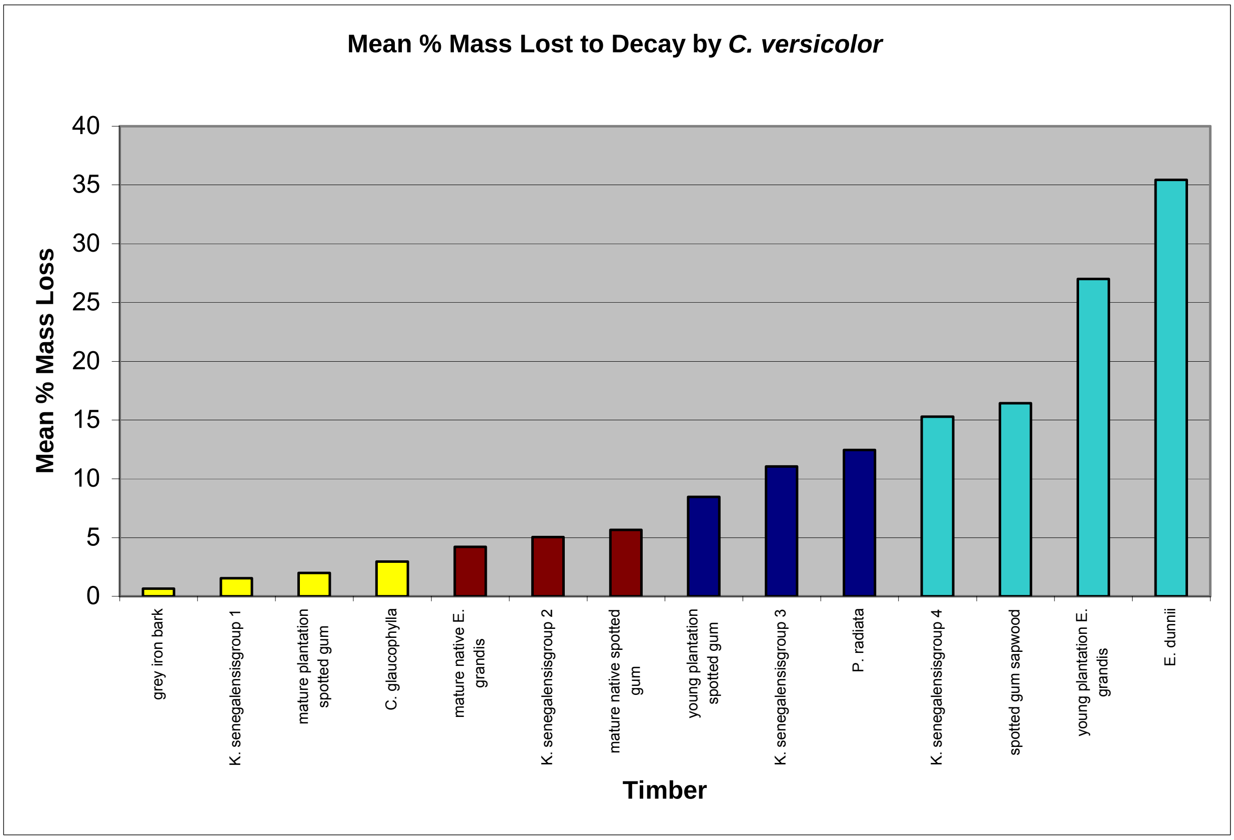


Figure 5. Approximate classifications similar to conventional interpretation systems, C. versicolor example.

Table 10: Example of approximate classification for Fomitopsis lilacino-gilva (brown rot, 11 week *K. senegalensis* incubation)

Timber	Mean % Mass Lost to Decay
C. glaucophylla	1.41
***K. senegalensis* group 1** (0 – 3% mass loss)	1.68
grey iron bark	2.83
mature native *E. grandis*	3.78
mature plantation spotted gum	4.25
mature native spotted gum	4.55
spotted gum sapwood	4.66
***K. senegalensis* group 2** (3.1 – 7.4% mass loss)	5.01
E. dunnii	7.12
young plantation spotted gum	8.97
***K. senegalensis* group 3** (7.5 – 13.4% mass loss)	9.34
young plantation *E. grandis*	10.12
P. radiata	19.84

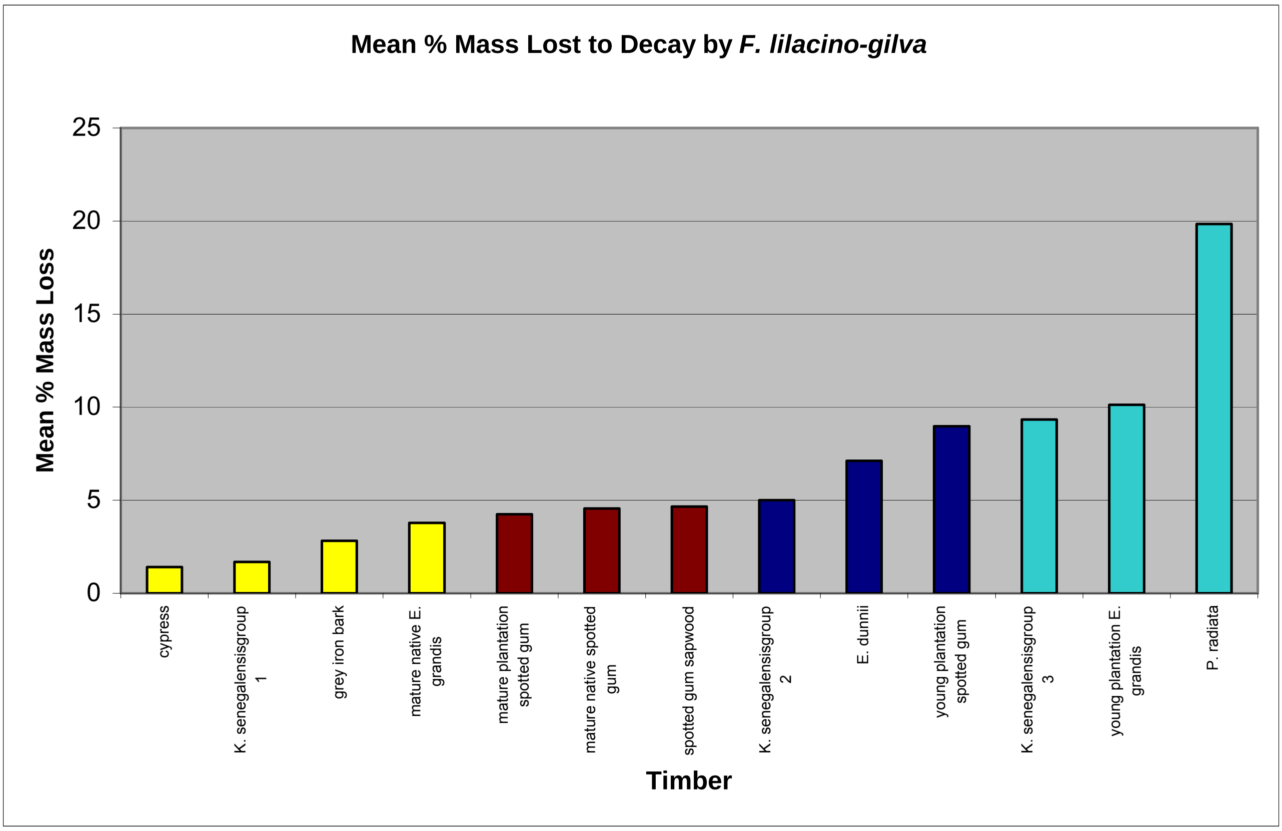


Figure 6 Approximate classifications similar to conventional interpretation systems, *F. lilacino-gilva* example.

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Appendix D: Industry Assessment

Companies that responded:

- Queensport Furniture, 71 Gosport St, HEMMANT QLD 4174
- Furniture Concepts Queensland, 64 Randolph St, Rocklea QLD 4106
- Paragon Furniture, 34 Annerley Rd, Woolloongabba QLD 4102
- Brims Wood Panels Pty Ltd, Station Road, Yeerongpilly QLD 4105
- Proveneer, Shed 4/17 River Rd, Redbank QLD 4301
- Gerard Gilet and Guitarwood, Booralee Street, Botany NSW 2019
- Ochoteco Guitars, 115 Gotha St, Fortitude Valley QLD4006
- Doug Eaton and Dale Jacobsen River Music, PO Box 456, Maleny QLD 4556
- Trend Timbers Pty Ltd, Cuneen St, Windsor NSW 2756
- Lazarides Timber Agencies, 15 Hurricane St, Banyo QLD 4014
- Weisner, Toowoomba

Questionaries

SURVEY QUESTIONNAIRE

1. What is your activity?

Furniture	Yes ☐	No ☐
Instrumental	Yes ☐	No ☐
Supplier	Yes ☐	No ☐
Import-Export	Yes ☐	No ☐
Cabinet kitchen	Yes ☐	No ☐
Merchant	Yes ☐	No ☐
Veneer	Yes ☐	No ☐
Joinery	Yes ☐	No ☐

Other Please specify:________________

2. Are you using African mahogany timber? Yes ☐ No ☐

If Yes, from where is it sourced? ________________________________

If Yes go to question **3**, if No go to question **9**

3. Which sort of products?

____

4.

Strengths	Weaknesses

5. Wood appearance?

Colour	Good ☐	Average ☐	Poor ☐
Aesthetics' aspect	Good ☐	Average ☐	Poor ☐
Texture	Good ☐	Average ☐	Poor ☐

6. Comments on wood properties (eg stability, density, strength, shrinkage, hardness, other properties)

____

7. Do you export your products? Yes ☐ No ☐

8. If yes, to which countries?

____

9. Do you think there is a potential domestic market? Yes ☐ No ☐

10. Do you think there is a potential export market? Yes ☐ No ☐

11. From your knowledge, what is the African mahogany timber worth on the domestic and export market?

Have you an idea concerning wholesale prices and retail prices for this timber?

____

12. Are you interested in testing plantation grown African mahogany?

Yes ☐ No ☐

13. Which dimensions would you require for testing? (Thickness, Width, Length)

14. Do you require dressed or rough sawn timber?

Dressed ☐ Rough ☐

15. Could you tell me which grade you require? (eg totally clean, some sound defects, other)

END

ASSESSMENT QUESTIONNAIRE

1. Comments on utilisation potential and possible end-uses?

2. Grade, quality Good ☐ Average ☐ Poor ☐

Comments:

3. Density

Comments:

4. Blunting? Good ☐ Average ☐ Poor ☐

Effect on blades and tools?

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5. Sawing Good ☐ Average ☐ Poor ☐

6. Machining Good ☐ Average ☐ Poor ☐

7. Fastening (nails/screw) Good ☐ Average ☐ Poor ☐

8. Gluing Good ☐ Average ☐ Poor ☐

9. Mortising and Tenoning Good ☐ Average ☐ Poor ☐

10. Wood appearance?

Colour Good ☐ Average ☐ Poor ☐

Aesthetics' aspect Good ☐ Average ☐ Poor ☐

Texture Good ☐ Average ☐ Poor ☐

11.

Strengths	Weaknesses

12. Do you think there is a potential domestic market? Yes ☐ No ☐

13. Do you think there is a potential export market? Yes ☐ No ☐

14. Could you give the volume for domestic and export market?

____

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15. Have you an idea concerning price and value of this timber?

____

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16. If you already used African mahogany from Africa or other sources, how does this timber compare?

END

Appendix E: Log properties data

Provenance	Tree N°	Bark thickness (mm)	End-split (score)	Pith offset (mm)	Heartwood proportion (%)
New Caledonia D522	11	10	**3.25**	24.5	56.3%
Ghana d500	12	9.5	**4.25**	36.0	50.6%
Senegal D417	122	9	**2.63**	51.5	61.9%
Senegal S10066	14	10	**9.00**	21.3	47.0%
Ghana d500	15	8.5	**6.88**	55.5	45.3%
Senegal S10066	150	7.8	**7.50**	19.0	31.4%
New Caledonia D487	151	9	**3.25**	31.0	52.6%
New Caledonia D488	152	8	**4.88**	21.0	52.0%
Nigeria D486	153	10	**3.88**	16.5	46.2%
Sudan S9687	154	7	**2.75**	7.0	43.2%
Senegal D417	155	8	**4.25**	17.5	63.1%
Senegal D417	156	6	**4.88**	19.5	36.7%
Senegal D417	157	8	**3.50**	15.0	64.8%
Upper Volta D416	158	8.5	**5.63**	16.0	55.2%
Uganda S10053	16	9.75	**3.13**	52.8	57.5%
New Caledonia D487	18	8	**2.50**	30.5	38.2%
New Caledonia D487	19	7.5	**7.50**	20.0	48.7%
Sudan S9687	25	7	**1.38**	30.0	56.8%
Ghana d500	3	8	**4.88**	39.5	47.3%
Ghana d500	4	8	**4.94**	28.8	42.2%
Senegal D417	70	11.5	**4.88**	44.5	30.5%
Senegal S9392	77	9.5	**4.88**	24.5	50.9%
Togo D411	80	10	**1.88**	42.5	63.8%
Central Af Rep D391	84	7.5	**3.38**	32.0	42.9%
Upper Volta D415	86	9	**4.50**	18.0	55.4%
Senegal S9392	96	8	**6.50**	16.0	46.8%
Senegal D417	H1	7.5	**4.75**	29.0	32.9%
Senegal D417	H10	7	**5.38**	13.5	45.0%
Senegal D417	H11	7	**6.50**	25.5	58.2%
Senegal D417	H12	7.5	**1.69**	26.0	51.07%
Unknown	H13	6	**5.25**	47.5	81.1%
Unknown	H14	6.5	**3.88**	17.7	38.2%
Senegal D417	H2	7.5	**4.75**	30.0	41.0%
Senegal D417	H5	5.5	**3.38**	23.5	39.5%
Senegal D417	H6	6.5	**2.00**	29.0	47.9%
Senegal D417	H7	8.5	**2.00**	48.5	55.8%
Senegal D417	H8	8	**3.75**	17.0	66.7%
Senegal D417	H9	6.5	**4.00**	30.5	66.3%
Av		**8.1**	**4.3**	**28.1**	**50.3%**
Std. Dev.		**1.3**	**1.7**	**12.2**	**11.0%**
Max.		**11.5**	**9.0**	**55.5**	**81.1%**
Min.		**5.5**	**1.4**	**7.0**	**30.5%**
Med.		**8.0**	**4.3**	**25.8**	**49.7%**
Count		**38**	**38**	**38**	**38**

Appendix F: GOS Recovery

Tree	Log	Tag number	New log	Length	Diam. L	Diam. S.	Vol	GOS Rec	GOS vol
H7		277		4.18	400	295	0.405	45.3%	0.184
H6		276		5.5	300	200	0.281		
H6			A	2.7	300	225	0.149	41.2%	0.062
H6			B	2.76	225	200	0.098	42.8%	0.042
77		153		2.98	340	235	0.200	29.7%	0.059
152		135		3.8	335	260	0.268	38.5%	0.103
158		268		3.38	315	195	0.182	31.7%	0.058
H14		280		5.7	285	185	0.258		
H14			A	2.87	285	210	0.141	32.4%	0.046
H14			B	2.8	210	185	0.086	44.7%	0.039
155		157		3.61	305	215	0.197	41.1%	0.081
H8		278		4.41	385	305	0.418	34.1%	0.142
25		144		4.19	395	225	0.340	31.4%	0.107
19		137		5.89	475	310	0.744		
19			A	2.77	475	385	0.407	45.4%	0.185
19			B	3.05	385	310	0.293	42.3%	0.124
H10				4.52	340	230	0.299	31.1%	0.093
122A				3.49	545	405	0.632	50.6%	0.320
122B				3.48	410	410	0.459		
11		132/133		4.9	525	405	0.846	39.2%	0.331
H9		279		4.16	330	250	0.280	38.4%	0.108
12		928		3.9	385	305	0.369	33.0%	0.122
H11				4.75	380	270	0.405	68.2%	0.277
H2		270		5.34	370	255	0.423	36.3%	0.154
156		159		4.7	285	195	0.220	25.3%	0.056
H12A		271		3.62	375	285	0.315	42.7%	0.135
H12B		272		3.57	300	240	0.207		
157		158		4.7	350	248	0.340	38.5%	0.131
84		154		3.9	395	265	0.347	30.5%	0.124
H5?		275		4.68	355	250	0.346	38.2%	0.132
3		921		4.9	395	290	0.462	46.6%	0.215
15		931		4.2	490	365	0.616	39.0%	0.240
H1		269		4.82	520	355	0.750	34.7%	0.260
16A		129		3.56	610	525	0.906	50.9%	0.461
16B		130		3.29	495	480	0.614		
96		160		3.84	270	175	0.156	37.3%	0.058
14		126		5.06	505	365	0.771		
14			A	2.8	505	400	0.456	45.9%	0.210
14			B	2.33	400	365	0.268	41.5%	0.111
150		124		3.61	335	250	0.248	31.6%	0.078
153		145		4.4	335	215	0.274	26.0%	0.071
80		150		3.49	485	375	0.515	51.8%	0.267
H13				4.77	520	300	0.675	35.2%	0.238
70		156		3.57	500	355	0.527	39.2%	0.206
4A		924		3.65	490	355	0.525	39.4%	0.207
4B		926		3.59	365	360	0.371		
18		140		3.56	445	335	0.434	41.0%	0.178
154		147		3.87	280	195	0.177	39.5%	0.070
151		139		3.88	385	345	0.407	36.3%	0.148
86		155		4.22	360	260	0.327	50.9%	0.166

Sum				17.382		6.397
Average	3.8	388.8	294.7	0.378	39.5%	0.152
Std. Dev	0.8	90.4	81.5	0.197	8.0%	0.092
Min.	2.3	210.0	175.0	0.086	25.3%	0.039
Max.	5.3	610.0	525.0	0.906	68.2%	0.461

Appendix G: Tree Rankings

Provenance	Site	Tree	No. of 'top 10's'
Senegal D417	Gunn	122	7
Togo D411	Gunn	80	7
Uganda S10053	Gunn	16	6
Senegal D417	Howard	H8	4
Senegal D417	Howard	H11	4
Senegal D417	Gunn	157	4
New Caledonia D487	Gunn	19	4
New Caledonia D487	Gunn	18	4
Ghana d500	Gunn	15	4
Senegal S10066	Gunn	14	4
Ghana d500	Gunn	3	4
Senegal D417	Howard	H7	3
Senegal D417	Gunn	155	3
Senegal D417	Gunn	70	3
New Caledonia D522	Gunn	11	3
Senegal D417	Howard	H6	2
Senegal D417	Howard	H5	2
Unknown	Howard	H13	2
Senegal D417	Howard	H12	2
Senegal D417	Howard	H10	2
Senegal D417	Howard	H1	2
Senegal S10066	Gunn	150	2
Sudan S9687	Gunn	25	2
Ghana d500	Gunn	4	2
Senegal D417	Howard	H9	1
Unknown	Howard	H14	1
Upper Volta D416	Gunn	158	1
Senegal D417	Gunn	156	1
Sudan S9687	Gunn	154	1
Senegal S9392	Gunn	96	1
Upper Volta D415	Gunn	86	1
Central Af Rep D391	Gunn	84	1
Senegal S9392	Gunn	77	1
Senegal D417	Howard	H2	0
Nigeria D486	Gunn	153	0
New Caledonia D488	Gunn	152	0
New Caledonia D487	Gunn	151	0
Ghana d500	Gunn	12	0

Provenance	Site		Grand Total
	Gunn	Howard	
Central Af Rep D391	1.0		1.0
Ghana d500	2.5		2.5
New Caledonia D487	2.7		2.7
New Caledonia D488	0.0		0.0
New Caledonia D522	3.0		3.0
Nigeria D486	0.0		0.0
Senegal D417	3.6	2.2	2.7
Senegal S10066	3.0		3.0
Senegal S9392	1.0		1.0
Sudan S9687	1.5		1.5
Togo D411	7.0		7.0
Uganda S10053	6.0		6.0
Unknown		1.5	1.5
Upper Volta D415	1.0		1.0
Upper Volta D416	1.0		1.0
Average	2.5	2.1	2.4