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Pine health survey, Blackwood Valley, spring 1988

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1. Pathology

INTRODUCTION

In December 1987 the pine pathogen Sphaeropsis sapinea (Fr.) Dyko & Sutton (= Diplodia pinea) was recovered from dead shoots on rooted radiata cuttings from the Gnangara nursery. Within the next few weeks it was recovered from dead shoots on rooted pinaster cuttings and dead radiata seedlings at Gnangara, dead seedlings from Nannup nursery, and from radiata cones from Gleneagle, Grimwade and Manjimup.

Although S. sapinea was recorded in pine in W.A. in 1968 (file letter from Stahl to the Conservator of Forests 12.12.68), this fungus was not recognised when it was isolated in 1987 and the tentative identification had to be confirmed by a pathologist in Queensland.

S. sapinea is an important pathogen of pines in the southern hemisphere; Pinus radiata is particularly susceptible. Gibson (1978) records that although it may be damaging to seedlings in the nursery, it is much more important as a pathogen of plantation trees. Symptoms include the death of the current year's growth, stem cankers, crown dieback and tree death. S. sapinea can also cause blue stain of recently felled timber. In Queensland and the Transvaal radiata plantations have been severely damaged by infection following summer hail damage. Other, less susceptible pines are now grown.

During the past 10 years, pine pathology in W.A. has concentrated on Phytophthora spp. associated with tree deaths in the Sunklands area (Chevis and Stukely, 1982). The isolation methods used in these investigations are inappropriate for the recovery of S. sapinea and other pine pathogens unrelated to Phytophthora spp. The identity and status of other pine pathogens in the state is unknown.

Pines growing in the Blackwood valley area showed high mortality rates during the 1986/87 and 1987/88 summers. Concern at these deaths and concern too at the lack of knowledge of the local pine pathogens resulted in a pine health survey which was carried out in spring, 1988. The aims of the survey were:

1. to record symptoms occurring in P. radiata

2. to determine which fungi are associated with these symptoms.

3. to determine whether known pine pathogens are likely to have contributed to the death of the trees.

The results of the survey are given below.

METHODS

Field survey

A systematic survey was carried out in Ellis plantation (Fig. 1) with additional sampling in Shelley and Lewana plantations. Plantation histories are given in Table 1. In Ellis trees were sampled at ten equally spaced locations along each of three transects: at the upper slope, along Glacier Road, and at mid-slope and lower slope positions on Butte Road. At each location, about 20 m inside the plantation, the best and worst tree in terms of general health were selected from the five trees closest to the sample point. These two trees were examined in a systematic manner; the following data was collected on the standing tree, after falling and in the laboratory:

dominance class

tree height

overbark diameter at 1.4 m (dobh)

underbark diameter at 1.4 m (dubh)

ring widths at 1.4 m

presence of Ips emergence holes at 1.4 m.

presence of blue stain on pruning wounds

The crown was subdivided by marking the major branch whorls. Symptoms on the needles, branches and stem between the whorls were assessed in the field. These included:

health of terminal shoot

number of live, dead or partly dead branches in each major whorl.

presence of cones

presence of erumpent pustules on the cones

symptoms on live needles

superficial phloem cankers in the stem

phloem and associated wood cankers in the stem

discolouration of the wood

The leaf litter and soil were raked away from the butt of the tree and five major roots exposed. The following symptoms in the root collar and major roots were assessed in the field:

presence of dead phloem

presence of discoloured wood.

Samples of a range of symptoms from stems, branches and roots were taken in the field for fungal isolations. A composite soil sample was taken from four positions around the base of the tree for soil baiting. In addition, any insects found on the tree were collected.

Laboratory isolations

Fungal isolations were made from small chips (about 2x2x2 mm) of discoloured tissue close to the margin of obvious lesions. Samples were surface sterilized for 20 sec. in 70% ethanol, rinsed in sterile distilled water, and then plated onto half strength potato dextrose agar (1/2 PDA), cornmeal agar (CMA) and 0.2% malt extract agar (0.2% MA). Samples from the root collar and roots were also plated onto antibiotic agar (P_{10} VPH) which is selective for Phytophthora spp. The plates were incubated at 20 ^{o} C and examined as appropriate. When necessary plates were incubated under near-UV light to stimulate sporulation.

Soil samples were baited with green needles of Pinus pinaster. After 7 days the needle bases were surface sterilized for 10 seconds in 70% ethanol, rinsed in sterile distilled water and then plated onto CMA and incubated at 20 ^{o} C.

Results

The size and status of trees used in the surveys is given in Table 2.

Symptoms

1. The crown

The selection of trees in Ellis and Lewana plantations was based on crown symptoms. The crown length was divided into three equal parts and symptoms on the major branch whorls in each third of the crown were treated separately.

1A. The branches

Branches were assessed as dead when they bore no green needles and live when they carried only green needles. There were more live and partly-dead branches on the upper, middle and lower third of the crowns of the best trees than the worst trees at Ellis and Lewana, while at Shelley there were only live branches (Fig 2.) In the best trees, there were fewer live branches in the lower third of the crown than in the upper two thirds (Fig 2.)

1B The needles

Apart from dead needles, two other symptoms were common: brown tips, and brown spots. They were present on all parts of the crown and on trees from Shelley, Ellis and Lewana plantations (Table 3). Brown spots were present on more portions of the crown than brown tips.

As needle spotting and tip death can be caused by insect damage, physiological disorders or fungal pathogens, these symptoms were not investigated further.

2. The Stem

2A Death of the terminal shoot, presence of forks

At both Ellis and Lewana plantations the current leader was dead in at least some trees of both the best and worst trees (Table 4). As this can lead to stem forking or a replacement leader, these symptoms were also recorded. The terminal shoot had died or a fork was present in the top third of the crown in 35% of the trees examined, but only in 10% and 5% respectively in the mid and lower thirds of the crown (Table 4).

2B Stem cankers

In most, but not all of the trees with dead needles, the stem was dry. In moist stems two symptoms were distinguished: superficial phloem cankers where the outer part of the bark was dead and discoloured, and perennial cankers in which the bark adjacent cambium and part of the wood had been killed (Fig 3). Both superficial phloem cankers and perennial cankers were seen on trees from Ellis and Lewana plantations but not on trees at Shelley (Table 5). Superficial cankers were more abundant then perennial cankers and were seen in all parts of the stem on trees in Ellis and Lewana; perennial cankers were not seen on the pruned stem of the best trees, mid-slope, in Ellis plantation, or on the lower half of the stem of the best trees (Table 5).

2C The cones

Cones were present on trees in Shelley, Ellis and Lewana plantations. A number of pine pathogens including S. sapinea, can infect cones causing erumpent pustules on the cone scales. Such symptoms were seen on cones from trees at Ellis and Lewana but not from Shelley (Table 6).

2D The wood

The stem was cut across between all the major whorls so that it could be examined for discoloured wood, blue stained wood and rots. Blue stained wood was present in all the stems which were dry, but also in some stems which were still sappy (Table 7). It was found more frequently at the top than the bottom of the trees: in the top third of the crown, wood of 52% of the trees was blue stained, but in the pruned stem only 30% of the trees had blue stain.

Blue wood was more common than discoloured wood. Rots were not seen.

Pruning wounds can be invaded by blue stain fungi. This was assessed in a disc taken from the pruned stem. Blue stain in pruning wounds was present in trees from both Ellis and Lewana plantations (Table 8).

2E Ips in the lower stem.

Ips will infest the bark of trees in which either the crown is dying or has recently died. They require moist, not dry bark for oviposition ( ). Ips infestation was measured by

counting the emergence holes in 10 cm^2 on the stem at 1.4 m. Counts were made on both the south and north facing sides of the stem.

Not all trees with no live needles in the crown had Ips emergence holes in the lower stem (Table 9). Two trees which still had green needles in the crown had Ips emergence holes in the butt. Both trees were from the lower slope in Ellis plantation.

3 Roots and root collar

Dead phloem and discoloured wood were present in the root collar of trees at Shelley, Ellis and Lewana plantations, they were more common in the worst trees (70% and 65% respectively) than in the best trees (5%) (Table 10). Dead phloem and discoloured wood were present in roots from trees at Shelley, Ellis and Lewana plantations. They were also more common in the worst trees (71% and 67% respectively) than in the best trees (18% and 8% respectively). Most, but not all discoloured wood was blue stained. No rots were seen.

Fungal isolations

Samples for fungal isolations were returned to the laboratory and tissue from the margin of the discoloured areas plated onto appropriate media. Results are expressed

in terms of numbers of samples of a particular symptom from which isolations were made, as well as the frequency with which commonest fungi grew from the number of pieces of tissue used in the isolations.

1. Phloem cankers

Phloem cankers were present on the branches, stems and roots. On branches the most common fungus isolated from phloem cankers was Sphaeropsis sapinea (Table 11). In stems, collars and roots S. sapinea and Ceratocystis ips were the commonest fungi (Tables 12 and 13) Phytophthora spp. were not isolated.

2. Discoloured wood

Discoloured wood, including blue stained wood was associated with perennial cankers as well as being present in recently dead trees. S. sapinea and C. ips were the commonest fungi isolated (Table 14 and 15). Phytophthora spp. were not recovered.

3. Soil samples

Soil samples taken from around the base of each sampled tree were baited with pine needles for Phytophthora spp. A number of potentially pathogenic soil fungi are

isolated by this method. Phytophthora spp. were not isolated from any of the plantations (Table 16). Pythium and Fusarium were isolated from all sites, and Cylindrocarpon was isolated from part of Ellis and from Lewana (Table 16).

Insects

Insects were collected opportunistically. Apart from Ips grandicolis, Hylurgus ligniperda, a sap sucking Pentatomidae and a Noctuidae larva were the only other insects which could be considered important pests if present in sufficient numbers.

Discussion

To cover:

1. The association of *S. sapinea* with various symptoms.

2. The effect of drought stress on infection and spread of *S. sapinea*.

3. The association of *Ceratocystis ips* with *Ips grandicolis*.

4. The role of *Fusarium* and other fungi.

5. Suggested time course.

6. When is a tree dead?

2. Pine growth, Ellis Plantation

The trees sampled in the pine health survey were sampled on the basis of general health, not size or dominance class (Table 2). As tree health might be related to size and growth, measurements of the trees from the Ellis plantation were compared to see whether the biggest trees were the healthiest.

Tree size, spring 1988

Combining data from each slope position, the best trees were significantly taller (Table 17) and had greater girth than the worst trees (Table 18). They were also more likely to be in a higher dominance class than the worst trees (Table 19). Combining the best and worst trees at each slope position, trees on the upper slope were smaller than trees in the mid and lower slopes, with trees at the lower slope being tallest (Table 20). Trees on the upper slope are one year younger than trees in the mid and lower slopes (Table 1). Stem diameter was similar at all slope positions (Table 21).

When just the best trees are considered, trees in the upper slope are shorter (Table 22) and of smaller dob (Table 23) than trees in the mid slope and lower slope. This may be solely because they are younger.

Tree growth, 1978 - 1987

Measurements of ring widths has enabled us to estimate area increment of the sampled trees between 1978 and 1987. The area increment was not constant for every year. It increased until age 7 or 8 and decreased sharply after age 10 (Fig. 3), i.e. in 1985 (mid and lower slope positions) and 1986 (upper slope position). The best trees and worst trees at each slope position showed similar trends, but the area increment of the worst trees was consistently less than that of the best trees after age 4 (Fig. 3).

DISCUSSION

To cover:

1. Projected rate of growth

2. Actual rate of growth

Table 1 Plantation histories of pines used in the health survey

Location	Planting date	Culling date	Stems ha^{-1} in 1988	No. trees examined
Shelley Plantation	1983	-	1 100	14
Ellis Plantation, upper slope	1976	-	1 100	20
Ellis Plantation, mid slope	1975	1978	750	20
Ellis Plantation, lower slope	1975	1978	750	20
Lewana Plantation	various	various	various	14

Table 2 Pine health survey, tree parameters

Location	Sample size	Height (m)	Crown length (m)	DBH (cm)		Tree class			
				overbark	underbark	Dom.	Co-dom.	Subdom.	Supp.
Shelley	14	6.7 (1.7)*	6.2 (1.7)	9.3 (3.1)*	7.8 (3.4)*	not determined			
Ellis, upper slope, best	10	17.8 (1.1)	15.3 (1.0)	26.5 (2.8)	23.7 (2.7)	3	7	0	0
Ellis, upper slope, worst	10	16.2 (2.0)	12.8 (1.6)	22.0 (3.8)	19.8 (3.7)	0	5	4	1
Ellis, mid slope, best	10	20.8 (1.5)	17.6 (1.7)	31.2 (4.3)	26.9 (3.7)	7	2	1	0
Ellis, mid slope, worst	10	15.6 (4.1)	15.2 (3.3)	22.7 (4.0)	20.3 (3.5)	1	2	7	0
Ellis, lower slope, best	10	20.7 (1.7)	16.2 (2.5)	29.9 (4.0)	26.5 (3.4)	5	5	0	0
Ellis, lower slope, worst	10	18.1 (1.5)	13.2 (1.2)	22.0 (2.9)	19.9 (2.6)	0	3	7	0
Lewana, best	7	24.0 (3.9)**	20.3 (5.0)**	30.6 (5.3)	25.9 (4.6)	0	7	0	0
Lewana, worst	7	24.2 (3.7)**	20.6 (2.8)**	28.7(6.4)	25.3(6.2)	0	5	2	0

Standard deviations given in parenthesis.

* 13 trees only measured
** 5 trees only measured

Table 3 Pine health survey, symptoms on needles

Location	No. trees examined	Top third of crown			Mid third of crown			Lower third of crown		
		Dead needles only	Brown spots	Brown tips	Dead needles only	Brown spots	Brown tips	Dead needles only	Brown spots	Brown tips
Shelley	14	0	12	2	0	13	9	0	14	13
Ellis, upper slope best	10	0	6	4	0	8	6	0	6	6
Ellis, upper slope, worst	10	10	-	-	10	-	-	8	2	1
Ellis, mid slope, best	10	0	7	7	0	7	8	0	6	6
Ellis, mid slope, worst	10	8	1	1	7	3	2	7	2	2
Ellis, lower slope, best	10	0	10	10	0	10	10	0	10	10
Ellis, lower slope, worst	10	7	2	3	7	2	3	7	2	2
Lewana, best	5	0	5	4	0	5	5	1	4	4
Lewana, worst	5	4	1	1	4	1	1	5	-	-

Table 4 Pine health survey: death of terminal shoot, or stem dividing into more than one leader

Location	No. trees examined	Current leader dead	Previous leader death or position of forking		
			Top third of crown	Middle third of crown	Lower third of crown
Shelley	14	0	0	1	0
Ellis, upper slope, best	10	7	2	2	0
Ellis, upper slope, worst	10	10	3	0	1
Ellis, mid slope, best	10	6	3	0	3
Ellis, mid slope, worst	10	10	6	2	0
Ellis, lower slope, best	10	2	6	2	0
Ellis, lower slope, worst	10	9	2	0	0
Lewana, best	7	3*	2	1	0
Lewana, worst	7	7	7	1	0

*Only 6 trees assessed (1 top missing in action)

Table 5 Pine health survey, stem cankers, presence or absence

Location	No. trees examined	Top third of crown			Mid third of crown			Lower third of crown			Pruned stem		
		Dry stem	Phloem cankers	Phloem and wood	Dry stem	Phloem cankers	Phloem and wood	Dry stem	Phloem cankers	Phloem and wood	Dry stem	Phloem cankers	Phloem and wood
Shelley	14	0	0	0	0	1	0	0	2	0	0	0	0
Ellis, upper slope, best	10	1	8	4	0	8	5	0	9	6	0	4*	4*
Ellis, upper slope, worst	10	9	1	1	9	1	1	8	2	2	8	2	2
Ellis, mid slope, best	10	0	9*	9*	0	9	6	0	10	3	0	5	0
Ellis, mid slope, worst	10	4	6	6	3	7	6	1	9	8	1	9	8
Ellis, lower slope, best	10	0	4	2	0	4*	0*	0	6*	0*	0	5	1
Ellis, lower slope, worst	10	7	2	2	6	3	1	6	3	1	6	1	1
Lewana, best	5	1	4	1	0	5	2	0	1	0	0	1	0
Lewana, worst	5	2	3	2	1	4	3	1	3	3	1	2	2

* only 9 trees measured

Table 6 Pine health survey, cones with erumpent pustules

Location	No. trees examined	Number of trees with cones at the major whorls					
		Top third of crown		Mid third of crown		Lower third of crown	
		Cones present	Cones with symptoms	Cones present	Cones with symptoms	Cones present	Cones with symptoms
Shelley	14	1	0	2	0	0	0
Ellis, upper slope, best	10	7	7	6	6	3	2
Ellis, upper slope, worst	10	8	8	7	7	4	3
Ellis, mid slope, best	10	5	4	7	7	2	2
Ellis, mid slope, worst	10	7	7	7	7	1	1
Ellis, lower slope, best	10	7	7	6	6	3	3
Ellis, lower slope, worst	10	7	7	8	8	2	2
Lewana, best	5	4	4	3	3	0	0
Lewana, worst	5	3	3	4	4	2	2

Table 7 Pine health survey, discoloured and blue stained wood

Location	No trees examined	Top third of crown			Mid third of crown			Lower third of crown			Pruned stem		
		Dry stem	Discoloured wood	Blue stained wood	Dry stem	Discoloured wood	Blue stained wood	Dry stem	Discoloured wood	Blue stained wood	Dry stem	Discoloured wood	Blue stained wood
Shelley	14	0	0	0	0	0	0	0	0	0	0	0	0
Ellis, upper slope, best	10	1	0	5	0	0	2	0	1	0	0	1	0
Ellis, upper slope, worst	10	9	0	10	9	0	10	8	0	10	8	0	9
Ellis, mid slope, best	10	0	2	4	0	2	2	0	0	0	0	0	0
Ellis, mid slope, worst	10	4	1	10	3	0	9	1	0	8	1	0	8
Ellis, lower slope, best	10	0	1	1	0	0	0	0	0	0	0	0	0
Ellis, lower slope, worst	10	7	0	10	5	0	10	6	0	8	6	0	6
Lewana, best	5	1	0	1	0	0	1	0	0	0	0	0	0
Lewana, worst	5	3	0	3	3	0	3	2	0	2	2	0	2

Table 8 Pine health survey, blue stain in pruning wounds

Location	No. trees examined	No. trees with blue stain in the pruning wounds
Shelley	14	N/A
Ellis, upper slope, best	7	3
Ellis, upper slope, worst	8	5
Ellis, mid-slope, best	5	1
Ellis, mid-slope, worst	7	3
Ellis, lower slope, best	10	2
Ellis, lower slope, worst	10	3
Lewana, best	7	4
Lewana, worst	7	4

Table 9 Pine health survey, *Ips* infestation in the butt

Location	No. trees sampled	No. trees with no live needles	No. trees with *Ips* emergence holes at 1.4 m	No. emergence holes 10 cm^{2} $^{-1}$
Shelley	14	0	0	0
Ellis, upper slope, best	10	1	1	1.0 (0)
Ellis, upper slope, worst	10	9	6	3.0 (2.8)
Ellis, mid slope, best	10	0	0	0
Ellis, mid slope, worst	10	8	4	3.0 (1.4)
Ellis, lower slope, best	10	0	0	0
Ellis, lower slope, worst	10	7	8	1.7 (1.0)
Lewana, best	7	0	0	0
Lewana, worst	7	6	3	2.5 (1.9)

Standard deviations given in parenthesis.

Table 10 Pine health survey, symptoms on root collar and roots

Location	Root Collar			Roots		
	No. sampled	Dead phloem present	Discoloured wood present	No. sampled	Dead phloem present	Discoloured wood present
Shelley	14	1	1	70	1	1
Ellis, upper slope, best	10	2	2	50	16	9
Ellis, upper slope, worst	10	9	9	50	45	45
Ellis, mid slope, best	10	0	0	50	15	5
Ellis, mid slope, worst	10	7	6	50	32	28
Ellis, lower slope, best	10	0	0	50	2	1
Ellis, lower slope, worst	10	5	5	50	32	30
Lewana, best	7	0	0	35	0	0
Lewana, worst	7	5	3	35	22	21

Table 11 Pine health survey, phloem cankers (branches)

Location	No. cankers sampled	Fungi isolated				Neither
		Sphaeropsis sapinea		*Ceratocystis ips*		
		No. cankers	Frequency (%)	No. cankers	Frequency (%)	
Shelley	2	0	-	0	-	2
Ellis, upper slope, best	6	6	79	0	-	0
Ellis, upper slope, worst	1	1	8	0	-	0
Ellis, mid slope, best	9	9	87	0	-	0
Ellis, mid slope, worst	3	2	50	0	-	1
Ellis, lower slope, best	10	10	55	0	-	0
Ellis, lower slope, worst	4	4	79	0	-	0
Lewana, best	6	5	48	0	-	1
Lewana, worst	0	0	-	0	-	0
Total	41	37		0		4

Other fungi isolated include *Cephalosporium, Cytospora, Fusarium,* and *Phoma*

Table 12 Pine health survey, phloem cankers (stem)

Location	No. cankers sampled	Fungi isolated				
		Sphaeropsis sapinea		*Ceratocystis ips*		Neither
		No. cankers	Frequency (%)	No. cankers	Frequency (%)	
Shelley	4	1	75	1		2
Ellis, upper slope, best	15	15	58	0		0
Ellis, upper slope, worst	1	1	66	0		0
Ellis, mid slope, best	12	12	63	6	25	0
Ellis, mid slope, worst	5	5	73	2	5	0
Ellis, lower slope, best	7	4	35%	0		3
Ellis, lower slope, worst	3	3	39	2	13	0
Lewana, best	9	8	41	0		1
Lewana, worst	1	1	17	1	50	0
Total	57	50		12		6

Other fungi isolated from cankers include *Fusarium, Leptographium, Phoma, Phialophora.*

Table 13 Pine health survey, phloem cankers in collar and roots

Location	No. samples examined	Fungi isolated				Neither
		Sphaeropsis sapinea		*Ceratocystis ips*		
		No samples	Frequency (%)	No samples	Frequency (%)	
Shelley	2	0		0		2
Ellis, upper slope, best	6	4	46	0		2
Ellis, upper slope, worst	5	4	77	0		1
Ellis, mid slope, best	11	8	26	0		3
Ellis, mid slope, worst	12	6	58	2	50%	5
Ellis, lower slope, best	1	1	33	0		0
Ellis, lower slope, worst	4	1	17	2	33	2
Lewana, best	2	0		0		2
Lewana, worst	3	0		1	83	2
Total	46	24		5		19

Other fungi isolated from collar and root phloem cankers include *Chalara, Cylindiocarpon, Fusarium* and *Phoma.*

Table 14 Pine health survey, discoloured, but not blue stained wood from stems, collars and roots.

Location	No. samples examined	Fungi isolated				Neither
		Sphaeropsis sapinea		*Ceratocystis ips*		
		No. samples	Frequency (%)	No. samples	Frequency (%)	
Shelley	1	0		0		1
Ellis, upper slope, best	5	2	25	1	17	3
Ellis, upper slope, worst	2	1	17	0		1
Ellis, mid slope, best	7	4	71	0		3
Ellis, mid slope, worst	3	3	75	0		0
Ellis, lower slope, best	0	0		0		0
Ellis, lower slope, worst	2	1	83	0		1
Lewana, best	1	0		0		1
Lewana, worst	6	1	8	2	46	3
Total	27	12		3		13

Other fungi isolated from discoloured wood include *Chaetomium, Cylindrocarpon, Fusarium, Leptographium,* and *Phoma*

Table 15 Pine health survey, blue stained wood from stems, collars and roots.

Location	No samples. examined	Fungi isolated				Neither
		Sphaeropsis sapinea		Ceratocystis ips		
		No samples	Frequency (%)	No samples	Frequency (%)	
Shelley	1	0		0		1
Ellis, upper slope, best	2	2	100	0		0
Ellis, upper slope, worst	4	4	56	0		0
Ellis, mid slope, best	4	4	100	0		0
Ellis, mid slope, worst	4	3	67	2	13	0
Ellis, lower slope, best	0					
Ellis, lower slope, worst	0					
Lewana, best	2	1	100	0		1
Lewana, worst	0					
Total	16	14		2		2

Other fungi isolated from blue stained wood include *Fusarium* and *Leptographium*.

Table 16 Pine health survey, soil baiting

Location	Sample size	Fungi isolated			
		Phytophthora spp.	*Pythium* spp.	*Fusarium* spp.	*Cylindrocarpon*
Shelley	14	0	12	14	0
Ellis, upper slope, best	10	0	9	10	3
Ellis, upper slope, worst	10	0	7	10	4
Ellis, mid slope, best	10	0	10	7	4
Ellis, mid slope, worst	10	0	10	10	0
Ellis, lower slope, best	10	0	3	10	0
Ellis, lower slope, worst	10	0	2	10	0
Lewana, best	7	0	3	6	6
Lewana, worst	7	0	1	5	6

Species isolated include:

Ellis: *Pythium irregulare, P. mamillatum, Fusarium oxysporum*
Shelley:
Lewana: *P. irregulare*

Table 17 Analysis of variance of the height of the best and worst trees at Ellis plantation.

Status	Sample size	Height (m) $\bar{x}$	s	F	p
Best	30	19.8	2.02	23.62	< .0001
Worst	30	16.6	2.88		

Table 18 Analysis of variance of the dob and dub at 1.4m of best and worst trees at Ellis plantation.

Status	Sample size	Height (m) $\bar{x}$	s	F	P
dob:					
Best (dob)	30	29.2	4.15	49.90	< .0001
Worst (dob)	30	22.25	3.46		
dub:					
Best (dub)	30	25.7	3.49	43.72	< .0001
Worst (dub)	30	20.15	3.15		

Table 19 Comparison of expected and observed dominance class of the best and worst trees at Ellis plantation

Status	Dominant	Co-dominant	Sub-dominant	Suppressed	Total
Best trees:					
observed	15	14	1	0	30
expected	8	12	9.5	0.5	30
Worst trees:					
observed	1	10	18	1	30
expected	8	12	9.5	0.5	30
Total	16	24	19	1	60

$\chi^2 = 29.13$ $P < 0.0001$

Table 20 Analysis of variance of the height of trees from the upper, mid and lower slope positions, Ellis plantation.

Status	Sample size	Height (m) $\bar{x}$	Height (m) s	F	P
Upper slope	20	17.0	1.75	3.76	0.029
Mid slope	20	18.2	4.03		
Lower slope	20	19.4	2.05		

Table 21 Analysis of variance of dob and dub of trees from the upper, mid and lower slope positions, Ellis plantation

Status	Sample size	Height (m) $\bar{x}$	s	F	P
dob:					
Upper slope	20	24.3	3.97	1.36	0.265
Mid slope	20	27.0	5.95		
Lower slope	20	26.0	5.29		
dub:					
Upper slope	20	21.8	3.68	0.93	0.401
Mid slope	20	23.65	4.87		
Lower slope	20	23.2	4.48		

Table 22 Analysis of variance of the height of the best trees from the upper, mid and lower slope positions, Ellis plantation

Status	Sample size	Height (m) $\bar{x}$	s	F	P
Upper slope	10	17.8	1.13	13.95	.0001
Mid slope	10	20.8	1.50		
Lower slope	10	20.7	1.71		

Table 23 Analysis of variance of the dob and dub of the best trees from the upper, mid and lower slope positions, Ellis plantation

Status	Sample size	Diameter (cm) x	Diameter (cm) s	F	P
dob:					
Upper slope	10	26.6	2.78	4.04	0.029
Mid slope	10	31.2	4.34		
Lower slope	10	29.9	4.01		
dub:					
Upper slope	10	23.8	2.69	2.64	0.090
Mid slope	10	27.0	3.74		
Lower slope	10	26.5	3.40		

FIG 2. LIVE, PARTLY DEAD AND DEAD BRANCHES IN THE CROWNS OF SAMPLED TREES.

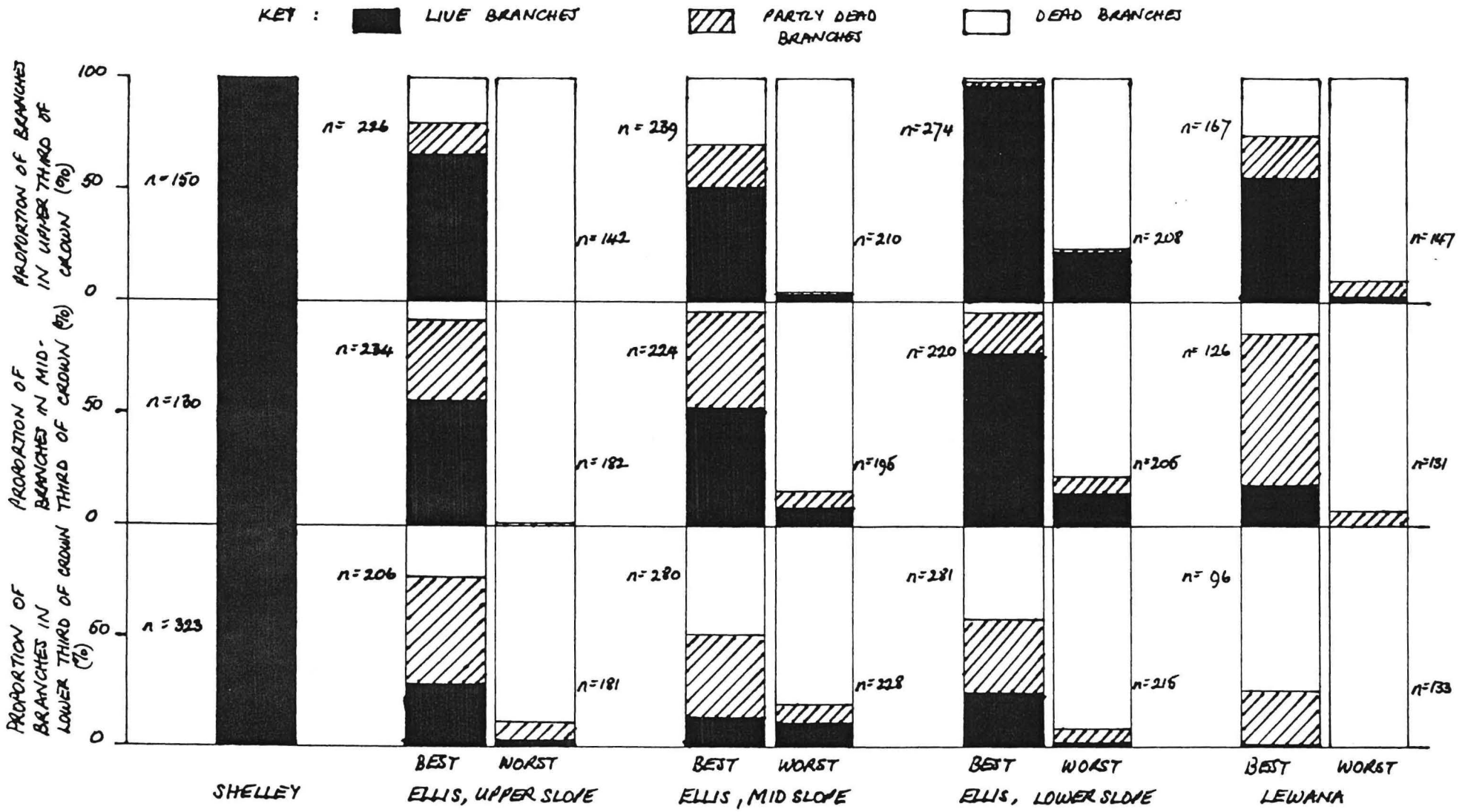

Fig 3. MEAN TREE AREA INCREMENT AT 1·4m, BETWEEN 1978 AND 1987, ELLIS PLANTATION.