Report on the Ninghan Sandalwood Ecology and Establishment Trial, June 1996.

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Introduction

Grazing and harvesting are two factors which affect sandalwood regeneration. Sandalwood leaves and seedlings are readily grazed by sheep, goats, rabbits and other herbivores. Heavy grazing greatly reduces or eliminates sandalwood regeneration in certain regions (Kealley, 1991). Harvesting commercial size trees without sufficient regeneration can also lower the seed reserves for future sandalwood regeneration.

Loneragan (1990), used a series of fencing trials to examine the effect of reduced grazing pressure on sandalwood seedling survival in the Kalgoorlie area. Sandalwood seedling survival was greater in fenced plots than unfenced plots on pastoral stations and to a lesser extent on reserves. This trial provided valuable information about sandalwood regeneration, but was limited by its size. There were only two replicates of each of the four treatments tested, and the treatments were only 0.16 ha in area each. The effect of harvesting and different host species on sandalwood regeneration was not examined.

Germination of sandalwood seeds and regeneration can be enhanced by sowing seeds near suitable host trees. Although sowing sandalwood seeds is labour intensive and not guaranteed of success due to irregular rainfall and grazing (Loneragan, 1990), seed planting has been incorporated into the harvesting contract. Sandalwood cutters are required to replace any sandalwood seed available from a harvested tree back into the holes created by pulling the tree out of the ground. Sandalwood cutters could also do additional regeneration by collecting seed from harvested trees and sowing them beneath nearby suitable host trees. Havel (1993) recommended that sandalwood nuts together with the leaf litter beneath parent trees should be raked and heaped below host plants. Alternatively, a shovel full of sandalwood seed could be buried beneath the host plant. Host species with thorny branches and leaves such as *Cratystylis subspinescens* (sage) or *Acacia tetragonophylla* (curara) are especially recommended because they have the capacity to protect sandalwood seedlings from grazing.

Sandalwood regeneration is required to conserve natural populations of the species and provide a renewable commercial resource. The exact impact grazing and harvesting have on natural regeneration within sandalwood populations needs to be quantified. Sowing sandalwood seeds beneath host trees (enrichment planting) after harvesting also requires investigation to determine whether this is a practical technique. Increased knowledge of sandalwood ecology and regeneration will enable more efficient and appropriate management of the species.

Objectives

The general aim of this trial will be to examine the level of sandalwood regeneration in the field that occurs under different management regimes. The individual and combined effects of grazing, harvesting and seed enrichment planting on sandalwood regeneration will be investigated. Sandalwood regeneration in unfenced and fenced plots will be examined to compare the effect of grazing. Within plots some trees will be harvested to quantify the long term impact of harvesting on sandalwood regeneration. Sandalwood seeds will also be sown beneath suitable host plants to determine whether this significantly increases germination and regeneration.

Materials and Methods

To examine the effects of grazing, harvesting and seed enrichment planting on sandalwood regeneration, a trial site was chosen at Ninghan station. Ninghan is a pastoral lease located about 40 km south-west of Paynes Find. There are currently about 13,000 sheep on Ninghan, over an area of 207,000 ha. Sandalwood is relatively abundant on this station and has been harvested at a rate of about 100 tonnes per annum, for the past 18 years.

Trial site

A large stand of sandalwood located about 15 km south west of Ninghan homestead was selected for the trial. Before establishing plot boundaries the site was surveyed for differences in ecological factors which may affect sandalwood regeneration such as: landforms, vegetation types, and sandalwood size and stocking density. The landform and vegetation types were relatively uniform at the site, consisting of plains with minor calcrete inclusions with *Acacia* shrublands and *Eucalyptus* woodlands. Sandalwood size classes and stocking densities were variable at the site.

Sandalwood with stem diameters less than or equal to 25 mm at 150 mm from the ground were described as seedlings, while trees were described as plants with stem diameters greater than 25 mm from the ground. Sized trees large enough for harvesting were described as any sandalwood with a stem diameter greater than or equal to 127 mm at 150 mm from the ground.

After surveying the site a large 32 hectare plot was marked and then divided into two 16 hectare plots that contained a similar number of sandalwood. The unfenced plot contained a total of 173 sandalwood, while there were 163 sandalwood in the fenced plot. The first plot will not be fenced while the second plot will be fenced to compare the effect of grazing on sandalwood regeneration. The fence will be constructed to exclude sheep, cattle, goats and kangaroos, while the unfenced plot will be open to grazing by all herbivores.

Sandalwood measurements

The fenced and unfenced sandalwood plots were further divided into 32 one hectare sub-plots. Within each of these sub-plots all sandalwood trees and seedlings were numbered and their positions recorded. Sandalwood dimensions were measured from each of these trees and seedlings between 27-29 May 1996. Dimensions recorded were: stem diameters, heights and crown dimensions. Tree and seedling stem diameters were measured to 1 mm, using a tree diameter tape at 15 cm, 50 cm and 130 cm from the ground. Heights were measured to 1 cm using a measuring pole. The north-south and east-west crown diameters of each tree and seedling were measured to 1 cm using an 8 metre metal tape and a Suunto compass. The crown areas in m^2 were also derived from each tree and seedling using the mean radius of the crown.

The number of sandalwood trees in each 1 ha sub-plot ranged from 3 to 31 (Figure 1). Within the unfenced plot there were 89 sized trees, 83 undersized trees and 1 seedling. The fenced plot contained 76 sized trees, 84 undersized trees and 3 seedlings.

		Unfenced length 400 m				Fenced length 400 m			
	100 m								
400 m	100 m	9(5)	6(1)	19(9)	10(4)	6(4)	10(6)	10(4)	6(1)
		9(5)	11(4)	15(12)	10(4)	20(12)	31(18)	3(2)	3(2)
		9(5)	7(3)	19(10)	14(6)	14(9)	19(8)	9(5)	3(2)
		6(2)	11(7)	5(4)	12(2)	16(5)	4(1)	3(2)	3(3)

Figure 1. The total number of sandalwood trees and the number of sized trees in parenthesis contained within each 1 ha sub-plot in both unfenced and fenced 16 ha plots.

Sandalwood treatments

To examine the effects of fencing, harvesting and seed enrichment on sandalwood regeneration a factorial design was used. The individual and combined effects of each of these factors were tested using eight different treatments. Each treatment was replicated 4 times in a randomised block design (Figure 2).

The eight treatments were as follows:

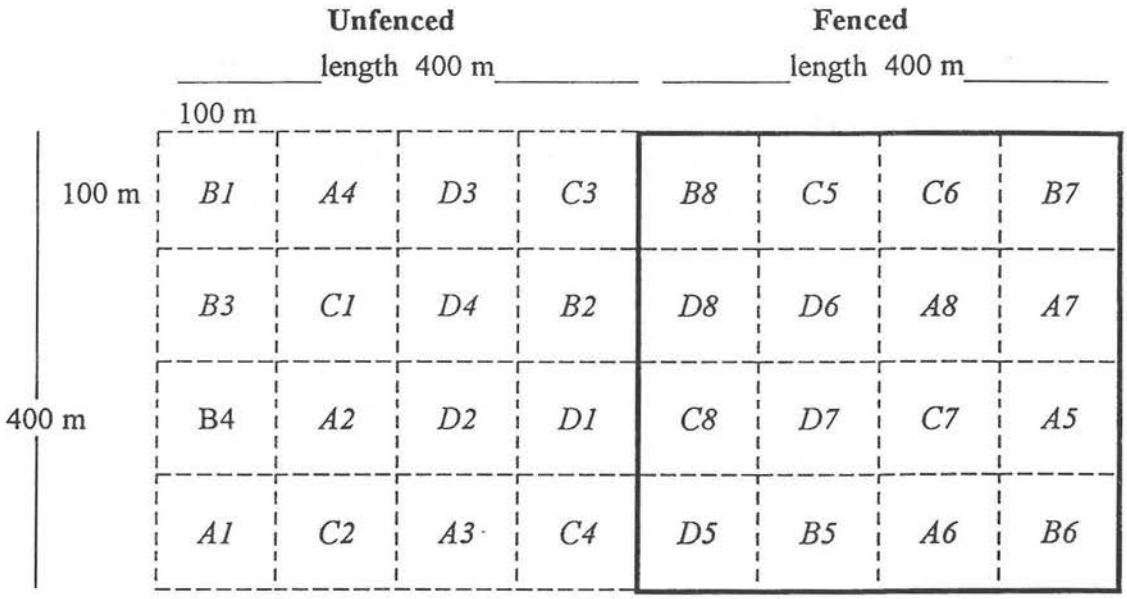
1 Unfenced and not harvested (control)
2 Unfenced, not harvested and seed enriched
3 Unfenced and harvested
4 Unfenced, harvested and seed enriched
5 Fenced and not harvested
6 Fenced, not harvested and seed enriched
7 Fenced and harvested
8 Fenced, harvested and seed enriched

Before allocating 1 hectare sub-plots to different treatments they were firstly ranked based on the number of sandalwood trees in each sub-plot. Within both unfenced and fenced 16 ha plots the 1 ha sub-plots were grouped into 4 blocks containing 4 sub-plots each. Sub-plots were grouped into blocks based on the number of sandalwood trees per hectare. Sub-plots were grouped to quantify the effects of tree size and stocking density on sandalwood regeneration. Within blocks the treatments were randomly allocated to sub-plots (Figure 2).

The total number of sandalwood in each of the eight treatments was relatively uniform ranging from 35 to 48 (Table 1). The number of undersized trees per treatment ranged from 16 to 23, while there were between 17 and 27 sized trees in each treatment. There were only 1-2 sandalwood seedlings in three of the treatments.

Table 1. The number of sandalwood seedlings, undersized trees and sized trees allocated to each treatment, at the Ninghan sandalwood plot.

Treatment	Seedlings ≤25 mm	Trees <127 mm	Trees ≥127 mm	Total
1	-	23	17	40
2	-	23	24	47
3	-	21	22	43
4	1	22	20	43
5	2	19	14	35
6	1	20	27	48
7	-	20	17	37
8	-	16	27	43
Total	4	164	168	336



Key to layout:

Blocks	Unfenced plot (trees/ha)	Fenced plot (trees/ha)
A	4-7	3
B	8-10	3-6
C	10-12	9-14
D	14-19	16-31

Treatments:

1 Unfenced and not harvested (control)

2 Unfenced, not harvested and seed enriched

3 Unfenced and harvested

4 Unfenced, harvested and seed enriched

5 Fenced and not harvested

6 Fenced, not harvested and seed enriched

7 Fenced and harvested

8 Fenced, harvested and seed enriched

Figure 2. Ninghan sandalwood regeneration plot lay out. Eight different sandalwood regeneration treatments were used in a factorial design. Sub-plots were grouped into 4 blocks based on sandalwood stocking density. Each sub-plot was 1 ha in area and each treatment contained four sub-plots.

Harvesting

In the harvested treatments (ie. *3,4,7* and *8*) all merchantable sized trees with stem diameters over 127 mm at 150 mm from the ground were harvested on the 29 May 1996. The trees were mechanically pulled out of the ground using a chain wrapped around the tree butt and attached to a Toyota Landcruiser. After each tree was pulled out, all remaining roots with diameters greater than 5 cm were removed from the ground.

A total of 86 sized sandalwood trees were harvested from the 32 hectare trial site (Table 2). The harvested treatments contained a total of 79 trees after harvesting, compared to 167 trees in the non-harvested treatments (ie. *1,2,5* and *6*).

Table 2. The number of sandalwood trees removed from the harvested treatments within the Ninghan sandalwood plot.

Treatment	Initial No. of trees	No. of trees harvested	Remaining trees
3	43	22	21
4	42	20	22
7	37	17	20
8	43	27	16
Total	165	86	79

Seed Enrichment

Sandalwood seeds were gathered beneath 30 sandalwood trees on Ninghan station on the 19 April 1996. The seeds were collected about 200 m outside the 32 ha hectare Ninghan plot on the northern boundary. The seeds from the 30 trees were mixed before sowing in the trial plot.

In each seed enriched treatment (ie. *2,4,6* and *8*), 10 sandalwood seeds were sown beneath each of 160 host plants. Sandalwood seeds were sown beneath four different host species already present at the site which were: *Acacia acuminata*, *Acacia ramulosa*, *Acacia tetragonophylla* and *Hakea recurva*. Host plants were chosen randomly within sub-plots and ranged from 50 cm high seedlings to trees over 6 m in height. All seed enriched host trees were tagged and their height and crown dimensions measured.

Beneath each host tree, five sandalwood seeds were sown on the north side and five seeds were sown on the south side. Seeds were sown 50 cm from the base of the stem at a depth of 2-3 cm.

In the unfenced seed enriched sub-plots, 10 trees from each of the four host species were seed enriched. A total 40 trees from each of the four host species were seed enriched in the two unfenced treatments *2* and *4* (Table 3).

In the fenced seed enriched treatments (*6* and *8*), unequal numbers of trees were seed enriched due to less than 10 *Hakea recurva* plants being present in four of the eight seed enriched sub-plots. There were no *Hakea recurva* plants present in one of the sub-plots and the other three had only 1-5 *Hakea recurva* plants. In these four sub-plots, extra plants from the three *Acacia* species were seed enriched to increase the number of seed enriched plants in each sub-plot to 40 (Table 3).

Table 3. The number of host trees enriched with sandalwood seed within each treatment at the Ninghan sandalwood plot.

Treatment	Species	No. of plants	No. of sandalwood seeds enriched
2	*Acacia acuminata*	40	400
	Acacia ramulosa	40	400
	Acacia tetragonophylla	40	400
	Hakea recurva	40	400
4	*Acacia acuminata*	40	400
	Acacia ramulosa	40	400
	Acacia tetragonophylla	40	400
	Hakea recurva	40	400
6	*Acacia acuminata*	47	470
	Acacia ramulosa	46	460
	Acacia tetragonophylla	43	430
	Hakea recurva	24	240
8	*Acacia acuminata*	49	490
	Acacia ramulosa	44	440
	Acacia tetragonophylla	41	410
	Hakea recurva	26	260
Total		640	6400

Fence

A fence will be constructed to exclude sheep, goats, cattle and kangaroos from grazing on sandalwood and other vegetation within half of the 32 ha sandalwood plot. The fence will consist of 7 line ring-lock attached to 5 foot 6 inch star pickets with a line of barbed wire along the top.

Vegetation assessment

A point intercept plot of 50 m by 2 m was established within each of the eight treatments. All plant species within the point intercept plots were identified or collected for identification. Frequencies of each plant species were recorded and used to determine vegetation cover. Vegetation surveys will be conducted every two years.

New sandalwood seedlings

All new sandalwood which germinate after the trial is established will be numbered, pegged and their positions within the plots recorded. Seedling height, stem diameter, and crown of the new sandalwood seedlings will be recorded using the same procedures as the existing sandalwood. Seedling measurements will be recorded twice a year in spring and autumn and the research will be ongoing.

References

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