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Report on host and sandalwood survival at Highbury, 2-10 March 1995.

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Aim

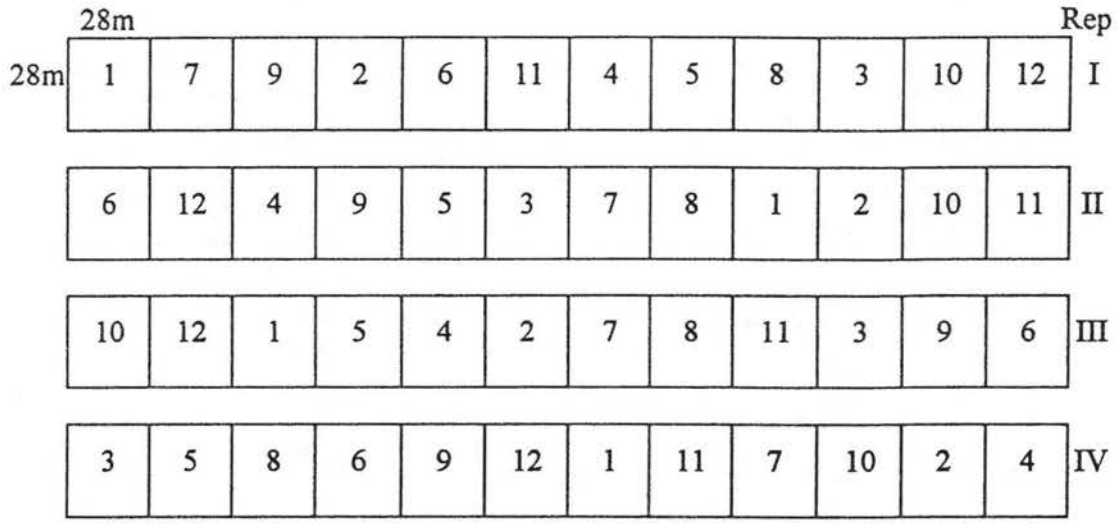
To investigate the effects of different host species and sandalwood sowing densities on sandalwood establishment and growth. The results to form a basis for commercial plantation recommendations.

Background

A Western Australian Sandalwood (*Santalum spicatum* (R.Br) A.DC.) host trial was established at Highbury, near Narrogin in July 1991. The mature trees at the site were cleared and then the site was ripped in lines 4 m apart using a plough. Seedlings from three different host species were planted along the rip lines 4 m apart. The host species were Jam *Acacia acuminata* Benth., York gum *Eucalyptus loxophleba* Blazely and Sheoak *Allocasuarina huegelliana* (Miq.) L.Johnson. The three species were chosen because they have commercial potential and have been observed growing with sandalwood. Individual host species and a mix of the three hosts were planted in plots of 49 trees over an area of about 3.7 hectares (Figure 1). Adjacent to the host trial, a mix of the three host species were planted over an area of about 4.8 hectares for a future provenance trial.

In June 1993, sandalwood seeds were directly sown in the host trial plots. Three different sandalwood sowing densities were incorporated into the host trial. The three stocking densities were: no seed, 3 seed/host and 5 seed/host. There were 12 different host/sandalwood density treatments which were randomised within a block and each block was replicated 4 times (Figure 1).

Host height and sandalwood germination were first measured at Highbury in December 1993 (Appendix 1). The total survival of all host species in 1993 was 86.9 % and only 5 % of sandalwood had germinated.



Key:

Treatments	Host species	Seed pre-treatment
1 *A1* 7 *C1*	*A Acacia acuminata*	*1* No seed
2 *A2* 8 *C2*	*B Allocasuarina huegelliana*	*2* 3 seed/host
3 *A3* 9 *C2*	*C Eucalyptus loxophleba*	*3* 5 seed/host
4 *B1* 10 *D1*	*D* Mix of above 3 species	
5 *B2* 11 *D2*		
6 *B3* 12 *D3*		

Figure 1. Sandalwood host trial with 12 treatments randomised in four reps of a complete block. Plots are 28 m by 28 m, reps are 336 m long and spaced 4 m apart. Host trees planted in rip lines 4 m by 4m with 49 trees per plot (ie. 625/ha).

Methods

Assessment

Host and sandalwood survival were recorded from the Highbury sandalwood host trial between the 2nd and 10th March 1995. The number of dead sandalwood seedlings was also recorded.

Analysis

Percentage survival of host species and sandalwood were transformed into arcsin values (x_T = arcsin $\sqrt{x}$). Means were then compared using two-way analysis of variance and Tukey tests.

Results

Host survival

Overall survival of hosts in March 1995 was 85.8 %. Mean survival was significantly different between host treatments at $p<0.05$ (Table 1). Percentage survival of *A. acuminata* (91.0 %) and *E. loxophleba* (90.5 %) were significantly higher than *A. huegelliana* (74.5 %). There were no significant differences between replicates.

Table 1. Percentage survival of host species at Highbury aged 5 yrs, 1995. Percentages transformed into arcsin values and means compared using Tukey tests. Values with the same letter are not significantly different ($\alpha = 0.05$).

Species	Total trees	Mean Survival (%)
A. acuminata	588	91.0 ± 11.8 a
E. loxophleba	588	90.5 ± 10.0 ab
Mixture	588	87.2 ± 11.4 ab
A. huegelliana	588	74.5 ± 12.6 b

Sandalwood germination and survival

Total germination and survival of sandalwood seedlings at Highbury in March 1995 was only 4.0 % (251 seedlings) out of 6272 seeds sown. An additional 128 sandalwood seedlings were dead at the time. Between December 1993 and March 1995 a total of 67 sandalwood seeds germinated and 70 seedlings died.

Although sandalwood germination was low there were some significant differences between sandalwood survival with different hosts at $p<0.05$ (Table 2). Sandalwood survival with a mixture of hosts (5.7 %) and *A. acuminata* (5.1 %) were significantly higher than *E. loxophleba* (0.4 %). There were no significant differences between sowing densities and the replicates were the same.

Table 2. Percentage germination and survival of sandalwood seedlings at Highbury. Percentages transformed into arcsin values and means compared using Tukey tests. Values with the same letter are not significantly different ($\alpha = 0.05$).

Species	No. sandalwood seed	Mean Survival (%)
Mixture	1568	5.7 ± 5.6 a
A. acuminata	1568	5.1 ± 3.7 a
A. huegelliana	1568	4.5 ± 4.1 ab
E. loxophleba	1568	0.4 ± 0.7 b

Discussion

Host survival

Total survival of host trees was 85.8 % after 5 years. Only 26 host trees had died since the last time the plots were assessed in December 1993 (Appendix 1). Survival of *Acacia acuminata* and *Eucalyptus loxophleba* were significantly higher than *Allocasuarina huegelliana*. The poor survival of *A. huegelliana* could be due to saline soil in the middle plots of the trial. A low-lying drainage line runs through the middle of the trial which appears to be salt affected.

Sandalwood germination and survival

Germination and survival of sandalwood seedlings after 2 years was only about 4 %. Sandalwood survival with a mixture of hosts and *A. acuminata* were significantly higher than *E. loxophleba*. Although overall survival was very low these results indicate that sandalwood should not be grown in pure stands of *E. loxophleba*. If York gum is to be used as a sandalwood host it should be grown with a mixture of other host species.

The low germination and survival of sandalwood may have been due to factors such as viability, low rainfall, weeds or soil conditions. Low sandalwood germination due to viability is unlikely because the seeds sown in 1993 were less than 1 year of age. Loneragan (1990) has shown that sandalwood seeds still have a high viability (76 %) after two years. Viability can be improved by nicking or cracking the nut, but survival is not enhanced.

In 1993, the total rainfall at Narrogin was 524 mm which was 17 mm above average. Narrogin received a lot of this rainfall during the winter months which indicates that water was not a limiting factor in 1993. However in 1994, Narrogin only received 351 mm which may have resulted in some sandalwood seedling deaths and low germination.

Between 1993 and 1995 the site at Highbury appeared to be infested with weeds such as ryegrass and barley grass. Roundup was sprayed beneath the host trees to control weeds after the break of the season in June 1993. The sandalwood seeds were then sown in early July 1993 after the effects of Roundup had dissipated into the soil. This late sowing would have shortened the growing season for sandalwood which may have reduced germination and survival. In 1994, Roundup was not used, resulting in large weed numbers which may have outcompeted sandalwood.

As discussed earlier, the middle region of the Highbury trial appears to be salt affected. A drainage line bisects each of the four replicated blocks and the low sandalwood germination and survival may have been due to salinity.

Conclusions and Recommendations

Establishment of *Acacia acuminata* and *Eucalyptus loxophleba* at Highbury has been successful. Survival of *Allocasuarina huegelliana* has been less successful and it appears this species is not suited to this site which may be salt affected. To determine whether part of the site is saline a soil survey should be conducted.

Germination and survival of sandalwood has been very poor, especially in pure stands of *E. loxophleba*. This trial should be repeated in 1996 using the same procedures as before except some sandalwood seed should be cracked before sowing to enhance germination. Plots with 3 uncracked seed/host could be replaced by 4 uncracked seed/host, and plots with 5 uncracked seed/host could be replaced by 4 cracked seed/host. This would help determine whether cracking of the seed improves germination and survival.

Future sandalwood establishment trials in the Wheatbelt should also examine the merits of planting sandalwood seedlings rather than direct seeding. Loneragan (1990) planted sandalwood seedlings with *Acacia aneura* and *Acacia acuminata* seedlings in the field, but sandalwood survival (2%) was unsuccessful. However, inspection of the roots revealed that the sandalwood seedlings had not made haustorial attachments to the host roots. Another pot host trial could be conducted to determine the time required for successful haustorial attachment. A range of intermediate host species (e.g. *Desmanthus*) could be examined to find the best hosts to grow sandalwood with in the nursery. After a sufficient number of sandalwood seedlings have successfully attached to intermediate hosts they could then be planted next to long term hosts in field trials.

References

Loneragan, O.W. (1990). Historical review of Sandalwood (*Santalum spicatum*) research in Western Australia. **Research Bulletin No 4**. Department of Conservation and Land Management.

Appendix I

Report on host height measurement and first sandalwood germination count at the sandalwood host trial, Highbury, 14-16th December 1993.

R. Mazanec

Background

The trial was established as a result of a proposal by Regional Manager Mr K. Wallace (1989) to grow specialty timbers in the wheatbelt. The emphasis was to be on Sandalwood (*santalum spicatum* (R. Br) A.DC.) and its hosts.

The aim of the trial is to investigate establishment densities, long-term growth and host relationships of sandalwood as the basis for commercial plantation recommendations.
Three known host species with commercial potential, York Gum *Eucalyptus loxopheba* Blazely, Rock casuarina *Allocasuarina huegelliana* (Miq.) L. Johnson and Jam *Acacia accuminati* Benth, were established at the Highbury trial site by research scientist P.Piggot in July 1991.

Survival was 79% in November 1991. Gaps in the host trial were infilled with appropriate host species in June 1992. Uncracked sandalwood seeds were soaked in water overnight and planted according to the trial prescription in June 1993. On December 7, 1993, a meeting with the regional manager Mr K. Wallace, research scientists P. Piggot and R. Mazanec was held at the trial site to discuss measurement of the trial. It was agreed that 2 year host height, survival and sandalwood germination should be assessed.

Methods

Assessment:
Host height to the nearest 10cm was measured at age 2 years using height sticks. Death of host trees was recorded and the number of germinated sandalwood and recently dead sandalwood germinants was counted for each host.

Analysis:
Height data was tested for skewness and kurtosis. No need for transformation was found . Host survival and sandalwood germination data was arcsin square root transformed. The data was subject to analysis of variance using the fixed effects model:

$$Y_{ijkl} = \mu + b_i + h_j + d_k + (h*d)_{jk} + e_{ijkl}$$

where ;

b_i = Block effect
h_j = Host effect
d_k = Sandalwood planting density effect
e_{ijkl} = error

Contrasts comparing each host treatment against the remaining host treatments and the effects of sandalwood density on the dependant variables were used. Ryan-Einot-

Gabriel-Welsh (Regwq) multiple range test was used subsequent to the analysis of variance to further examine differences between treatments.

Results

Host Survival.

Overall survival of hosts for the trial was 86.9%. Between hosts, best survival was for *E. loxolphleba* and *A. acuminata. A. huegelliana* had relativley poor survival (table 1.). Differences between replicates were not significant.

Contrast analysis indicated that *A. huegelliana* survival was significantly worse than the remaining species ($p<0.001$). Planting density of sandalwood had no effect on host species mortality.

Table 1. Host survival at age 3yrs with Regwq groupings.
Sandalwood Host trial Highbury.

Species	Total Trees.	% Survival.
E. loxophleba	588	92.5a*
A. acuminata	588	91.3a
Mixture	588	86.6a
A. huegelliana.	588	75.0b

*Values with the same letter are not significantly different ($\alpha = 0.05$).

Host Height:

Height differences between host treatments were significant ($p<0.001$). Contrast. analysis indicated that *A. acuminata* was significantly shorter than other hosts and that *A. huegelliana* was significantly taller than other host treatments. Sandalwood planting density had no affect on tree height at this early stage.

Table 2. Mean heights of host species with Regwq groupings at 3 years.
Sandalwood Host trial Highbury

Species	Mean height (m).	Rank
A. huegelliana.	2.10	1a*
Mixture	2.03	2b
E. loxophleba	1.93	3b
A. acuminata	1.69	4c .

*Values with the same letter are not significantly different ($\alpha = 0.05$).

Sandalwood Germination

A total of 312 sandalwood seedlings had germinated out of 6 272 sandalwood seeds planted or 5% germination. At the time of assessment 254 sandalwood seedlings had survived (81.4% survival).

Of a total of 1 366 trees with sandalwood planted 200 trees had one surviving sandalwood, 50 hosts had 2 sandalwood seedlings and 4 hosts had 3 sandalwood seedlings

Germination differences between repliciates were not significant. Contrast analysis showed no significant difference in germination between planting densities of three or five sandalwood. Germination was significantly different ($p < 0.001$) between the control treatment of no sandalwood and other planting density treatments.

Discussion

Host survival.

Overall survival rose from 79% to 86% following infilling. Acacia and york gum survival were quite high despite saline soil in some plots. The presence of saline soil in a low-lying drainage line in the middle of the trial was mostly responsible for the poor *Allocasuarina* survival. It is apparent that this species has very low salt tolerance.

Sandalwood germination.

Sandalwood germination was very poor. Earlier research on germination techniques (Loneragan, 1990) has shown that i) adequate supply of water is necessary for germination and ii) removing the endocarp favours germination but not survival.

Reasons for the poor germination at Highbury are not obvious. Limiting factors may include seed viability and water at the site. Poor seed viability is not likely to be a problem since the seed was collected in 1992. Earlier research (Loneragan 1990) indicates that seed viability of 76% is retained for up to 2 years in storage. Localized drought is unlikely to have been a problem. Weather Bureau records for 1993 show that Narrogin recieved 524mm rainfall, 17mm above average. In addition, during the months of May, June, August and September Narrogin recieved between 60 and 80mm rainfall.

It is possible that further sandalwood germination will occur in winter 1994 given adequate rainfall and if seed viability has not degenerated too far.

Conclusions and recommendations

Poor survival of *A.huegelliana* seedlings in the salt affected parts of the trial indicates that this host is better suited to non saline areas.

If further germination does not occur in winter 1994, supplemental sandalwood seedlings will be required. To boost the chances of germination, half of the supplemental seed should be cracked. The number of supplemental seeds to be planted will depend on the quantity of seed available at the time. Additional seed collections may be necessary. A reasonable supplemental planting may be two cracked and two uncracked seed per host tree for those hosts where germination has failed.

References

Loneragan, O. 1990. Historical review of Sandalwood (Santalum spicatum) Research in W.A. Research Bulletin No. 4 Department of Conservation and Land Management.