Sandalwood (*Santalum spicatum*) stem coppice and the influence of dune position on seedling survival near Shark Bay, Western Australia

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Summary

At Nanga station, 200 naturally occurring *S. spicatum* trees were harvested by cutting the stem at 150 mm above the base, in August-December 1988. Twelve years after harvesting, 40.8 % of the trees were alive. At this age, mean height of the coppice was 1.7 m and mean stem diameter was 28 mm. The mean number of coppice stems per tree was nine. Coppice survival and growth were not significantly affected by grazing.

In May 1990, 900 *S. spicatum* seeds were planted in natural vegetation on four dune face slopes: west facing, valley, east facing and ridge top. In October 1990, 40 % of the seeds had germinated. At age 10 years, *S. spicatum* seedling survival was highest on the west facing slope (41.5 %). However, dune position had no significant influence on seedling survival. Growth was similar between treatments, with mean height of 1.9 m and a mean stem diameter of 32 mm.

Introduction

In Western Australia, approximately 2000 tonne of *S. spicatum* is harvested per annum (Jones, 2001). Harvesting occurs mainly from natural stands in the semi-arid regions of the Goldfields and Midwest. The entire tree is normally removed using a four-wheel-drive vehicle because the roots also contain valuable oils, and stem coppice survival is generally low in places such as the Goldfields (Loneragan, 1990). Low stem and root coppice success rates have also been recorded for *Santalum lanceolatum* growing in Queensland (Bristow *et al.*, 2000). However, stem coppice occurs frequently in *S. spicatum* after harvesting on Nanga and Peron stations, near Shark Bay, Western Australia (Garf Taylor, personal communications). *S. spicatum* trees growing at Shark Bay use to be harvested by cutting the stem at ground level because the vegetation is too dense to harvest with vehicles. In this region, the *S. spicatum* grow on deep red sand dunes that support a dense covering of *Acacia*

and soil too sandy to have suitable tractors. Garth Pinnegar.

shrubs (Payne *et al.*, 1987). In 1988, 71 mature *S. spicatum* growing naturally at Nanga were cut near the base and 58 % of these had live coppice three years later (Doronila and Fox, 1991). Stem coppice may be a useful method of regenerating *S. spicatum.*

Evidence of undisturbed trees from previous coppice

At Nanga, the *S. spicatum* trees also appear to be more common on south and west facing dune slopes than north and east facing slopes (Garf Taylor, personal communications), which may be due to the cool sea breeze. The *S. spicatum* are growing within 10 km of the ocean and the south-westerly sea breeze in the summer may reduce heat stress and promote survival on the south and west sides of sand dunes. The influence of dune position on seedling survival may need to be taken into account when trying to re-establish *S. spicatum* in these environments. An effective method to grow *S. spicatum* in semi-arid regions is by direct seeding near suitable host species, especially *Acacias* (Brand, 2000). Sowing seeds on different dune faces may help show whether dune face direction affects *S. spicatum* survival

The aim of this study was to (i) determine the level of *S. spicatum* coppice survival after harvesting and (ii) examine whether *S. spicatum* seedling survival was affected by position on red sand dunes.

Methods

On Nanga station (26°13'S, 113°52'E), *S. spicatum* coppice and seedling trials were established in natural vegetation on deep red sand dunes. The trial sites consisted of a dense covering of potential host species including *Acacia ramulosa, A. sclerosperma* and *A. tetragonophylla*. The mean annual rainfall at Denham (25°56'S, 113°32'E) is 227 mm, and between 1989 and 2000 the annual rainfall ranged from 171 to 375 mm.

Stem coppice

In 1988, 200 mature *S. spicatum* trees growing naturally at the site were selected within an area of approximately 30 ha. All trees were commercial size, with stem diameters at 150 mm above the ground between 151 and 364 mm. In August-December 1988, each *S. spicatum* tree was harvested by cutting the stem (at 150 mm) with a chainsaw. The harvested trees were randomly allocated to four protection treatments: control, brambles, ringlock and rabbit netting. No protection was given for the control stems. Discarded branches (brambles) were placed on the stems for brambles. Standard ringlock and rabbit netting was fenced around the other stems in a radius of approximately 1 m and a height of 1 m. Each treatment contained 10-15

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stems and was replicated four times. Coppice survival, height, stem number and diameter (at 150 mm) were measured at age 4, 8 and 12 years

Seedling establishment

The effect of dune face on sandalwood seedling survival and growth was examined on four different dune faces: east facing slope, valley floor, west facing slope and ridge top. On each dune face, three seeds were planted 2.5 m apart in a row (or plot) containing ten planting spots. Plots were established 4 m apart in a grid pattern and pseudoreplicated 20-30 times, giving a total of 200-300 planting spots on each dune face. Each dune face treatment was 0.2-0.3 ha and within 1 km of the other treatments. The *S. spicatum* seeds were collected from Nanga and were sown 2-3 cm below the surface in May 1990. Seedling survival, height and stem diameter (at 150 mm) were measured at age 1, 2, 3, 4, 6 and 10 years.

Statistics

Mean *S. spicatum* survival and growth measurements (height, stem diameter and number of stems) were compared between treatments using one-way and two-way Analysis of Variance (ANOVA). *S. spicatum* survival was angular transformed and Systat® was used to analyse the data.

Results

Stem coppice

After harvesting, the proportion of *S. spicatum* trees with live coppice was 53.1± 4.7 % at age 4 years, 44.4± 4.6 % at age 8 years, and 40.8± 4.6 % at age 12 years (Figure 1). At age 12 years, survival was highest within rabbit netting (56.7 ± 8.4 %, Figure 2) and lowest in the control (31.7 ± 5.7 %) but there were no significant differences between treatments ($p = 0.276$).

Growth was similar between treatments, with mean heights of 0.8 ± 0.05 m at age 4 years, 1.3 ± 0.05 m at age 8 years and 1.7 ± 0.1 m at age 12 years (Figure 3). At age 12 years, there were no significant differences between coppice treatments ($p = 0.123$). At the same age, the mean number of coppice stems per tree was 9.1 ± 0.6 and was not significantly different between treatments ($p = 0.066$). The mean diameter of the largest stem from each tree was 28 ± 1 mm and was similar between treatments ($p = 0.630$).

Seedling establishment

In October 1990, *S. spicatum* germination was 40.0 ± 2.1 % % and was similar between treatments. Between 1991 and 2000, *S. spicatum* survival was consistently higher on the west slope (Figure 4), but there were no significant differences between treatments at age 2 years ($p = 0.052$), 4 years ($p = 0.084$), 6 years ($p = 0.108$) or 10 years ($p = 0.108$). In November 2000, mean seedling survival was 41.5 ± 6.5 % on the west, 36.3 ± 7.7 % on the hill, 24.1 ± 5.9 % in the valley, and 22.3 ± 6.3 % on the east.

At age 10 years, mean height was 1.9 ± 0.1 m, and was not significantly different between treatments ($p = 0.393$). At the same age, mean stem diameter was 32 ± 2 mm, and was also similar between treatments ($p = 0.273$).

Photo

Figure 1. *S. spicatum* stem coppice at age 12 years. This individual had over 20 stems.

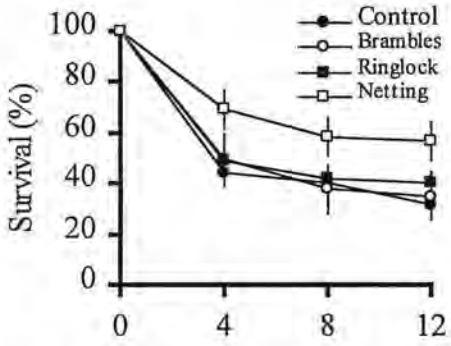

Figure 2. Mean survival (± standard error) of *S. spicatum* coppice treatments at Nanga over 12 years.

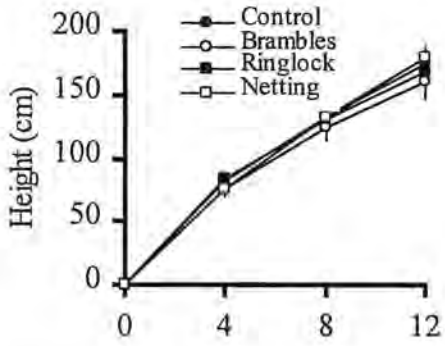

Figure 3. Mean height (± standard error) of *S. spicatum* coppice treatments at Nanga over 12 years.

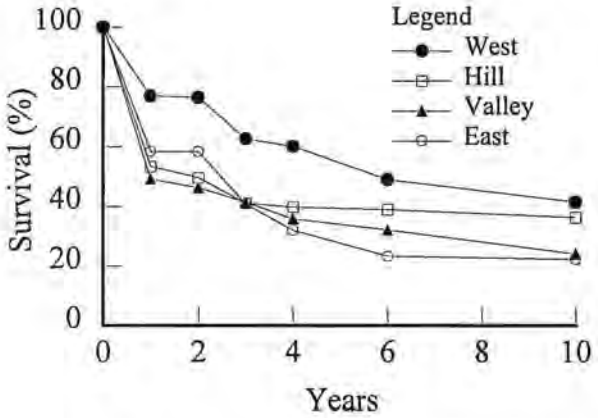

Figure 4. *S. spicatum* survival on four different dune faces: west, hill, valley and east.

Discussion

At Nanga, mean survival of *S. spicatum* stem coppice was 40.8 % at age 12 years. This survival rate after harvesting is relatively high, considering the mean annual rainfall near Nanga was only 229 mm during the trial. The high coppice rate at Nanga may be related to the trees growing on deep red sands. The soft soils may have enabled a relatively large root system to develop, thus providing a large resource base to successfully coppice.

Regenerating *S. spicatum* using stem coppice might be a useful method of obtaining a second rotation of commercial timber from a plantation, especially in the higher rainfall regions. *S. spicatum* plantations are currently being established on farmland in the 400-600 mm annual rainfall regions of the Wheatbelt and Midwest (Shea *et al.*, 1998). The effectiveness of stem coppice on these plantations should be investigated.

Coppice survival was higher within the fenced plots, but not at a significant level. It appears that grazing was not affecting survival at Nanga. Growth was similar between treatments, with stem diameters (at 150 mm) increasing only 2-3 mm yr^{-1}. These slow growth rates are typical of *S. spicatum* growing in semi-arid regions (Loneragan, 1990). Each tree had a mean of nine coppice stems, which indicates that extensive pruning is required to grow coppice stems with desirable form for plantations.

Although *S. spicatum* seedling survival was highest on the west face (41 %), dune face direction had no significant impact on seedling survival. Survival rates were highly variable within treatments, which was probably due to the availability of suitable host roots. The *S. spicatum* seeds were planted in a grid pattern in vegetation that contained a range of species. Therefore, suitable host roots may not have been available to all *S. spicatum* seedlings. At age 10 years, growth was also similar between treatments.

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