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SANDALWOOD SEED NURSERY AND PLANTATION TECHNOLOGY

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Planting Sandalwood, the New Caledonian Experience

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Abstract
This paper is a brief synopsis of the New Caledonian experience on sandalwood planting with the aim of proposing some practical planting methods. It is largely based on trials established by CIRAD-Forêt and/or the South Province Forestry Service but also on current practices carried out by local peoples. It is assumed here that nursery techniques are mastered and that production of large quantities of healthy plantable seedlings can be realized on a routine basis, which is only partly true to date.

Site Selection

From its natural range and from previous planting experiments, it seems that sandalwood (*Santalum austrocaledonicum*) can grow on almost every type of soil provided that elevation is less than 300m a.s.l. This altitudinal limit corresponds, in fact, to a temperature limitation: the optimum range of temperature for adequate growth in natural conditions being between 15 °C and 35 °C, with a necessary 'germination' period of 5 to 6 months at diurnal temperature above 25 °C.

Within the natural range, rainfall varies from 700 mm to 1 700 mm per annum, but plantations have been successfully established in wetter areas. *S. austrocaledonicum* cannot grow properly under 700 mm in New Caledonia.

Ecological and distribution studies (Quemin 1988, Friou *et al.* 1994), suggest that the following sites must always be avoided for planting even when their climatic or altitudinal characteristics seem adequate, as sandalwood is never found in such ecological conditions:

- *Melaleuca* (Niaouli) savannas are subject to frequent fires and Niaouli does not seem a suitable host.

- Rain forest: *S. austrocaledonicum* is a component of the dry sclerophyllous forest (Veillon 1994) and is not recorded in the rain forest.

- Waterlogged areas are totally inadequate for sandalwood planting as the species is very sensitive to hydromorphy.

Site Preparation

Given the parasitic nature of sandalwood, it is necessary to ensure a good development of the superficial lateral roots, that part of the root system directly involved in the parasitic process. Consequently, anything that can improve the

texture and structure of the top-soil layer will be beneficial. Site preparation will, however, be different according to site and planting characteristics.

In the case of mechanized open-planting (seed orchards, industrial plantations), the existing vegetation, generally a secondary forest or bush, has to be totally removed. This can be done with a bulldozer. Then, if the soil contains a large proportion of clay or has an iron-pan close to the surface, it will be beneficial to do a cross-subsoiling at 50-60 cm during the dry season preceding the planting. In all cases, except perhaps for some soils derived from volcanic material, a cross ploughing using a disc harrow is highly recommended; this operation being absolutely necessary after subsoiling.

In the case of a traditional planting in a temporary garden, the preparation is made for the gardening by manually cutting the woody vegetation to a certain size, girdling and lopping off the largest individuals and spreading the debris on the ground. After allowing a period for drying, the debris is set on fire and the site is ready for planting. This type of site preparation is recommended on volcanic calcareous soils of the Loyalty Islands where mechanized preparation could be detrimental to the soil structure.

Sandalwood is fire-sensitive and plantations should be protected against fire, although *S. austrocaledonicum* is seldom killed by fire and has a rather strong coppcing ability.

The species is also very palatable and is readily browsed by sheep, goats, cattle and deer. Plantations should therefore be fenced, if necessary, to avoid damage that can be very serious if nothing is done.

The Choice of a Secondary Host Plant

S. austrocaledonicum clearly needs one (or several) host plant(s) throughout its life (Quemin 1988).

In the nursery, seedlings are raised with a primary host plant. In New Caledonia several trials (Chauvin 1988) has shown that one of the best choices is *Althernanthera sessilis* (a common weed of wet places, and often grown for ornamental purposes). This primary host, raised in the same bag as the sandalwood seedling, is planted in the field but, in most cases, it does not persist for more than one year after establishment. There is, therefore, a need for secondary long-lived host plants in sandalwood plantations.

Sandalwood appears to accept almost anything as a host plant from grasses or sedges to large trees (Rai 1990). However some host species seem to ensure better sandalwood growth than others. It is necessary to choose the best possible host to avoid subsequent costs in additional planting through an incorrect selection at the start. The selected species should ideally, promote sandalwood growth as well as being a useful species in its own right (fuelwood, fodder, fruits, *etc*).

Parasitic relations between sandalwood and its hosts are far from simple, partly because it is only a semi-parasite able to obtain some of its necessary nutrients from the ground. The complete role of the host is still largely unknown. For some other

species (*S. album* and *S. spicatum*) it is known that solutes entering sandalwood from the hosts include nitrogen, sodium, potassium, phosphorus, water and amino acids (Fox & Barrett 1994). However, studies carried out in controlled conditions (Barrett *et al* 1985, Crossland 1982, Hirano 1990) and in the field (Chauvin, unpublished data) with or without hosts have shown that sandalwood reacts well to fertilizer and is able to obtain at least some part of its nutrient requirements directly from the soil.

To date, it is possible to infer that sandalwood :

- obtains the largest part of its requirement of nitrogen and phosphorus as well as potassium, copper and amino acids from the host plant;

- is able to extract nitrogen (only a small part of its requirement), potassium, calcium (the main part of its requirement) and iron from the soil.

Foliar analyses of *S. austrocaledonicum* (Veillon & Jaffré 1994) have shown that sandalwood leaves contain high levels of nitrogen and potassium and a low level of phosphorus. In most conditions, even on ultramafic soils, quantities of major nutrients contained in sandalwood leaves are higher than those of the surrounding vegetation. Sandalwood seems, therefore, to possess a considerable demand for nitrogen but it is not able to extract an adequate supply of this nutrient from the soil.

Thus, a suitable long-term secondary host has to be able to extract large quantities of nitrogen from the soil: a nitrogen fixing tree (N.F.T.) seems therefore a natural choice. This has been confirmed in a trial associating *S. austrocaledonicum* with several long-term hosts set up on ultramafic soils. The best growth has been achieved with N.F.T.'s well adapted to these very peculiar conditions: *Acacia spirorbis, Casuarina collina, Gymnostoma deplancheana.*

Planting Layout

Two main types of plantation must be considered: planting in gardens or in areas where sandalwood grows naturally, open-planting in areas without sandalwood. The first case is rather simple: seedlings are generally planted with (or without) systematic spacing in the garden. Associations are rather variable and there are examples of sandalwood planted with pineapple, sweet potatoes, salads, *etc.* Plants are maintained at the same time as the main crop and benefit from any site improvement (fertilizer, weeding, *etc*)

One interesting method is actually used by some Melanesian small-holders on the Isle of Pines. Sandalwood fruits, freshly collected, are spread onto the ground among the wooden debris derived from cutting. Then everything (debris and fruits) is burned to clear the site. Traditional crops are then planted and cultivated, generally for one year. At the same time one observes the appearance of numerous sandalwood seedlings. It seems that the burning of the fruit has a very beneficial effect on alleviating seed dormancy and integument inhibition. Seedlings are then protected throughout the whole cultivation period. After harvest, the site is abandoned to allow a fallow period and it is quickly recolonised by secondary species

among which *Acacia spirorbis* and *Melia azedarach* are frequent and known to be suitable sandalwood hosts. The result after several years can be rather impressive.

The second case is slightly more complicated as one has to consider planting sandalwood as well as one or several secondary host plants. Once again two cases should be distinguished: (1) planting on ultramafic soil, (2) planting on other types of soil.

Several problems are linked with planting on ultramafic soil: lack or deficiency of major nutrients (nitrogen, phosphorus, potassium, calcium), chemical toxicity (high concentrations of nickel, manganese, cobalt, chrome), lack of any intermediate host after site preparation (grasses do not grow naturally on these soils). In such cases, the planting layout should allow the quick establishment of the parasitic link and the host should be adapted to the rather special soil characteristics. *In situ* studies have shown (Quemin 1988) that *S. austrocaledonicum* planted on ultramafic soils are able to parasitise most of the endemic herbaceous plants, such as *Sphenomeris alutacea, Lindseaceae; Costularia spp.* and *Cladium deplanchei,* (*Cyperaceae*) and to expand their root system on a several metres wide radius to reach long-lived hosts (*Paraserianthes falcataria* in this case). On the other hand planting, at the same time, of sandalwood and secondary hosts (*Acacia spirorbis*) with a 3 m by 3 m spacing gave poor results because of the slow growth that delays the establishment of effective parasitic links.

As a result, the following method is recommended when planting on such adverse sites:

(1) ensure a good site preparation;
(2) plant adapted hosts at least one year before sandalwood to allow an adequate development of the root system;
(3) host plants and sandalwood plants should not be planted at a distance greater than 2m;
(4) if possible, do not carry out complete weeding as it may suppress links with some intermediate hosts and depress the growth;
(5) apply fertilizer to promote both host and sandalwood growth.

The range of suitable host plants for such sites is rather limited: *Acacia spirorbis, Casuarina collina,* and *Gymnostoma deplancheana* are the best among endemic species, and *Paraserianthes falcataria* is the most promising exotic.

When planting is carried out on other types of soils, site fertility is generally better and, even after a total land clearing, weeds invade the site quickly ensuring the presence of a large number of possible intermediate hosts. In such a case, sandalwood and host plants can be planted as the same time. The range of suitable secondary host plants is larger and include, in addition to those already recommended for ultramafic soils, *Calliandra calothyrsus* and other legumes, *Melia azedarach, etc.*

In both cases several layouts can be considered (Figure 1), although at present it is still too early to conclude definitely which is the best.

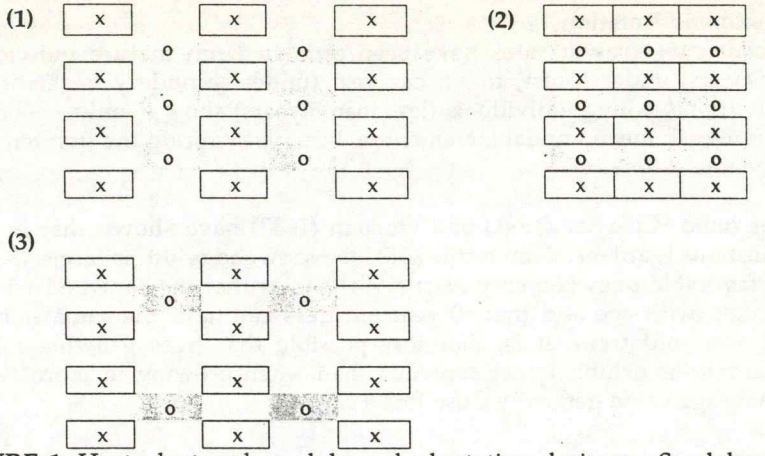

FIGURE 1. Host plant and sandalwood plantation designs. x Sandalwood plant; o Host plant

According to the purpose of the planting (wood or seed production), the possible intrinsic value of the host plant, the site fertility and the type of maintenance (manual or mechanized), spacing between sandalwood plants can vary from 2 m to 4 m but the distance between sandalwood and host plants should not exceed 2.5 m. Care must be taken with fast growing host plants (such as *Acacia auriculiformis* or *Paraserianthes falcataria*) to avoid strong competition with sandalwood. The stand has to be managed primarily for sandalwood production and 'aggressive' hosts kept under control.

Maintenance and Fertilization

In all cases, fertilization after planting has been beneficial and has induced a better growth of both sandalwood and host plants. It is therefore highly recommended except, of course, for very rich soils, to apply a N-P-K fertilizer during one or two years after planting. On soils with low calcium contents, an improvement of the soil with this nutrient will benefit the sandalwood plant. On the other hand, if the soil is alkaline, an improvement in other nutrient intake (of the sandalwood plant and the host) can be obtained with chelated iron.

Sandalwood planting must be protected against fire and browsing animals, especially when the host plant is also very palatable. Thinning is not necessary in such plantations, however it is essential to keep the host plant under control, especially on good sites and with fast growing species.

Sandalwood tree form is not naturally good but an early pruning of multiple leaders allows it to obtain a reasonably straight bole. The aim being to get a single stem, relatively straight and with as few nodes as such sandalwood pieces can fetch a very good price on the international market.

Estimated Yield and Rotation

S. austrocaledonicum growth rates have been estimated, on mature individuals, from 1.1 cm/year (under forest) to 1.5 cm/year (under secondary vegetation) in girth. In plantations, young individuals (less than 5 years) show mainly an increase in height, but a girth mean annual increment of 2 cm/year during the first ten years seem a reasonable estimate.

On the other hand, Cherrier (1991) and Quemin (1988) have shown that in good growing conditions (gardens, deep fertile soils) the sapwood width is larger (3.2 cm) than in less favorable ones (2.5 cm). Nasi (1994) shows that the sapwood width is not really linked with age and that 60 year old trees can have the same sapwood width as 30 year old trees. It is, therefore possible that trees growing in well managed plantations exhibit larger sapwood than when growing in more natural conditions (average value generally close to 2.6 cm)

Considering now a 'classical' planting of sandalwood plus host plant, on a reasonably fertile soil (not one derived from ultramafic material), with the following spacing: 4 m between lines, 2.5 m along the line, sandalwood and host plants alternate along the line (equivalent to layout (2) of Figure 1). The sandalwood density will be 500 plants/ha.

From existing trials (on adverse sites) and from histograms of girth classes (Friou, Nasi & Cornu 1994), one can estimate that 10 years after planting, 60% of the plants will have a normal growth and that from year 10 onwards, the mortality (except in the case of fire, browsing damages or cyclones) will be 10%/year.

Assuming that this plantation is either of poor, average or good quality, the expected heartwood yield can be roughly estimated following a simple simulation model (Figure 2).

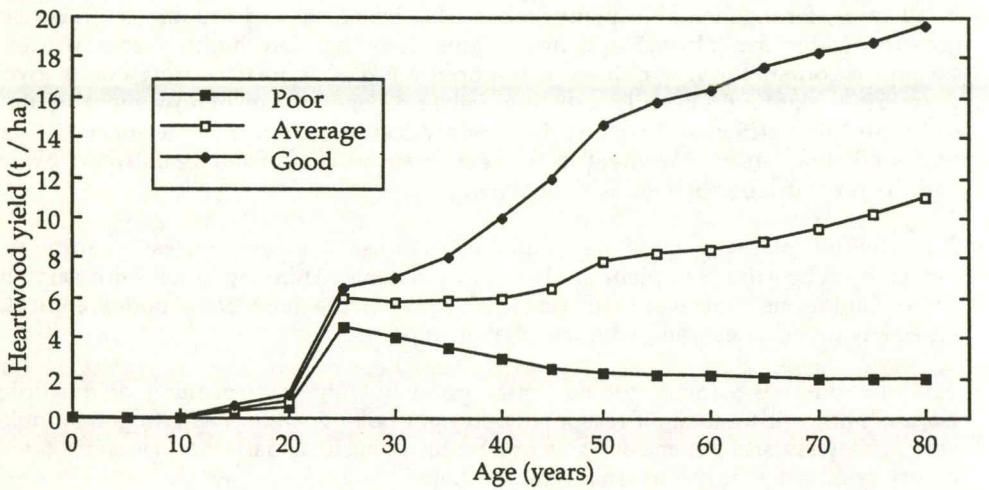

FIGURE 2. Heartwood yield simulation in a poor, average or good plantation

While keeping in mind that this estimation is very 'crude', it is interesting to note that, in all cases, the expected yield at age 25 is close to 4-5 metric tons of heartwood

per hectare. Data and hypotheses used in the above simulation are summarized in the appendix.

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Appendix

Sandalwood plants/ha at planting time: 500

Rate of mortality

Quality	Before 10 years	After ten years
Poor	25% per 5 years period	15% per 5 years period
Average	20%	10%
Good	20%	10%

Growth rates (M.A.I in girth)

	Before 10 years	From 10 to 50 years	After 50 years
Poor	1.0 cm/yr	1.0 cm/yr	1.0 cm/yr
Average	1.5 cm/yr	1.5 cm/yr	1.1 cm/yr
Good	2.0 cm/yr	2.0 cm/yr	1.1 cm/yr

Sapwood width

Poor : 2.5 cm
Average : 3.5 cm
Good : 4.0 cm

Percentage of trees really producing heartwood for a given girth.

	From 20 to 80 cm	Above 80 cm
Poor	40%	60%
Average	40%	60%
Good	40%	60%

Weight model

$$W = 4.831210^{-4} (C_{0.20}-2\pi S)^3 + 60.4774 \qquad (1)$$