

Growing Sandalwood in Nepal—Potential Silvicultural Methods and Research Priorities¹

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Abstract: Interest in sandalwood has increased recently in Nepal as a result of a royal directive to plant it in the Eastern Development Region. The most suitable seed sources, seed acquisition, nursery techniques, direct sowing and plantation establishment methods are discussed here on the basis of results from elsewhere. Suggestions are made as to what research is most needed to assist with successful establishment of sandalwood in Nepal. The silvicultural methods discussed could well be of use to other countries that are interested in introducing and establishing sandalwood plantations.

This paper is related to one that was recently published in *Banko Janakari*, a forestry journal in Nepal (Neil 1990). It summarizes knowledge on the propagation and silviculture of sandalwood so that it can be successfully established in the kingdom. It also summarizes research results from elsewhere so that any new research will not repeat completed work or continue to investigate methods that have already been proved unsuccessful. The need for research into the establishment of sandalwood in Nepal has arisen because of the interest that His Majesty the King has shown in the species, which has led to a royal directive to plant it in the Eastern Development Region.

The methods discussed and recommended for adoption in Nepal may well prove useful for other countries that wish to establish sandalwood plantations. This could apply particularly to countries that are interested in introducing the species, or that would like to plant their indigenous sandalwood species but are unsure of how to go about it.

SANDALWOOD

The genus *Santalum* belongs to the family Santalaceae, which comprises herbs, shrubs, and small trees. It has long been a source of sandalwood, a fragrant wood prized for its use in producing ornaments, cabinets, and chests; incense for religious rites; and oil for perfume and medicines. *Santalum album* is the best known commercial species. It is found in southern India (but may have originally been introduced from Java, Indonesia), especially in Karnataka, Kerala, and Tamil Nadu, and also in Sri Lanka and other parts of south-eastern Asia (Brandis 1978). Various descriptions of it occur in Hindu mythology. Powdered wood in the form of a paste, with added pigments, is used in caste distinguishing marks (Drury 1985).

Other species are found in the Pacific region and Australia. The natural resource of Pacific sandalwood species has been heavily exploited since the early 19th century (Shineberg 1967), and on some islands, the resource has been practically exhausted (Nor 1982, Neil 1986, Barrance 1989). Some confusion exists over the taxonomy of these species due to variations in appearance and habit. For example, *S. insulare* from French Polynesia and *S. marchionense* from the Marquesas may be varieties of the same species (Neil 1986).

Sandalwood is generally considered a slow-growing tree in natural forest conditions, although it varies considerably, and in favorable conditions its annual girth increment can be 5 or 6 centimeters. In plantations it usually grows faster; in Vanuatu *S. austrocaledonicum* was 3 meters tall with a d.b.h. of 4 centimeters at 3 years (Neil 1986), and similar growth has been recorded for *S. album* (Barrett 1988).

Santalum species are capable of developing haustoria and are usually partially parasitic on the roots of other plants. *S. album* is said to be an obligate parasite and must therefore be associated with suitable hosts if it is to survive (Sinha 1961, Mathur 1961). However, there have been suggestions that some sandalwood species, including *S. album*, are not necessarily obligate parasites. Nagaveni and Srimathi (1985a) report the occurrence of haustoria-less *S. album*, although the majority of sandalwood plants produce haustoria when still in the seedling stage. Likewise, *S. austrocaledonicum* is sometimes found in apparent isolation with no potential host plants present (Barrau 1960). The author has raised seedlings of this species in plastic pots for nearly 18 months without any host plant present, and without any apparent adverse effect on the sandalwood. Research results from New Caledonia, on the other hand, suggest that *S. austrocaledonicum* seedlings are able to survive for only a short time without a host; otherwise, they soon turn chlorotic and die (Douheret 1981).

Evidence shows that sandalwood obtains nitrogen, phosphorus, and basic amino acids from its hosts, and calcium and potassium from the soil (Iyengar 1960, Sen-Sarma 1975, Struthers and others 1986, Angadi and others 1988). In concurrence with this, it is interesting to note that many of the species parasitized by sandalwood are nitrogen-fixing.

Sandalwood's aromatic oil, which is contained in the heartwood, is only produced when the tree reaches a certain maturity. Some trees develop heartwood between 4 and 6 years of age, others when they are between 15 and 20 years old, and others never develop it at all. Depending on genetic and environmental factors, trees are in their prime as heartwood producers between 30 and 80 years of age. The color varies from yellow through light brown to a deep chestnut. Light brown wood contains the most oil.

S. album in India is commonly attacked by "spike disease" caused by a mycoplasma-like organism. There is a very large literature on this subject (Mathur 1979), but apparently spike disease is not present in sandalwood outside India (Ramaswamy 1956).

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SANDALWOOD IN NEPAL

The typical Nepali name for sandalwood is "shrikhand," although the Hindi name, "chandan," is also used. In Sanskrit it is called "malayaja." It is much used in both Hindu and Buddhist religious rites. For example, it is occasionally burnt on the funeral pyre of Hindus and is often a traditional offering at religious worship. Newars offer sandalwood during the Navaratri festival during Desain. Sandal paste is offered to Jupiter in the "puja" to the nine planets.

Majupuria and Joshi (1988) report that it grows in Gorkha district, but add that it has been imported into the country. It is not indigenous to Nepal, although four other genera from the family Santalaceae are represented (Hara and others 1982). Some trials with *S. album* have been carried out by the Royal Botanical Garden and Royal Palace Garden, but these have been with very limited quantities of seed (Anon., 1987). A few trees still survive in the terai from these trials, suggesting that it might be possible to grow sandalwood commercially at low altitudes in Nepal. His Majesty's directive to plant it in the East of the country has prompted new efforts to establish plantations. However, the most suitable techniques for establishing plantations are not yet known. A summary of research findings from other countries is given below. These results should be used as the basis for new research to be carried out in Nepal and potentially in other countries interested in planting sandalwood. Time should not be wasted in testing methods that have already failed; instead, new work should build on proven and successful methods.

SEED ACQUISITION

Since sandalwood is not indigenous to Nepal, seed will have to be imported. Conflicting reports concerning the germinative capacity and quality of *S. album* seed exist (Sinha 1961, Bagchi and Kulkarni 1985, Ananthapadmanabha and others 1988). High quality seed is important, i.e., seed that has been collected at the right time and been properly stored. Trees can produce fertile seed from 3 or 4 years of age, but as they get older, they produce more seed, and a larger proportion of it is fertile. For maximum viability, fruit must be picked from the tree or collected from the ground when fresh, completely depulped by washing in water, dried in the shade, and stored in a dry place.

Traditionally it has been thought that the harder or harsher sites produce sandalwood with a much higher oil content in the heartwood than sandalwood planted on more fertile sites (Troup 1921). However, results from the Sandal Research Centre, Bangalore, India, suggest that genetic factors are more important than edaphic factors. If *S. album* seed from India is to be used, it would be desirable to obtain seedlots from stands that have been selected as seed production areas, such as those in Kerala, Tamil Nadu, and Karnataka. The Sandal Research Centre has already surveyed and assessed sandalwood characteristics for both quality and quantity as a gene resource for breeding and conservation. "Plus-trees" have been selected on the basis of fast growth, maximum heartwood volume and fragrance, straight boles, resistance to pests and diseases, and

flowering and fruiting ability (Barrett 1988).

The Forestry Research Division has obtained a seedlot of the Western Australian *S. spicatum*, and proposes to raise it for testing in the terai. This species is of interest since it will tolerate much more and conditions than *S. album* and may be more cold tolerant; there are often mild frosts (-2°C) in the desert where it grows naturally. It may therefore be more suited to Nepal than *S. album*. *S. spicatum*, however, has a relatively low oil content.

SEED PRETREATMENT

Santalum album seed has a minimum dormancy of 50 to 60 days, and untreated seed does not normally germinate for another 30 days or so (Ananthapadmanabha and others 1988). For 80 percent germination, about 7 months may be required (Barrett 1988). To speed up the germination, various pretreatments have been tested. The most successful appear to be some form of scarification (removing or nicking the seed coat) or soaking in gibberellic acid (Nagaveni and Srimathi 1980, 1981, 1985b; Mahdi 1986; Nagaveni and others 1989). Similar pretreatments are recommended for *S. spicatum* (Fox 1989, CALM undated). Results from New Caledonia have shown that scarification followed by soaking in water is the best pretreatment for *S. austrocaledonicum*, and that optimum temperatures for germination are between 28°C and 30°C. Manual techniques of nicking the seed coat and soaking in water are thought most suitable for propagation in Nepal.

NURSERY TECHNIQUES

Much research has been carried out into how best to propagate sandalwood. Techniques have been developed and undergone revision as understanding of its parasitic nature has increased.

In general, vegetative propagation methods have not been successful (Uniyal and others 1985).

Seed propagation techniques that are most suitable for nurseries in Nepal are those developed by the Sandal Research Centre at Bangalore. In these, sandalwood is raised in open beds, either sunken or raised, according to the climate. Barrett (1988) reports on techniques that require a greenhouse or shade house during the germination and subsequent potting out, but it would seem that these are less suited to Nepal.

Great attention should be given to treating seed, seedlings, and potting soils with fungicides and nematicides (Sandal Research Centre 1983, Sivaramakrishnan and others 1984). Germination is normally carried out in sand, sand and soil mixes, or vermiculite. Research in New Caledonia suggests that vermiculite is the best medium. Seedlings should be shaded 50 percent and protected from extremes of temperature, frost, and wind. They should not be over- or under-watered.

Sandalwood seedlings should be grown in pots with a suitable host. At present, a project funded by the Australian Centre for International Agricultural Research (ACIAR) is investigating a method of raising sandalwood seedlings in a dual-host system. This system involves a short-lived "primary" host in the nursery stage and for the first few months after planting in the field. Later a longer-lived "secondary" host is planted near the sandalwood

to support it. For *S. album*, good results have been obtained in Timor, Indonesia, with *Sesbania grandiflora*, *Breynia cerrua*, or a local species of *Amaranthus* as the primary host (F. McKinnell, Project Leader, ACIAR Sandalwood Project, pers. comm.). Other primary hosts can include tomato, *Mercurialis*, *Calitropis*, *Capsicum*, or any small legume such as *Cajanus* or acacias. Various grasses, herbs, and bushes make good intermediate hosts. Good secondary hosts include *Albizia* spp., acacias and other large legumes. Padmanabha and others (1988) suggest that *Casuarina equisetifolia*, *Melia dubia* [azedarach?] and *Acacia nilotica* are the best secondary hosts for *S. album*, although the following are also known hosts: *Acacia catechu*, *Bauhinia biloba*, *Cassia siamea*, *Dalbergia sissoo*, *Pongamia pinnata*, *Terminalia alba*, *T. arjuna* and *Wrightia tinctoria*. In New Caledonia *S. austrocaledonicum* is being very successfully raised using a small shrub, *Alternanthera* sp. as a primary host and *Paraserianthes falcataria* [*Albizia falcataria*] as the secondary host, although *Acacia spirorbis* is apparently sandalwood's most common natural host in New Caledonia and Vanuatu (Neil 1986, 1989).

Nepal could easily adopt this dual-host approach, as some of the potential hosts for each stage are already successfully grown in the country.

DIRECT SOWING

Direct sowing has been successfully practiced in a number of places (Dayal 1986). The seed needs to be treated with some form of poison to discourage predators. Seedlings will not survive the hot weather if they are not well established when the dry season begins or if they cannot be irrigated. Broadcasting does not generally give good results (Sinha 1961). Dibbling is the most successful and widely used technique (Troup 1921, Fox 1989). Pretreated seed is dibbled into the ground in areas that already have potential hosts either naturally present or artificially established. Some have suggested that for *S. spicatum*, direct sowing appears to produce plants of greater vigor than nursery-raised seedlings (CALM undated).

It would be interesting to test this technique in Nepal in areas where *Acacia catechu*, a recognized host for *S. album* in India (Sinha 1961), occurs naturally. The *A. catechu* would not only act as the host, but would provide shade and protection from browsing because of its thorns. Having said that, it is more likely that Nepal will adopt methods that utilize nursery-raised seedlings to establish stands of sandalwood.

PLANTATION ESTABLISHMENT

S. album will grow under a wide range of conditions. It will tolerate an annual rainfall from 500 to 3000 mm, temperatures from near zero to 40°C once it is established, altitudes up to 1800 m, depending on how cold it is, and various soil types from sandy to poor, rocky soils. Most often it grows on red ferruginous clay soils (Troup 1921).

Despite this potential to grow in a wide range of conditions, plantation sites should be carefully chosen. Annual rainfall ideally should be 600 to 1600 mm, and temperatures an annual

minimum of about 10°C and maximum of about 35°C. There should be plenty of sun, although seedlings should be protected against excessive drought or heat. Altitudes of 700 to 1200 m are most suitable. Waterlogged soils should be avoided, while rich, fairly moist, fertile, iron-rich clay soils give best growth.

Many types of sites will likely exist in a given locality, but sandalwood will do best if planted in cultivated soils with host plants already established to provide shade (Mathur 1961, Streets 1962, Neil 1986, Fox 1989). Young sandalwood do not tolerate drought and should be planted into pits at the start of the rainy season. Sandalwood seedlings are occasionally planted in the same pit as their host; otherwise hosts are planted in alternate or adjacent pits. Trials have shown that hosts should be not farther than 2.2 m from the sandalwood, otherwise growth is very significantly affected (Ananthapadmanabha and others 1984). Hosts should be pruned if they overgrow the sandalwood, and weeding around both plants is necessary to maintain good growth.

Since sandalwood is very palatable to animals, it should be protected from browsing by fencing or surrounding it with thorny branches. It is also sensitive to fire, and appropriate precautions should be taken to protect it from this hazard.

CONCLUSIONS

Since sandalwood has previously been successfully established in Nepal, albeit only on a very limited basis, there appears to be potential for planting it here. On the basis of the methods described above, the following procedures for establishing sandalwood plantations should be followed until more reliable techniques are proven. These procedures could be just as easily applied to other countries interested in artificially establishing their indigenous or imported sandalwood.

- Use only a reputable source of high quality seed (e.g., genetically selected *S. album* seed from seed production areas in south India).
- Pretreat all seed by scarification, followed by soaking.
- Germinate the seed in beds of a 1:3 sand to soil mixture that has been treated with nematicides and fungicides. If available, vermiculite or a similar medium would be preferable.
- Move the sandalwood seedlings into large plastic pots (13 x 30 cm) at the four-leaf stage. A primary host such as *Sesbania* spp., *Cajanus cajan*, *Acacia* spp., tomato, or *Capsicum* spp. should be transplanted into the pots. Keep the seedlings under 50 percent shade and protect them from extremes of weather. Fertilizer should not be needed if a good potting mixture is used.
- Plant out seedlings at the start of the monsoon. The ideal planting site would be at an elevation of 700 to 1200 m, with annual minimum and maximum temperatures of 10°C and 35°C respectively, and an annual rainfall of 600 to 1600 mm. Soils should be fairly moist, fertile, iron-rich clays. A secondary host should be present before planting, or introduced at the same time as planting the sandalwood. The site should be fenced to reduce the possibility of grazing damage. Precautions should be taken against fire.

- Seedlings should be well weeded, although some side shade should be maintained. Large host trees may require lopping to avoid overshadowing.

The priority areas for research should be:

- Selection of the most suitable primary and secondary hosts for sandalwood in Nepal—preferably indigenous species.
- Testing of various species of sandalwood that seem appropriate to conditions here (e.g., *S. album*, *S. spicatum*).
- Direct sowing of degraded forest areas that still retain potential host species, and that can be protected from grazing.

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