

# Status and Cultivation of Sandalwood in India<sup>1</sup>

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**Abstract:** Sandalwood (*Santalum album*) has been part of Indian culture and heritage for thousands of years, and was one of the first items traded with other countries. The heartwood yields fragrant oil, which is used mainly in the perfume industry but also has medicinal properties. The wood is used for carving and manufacturing incense. Generally *S. album* is found in the dry deciduous forests of Deccan Plateau, mostly in the states of Karnataka and Tamil Nadu. The evergreen tree regenerates naturally when conditions are favorable and has been spreading in its distribution. Lack of understanding of the dynamics of hemiparasitism by sandalwood has caused failure of pure plantations in the past; haustorial connections with its hosts supply sandalwood with nitrogen, phosphorus, and potassium. Plantable seedlings can now be raised in the nursery in 6-8 months with the protection of a nematicide and fungicide. Several techniques for planting seeds directly in the field have also been developed. A tree that is growing well can put on an annual increment of 1 kg per year. The sandalwood resource in India is currently threatened by four factors: fire, browsing by livestock, spike (little leaf) disease, and smuggling.

Sandalwood (*Santalum album*) is a part of Indian culture and heritage. It is the epitome of human excellence, imparting fragrance even to the axe that fells it.

Sandalwood finds description in the oldest of Indian literatures. It finds a mention in the ancient epic Ramayana (around 2000 B.C.). It has been used as an object in ritualistic offerings and also as an ointment for beauty aid. It has nearly 15 different names in the Indian languages, "chandan(a)" being the Hindi name. In Indonesia too it is called "cendana."

In the past, it has been said that *Santalum album* was introduced in India from Timor Island of Indonesia. But sandalwood has such inextricable links with Indian culture, literature, and ethos that it is difficult to support the hypothesis of its introduction.

Sandalwood is growing and regenerating naturally under favorable conditions in India. It is part of the indigenous vegetation and has been spreading in its distribution. However, several factors now threaten the important status of sandalwood.

This paper describes the distribution, ecology, growth habit, and uses of sandalwood in India. Nursery and plantation techniques for growing sandalwood from seeds are given. Current threats to the resource are identified.

## DISTRIBUTION

In India sandalwood is mainly distributed on the Deccan Plateau. The total extent of its distribution is around 9000 km<sup>2</sup>, of which 8200 km<sup>2</sup> is in the states of Karnataka and Tamil Nadu (fig. 1). In the past, it naturally occurred in peninsular India, but subsequently it has been introduced in other parts too. It generally occurs in the dry deciduous forests of Deccan Plateau

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at the edge of the Western Ghat Range. A circle with Bangalore city as the center and a radius of 200 km could be said to be the main zone of natural distribution of sandalwood. It thrives best under rainfall conditions of 500-2000 mm and at elevations of 650-1200 m. It can occur beyond these ranges too, but under high rainfall conditions the growth is luxuriant yet the heartwood formation is absent or negligible.

Sandalwood is capable of growing in different kinds of soils like sand, clay, laterite, loam, and black-cotton soil (avoiding water-logged conditions). Even very poor and rocky soils can support sandalwood. It is capable of regenerating profusely in the absence of fire and grazing. If protected, established plants start fruiting and regenerating naturally, and birds may help in propagation.

## HABIT AND HABITAT

Sandalwood is an evergreen tree. It can grow to a height of 20 m and attain a girth of over 1.5 m. It flowers and fruits twice a year during March-April and September-October. Trees start flowering from 3 years of age. Seed production generally is good in one of the seasons. Certain trees flower only once a year, and some do not flower regularly. About 6000 seeds make 1 kg. Seeds can be collected directly from the tree. The fruits should be depulped, washed thoroughly in water, dried under shade, and stored in airtight containers.

Sandalwood is a hemi root parasite. It can parasitize over 300 species from grass to another sandal plant. Under gregarious growing conditions, self-parasitism is common. Lack of understanding of the dynamics of parasitism has been the cause of



**Figure 1**—Distribution of sandalwood in India. Areas in square kilometers are as follows:

Karnataka	5,245	Maharashtra	8
Tamil Nadu	3,040	Kerala	7
Andhra Pradesh	175	Uttar Pradesh	Less than 1
Nadhya Pradesh	33	Private lands	500
Orissa	25		
	<b>Total .....</b>		<b>9,034</b>

**Table 1—Influence of host plants on the growth of sandal seedlings (pot culture studies)**

Species	Sandal				Host				Number Haustorial Connections
	Ht. cm	Biomass grams			Ht. cm	Biomass grams			
		Stems	Roots	Total bio- mass		Stems	Roots	Total bio- mass	
<i>Casuarina equisetifolia</i>	110	48	38	86	152	141	113	254	390
<i>Melia dubia</i>	88	43	33	78	110	48	85	133	107
<i>Acacia nilotica</i>	74	43	30	73	82	22	18	40	124
<i>Wrightia tinctoria</i>	71	40	32	74	70	23	40	63	117
<i>Pongamia pinnata</i>	70	40	30	70	87	31	50	81	175
<i>Terminalia arjuna</i>	70	39	25	64	103	42	60	108	108
<i>Terminalia alata</i>	69	37	26	63	80	44	65	109	140
<i>Dalbergia sisso</i>	68	29	32	61	91	48	85	133	120
<i>Dalbergia latifolia</i>	62	31	29	60	80	30	60	90	78
<i>Cassia siamea</i>	64	28	27	55	73	47	68	115	120
<i>Bahunia biloba</i>	49	15	16	31	102	79	103	181	125
<i>Tectona grandis</i>	50	14	16	30	105	140	160	300	110
<i>Azadirachta indica</i>	39	22	20	40	61	20	30	50	100
<i>Adenantha pavonina</i>	38	9	11	20	86	70	95	165	53
<i>Moringa pterigosperma</i>	35	10	9	19	103	60	45	105	62
<i>Anogeissus latifolia</i>	32	10	8	18	108	70	110	180	49
<i>Pterocarpus santalinus</i>	30	9	8	17	30	8	18	26	28
<i>Tamarindus indica</i>	31	8	7	15	58	30	27	57	31
<i>Pterocarpus marsupium</i>	30	7	8	15	67	17	30	47	28
<i>Eucalyptus hybrid</i>	30	9	8	17	130	59	80	139	37
<i>Syzygium cumini</i>	30	8	7	15	100	38	56	94	21
<i>Phyllanthus emblica</i>	30	8	6	14	122	57	49	106	18
<i>Ailanthus' malabaricum</i>	28	10	9	18	89	54	54	108	20
<i>Madhuca indica</i>	28	8	8	16	90	90	80	170	60
<i>Swietenia mahogany</i>	28	8	6	14	140	170	80	250	48
<i>Artocarpus integrifolia</i>	26	8	6	14	75	45	40	85	36
<i>Leucena leucocephala</i>	28	6	5	11	140	159	116	276	18
<i>Cassia fistula</i>	28	7	8	15	30	13	28	41	18
<i>Acacia auriculiformis</i>	28	8	6	14	154	69	58	127	17
<i>Mundelea suberosa</i>	27	7	6	13	73	32	27	59	28
<i>Albizia lebbek</i>	28	9	7	16	65	25	37	62	52
Control	27	6	4	10					8

**Table 2—Photosynthetic activity of sandal seedlings grown with different hosts**

Species	Photosynthetic rate mg/cm <sup>2</sup> /s	Chlorophyll			Stomatal frequency per mm <sup>2</sup>
		a	b	Total	
<i>Casuarina equisetifolia</i>	4.15	41.42	32.84	73.76	7.4
<i>Melia dubia</i>	4.53	51.35	25.27	76.82	7.3
<i>Acacia nilotica</i>	5.2	30.62	23.83	54.45	7.6
<i>Wrightia tinctoria</i>	3.6	27.52	20.89	48.41	7.6
<i>Pongamia pinnata</i>	2.3	49.67	36.69	86.36	5.7
<i>Terminalia arjuna</i>	2.83	27.23	22.88	50.11	8
<i>Dalbergia sisso</i>	2.12	33.09	34.60	67.69	6.8
<i>Cassia siamia</i>	1.76	25.63	41.41	67.04	7.5
<i>Azadirachta indica</i>	1.32	20.74	18.81	39.55	5.7
<i>Acacia indica</i>	1.5	21.99	14.99	36.97	4.7
<i>Albizia lebbek</i>	1.7	15.55	14.37	29.92	5.5
<i>Artocarpus integrifolia</i>	0.77	6.71	8.53	15.24	5.6
Control	0.83	10.67	16.49	27.16	5.3

failure of pure plantations in the past. Sandalwood establishes haustorial connections with the host plants and depends on them for its requirement of nitrogen, phosphorous, and potassium. It can obtain other nutrients on its own. Seedlings can survive without a host for 3 years but thereafter they tend to die. In a natural population 2 percent of seedlings do not produce haustoria, and they fail to survive on their own beyond 3 years of age.

Pot culture experiments have indicated the efficacy of secondary hosts for sandal. Average stem, root, and total biomass (dry weight at 85 degrees C for 24 hours) of host and sandalwood plants, and the average heights are given in *table 1*. *Table 2* gives photosynthetic rate, chlorophyll content, and stomatal frequency of the first 12 most suitable host plants. In our studies, we found that *Cajanus cajan* acted as the best primary host. A primary host must have a life cycle of 1 or 2 years so that it does not compete with the sandalwood plant.

## USE OF SANDALWOOD AND OIL

Heartwood of the sandalwood tree is the most valuable part. It yields fragrant sandalwood oil. In India sandalwood and its oil were among the first items traded, along with spices and silk, to

Middle Eastern and other countries. The wood is used for burning in certain rituals by Hindus, Buddhists, and others. The wood paste and oil are used as coolants. The wood paste is also used as an ointment to dissipate heat and as a beauty aid. There are excellent descriptions by Kalidasa of this use of sandalwood in his *Sanskrit* epics (300 B.C.).

Sandalwood oil is mainly used in the perfume industry. The oil is an excellent base and fixative for other high grade perfumes. Most top grade perfumes have sandalwood oil as their base. In itself it is an excellent, mild, long-lasting, and sweet perfume, yet the industry finds that it can blend very well with other perfumes and does not impart its fragrance when used as a base. It can also fix the better perfumes, which are volatile, for longer hours. Several chemicals have been tried in this role, yet sandalwood oil has retained its place of pride. From perfumery to joss sticks, there are several hundred products that use sandalwood oil. It is also used in the soap industry.

Sandalwood oil has antipyretic, antiseptic, antiscabietic, and diuretic properties. It is also effective in the treatment of bronchitis, cystitis, dysuria, and diseases of the urinary tract. The oil has an important place in the indigenous system of medicine. It is considered a cure against migraine.

Sandalwood is used for carving and other artifacts. The sapwood and sometimes the mixed woods are used for manufacturing joss sticks. From the exhausted sandalwood powder, an entirely new essential oil has been produced by the process of hydrolysis.

## TRADE

As mentioned earlier, trade in sandalwood dates back to the dawn of trading by India. Realizing its value, the Sultan of Mysore declared it a royal tree during 1792. It continues to retain that place even today, although individuals are entitled to receive 75 percent of its value as a bonus for growing and protecting the trees. Due to its high value and steeply rising demand both in internal and external markets, sandalwood prices have skyrocketed, as can be seen from the price per ton:

Year	Rs/Ton <sup>1</sup>
1900	365.00
1933	1,000.00
1965	6,000.00
1970	10,000.00
1980	31,000.00
1987	78,000.00
1990	160,000.00

<sup>1</sup>US\$ = Rs 17

The rise in prices was partly due to decrease in supplies. During the 1930's through 1950's, the country's production was roughly 4000 tons of heartwood per year; now it is only around 2000 tons.

On an average, 60 kg of oil is obtained for every ton of wood. Quite a sizable proportion of the wood produced is used for distillation of oil which is exported outside the country for use in the perfume industry.

## HEARTWOOD FORMATION AND OIL CONTENT

Heartwood formation in sandal trees generally starts around 10-13 years of age, but what triggers this process has not been very well understood. Certain factors, generally relating to stress, such as gravelly dry soil, insolation, and range of elevation (500-700 m), seem to provide the right environment for the formation of heartwood, irrespective of the size of the stem after 10 years of age. The occurrence of heartwood varies. Most of the root portion after a certain age is heartwood; however, in the stem it is highly variable from place to place. It can range from 90 percent of the stem wood to a negligible amount, or be absent. The value of heartwood is due to its oil content, and the superiority of the oil is due to the percentage of santalol.

(i) In a tree the oil content is highest in the root, next highest in the stem at ground level, and gradually tapers off towards the tip of the stem.

(ii) Similarly, there is a gradient in oil content from the core to the periphery of the heartwood in a stem.

Depending upon their age, trees can be called young or mature, although this is an empirical classification and holds good only for a particular population. The oil content and its composition may differ at the same age:

(i) Young trees (height less than 10 m, girth less than 50 cm, and heartwood diameter 0.5-2 cm) have heartwood with 0.2-2 percent oil content, which has 85 percent santalol, 5 percent acetate, and 5 percent santalenes.

(ii) Mature trees (height 15-20 m, girth 0.5-1 m, and heartwood diameter 10-20 cm) have heartwood with oil content of 2-6.2 percent, which has over 90 percent santalol, 3-5 percent acetate, and 3 percent santalenes.

The heartwood of sandalwood is yellowish to dark brown. This again is an indicator of oil content. Yellowish heartwood has 3-4 percent oil and 90 percent santalol; light brown heartwood contains 3-6 percent oil and 90-94 percent santalol. Brown and dark brown wood has only 2-5 percent oil and 85-90 percent santalol. Hence, lighter heartwood is better and superior.

Using oil as the main criterion, elite trees were selected based on rate of growth, and heartwood and oil content for future propagation through seed and tissue culture. The work has been on going. Several clonal orchards have been established for production of seed.

## ECOLOGY AND FLORISTICS

Sandal is primarily a tree of dry deciduous forests. It is prone to fire damage. It generally avoids hill slopes and grassy banks that are prone to annual fires; however, when these areas are protected from fire, sandalwood appears again. Similarly, under moist deciduous conditions when a site becomes more mesic, sandalwood recedes to drier portions. Its main associates in the top canopy are these: *Terminalia tomentosa*, *T. chebula*, *Anogiessus latifolia*, *Sapindus trifoliatus*, *Diospyros melanoxylon*, *Albizia lebbek*, *A. odoratissima*, *A. amara*, *Chloroxylon swietenia*, *Feronia elephantum*, *Limonia acidissima*, *Zizyphus xylopyrus*, *Grewia tilaefolia*, *Bridelia retusa*, *Ixora*

*parviflora*, *Pterocarpus marsupium*, *Dendrocalamus strictus*, *Bauhinia racemosa*, *Acacia sundra* and others. The undergrowth consists of *Carissa carandus*, *Dodonea viscosa*, *Randia dumetorum*, *Cassia fistula*, *C. auriculata*, *Lantana camara*, *Zizyphus oenoplea*, *Flacourtia montana* and others.

Sandalwood regenerates naturally under the protection of thorny bushes, along streams (some seeds that float in water germinate faster), and under trees where birds generally roost. Dispersal of seeds and spread of the species effectively takes place through birds, provided the area is free from recurrent fire and browsing animals.

Initially, seedlings need shade for survival, and in the sapling stage they need diffused light for proper growth. However, once the trees are nearly 4 meters high, they can grow under full overhead light. Plants growing under full exposure have yellowish leaves while those under lateral shade have dark green leaves.

Up to 50 sandalwood stems are generally found per hectare, which could be roughly 2 percent of the composition in a forest. Higher populations are found under certain favorable and protected conditions for regeneration.

## REGENERATION FROM SEED

Seed from known superior populations is desirable. Sandalwood flowers and fruits twice a year, i.e., in September/October and in March/April. The seeds of both the seasons perform alike.

Sandal fruits are collected fresh from the tree, soaked in water, and rubbed to remove the soft pulp. The wet seeds are dried under shade, then the dry seeds are stored in polyethylene bags or gunny bags. About 6000 seeds weigh 1 kilogram.

Fresh seeds usually have a dormancy period of 2 months. The seed takes 4 to 12 weeks to germinate after the dormancy period. Eighty percent of the seeds are viable up to 9 months. The germination rate is about 80 percent under laboratory conditions and 60 percent under field conditions. Germination can be hastened by cracking the hard seed coat. Soaking seeds in 0.05 percent gibberellic acid overnight before sowing, ensures uniform germination.

## Nursery Techniques

Two types of seed beds are used to raise sandalwood seedlings: sunken and raised beds. Both beds perform equally well under different climatic conditions.

Both seed beds are formed with only sand and red earth in a 3:1 ration and are thoroughly mixed with nematicides (Ekalux or Thimet at 500 g per bed of 10 m by 1 m). The seeds are soaked in 0.02 percent Agallol (organo mercuric compound) solution for half an hour to remove surface contamination. Then the seed is spread uniformly over the bed. About 1 cm of sand is spread over the seed. Around 2.5 kg of seed is used for one bed. The bed is covered with straw which should be removed when the leaves start appearing on the seedlings.

The seed beds are sprayed with (1) the fungicide Dithane Z-78 (0.25 percent) once in 15 days to avoid fungus attack, and (2) 0.02 percent Ekalux solution once a month to avoid nematode

damage. Sandalwood seedlings suffer from a virulent disease caused by a combined fungal and nematode infection. The initial symptom is wilting of leaves followed by sudden chlorosis and root decay. On account of this disease the mortality rate is very high, but this can be controlled by the application of nematicide and fungicide (Ekalux and Dithane) as mentioned above.

When the seedlings have 5 to 6 leaves, they are transplanted to the polyethylene bags along with the seed of the primary host *Cajanus cajan*. The seedlings are carefully removed from the bed with all the roots intact and then carried in a container with fungicide solution [sic] (Agallol 0.1 percent). Roots should not be allowed to dry.

Shade can be provided for a week immediately after the transplanting. Watering should be done daily, but excess moisture is to be avoided. Host plants are pruned frequently, so that they do not overgrow the sandal and hamper its growth. Poly bags should contain a soil mixture in the ratio 2:1:1 (sand:red earth:farmyard manure). Poly bags 30 by 14 cm are best. To avoid nematode damage, Ekalux at the rate of 2 g/poly bag or 200 g for 1 m<sup>3</sup> of poly bag mixture should be thoroughly mixed in before filling the bags.

A plantable seedling of about 30 cm height can be raised in 6-8 months. A well-branched seedling with brown stem is ideal.

At the time of planting in the field a perennial host, if given, increases the growth of sandal. Sandal has over 300 host plants; some of the good hosts are *Casuarina equisetifolia*, *Acacia nilotica*, *Pongamia binnata*, *Melia dubia*, *Wrightia tinctoria*, and *Cassia siamea*. It is ideal to plant sandal in 50 cm<sup>3</sup> pits, 3 by 3 m apart in alternate rows with host plants.

### Plantation Techniques

Sandal has been successfully regenerated by the following techniques:

- (i) Dibbling seeds into bushes
- (ii) Dibbling seeds in pits or mounds
- (iii) Planting container-raised seedlings.

### Dibbling of Seed Into Bushes

This planting method is adopted in open scrub jungles with lots of bushes. The seeds are sown during monsoon. An instrument can be made using a bamboo pole of 4 to 6 cm internal diameter and 1.5 m long to sow the seeds. The septa at the nodes are removed and one end of the pole is sharpened, or a hollow metal piece is attached to rake the soil. The pole is introduced at the base of the bush and through the hole four to five seeds are transferred to the base of the bush. Fairly good success has been achieved by this method.

### Dibbling of Seeds in Pits or Mounds

The usual trench mound technique adopted for afforestation for other species of trees has also been adopted for sandal, but here a perennial host plant is also grown along with sandal either on the mound or by the side of the pit.

### Planting Container-Raised Seedlings in Nurseries

The area required for this purpose is completely clear felled. Pits of 50 cm<sup>3</sup> are dug out at a spacing of 3 m. Healthy sandal seedlings, preferably above 30 cm in height, are planted in the pits. Miscellaneous secondary host plants are planted in the alternate rows. This method has proved successful in many areas. *Figure 2* gives a diagrammatic sequence of nursery to planting stages of sandal.

### After Care

Working the soil to a radius of 50 cm once in 6 months is recommended. The host plant tends to overgrow sandalwood and may be pruned, so that sandal gets maximum sunlight. Adequate protection against fire and grazing is necessary.

### GROWTH AND YIELD

Though sandal is considered to be a slow-growing tree under forest conditions (1 cm girth/year), it can grow at a rate of 5 cm of girth or more per year under favorable soil and moisture conditions. The heartwood formation in sandal starts around 10-13 years of age. So far the growth data is available only in respect to natural forests, mainly from Javadis in Tamil Nadu and the Dharwad area of Karnataka. *Table 3* gives an idea of its growth.

Assuming about 250 trees are growing well, they can put on an annual increment of 1 kg per year per tree, thus giving an overall increment of 250 kg of heartwood per year. The returns can be increased by adopting intensive practices.

### CURRENT PROBLEMS WITH THE RESOURCE

Sandalwood as an important species has been losing ground in India, mainly due to four factors: (i) recurrent annual ground fires in its zone of occurrence; (ii) browsing and lopping of trees for fodder; (iii) "spike" (little leaf) disease in a part of its zone of distribution where maximum temperatures do not go beyond 38 degrees C; and (iv) smuggling of sandalwood for clandestine trade.

The first two factors generally have prevented occurrence of natural regeneration and the establishment of artificial regeneration.

The spike disease causes mortality across all age groups to the extent of 1 to 1.5 percent. Sandalwood spike now is considered to be caused by a mycoplasma-like organism, which is transmitted from one live plant to another through sap-sucking insects.

**Table 3**—Growth of sandal in natural forests, mainly from Javadis in Tamil Nadu and the Dharwad area of Karnataka

Age (years)	GBH (cm)	Heartwood (kg)	Sapwood (kg)
10	10	1	5
20	22	4	25
30	33	10	60
40	44	20	100
50	55	30	135

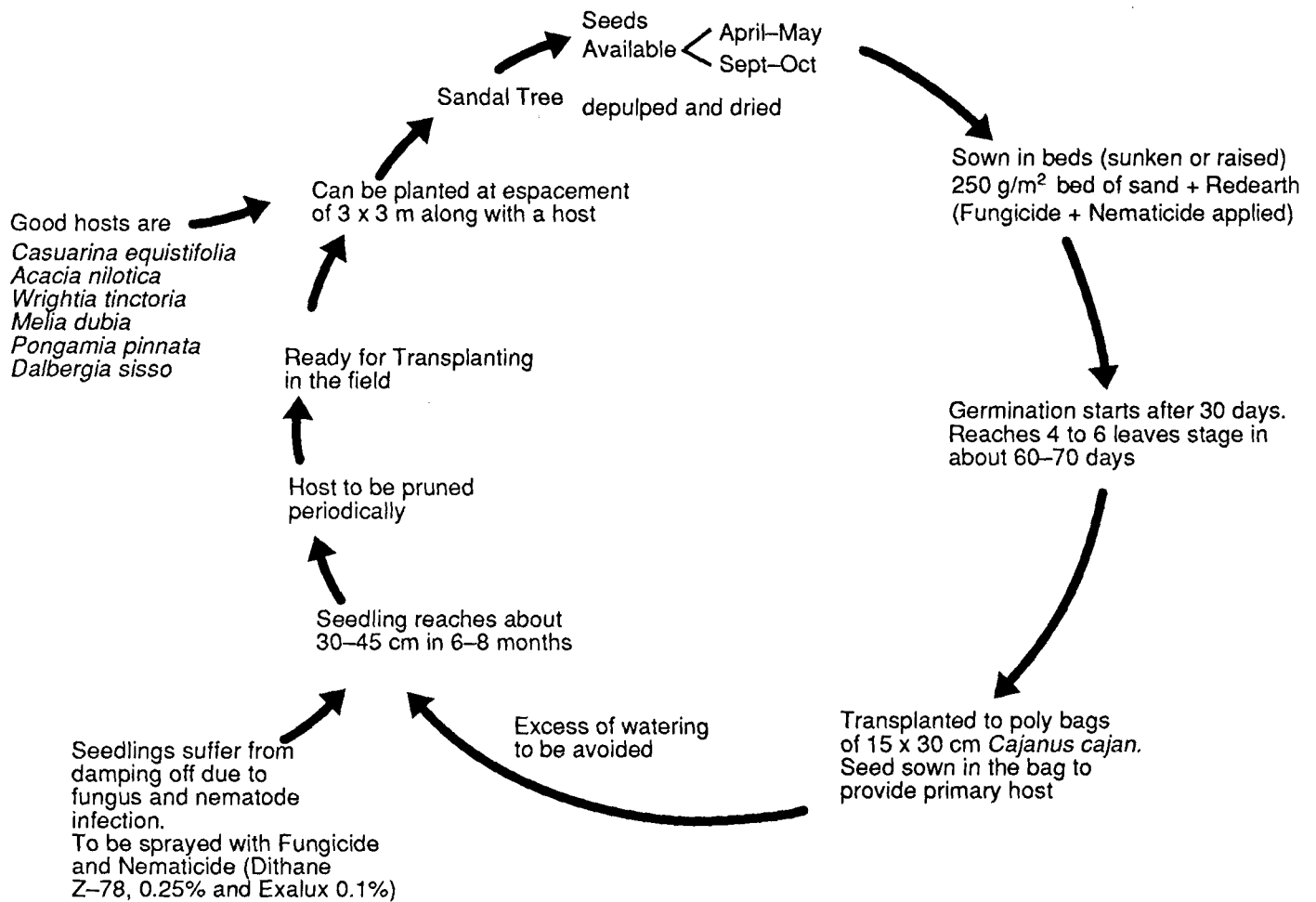


Figure 2—Cultivation of sandalwood from seeds.

Remission in symptoms was obtained by drip application of tetracycline to the stem. However, curative measures have not been found so far. Spike disease has been found to appear and disappear in a cyclic fashion from certain infected areas. Some tracts are free from it, but it seems to be spreading. Even in the zone where it occurs, all trees are not affected. However, at the same time, in the process of screening by inoculation we have not found resistant trees so far.

Smuggling of sandalwood has been causing grave concern. The government of India is about to bring in a uniform law for the entire country on use and transport of sandalwood.

#### REFERENCE

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