

Propagation of *Santalum*, Sandalwood Tree¹

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Abstract: The history of the genus *Santalum* (sandalwood) in Hawaii is reviewed, along with all the early reference regarding its botany and horticulture. This paper gives some seed germination and viability information on *Santalum haleakalae* Hbd. and *S. paniculatum* H. & A. both native to Hawaii and *Santalum album* L. native to Indonesia. Germination was shown to be highly variable: as early as 26 days after sowing for *S. album*, 75 days for *S. paniculatum*, and 155 days for *S. haleakalae*. Seed viability varied from 324 days in *S. album*, 387 days in *S. haleakalae* and 824 days in *S. paniculatum*. Germination percentages ranged from 38 percent to 77 percent.

This study also showed that supplemental chelated iron is essential in the propagation of all the species tested.

The genus *Santalum* (sandalwood) includes several species which are highly prized for their fragrant heartwood and aromatic oils which has been in great demand throughout history especially in the orient. Edwards (1951) dates it as far back as the fifth century B.C. It is also mentioned in passages of the Bible (Modenke and Noldenke 1952). Its value in the orient was well known by the early sea captains and when it was found that sandalwood existed in Hawai'i, it was soon exploited. Records are inconclusive as to who exported the first shipment of sandalwood from Hawai'i; however, this product formed the basis for Hawai'i's first profitable major export which according to Smith (1956) lasted for 52 years, from 1784 to 1836, "when all Hawaii woke to the fact that every tree had been cut." This statement, like those of Mesick (1934) and Kuykendall and Gregory (1926) greatly exaggerated the rarity of this genus and was corrected by St. John (1947) who documented their relative abundance. It is apparent that many of the sandalwood trees were destroyed during the height of this trade and Rock (1974) estimated that over 90 percent of the trees were destroyed.

The genus *Santalum* belongs to the family Santalaceae which includes 29 genera with approximately 400 species, many of which being completely or partially parasitic. St. John (1947) records 19 species of this genus, extending from Java to Juan Fernandez, Hawai'i and the Bonin Islands. The genus is described by Rock (1916) as being hemiparasitic, obtaining part of its nutrients from roots of other plants by means of a haustoria or suck organ. He also found *Santalum cuneatum* growing all alone with not [sic] trees or other plants within a radius of 1 mile, indicating that this species is not always dependant [sic] on host trees for nutrients.

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The first attempt to cultivate native sandalwood is recorded by Hillebrand (1888) who states that "bur trees are probably parasites as is the Indian *S. album*; at least all attempts to cultivate them in my garden have resulted in failure." Rock (1974) also remarked "that any attempt to germinate seeds of the Hawaiian sandalwoods resulted in failure."

Encouraged by Rock's (1916) statement showing that sandalwood was not always dependent on host trees for nutrients, and the fact that he (Judd) also noted a flourishing tree of *Santalum freycinetianum* growing without any apparent host plants within 299 feet of it, Judd (1933) planted seeds of native *Santalum* species. This is the first recorded sowing of native Hawaiian *Santalum* species.

A few years later, Judd (1935, 1936) reported that the Forest Service of the Territory of Hawaii was having difficulty growing native sandalwood seedlings because, "the young seedlings ceased to grow after one year, and died in the nurseries after reaching six inches in height." They were, however, successful in developing a system for growing *Santalum* seedlings. It consisted of planting 5-7 month old seedlings in a container with a few seeds of *Casuarina equisetifolia* (ironwood) to act as host plants and subsequently transplanting them together into the field when the sandalwood was about a year old. Using this method, 100 percent survival was reported. It is unclear whether this success was with the native as well as with the introduced species, *Santalum album*; for, Judd (1936) also states that experiments were first started with seeds of native species but later with *S. album* when they could not germinate the native species. Seeds of *S. album* germinated well and seedlings survived with their new system of propagation and planting.

The use of ironwood seedlings is briefly mentioned by Edwards (1951) as being used by Foresters at Volcano National Park, Hawaii. Le Barron (1970) also states, "When the Division of Forestry propagated sandalwood seedlings, a *Casuarina* or koa seedling was placed in a pot together with each sandalwood to serve as a host." The only other reported unsuccessful attempt at germination of native sandalwood seed is by Obata (1967).

Since studies on the propagation of native sandalwood are lacking these studies (on germination and propagation) were initiated at the Lyon Arboretum. Preliminary results are being reported since substantial success has been obtained in seed germination and seedling growth. Furthermore, this report might stimulate others.

SEED GERMINATION

Seeds of three species, *Santalum haleakalae* Hbd. and *S. paniculatum* H. & A. native to Hawai'i and *S. album* L. native to Indonesia, were used in these studies. Sources are included in table 1.

After the fruit pulp was removed, the seeds were treated with Dithane M-45 (2 tablespoons per gallon of water) for five minutes and sown in seed flats containing horticultural vermiculite (grade 3). The flats were placed on open benches in the greenhouse with a mean temperature of 78 degrees. Germination dates were recorded.

Species	Source	No. of Seeds	No. germinated	Percent germination	No. of days required for first seed to germinate	Total no. of days between first and last seedling
<i>Santalum album</i> L.	Taiwan Forestry Research Inst., Botanical Garden, Taipei, Taiwan	33	20	67	26	324
<i>S. haleakalae</i> Hbd.	Haleakala, Maui Hawaii	32	12	38	155	387
<i>S. paniculatum</i> H. & A.	Kohala, Hawai'i	136	105	77	75	824

Germination was highly variable (table 1). Seeds of *S. album* began germinating 26 days after sowing while those of *S. paniculatum* and *S. haleakalae* required 75 and 155 days respectively. The total number of days (germination period) required for all viable seeds of each species to germinate varied from 324 in *S. album* to 387 in *S. haleakalae* and 824 days in *S. paniculatum* seed lots.

Seedlings appeared normal and growth was normal until cotyledons shriveled and dropped off. The seedlings then began to decline in producing smaller leaves with each new flush of growth; with extremely chlorotic leaves, by reduction in internode length and die-back of short tips. Death occurred shortly thereafter.

SEEDLING GROWTH

Seedlings were potted into media consisting of: 2 parts vermiculite, 2 parts perlite, and 1 part peat plus osmocote (18-6-12) at the rate of 0.25 cup per 5 gallons of mixture. Some seedlings were planted with native Hawaiian host plants, others treated with foliar fertilizer (Nutrileaf 60 20-20-20) and others with chelated iron (Sequestrene 138 Fe).

The first three seedlings of *S. haleakalae* were planted with native *Dodonea* sp. and *Tetraplasandra* sp. seedlings as hosts. These genera were selected since they have been associated with sandalwood populations in native forests. These three plants expired within a year without showing any signs of growth. Subsequently, seedling of *S. paniculatum*, *S. haleakalae* and *S. album* did not respond to applications of foliar fertilizer (20-20-20). When 0.125 teaspoon chelated iron per 3 inch pot was applied to severely chlorotic seedlings of *S. album*, within 2-5 weeks, most of the chlorotic leaves became green and growth resumed. Likewise, 2 weeks after application of chelated iron on eight chlorotic seedlings of *S. paniculatum*, all the new growth was normal green while those treated with ammonium sulfate only showed no response. Three months after treatment, the remaining chlorotic foliage turned green in those plants treated with iron while those treated only with ammonium sulfate remained chlorotic. The average increase in height over a period of 18 months for the treated plants was 39.0 cm while those untreated averaged only 15.3 cm (table 2).

In the experiment using seedlings of *S. paniculatum*, four were

Table 2—Growth response of *Santalum paniculatum* to chelated iron and ammonium sulfate at a rate of 1/8 teaspoon each per 3 inch pot

Treatment	Plant	HEIGHT (CM)			
		Initial	18 months	Net Increase	Average
(Control) Ammonium sulfate	1	5.7	17.4	11.7	15.3
	2	4.9	17.3	12.4	
	3	6.3	23.0	16.7	
	4	6.5	27.0	20.5	
Ammonium Sulfate Plus Chelated Iron	1	5.3	36.8	31.5	39.0
	2	5.1	42.3	37.2	
	3	6.1	48.7	42.6	
	4	6.3	50.9	44.6	

treated with 0.125 teaspoon ammonium sulfate per 3 inch pot while another four were treated with 0.125 teaspoon chelated iron plus 0.125 teaspoon ammonium sulfate. Seedling height was measured before and 18 months after treatment (table 2).

Chlorotic seedlings of *S. haleakalae* were treated with 0.125 teaspoon chelated iron plus 0.25 teaspoon osmocote (18-6-12) per 4-0.75 inch pot. After 3 months these plants were divided into two lots of four plants each. One lot was treated with 0.25 teaspoon osmocote and the second lot with 0.25 teaspoon osmocote plus 0.125 teaspoon chelated iron. The plants were re-treated after 6 months. Plant height was recorded before and at 6 month intervals up to a year after treatment (table 3).

The trial using seedlings of *S. haleakalae* again showed response to chelated iron. The total net increase in height was

Table 3—Growth response of *Santalum haleakalae* to chelated iron at a rate of 1/8 teaspoon per 4-3/4 inch pot

Treatment	Plant No.	HEIGHT (CM)				
		Initial	6 months	12 months	Increase Net	Average Increase
Control (No Chelated Iron)	1	23.9	35.5	44.5	20.6	25.7
	2	34.5	47.7	58.6	24.1	
	3	24.5	38.3	50.8	26.3	
	4	26.0	39.5	57.6	31.6	
Plus Chelated Iron	1	16.5	27.5	39.4	23.9	38.0
	2	34.0	55.1	72.7	38.7	
	3	15.0	45.2	66.3	42.3	
	4	20.5	14.1	63.1	47.1	

Table 4—Germination of three seedlots of *Santalum paniculatum*

<i>Santalum paniculatum</i> seed lots	No. of seeds	No. of days from collection to sowing	No. of days (from sowing) required for first seed to germinate	No. of days from collection to emergence of last seedling	No. of days between germination for first and last seedling	Percent germination
1. L-71.377	27	69.0	866	1759	824	70
2. L-75.148	17	0.5	207	369.5	162	94
3. L-75.186	92	8.0		174		76

greater in those plants treated with iron, averaging 38 cm.; while those untreated, increased in height only 25.7 cm after 12 months. The increase in height of treated vs. untreated was not as great when compared with the *S. paniculatum* trial. It should be noted that all of the plants involved in this trial were treated with chelated iron before the trials began.

DISCUSSION

The germination data seem to indicate some type of dormancy mechanism(s) controlling germination of the *Santalum* spp. included in these studies. The extreme variation in the number of days 75, 207, and 866, to initial germination for different seed lots of *S. paniculatum*, seems to reflect this (table 4). Further evidence is indicated by seed lot number L-71.377 which was not sown until 69 days after collection. This lot required 866 days to germination of first seedling followed by a germination period of over 2 years with 70 percent germination.

The data also show the longevity of the seeds which germinated in a range from a low of 174 days in the case of L-75.186 *S. paniculatum* to a high of 1, 759 days in L-71.377 *S. paniculatum*: indicating seed viability of nearly 5 years (table 4) in the latter case. Seeds of this were allowed to dry out for 69 days before being sown and this factor may have contributed to its longevity.

Germination percentages ranged from 38 percent to 77 percent. The data do not show that older seeds tend to be less viable than fresher ones. However, it does show that seeds of *S. haleakalae* have a lower germination percentage when compared with both *S. album* and *S. paniculatum* seed lots. It was shown in the case of L-71.377 where the seeds were held for 69 days before sowing that over 2 years were required before the first germination occurred. It appears that seeds of those species should not be allowed to desiccate in order to hasten germination.

Previous fertilizer practices using both osmocote and foliar fertilizer in scheduled application proved ineffective in promoting growth of the *Santalum* spp. included in this study. The plants gradually declined and their leaves gradually became

severely chlorotic, turning a yellowish-white. With each subsequent leaf flush, the leaves became smaller and smaller until the growing tip died. Death followed shortly. With the addition of chelated iron foliage color was restored and growth resumed. Ammonium sulfate applications showed no response and was discontinued after the first trial. It is evident that supplemental chelated iron is essential in the propagation of *S. album*, *S. haleakalae* and *S. paniculatum* since all of these species responded to the addition of chelated iron as indicated by the data. These studies show that these species can be grown without any host plants. Although the number of plants used in these trials was small, the results are encouraging and further studies are being conducted with larger numbers for statistical analysis.

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