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RESEARCH ARTICLE

ROLE OF HOST PLANTS FOR WHITE SANDAL (*SANTALUM ALBUM* L.)CULTIVATION IN WEST BENGAL

***[1]Sudhir Chandra Das and [2]Jagatpati Tah**

[1]Office of the Conservator of Forest, Parks and Garden Circle, 10-A Auckland Road, Eden Garden, Kolkata – 700 021, West Bengal, India
[2]Department of Life Science and Biotechnology, Jadavpur University, 188 Raja Subodh Chandra Mullick Road, Jadavpur, Kolkata – 700 032, West Bengal, India

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ABSTRACT

White sandal (*Santalum album* L.) grows in sandy alluvial or laterite soil having adequate edaphic as well as environmental factors. But, it is ensured its survivility when specific host plants are available in its surrounding root zone. It has also been found that host is no more required for its proper growth and development after 3-4 years. Consideringall these facts a venture was undertaken to conduct an experiment for its mass propagation in the forest gardens under Bankura(S), Bankura(N) and Burdwan Forest Divisions in West Bengal. The aims and objects of the study were to observe the role of suitable host plant and influence of edaphic factors of the locations in favour of the growth and development of *Santalum album* L.

INTRODUCTION

Sandalwood (White Sandal) is the fragrant heartwood of some species of genus *Santalum*. The widely distributed and economically important *Santalum* genus belongs to the family Santalaceae which includes 30 genera with about 400 species, many of which being completely or partially parasitic (John, 1947). The word Sandal has been derived from Chandana (Sanskrit), Chandan (Persian), Savtador (Greek) and Santal (French). There are references of Sandalwood in Indian mythology, folklore and ancient scripts. 'Chandana' the Sanskrit name ascribed to *Santalum album* L. was known and used in India from the earliest historic times and is frequently mentioned in the ancient Sanskrit writings, some of which dated before Christian era. Kautilya's Arthashastra (320 B.C.) considered Sandal as one of the important forest products to increase royal revenue. Charaka Sanhitha, the major text book of internal medicine in Ayurveda (300 B.C.) quotes uses of Sandal over 160 time in the entire text. In treatment of major diseases like fever, piles, hemorrhagic conditions, diabetes, dropsy, mental disorders, management of poisons and skin disorders wide spread uses of sandal is seen.

Corresponding author: **Sudhir Chandra Das**
Office of the Conservator of Forest, Parks and Garden Circle, 10-A Auckland Road, Eden Garden, Kolkata – 700 021, West Bengal, India

Susrutha Samhita (150 B.C.) a great text on Indian wisdom on surgical procedures, equally preferred sandal for the management of wounds. Sandal fumigation is indicated in warding off evils and organisms, which contaminate the wounds. Such fumigations hasten the wound healing andsurgical wards remain aseptic. Dusting of wounds with sandal for early healing is common. In the Amarkosha (Lexicon 3rd or 4th Century A.D.) sandal is mentioned and it is said that 'Vina-malayam anyathra chandanam vivarditha' (Majumdar, 1941).

The extraction and disposal of sandal came under the Forest Department in 1864 in Mysore state (Adkoli, 1977). In Karnataka (formerly Mysore) the forest working plan for sandal extraction were prepared for Hunsur Talik in 1910, Heggadadevanakote in 1920 and Narasimharajapura in 1926. In 1871, the parasitic nature of sandal was reported by John Scott. Watt (1893) described the technique of raising sandal seedlings in tile pots in the nurseries and planting in the field. McCarthy (1899) first noticed the spike disease of sandal in Coorg. Brandis (1903) suggested that though sandal is a root parasite, it may derive part of its nutrition from the soil as well. Barber (1905) noted that haustoria formation occurred only on certain roots of sandal and not on all of them. Ecologically sandal has adapted various agro - climatic and soil conditions for *in situ* regeneration with an exception of

waterlogged areas and very cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain *et al*., 1998). The provenances vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of *Santalum album* in India (Srinivasan *et al*., 1992). Distribution of *Santalum album*is also found outside India, e.g. in Sri Lanka and South East Asia (Timor, Indonesia, Malaysia, Cambodia, Vietnam, Myanmar, Thailand and China), the Pacific (Papua New Guinea, Fiji, New Caledonia and Hawaii) and to some extent northwest of Western Australia (Kanunurra). Recently the Govt. of Australia had undertaken the venture of commercial cultivation of Sandalwood specially they considered the Indian Sandalwood species (*Santalum album*) is the best due to its higher oil (β-Santalol) content. In Sri Lanka natural stands of sandalwood are present in the districts of Kandy, Nuwara Eliya, Ratnapura and Badulla belonging to the wet and intermediate climatic zones (Panabokke, 1996; Mapa *et al*., 1999). It is believed that *S. album* is an exotic in India, having been taken there from East Indonesia by traders of the fragrant wood and holding a pre-eminent position in the Indonesian island (Malay Archipelago), Timor (Ajaubaki, Siso, Buat, Niki –Niki, Kokoi and Netpala districts) (Effendi, 1994) and to a small extent in Alor, Roti, Sumba and Flores islands. There are two types of *S. album* found across Timor, a small-leaf variety and a large-leaf variety (Harisetijono and Suriamihardja, 1993). In Australia, a small naturalized area in the northwest of Western Australia which is believed to have been established through the activities of Mallacan traders. *S. album* was believed to be first grown experimentally in the Ord River Irrigation Area, Kununurra Western Australia in 1983. The first private sector commercial plantations of *S. album* were established in Kununurra in 1999 (Clarke, 2006).

Sapwood is white to pale yellow, sharply demarcated from the yellowish brown to dark brown heartwood, hard, heavy, lustrous, straight-grained to slightly wavy, fine textured with pleasant characteristic smell (Rao *et al*., 2007). Sandalwood trees are famous and very costly because of its fragrant heartwood and oil. White Sandal (*Santalum album* L.) was tried in various locations of South West Bengal since nineteen sixties. The area has predominantly laterite soil having rainfall from 1200mm to 1600mm with maximum temperature $45C^0$ and minimum temperature $7C^0$. To ensure protection, Sandal was grown in various forests Range and Beat Office compounds located in the district of Bankura, Birbhum, Burdwan, Purulia and West Midnapur bringing quality seeds from Institute of Wood Science and Technology (IWST), Bangalore time to time. Sandal is one of the very few tree species in which research has been carried out for more than a century. The demand for Sandalwood and Oil is increasing and the gap between demand and supply is widening. To bridge the gap between demand and supply, afforestation and plantation programme should aim at increasing the productivity of plantations. In sixties Sandalwood trees were also planted in Hirbundh Beat Office compound under Khatra Range of Bankura District. Trees started flowering after 10-12 years and lot of natural regeneration has started coming up in Hirbundh Block both in forest areas and in the adjoining non-forest areas of the Block. But very few records of growth and yield of white sandals grown in South West Bengal is available. An attempt was being taken in 2009-10 to study growth and yield of sandal trees grown in Hirbundh Beat office compound of Khatra Range in Bankura (South) Division (Das, 2013). Some hindrances and problems for its propagation were observed by various workers in these areas. Keeping all these views in mind we are going to undertake the venture for its mass propagation through seeds and its cultivation with their agronomical maintenance properly.

MATERIALS AND METHODS

Materials

- **Sandalwood seeds:** Seeds of *Santalum album* L. were collected from Hirbundh mouza of Hirbundh Range under Bankura (South) Forest Division during the month of November-December and May-June of 2011 and 2012 for experimentation. Simultaneously, seeds of *Santalum album* L. were also procured from Institute of Wood Science and Technology, Bangalore in the month of February, 2012 for the same experimentation purposes.
- **Chemicals :** Gibberelic acid(GA_3)
- **Apparatus:** Container, Markin cloth, Polypots, Hycopots.
- **Miscellaneous :** Sand, bricks, Seive, FYM, Water, etc.
- Meteorological Information.

A month wise account of mean maximum and minimum temperatures from 2006 to 2009 (upto March) is presented in Table 1. The minimum temperature was 7°C in both 2007 and 2008 (Key Statistics, Bankura, 2008).

Table 1. Maximum and Minimum temperature regime of the district of Bankura (Center - Bankura) in degree Celsius

Months	2011		2012		2013		2014	
	Max	Min	Max	Min	Max	Min	Max	Min
Jan	27	09	27	9	27	9	28	7
Feb	32	11	34	9	32	9	32	11
Mar	39	14	38	15	37	16	34	4
Apr	43	20	42	9	38	18	39	19
May	44	24	45	22	43	21	45	21
Jun	39	24	37	22	41	23	47	23
Jul	38	24	37	25	35	25	37	25
Aug	35	23	34	24	35	25	36	23
Sep	34	24	36	24	35	22	32	21
Oct	34	16	35	20	34	18	31	20
Nov	32	11	32	13	32	16		
Dec	29	10	29	7	27	9		
In year	44	9	45	7	43	9		

Table 2. Monthly rainfall in the district of Bankura (Centre-Bankura) ml

Month	Normal	2011	2012	2013	2014
		20	3	7	0
February	12	13	40	15	0
March	19	7	9	4	6
April	27	4	57	66	12
May	65	52	76	77	0
June	198	213	247	183	20
July	272	331	255	471	276
August	293	332	445	386	450
September	246	358	139	384	425
October	122	18	95	0	190
November	15	99	00	0	
December	03	6	00	0	
Total for the year	1289	1453	1366	1687	Upto Oct. '14

Information on Sites

Abbreviation	Full name	Total
L	Location	4
P	Plantation	3
T	Treatment	9
Y	Year	3

Name ofLocation

No.of Location	Name of Location
L_1	Bagaldhara
L	Rangamati
L_3	Kamalpur
L_4	Beliatore

Information of Treatments

No.of Treatment	Composition [Host(S)]
T_0	No Host
T_1	Arhar
T_2	Tulsi
T_3	Arhar+Tulsi
T_4	Akand
T_5	Arhar+Akand
T_6	Ghantu
T_7	Arhar+Ghantu
T_8	Nayantara
T_9	Tulsi+Nayantara

Information of Plantation

No. of Plantation	Year
P_1	2011
P_2	2012
P_3	2013

Growth Parameters, viz. plant height (cm) and basal girth (cm), were measured out of all planted saplings year-wise from each and every forest garden. *Santalum album* L.

MATERIALS AND METHODS

AGermination Study in Nursery

Pretreatment by soaking in water: Sandalwood seeds are soaked in water for 24 hours before sowing. Seeds are sown in sand bed (6 mm deep). Germination starts after 60 days. In-between 61 to 100 days, only 3-4% germination is obtained.

Pretreatment by boiling water: Sandal seeds are pretreated with boiling water (10 parts of boiling water with one part of seeds) for 1 minute and then kept in normal water overnight for soaking. Treated seeds are sown in sand bed. Germination starts after 50 days. In-between 51 to 100 days, hardly 8% germination is obtained.

Pretreatment by alternate wetting and drying: Sandal seeds are exposed to alternate wetting and drying for 12 hours wetting followed by 12 hours drying in sun. This process is repeated for 7 days and then the seeds are sown in sand bed (6 mm deep). Germination starts after 40 days. In-between 41 to 100 days, 8 to 9% germination is obtained. Few germination is found even after 100 days upto 150 days.

Pretreatment by Gibberellic Acid: Matured seeds were collected from the sandalwood trees of Hirbandh Block in November- December, depulped, dried in sun and stored in polybags for germination test. 6 samples each of 300 sandalwood seeds were taken and tied in markin cloth. 3 containers (1 liter each) were taken for 3 different concentrations (0.0125%, 0.025%, 0.05%) of gibberelic acid. 2 seed samples were dipped in each container for 16 hours and 24 hours soaking. The treated sandalwood seeds were then sown in the sand bed. The sand beds were watered twice daily in the morning and afternoon. First germination was started after 24 days of seed sowing. The number of seeds germinated in each treatment is recorded and the germination is continued upto 90 days after sowing. The results were shown in the Table. The germinated seedlings were transplanted in polypot (8″x4″ and 9″x 5″) and 300 cc hycopots in nursery at 3 to 4 leaf stage. Sandal seeds have a post drop dormancy of two months due to presence of hard seed coat or due to presence of chemical substances in the seed coat which are impervious to water and gases. Germination of Sandal seeds are found profuse from the bird droppings in the forest floor as well as in the village yards and bunds of the agricultural fields. Sandal is also found growing wild in some farmlands, homesteads and wastelands in Hirbundh block of Bankura District and Arabari forests of Midnapur District. This indicates the potential of growing the tree in the farmlands.

However, germination of seeds are very low (10-15% within 60 days) when the seeds are sown in mother bed (sand beds) after hot and cold water treatment or alternate wetting and drying due to its hard seed coat and dormancy. Sandal seeds have been found to germinate faster when the seed coat is completely removed, or seeds are soaked in 0.05% gibberelic acid for 12-16 hours (Nagaveni and Srimathi, 1981). In sandal seeds, the duration of germination is much prolonged after the dormancy period. It starts in 25 days and reaches hardly 50% in 90 days with 0.05% GA_3 soaking for 16 hours (Das and Tah, 2013). Germination study conducted in Hirbundh and Kamalpur nurseries of Bankura (South) Division in 2011, 2012 and 2013 where seeds are soaked in different concentration (0.0125%, 0.025%, 0.05%) of gibberelic acid for 16 hours and 24 hours respectively and sown in sand beds of nursery. The germinated seedlings are pricked out from sand bed and planted in polypot and hycopot beds of nursery at 3 to 4 leaf stage and kept in nursery without and with host (*Cajanus cajan*).

Cultivation of Sandal and Host-Parasite Study in Field

Sandal can grow in comparatively poor agricultural soil and also in derelict forest areas of laterite tract (Lahiri, 2010) but it can't withstand waterlogging. It can also be cultivated in farmland/homestead land. So a serious thought need to be given for introduction of sandalwood in the area (laterite tract of South West Bengal). To popularize sandalwood cultivation in this area, Bankura (South) Division is raising 2000 sandal seedlings every year and distributing those seedlings free of cost during Aranya Saptah (Forestry Week) from 14-20th July to the villagers for planting in their homestead land. The hemi–parasitic nature of sandalwood is not fully understood and silvicultural techniques to establish it are not fully known. Ananthapadmanabha *et al*. (1984) reported that sandalwood plants established haustorial connections with the secondary hosts (e.g. *Pongamia pinnata*). Though sandalwood plants can survive without host, their experiment has proved beyond

doubt that the host plants are absolutely necessary for the better growth of sandal plants.

Efforts are taken to cultivate sandalwood seedlings in two Joint Forest Management Committee (JFMC) areas viz. Bagaldhara FPC and Rangamati FPC of Hirbundh -I Beat in 2011 for protection with the help of community. It is also planted in some Beat/Range office compounds in laterite tract of South - West Bengal during 2012 and 2013. As it is a hemi-(root) parasite, it needs host plant to grow in the initial stage. Host plants like Arhar (*Cajanus cajan*), Tulsi (*Ocimum sanctum*), Nayantara (*Catheranthus roseus*), Akand (*Calotropis procera*), etc. are planted along with sandal seedlings (6 month old seedlings) singly as well as in combination of hosts in the field. Pits of size (60cm x 45cm x 45cm) cm were dug in the field in March-April for planting of the potted seedlings. The pits were filled with soil and 500 gms of cowdung manure in the month of June. The potted seedlings (6 month old) were planted in the field in July after getting a good rain at a spacing of 2.5m x 2.5m.

After planting, a host plant (Arhar, Tulsi, Nayantara, Akand) was planted at the side of the sandalwood sapling singly as well as in combination of hosts. Some sandalwood saplings were allowed to grow without host. Growth parameters (basal girth and height) were measured after 1 year, 2 year and 3 year. The results were presented in the Table 4 to 5.

Statistical Models

Statistical Models and methods were done as followed by Singh and Chaudhary (1995) and Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

Host Performance Study

Cultivation of Sandal and Host-Parasite Study in Field: Field experiment was conducted in Bagaldhara FPC and Rangamati FPC of Hirbandh Block, Bankura (South) Division. The sandal seedlings were planted in the field along with host

Table 3. Plantation of Sandal plant in different forest gardens in South West Bengal

Sl. No.	Location	Year of Planting	No. of seedlings Planted
1	Rangamati-Bhubandihi FPC, Hirbundh-I Beat	2011	100
2	Bagaldhara FPC, Hirbundh-I Beat	2011+2012	150+ 200
3	Kamalpur Range office compound	2012	30
4	Khandari Beat compound, Panagarh Range	2012	100
5	Beliatore Range office Compound	2013	100

Photo 1. Sandal with *Cajanus* host

Photo 2. Sandal with *Ocimum* host

Photo 3. Sandal with *Catharanthus* host

Photo 4. Sandal with *Calotropis* host

Some seedlings were planted without host at a spacing of 2.5 m x 2.5 m in the month of July. Soil work was done periodically and inter-culture operation was done 3 –times after planting at 3 weeks interval. Manure (cowdung/vermicompost) @500 gm/ pit was applied at the time of pit filling. Fertilizer (NPK – 10:26:26) was applied twice @ 40 gm/plant. Plant height, collar girth and survival % was measured after 12 months and 24 months respectively for study of growth of sandal saplings in 1st year and 2nd year.

The following table- VIII and IX shows that growth of sandalwood saplings is better with Arhar + Tulsi combination of hosts followed by Arhar (*Cajanus cajan*) followed by Arhar+Akand combination of hostas single host followed by Tulsi(*Ocimum tenuiflorum)* as single host both in 1st year and 2nd year. The survival % also follows the same trend. The survival % varies from 70 to 82 % in 1st year and 66 to 76% in 2nd year depending on the type of host. The results are presented in Table 8- 9.

Photo 5. Sandal with *Clerodendron* host

Photo 6. Sandal with *Catharanthus+Ocimum* host

Table 4. Growth of sandal seedlings without & with hosts in Bagaldhara 2011 plantation

Type of Host (Bagaldhara-2011)	Growth in 1st year (Sample size:30-40/treatment)				Survival %
	Height (Cm)	Av. Height (Cm)	Collar Girth (Cm)	Av. Girth (Cm)	
Arhar (*Cajanus cajan*)	70-170	99.32	3-7	4.45	80%
Tulsi (*Ocimum sanctum*)	52-115	85.58	3-5	3.75	70%
Akand (*Calotropis procera*)	50-95	63.67	2-4	2.42	40%
Arhar+Tulsi	75-183	110.58	3-7	4.50	82%
Arhar+Akand	63-110	84.00	2.5-6	3.78	72%
Without host	33-64	48.28	1-2.5	1.71	34%

Type of Host (Bagaldhara-2011)	Growth in 2nd year (Sample size:30-40/treatment)				Survival %
	Height (Cm)	Av. Height (Cm)	Collar Girth (Cm)	Av. Girth (Cm)	
Arhar (*Cajanus cajan*)	130-295	196.83	4-11	6.88	74%
Tulsi (*Ocimum sanctum*)	120-200	158.33	4-8	6.17	66%
Akand (*Calotropis procera*)	110-150	124.17	3-5	4.30	32%
Arhar+Tulsi	140-295	213.33	6-11	8.08	76%
Arhar+Akand	125-180	148.57	4-7	6.00	68%
Without host	80-110	95.00	2.5-4	3.00	20%

Table 5. Growth of sandal seedlings without & with hosts in Rangamati 2011 plantation

Type of Host (Rangamati-2011)	Growth in 1st year (Sample size:30-40/treatment)				Survival %
	Height (Cm)	Av. Height (Cm)	Collar Girth (Cm)	Av. Girth (Cm)	
Arhar (*Cajanus cajan*)	50-77	61.57	1.5-4	2.78	74%
Tulsi (*Ocimum sanctum*)	30-95	59.22	1-4	2.28	66%
Nayantara (*Catheranthus roseus*)	45-60	51.00	1-2	1.75	50%
Arhar+Tulsi	40-79	55.50	1-4	2.31	76%
Tulsi+Nayantara	33-85	51.85	1-4	2.07	68%
Without host	30-45	35.75	1-1.5	1.15	30%

Type of Host (Rangamati-2011)	Growth in 2nd year (Sample size:30-40/treatment)				Survival %
	Height (Cm)	Av. Height (Cm)	Collar Girth (Cm)	Av. Girth (Cm)	
Arhar (*Cajanus cajan*)	70-150	109.33	3-6	4.33	68%
Tulsi (*Ocimum sanctum*)	50-132	87.32	2-6	3.32	62%
Nayantara (*Catheranthus roseus*)	50-87	70.33	2-3	2.67	40%
Arhar+Tulsi	50-150	102.00	2-5	3.88	70%
Tulsi+Nayantara	50-115	88.14	2-4	3.28	64%
Without host	40-55	42.50	1.5-2.5	2.00	20%

The sandal seedlings, which were planted without host, has survived 30% in 1st year and 20% in 2nd year. The growth of sandal saplings are better (almost double) in Bagaldhara than in Rangamati because the soil of Bagaldhara is loose and contains more of mica but the soil of Rangamati is slightly rocky, compact and full of laterite. Akand (*Cajanus cajan*) and Nayantara (*Catharanthus roseus*) seems to be poor host as survival % is 40% and 50% respectively though combination of host of Arhar+Akand (72% and 68% in 1st year and 2nd year respectively) and Tulsi+Nayantara (68% and 64% in 1st yr. and 2nd yr. respectively) performs better.

DISCUSSION

Host Performance Study

Cultivation of Sandal and Host-Parasite Study in Field

It has been observed that tulsi (*Ocimum sanctum*) combined with arhar (*Cajanus cajan*) gave the best performance as host plants in all the locations for the growth and development of the sandal plants. In some cases, nayantara (*Catheranthus roseus*) gave the similar significant result for the growth and development of the sandal plants, though; it has also been proved that sandal plant can survive without any host plant association. This might be the effect of soil environment which will be explored in near future. However, it is clear that there is a certain edaphic factor for the growth and development of sandal plant. Sandal is a hemi – root parasite, first reported by Scott (1871), the importance of this fact was realized when Barber (1902, 1906 and 1907) reported the details of haustorial formation, growth and development of haustoria. Formation of haustoria is more or less confined to younger roots and they arise from external layers of rootlets, unlike lateral rootlets, which are formed deep in its tissues.

The establishment of connection and histological changes that take place during contact have been explained in detail by Barber (1906 and 1907), Bhatnagar (1965) and others. It was also reported that sandal requires a primary host at nursery stage (Annapurna *et al.,* 2006) and secondary long term host in the field. Being hemi – parasite the Silvicultural requirements are unique and there is no adequate understanding of the same. Its regeneration and establishment has been problematic because of the poor understanding of host – parasite relationships (Surendran *et al.,* 1998). Sandal plants in agro-forestry or forestry systems may have to tolerate varying levels of competition and complementary interactions from the component crops or plants. So, an understanding of the complementary and competitive influence of the host on sandal is necessary for successfully growing of sandal. When host is introduced in the pot at the early phase there is possibility of competition for soil moisture and nutrient between sandal and host. Most of the research in India on sandal has been focused on spike disease and host species selectively. However, little work has been carried out on nourishing sandal in the nursery with organic, inorganic and bio-fertilizers.

The plant with a haustorial adaptation on its own roots which parasitise the roots of other tree, but without major harm to its hosts. This plant forms a non-obligate relationship with a number of other plants like *Pongamia pinnata* and *Casuarina equisetifolia* (Nagaveni and Vijayalakshmi, 2004). Subbarao *et al*., (1990) worked on nodule haustoria and microbial features of Cajanus and Pongamia parasitized by sandal. They concluded that the parasitic dependence of sandal plants on nodulated host plants was evident in the gradual increase in their nitrogen content. In nature, the establishment and survival of sandal trees is enmtirely dependent on other woody plants in its vicinity which serve as host. Whether nodulated nitrogen fixing trees are better hosts for sandal thanb non-nodulated trees is a question which remains to be answered by conducting more experiments under controlled conditions.

Sandal can be parasite over 300 species of host plants found in nature from grasses to leguminous trees. This species shows different growth patterns with different host species. Lack of understanding of the host plants relationship cause the failure of sandal seedling production. Srinivasan *et al*. (1992), Surata *et al*(1995) and Fox *et al*(1996) has reported that *Cajanus cajan* is the best host plants for sandal in nursery. Four different host species, which were the best as reported by different scientists, were selected by Kala *et al.* (2007b) as secondary host plants for the main field. These were *Cynodon dactylon* (Kushalappa, 1995); *Albizzia saman* (Surrendran *et al.*, 1998); *Casuarina equisetifolia* (Rai, 1990, Taide *et al.,* 1994 and Srivastava, 2003); *Pongamia pinnata* (Nagaveni and Vijayalakshmi, 2004).

According to the findings of Rangaswamy *et al*., (1986) and Ananthapadmanatha *et al*., (1988b) sandal cannot be grown normally without a host plant. It depends on its host for P, K. and Mg. Tennakoon *et al*., (2000) reported that perennial host is the best for sandal growth.

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