International Seminar on
Sandalwood: Current Trends and Future Prospects
26th - 28th February 2014 • Bangalore

ABSTRACTS

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY
Indian Council of Forestry Research and Education

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Preface

The Institute of Wood Science and Technology (IWST), Bangalore, under the Indian Council of Forestry Research and Education, Ministry of Environment and Forests, Government of India, has a mandate to conduct research on wood science and technology at the national level. This Institute, which had its beginning as Forest Research Laboratory in the year 1938 is celebrating its Platinum Jubilee.

IWST has been conducting research in various aspects like silviculture, management, genetics, chemistry and entomology, and takes the credit for publishing over 200 scientific articles on Sandalwood. As a part of a year long celebration, the Institute, as Centre of Excellence for Sandalwood Research is organizing this International Seminar on Sandalwood.

The word sandalwood comes from the Sanskrit word Chandana. There are 16 species belonging to the family Santalaceae which have scented heartwood, often referred to as ‘tree gold’ is valued not only in trade and commerce, but have been a part and parcel of every day life of people in the countries where they occur. In India, Sandalwood is restricted in distribution to Peninsular India, though, now over the past several decades it has spread across the country. However, despite stringent laws, owing to illicit felling and smuggling, of recent, there is near decimation of population of Sandalwood in India, as we hardly find mature trees in natural forests. Also, in countries like Australia, Hawaii, Fuji, Pacific Islands etc., where Sandalwood occurs naturally, it is becoming increasingly difficult to conserve the species and harvest it sustainably.

IWST had successfully organized an International Seminar on ‘Sandalwood and its products’ in the year 1997, and the Institute has been making sustained efforts in the conservation. With the liberalized policies of the State Governments, the farmers are coming forward to raise Sandalwood as a part of agroforestry and as plantations. The Institute has perfected the nursery techniques, and is imparting training to farmers.
As the prospects of conservation and sustainable utilization of sandalwood is becoming an increasingly difficult task, we felt the need to bring together Scientists, Foresters, NGOs, Academicians, Entrepreneurs, Progressive Farmers and other Stakeholders associated with Sandalwood Plantation, Research, Utilization and Trade under one umbrella. Hence, this International Seminar with the theme “Sandalwood: Current Trends and Future Prospects”. The response has been quite encouraging as seen from the abstracts received under various themes of this Seminar.

I hope this International seminar helps in the dissemination of knowledge and skills which will go a long way in reviving the glory of Sandalwood in its native lands and spreading the unparalleled fragrance across the globe.

We record our sense of appreciation for the efforts and hard work put in by Dr. Avinash Kanfade, GCR, Shri M. Srinivasa Rao, CF, Dr. K.K. Pandey, Dr. R. Sundararaj, Dr. V. P. Tewari, Dr. Syam Viswanath, Dr. Pankaj Agarwal, Dr. K. Murugesan, Dr. Shakti Singh Chauhan, Dr. Geeta Joshi, Dr. A. N. Arun Kumar, Shri Y. B. Srinivasa, Dr. Ashutosh Srivastava, Shri S. H. Jain, Sinduveerendra, and Shri G. Ravi Kumar.

We thank Dr. S. Rajagopalan, I.A.S., Secretary, Ministry of Environment and Forests, Government of India for giving us encouragement in conducting this International Seminar. We acknowledge the support and encouragement given by Dr. S.S. Garbyal, IFS, Director General, ICFRE and Director General of Forests and Special Secretary to the Government of India. We also thank Shri Jude Shekar, the former DGF and Special Secretary to the Government of India.

Dr. V. Ramakantha
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Theme – 1: Sandalwood across the globe
Renewing the wooden gold of Western Australia

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The Western Australia (WA) land area is 80% of that of India, however the population is only 2%. WA is Australia’s most productive State by GDP with an economy driven by the production and export of non-renewable mineral resources such as gold. WA also has wooden gold in the form of wild Sandalwood (Santalum spicatum) which unlike mineral gold is a renewable resource. Wild Sandalwood harvesting occurs mainly from stands in semi-arid and arid regions (typical annual rainfall 150-300 mm). Wild Sandalwood regeneration in these regions has been low since landscape changes following European settlement causing over-grazing and loss of seed dispersing marsupials from predation with the additional impact of increasing drought. The WA State Government forestry agency is the Forest Products Commission (FPC). The FPC’s Operation Woylie research program improved understanding of the relationship between Sandalwood establishment and rainfall. From these studies the FPC implemented a Sandalwood seeding program, however labour costs in WA are high and the working environment hostile and dangerous making hand planting seeds unsustainable in the long term. From 2011 to 2013, the FPC experimented with mechanized processes for wild Sandalwood seeding. The successes in the experiments were combined to construct a mechanical seeder with adjustable seed metering and soil cutting and ripping mechanisms to enable dormancy treated seed to utilize harvested surface water flow. From 2014, over 3.5 million seeds per year will be sown using the seeder. This seeding rate has been determined to establish a sufficient number of Sandalwood to replace the current harvest with allowance for seedling mortality and fluctuating annual rainfall. The challenge now is to implement economic structures to ensure that seeding programs are maintained. Future generations will then be able harvest wild trees with heartwood oil that has slowly accumulated over 150 years in a wild environment. Old wild trees have an intrinsically high value by comparison to young plantation trees and WA is in a unique position to renew its wooden gold indefinitely.

Keywords: arid, mechanized process, regeneration, renewable resource, Sandalwood

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Status of Hawaiian Sandalwood

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Even though Hawaii has had a long history with the international Sandalwood trade, there is a surprising limited amount of information collected and available on Hawaiian Sandalwood. What we do know is during the days of the Kingdom of Hawaii, much of the Hawaiian Sandalwood was over harvested - to the extent, that today it can be difficult to find Sandalwood in many of our forests. Hawaii has six different species of Sandalwood with one species that is recognized internationally as containing superior oil qualities. Most recently, through the State of Hawaii’s 2012 legislative process, the Division of Forestry and Wildlife was asked to research and support an initiative focused on Hawaiian Sandalwood, ‘iliahi. Prior to this initiative, however, the State government was not focused on Sandalwood as a target species for restoration or for production. There are a few people in Hawaii that are working on different aspects of Sandalwood silviculture and ecology, and we have been working on pulling together relevant information on the Hawaiian Sandalwood species, as well as looking to other nations for potential similarities between species found throughout the Pacific. The Division of Forestry and Wildlife is interested in growing a Hawaiian Sandalwood industry and seeking expertise and resources to help guide the State of Hawaii in making appropriate management decisions for this species. Thanks to connections made at the International Sandalwood Conference in October 2012, the Division has been working with a number of organizations throughout the Pacific and looking for support from countries that have more development market and/or conservation initiatives to provide information that would support management of this unique tree.

Keywords: Hawaii, ‘iliahi, Sandalwood, status

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Sandalwood cultivation in Karbi Anglong district of Assam, India: A study from Geo-Environmental perspective

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Santalum album, the Indian Sandalwood is one of the most valuable trees in the world today. Whether, this species is native or not to this North-Eastern part of India, is not clear. Recently, people of this region could understand its value and have started to grow this plant especially in the district of Karbi Anglong of Assam. Record says that it was in 1978, by the initiative of a forest official, this species was introduced officially in the district bringing from Deccan region of India. The luxuriant growth and structure of the existing plants in the region proves that the geo-environmental conditions, especially the soil type is much suitable for this species. Under the initiative approach of the Department of Environment and Forest, Karbi Anglong District, people are getting more interested in the cultivation of Sandalwood plant for its better economic prospect. Accordingly, nurseries have been developed departmentally as well as privately in different parts of the district to meet the increasing demand for seedlings. This part of North-East India seems to be one of the most significant areas of Sandalwood production of the country in the near future.

Keywords: Assam, Karbi Anglong, Santalum album

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Present status and distribution pattern of Sandalwood with its culture and heritage across the globe

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Sandalwood trees are medium sized hemi parasitic in nature falls under the same botanical family of European mistletoe with the notable members like Indian sandal wood (Santalum album) and Australian Sandal wood (Santalum spicatum) which are found in India, Bangladesh, Srilanka, Australia, Indonesia, Hawai and other pacific Islands. Indian Sandalwood is a threatened species and indigenous to South India, and grows in the Western Ghats and a few other mountain ranges like the Kalrayan and Shevaroy Hills. Sandalwood from the Mysore region of Karnataka and Marayoor forest in Kerala, Southern India is high quality. New plantations were created with international aid in Tamil Nadu for economic exploitation. Producing commercially valuable Sandalwood with high levels of fragrance oils, requires Santalum trees to be a minimum of fifteen years old (Santalum album) at which age they will harvested in Western Australia - the yield, quality and volume are still to be clearly understood. However it is believed that Australia will be the largest producer of Santalum album by 2018, the majority grown around Kununurra, Western Australia. West Australian Sandalwood is also grown in plantations in its traditional growing area east of Perth in the Wheatbelt where more than 15,000 hectares can be found in plantations. Currently WA Sandalwood is only wild harvested and can achieve upwards of $16,000 AUD per tonne which has sparked a growing illegal trade speculated to be worth $2.5 million AUD in 2012. In Hinduism, Sandalwood paste is integral to rituals and ceremonies, to mark religious utensils and to decorate the icons of the deities. Sandalwood is considered to be of the padma (lotus) group and attributed to Amitabha Buddha. Sandalwood scent is believed to transform one’s desires and maintain a person’s alertness while in meditation. Sandalwood is also one of the more popular scents used when offering incense to the Buddha. In Sufi tradition Sandalwood paste is applied on the Sufi’s grave by the disciples as a mark of devotion. Sandalwood, along with agarwood, is the most commonly used incense material by the Chinese and Japanese in worship and various ceremonies. Zoroastrians offer Sandalwood twigs to the fire keeping priests who offer the Sandalwood to the fire which keep the fire burning. Sandalwood is called sukhār in the Zoroastrian community.

Keywords: economic exploitation, hemi-parasite, mistletoe, threatened species

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The status of timber identification vis-à-vis Santalum L.

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Santalum L. is a small genus of trees or shrubs usually semi-parasitic comprising about 25 species distributed in India, East Malaysia, Australia and East Polynesia. In India only one species occurs mainly distributed in southern India and is called S. album furnishing the true Sandalwood. India although is bestowed with more than 1600 timber yielding tree species, trees like S. album (Sandalwood), Pterocarpus santalinus (red sanders) and Aquillaria agallocha (agarwood) drew the attention of international market and also smuggling outside the country by virtue of its high saleable value. Institute of Wood Science and Technology, Bangalore, Forest Research Institute, Dehradun and Kerala Forest Research Institute, Peechi involved in timber identification as a service to the public and government often received samples ranging from matchsticks to billet size for authentification including the species mentioned above. The expertise and experience in the field of wood anatomy is applied for correct identity. S. album despite being smuggled also gets adulterated by the sellers with other timber species having similarity in its external features. However, the identity of the unknown sample at the generic level can be made using wood anatomical tools and samples can be identified. In recent times there is an international free trade and marketing of other possible species of Santalum happening. In view of this the identity of the sample with reference to Santalum is gaining importance. However, review of literature has indicated lack of wood anatomical information on all the species of Santalum. There is an urgent need to create a database of wood anatomical features of the genus alongwith DNA fingerprinting of the wood samples and chemical investigation to find differences at species level, if any. Depending upon the level of enquiry the different tools required to be used for the identification of the samples need to be considered. Another problem this species shows is determination of its age. The status of its research on this aspect is also presented in this paper.

Keywords: adulteration, anatomy, identification, Santalum

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History, traditional values, uses of the Sandalwood in the current scenario and approaches to revive the lost glory of a precious paragon

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Sandalwood is the blend of economic and traditional culture from time immemorial. It not only finds its place in the modern era but has a history of 3000 years in the medicinal system of Ayurveda by Susrutha and Charaka Samhita. The oil present in the heartwood of the tree makes it a unique and valuable asset of the plant kingdom. Sandalwood is used to make artifacts and intrinsic carvings and its oil is used in manufacturing perfumes, incense sticks and in medicines. The paper deals how Sandalwood is embedded in the Indian culture.

Keywords: commercial, Indian culture, plantations, Sandalwood

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Theme – 2:
Silviculture and plantation management
Two decades of Sandalwood - research at College of Forestry, Kerala Agricultural University, Thrissur, Kerala, India

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Sandalwood (*Santalum album* L., Family: Santalaceae) is a sub-tropical evergreen tree, highly valued for its aromatic heartwood. Over-exploitation of natural populations, monopoly of Sandalwood trade by the Governments of Karnataka, Tamil Nadu and Kerala and its consequences have resulted in severe exploitation, pushing *S. album* into the vulnerable category of the IUCN Red List. College of Forestry is involved in the Sandalwood research since 24 years. Standardization of the nursery technology including the different pretreatments, irrigation schedule of seedlings and age of transplanting the seedlings to the field were done. Results indicated that treating the seeds with GA$_3$ 25 ppm and IAA 100 ppm can be recommended for better germination and production of vigorous seedlings. Irrigating once in three days was found to be the best and economical. Combination of 50% shade and red light quality and 25% shade and blue light were found to be the best with regard to rate of photosynthesis in seedlings. Research works were also concentrated on finding out suitable host plant. Out of the 15 host species tried, five Sandalwood-host combinations were identified among which the best host was *Casuarina* followed by *Terminalia, Albizia, Dalbergia* and *Pongamia*. Introduction of host species at 300 days after planting gave the best results. Preliminary studies revealed that Sandalwood had association with Arbuscular Mycorrhizal fungi and seedlings grown in soils inoculated with *Glomus mosseae* showed maximum growth. Interactions between shade and mycorrhizae were the best under 50% shade level especially for those seedlings inoculated with *Glomus mosseae* (average root colonization 68%). Crops in the homesteads may support Sandalwood establishment and growth, but the growth of agricultural crop is not affected by Sandalwood and further the fertilizer levels tried in this experiment had not caused any significant influence on the growth of Sandalwood seedlings. Sandalwood can take up elements like calcium, sulphur and phosphorus directly from soil and a small fraction of these is obtained from host. Investigations were also carried out to see the effect of host on the carbon assimilation, water and nutrient absorption, water relation in field grown Sandalwood. Host plant *Casuarina* did not influence the height and diameter of the Sandalwood tree significantly during its six years growth. Plant water potential for Sandalwood decreased significantly after the removal of host plant. The valuable information on the host parasite relations, haustorial anatomy, resource sharing, and water relations, generated from the study will be useful for farmers who wish to cultivate Sandalwood in their farm lands and for large scale plantation.

Keywords: Arbuscular Mycorrhizal fungi, casuarinas, nursery technology, Sandalwood–host combinations, seed-treatment

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A non-conventional approach to Indian Sandalwood production

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Santanol developed a host-tree free system for the sustainable production of Indian Sandalwood in the Ord Valley Western Australia using legume mulch crops and areal application of fertiliser. Although the trees are shorter than those found in a host-tree plantation system, growth is good and higher stocking rates mean more wood per hectare. The lack of shading results in early onset of oil, even in branches and opportunity for early harvest. Steam distillation has produced good quality oil from eight year old trees. Tree improvement was integrated into this system and is focused on clonal development through tissue culture. The first generation field planted clones are now four years old, growth and form improvements are significant as are oil yields and potential for rotation reduction. With the recent acquisition of the Elders Sandalwood estate, Santanol has about 2,000 ha of Sandalwood, with around 12,000 tonnes of wood. Santanol has commenced harvesting and anticipates production of 500 tonnes of Sandalwood in 2014. This wood will be used for carving logs, oil production and the agarbatti market.

**Keywords:** clones, Indian Sandalwood, Santanol

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Sandalwood plantations in agro-forestry systems: different growth models with host species

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Sandalwood and Sandalwood oil industry is one of the oldest in world of perfumes. Since the oil can blend well with most of the natural essential oil, it is in more demand in perfumery industries. New Sandalwood based industries have evolved after 1990 using more and more natural Sandalwood oil. As a result there is over exploitation of the species in the world, consequently the production is on the decline. Sandalwood is naturally found in the forest and due to over exploitation there is no sustainable supply to the industries and the price of wood and oil is fluctuating. Afforestation programmes have suffered from technological weakness, which has limited the productivity and impact of these efforts are clearly visible. On account of this our forests are unable to meet the demand. There is a need of quality planting material, appropriate models and modalities of management techniques and primarily lack of private participation. Sandalwood trees has been successfully grown as commercial crop in different countries including India and the harvesting period has been reduced significantly compared to the wildly grown trees. The fragrant heartwood and oil obtained in 15 years has all the qualities of a well grown tree and it can be commercially harvested. Agro forestry systems with appropriate commercially important trees with Sandalwood offer promising options. These models are not only commercially viable but has an impact on the microclimate changes of the region, influencing radiation flux, air temperature, wind speed, saturation deficit of under story crops. Different growth models for Sandalwood have been discussed with host species, benefiting large to medium farmers and corporate bodies. These models are sustainable and will reduce the management costs and provide periodic additional revenue before the final harvest without risks. The agro forestry systems can be taken as a challenging programme to save other Santalum species in the world.

Keywords: agroforestry, host plants, plantations, Sandalwood

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Sandalwood (Santalum album L.): its adaptability with different host species in varied edaphic condition of South-West Bengal

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Sandalwood is the fragrant heartwood of some species of genus Santalum. The widely distributed and economically important Santalum genus (Family: Santalaceae) which include 30 genera with about 400 species, many of which being completely or partially parasitic. The hemi-parasitic nature of Sandalwood was first reported by Scott in 1871. Ecologically, Sandalwood has adapted various agro-climatic and soil conditions for in situ regeneration with an exception of waterlogged areas and very cold places. Congenial environmental factors are the prime need for producing any healthy, high productive crop plant. Till date, there is a great problem of seed germination and adaptability for growing Sandalwood in different soil conditions prevailing wide range of agro-climates. In case of Sandalwood, the basic problem in seed germination is due to seed dormancy. Another prime problem is raising healthy seedlings in nursery and subsequent adaptation in field due to its parasitic nature. Sandalwood can be a parasite on a wide variety of plants found in nature from grasses to trees. But Sandalwood shows different growth pattern with different host species. Practically, few studies were conducted in field conditions by means of artificial processes. Experiments were conducted both in nursery and field after transplantation of saplings with different host plants. Growth parameters like survival, collar girth and plant height were measured while grown with arhar (Cajanus cajan L.), tulsi (Ocimum sanctum), akand (Calotropis procera L.), nayantara (Catheranthus roseus) as host and also in combination of hosts like arhar and tulsi, arhar and nayantara, tulsi and nayantara etc. Though, it has been observed that Sandalwood can survive in some fields without having any host plant association. The later observations have also been focused in this present submission. Lot of peculiarities and new findings are discussed in this context. The aims and objects of this study were to find out the integrated approach of seed germination, its growth in nursery and assessment of survivability of Sandalwood in field with different hosts plants in different soil environments of South-West Bengal.

Key words: artificial processes, congenial, edaphic factors, parasitic, survivability

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Responses in nutrition status of Sandalwood (Santalum album L.) seedlings to shade, host and mycorrhizal association

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Sandalwood (Santalum album L.) is a prized gift of the plant kingdom woven into the culture and heritage of India. The production of Sandalwood in India has been decreasing at an annual rate of 20 percent since 1995 owing to various reasons such as Sandalwood spike disease, illicit felling and failures in regeneration efforts (mainly due to the semi-parasitic nature of the species as well as the failures in the standardization of the silvicultural techniques). The prevailing demand and supply gap could be met to a large extent by promotion of the extension of Sandalwood growth outside the conventional area of growth in forest areas. Though Sandalwood is a difficult species to establish, the studies on the other species showed that Arbuscular Mycorrhizal Fungi (AMF) association has an important role in the growth and establishment. In Sandalwood as well, the preliminary reports suggest the presence of AMF associations. The investigations on this direction revealed that the growth of Sandalwood seedlings inoculated with Glomus spp. performed better than the non inoculated sandal seedlings. In these premises, an experiment was conducted to investigate the influence of shade, host and AMF on nutrient absorption of sandal seedlings. The results showed that the nutrient status of the sandal seedlings inoculated with AMF was higher compared to the non inoculated seedlings. Glomus mosseae was found most effective in improving the nutrient contents of the sandal saplings, compared to other species of AMF. It was also seen that the colonization of the roots was higher for the seedlings inoculated with Glomus mosseae (average root colonization of 68 percent). The shade levels were also found to have significant effect on the nutrient status of the seedlings. However, the host species did not show any significant influence on the growth of Sandalwood seedlings but there existed higher level of interactions between shade and mycorrhizae. The result of the study shows that Sandalwood-AMF association has led to the improved growth of sandal seedlings, which adds to the knowledge support in extension of the Sandalwood cultivation/growth out side the naturally growing areas.

Keywords: host, nutrient absorption, Sandalwood, vesicular arbuscular mycorrhizae

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The high demand and remunerative prices of Sandalwood (Santalum album L.) have motivated private individuals to take up Sandalwood cultivation in a big way. Farmers have shown a distinct preference for horticulture species rather than conventional forest species as long term secondary host with the objective of getting intermediary returns during the long gestation period of Sandalwood. However data on the performance of Sandalwood under managed conditions in agroforestry systems are lacking. On-farm demonstration trials were established in three sites in Karnataka viz. Muddenhalli, Chickaballapur district Bevanahalli, Doddaballapur district and Koppa, Chickmagalur district using Quality Planting Material (QPM) of Sandalwood raised with Cajanus cajan as primary host in IWST, nursery in 2007-08 under a National Medicinal Plant Board funded project. The hosts were planted in the centre between four Sandalwood trees maintaining a spacing of 6x3 m for both Sandalwood and secondary host. The hosts planted in Muddenhalli was grafted amla (Emblica officianalis), while it was grafted mango (Mangifera indica variety Mallika) in Bevenahalli and coffee (Coffea arabica) in Koppa. The first two sites were under semi-arid conditions with <700 mm annual rainfall while Koppa was under tropical humid conditions with annual rainfall slightly in excess of 2000mm. After six years, the best growth of Sandalwood was recorded in Bevanahalli under intensively managed conditions and the least was in Muddenhalli under slightly less intensively managed conditions. The maximum collar girth recorded in Bevanahalli was 44.4 cm (height 4.4m) whereas the maximum collar girth recorded in Muddenhalli was 58.2 cm (height 5.67 m) and in Koppa 37cm collar girth (height 4.5 m). Core samples taken from these higher girth class trees revealed initiation of heartwood while core samples taken from the other lower girth class trees did not reveal heartwood initiation. The studies also reveal that under managed conditions in agroforestry, it is possible to attain mean annual increment in excess of 4 cm in a year.

Keywords: agroforestry models, horticulture crops, Sandalwood

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Combined function of Arbuscular Mycorrhizal fungi and haustoria in growth of Sandalwood plants

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Sandalwood plants (*Santalum album* Linn.) are a hemi root parasite and can be a parasite on over 300 species of plants found in nature from grasses to another Sandalwood plant. But, some host plants support good growth of Sandalwood plant and some do not. In addition to its parasitic habit, it can also have symbiotic association with endomycorrhizal fungi and gets additional nutrients which helps further to boost the plant growth. Mycorrhizal fungi populate the area around a plant’s roots and form very thin filaments, adding to the length and efficiency of a plant’s roots. This is like having a second set of roots for the plants and these fungi have a vast host range and enable the presence of Arbuscular Mycorrhiza (AM) species in a wide variety of ecological conditions. A detailed survey to observe the symbiotic relationship with Sandalwood plants with that of AM fungi revealed that plants growing in different places showed diverse AM species association. It was also observed that the intensity of colonization was higher in Sandalwood roots than the host. AM colonization and spore number in the rhizosphere of Sandalwood plants varied with area and season. Good growth of Sandalwood plant not only depends on the good haustorial connection with the particular host plant but also with the AM fungi association.

**Key words:** AM fungi, biofertiliser, diversity, parasitism, *Santalum album*

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The effect of long term hosts species on *Santalum album* L. growth under agroforestry in semi arid condition of North Gujarat, India

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Six-years-old *Santalum album* L. trees cultivated on a farm land in association of *Citrus aurantium*, *Punica granatum* and *Casuarina equisetifolia* trees in semi arid region of North Gujarat, India were studied for their relation with host species in terms of growth and heartwood formation. Height, collar diameter, crown size and clear bole and survival of *S. album* trees were greater with *C. aurantium* as compared to the other two hosts. This was followed by association with *Casuarina equisetifolia* trees for overall growth. Heartwood formation in *S. album* was observed in >10 cm DBH, irrespective of host association. A lesser relationship between height and diameter of *S. album* trees was observed, in which $R^2$ was relatively higher for *S. album* trees grown with *C. aurantium* as compared to the other two hosts. Conclusively, *C. aurantium* was found to be the best host for growth of *S. album* and may be replicated for greater benefits to the farmers.

**Key words:** growth, heartwood, host, Sandalwood, semi arid region

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Seed germination studies in Sandalwood (Santalum album L.): problems and solution

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Santalum album L., Indian Sandalwood, is one of the commercial important tree species of India. Globally, Indian Sandalwood is recognized well for its fragrant heartwood. Oil extracted from the heartwood produces sweet fragrance, persistent aroma and has fixative property. Therefore, there is a huge demand for both wood and oil in domestic as well as international market. Several researchers pointed out the problems of seed germination and its storage in Sandalwood. The present study was carried out in the College of Forestry, DBSKKV, Dapoli to understand the problems of seed germination and solution to improve it. Seed lots were collected from the campus of Forest Training Institute, Gungaragatti, Dharwad, Karnataka. Various experiments were conducted on seed germination. In the first experiment, 16 different seed sowing treatments were imposed. Overnight soaking of seeds in GA₃ solution @ 300 ppm (68%) and @ 500 ppm (63%) resulted in better germination over control (38%). Further, seeds collected from 10 different trees were tested for germination. Result showed significant variation in germination among different trees and it varied from 58 to 82%. Germination of bird dispersed seeds was compared with depulped seeds and whole fruits. Results showed that bird dispersed seeds achieved highest seed germination within short time as compared to depulped seeds. However, matured fruits sown on nursery bed resulted in low germination of 18% within 45 days from the sowing. Seeds were collected from two trees at two different seasons and tested for germination. The depulped seeds were soaked overnight in GA₃ solution @ 300 ppm. Seeds collected during May-June (sown in June under mist chamber), had maximum seed germination of 52% and 67% as compared to seeds collected during second season December-January (sown in January month had 42% and 53% germination. Overall result indicated that seed germination in Sandalwood is affected by several factors like genotype, dormancy, phenology and others. To improve germination, overnight soaking of seeds in GA₃ solution @ 300 ppm may be used.

Keywords: bird dispersal, germination, pre-sowing treatment, Sandalwood

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Anatomy and functional status of haustoria in field grown Sandalwood tree

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To study the anatomy and functional status of Sandalwood tree haustoria, two treatments of six year old trees growing with *Casuarina* and without host were investigated. Sandalwood tree was observed to form haustoria with host *Casuarina* and the wild grass grown around it. Sandalwood tree planted without host formed haustoria with the roots of nearby trees. However, maximum numbers of haustoria were observed in the Sandalwood tree growing with host in the same pit. Anatomical studies of haustoria with host *Casuarina* reveals that vascular connections between the host and the Sandalwood tree became so close that the host and the parasitic root became almost a single physiological unit catering to the nutritional requirement of Sandalwood tree. Further, our investigations revealed that direct lumen-lumen xylem connections between the xylem of the host and the parasite were absent. Functional status of Sandalwood-haustoria was also studied by observing the translocation of radio-labelled phosphorus ($^{32}$P) from host to Sandalwood tree by labeling of hosts and wild grass with $^{32}$P and tracing it in Sandalwood tree. After 2 hours and 4 hours of labeling *Casuarina* with $^{32}$P, no notable counts were observed. Higher counts of translocated $^{32}$P were observed in Sandalwood tree after 6 hours of labeling the host plant. There were marginal increase in $^{32}$P count in Sandalwood tree with time and this increase continued to eight days and subsequently observed a reduction up to 16 days, indicating the decay of already translocated $^{32}$P after eighth day. $^{32}$P count also observed in Sandalwood tree when wild grass was inoculated with $^{32}$P. Translocations from the host plants other than *Casuarina* planted in the same pit were also investigated and its translocation varied with host species. The translocations from cocoa to Sandalwood tree and *Casuarina* to Sandalwood tree were the most efficient. The possible reverse translocation from Sandalwood tree to host plant was also observed when $^{32}$P applied to Sandalwood tree. The results from the radio tracer studies indicated that Sandalwood tree forms a network of roots, connected through haustoria, between Sandalwood tree and different hosts including the grass species growing around it. The implication of these results suggest that the host plants need not be present in the same pit of Sandalwood tree as it can extend its root to distance of 1.5 to 3 m to form haustoria on neighbouring plants.

**Key words:** haustoria, host, radio-labeled phosphorus, Sandalwood tree

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Distribution, growth and yield, and demand and supply of *Santalum album*: survey and review

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*Santalum album*, a native tree species to India, is world famous for its fragrant heartwood and oil. The species has been overexploited in many parts of their natural distribution. Reliable information about its distribution, growth and availability is wanting since the first sandalwood population survey of the country regarding population density, tree size, and the extent of heartwood was carried out long back and recently the population of the species is dwindled due to heavy abiotic interference. This article summarizes, in brief, about the distribution, growth and yield, trade and demand and supply of Sandalwood based on information compiled from the available literature. The growth data collected from the natural regeneration and young plantations in Bangalore (urban) forest division is also presented.

**Keywords:** distribution, edaphic and climatic conditions, growth and yield, Sandalwood, trade

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Stomatal regulation - a growth attribute for transpiration and gas exchange in Sandalwood (*Santalum album* L.) – vital process in plant metabolism

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Transpiration is basically the physical processes of evaporation which is controlled by physical factors. Transpiration is also a physiological process, and as such it is affected by plant factors such as leaf structure, exposure and the behaviour of stomata. It usually occurs in two stages, evaporation of water from the cell walls, into the intercellular spaces, and the diffusion of water vapor into the outside air. A field study was conducted in Sirsi during winter 2013 to know the stomata movements which regulate the amount of water loss from the transpiration alone. The observations were recorded at three times with interval of four hours. At the same time stomata studies were also recorded in both upper and lower surface of leaves. The results indicated that highest number of stomata were 47, 51, and 48 recorded in 9.00 am, 1.00 pm and 5.00 pm respectively in lower surface while no stomata were noticed on upper surface. Maximum numbers of opened stomata were 45, 41, and 30 were recorded in morning 9.00 am, 1.00 pm and 5.00 pm respectively. Maximum numbers of closed stomata were 2, 10, and 18 recorded at 9.00 am, 1.00 pm and 5.00 pm respectively. Shape of the leaf, colour, and orientation were oblong with pointed tip, light to dark green, and acute angle to the main stem. The amount of water lost was highest in the morning and least in the evening. Maximum transpiration was in early morning, gradually decreases in the mid day and transpiration was minimum in the evening. The Sandalwood tree growth is very slow in almost all ecological systems with minor growth differences. It was concluded that the transpiration is a vital physiological processes that eventually control the plant growth.

**Keywords:** plant growth, stomata, transpiration, Sandalwood

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Effect of quality and quantity of radiation on growth of Sandalwood (*Santalum album* L.) seedlings

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A study was conducted at College of Forestry, Kerala Agricultural University, Thrissur, Kerala (10°31′N and 76°13′E, 22.25) to understand the effect of light on the growth and development of Sandalwood seedlings. Two month old seedlings of uniform growth were used for the study. For measuring the effect of different light qualities and quantities on the growth, the seedlings were grown in polythene bags under combination of various shade levels and filters for a period of seven months without any hosts. The required shade levels and light quality were created by putting different layers of nylon shade nets and plastic colour film. It was observed that both quantity and quality of light had significant influence on height, relative growth rate, photosynthetic rate and chlorophyll content of sandal seedlings. At the end of seven months, seedlings grown under 75% shade, exposed to green light had recorded the maximum height (8.78cm) followed by blue (7.52cm) and red (7.29cm) lights. In the case of collar diameter plants grown under 50 per cent shade and green light (2.21mm) showed best performance. Photosynthetic rate of seedlings did not differ significantly under different shade levels, but it was highest under red and green light conditions with mean values of 25.18 µmol/m²/s and 23.92 µmol/m²/s respectively. In the case of RGR, seedlings under 50 and 75 per cent shade levels (respective mean values being 0.340 mg/month and 0.334 mg/month) recorded maximum values. It was also noticed that quality of light had no significant effect on the RGR of dry weight of shoot. Results of this study are in contrast to the most accepted conviction that green light is inefficient for photosynthesis in green leaves. This may be due to the fact that, red light is more effective than green light in white light at low PPFDs, but as PPFD increases, light energy absorbed by the uppermost chloroplasts tends to be dissipated as heat, while penetrating green light increases photo synthesis by exciting chloroplasts located deep in the mesophyll.

**Keywords:** growth, light quality, Sandalwood nursery, shade

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Effect of soil type on the growth and survival of seedling of Indian Sandalwood (Santalum album L.)

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Studies were carried out to find the effects of soil type on the growth of Indian Sandalwood (Santalum album L.), a hemi root parasite. Two types of soil - Red and Yellow were used as potting medium ingredient consisting of sand, soil and compost. Cajanus cajan was used as a primary host. Survival and overall growth of six months old seedlings for height, collar diameter and survival rate were similar in potting medium having Red and Yellow soil type. Seedlings with > 17 cm high, > 2.5 mm collar diameter and > 95% survival rate can be obtained in six months in 800 ml polythene bags using red or yellow soil as potting medium ingredient.

Keywords: Cajanus cajan, hemi root parasite, potting medium ingredient

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Phenological variation and natural regeneration in *Santalum album* Linn.: implication for management

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Study pertaining to phenology and natural regeneration of Sandalwood (*Santalum album*) was carried out in the campus of Forest Training Institute, Gungaragatti, Dharwad, Karnataka. Totally 15 trees of different ages were selected and marked in the campus for phenological observation. At every fortnight, these were monitored for flowering and fruiting behaviour. Result showed tree to tree variation in flowering, fruiting time and intensity. Most of the trees showed peak flowering twice in a year and it was found that July-August being the first peak followed by December to January as the second peak season. Interestingly, only one tree showed peak flowering during September to October. Further, three more individuals flowered during February to March. However, fruit collection in large quantity can be made during May to June as well as during October to November. Result clearly shows that phenological study is very important before initiation of any breeding work in the Sandalwood. Further, this information may also be important while selection of clones for establishment of seed orchards, where clones having synchrony in flowering can be grouped together to obtain genetic quality seeds in large quantity. In another experiment, regeneration of Sandalwood was assessed under different plantations/ecosystems like Bamboo, Eucalyptus, Acacia, medicinal plants garden and Natural forest of the campus, where several bird species are involved in dispersal of seeds. Regeneration count was made by adopting three regeneration classes according to height of wildings. Result showed that the overall regeneration was highest in medicinal plant garden, followed by natural forest and bamboo plantation. Further, 70% of wildlings represented in first regeneration class (< 1m height), followed by second (1- 2 m height) representing 26.0%. However, only about 4% of wildlings were in the third regeneration class (> 2 m height). The study indicated that habitat, branching habit, density of trees, distance from Sandalwood trees, etc. may highly influence the regeneration. Being a semi-parasitic, establishment and growth of regenerated seedlings of Sandalwood may depend on host plant and surrounding environment.

**Key words:** flowering phenology, natural regeneration, *Santalum album*

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Variation in seedling emergence time and its contribution to seedling morphology and early establishment in provenances of *Santalum album* L.

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Differences in seedling weight were partly due to differences in seed weight and partly to differences in earliness of emergence. Though the genetic variation for initial status is very small, such small initial differences between genotypes have strong influence on their final biomass. Hence germination pattern and seedling weight in *Santalum album* from 12 provenances was studied. Time taken for first emergence of plumule has been recorded for all seedlots. After completion of germination, collar diameter, root length, shoot length, number of leaves and total height were recorded for each seedlot. Inventory of data revealed significant variation in all seedling traits suggesting influence of genetic factors in seedling establishment traits. Time taken for first emergence varies from a minimum of 18 days (Yadehally) to a maximum of 39.5 days (Rama Nagara) indicating existence of seed polymorphism in Sandal. Kruskal-Wallis One-way ANOVA indicated that time taken for emergence has greater influence on all seedling traits (p = <0.001). Further, all pairwise multiple comparisons through Student- Newman-Keuls method suggested significant differences among the seedling traits. Root length is strongly positively correlated with time of emergence (r = 0.83; p = <1%) where as shoot length (r = -0.77; p = < 1%) and total height (r = -0.63; p = <1%) were negatively correlated indicating that longer the time for germination, seedling establishment will be better in forest floor. Root length is strongly but negatively correlated with shoot length and total height suggesting that root establishment is most important determining factor in seedling establishment in forest floor. Shoot length is highly positively correlated with total height (r = 0.9; p = 1%) suggesting that once seedlings are established comfortably, growth will resume irrespective of the time taken for emergence. Seedlings from 110-140, 141-160 and 161-180 mg weight ranges suggested a good amount of variation in fresh weight and dry weight. Two-tailed Student’s t-test is significant, suggesting that Sandalwood produce polymorphic seeds to overcome evils of environment while establishing in the forest floor (t = 0.96; 0.78 and 0.8; p = 0.4% level for each group). The differential seedling morphology facilitate establishment of seedlings in the forest for a greater extent.

**Keywords:** provenances, root establishment, root length, shoot length

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Domestication of Sandalwood in non-traditional areas – problems and prospects

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Santalum album Linn. is reported to occur naturally in the peninsular India states of Karnataka, Tamil Nadu and Kerala. Since liberalization of rules governing Sandalwood growing in 2001, there has been a lot of demand for growing this bio-resource outside its traditional areas especially in northern, central and western India. Although isolated populations of Sandalwood has been reported to exist in Udaipur (Rajasthan), Jwalajee in Kangra district (H.P.), Katni, Seoni, Mandsour, Jabalpur (M.P.) and Mehsana (Gujarat), there is lot of skepticism on Sandalwood growth and performance in non-traditional areas especially in Indo Gangetic belt under cultivated landscapes. Under a Punjab Forest Department sponsored project to promote Sandalwood cultivation in the state demonstration plots of Sandalwood in one hectare were raised in Ropar (Undulating Plain Region), Ludhiana (Central Plain Region), Mohali and Talwara, Hoshiarpur Districts (Sub-Mountain Undulating Region) virtually covering three agroclimatic zones out of five in Punjab. Around 4000 quality planting material (QPM) of Sandalwood seedlings raised in Nagrur nursery of IWST, Bangalore were transported to Punjab in July 2013 and planted in each site at spacing 6X3 m in September 2013 with primary host red gram (Cajanus cajan) and Aonla (Emblica officinalis) as secondary host. Survival as observed in December 2013 ranged from 70% in Talwara to 40% in Ludhiana, followed by 60% in Mohali and more than 90% in Ropar. The cause of casualty observed was primarily due to damage caused by Indian hare (Lepus nigricollis). The greatest threat to seedling survival in the Indo-gangetic plain has been due to frost in winter. To minimize frost damage, seedlings were covered with transparent polybags as control measure. The plots were also protected with chain-link fencing to prevent stray grazing.

Presence of several old Sandalwood trees with good heart wood formation in an ancient temple complex in Sansarpur terrace located near Punjab-Himachal Pradesh border near Talwara, Hoshiarpur is additional cause for encouragement to prospective Sandalwood growers in Punjab. Isolated trees have also been reported from Bhatinda (Western Region) and Punjab Agricultural University Ludhiana campus also lending credibility to Sandalwood cultivation in Punjab. These observations may be indicators of success in supporting the hypothesis that Sandalwood can not only grow in Punjab but will also yield heartwood, provided QPM from assured known sources are used.

**Keywords:** heartwood formation, Punjab state non-traditional areas, Sandalwood

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Effectiveness of plant growth enhancers in production of quality planting material Sandalwood seedlings in nursery

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The relaxation of rules for cultivation of Santalum album L. has led to increase in demand of Quality Planting Material (QPM) for raising plantations throughout India. IWST has standardized a cost effective package of practice for raising QPM stock of Sandalwood seedlings. The Sandalwood nurseries are generally raised in December/January after collection of mature seeds in October/November and maintained in 270cc root trainers with a primary host (Cajanus cajan) for a six month period. Besides standard plant protection measures, micronutrients and NPK are sprayed at a fortnightly intervals to enhance the growth as part of the standardized technology package.

A trial was conducted in IWST nursery in 2012-13 to test the efficiency of commercially available growth enhancers with the standard technology for QPM production. Three root trainer blocks with twelve plants in each block of 300 cc was considered as a replicate and three replications per treatment with 36 plants per replicate for each treatment were maintained during the 6 month observation period. Five commercially available growth enhancers viz. Sun Beam growth enhancer (1500 ppm), BCX Humic rooting solution (1500 ppm), BCX Foliar spray (1500 ppm), BCX Total solution (1500 ppm) and Multiplex (2500 ppm) were compared with the IWST recommended treatment (Multiplex + NPK solution) including control (water). Foliar spray of treatments was done at fortnightly intervals over a six month period for the plants maintained in IWST nursery at Nagrur. Observations on collar diameter and shoot length at fortnightly intervals were recorded. After six months, the plants were taken out from the root trainers and fresh weight of shoot and root recorded treatment wise. The dry weight was also recorded after separating the above ground and below ground portions and drying to constant weight at 80±5°C. Significant variation in collar diameter and root dry weight between the treatments was recorded. The root to shoot ratio recorded was highest for the standard IWST recommended treatment (Multiplex + NPK). The overall results indicate that Multiplex or its combination has a significant impact on quality of Sandalwood seedlings produced in nursery which in turn may have some practical implications to nurserymen.

Keywords: plant growth enhancers, quality planting stock, root shoot ratio, Sandalwood nursery

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Field performance of tissue culture raised Sandalwood plants as agroforestry models

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Agroforestry is the production of trees and non-tree crops on the same piece of land. The crops can be grown together at the same time, can be grown in rotation, or can even be grown in separately when materials from one are used to benefit another. Sandalwood (Santalum album L.) belongs to family Santalaceae, an economically important aromatic tree, commonly known as Sandalwood (Srigandha or Chandan) is a semi root parasite, medium growing tree. Illicit felling for its prized heartwood and cyclic spike together have drastically reduced the tree population. Regeneration by silvicultural methods being insufficient to meet the demand, biotechnological tools of propagation has been tried. Tissue culture through axillary proliferation and somatic embryogenesis offers highest clonal propagation efficiency. Tissue culture raised sandalwood plants were integrated with mango and pomegranate, the horticultural species. Sandalwood saplings were planted along with pomegranate at a spacement of 15x15 feet and pit size of 2x2 feet. Each plant was given 5kgs of FYM, 100g of single super phosphate, 25g of dithane-M-45. Water facility was made available through drip irrigation. A mortality of 5% was observed. This mortality was replaced within 2 months period. Ekalux (0.25%) and bavestin (0.25%) spray was given fortnightly. Fertilization and soil working was done. FYM at the rate of 4kgs/plant was applied from second year onwards. In the 1st year, the vigorous uniform growth was observed. The average growth was 6.67 feet with healthy and uniform crown. The average collar girth was observed 10.33cm. Fortnightly each plant was given 1 kg of de-oiled neem cake and fertigation. No diseases was observed 1st year. During the second year the average growth was 12.87 feet with collar girth of 21.55cm. It was observed that, during the third year the plants were growing vigorously. Insecticide and fungicide spray was given as and when the mango and pomegranate was given. The growth of pomegranate was stunted but growth of mango was not disturbed. During 4th year, it was observed that the average height was 18.55feet with average collar girth 34.67 cm

Keywords: agroforestry, fertigation, Sandalwood, tissue culture

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Theme – 3:
Tree improvement and conservation
Application of traditional and biotechnological methods of propagation, improvement and conservation of Sandalwood (Santalum album L.) – an over view

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Indian Sandalwood is highly prized in international markets due to its high oil content (upto 6%) and α and β santalol (90%). There is a gap between demand and supply of Sandalwood and oil in domestic and international markets. In past, attempts were made for the propagation, improvement and conservation of Sandalwood employing traditional and non-traditional methods. After liberalization of polices for Sandalwood cultivation, farmers and Sandalwood based industries have taken interest in its cultivation and as a result, demand of quality seedlings has increased. This paper deals with an over view on the traditional and biotechnological methods of propagation, improvement and conservation of Sandalwood. Modern nursery practices were developed for the production of quality planting material using seeds from known and superior sources, using root trainers (270 cc black type) and poly bags of (600 cc) and Mimosa pudica as a primary host. Vegetative propagation by root suckers was successful by treating the root suckers with 1000-2500 ppm IBA for 30 min, followed by planting cuttings in sand bed medium in mist chamber at 30 ± 5°C temperature and 80±5% relative humidity (RH) and rooting was observed in 45 days period. Root suckers method has limitation of small scale production potential, which can be overcome by the biotechnological methods. In vitro cloning was achieved through i) axillary shoot proliferation ii) somatic embryogenesis and iii) direct adventitious shoot regeneration. Ex vitro rooting of in vitro shoots was also successful by the pulse treatment of shoots with the IBA. Hardening of plants was found essential for 10-15 weeks in green house condition in soil rite medium. Plants raised through above modes of regeneration had genetic stability based on DNA markers. In vitro shoots of five clones of S. album were maintained under in vitro conditions on low nutrient, sugar and hormone containing medium up to six months without sub culturing on the fresh medium for ex situ conservation. In vitro cultures were maintained for 5 years by subculturing on fresh medium. Traditional and biotechnological methods developed will be useful for the production of quality planting material of S. album for planting programmes.

Keywords: biotechnological methods, conservation, improvement, Santalum album

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Heartwood and oil content variation in *Santalum album* – implications in tree improvement

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Documenting variability is a pre-requisite for initiating any tree improvement programme. Generally, the traits targeted for improvement in non timber forest species are mostly those having commercial importance. Sandalwood (*Santalum album L.*) is valued for two important traits, heartwood and the essential oil obtained from the wood. Both these are considered to be highly prized among non timber forest produce in India. Numerous studies have reported considerable variation in heartwood and oil content. However, in most of the cases two important variable factors, age and growing conditions have not been particularly considered though they significantly affect heartwood and oil content. To have a better understanding about the inherent variability in heartwood and oil, a study was conducted in a clonal germplasm bank of different accessions having uniform aged trees and growing in identical conditions. From the core samples collected, significant variability was observed for heartwood and oil content among the different accessions. The heartwood radial length ranged from 0 to 3.77 cm and the oil content varied from 0 to 2.42%. We discuss the implications of this information from tree improvement perspective.

**Keywords:** heartwood, oil, *Santalum album*, tree improvement, variation

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Genetic improvement of Sandalwood (*Santalum album*): identification and rapid multiplication of elite clones

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In the Indian Sandalwood (*Santalum album*), the most important commercial trait is Sandalwood oil and its biosynthesis is still not sufficiently understood in terms of genetics and molecular biochemistry. Preliminary research suggests that the Sandalwood oil biosynthesis is a highly regulated sesquiterpenoid pathway. Systematic research efforts on the Indian *S. album* germplasm with respect to Sandalwood oil biology are lacking. Modern plant biotechnology offers powerful tools such as genomics and metabolomics to not only develop knowledge about heartwood Sandalwood oil biosynthesis in the Indian *S. album* accessions but also undertake intensive improvement programs in terms of precise identification of superior and elite clones and rapid micropropagation. Candidate genes of the oil trait can be identified and used to establish gene-trait associations in terms of genotypic variability, oil variability and differential gene expression *in vivo* through metabolomic analysis. Using these, the germplasm and selected genotypes can be re-evaluated by recruitment of additional genetic determinants. In this paper, methods have been discussed for identification and rapid multiplication of high yielding Sandalwood clone thereby develop a knowledge database on the molecular genetics and metabolomics of Sandalwood oil biosynthesis, also establish its applicability in the identification of superior and elite clones for possible commercialization.

**Keywords:** elite clones, micropropagation, *S. album*, oil biosynthesis

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Heartwood formation is one of the significant ecological secondary differentiation processes. The programmed cell death (PCD) of parenchyma cells during heartwood formation shares some similarities with PCD during xylem formation. It is the end result of changes in the living cells of the sapwood connected with their aging and it is an analogous developmental process of a tree compared to other developmental processes. From a natural population, 38 Sandalwood trees were selected and heartwood diameter was estimated from each tree using core samples obtained through increment borer. From these, oil content, volume of heartwood as full fulcrum excluding branch wood, weight of heartwood as volume × 930 and K-factor from heartwood weight × oil percentage were estimated. All these variables exhibited higher variability in the population indicating influence of genetic factors over them. Null hypothesis suggested that development of heartwood in Sandalwood is highly variable and independent of oil formation. Student’s $t$-test revealed that heartwood diameter significantly differed with volume of heartwood, K-factor and oil content ($t = 2.55$, $t = 5.67$ and $t = 8.5$ respectively). Similarly, weight of heartwood significantly differed from K-factor, oil percent and heartwood percent ($t = 2.25$, $t = 3.38$ and $t = 8.5$ respectively). Weight of heartwood significantly differed from K-factor ($t = 4.06$) and oil-percent ($t = 2.9$) where as K-factor was significantly different from oil-percent ($t = 2.96$). Spearman’s correlation studies indicated strong positive correlation among heartwood and its variables and oil percent ($p = < 0.01$). However, oil content was positively correlated with only K-factor ($r = 0.51; p= < 0.01$) suggesting that heartwood content was directly responsible for oil percent. Strong correlation of heartwood and its variables were important for plantation management since most of the variation in heartwood is associated with plantation location rather than seed sources and such variation can be exploited through selecting desired individuals. Heartwood was highly correlated with oil percent suggesting correlated growth traits which facilitate simultaneous improvement of heartwood and oil percent by selecting trees with high heartwood. Tree no. 2 (400.02 – Heartwood weight × oil percent in kg), Tree no. 6 (360.5), tree no. 18 (496.84), Tree no. 25 (405.57) and Tree no. 21 (315.2) have maximum heartwood and oil percent may be selected and can be deployed for further improvement through clonal forestry. From breeding perspective, much emphasis must be given to select genotypes with good heartwood since the heartwood is the carrying agent of oil, hence both the traits can be improved simultaneously.

**Keywords:** heartwood formation, oil formation, selection, *Santalum album*

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In vitro regeneration of Sandalwood (Santalum album L.) plants through somatic embryogenesis

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Santalum album L. belongs to family Santalaceae, commonly known as Sandalwood (Srigandha or Chandan) is a hemi root parasite, medium growing tree. Among the genus Santalum, S. album (Indian Sandalwood) consist highest (up to 6%) oil and α and β santalols (about 90%). Indian Sandalwood is highly priced due to its fragrance, heart wood oil used in world class perfumes, aromatherapy, various pharmaceutical preparations and cosmetics. Sandalwood is also being used for carving only next to ivory. Sandalwood demand is 10-15,000 tonnes of heartwood and more than 100 tonnes of its oil in the international markets. Sandalwood is an out breeding species, possess variability in heartwood and oil contents, seed based progenies are not true to type plants. Vegetative propagation through cuttings is not successful whereas grafting and root suckers can be used only for small scale production. Tissue culture based biotechnological tools have potential of large scale production. Basic protocols have been developed for in vitro cloning of Sandalwood through axillary shoot proliferation and somatic embryogenesis, which require scale up for rapid and mass clonal propagation of quality planting material. A protocol for somatic embryogenesis and plantlet formation of Sandalwood has been developed. Among the various explants used viz., nodal segments, internodes and leaves, maximum quantity of callus was obtained from leaves in MS medium supplemented with 2, 4-D 2.0 mg/l with additives (Ascorbic acid 50 mg/l+citric acid 25.0 mg/l+cysteine25.0 mg/l+glutamine100 mg/l). Further multiplication of callus was carried out in the same medium. High frequency of somatic embryos was induced in Woody Plant (WP) medium fortified with IAA 1.0 mg/l + BAP 1.0 mg/l. Embryo maturation was more in WP liquid medium fortified with PEG 3.75%, ABA 1.0 mg/l Maximum embryo germination was observed in WP medium fortified with IAA1.0 mg/l and GA₃ 1.5 mg/l. Forty five days after germination plants were shifted to mist chamber for hardening. Rooted plants were directly transferred to sieved sand for primary hardening, later on plants were shifted to potting mixture (Sand: Soil: Compost in the ratio of 6:1:3) with Mimosa pudica or Cajanus cajan as host. Plantable plants were obtained after 8 months.

Keywords: in vitro, MS medium, Santalum album, somatic embryogenesis, woody plant medium

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In vitro regeneration of *Santalum album* L. from the explants of aseptically raised seedlings

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*Santalum album* L. family Santalaceae, commonly known as Sandalwood or *Chandan* is a hemi root parasite tree species. Indian Sandalwood has the highest oil content (4-6%). It is highly valued for its fragrant heartwood consisting oil which is in high demand for perfumes, cosmetics and aromatherapy. Sandalwood is over exploited due to its high prized heartwood and oil and it is a threatened species in its natural habitat. There is a need for improvement and conservation of *S. album*. This paper deals with high efficiency multiple shoot regeneration, multiplication and rooting for raising *in vitro* raised Sandalwood plants. Hypocotyl as an explant showed superiority over cotyledonary leaf and internodal segment. Maximum number of shoots (average 83.21 shoots per explants) regeneration was obtained from hypocotyl explants on MS medium supplemented with NAA 0.1 mg/l + BAP 2.5 mg/l and additives; ascorbic acid (50 mg/l) + citric acid (25 mg/l) + cysteine (25 mg/l). Regenerated shoots were dwarf and elongated on basal MS medium. Elongated shoots were further multiplied in MS medium supplemented with different combinations of auxins and cytokinins. Maximum shoots were obtained in MS medium supplemented with IAA 0.1 mg/l + BAP 1.0 mg/l and additives. Shoots were rooted on MS/4 medium incorporated with IBA and IAA within 40 days. Cultures were incubated at 25±2°C temperature and light intensity of 2500 lux for 12 hours photoperiod. Plantlets were hardened in soilrite medium for 12 weeks under green house condition with intensive care and management. Host requirement was found essential for better survival and growth and was provided after six weeks of hardening.

**Keywords:** hypocotyl, *in vitro* regeneration, hardening, *Santalum album*

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Hardening and field trial of micropropagated plants of *Santalum album*

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*Santalum album* L. commonly known as Sandalwood belongs to the family Santalaceae. Indian Sandalwood is highly prized for fragrant heartwood, The essential oil obtained from it is used as a fixative in world class perfumes, aromatherapy, various pharmaceutical preparations and cosmetics. As an out crossing species, seed based progenies are not true to type to mother plants resulting in large variability. Plant tissue culture based biotechnological tools have potential of producing clonal planting material. Being a hemi root parasite tree species, it is not only difficult to propagate *in vitro* but also has problems of high mortality during hardening. In this study, *in vitro* plants produced through axillary shoot proliferation and somatic embryogenesis were subjected to hardening. It was carried out in two steps *i.e.*, primary and secondary hardening. For primary hardening, sand and soilrite in different combinations were used. Highest survival was recorded in sand media. Secondary hardening was carried out in media consisting of sand:soil:compost (60:10:30 v/v.). Survival of 57% was observed for axillary shoot proliferated plants and 75% for somatic embryogenesis raised plants. Field trial of micropropagated plants of *S. album* has been carried out for the first time with 70% survival by the end of six months.

**Keywords:** field trial, micropropagation, hardening, *Santalum album*

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Structure, composition and regeneration of a new population dominated by *Santalum album* L. (Sandalwood) from Attapadi, Palakkad district, Kerala

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In India, natural populations of Sandalwood are more concentrated in the Southern region, especially in Karnataka, Tamil Nadu and Kerala. Most of the populations are under severe threats due to natural and anthropogenic reasons and many of them are fragmented and isolated. There is an urgent need to protect and enhance the abundance of this culturally and commercially significant species which has both genuine demands in India as well as in abroad. In this regard, in addition to protect the existing populations, we have to explore new populations and to assess its present status in the wild. In Kerala, natural populations of Sandalwood are mainly reported from Marayoor forests and several small fragmented populations in other forest areas also. A new population of Sandalwood was identified in Agali Range of Mannarkkad Forest Division and its phytosociological parameters were studied. The study shows that the total extent of the new Sandalwood population is 83.4 ha. Phytosociological analysis of the population show that among 20 tree species, *Santalum album* and *Naringi crenulata* is over dominated by representing more than 50% of the total IVI. Sandalwood excel over remaining species in almost all phytosociological parameters with more than 30% of IVI, 36% of total basal area and 38% of total density and it is the only species with 100% frequency of distribution. We have also analysed the regeneration pattern of the population, in mature phase (>10.0 cm gbh) among 1020 individuals recorded per hectare, more than 38% represented by Sandalwood, while in seedling phase only 4% of the total density was represented by Sandalwood which indicates the poor regeneration and severe threat to the species. In mature phase, among 390 individuals of sandal only 10 attained a girth over 40.0 cm and the maximum girth attained by Sandalwood was 43.0 cm. Poor representation of individuals at larger girth class is a clear indication of illicit felling and large number of cut stumps in the study area also supports this view. The entire population is also threatened by large-scale grazing and attack of wild boar which contributes for poor regeneration and failure of establishment of new individuals. Thus a detailed management and conservation plan has to be evolved and implemented with suitable measures to prevent this population from the treat of extinction.

**Keywords:** Kerala, population, regeneration, Sandalwood

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Effect of sucrose, agar-agar concentrations and pH on somatic embryogenesis in *Santalum album* L. from the leaf of mature trees

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*Santalum album* L. is a hemi root parasite threatened tree species in natural habitats which requires primary host at nursery stage and secondary long-term host in the field. Owing to cross pollination, the progenies are variable. Current world demand for Sandalwood is about 5000-6000 tons/year and oil is 100 tons/year. To bridge the gap between demand and supply, biotechnological tools have provided vast scope to overcome limitations of traditional methods of propagation and tree improvement. Somatic embryogenesis has potential of mass production of plants. Various parameters such as; growth regulators and their combinations, media, carbohydrates source, light, temperature, nature of explant, gelling agent, pH range and genotype are important factors controlling the induction of somatic embryos and their subsequent conversion into plantlets have been elucidated for many plant species. The present investigation was aimed to find out the effect of sucrose and agar-agar concentrations and pH of the media on somatic embryo induction, maturation and germination from the explant of the mature trees. In vitro shoot cultures obtained from the mature tree were used as the source of explants for callus induction. After 4 to 5 passages of callus multiplication, the freshly multiplied callus clump (50 to 60 mg) was used for the somatic embryo induction. To standardize optimum conditions for somatic embryogenesis; various concentrations of sucrose (0.0% to 6.0% w/v), agar-agar (0.4 to 0.7%) and pH range (4.0 to 7.0) were used in MS or modification of MS medium with additives (ascorbic acid 50 mg/l + citric acid 25 mg/l + cysteine 25 mg/l + glutamine 100 mg/l). MS medium with 3% sucrose, 0.6% agar-agar and pH of 6.0 proved the best for somatic embryo induction with frequency of 90.33% and better synchronization of 84.33% globular stage. During maturation, size of the somatic embryos increased with increase in the concentration of sucrose (6.0%) in the medium favouring adventitious shoot induction and embryo cracking. Formation of secondary embryos and abnormality was noticed during the germination of somatic embryos at sucrose 6.0%. Increase in the pH (7.0) resulted in the browning of the embryos. Medium with lower agar-agar concentration (0.4 and 0.5%) was not solidified completely leading to the deterioration and increase in the concentration beyond 0.6% resulted in compactness of the medium leading to the browning of the embryos and poor synchronisation.

**Keywords:** agar-agar, pH, *Santalum album*, somatic embryogenesis, sucrose

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Ethnomedicinal uses, collection and conservation of Sandalwood (*Santalum album* L.) germplasm

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Sandalwood (*Santalum album* L.), belonging to family Santalaceae, a valuable medium-sized evergreen tree with almost drooping branches, dark rough bark and scented mature wood, is associated with Indian culture, heritage and Ayurveda, the Indian system of medicine since ancient time. It is believed to be indigenous to India. The natural distribution of Sandalwood extends from 30° N to 40° S from Indonesia in the east to Juan Fernandez Islands (Chile) in the West and from Hawaii Archipelago in the north to New Zealand in the south. Its populations are more concentrated in the southern region of India especially in Karnataka, Tamil Nadu and Kerala states. Both the Sandalwood powder and its essential oil have been used in Ayurveda for curing genito-urinary disorders, gastric irritability, dysentery, prickly heat and excessive sweating, high blood pressure, heart pain, inducing sleeping, cleaning wounds, respiratory disorders, fever and different skin diseases. Continuous over exploitation and requirement of it insist to collect, characterize, evaluate, maintain and multiply through different methods including biotechnology for future demand and proper utilization in the service of mankind. Two accessions of this important tree collected from the region are being maintained at this regional station and in-vitro regeneration and multiplication work on this sacred tree is also in progress at this station.

**Keywords:** collection, conservation, ethnobotanical uses, Sandalwood germplasm

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Theme – 4: Chemistry of wood and oil
Santalum album distribution in Sri Lanka and the variation of oil contents and compounds

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Santalum album has a cultural and economic attraction mainly because of its fragrant oil produced in the heartwood. Due to this reason, the demand and value are increasing which has created a high market interest. Early studies indicated that S. album showed a highly localized distribution in Sri Lanka. However, recent studies have proven that it has a wider distribution in the country. According to the literature, Sandalwood oil content and quality vary within the trees growing in the same area. Therefore, this study was designed to identify the oil content and oil quality variation in three districts of Sri Lanka, namely, Badulla, Kurunegala and Hambantota. All three districts belong to the intermediate zone, however, with different rainfall, temperature and elevation figures. Core samples and whenever possible, cross sections were extracted from randomly selected trees in each district. Oil was extracted by hydro-distillation and the different compounds present in oil were measured by gas chromatography analysis. The results showed a large variation of oil contents present in the sampled trees. Selected oil compounds, i.e., cis-α-santalol, cis-β-santalol, epi-β-bisabalol, epi-β-santalol and t,t-farnesol showed little or no variation between the three selected districts. However, cis-t-bergamotol was high in the sampled trees of Hambantota district. Those compounds did not have significant correlations with tree parameters, geographic and topographic parameters, i.e., dbh, height and heartwood content.

Keywords: cis-α-santalol, oil quantity, oil constituents, Santalum album

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Molecular approaches to understand/decode oil production in Sandalwood

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Plants synthesize a plethora of low molecular weight compounds called secondary metabolites, formation and storage of which is organ, tissue, cell and development specific. One of such examples is the commercially important oil produced by *Santalum album* that is stored in the wood region of the plant. The principle chemical constituents are sesquiterpenoid compounds mainly $\alpha$-santalol (40-55%) and $\beta$-santalol (12-27%) that constitute more than 90% of the distilled oil. The volatile oil is of great economic value because of medicinal properties. Sandalwood uses terpenoid pathway primarily for the synthesis of quality oil through recruitment of prenyltransferases. Isopentenyl pyrophosphate is the building block of terpenoid biosynthesis that through two consecutive reactions gives rise to farnesyl pyrophosphate (FPP). Both the consecutive reactions are catalyzed by farnesyl diphosphate synthase (FDS). Further, FPP is cyclized into various cyclic sesquiterpenes such as endo-bergamotene, $\alpha$-santalene, epi-$\beta$-santalene and $\beta$-santalene by the activity of a terpene cyclase. Although santalol is the most important constituents of Sandalwood essential oil, there is a lacuna in the detailed studies on molecular mechanisms involved in its biosynthesis. In the present work, key regulatory genes namely farnesyl diphosphate synthase and santalene synthase involved in santalol production were isolated utilizing SSH and RACE techniques. The isolated genes were functionally characterized by *in vitro* expression and enzyme assay. Tissue specific expression of genes showed higher expression in outer sap and middle transition zone of wood region as compared to leaf and fruit. A positive correlation was observed between santalol biosynthesis and gene expression indicating that isolated genes are critical genes in regulating santalol biosynthesis in Sandalwood. Since santalol biosynthesis in Sandalwood starts after attaining certain age, the isolated genes can be utilized for *in vivo* santalol production in transformed calli to fill the gap between availability and demand of oil which at present is increasing day by day.

**Keywords**: farnesyl diphosphate synthase, RACE, santalol, santalene synthase, sesquiterpenes

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Sandalwood in Ayurvedic perspective

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Chandana or Sandalwood, according to Ayurveda, has wide range of therapeutic activity and hence has been used in Ayurveda to treat various disease conditions. The heartwood of the plant is sweet and bitter in taste, and is Laghu and Ruksha in property. Thus Chandana, on the levels of Dosha, pacifies vitiated Pitta and Kapha. It acts on tissues (Dhatu) like Rakta, Meda, Majja, and Shukra. It works on higher centers and thus has action on mind. Hence, classically it is used to treat burning sensation, headache, perspiration, skin disease, urinary disorders, cardiac ailments, cough, ulcerations, jaundice, and psychiatric ailments. Research in last few years have shown anti-hyperglycemic and antioxidant potentials of α-santalol and sandalwood oil, antimicrobial and antioxidant properties, possibly attributed to sesquiterpenoids, shikimic acid, etc. Traditionally it is being used in many Ayurvedic formulations such as Ayaskrti, Asvagandhadyarishta, Sarvivadasava, Arimedadi Taila, Baladhatryadi Taila, Marma Gulika Candanasava etc. The presentation highlights the Ayurvedic concept behind the therapeutic uses of Chandana and its scientific validation based on modern parameters.

Keywords: Ayurveda, anti-hyperglycemic, therapeutic uses

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Shockwave assisted hydro distillation of Sandalwood oil – a new innovative method

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Shock waves have been traditionally considered to be an integral part of flow field features in the area of high-speed aerodynamics. Physically the propagation of shock waves in any media is invariably associated with instantaneous increase in pressure and temperature behind the shockwave. The capability of shock waves to generate non-linear pressure and temperature spikes in the medium of propagation finds very interesting applications in variety of areas such as medicine, biological sciences, material processing, manufacturing, and microelectronic industries. Sandalwood is recognized as the most valuable woody species in the world for its fragrant oils within its heartwood. The oil from the Sandalwood is extracted by various techniques like hydro distillation, steam distillation and super critical carbon dioxide. Sandalwood essential oil is extracted primarily by steam distillation, a process in which super heated steam is passed through the powdered wood. The total process of hydro distillation takes longer duration (>12h) to yield the oil. Shockwave assisted system of distillation of Sandalwood oil has shortened the process of extraction of oil. This paper reviews new industrial applications of shock waves that have been developed in the Shock Waves Laboratory (SWL), Department of Aerospace Engineering, Indian Institute of Science, Bangalore India for extraction of Sandalwood oil.

**Keywords:** hydro-distillation, Sandalwood oil, shockwave

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“Snakes encircling Sandalwood” – a chemical investigation

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Sandalwood industry around the globe is facing numerous threats from poaching, counterfeits and inferior products. In the current review a chemical investigation was conducted on the effect of these threats on fragrance and incense markets. Samples were collected as consumer products, Sandalwood powders and confiscated illegal wood during the past two years from local and international markets. Volatile contents were isolated by solvent extraction or hydro-distillation, these isolates were analysed by gas chromatography with mass spectroscopy to identify the changes in composition. The sources of adulterants and substitutes were determined based on the above findings. Sandalwood poaching in Western Australia has damaged the market in addition to the destruction of arid ecosystem. The quality of illegal wood found to be far inferior as a result of incorrect methods and failure to identify correct sources. Plantation Sandalwood from different sources were analysed for its heartwood, essential oil and santalol contents. It was evident that harvesting of juvenile trees and poorly manage plantations would provide substandard product, thus jeopardising the trust kept upon plantation Sandalwood. Substitution from non-Sandalwood timbers such as Ermophila mitchelli and Santalum accuminatum seen a common occurrence in Asian markets. Though it is a competition for authentic Sandalwood these woods not used for their aromatic properties. Synthetic compounds with structural activity relationship for santalols are available for perfumary; however the vast majority chemicals used as Sandalwood oil are of obscure sources. There was an increased use of a diethyl phthalate in products labelled as Sandalwood. The source of this adulteration was traced during the current investigation. Malpractices discussed above are damaging the reputation of Sandalwood as a reliable and sustainable source. Diminution of quality would ultimately results in Sandalwood losing the acceptance as an authentic commodity.

Keywords: diethyl phthalate, Sandalwood industry, Santalum spicatum, substitutes

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Thermal degradation studies of *Santalum album/spicatum* wood and Sandalwood incenses

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The sensory system of human being is the product of millions of years of evolution. Natural selection has resulted in our capacity to detect a wide range of compounds present in environment. The fragrance emitted by natural products in the environment is the first experience of sensing smell by the early man. The early man used basic techniques like crushing, burning, boiling and grinding to liberate fragrant molecules from the different parts of the plant. The fragrance emitted was used in religious ceremonies as perfume and therapeutic agents. *Santalum album/spicatum* species are used in incense manufacturing. Incense can be considered as controlled fragrance release devise. It releases desired Sandalwood fragrance along-with harmful pollutant. Pollutants are formed by degradation of wood polymers during the smouldering combustion of incense and are released along with fragrance in the environment. In the present study different parts of Sandalwood smouldering incenses are identified, namely drying, charcoal forming, and glowing regions by using thermocouples. To understand the mechanism of thermal degradation and its relation with different regions in smouldering combustion of incense, *Santalum* wood powder degradation was studied using TGA and DTA. Different temperature range of degradation of cellulose, hemicellulose, and lignin are identified by comparing it with literature values. Factors affecting smouldering rate of incense are discussed in detail. Possible release of pollutant molecule as a result of degradation of incense is discussed along with fragrant molecules. Changes in the chemistry of wood polymer degradation of different regions are also studied by FTIR.

**Keywords:** FTIR, thermal degradation, TGA, DTA, *Santalum album/spicatum*

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Adulteration of Sandalwood oil - detection and purity evaluation

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Santalum album L., the Indian Sandalwood valued for its fragrant oil yielding heartwood is a major ingredient in indigenous medicines and perfumes. Increased demand of the oil in the international market, its skyrocketed price and scarcity of Sandalwood has led to illegal felling of trees and adulteration of oil. The species has been categorized as ‘Vulnerable’ by International Union for Conservation of Nature. Adulterating an essential oil is relatively easy; forms of adulteration may include introducing an alcohol, producing synthetic products, substituting or reconstituting different and cheaper oils and synthetic chemicals and passing them off as natural oils. In addition, adulteration radically changes or reduces the perfumery and therapeutic properties of the valued oil. Due to its commercial importance, Sandalwood arriving for trade in the market is adulterated with many other indigenous as well as imported scented wood species and synthetic organic solvents and chemicals. The purity of the Sandalwood oil is found out by solubility test and UV spectroscopic method. In this paper different important analytical tools and chemical analysis techniques to detect purity and evaluate quality of Sandalwood oil are discussed.

Keywords: adulteration, oil, Santalum album, solubility, UV spectroscopy

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Vibrational spectroscopy of Indian Sandalwood oil – a short review

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Primary constituents of Indian Sandalwood oil are the sesquiterpene alcohols, namely, α-santalol and β-santalol. Almost 90% of the total alcohols are santalol, around 2-4% of santalol are present as esters. Indian Sandalwood oil has a specific gravity slightly less than water (0.96-0.98 at 25 °C) and has a refractive index of 1.5-1.51 at 20 °C. Indian Sandalwood oil is sparingly soluble in water and insoluble in glycerin. Nearly 46 compounds have been chemically isolated from the Indian Sandalwood oil. The above diversity in chemical characteristics makes it difficult to properly explain the FTIR- spectra of Sandalwood. The objective of this paper is to perform literature survey to identify the infrared absorbance peaks and assign them to chemical moieties. Prominent infrared (IR) peaks have been observed at 3350 cm⁻¹, 3053 cm⁻¹, 2968 cm⁻¹, 2875 cm⁻¹, 1567 cm⁻¹, 1459 cm⁻¹,1374 cm⁻¹, 1003 cm⁻¹, 876 cm⁻¹ and 853 cm⁻¹ that contain signatures of wood and water along with other chemical groups.

Keywords: FTIR, Sandalwood, Sandalwood oil, Santalol

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Yield and GC-MS compositional assessment of essential oil from Sandalwood trees grown in Uttarakhand State of India

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The Indian Sandalwood tree, Santalum album L. belonging to the family Santalaceae, is sought for its fragrant essential oil and heartwood since time immemorial and is one of the oldest known perfumery materials having over 2000 years of uninterrupted history. Expanded trade of Sandalwood and resultant over-exploitation and poaching have resulted in a severe decline among its natural populations; as such only ~10% of the total demand is now met from natural sources. In this context, accurate determination of yield and quality of Sandalwood oil for deciding its application and market value is important. However, only a few major natural populations of Sandalwood have so far been assessed for content and quality of essential oil. Therefore, need for systematic study on content and quality of essential oil in other natural tracts and plantations of S. album has become crucial to explore further source of Sandalwood heartwood and oil. The study presented is focused on evaluating Sandalwood tree habitat in the state of Uttarakhand, India for yield and quality of essential oil. In Uttarakhand, natural tract and plantation of Sandalwood tree are located at an altitudinal range of 1200-3900 ft. Sandalwood heartwood samples collected from Haldwani region were examined for content and chemical composition of essential oil. The yield of essential oil obtained by different distillation methods were in the range of 3-3.5 %. The percentage composition of major constituents of essential oil through GC-MS analysis was found to be α-santalol (60.71%), β-santalol (26.63 %), β-santalene (0.70 %), α-santalene (0.35 %), teresantalol (0.27 %) and sabinene (0.23 %). The recorded value of yield and composition of essential oil are consistent with standard norms of commercial grade Sandalwood oil. The present study which is the first report on content and quality of essential oil derived from Sandalwood trees of Uttarakhand origin, established the region as potential source of Sandalwood with commercially acceptable essential oil. Considering the impact of agro-climatic and phytogeographic conditions on essential oil and findings of the present study, it can be credibly postulated that the state of Uttarakhand may be a promising destination for large-scale plantation of S. album.

Keywords: essential oil, GC-MS analysis, oil yield, Santalum album, Uttarakhand

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Gas chromatography–mass spectrometry (GC-MS) profiling of Sandalwood oil composition from 15 year old trees

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One of the most important commercially valued products of Sandalwood is its aromatic essential oil obtained from the heartwood. The oil commercially known as Indian Sandalwood oil is being extensively used in diversified industries like - perfumery, cosmetics, pharmaceutical and aromatherapy. Extensive studies carried out confirm variation in oil content and its composition. It has been found that in most of the studies the tree age and the growing conditions are not similar and they play an important role in oil quality and quantity. Therefore, it is imperative to understand the variation in Sandalwood oil composition among the similar aged trees grown in homogenous conditions. Fifteen year old trees growing at Institute of Wood Science and Technology campus were considered and core samples were collected from five trees having different girth. Oil content extracted from these cores varied from 9 to 43 mg/g of wood. Volatile metabolites were detected and quantified by using gas chromatography-mass spectrometry (GC-MS) method. A variety of n-alkanes, sesquiterpenoids, sesquiterpene, fatty acids, naphthalene derivatives, azulene derivatives, methyl esters, alcohols, spiro-, bicyclo- compounds and acetates were observed. The major constituents were α-santalol, epi-β-santalol, α-santalene, β-santalene, santolina triene and sesquiterpene hydrocarbons.

**Keywords**: gas chromatography-mass spectrometry, metabolites, Sandalwood oil

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Emission of gaseous pollutants during burning of natural and synthetic Sandalwood oil based agarbatti

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The burning of agarbatti in religious and social functions has been practiced since early times. It is burnt for fragrance and from mythological viewpoint. The agarbatti based industries are using synthetic as well as natural Sandalwood oil as an essence component. The quality of agarbatti depends on the ease of burning, release of soothing essence and emission of less toxic gases. There are not many studies available in literature on emission of gaseous pollutants during agarbatti burning. In the present study we have observed the concentration of gaseous pollutants such as carbon dioxide, carbon monoxide, etc. emitted during burning of synthetic as well as natural Sandalwood oil based agarbatti.

**Keywords:** agarbatti, burning properties, gaseous pollutants, Sandalwood

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Santalum album Linn.: a traditional medicine with versatile pharmacological activities

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Santalum album Linn. (Family: Santalaceae) is commonly known as white Sandalwood, Sandal safaid and safed chandan. It is one of the most valuable trees in the world and second costliest wood in the world. Sandalwood and its oil is extensively used in Unani and traditional system of medicine as it has musafii khoon (blood purifier), muhallil warm (anti-inflammatory), musakkin (analgesic), mufarreheh (exhilarant), muqawwie qalb (cardio-tonic), dafe taffun (antiseptic), muqawwie dimagh (nervine tonic) and munaffise balgham (expectorant) properties. Hence, it is useful in skin, cardiac, liver, gastrointestinal, respiratory, urinary disorders etc. These uses are supported and proven by many in vitro or in vivo studies. The proven pharmacological activities of S. album are anti-bacterial, anti-viral, anti-fungal, anti-oxidant, anti-inflammatory, antimutagenic, anti-fatigue etc. Sandalwood oil or its constituents were found to have anti-microbial activity against gram positive and gram negative bacteria, fungus and virus. Sandalwood oil showed skin cancer preventive effect in mice. Alpha santalol obtained from Sandalwood oil showed delayed papilloma growth, reduce tumor multiplicity and inhibit in vitro lipid peroxidation in skin and liver. The methanolic extract of wood was confirmed for antioxidant, free radical scavenging, analgesic and anti-inflammatory activities. α - and β-santalols present in Sandalwood oil showed sedative effects. Sandalwood oil elevates pulse rate, systolic blood pressure and skin conductance level. Sandalwood tea significantly increased the myocardial contractility; heart rate of the isolated and failed frog heart significantly and contracted the smooth muscle of isolated rabbit aortic strips. Sandalwood oil showed significant changes in hepatic xenobiotic metabolizing enzymes. Sandalwood oil and its major constituents have low acute oral and dermal toxicity in laboratory animals, however, occasionally sensitization reaction in humans is reported. Hence, studies justify the use of Sandalwood and its oil mentioned in classical Unani literature. However, further clinical trials are recommended to prove its efficacy and safety.

Keywords: antioxidant, cardiotonic, Santalum album, Santalol, Unani medicine

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Medicinal value of Sandalwood and its oil in Unani system of medicine

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Since centuries Sandalwood and its oil are used by Unani physicians as a therapeutic agent. *Sandal Safaid* (white Sandalwood) and *Sandal Surkh* (red Sandalwood) two varieties are described in Unani literature, both are used as medicine but *Sandal surkh* is very dry in nature so used externally as a *zimaad* and *tila* (paste and liniment). In Unani classical literature Sandalwood is reported to possess *Mufarreh wa Muqawwi qalb* (exhilarant and cardiotonic), *Muqawwi dimagh* (brain tonic), *muqawwi meda* (stomachic), *Qabize ama* (bowel astringent), *Musakkine hararat* (febrifuge), *Musaffi-e-dam* (blood purifier) properties. It is an important cardiac drug which is exclusively used by the Unani physician in the treatment of *Khafqan* (palpitation). Ibn Sina the most eminent physician of Arab period listed *Sandal* as a cardiac active drug in his book *Al- Adwiyah Al- Qalbiyah*. According to him *Sandal* dissolves inflammation and tumors, and stabilizes palpitation. Sandalwood is used as a disinfectant in bronchial and genitourinary tract infections. A paste of the wood is applied in burns, fever and headache. It relieves thirst. It is also used in acne, biliousness, blood impurities, bronchitis, cough, depression, diarrhea, itch, leucorrhoea, menorrhagia, persistent infection due to low immunity, sexual debility and sore throat. It is one of the potential anti-ulcer drugs used in Unani system of medicine and as a component of certain polyhedral preparations for prevention and healing of gastric ulcers. Its analgesic, anti inflammatory, anti ulcer, cardio tonic, anti bacterial and anti oxidant activities have been investigated scientifically. It is used in many dosage forms i.e. cold and hot infusion, powder, and decoction. It is also included as an ingredient in many Unani formulations i.e. *Khamirah Sandal, Majoon Sandal, Khamirah marwareed, Sharbat Sandal and Khamirah Abresham Hakim Arshad wala*. *Roghan Sandal* (Sandalwood oil) has pleasant odour and pungent taste, used in acute and chronic gonorrhoea, burning maturation and cystitis. Present communication reviews the Unani literature on *Sandal* and highlights its uses in Unani Medicine both as a single drug and also in combination with other drugs.

**Keywords:** Sandalwood, therapeutic uses, Unani medicine, Unani formulations

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EiGAS technology for steam distillation of Sandalwood oil and use of biochar for producing bio-organic compost

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There has been continuous effort all along in developing fuel efficient biomass based combustion systems. CGPL, IISc has developed a biomass based combustions system that works on the principle of gasification – it is reverse down draft gasifier that generates clean gas that could be combusted with least emissions. This technology is called Ejector Induced Gasification System or EiGAS system. Biomass in any form viz., sticks, twigs, logs and chips can be fed on a continuous basis to generate clean gas that is combusted with least emissions. Pointec Pens and Energy Private Limited (PPEPL) has licensed this technology. PPEPL has developed small steam generators to generate 20 Kgs/ hr to 200 Kgs / hr of steam that can be used by farmers for use in steam distillation process for extraction of Sandalwood oil. Biochar is a very useful by-product that is generated by the EiGAS system. The efficacy of biochar as soil productivity enhancer is very well documented. Biochar amendments the soil by improving the soil organic matter, helps in microbial colonisation of amended soils, improves the water holding capacity, root zone aeration in addition to increase in cat-ion exchange capacity. PPEPL has developed microbial composting of farm waste, kitchen waste and plant residue using effective micro-organisms (EM) and biochar. The process is fast, effective and simple. Using the above two technologies, small farmers can set up small steam distillation units which are non-polluting and energy efficient to produce Sandalwood oil and generate biochar. Using the biochar and EM the herbage generated from horticulture and aromatic crops used as understory crops can be converted to useful biochar amended bio-organic fertilizer for enhancing soil fertility and carbon sequestration. This will help small scale farmers to self-generate biochar amended quality compost for their plantation activities and reduce the operational cost. The exhausted Sandalwood powder after oil extraction also has commercial value. Using this model complete cycle can be made for better utilization and value addition for each of the byproducts.

Keywords: distillation, gasification, oil distillation, Sandalwood oil

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Emerging trends in extraction methods of Sandalwood oil

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Sandalwood recognized as one of the most valuable woody species in the world for its fragrant oils within its heartwood. The extracted oils are valued in the manufacture of perfumes, soaps, cosmetics and medicines. The oil from the Sandalwood is extracted by various techniques like hydro distillation, steam distillation, solvent extraction, microwave extraction and supercritical carbon dioxide. The composition of the extracted oil may vary from one extraction method to another. Head space analysis offers a potentially rapid method to extract essential oils and requires very little plant material, but complete recovery occurs only for highly volatile materials. Sandalwood essential oil is extracted primarily by steam distillation, a process in which superheated steam is passed through the powdered wood. The steam helps to release and carry away the essential oil that is locked in the cellular structure of the wood. Steam distillation takes longer duration (>10h) to yield the oil. Steam distillation and hydro distillations suffered the loss in yields for the reason of longer processing and solublization of major constituents in the distilled water. Furthermore, Sandalwood oil is evaluated internationally for its olfactory properties by experienced perfumers and these olfactory qualities supersede variations in the chemical constituents of the extracts which needs standardized procedures of extraction. This paper discusses technological advancement, different methods of extraction of oils which are most widely used on commercial scale and new emerging techniques which may not necessarily be used for commercial production but are considered valuable in certain situations.

Keywords: carbon dioxide, distillation, Sandalwood oil, solvent extraction

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Theme – 5:  
Trade and Commerce
Transition of the Indian Sandalwood: a royal tree status to a loyal tree of the farmers

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Indian Sandalwood (Santalum album L.), compared to any other tree, has always held a supreme position in India from time immemorial. Apart from fetching handsome returns, due to its multifarious utility in the day to day existence of people, over time it became an epitome of Indian culture and civilisation, enjoying royal patronage. However, realising the commercial importance of the tree, Tipu Sultan, the ruler of Mysore kingdom, whose large empire encompassed almost all parts of the natural habitat of Sandalwood declared it to be a ‘Royal Tree’ in the eighteenth century. A critical analysis indicates that such a declaration has in no way helped either the conservation or the commercial utilization of this most valued tree species of India. As the tree belonged to the State, and as people were held accountable for missing Sandalwood trees even in their private land holdings, a natural product that was revered and valued started eliciting fear and resentment in the hearts of the people. Smuggling was rare in the times of monarchies, but with a democratic, independent India, over the decades, fear of the State diminished and despite stringent laws, illicit felling and smuggling was uncontrollable. The result is that, as of now, any tree beyond the girth of 30 cm is hard to be seen in its entire natural habitat. It is the observation of the authors that even highly protected areas like the National Parks and the Wildlife Sanctuaries do not boast of large sized Sandalwood trees. Realising the drastic decline in the natural Sandalwood populations, the States of Karnataka and Tamil Nadu have liberalized the rules with a view to encourage farmers to grow in their private land holdings. However, much more needs to be done to ensure that this heritage tree of India regains its past glory and becomes a loyal tree of the farmers from its unnatural status of a Royal tree. The measures necessary for this smooth transition is discussed in this paper.

Keywords: commercial utilization, loyal tree, royal tree, Sandalwood

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Sandalwood - need for amending existing policy/legislation for cultivation by farmers in India

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Sandalwood (Santalum album) is a small evergreen tree and a hemi-root parasite occurring mainly in open scrub forest in India. It grows well at the elevation of 700 to 1500m, a rainfall of 600 to 1500 mm in red ferruginous loam of varying fertility and also in other soil types. In Indian forests, it is distributed over 9044 sq km in the states of Karnataka, Andhra Pradesh, Tamilnadu, Kerala, Odhisa, Maharasra, Rajasthan and Uttar Pradesh. According to Tamil Sangam literature (22 BC – 200 AD) Sandalwood has existed in India as part of vegetation for more than 2500 years. Amongst the forestry species Sandalwood is considered as most economically important species. The current price in public auction in state of Tamilnadu is Rs 6500 a Kilogram. The high price of wood and its oil have lead to smuggling in international market. Due to organized smuggling, the growing stocks of Sandalwood in forest area have dwindled and at present no harvestable stock is available. Unlike other species it can be cut into small pieces without loosing its value and kept or moved in concealed condition. The tract where Sandalwood are found in India are surrounded by economically poor population and also having very low rate of literacy. Coupled with high price of Sandalwood, motivates local population to cut these trees. Even they bury wood in soil and at convenient time, they sell to local traders. The local traders sell this wood to international smugglers who in turn send wood and oil to international market through cargo in containers along with other material. The Southern States of India, where it occurs naturally viz., Karnataka, Tamilnadu, Kerala and Andhra Pradesh have stringent Forest Acts/Rules for protecting Sandalwood but it has failed and natural stock have dwindled to mere few saplings of less than 10-15 cm girth. Since, the Sandalwood trees are illegally cut and removed from forest area, these regulations are of very limited purpose. Now, one of the best options is to analyze these regulations and amend in such a way that farmers can cultivate Sandalwood in their farmland, harvest and trade. In USA, this kind of liberalization approach have been done in Co-operative Farm Forestry Act of 1937 by amending in 1950 with respect to management of forest lands and the harvesting, marketing, and processing of forest product to include private forest land owners and also processors of primary forest products.

Keywords: Forest Acts/Rules, Sandalwood

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Sustainable supply of global Sandalwood for the industries

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There are 16 recognised species of Sandalwood in the world; broadly they can be grouped as Indian Sandalwood, Australian Sandalwood, Hawaiian Sandalwood and Sandalwood of the Pacific Islands. Many of these are under the threat of extinction due to over exploitation. Some of the countries are taking steps to cultivate using modern techniques to save the species. Indian Sandalwood (Santalum album L.) is the queen among the species yielding supreme quality essential oil much required by the perfume and allied industries. India was producing large quantity of Sandalwood oil meeting the world demand of over 80 per cent during the past decades, but due over exploitation and various other reasons the quantity of production to has come down drastically. Many Sandalwood based industries have come up recently in India as well as abroad on its proven importance and sustainable supply of wood and essential oil. Based on the importance of natural Sandalwood oil, many countries like, Australia, Sri Lanka, Thailand, Cambodia, Costa Rica, Pacific Island nations etc., are trying to grow different species of Sandalwood to meet global demand. India is not lagging behind in its attempt to grow more Sandalwood to bring back the past glory and very soon it may meet the demand of both domestic and international market.

Keywords: global demand, Sandalwood, sustainable supply

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Indian Sandalwood market trend and production

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Sandalwood and Sandalwood oil is one of the oldest known perfumery materials and is being used for more than four thousand years in the East. The wood being closely grained and is one of the finest materials for carving. The essential oil is used as perfume and a fragrance fixative in cosmetics which appeal equally to both the sexes. Sandalwood oil is non toxic, non-sanitizing and non-irritant. Sandalwood trade in India was started as early as 17th century. Realizing the value of Sandalwood, Tippu Sultan, the King of Mysore (India) declared Sandalwood tree as a Royal tree in 1772. The earliest Sandalwood trade data available was during 1885-86, Government of India exported Sandalwood stock worth Rs. 4,44,241 (US$ 11160) and imported the value added product worth Rs. 16,404 (US$ 4104). The price of Sandalwood during 1882-83 was Rs. 328/- a tonne (US$ 82), where as the value of oil was Rs.16 per kg (US$ 3.5 per kg). The highest annual production of wood in India was about 5000 tonnes and the oil was around 150 tonnes during 1970s. The price for wood and oil has increased at an annual premium of six per cent initially, but later annual increment from 1990 increased by more than 20% due to short and inconsistent supply and high demand. The present production has declined sharply to 400 tonnes and the value has increased prohibiting the small traders to use in their formulations. The current price for Sandalwood is Rs. 60,00,000 per tonnes (US$ 125,000) and the price for Sandalwood oil is Rs. 1,35,000 per kg (US $2200 per kg) The price trend may continue to rise at the annual premium of six per cent for both wood and oil. Since Sandalwood is in great demand and due to high expected returns in a short period many plantations using new technology have come up in different countries including India for the sustainable supply of wood, so that there may not be fluctuations in the price in the years to come.

Keywords: market trend, production, Sandalwood

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Identification of market adulterants in Sandalwood and red sanders using DNA barcodes

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Indian Sandalwood (*Santalum album* L.) and red sanders wood (*Pterocarpus santalinus* Linn. f.) in commercial markets are highly prone to adulteration. The global supply of both the species has reached critical levels due to poaching and overharvest with the trees being recognized as a vulnerable species on the World Conservation Union’s (IUCN) Threatened Species Red List. A number of lawsuits were registered with regard to the adulteration of both these woods, but the lack of technical tools for the precise species identification of the source wood stalled most of the cases. The ability to track or identify timber resources of economic value is essential for the effective management and appropriate regulation of timber trade. The standard DNA barcode regions (viz. *rbcL*, *matK*, *trnH-psbA* chloroplast genomic sequences as well as nuclear *ITS* regions) recommended by the Consortium of Barcode of Life (COBOL) were analysed for their potential to identify wood adulterants of Sandalwood and red sanders wood. Standard polymerase chain reactions with universal primers were performed for all the barcode loci. The PCR products after gel elution were sequenced and alignments were performed using *CLUSTALX*. Sequence analysis was performed using MEGA version 4.0. The common substitutes of Sandalwood (*Osyris wightiana* Wall ex, *Erythroxylum monogynum* Roxb.) and red sanders wood (*Pterocarpus marsupium* Roxb., *P. dalbergioides* Roxb.) were found to have very specific sequence barcodes. Single Nucleotide Polymorphisms (SNPs) identified in the present analysis could be efficiently utilized for the detection/monitoring of wood adulterants of both these trees. The study demonstrated the potential of DNA barcoding technique using standard barcodes to trace adulterated timber products. Practical checks at the credible voluntary wood certification agencies as well as in the court of law could be made tamper proof by the implementation of DNA barcoding as a confirmatory tool along with the existing traditional techniques for timber monitoring.

**Keywords:** DNA barcoding, red sanders wood, Sandalwood, Single Nucleotide Polymorphisms (SNPs), wood adulterants

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Trade scenario of Sandalwood and its valued oil

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Due to increased global and domestic demand, and also decrease in supply, Sandalwood prices have skyrocketed in the past few decades. The country’s production of Sandalwood during 1930s through 1950s was around 4000 tonnes of heartwood a year, which has now decreased to a meager 500 tonnes of wood a year or even less approximately, while the price was Rs. 20,000 per tonne in 1980, it increased to Rs. 200,000 per tonne in 1990’s; Rs. 400,000 per tonne in 2004 and presently it is around 700,000 per tonne (2013). Export of Sandalwood from India is totally banned except for handicraft pieces of Sandalwood up to 50g weight. International demand for Sandalwood is estimated to be around 10,000 mt /year. USA and France are the two largest importers of Indian Sandalwood oil and of late imports into the Middle East are increasing. At the same time, it is disheartening to note that the import of Sandalwood oil to India during 2008-09 was as high as 61.1 thousand Kg for reasons unknown. Currently, Sandalwood oil is sold in the market at the rate of Rs.1,00,000 to 1,20,000 per Kg. In this paper, the present status of production and marketing aspects of S. album is discussed in detail.

Keywords: export, perfume, Sandalwood oil, trade

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Balancing ecology and economics using Sandalwood as medium- prospect and retrospect

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The liberalised government policies have made the Sandalwood tree (*Santalum album* L.) a commercial crop by real estate companies. It is no more a tree grown, available in the forest. The demand for use of Sandalwood is on rise over the passage of time. It is no more a plant limited to use in worshiping God/Goddess, rather have been in use as decorative material, medicinal product and for preparation toys. The ever increasing demand, though has built up immense pressure on available sandal trees in the forest, consequent encouragement of private plantation has made the pressure easy to some extent and thereby balancing the ecological need of the mother earth. The paper in its conclusion high lights the multiple ecological benefits of Sandalwood plantation also vehemently argues the tall promises made to thousands of investors on its economics yields and revenues.

*Keywords*: balancing ecology, economy, economic yield, multiple use, revenue

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Theme – 6:
Trends in protection
Augmentation of Coccidophagous coccinellids, an ideal option to manage insect pests of Indian Sandalwood (Santalum album Linn.) in the present scenario of its cultivation

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Biological control has been accepted as an effective, environmentally non-degrading, technically appropriate, economically viable and socially acceptable method of pest management. There are three basic types of biological control strategies; conservation, classical, and augmentation. Augmentative biological control, involves the supplemental release of natural enemies. Of the predaceous natural enemies, coccinellids feed on coccids, aphids, whiteflies and other injurious insect and mites, and keep the insect populations under control. Coccids alone comprise 36% of the essential food for a large proportion of coccinellid species globally, especially in the tropics and subtropics. Coccids damage many crops of economic importance, particularly woody species including Indian Sandalwood (Santalum album Linn.). Detailed surveys revealed that Sandalwood is being grown with many agricultural, horticultural and commercial crops in addition to other tree species as per the choice of farmers and 25 species of coccids were found breeding on Sandalwood under different farming systems. Coccids are ‘hard to kill pests’ and their damage is caused by sap drainage resulting in die-back symptoms and secreting copious amount of honeydew on which black sooty mould fungus develops. Eggs of the coccids are protected by waxy filamentous secretions of ovisacs and are almost impossible to reach with insecticides. Late instar nymphs and adult female mealybugs are not affected by foliar application of insecticides since they are covered with waxy coating. The study also revealed the existence of 24 species of coccinellids in these Sandalwood growing areas and they were found actively predating on these coccids thereby keeping them under control. Added to this advantage, most of the coccids, being sessile quite amenable to biological control by augmentation of coccinellids. The observations outlined above emphasizes to develop ecologically and environmentally sound insect pest management in Sandalwood plantations by augmenting more effective coccinellids like Cryptolaemus montrouzieri Mulsan and Chilocorus nigrita (Fabricius) as multiplication technology is available for these coccinellids.

Keywords: coccinellids, Indian Sandalwood, mealybugs, scales

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Wireless sensor network for protection of high cost trees from fire and poaching

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The paper describes the design and deployment strategy for the Low cost Wireless Sensor Network (WSN) for protection of high cost trees like Sandalwood, Teak, Pine & Rosewood in remote jungles / farms from poaching and fire. Each tree will have low cost microcontroller based node with inbuilt sensors for sound, motion, temperature and smoke detection. The system will automatically generate alarms in case of any behavioural change in the environment to protect the tree against fire and theft. The G-sensors / Accelerometer / magnetic compass and tiny mikes will be mounted on the trunk of the tree. The mechanical vibration and sound generated while cutting branches can be picked by the sensor. This sensed information will then be signal conditioned and digitized to get proper vibration signatures of detection of cutting of tree using different types of tools. Similarly inputs from temperature and smoke detector will help in detecting fire / smoke in the nearby area. The microwave based motion detector units (MDU) capable of detecting human movements within perimeter of 25 meter can be also mounted on few trees to cover entire zone area. The MDU will detect movements of animals and humans in the zone. Appropriate analysis of data will be required to differentiate between human or animal movements. These nodes will transmit the status to the control room through wireless network. A cluster of 15 -20 trees can be formed to have master node with additional resources and intelligence to communicate with base station. The base station will be located at the entrance of the jungle / farm which will communicate with Control room server through GSM network.

Keywords: fire and poaching, motion and vibration sensor, Sandalwood trees, wireless sensor network

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Population dynamics of insect pests in Indian Sandalwood based silvi-horti plantations of Karnataka

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Indian Sandalwood, Santalum album Linn. is indigenous to India and more than 90% of it lies in Karnataka and Tamil Nadu. Following the state government’s liberalizing policies for cultivation of Sandalwood, many farmers and entrepreneurs have now started cultivating Sandalwood in their farmlands. Surveys conducted during 2008-2013 in Karnataka have shown that Sandalwood is being grown with horticultural trees of their own choice as hosts for Sandalwood. Investigations were made to assess the insect pest status in different Sandalwood based silvi-horticultural plantations. The study revealed that mainly sap-suckers followed by stem-borer Zeuzera coffeae Nietner and Indarbela quadrinotata Walker were dominant insect pests, in almost all Sandalwood based silvi-horticultural plantations. This paper deals with population dynamics of different insect pests on Sandalwood and the different horticultural trees provided as hosts for cultivation of Sandalwood.

Keywords: horticultural crops, Sandalwood, sapsuckers, stem borers

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Theme – 7:
Experience sharing
Modern nursery practices for quality seedling production of *Santalum album* – its adaptation and technology transfer

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*Santalum album* L. is a hemi-root parasite, over exploited and threatened tree species in its natural habitat. It is highly valued for its heartwood and oil content, which varies from 4-6%. Liberalization of rules for cultivation of Sandalwood has resulted in heavy demand for the planting stock. The adages like, ‘As you sow so you reap’; ‘Well begun is half done’ are as such relevant to forestry as any other human endeavor. Protocol was developed for production of quality seedlings with 25-30cm height, 3.5 to 4.5mm collar diameter, 3-3.5 quality index and good fibrosity in 270cc root trainers or 600cc polybags within six months period. The above protocol was achieved by integrating the best treatments based on the studies on the factors like; seed source, seed pre treatment, germination medium, stage of transfer of seedling, type of container, potting mixture, primary host, stage of introduction of host species, biofertilizer, supplementary nutrition, pest control measures, and quality seedling parameters. The process of ‘lab-to-land’ transfer of technology was quite successful through field evaluation, various extension and educational programmes, viz, demonstrations, exhibitions, trainings, seminars, Farmers group visits, publishing technical bulletins, leaflets and CDs. Institute of Wood Science and Technology (IWST) has been conducting training programme on Sandalwood nursery technology since 2007. Based on the hands on trainings, many farmers have started nurseries and producing seedlings throughout India particularly in states like - Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Madhya Pradesh and Gujarat. The training has encouraged Sandalwood cultivation in non-traditional states like - Gujarat, Maharashtra and Madhya Pradesh. Based on this modern nursery technology ~ 1,75,000 sandal seedlings have been produced in IWST and distributed to different end users. The protocol has been widely accepted due to suitability and adaptability of the technology over large areas.

**Keywords:** nursery technology, quality seedling, Sandalwood, training

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Role of Karnataka Soaps and Detergents Limited in commercial Sandalwood cultivation

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Karnataka Soaps and Detergents Ltd. (KS&DL), a 98 year old high heritage traditional and historic company of Government of Karnataka was started during 1916 with the premier prime product Mysore Sandal Soap incorporating natural Sandalwood oil distilled by its own facility. Sandalwood species in the world is fast depleting either due to over exploitation or lapse in the conservative methods. The country is facing acute shortage of natural Sandalwood since the year 2001. Hence, the price of natural Sandalwood of *Santalum album* Linn has steeply gone up to the extent of over $1,00,000 per MT of good class of scented heartwood. To meet the demand of Sandalwood, it is essential and also a challenging assignment to the scientists, foresters, environmentalists and the law makers to make the progressive forest and environmental laws to facilitate the growers and entrepreneurs to commercially cultivate the Sandalwood. In this direction, KS&DL, a State owned sector in India, which is pioneer in distillation of natural Sandalwood oil in India since nine decades, taking lead in propagating the cause of cultivating the Sandalwood in a big way by introducing “Grow More Sandalwood” program. The paper presents the details of ‘Grow More Sandalwood’ program for cultivation of Sandalwood, measures adopted, seminars conducted, programs carried out to create awareness in farmers to grow Sandalwood in private lands and its benefits to farmers and simultaneously achieving the objective of producing the best quality natural Sandalwood and oil in the coming years to achieve the desired success and to regain the lost glory of producers of natural Sandalwood.

Keywords: Sandalwood cultivation, Sandalwood oil

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Emerging trends on sustainable production of natural Sandalwood in India

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The demand for natural products including Sandalwood, is growing worldwide due to paradigm of customers. They require legal, ethical sustainable supply of natural Sandalwood and its oil. In view of the importance this in the larger areas of applications viz., religious, handicrafts, perfumes, fragrances, flavours, pharmaceutical, and cosmetics. The ‘Grow more Sandal Wood’ programme is a pragmatic approach, inclusive growth oriented approach to boost the commercial scale cultivation of Sandalwood by joint cultivation on ‘Share and Prosper’ basis in the line of ‘cradle to cradle’ concept. The Directions of the Honourable Supreme Court of India is a boon to the growers, in its order dated 13th February 2012 directed the Government of India to formulate Rules and Regulations under Section 3 & 5 of the Environment Protection Act 1986, for effective monitoring, control and regulations of Sandalwood Industries and factories, that it should also formulate rules to ensure that no imported Sandalwood is sold under the name of Indian Sandalwood and adequate labeling for this effect to be mandatory for the products manufactured from the imported Sandalwood. Meanwhile, Sandalwood growing states viz., Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala, already liberalized the Sandalwood trade for the benefit of the growers. However Government of India is in the process of bringing out a comprehensive uniform legislation applicable to the entire country. In the context of gestation period of harvesting of Sandalwood spread over 15 years, the inter-planting with fruit crops can be made for regular income returns from the plantation. Some of the long term inter planting materials identified as best intercrops for Sandalwood with Indian conditions viz., drum stick (Moringa oleifera), gooseberry (Emblica officinalis), grafted Tamarind (Tamarindus indica), grafted Pomegranate (Punica granatum), Melia dubia, Silver oak (Grevillea robusta), Pongamia pinnata, Dalbergia latifolia, and Casurina would help to reduce the gestation period of harvesting and improve the heartwood formation of Sandalwood. The economic model worked out by Karnataka Soaps and Detergents Limited under public private partnership model is being well accepted by the potential growers in India due to the phenomenally high returns over a period of 15-16 Years.

Keywords: Environment Protection Act, harvesting, Sandalwood, sustainable production

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Sandalwood as an inter crop in dry land horti-silvi cropping system

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Indian Sandalwood (Santalum album L.) is commercially valued globally for heartwood and is highly prized for its superior quality oil. After the liberalization of policy on Sandalwood growing, the potential of the tree can be further exploited in existing farming, i.e., Horti-Silvi-Agri cropping systems with dry land grown horticultural plants as secondary host for Sandalwood. Under dry land farming, farmers can improve their livelihood, generate employment opportunities and enhance farm income by following this cropping system. Sandalwood based Silvi-Horti, Silvi-Horti-Agri cropping systems viz., Sandalwood + Aonla, Sandalwood + Aonla + Pulses (Horse gram, Red gram, Green gram, Black gram, Cowpea, Avare)/Cereals (Finger millets). Planting of perennial fruit plants (Aonla /Mango/Tamarind/Jamun) with Sandalwood as an intercrop in quincunx system of planting under dry land farming with pulses/millets as filler crops is found to be ideal.

Keywords: agri, Aonla, horti, pulses, silvi

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Demands from farmer

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Sandalwood is one of the most important economic tree species. The tree is harvested mainly for its fragrant heartwood and oil. Sandalwood tree has been categorized as vulnerable by international union for conservation of nature and natural resources because of over-exploitation. Sandalwood resource in India is currently threatened mainly because of smuggling, spike disease and forest fire. Smuggling of Sandalwood has created socio-economic, and law and order problems in all sandal producing states in India. The conservation status of Sandalwood in India is not good. Land, water, rainfall, and climate are available in different types. All fruits, vegetables, crops, trees, medicinal plants are grown in India in large scale. Irrigated, dry and forest lands are available in India. Rising inflation, low production and productivity, raw labour problem, is seen by the private land holders. Due to this the cultivated land is converting in to non cultivated area. Many farmers came in contact with this problem in India. If we promote farmers to grow Sandalwood trees in their lands, large amount of Sandalwood plantation is possible. However, for that farmers demand 1) establish Sandalwood board for plantation and cultivation like tea coffee board; 2) remove restrictions on tree farming, tree cutting, wood transportation from one state to other state and export of Sandalwood goods; 3) formation of a market yard to sale and buy seed, seedlings, wood and oil; 4) promotion for small industry; 5) make Sandalwood policy in favour of Sandalwood tree growers; 6) insurance cover for Sandalwood tree plantation in private land to fight tree theft, smuggling and also natural calamity.

Keywords: policy, plantation, Sandalwood

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The National Medicinal Plants Board (NMPB), Department of AYUSH has been set up by the Government of India as the apex body with the inter-sectoral mandate of coordinating all matters related to Promotion & Development of Medicinal Plants at the National Level. Among other things, NMPB supports initiatives for conservation and sustainable use of medicinal plants along with income generation for local communities by augmenting resources of critically endangered Medicinal Plants and other medicinal species in High Demand. So far the Board has supported:

- 62,000 ha. Under resource augmentation in forest areas, including 75 Medicinal Plants Conservation Areas (MPCAs) covering 13,947 ha.
- 1,50,000 ha. Of cultivation of medicinal plants on farmers lands.
- 2207 herbal gardens across the country.
- Research studies on bioactivity guided fractionation studies, sustainable harvest, post harvest management, multiplication of RET species etc.
- Developed agro techniques of 85 selected medicinal plants.
- Developed standards for Good Agricultural Practices (GAPs) and Good Field Collection Practices (GFCPs) in collaboration with the Quality Council of India (QCI).
- Supported 633 Joint Forest Management Committees (JFMCs) for income generation through value addition activities.

The Board is also actively engaged in dealing with globally emergent issues like those arising out of international treaties and Protocols.
ಸಾಂಪ್ರದಾಯಿಕತೆಗಳು

ಎಲ್ಲೆಗೆಯೇ ಸಾಂಪ್ರದಾಯಕವಾಗಿ ನೃತ್ಯವನ್ನು ಹಾಗೂ ಸಾಂಪ್ರದಾಯಿಕ ಮೂಲಕ ಪರಿಚಯಿಸುವ ಹಾಗೆಯೂ ಸಾಂಪ್ರದಾಯಿಕ ವಿವಿಧ ಸಮಾಜದ ಸಾಂಪ್ರದಾಯಿಕ ವಿಶೇಷಾಂಶಗಳನ್ನು ಹಾಗೂ ಉದಾಹರಣೆಗಳನ್ನು ಗೆದ್ದು ಕ್ರಮೇಣ ಪರಿಚಯಿಸಲಾಗಿದೆ. 9 ದೇಶಗಳುಳ್ಳ ಭಾರತದ ಅಡುಗೆ ಸಾಂಪ್ರದಾಯಿಕ ಸಾಂಪ್ರದಾಯಿಕವಾಗಿ ಪರಿಚಯಿಸಲಾಗಿದೆ. Sanatam Album ನಯಾ ಸಮರ್ಪಿಸಲಾಗಿದೆ.

ಸಾಂಪ್ರದಾಯಿಕ ತರಬೇತಿಯ ಸಾಮರ್ಥ್ಯವು 85%ರಿಂದ 95%ಗಳೆಂದೇ ಜೊತೆಗೆ ತೆರೆಯುವವು. ನೃತ್ಯ ಸಾಮಗ್ರಿಯ ವಿಷಯವನ್ನು ಹೊಂದಿದರೆ 70%ರಿಂದ 80%ಕ್ಕಿರುವ ಸಾಂಪ್ರದಾಯಿಕ ವಿದ್ಯಾವಿದ್ಯಾಕ ಸಾಮರ್ಥ್ಯವು ಉಂಟು. ಹಾಗೆಯೂ ಸಾಂಪ್ರದಾಯಿಕ ನೃತ್ಯವನ್ನು ಹೊಂದಿದರೆ ಸಾಮರ್ಥ್ಯವು ಹೆಚ್ಚು ಇರುವುದು. ನೃತ್ಯದ ರೂಪದ ಸಾಂಪ್ರದಾಯಿಕ ವಿಶೇಷಾಂಶಗಳು ಆಧಾರದ ಹೊಂದಿದರೆ 2008-09ರಲ್ಲಿ ನೃತ್ಯದ ಸಾಮರ್ಥ್ಯವು ಪ್ರಮಾಣಿಸುತ್ತದೆ. 2013-14ರಲ್ಲಿ ನೃತ್ಯದ ಸಾಮರ್ಥ್ಯವು ಪ್ರಮಾಣಿಸುತ್ತದೆ. ಹೇಳ್ಳಿಯ ರೂಪದ ಸಾಂಪ್ರದಾಯಿಕ ವಿಶೇಷಾಂಶಗಳು ನೃತ್ಯದ ಸಾಮರ್ಥ್ಯವು 2008-09ರಲ್ಲಿ ಕೆಲಸುವ ಸಮಯದಲ್ಲಿ ಸಾಮರ್ಥ್ಯವು ಹೆಚ್ಚು ಇರುತ್ತದೆ.

1. ಇದ್ದು ಉಪಯೋಗಿಸುವ ಸಾಮರ್ಥ್ಯವು ಸಾಮರ್ಥ್ಯವಾದವು. ಈ ಸಾಮರ್ಥ್ಯವು ವಿದ್ಯಾವಿದ್ಯಾಕ ಸಾಮರ್ಥ್ಯವು ಕೆಲಸುತ್ತದೆ.
2. 3500 ರೂಪಾಯ ಸಾಮರ್ಥ್ಯವು ಉಂಟು ಹೆಚ್ಚು ನೋಡು ಮತ್ತು ಪರಿಚಯ ಸಾಮರ್ಥ್ಯವು ಪರಿಚಯಿಸುತ್ತದೆ.
3. ನೃತ್ಯದ ಸಾಮರ್ಥ್ಯವು ಸಾಮರ್ಥ್ಯವಾದವು. ಹೇಳ್ಳಿಯ ರೂಪದ ಸಾಮರ್ಥ್ಯವು ಕೆಲಸುತ್ತದೆ.

ಈ ಕ್ರಮದಲ್ಲಿ ಪ್ರವೃತ್ತಿಯ ಸಾಮರ್ಥ್ಯವು ಎಲ್ಲೆಗೆ ಸಾಮರ್ಥ್ಯವಾದವು. ಈ ಸಾಮರ್ಥ್ಯವು ಕೆಲಸುತ್ತದೆ. ಈ ಸಾಮರ್ಥ್ಯವು ಸಾಮರ್ಥ್ಯವಾದವು. ಈ ಸಾಮರ್ಥ್ಯವು ಕೆಲಸುತ್ತದೆ. ಈ ಸಾಮರ್ಥ್ಯವು ಸಾಮರ್ಥ್ಯವಾದವು. ಈ ಸಾಮರ್ಥ್ಯವು ಕೆಲಸುತ್ತದೆ.

(ಸ.ಜಿ.ಜಿ.ಜೆ.)
ನಾಮ ಸಂಪ್ರತಿಯ ಮುಖ್ಯ ನೃತ್ಯ ನ್ಯಾಯಾಲಯದಲ್ಲಿ (ಡಾ.ನಾಮ), ಹಾಗೆಯೂ -
The National Medicinal Plants Board (NMPB), Department of AYUSH has been set up by the Government of India as the apex body with the inter-sectoral mandate of coordinating all matters related to Promotion & Development of Medicinal Plants at the National Level. Among other things, NMPB supports initiatives for conservation and sustainable use of medicinal plants along with income generation for local communities by augmenting resources of critically endangered Medicinal Plants and other medicinal species in High Demand. So far the Board has supported:

- 62,000 ha. Under resource augmentation in forest areas, including 75 Medicinal Plants Conservation Areas (MPCAs) covering 13,947 ha.
- 1,50,000 ha. Of cultivation of medicinal plants on farmers lands.
- 2207 herbal gardens across the country.
- Research studies on bioactivity guided fractionation studies, sustainable harvest, post harvest management, multiplication of RET species etc.
- Developed agro techniques of 85 selected medicinal plants.
- Developed standards for Good Agricultural Practices (GAPs) and Good Field Collection Practices (GFCPs) in collaboration with the Quality Council of India (QCI).
- Supported 633 Joint Forest Management Committees (JFMCs) for income generation through value addition activities.

The Board is also actively engaged in dealing with globally emergent issues like those arising out of international treaties and Protocols.

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Food and Agriculture Organization (FAO) was established as a specialized United Nations agency in 1945. FAO’s vision is “A world free from hunger and malnutrition where food and agriculture contribute to improving the living standards of all, especially the poorest, in an economically, socially and environmentally sustainable manner”. Three Global Goals of FAO are: eradication of hunger, food insecurity and malnutrition; elimination of poverty and the driving forward of economic and social progress for all; and the sustainable management and utilization of natural resources for the benefit of present and future generations. Five strategic objectives that represent the main work areas of FAO at present are: help to eliminate hunger, food insecurity and malnutrition; make agriculture, forestry and fisheries more productive and sustainable; reduce rural poverty, enable inclusive and efficient agricultural and food systems; and increase the resilience of livelihoods to disasters. FAO serves as a neutral forum for policy dialogue and as a reliable information source on forests and trees. FAO’s Forestry Department helps nations in managing the forests and trees and using them sustainably and thereby achieving the FAO’s goals. See more at http://www.fao.org/about/en/ and http://www.fao.org/forestry/en/.