"Assessment of the Role of Environmental factors and Associated Plants for the Mass Cultivation and quality improvement of *Santalum album* L. in India and Nepal"

Thesis submitted for the Degree of
Doctor of Philosophy (Science)
Of
Jadavpur University

Submitted by
Roshan Kumar Yadav
Department of Life Science & Biotechnology
Jadavpur University
Kolkata – 700032
India

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যাদবপুর বিশ্ববিদ্যালয় JADAVPUR UNIVERSITY

কলকাতা-৭০০ ০৩২, ভারত KOLKATA-700 032, INDIA

FACULTY OF SCIENCE: DEPARTMENT OF CHEMISTRY: INORGANIC CHEMISTRY SECTION

CERTIFICATE FROM THE SUPERVISORS

This is to certify that the thesis entitled "**Assessment of the Role of Environmental factors and Associated Plants for the Mass Cultivation and quality improvement of *Santalum album* L. in India and Nepal"** submitted by Roshan Kumar Yadav who got his name registered on 25. 07. 2017 for the award of Ph.D. (Science) degree of Jadavpur University, is absolutely based upon his own work under the joint supervision of Dr. Subrata Mukhopadhyay, Professor, Department of Chemistry, Jadavpur University, Kolkata – 700 032 and Dr. Jagatpati Tah, Professor (Retired), Department of Botany (UGC CAS), The University of Burdwan, Burdwan – 713 104, West Bengal. It is mentioned that neither this thesis nor any part of it has been submitted for either any degree/ diploma or any other academic award elsewhere before.

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Dedicated

To

My

Parents

Sri Abadh Narayan Yadav

And

Smt. Sarswati Devi Yadav

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Forward

When any experiment is undertaken by any person or institute, it is assessed by suitable parameter as need of the moto of experimentation. In this case, we had the following criteria to fulfil the experimentation successfully.

The plant material as chosen for the PhD research is an excellent one which indigenous one and one of the most precious timbers as well as medicinally important. Indeed, this has recognized as Indian national crop calendar in the year 2013 in an International Conference in Institute of Wood Science Technology (IWST), Bangalore from the state of West Bengal by one of supervisors of this PhD thesis. Though it is an ancient timber as well as medicinally important plant many unknown findings have not been explored earlier in the context of its adaptation and suitable edaphic factor(s). Now, this plant has occupied its international agronomical position in various countries like Austrelia, Nepal, China etc. Considering all these factors this research study was experimented in Nepal and Indian different locations which have been highlighted here as a case study.

Introduction

Reconsidered the known hypothesis of Indian sandalwood we came to understand easily it's Nomenclature, Status of Sandalwood in West Bengal, General information, Cultivation details, Botanical classification, Know your sandal trees, Tree Improvement, Distribution in West Bengal (in tabulated form), Detailed enumeration of Sandalwood, Site study in West Bengal, India and Nepal, Morphology and Phenology, Biological phenomenon, Moto of study, Required Types of Soil, Growing and cultivation of trees, Cultural operation, Vegetative propagation, Phytohormones, Heartwood formation, Growth and yield, Life process of plants, Objectives. Cultivation, Disease and Pest etc. All these have been noted in this chapter.

Review of Literature

Before taking up any venture of the research work a thorough review of early works are necessary. We have reviewed the necessary aspects as discussed in this work viz. Soil, Silviculture, Vegetative propagation, Heartwood formation, Growth and yield, Germination and dormancy, Host –Sandal Plant Parasitism, Trees improvement, Chemistry and Utilization, Uses, Plant description, Habitat and Distribution, Cultivation and harvesting, Products, Traditional uses, Religious Importance, Additional benefits of sandalwood, Selection and storage of Sandalwood oil, Industrial uses, Prolong Human Hair Growth, Anti-inflammatory and Antioxidant activity sandalwood album Oil (SAO), Anti-microbial and Antifungal Activity, Tetranychus Urticae Repellent Effect of Santalol from Sandalwood Oil, Apoptotic Effects of α-Santalol in Inhibiting the Growth of Human Prostate Cancer Cells, Insect growth inhibitor, Insect Growth Inhibitor from Bark of *S. Album*, effect on nervous system, Antineoplastic effects of α-santalol on estrogen receptor-positive and negative breast cancer cells, Hepatoprotective activity, Anti-tyrosinase and Anti-cholinesterase potentials of

sandalwood oil, Olfactory Receptor Neuron Profiling, Effect of geneturinary system, Antihyperglycemic and antihyperlipidemic activity, Anti-ulcer activity, Antipyretic Effect, Antispasmodic effect, Astringent, Anti septic effect, Homemade remedies of *Santalum album.*

Materials and Methods

Homemade remedies of *Santalum album*, Sandal and Host-Parasite Study in Field, Plantation and growth study in different location in West Bengal, India and Nepal, Growth parameters, Meteorological monthly information of location round the year, Soil sample study of the location, Morphogenetic peculiarities of *S album* L., Morphogenetic peculiarities of *S album* L.

Information of sites, Information location, Information of treatment, Information of plantation, Growth parameter, Lay-out and Design, Meteorological information of both the countries, Germination study, Soil testing method,

Results

Soil Test Reports of Macronutrients, Soil Test Reports of Micronutrients, Study of different growth parameter and their biometrical study.

Discussion

Experiment wise discussion on respective result tables, Useful part of sandalwood, Nutritional Information and Properties, Discussion on soil report, Quality Assessment (oil content) of sandalwood.

Comments

Comments were noted considering its results and discussion experiment wise.

Future task

There are lots of useful future task are visible at our door step and in hand by which bi-lateral research collaboration gateway will be opened with various neighbouring countries or continents.

Roshan Kumar Yadav

Contents

List of Abbreviations

µg – Microgram	GEI / G x E – Genotype Environment Interaction	Na_2CO_3 – Sodium carbonate
^0C – Degree Celsius	H^+ - Hydrogen ion	NaOH – Sodium hydroxide
Al – Aluminium	h^2 – Heritability	NBPGR - National Bureau of Plant Genetic Resources
ANOVA – Analysis of Variances	H_2SO_4 – Sulphuric acid	NH_4F – Ammonium fluoride
BSA – Bovine serum albumin	H_3O^+ - Hydronium ion	nm – Nanometre
cm - Centimetre	ha – hectare	O. D. – Optical density
CO_2 – Carbon dioxide	HCl- Hydrgen chloride	P – Phosphorus
conc. – Concentrated	HIV – Human Immunodeficiency Virus	PCV – Phenotypic Co-efficient of Variance
Cu – Copper	IC – Indigenous Culture	ppm – parts per million
$CuSO_4$ – Copper sulphate	K – Potassium	RBD - Randomised Block Design
CV – Critical Variance	$K_2Cr_2O_7$ – Potassium dichromate	RMS – Replication Mean Square
D – Dextrorotatory	kg – Kilogram	rpm – Revolutions per minute
df – Degree of freedom	$KMnO_4$ – Potassium permanganate	Sb – Antimony
ds – Decisiemens	L. – Linnaeus	SS – Sum Square
DTPA – diethylene triamine pentaacetic acid	m – metre	SV – Source of Variation
EC – Electrical Conductivity	Max. – Maximum	Syn. – Synonymous
et al.- latin phrase et alia (in English- and others)	mg – Milligram	TCA – trichloro acetic acid
F – Fisher's ratio	Min. – Minimum	Temp. - Temperature
Fe – Iron	min. – minutes	Verdc. - Verdcourt
g – Gram	ml – Millilitre	Vis – Visible
GA – Genetic Advance	mm – Millimetre	Zn – Zinc
GCV – Genotypic Co-efficient of Variance	Mn – Manganese	
	Mo – Molybdenum	
	MSS – Mean Sum Square	

ABSTRACT

Title of the Thesis: Assessment of the Role of Environmental factors and Associated Plants for the Mass Cultivation and quality improvement of *Santalum album* L. in India and Nepal

White sandalwood is also known as East Indian Sandalwood. White sandalwood is not fussy about where it grows, whether in fertile valleys or on dry mountain sides, it thrives anywhere. White sandalwood has been recognized as a "Royal Tree" in India since 1792. One sandalwood tree in a forest makes the whole forest smell of sandalwood as the scent cling to other trees. Sandalwood is a root parasite and extracts nutrients from the host plant by means of special formations called haustoria.

It is not a single species of tree that nourishes the sandalwood but several and it is not yet fully understood what the exact conditions are that allow the tree to thrive. White sandalwood aroma spreads all over when it comes to extract oil from it. It is generally employed for skin care. It is endowed with antiseptic, anti-flammatory, disinfectant, astringent and emollient properties. That is why, so many people use sandalwood to treat acne, skin rashes, blackheads, dark spots blemishes and to get a fair and flawless complexion. In a word it has immense important uses since ancient Indian era. But it grows in specific edaphic conditions.

These experiments were conducted to explore its growth and development in different locations in India and Nepal to survey its qualitative and quantitative aspects.

The objectives were:

- Manipulation of seed germination by different concentrations of chemicals like IAA/ kinetin/ GA_3.
- To explore the suitable conditions for the proper growth of this plant with various associated plants in Nepal.
- Quantitative assessment of growth data till its establishment.
- To study any morphogenetic peculiarities & to study differential seeding of each type.
- To assess the qualitative parameters through biochemical analyses

25/06/2024

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Chapter –1

Introduction

Chapter –1

Sandalwood (White Sandal) is the fragrant heartwood of some species of genus *Santalum*. The widely distributed and economically important *Santalum* genus belongs to the family Santalaceae which includes 30 genera with about 400 species, many of which being completely or partially parasitic (John,1947). The word Sandal has been derived from Chandana (Sanskrit), Chandan (Persian), Savtador (Greek) and Santal (French). There are references of Sandalwood in Indian mythology, folklore and ancient scripts. 'Chandana' the Sanskrit name ascribed to *Santalum album* L. was known and used in India from the earliest historic times and is frequently mentioned in the ancient Sanskrit writings, some of which dated before Christian era. Kautilya's Arthashastra (320 B.C.) considered Sandal as one of the important forest products to increase royal revenue. Charaka Sanhitha, the major text book of internal medicine in Ayurveda (300 B.C.) quotes uses of Sandal over 160 time in the entire text. In treatment of major diseases like fever, piles, hemorrhagic conditions, diabetes, dropsy, mental disorders, management of poisons & skin disorders wide spread uses of sandal is seen. Susrutha Samhita (150 B.C.) a great text on Indian wisdom on surgical procedures, equally preferred sandal for the management of wounds. Sandal fumigation is indicated in warding off evils and organisms, which contaminate the wounds. Such fumigations hasten the wound healing & surgical wards remain aseptic. Dusting of wounds with sandal for early healing is common. In the Amarkosha (Lexicon 3rd or 4th Century A.D.) sandal is mentioned and it is said that 'Vina-malayam anyathra chandanam vivarditha' [Majumdar, 1941].

Santalum album, or **Indian sandalwood**, is a small tropical tree, and is the most commonly known source of sandalwood. It is native to India, Indonesia, and the Malay Archipelago (Sandal wood uses… effects, 2017). Certain cultures place great significance on its fragrant and medicinal qualities. It is also considered sacred in some religions and is used in different religious traditions. The high value of the species has caused its past exploitation, to the point where the wild population is vulnerable to extinction. Indian sandalwood still commands high prices for its essential oil, but due to lack of sizable trees it is no longer used for fine work as this wood can work. The plant is widely cultivated and long lived, although harvest is only viable after many years. Etymologically it is derived from Sanskrit (चन्दनं) *chandanam* (www.etymonline.com).

A flowering twig of white sandal (*Santaalum album* L.)

The height of the evergreen tree is between 4 and 9 metres. They may live to one hundred years of age. The tree is variable in habit, usually upright to sprawling, and may intertwine with other species. The plant parasitises the roots of other tree species, with a haustorium adaptation on its own roots, but without major detriment to its hosts. An individual will form a non-obligate relationship with a number of other plants. Up to 300 species (including its own) can host the tree's development - supplying macronutrients phosphorus, nitrogen and potassium, and shade - especially during early phases of development. It may propagate itself through wood suckering during its early development, establishing small stands. The reddish or brown bark can be almost black and is smooth in young trees, becoming cracked with a red reveal. The heartwood is pale green to white as the common name indicates. The leaves are thin, opposite and ovate to lanceolate in shape. Glabrous surface is shiny and bright green, with a glaucous pale reverse. Fruit is produced after three years, viable seeds after five. These seeds are distributed by birds.

Flowers in Hyderabad, India.

A ripened fruit of *Santalum album* from Panchkhal Valley, Nepal.

Nomenclature

The nomenclature for other "sandalwoods" and the taxonomy of the genus are derived from this species' historical and widespread use. *Santalum album* is included in the family Santalaceae, and is commonly known as white or East Indian sandalwood (*Santalum*, IPNI). The name, *Santalum ovatum*, used by Robert Brown in *Prodromus Florae Novae Hollandiae* (1810) was described as a synonym of this species by Alex George in 1984 (George and Hewson, 1984). The epithet *album* refers to the 'white' of the heartwood.

The species was the first to be known as sandalwood. Other species in the genus *Santalum*, such as the Australian *S. spicatum*, are also referred to as true sandalwoods, to distinguish them from trees with similar-smelling wood or oil.

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

There are at least 3 kinds of Sandal namely White Sandal (*Santalum album)* called ‘Sweta Chandana’, Red Sandal (*Pterocarpus santalinus)* called ‘Rakta Chandana’ and interior Sandal Ku-chandana (*Adenanthera pavonina).* These plants belong to different species and

families and have different properties as evidenced from their synonyms. Sandal is a moderate sized evergreen large shrubs or small trees (*S. spicatum*) to tall trees of 12-15 m. in height (*S. album* in India and *S. paniculatum* in Hawaii) and the girth of 1.0 -2.4 m. (Sen Sarma, 1982). The species (*S. album)* is distributed from Indonesia in the West to Juan Fernandez Islands in the East and from Hawaiian Archipelago in the North (30^{o} N) to New Zealand in the South (40^{o} S). It is believed that Sandal was introduced to India from Timor in Indonesia (Shetty, 1977). In India, *S. album* is mainly distributed in the Deccan Plateau. The total extent of its distribution is around 9600 km^2 of which 8200 km^2 is in the states of Karnataka & Tamilnadu (Srinivasan *et al*., 1992) and in Karnataka, Tamil Nadu & Kerala (Srimathi et al.,1995). Sandal is also found distributed in Andhra Pradesh, Maharastra, Madhya Pradesh, Orissa, Rajasthan, U.P., Bihar and Manipur. In Tamil Nadu, Sandal trees are distributed (3045 km^2) mainly in Javadis & Yelagiri hills & Nilgiri hills. In Andha Pradesh (175km^2), it is mainly distributed in Chittoor, Cuddapah, Hyderabad & Kurnool districts. In Madhya Pradesh (33 km^2), it is found scattered in Forest Divisions of Sehora, Sagar & Seoni. In Kerala (7 km^2) in Wayanad, Marayoor & Tenmalai,. In Maharastra (8 km^2), they are spread in small pockets only. In Orissa (25 km^2), it is found in Joypore, Kalahandi & Parlekmandi Forest Division. In Uttar Pradesh, sandal trees occur naturally in small patches in forests and attempts have been made for artificial regeneration. Only few thousand trees are located in Kangra valley near Jwala devi of Himachal Pradesh. Occurrence of sandal has also been reported in Manipur & Gujarat states (ICFRE,1992).

Ecologically sandal has adapted various agro - climatic and soil conditions for *in situ* regeneration with an exception of waterlogged areas and very cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain *et al*., 1998). The provenances vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of *Santalum album* in India (Srinivasan *et al*., 1992).

Distribution of *Santalum album* is also found outside India, e.g. in Sri Lanka and South East Asia (Timor, Indonesia, Malaysia, Cambodia, Vietnam, Myanmar, Thailand and China), the Pacific (Papua New Guinea, Fiji, New Caledonia and Hawaii) and to some extent northwest of Western Australia (Kanunurra). Recently the Govt. of Australia had undertaken the venture of commercial cultivation of Sandalwood specially they considered the Indian Sandalwood species (*Santalum album*) is the best due to its higher oil (β-Santalol) content.

In Sri Lanka natural stands of sandalwood are present in the districts of Kandy, Nuwara Eliya, Ratnapura and Badulla belonging to the wet and intermediate climatic zones (Panabokke, 1996; Mapa et al., 1999). It is believed that *S. album* is an exotic in India, having been taken there from East Indonesia by traders of the fragrant wood and holding a pre-eminent position in the Indonesian island (Malay Archipelago), Timor(Ajaubaki, Siso, Buat, Niki –Niki, Kokoi and Netpala districts) (Effendi, 1994) and to a small extent in Alor, Roti, Sumba and Flores islands. There are two types of *S. album* found across Timor, a small-leaf variety & a large-leaf variety (Harisetijono and Suriamihardja, 1993). In Australia, a small naturalized area in the northwest of Western Australia which is believed to have been established through the activities of Mallacan traders. *S. album* was believed to be first grown experimentally in the Ord River Irrigation Area, Kununurra Western Australia in 1983. The first private sector commercial plantations of *S. album* were established in Kununurra in 1999 (Clarke, 2006).

Sapwood is white to pale yellow, sharply demarcated from the yellowish brown to dark brown heartwood, hard, heavy, lustrous, straight-grained to slightly wavy, fine textured with pleasant characteristic smell (Rao *et al*., 2007). Sandalwood trees are famous and very costly because of its fragrant heartwood and oil.

White Sandal (*Santalum album* L.) was tried in various locations of South West Bengal since nineteen sixties. The area has predominantly laterite soil having rainfall from 1200mm to 1600mm with maximum temperature $45C^0$ and minimum temperature $7C^0$. To ensure protection, Sandal was grown in various forests Range & Beat Office compounds located in the district of Bankura, Birbhum, Burdwan, Purulia and West Midnapur bringing quality seeds from Institute of Wood Science and Technology (IWST), Bangalore time to time. Sandal is one of the very few tree species in which research has been carried out for more than a century. The demand for Sandalwood and Oil is increasing and the gap between demand and supply is widening. To bridge the gap between demand and supply, afforestation and plantation programme should aim at increasing the productivity of plantations.

In sixties Sandalwood trees were also planted in Hirbundh Beat Office compound under Khatra Range of Bankura District. Trees started flowering after 10-12 years and lot of natural regeneration has started coming up in Hirbundh Block both in forest areas and in the adjoining non-forest areas of the Block. But very few records of growth and yield of white sandals grown in South West Bengal is available. An attempt was being taken in 2009-10 to study growth & yield of sandal trees grown in Hirbundh Beat office compound of Khatra Range in Bankura (South) Division (Das, 2013).

Some hindrances and problems for its propagation were observed by various workers in these areas. Keeping all these views in mind we are going to undertake the venture for its mass propagation through seeds and its cultivation with their agronomical maintenance properly.

Status of Sandalwood in West Bengal

White Sandal is an exotic in West Bengal. The principal sandal tracks are confined to some parts of Karnataka (70%), Kerala & Tamilnadu, though it is reported in other parts of India sporadically. It thrives best at an elevation of 600 to 900 m. It was tried experimentally in Sukna & Arabari nurseries in 1960s. Sandalwood (*Santalum album* L.) is found mostly in the laterite tracts having rainfall from 1200mm to 1600mm with maximum temperature $45C^0$ and minimum temperature $7C^0$ of the following areas of South West Bengal both in forest area and in adjoining non-forest areas of the blocks.

S. album is recognized as a "vulnerable" species by the International Union for the Conservation of Nature (IUCN; Conservation and Environmental (Sandalwoodoilspecialist.com). It is threatened by over-exploitation and degradation to habitat through altered land use, fire (to which this species is extremely sensitive), Spike disease, agriculture, and land-clearing are the factors of most concern. To preserve this vulnerable resource from over-exploitation, legislation protects the species, and cultivation is researched and developed (www. newcrops.ug.au; Australian Arid Land; Archived copy, PDF, 2007).

Until 2002, individuals in India were not allowed to grow sandalwood. Due to its scarcity, sandalwood is not allowed to be cut or harvested by individuals. The State grants specific permission to officials who then can cut down the tree and sell its wood (Vijoy Hema, 2017). The Indian government has placed a ban on the export of the timber (Asian Regn Work, 1998).

General Information

Sandalwood is a small, very slow-growing, elegant, evergreen shrub or tree, growing from 4 - 20 metres tall. The bole can have a diameter of around 20cm. A semi-parasitic plant, it depends on the presence of certain other tree species, especially nitrogen-fixing species, in order to obtain part of its nutrition.

The plant has a very long history of use, being highly valued for its sweet fragrance and used as a medicine, perfume and incense in the East for at least 4,000 years. The plant has special significance in Hindu devotional practices, but is also commonly used by Buddhists, Muslims and many other people. The tree has many other uses and is often cultivated in parts of tropical Asia and Australia for its essential oil, which is used in perfumery, as a food flavouring etc. Fire, grazing and most importantly exploitation of the wood for fine furniture and carving and also oil are threatening the species. Smuggling has assumed alarming proportions. The plant is classified as 'Vulnerable' in the IUCN Red List of Threatened Species (2011).

Cultivation Details

Grows in tropical and subtropical areas, usually at elevations below 1,200 metres but occasionally as high as 2,500 metres. The reported temperature range for growth is 10 - 38Â°c, with the optimum between 22 - 30Â°c. It can survive temperatures down to 2Â°c. The reported annual rainfall range for growth is 450 - 2,500mm, with the optimum between 800 - 1,400mm.

Prefers a fertile, moist but well drained soil in sun or partial shade. Prefers a slightly acid soil and a position in full sun. Highest quality essential oils are produced when the tree is grown in dry, rocky areas. Established plants are fairly drought tolerant. Dislikes waterlogged soils. Prefers a pH in the range 6 – 7, tolerating 5 – 9.

A semi-parasitic plant, obtaining some of its nutrient from the roots of other plants. The plant has green leaves containing chlorophyll, and is thus able to photosynthesize - it relies on host plants only for water and soil nutrients, not for sugars, which it can produce itself. In a natural situation, the plant seems to rely on nitrogen fixing trees such as Acacia and Casuarina, though it is known to parasitize many other legumes, shrubs, herbs and grasses. It normally has more than one host at a time.

A most probable natural host is *Drypetes lasiogyna,* observed to be the most prolific species in the vicinity of *S. Album*.

The species is spread rapidly through seed dispersal by birds, which feed on the outer fleshy pericarp. Viable seed production occurs when the tree is 5 years old. Sandalwood is highly valued for its fragrant heartwood which is used as a timber and source of an essential oil However, because it is very slow growing, taking up to 40 years to develop its heartwood fully, the tree has been overexploited and has become endangered in the wild.

It is desirable not to clean-weed all-round the sandal seedlings, as the roots form haustorial connections with adjoining weed growth.

It has been suggested that the original source of the incense in India may have been *Pterocarpus santalinus* (red sandalwood), and that this was gradually replaced by *Santalum album* after its introduction from Indonesia.

Botanical classification

Common names

Taxonomic position of *Santalum album* –

Kingdom – Plantae;

Division – Magnoliophyta;

Sub division – Magnoliophytina;

Class – Magnoliopside;

Subclass – Rosidae;

Superorder – Santalanae ;

Order – Santalales;

Suborder – Santalineae ;

Family – Santalaceae;

Subfamily – Santaloideae;

Tribe- Santalaceae;

Subtribe –Santalinae;

Genus – *Santalum*;

Species – *Santalum album*.

Indian Sandalwood, White Sandalwood (English); Chandana, Hari-chandana (Sanskrit); Chandan (Hindi); Chandan (Bengali, Punjabi); Srigandha, Chandana (Kannada); Chandanam (Malayalam); Santhanam, Srigandhara (Tamil); Chandanamu, Hari-chandanam (Telugu); Boga chandon (Assamese); Cha-chandan (Manipuri); Chandono, Gondassaro (Oriya); Sukhad, Suket (Gujarati); Sukhad (Sindhi). Bois de santal (French); Sandelholz (German); Sandalo (Spanish); Sandalo (Italy); Sandalo branco; (Portugese); behman surkh, sandal-abiyaz, sandale-abiaz (Arabic); Sandal suped, Sandale-suped (Persian); Sandal safaid (Urdu); vitt sandelträd (Swedish); Cendana (Indonesia), Ai nitu (Sumba), Hau meni (Timor), Chendana (Malaysia).

The most common and widely accept fragrant tree referred to as Sandalwood tree is from the family Santalaceae and belongs to genus *Santalum*. Santalaceae consists of 29 genera with ~400 species, out which 19 species are specific to Santalum genus (Fox 2000; Harbaugh 2007; Harbaugh and Baldwin 2007; Nageswara Rao et al., 2010; Harbaugh et al., 2010; Butaud 2015, Teixeira da Silva et al., 2016). Though various authors differ in reports regarding the genera or number of species, Teixeira da Silva et al. (2016) report that considering the Plant List (2015), only 12 species names are accepted while 41 remain unresolved. Out of the 18 species listed by them, one of the species *Santalum fernandezianum* has been reported to be extinct.

Therefore, there is a stress on diverting attention particularly in the area of taxonomy of the genera. Among various Santalum species, Indian Sandalwood (*Santalum album*) also sometimes referred as East Indian Sandalwood stands out for its highly valued oil and wood. Sandalwood and oil have earned some popular sobriquets like Dollar earning parasite, Queen of Essential oil and such others. Indian Sandal wood is naturally distributed from 30 N to 40 S, from Indonesia in the east to Juan Fernandez Islands (Chile) in the west and from Hawaiian Archipelago in the north to New Zealand in the south (Srinivasan, 1992). The first Sandalwood survey carried out in India during 1977-78. It revealed that Sandalwood has been found to be distributed all over the country with Southern part of Karnataka and Northern part of Tamil Nadu being the natural area. It was estimated that ~90% of the population was found in these two states covering an approximate area of 8300 sq. kms. Other peninsular states in which Sandalwood is found include Kerala and Andhra Pradesh. Isolated populations have been reported in various states such as Bihar, Gujarat, Haryana, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Recently some of the other states in which Sandalwood is reported are Himachal

Pradesh and Assam. Sandalwood is a moderate sized evergreen tree that can attain a girth of 1 to 2.4 metres and height of 12 to 15 metres (Sen Sarma, 1982). The branches are erect as well as slenderly drooped. Sandalwood grows well in early

Know Your Trees – stages under partial shade but being a light demander, at the middle and late stages shows intolerance to heavy overhead shade. Sandalwood is not an exacting species and the tree grows well under varied set of conditions such as from sea level up to 1800 m altitude, moderate rainfall of 600 to 1600mm, in cool climate with long periods of dry weather (Troup, 1921). It also adapts well in different type of soils like sand, clay, red soils, laterite loam and even in black cotton soils, but has a preference for red ferruginous loam with varying fertility (Singh, 1995). However, it does not come up well in water logged or very cold areas.

Trees growing on stony or gravelly soils are known to have higher scented wood. Bark is reddish brown or dark brown in colour. The inner part of the bark is red. It is smooth in young trees, and becomes rough with deep vertical cracks as tree matures. Leaves are opposite, sometimes alternate, occasionally ovate or ovate-lanceolate, 1.5 to 3 inch long, sometimes larger in fertile localities, glabrous and shining above and glaucous beneath (Kulkarni, 1995). Young leaf is lush green or pinkish green and is truly evergreen (in very dry places it sheds its leaf). The colour of matured leaves varies from bluish to greenish yellow (Srimathi et al., 1983). The crown has varied shapes like conical, round, obovate, elliptic or irregular. Prediction of seed production based on dimensions reveals that crown size especially length, has positive correlation to fruit production (Susila et al., 1995). Initially, the flowers are straw yellow coloured and gradually turn to deep purplish brown on maturation. The flowers occur in axillary or terminal cymose panicles that are shorter than leaves and the floral organs develop in acropetal succession. It takes 30 to 35 days from initiation of bud stage to the anthesis and 85 to 95 days from initial stage to ripening of the fruit (Srinivasan et al. 1992). Generally, the tree starts flowering at an early age of 2 to 3 years and flowering and fruiting season vary. Flowering time differs according to altitude. Trees growing in lower altitudes initiate flowering about a month earlier than those growing in higher altitude (Susila et al., 1995). According to Brandis (1906) the flowering season is from February to July. Based on the flowering calendar, Ananthapadmanabha et al. (1991) classified sandalwood trees into three distinct groups i) Trees flowering twice a year (Once during March – May and second time during Phenology, Reproductive Biology and Breeding System September – December) ii) Trees flowering once a year (September – December) and iii) Trees which do not flower even after 15 years of age. It has been described that the breeding

system of *Santalum* species in general is facultatively allogamous with variation found between families and individuals at the level of self-incompatibility and having no ability for apomixis or parthenocarpy (Ma et al., 2006; Muir et al., 2007; Tamla et al., 2012, Page et al., 2012). This nature of outcrossing and the ability to self-fertilize has provided an advantage for *Santalum* species to grow and survive in new areas (Teixeira da Silva et al., 2016).

Chromosome number of *S. album* was reported as 2n = 20 and with basic chromosome number x = 10 (Rao, 1942; Goldblatt and Johnson, 2000; Harbaugh, 2008). In a recent study on Know Your Trees - Indian Sandalwood karyotype analysis conducted by Zhang et al. (2010), for the first time a mixoploid was found (2n = 2x = 20 and 2n = 4x = 40). They also found predominance of chromosomes with centromeres in a median position and a few sub median centromeres. The authors also mention that considering the karyotypic analysis, S. album is a more primitive taxon. However, they stress that the occurrence of polyploidy and mixoploidy needs further investigation giving due importance to the geographical distribution. Even though there is definite geographical isolation and considerable morphological variation between *Santalum* species, reports indicate that viable hybrid progeny has been developed for crosses between *S. album* with each of *S. austrocaledonicum* (Tamla et al., 2011), S. lanceolatum (Tamla et al., 2011), and S. yasi (Bulai and Nataniela 2005; Doran et al., 2005).

The fruits are succulent drupes, 0.3 to 0.5 inch in diameter and purplish black when fully mature. The colour of the fruit changes from green to purplish black at maturity. The fruit has a single seed with brown endocarp which is moderately hard. The fruit shape varies from globose, ovate to elongate and sometimes show tapering ends. Some plants have large fruits, while others persistently bear smaller ones. The base of the fruits may be round or smooth or elongated and swollen. The green fruits are considered matured when they are purplish black in colour. It is suggested to clean the floor beneath the tree so that the fruits fallen on the ground may be collected. As the fruit pulp is susceptible to fungal infection, the fruits are soaked in water and pulp is rubbed on a rough surface so that seeds are obtained.

Seed Collection, Processing and Nursery Techniques shade to remove the excess of moisture. Direct sun drying should be avoided as it causes a significant reduction in seed viability (Setiadi and Komar, 2001).The seeds are spherical with a diameter of 0.5 - 1cm and the weight ranges from 0.1 to 0.2g. The seeds may be grouped based on the size and weight as small, medium and big. Nagaveni and Ananthapadmanabha (1986), found that in a seed lot, 82 to 87% were medium sized seeds (0.1-to-0.2-gram seed weight and 7 to 8 mm size). The weight

of seed is inversely proportional to the rate of germination and directly proportional to the seedling vigour. The seeds have inherent morphophysiological dormancy (Baskin and Baskin 1998) which is non deep simple (Dileepa et al., 2015) and seeds can be treated with Gibberellic acid solution (500ppm w/v) for 16 to 24 hours prior to sowing in the germination beds for better and uniform germination. It has been observed that November-

December is the ideal time to start raising sandalwood seedling in nursery as seedlings can be made available by July i.e. just before monsoon for field planting (Sivaramakrishnan et al., 1984). For germination, sand has been found to be the best medium. A germination tray or germination bed of one square meter can be used for germination of seeds. Srinivasan et al. (1992) recommended nursery bed of sand and soil in the ratio 1:3 for seed germination and sowing of 500 g of seed / sq.m. bed, from which about 1500 seedlings can be expected. Sandalwood seed has epigeal form of germination in which the radicle emerges out breaking the seed coat. The hypocotyl elongates with a pronounced arching, the loop Know Your Trees- lndian Sandalwood appearing above ground while cotyledons remain underground. The lower portion of the hypocotyl becomes swollen and fleshy. The nutrients from the albumen are translocated to this swollen hypocotyl which is also referred to as 'carrot' of the seedling. The germination starts from 20 day onwards and continues upto 95 days. The seedlings can be transplanted to polybag when they are at two to three leaf stage. It has been observed that root trainers are better compared to polybags as they avoid root coiling and are easy for handling and transportation. Annapurna et al. (2004; 2005) have recommended the use of 270cc root trainer with potting media containing sand, soil, compost, cocopeat, burnt irice husk and charcoal, in 25:15:50:5:5 ratio, sieved with 6X6 holes/sq. inch to obtain plantable seedlings in 6 months. As Sandalwood is a partial root parasite, they need a host for better survival and growth than those without hosts (Nagarajaiah and Rao, 1993; Shinde et al., 1993). Using leguminous host has distinct advantage over non leguminous hosts (Radomiljac and McComb, 1998). Fox and Doronila (1993) described that a suitable host should have, fine root growth, an even distribution of root growth within the pot, ability to withstand top pruning, low level of competition, low allelopathic influences, low growth structure, hemi parasitic compatibility.

Tree Improvement

Tree improvement work in Sandalwood gained momentum in 1977 when Sandal Research Centre was established by Government of India, which was located in the present campus of Institute of Wood Science and Technology, Bangalore. The first Sandalwood survey was carried out to document the extent of distribution of Sandalwood in India in terms of population density, tree size and extent of heartwood. During the process of survey, successful efforts were made in identifying superior genotypes by using various criteria such as growth rate, heartwood per cent, oil content, resistance to spike disease, heartwood rot and borer infestation (Srimathi, 1995).

A total of 79 plus trees were identified From different sandalwood growing states of South India, namely, Karnataka, Tamil Nadu, Andhra Pradesh and Kerala,. Tree improvement related activities in sandalwood gained momentum during 1980 to 1984 as evident in the table1. From tree improvement perspective, documenting variability in a tree species is a pre requisite before initiating any tree improvement programme. Considering this fact, numerous researchers have reported variability Table 1. Sandal tree improvement research plots established during 1980 to 1984.

Variability in flowering and fruit size has already mentioned. There is variation with reference to colour, texture and thickness in case of bark and Rust coloured bark is associated with fast growth in sandal, while six types of leaves - ovate, lanceolate, elliptic, linear, small and big have been identified (Kulkarni and Srimathi, 1982) and the most common being ovate leaves. Sandalwood trees generally flower twice in a year (60% of trees) while 36% trees flower once in a year and 4 % of trees flower throughout the year (Ananthapadmanabha et al., 1991). Various researchers have reported variability in seed trait such as size, shape, germination and vigour (Nagaveni and Ananthapadmanabha, 1986; Veerendra and Sarma, 1990; Ramalakshmi and Rangaswamy 1997; Annapurna et al., 2005).

Three phenotypes have been identified in Sandalwood namely - Thindlu, Chickballapur and Robust type by Srimathi et al. (1983). Thindlu sandal type was characterised by small diameter class trees around four to eight cm diameter at breast height having dark brown bark that comes out in irregular flakes and the heartwood being dark brown in colour. Chickballapur type was found to have small bluish green leaves similar to spiked plant and with broad sapwood. Robust type had compact crown with lush green foliage, thick sapwood and fast

growing as compared to all other types. The two commercially important traits having significant interest among researchers is the heartwood and oil. Various researchers have suggested, described or debated on different aspects of heartwood and oil (Cameron, 1894; Rama Rao, 1904; Puran Singh 1911, 1915; Troup 1921 and Fischer, 1927) but none could give a=ny satisfactory evidence as regards heartwood and oil.

In 1941, 5 Silvicultural Conference held at Dehra Dun received only three papers pertaining to heartwood and oil (Mitchell, 1941; Laurie, 1941 and Venkata Rao, 1941). Rao (1959) while discussing the future of tree genetics in India, emphasized that heartwood formation and its progress have to be critically observed using core samples. The importance of studying heartwood and oil was stressed even in First All India Sandal Seminar was held at Bangalore, Karnataka (Kaikini, 1977) and in the Second All India Sandal Seminar held later at Salem, Tamil Nadu (Shanmuganathan, 1981). Studies on heartwood have always been intriguing. Srimathi and Kulkarni (1980) carried out a study on variation in heartwood content among same girth trees growing in a single locality. They found enormous variability in heartwood content among the trees as 13% of the trees did not have heartwood. They opined that heartwood formation can start as early as five to six years in some of the trees and can be as late as over 15 years in other trees. A similar study conducted on 14-year-old Sandalwood trees in Australia by Brand et al. (2006) found that heartwood had not been formed in 20% of the trees. Arun Kumar (2005) reported considerable variability existed for heartwood diameter and oil in a known aged clonal germplasm bank of Sandalwood. From the perspective of selecting superior genotypes, Arun Kumar et al. (2011) reported that there was strong positive relationship between tree diameter and heartwood diameter. However, the intriguing story of heartwood and oil still continues. IWST identified nine sandalwood provenances across the country on the basis of population density, phenotypic character, latitude and longitude. The nine provenances were Bangalore, Tangali and Mandagadde from Karnataka, Chitteri and Javadi Hills from Tamil Nadu, Marayoor from Kerala, Koraput from Orissa, Seoni from Madhya Pradesh and Horsley Hills (Chittoor East) from Andhra Pradesh (Jain et al., 1998). Jayappa et al. (1981) studied regional variation in yield and quality of sandal oil. Wood samples used for this study were roots, Jaj, and Milwa (which are different heartwood grades of Sandalwood). Samples were collected from Shimoga, Hassan, Tarikere, Dharwad, Mysore, Salem and Satyamangalam and results are depicted in table below:

Table -1. 1: Showing distribution of Sandalwood in South - West Bengal.

Name of Division	Name of Range	Mouza where white Sandal is found	No. of Trees	Girth class	Remarks
Midnapur Division	Arabari Range	1.Arabari , 2.Burisal 3.Ghagra, 4.Chandmura	6,000 -8,000	< 20 cm bhg	Mostly natural regeneration
Bankura (S) Division	Hirbandh Range	1.Hirbandh (Forest) 2.Amjuri (Forest) 3.Basudevpur (Private) 4.Chakadoba (Private)	3840 316 1920 227	< 10-60 cm bhg < 10-50 cm bhg < 10-50 cm bhg < 10-30 cm bhg	
Burdwan Division	Guskara Range	Karotia (Aushgram Beat)	Forest land – 100, Private land - 150	20 – 40 cm bhg 10 – 30cm bhg	
	Panagarh Range	i) Khandari,(Forest) ii) Natungram, Kota, Gopalmath (Private)	2000 500	<30cm bhg 20-50cm bhg	
	Aara Range	Rest House compound	50	30-50cm bhg	
Birbhum Division	Bolpur Range	Bolpur Forest	20 04	< 20 cm bhg 20-40 cm bhg	

Table- 1.2: Detailed enumeration of Sandalwood trees in Bankura (South) Division, W.B., India

Girth Class	Mouza where Sandal wood trees are found			
	Forest bearing mouza		Non -forest mouzas adjacent to Hirbandh forest	
	Hirbandh	Amjuri	Basudevpur	Chakadoba
< 10 cm bhg	1850	250	1500	150
11-20 cm bhg	1150	38	200	40
21-30 cm bhg	450	20	150	37
31-40 cm bhg	250	6	35	0
41-50 cm bhg	130	2	25	0
51-60 cm bhg	10	0	0	0
Total no. of Trees	**3840**	**316**	**1920**	**227**

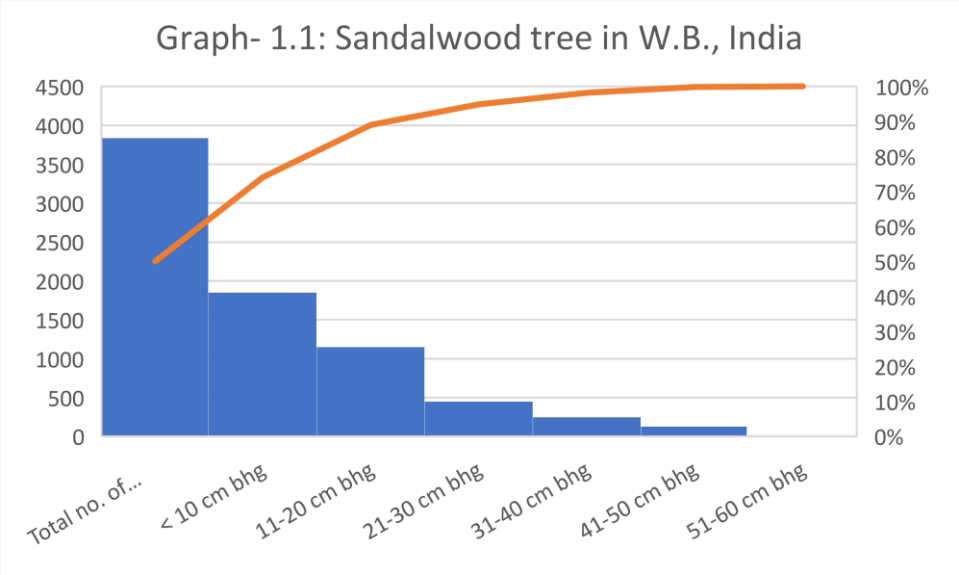
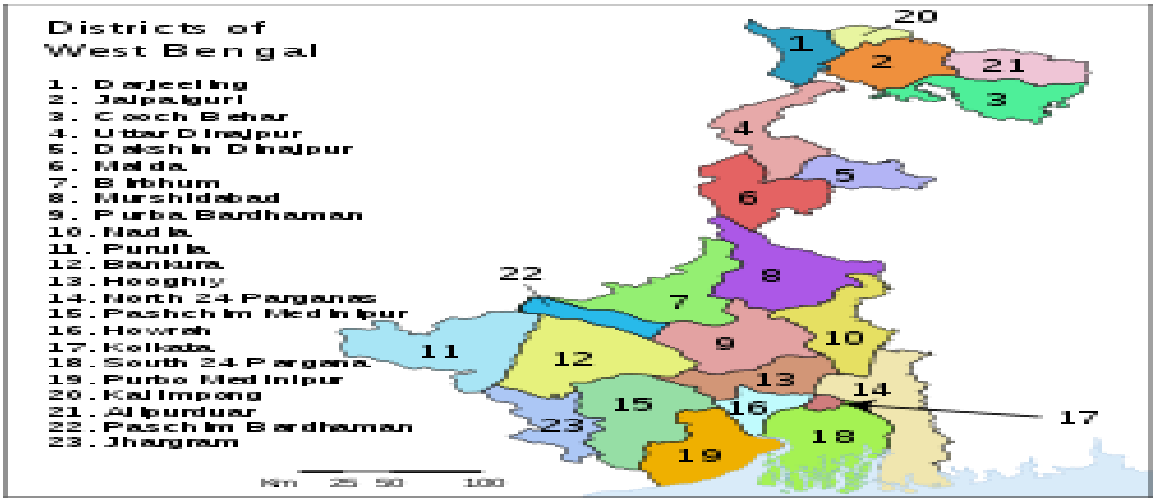


Table- 1.3: Detailed enumeration of Sandalwood trees in India

Girth Class	Mouza where Sandal wood trees are found			
	Forest bearing mouza		Non -forest mouzas adjacent to Hirbandh forest	
	Hirbandh	Amjuri	Basudevpur	Chakadoba
< 10 cm bhg	1850	250	1500	150
11-20 cm bhg	1150	38	200	40
21-30 cm bhg	450	20	150	37
31-40 cm bhg	250	6	35	0
41-50 cm bhg	130	2	25	0
51-60 cm bhg	10	0	0	0
Total no. of Trees	**3840**	**316**	**1920**	**227**

Figure-1.1: Showing site of study [West Bengal, India]



This study was conducted in Khandari (Burdwan), Basudevpur (Bankura), Bagaldhara (Bankura), and Rangamati (Bankura) , W. B., India

Figure-1.2: Showing site of study [Nepal]

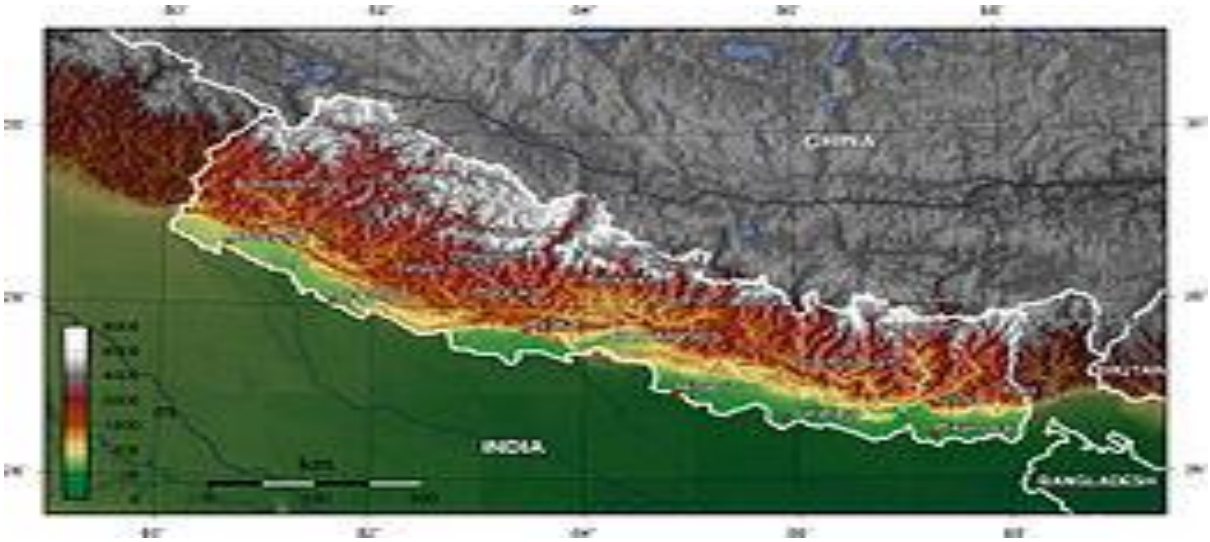


Table- 1.4: Nepal's highest mountains

Mountain	Height		Section	Location
Mount Everest (Highest in world)	8,848 m	29,029ft	Khumbu Mahalangur	Khumjung VDC, Solukhumbu District, Sagarmatha Zone (Nepal-China Border)
Kangchenjunga (3rd highest)	8,586 m	27,940 ft	kangchenjunga	Lelep VDC/ Yaamphudin VDC, Taplejung District, Mechi Zone (Nepal-Sikkim Border)
Lhotse (4th highest)	8,516 m	27,940 ft	Everest Group	Khumjung VDC, Solukhumbu District, Sagarmatha Zone (Nepal-China Border)
Makalu (5th highest)	8,462 m	27,762 ft	Makalu Mahalangur	Makalu VDC, Sankhuwasabha District, Kosi Zone (Nepal-China Border)
Cho Oyu (6th highest)	8,201 m	26,906 ft	Khumbu Mahalangur	Khumjung VDC, Solukhumbu Sagarmatha Zone (Nepal-China Border)
Dhaulagiri (7th highest)	8,167 m	26,795 ft	Dhaulagiri	Mudi VDC, Myagdi District, Dhawalagiri Zone

Manaslu (8th highest)	8,156 m	26,759 ft	Mansiri	Samagaun VDC, Gorkha Manang District, Gandaki Zone

Morphology and Phenology :

- Sandalwood is an evergreen tree, partial root parasite, generally grows in the dry, deciduous forests of the Deccan Plateau, and attains a height of 12 of 15 meters and a girth of 1 to 2.4 meters with slender drooping as well as erect branching.
- Bark is reddish brown or dark brown in colour, smooth in young trees and becomes rough with deep vertical cracks as the tree matures.
- Leaves are opposite and decussate, and sometime show whorled arrangement.
- Flowers are unscented straw yellow coloured at initiation but turns to deep purplish brown on maturation. They occur in axillary or terminal cymose panicles. The tree starts flowering at an early age of 4 – 5 years and flowering and fruiting season vary. Generally, tree flowers twice a year from March to May and September to November.
- The fruit is succulent drupe, purplish black when fully mature and single seeded. The shape of the fruit varies from globose, ovate to elongate. The colour of the fruit changes from green to purplish black at maturity.
- Fresh purple coloured fruits are preferably collected from the trees or those fallen on the ground. The fruits are collected during April - May and November - December. The seeds of both the season are similar in quality. Fruits are depuled by rubbing. The depulped seed are dried in shade, treated with fungicide and stored in air tight container.
- Seed weight is 6000 seeds/kg. The seed viability can be maintained for longer period when stored at low temperature (5^0C) in air tight container.

Photo- 1.1: A sandalwood tree

Photo- 1.2: Flowering twigs of sandal

Photo- 1.3: Mature heartwood of sandal

Photo- 1.4: Fruits of sandal

Photo 5: Varied Seed coat colour of sandalwood

Photo 6: Seeds of sandalwood

Biological Phenomenon:

- Sandalwood is an evergreen tree, partial root parasite, generally grows in the dry, deciduous forests of the Deccan Plateau, and attains a height of 12 of 15 meters and a girth of 1 to 2.4 meters with slender drooping as well as erect branching.
- Bark is reddish brown or dark brown in colour, smooth in young trees and becomes rough with deep vertical cracks as the tree matures.
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- Seed weight is 6000 seeds/kg. The seed viability can be maintained for longer period when stored at low temperature (5^0C) in air tight container.

Moto of Study

- Manipulation of seed germination of Sandal by different concentrations of GA_3.
- To explore the suitable conditions for the proper growth of this plant with various associated plants in Bankura and Burdwan districts, West Bengal, India and Nepal in forest areas and private gardens.
- Quantitative assessment of growth data till its establishment.

- To study any morphogenetic peculiarities & differential seeding of each type.
- To assess the qualitative parameters through biochemical analyses.

Required Types of Soil:

Sothers (1928) in the Working Plan for the sandal forests of the Khanapur, Nagargali and Gijnal Ranges observed laterite as the most common underlying rock in the higher hills with schists and trap rock on the north-west and an out crop of crystalline limestone on the south-west respectively. A detailed account of the geology, rock and soils of sandal bearing areas of the districts of North Kanara, Balgaum, Dharwar and Bijapur of Karnataka which were part of the erstwhile state of Bombay has been reported by Qureshi (1955).

In Malwa plateau of Gulbarga, Bidar in Karnataka and Bhir and Aurangabad in Maharastra the principle geological formation is Deccan Trap consisting of basalt and dolerite capped up in places by laterite. The soil in the sandal tract is black cotton except in the districts of Bidar and parts of Gulbarga and Bhir, where Deccan Trap being of metamorphic origin contains ferruginous loams commonly called lateritic soils [Khan, 1957].

In the Working Plan of Sirsi-Siddapur sandal bearing areas, Wesley (1970) reported the geologic formation of the area as archaic with characteristic features of laterisation. In Coimbatore Central Division of Tamil Nadu, sandal is found in almost every type of soil. Is is found in stony red soil along the higher reaches of Moyar valley, on alluvial soil along Hallurhalla, on rich loams in Hulical, Kallar, Jacanare Reserve Forest and shallow gravelly soil on the Melur and Pillur slopes [Jayaraman, 1973]. The dolerite dykes have weathered into characteristic spheroidal boulders and to reddish clayey soil [Rajagopal Shetty, 1981]. It has been reported that sandal occurs also on sandy soil of Quilon, Kerala [Rama Rao, 1908b]

A study of the soils of sandal bearing areas of Karnataka, Tamil Nadu and Kerala for their morphology, physical and chemical properties was made by Rangaswamy, *et al.,* (1986a). in Wattle plantation of Teragalli and Londa of Khanapur range, where sandal occurs, the soil pH varied from 6.7 to 7.5 [Quireshi, 1955]. The texture of soil in A, B and C horizons is sandy clay, clayey and gravelly loam respectively [Krishnamurthy *et al.*, 1983].

Sandal requires good drainage and does not stand water logged ground. Best growth of tree is on rich fairly moist soil such as garden loam and well drained deep

alluvium on the river banks [Troup, 1921]. A significant relationship between available nitrogen content in 'A' horizon and annual growth increment was observed in the soil of Talaalai range [Krishnamurthy *et al.*, 1983]. In a study carried out by Jain *et al.*, (1988) on soil properties and their relationship to the growth of sandal in three areas it is observed that lime status, water holding capacity, pore space, volume expansion on wetting, exchangeable calcium and magnesium and available potash, exert positive influence on the increment in girth and height. Requirement of host for proper growth of sandal was demonstrated in a field study by Ananthapadmanabha *et al.,* (1984). Further analysis of soil and leaf samples from this has shown that sandal depends on its host for potassium, phosphorous and magnesium [Rangaswamy *et al.*, 1986b]. Sandal can draw other nutrients directly from soil as its roots have good cation exchange capacity [Parthasarathi *et al.*, 1971]. It is believed that the wood with finest odour is obtained from the driest region particularly on red or stony ground [Gunther, 1952] and that yield of oil will be much higher than those grown in fertile tracts [Bhatnagar, 1965]. Puran Singh (1911) determined the variation in the oil content growing in different locations in different soils. This observation was supported by opinion expressed by Gildemeister and Hoffman (1952), that the wood of trees growing in 5 dry rocky mountainous soil is harder and richer in oil than those growing on fertile ones. It was also clear that the only factor which appears to influence the percentage of oil is the soil [Puran Singh, 1915]. However, Sreenivasaya and Rangaswamy (1931) are of the opinion that sandal growing on rocky soil and in association with xerophytic conditions having higher proportion of soil bearing heartwood than the one thriving on fertile soil enjoying good rainfall and nourished by vigorous hosts, are not comparable since in one case growth is exceedingly slow while in the other girth increment is rapid. In Pachamalai forests of Tiruchirapalli forest division the trees on the lower slopes and plains are generally stunted and poor in heartwood while those on the higher slopes and particularly those on the plateau have good growth with better development of heartwood [Bhaskardoss, 1968]. Heartwood formation in sandal trees on the sandy loams of the sea coast of Bhatkal and Honnavar was not as good as on the table land of the North Kanara district [Qureshi, 1955]. But in the forest college campus, where the soil is shallow and has pebbles and boulders, the sandal trees of even 30-45 cm girth had little or no heartwood [Nayar, 1974]. Ahir *et al* (2014) carried out studies to find the effect of soil type on the growth of Indian Sandalwood (*Santalum album* L.) and observed that survival and overall growth of six month old seedlings for height, collar diameter and survival rate were similar in potting medium having red and yellow soil type.

Growing and Cultivation of Trees:

Seed:

Generally, Sandal tree flowers twice a year from March to May and September to November. The fruits are collected during March / April and November / December. Fruits are depulped by rubbing, dried in shade, treated with fungicide and stored in air tight container. Freshly collected seeds are dormant for a period of 2 months and are viable upto 9 months. Germination is about 60% under field condition (ICFRE,1992). Soaking of seeds in 0.05% Gibberellic acid overnight and sowing ensures uniform germination upto 70% in 60 days [Nagaveni and Srimathi, 1980; 1981a]. About 6000 seeds weigh a kilogram. Rai and Kulkarni (1986) have reported that dibbling of seeds in bushes and sowing of seeds on the mounds in the trench-mound method were the most commonly followed in the past, success rate was normally around 30 - 40%. In sandal seeds, the duration of germination is much prolonged after the dormancy period. It starts in 25 days and reaches hardly 50% in 90 days with 0.05% GA_3 soaking for 16 hours (Das and Tah, 2013).

Planting in container for raising seedlings:

Transplanting of seedlings raised in the nursery is one of the commonly used methods for raising plantations. This method is costly, however, high success rate offsets the cost factor. Watt (1893) had described a method for raising sandal seedlings in the tile cylinders. Initially sandal seedlings alone were grown in baskets or bamboo or tile cylinders. Later, as an improvement of the techniques, host seeds were also introduced in the container. This method was also not successful due to high mortality of seedlings. Narasimhan (1930) reported that mortality is due to attack by fungi, *Phytophthora* sp. and *Rhizoctonia* sp. Nayar *et al.*, (1980) noticed that the death of the seedlings was due to attack by a combination of fungi and nematodes. Keeping this in view, a comprehensive method for raising and management of disease free seedlings was developed [Sivaramakrishnan *et al.,* 1984]. Annapurna et al (2005) enumerated that potting media ingredients sand, soil, compost, burnt rice husk and charcoal in a ratio of 25:15:50:5:5 gave the best growth seedlings and observed many desirable characteristics of suitable ideal potting mixture including low bulk density, good root formation and quick soil anchoring capability and to take part in transport system easily. It has found that texture size and shape had an important role for the proper growth and development due to soil factors.

Cultural Operations:

Nanaya (1949) suggested the sole subsidiary operations on natural sandal forests and prescription of tending in plantations.

All Sandal trees should be tended once in 4 years. Tending is better done from June to November, as far as possible it should be done along with extraction of Sandal. In case of seedlings and saplings, shrubs and plants useful as hosts are retained and other unwanted growths like Lantana should be removed to provide more space for development of Sandal.

Vegetative Propagation:

Vegetative propagation of sandal is done through air layering or through root suckers (adventitious roots). The later method, however, showed greater success [Rao and Srimathi, 1977; Vijayakumar *et al.,* 1981]. Cleft grafting method adopted for clonal multiplication using 8 to 12 month old seedlings gave 60% success [Srimathi, 1983]. A method of vegetative propagation through root cuttings was developed by Uniyal *et al.*, (1985). Success rate is upto 60% in this method.

Keeping all these in mind, this chapter provides us the issues of vegetative propagation of the plant at first through natural root suckers and then artificial propagation methods of stem-cittings and leyering. These experiments were conducted throughout the year and screening of performance of each method in a particular season was executed.

Root suckers

Sucker is a plant part developed from the meristematic part of the root at the base or at a certain developmental zone of root from the parent plant which may be a shrub or tree. Plant propagation through root sucker is an asexual mode of natural propagation and also known as vegetative propagation. Through this strategy of plant propagation mother plant and all of its clones remain genetically identical. As sucker plants are grou of genetically identical clones, it is also known as genet or clonal colony and individual plant in such a population is called as ramet.

In nature, sandal plant propagates vegetatively through its root. Earlier these horizontally scattered roots were called underground stem. These underground roots undergo ramification into secondary and tertiary roots. Plantlets grow from a particular region of this special type of root.

Working Materials and Methods

Plant materials: 1 – 15 years old (available in experimental field) sandal plants grown naturally in two different locations were used for the experiment.

Methos: ground soil of the forest gardens was dug for tracing the root suckers and to find out the connection with the parent plants. The distance between the plant(s) propagated through sucker and the plant was measured to observe the length of root sucker in two location.

Fig. 1: Healthy sucker

Fig.2: selection of sucker

Fig. 3: Plantlet separating from the host plant

Fig. 4: Selecting another one plantlet

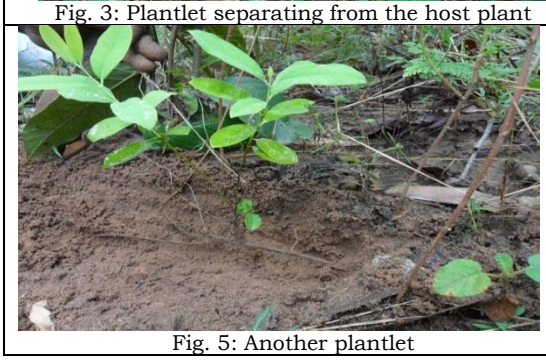

Fig. 5: Another plantlet

Fig. 6: One more plantlet

Photo plates (Root suckers)

Source: Ph.D. thesis, S. Batabyal, Burdwan University, 2015.

Stem cuttings

Four to five years of old sandal plants in the respective location were selected for the propagation work. The juvenile stems were chosen for the experiments.

Several types of vegetative propagation were practiced for multiplication of the parental lines of the experimental plant. In this case experimentation was undertaken for the vegetative propagation by means of stem cuttings with the help of different plant hormones having different concentrations and combinations. With the application of some phyto-hormones like IAA, IBA, GA_3, Kinetin (Cytokinin) and Cutting Aid (mixture of IBA, NAA, PHB, H_3BO_3, Vitamins of unknown ratio) the responses of stem cuttings were investigated. All the growth regulators were used singly and also in combinations. The work was undertaken throughout the year 2011 and 1012. Observations were recorded properly. These experimental findings have been noted and inserted in this context.

Air layering

The layering experiment was performed in different season viz., summer, rainy season, autumn and winter, in Khandari and Hirbandh forest garden of West Bengal. The optimum response was observed in mid rainy season to early autumn i.e. during the month of August-September.

Working Materials and Methods

Materials: Five to seven years old sandal plants (*Santalum album* L.) were selected for study in two locations viz. Hirbandh beat, Bankura(S) Forest Division and Khandari beat, Burdwan Forest Division.

Preparation of soil media: Compost soil was collected from the heap of the organic decomposition of bulk garbage. The mass of de-compost waste initially sun-dried in strong sun-light for 2-3 days before use. Sand and compost (2:1 ratio) treated with 1% liquid insecticide was used for layering experiment.

Phytohormones:

IAA, IBA, Kinetin, GA_3, Cutting Aid.

Wrapping meterials:

Transparent polythene sheet, cocoa coir and paddy straw.

Methods:

Suitable branches of one year growth were selected from 5-7 years old plant. Remove the outer layer of bark of 1.5cm of the juvenile part benath the node of the stem by making it in a ring form. Then mixture of semi-solid moistened materials of different chemical composition and sand-soil mixture were applied to make it a bandage like cover in each cut portion and covered with different wrapping material

separately for the experiment. The both ends of the wrappings were tied with fibre thread to check the entry of water from outside to inside. Root formations were found after 4-6/7 weeks. Observations were strictly maintained root initiation. This experiments were performed repeatedly in different seasons round the year to mark the effectiveness season wise.

Few photographs of the experiment:

Fig.13: Sand-soil mixture

Fig. 14: Tieing with straw

Fig. 15: Showing root formation

Fig.16: Before wrapping

Fig17: Crystal formation before rooting

Fig 18: Showing root prominently

Tissue Culture Technique:

Yeast extract was found to initiate and stimulate the proliferation of sandal endosperm. However, for a satisfactory proliferation an auxin (2-4 D) and a kinin (Kinetin) in conjunction with yeast extract are required [Rangaswamy and Rao, 1963]. Studies in culturing of lateral buds, root tips and haustoria of sandal were also carried out [Srimathi and Sreenivasaya, 1963b]. Induction of embryonal proliferation in sandal was studied and it was found that similarity existed in the morphogenetic potentialities of the embryo of sandal and other angiospermic parasites [Rao, 1965]. Somatic embryogenesis in seedling callus of sandal has been observed by Bapat and Rao (1979). Lakshmi Sita *et al.*, (1982) induced sandalwood somatic embryogenesis from shoot callus cultures derived from 20-25 year old trees. Lakshmi Sita (1986) and co-workers made exhaustive studies in tissue culture of sandal using different types of tissues. Rathore *et al* (2007) described micro propagation methods through axillary shoot proliferation have high potential for rapid and mass production of Clonal planting material of *S. album* from plus trees.

Joshi *et al* (2014) conducted field trial of micropropagated plants of *S. album* and found that the survival is 70% by the end of six months. Mamatha and Rathore (2014) studied the effect of sucrose, agar-agar concentration and pH of the media on somatic embryo induction, maturation and germination from the explants of the mature trees and found that during maturation, size of the somatic embryos increased with increase in the concentration of sucrose in the medium favoring adventitious shoot induction and embryo creaking.

Heartwood Formation :

Cameron (1894) reported that the tree attains commercial maturity at 27-30 years and at this period the heartwood is well developed at a depth of 5 cm below the surface. Ranganathan and Wilson (1934) and Mitchell (1941) observed that trees extracted from open fields or edges of plantation yield more heartwood than those of comparative size extracted from adjoining forests. Rama Rao (1911) from his investigations inferred that hosts influence heartwood formation also, in addition to growth and development. Srimathi and Kulkarni (1980) were of the view that heartwood formation is dependent on genetic factors of the individual tree and the phenotypic factors play only a secondary role.

Heartwood /sapwood ratio in sandal trees in different sandal tracts of Tamilnadu is study by Nayar (1974). He found that in the higher elvations of Mettupalayam Range where soils are fairly rich and trees are of good proportion, the heatwood formation is relatively poor. In Coimbatore where xerophytic conditions prevail even in the trees of smaller girth class (10-18 cm), the heartwood formation was good. But in Forest Collage Campus, where the soil is shallow and has pebbles and boulders, the sandal trees of even 30-45 cm girth had little no heartwood (Nayer,1974).

Growth and Yield:

Sandal is considered as a slow growing tree under forest conditions. Kushalappa (1995), Rai (1990), Nasi and Ehrhat (1997) reported that Sandal responses well to lime application. Application of biofertilizers to trees will greatly improve Sandal growth (Harley & Smith, 1983). Rajagopal Shetty (1977a) reported that growth rate of sandal in Javadis is 1 cm girth at breast height per annum (0.33 cm DBH). Similar growth behavior had also been reported by Ranganathan and Wilson (1934). More or less the same growth rate was observed on the trees in plantations also [Srimathi and Kulkarni, 1980, 1983]. The mean annual diameter increment in trees each from Andhra Pradesh (Horslekonda, Ananthpur district) and

Tamil Nadu (Sanamavu R. F., Salem North) was found to be around 0.287 and 0.195 cm respectively [Sarma and Rai, 1986]. Venkatesan (1980) has reported that though earlier studies had indicated a growth rate of 1.23 cm. girth per year, it could vary from 1 to 5 cm. per year. The relationship between DBH (X) and yield of scented heartwood (Y) per tree in different DBH classes of sandal at Belgaum-Karnataka is expressed in the form of a power curve, $Y = 0.001476 X (X^{3.3564})$ [Rai and Sarma, 1986b]. Karnataka Forest Department also computed expected weight of actual sandalwood (Heartwood) at various girth of sandal trees [Anon, 1985]. Studies indicate that a healthy Sandalwood tree growing under ideal conditions show an increment of 1.0 kg per year with a girth of 1.5 cm (Rai, 1990). Growth reported by Lahiri (2010) from Ballavpur in Mohammad Bazar Range of Birbhum Forest Division that sandalwood trees attained 60 cm bhg (over bark) in 21 years and height is 7.0 m. and heartwood girth at breast height is 26 cm. Somashekar et al (2014) studied the field performance of tissue culture raised sandalwood plants as Agro-forestry models and found that tissue culture through axillary proliferation & somatic embryogenesis offers highest clonal propagation efficiency. It was also observed that from 1st to 4th year the plants are growing vigorously attaining height 5.5m & collar girth 34 cm. at the end of 4th year. Nagaveni and Vijayalaxmi (2002) opined that microbial inoculation to the seedlings *of Eucalyptus camaldulensis, Wrightia tinctoria* and *Bombax ceiba* improved the growth and biomass under nursery conditions which may further result in better performance of seedlings in field planting.

Sandalwood oil :

Age of sandal tree and colour of heartwood influence the content and quality of sandal oil. Heartwood from young trees (around 10 years of age, height<10m, girth<0.5m, heartwood diameter 0.5 -2 cm) contains 0.2-2% of oil and that from the mature trees 30-50 yrs of age, height 20m, girth 1 m, heatwood diameter 10-20cm) contains 2.8-5.6% oil. Further, sandal oil from young trees contain 85% of santalos and level of santalones are higher compared to oil from mature trees (ICFRE,1992, Shankaranarayana and Parthsarathi, 1989a). Sandalwood oil content markedly decreases along the length of the tree (from root to tip) and across the diameter of heartwood (from core to periphery) in various proportions. Generally, there is a decrease of about 45% in oil content from root to tip and about 20% from care to periphery (Shankaranarayana and Parthasarathi, 1987a). The root contains 3.5-6.3%, stem 3-5% and branches 1-3% oil.

Life Process of Plants:

Scott (1871) first reported the parasitic nature of sandal. Barber made detailed investigations on parasitic nature of sandal [Barbar, 1903; 1906]. Rama Rao (1911) in his experiments on extent of root parasitism found that sandal seedlings were incapable of growing beyond one year without haustoria. It has been noticed that the roots of sandal had travelled a length of nearly 40 m and attacked the roots of a large *Pterocarpus marsupium* tree [Venkata Rao, 1938]. Rama Rao (1910) stated that sandal haustoria have a selective power and attack good hosts extensively and bad hosts very sparingly. Venkata Rao (1938) opined that good and bad hosts of sandal can only be differentiated when grown individually with host and differed, on the basis of selective tendency of haustorium [Rama Rao, 1911].

Iyenger (1955) felt that parasitism is also said to be the condition of life, normal and necessary to an organism for nourishment at the expense of another (the host) which, however, is not destroyed in this process. The possibility of absorbing some material from the host is not excluded, particularly at the early stage of development of parasite. Subsequent to the findings of the parasitic habit in sandal by Scott (1871), Barber (1907) made a number of observations on the structure of the haustoria beginning with the formation of cushion like bodies from sandal roots to complete penetration inside the host root and establishing intimate attachment between them. The haustorial connection proceeds in two stages, in the first stage, ruptures and then penetration of the host root till it reached the woody portion. In the next stage, a channel of communication between haustoria and vessels of the sandal root is formed.

Sreenivasaya Rao (1933c) reported that the osmotic pressure in the tissues in sandal is higher compared to that in the tissues of the host plant. This ensure unidirectional flow of nutrient from host to the parasitic sandal. The cation exchange capacity of the white succulent root in the young seedling of sandal was, however, reported to be at a slightly low level [Kunda S. Deval *et al.*, 1971]. Venkata Rao (1924) and Srimathi and Srinivasaya (1963a) have reported that certain principles of the host viz. the bitter principle in *Nux vomica* and *Azadirachta indica* were translocated to the sandal leaves. Srimathi *et al.*, (1961) found that in leaves of sandal plants, not associated with host, the basic amino acids were practically absent. However, when grown with leguminous plants the sandal leaves showed concentration of basic amino acids. The authors concluded that for its supply amino acids, sandal depends on its hosts.

Sandal haustorium was reported to contain auxin [Srimathi and Sreenivasaya 1962a]. Occurrence of endopolyploidy in sandal haustoium was also noted [Srimathi and Sreenivasaya 1962b]. They mentioned that the spectacular increase in the rate of growth of the Sandal was related to the increase in number and size of chromosomes and the endopolyploidy was associated with most of the secretion of glands as well as haustoria. This organ contains IAA and other phytohormones. Polyploidy is widely acknowledged as one form of breeding in plants. Polyploid plants usually have larger cells and plants are often larger, thicker shoots, larger leaves and fruits and a higher nutritional content, etc. In order to increase oil content and economic benefits from *S. album*, it was decided to induce polyploidy in this tree species (Zhang et al., 2010).

Brandis (1903) observed that sandal derives part of its nutrition from soil and does not exhibit host specificity. Iyengar (1965) and Bhatnagar (1965) also reported wide range of hosts. While Iyengar (1965) reported that plants belonging to Annonaceae are not parasitized by sandal. Anantapadmanava *et al.,* (1988b) reported that sandal raised with *Annonus squamosa* performed well at Srinivasapura (Karnataka).

Objectives:

- Manipulation of seed germination by different concentrations of chemicals like IAA/ kinetin/ GA_3.
- To explore the suitable conditions for the proper growth of this plant with various associated plants in Nepal.
- Quantitative assessment of growth data till its establishment.
- To study any morphogenetic peculiarities & to study differential seeding of each type.
- To assess the qualitative parameters through biochemical analyses.

Chapter –2

Review of Literature

Chapter –2

Sandalwood (*Santalum album* L.) is a small evergreen tree attaining a height of 12 to 15 metres and a girth of 1 to 2.4 metres with slender drooping as well as erect branching. The shape of leaf vary and six morphological types have been widely recognized. They are ovate, lanceolate, elliptic, linear, big and small [Kulkarni and Srimathi, 1982]. A study of isoenzyme pattern in respect of peroxidase, malate dehydrogenase and esterase in ovate, lanceolate, linear and elliptic shaped leaves showed characteristic differences at vegetative as well as flowering stages, whereas big and small leaved morphological types did not show difference in their isoenzyme pattern [Parthasarathi *et al*., 1985]. Variation in colour of leaves ranging from bluish/greenish yellow to green have also been reported [Srimati et al., 1983]. Sandal bark also contains small amounts of betasitosterol, fatty acids and 14% tannins [Shankaranarayan *et al*., 1980b]. *Staphylococcus aureus*, a virulent pathogen commonly occurring in abscesses, suppuration, speticaemia and urinary sepcis. This suggests its utility as an antibacterial or anticeptic agent [Parimala Varadaraj and Shankaranarayana, 1986]. Seeds of all members of Santalaceae possess santalbic acid which is a characteristic feature of the family [Hatt and Schoemfeld, 1956]. Sandal seed oil has been studied by many worker for it physio-chemical properties, chemical composition and structure of constituent molecules [Iyer, 1935; Sreenivasaya and Narayana, 1936; Madhurnath and Manjunath, 1938; Manjunath and Siddappa, 1943; Gunstone and McGee, 1954; Gunstone and Russell, 1955; Hatt *et al*., 1959; Morris and Marshall, 1966 and Hopkins *et al*., 1969]. The highly unsaponifiable matter constituting 7 to 17 % of oil could be easily separated by shaking seed oil with cold dilute alkali and ethyl acetate

[Shankaranaraya, 1988a]. by partial hydrogeneation i.e. reduction at the acetylenic bonds, using Lindlar's catalyst, sandal seed oil could be converted into a semi-drying oil [Shankaranarayana 1979b]. Four surface active products having good foaming capacity and foam stability were prepared by reaction of (i) methyl sulphate on sodium santalbate [Shankaranarayana and Krishna Rao, 1982], (ii) Seed oil with diehtanolamine, gelatin hydrolysate or sodium ammonia [Shankaranarayana and Parthasarathi, 1986]. On pharmacological screening sandal seed oil was found to possess diuretic hypotensive, antitremorogenic and antiviral activities [Desai and Shankaranarayana, 1990]. Seed oil finds use in treatment of skin diseases [Kritikar and Basu, 1987]. Sandal seeds from young trees (age around 10 years) were found to be as much potential rich in fatty oil, protein and mineral

as seeds from mature trees (age above 30 years). This shows their potential use as rich proteinaceous and nutritive source even at the young stage of the sandal plant [Shankaranarayana *et al.,* 1990]. Further, it has been found that non-viable sandal seeds contain slightly larger amount of fatty oil but less amounts of protein compared to viable seeds [Anathapadmanabha *et al*., 1989b]. They have reported that treatments with dilute solution of sodium hydroxide or dilute hydrochloric acid or gibberellic acid can remove the dormancy principle from the seed. Early and quick germination in a short time of 15 days by breaking the false seed coat, indicates the presence of inhibitory principles in the seed coat [Srimathi and Rao, 1969]. It was also found that treatment of seeds with hydrogen peroxide (1%) or, indole acetic acid (100ppm), or hydrochloric acid (0.5%) or gibberellic acid (0.05%) showed pronounced effect on germination [Nagaveni *et al*., 1989]. Scarified seeds with concentrated sulphuric acid also induces early germination [Nagaveni and Srimathi, 1981a]. Sandal seeds which exhibit polymorphic form maintains its identity in respect of germination, occurrence and other characters [Nagaveni and Ananthapadmanabha, 1986]. Studies conducted on the germinative capacity of floating and sinking sandal seeds [Nagaveni and Srimathi, 1985] have revealed that both the floating as well as sinking seeds are viable but the percentage of germination slightly varied between them.

While α- and ß-amylases are among the enzymes involved in the breakdown of starch in germination seeds, the formation of α- amylase activity is due to the de novo synthesis of this enzyme under control of the endogenous gibberellic acid [Bewley and Black, 1978]. ß-amylase activity is due to the activation of latent enzyme in the inhibiting seed [Goodwin and Mercer, 1975]. Also, it is known that exogenously applied gibberellic acid helps breaking the dormancy of seeds [Ovcharov, 1977]. In a study of the effect of exogenously applied gibberellic acid on the relative levels of α- and ß-amylase activities in germinating sandal seeds, it was observed that gibberellic acid treatment brought a decrease in α- amylase activity and increase in ß-amylase activity both in decoated seeds and in seeds with intact seed coat [Ananthapadmanabha *et al*., 1986].

However, germination of seeds are very low (10-15% within 60 days) when the seeds are sown in mother bed (sand beds) after hot and cold water treatment or alternate wetting & drying due to its hard seed coat and dormancy. Sandal seeds have been found to germinate faster when the seed coat is completely removed, or seeds are soaked in 0.05% gibberelic acid for 12-16 hours [Nagaveni and Srimathi, 1981]. In sandal seeds, the duration of germination is much prolonged after the dormancy period. It starts in 25 days and reaches hardly 50% in 90

days with 0.05% GA_3 soaking for 16 hours [Das and Tah, 2013]. Germination study conducted in Hirbundh & Kamalpur nurseries of Bankura (South) Division in 2011, 2012 & 2013 where seeds are soaked in different concentration (0.0125%, 0.025%, 0.05%) of gibberelic acid for 16 hours & 24 hours respectively and sown in sand beds of nursery. The germinated seedlings are pricked out from sand bed and planted in polypot & hycopot beds of nursery at 3 to 4 leaf stage and kept in nursery without & with host (*Cajanus cajan*).

Red ferruginous loam is the most common soil on which sandal tree occurs, the underlying rock often is metamorphic and is chiefly gneiss. It is not exacting as to the depth of the soil and is frequently found on rocky ground and on stony or gravelly soils [Troup, 1921].

2.1: Soil:

Sothers (1928) in the Working Plan for the sandal forests of the Khanapur, Nagargali and Gijnal Ranges observed laterite as the most common underlying rock in the higher hills with schists and trap rock on the north-west and an out crop of crystalline limestone on the south-west respectively. A detailed account of the geology, rock and soils of sandal bearing areas of the districts of North Kanara, Balgaum, Dharwar and Bijapur of Karnataka which were part of the erstwhile state of Bombay has been reported by Qureshi, 1955.

In Malwa plateau of Gulbarga, Bidar in Karnataka and Bhir and Aurangabad in Maharastra the principle geological formation is Deccan Trap consisting of basalt and dolerite capped up in places by laterite. The soil in the sandal tract is black cotton except in the districts of Bidar and parts of Gulbarga and Bhir, where Deccan Trap being of metamorphic origin contains ferruginous loams commonly called lateritic soils [Khan, 1957].

In the Working Plan of Sirsi-Siddapur sandal bearing areas, Wesley [1970] reported the geologic formation of the area as archaic with characteristic features of laterisation. In Coimbatore Central Division of Tamil Nadu, sandal is found in almost every type of soil. Is is found in stony red soil along the higher reaches of Moyar valley, on alluvial soil along Hallurhalla, on rich loams in Hulical, Kallar, Jacanare Reserve Forest and shallow gravelly soil on the Melur and Pillur slopes [Jayaraman, 1973]. The dolerite dykes have weathered into characteristic spheroidal boulders and to reddish clayey soil [Rajagopal Shetty, 1981]. It has been reported that sandal occurs also on sandy soil of Quilon, Kerala [Rama Rao, 1908b]

A study of the soils of sandal bearing areas of Karnataka, Tamil Nadu and Kerala for their morphology, physical and chemical properties was made by Rangaswamy, *et al.,* 1986a.

in Water plantation of Teragalli and Londa of Khanapur range, where sandal occurs, the soil pH varied from 6.7 to 7.5 [Quireshi, 1955]. The texture of soil in A, B and C horizons is sandy clay, clayey and gravelly loam respectively [Krishnamurthy *et al*., 1983].

Sandal requires good drainage and does not stand water logged ground. Best growth of tree is on rich fairly moist soil such as garden loam and well drained deep alluvium on the river banks [Troup, 1921]. A significant relationship between available nitrogen content in 'A' horizon and annual growth increment was observed in the soil of Talaalai range [Krishnamurthy *et al*., 1983]. In a study carried out by Jain *et al*., (1988) on soil properties and their relationship to the growth of sandal in three areas it is observed that lime status, water holding capacity, pore space, volume expansion on wetting, exchangeable calcium and magnesium and available potash, exert positive influence on the increment in girth and height. Requirement of host for proper growth of sandal was demonstrated in a field study by Ananthapadmanabha *et al.*, 1984. Further analysis of soil and leaf samples from this has shown that sandal depends on its host for potassium, phosphorous and magnesium [Rangaswamy *et al*., 1986b]. Sandal can draw other nutrients directly from soil as its roots have good cation exchange capacity [Parthasarathi *et al*., 1971]. It is believed that the wood with finest odour is obtained from the driest region particularly on red or stony ground [Gunther, 1952] and that yield of oil will be much higher than those grown in fertile tracts [Bhatnagar, 1965]. Puran Singh, 1911 determined the variation in the oil content growing in different locations in different soils. This observation was supported by opinion expressed by Gildemeister and Hoffman, 1952, that the wood of trees growing in 5 dry rocky mountainous soil is harder and richer in oil than those growing on fertile ones. It was also clear that the only factor which appears to influence the percentage of oil is the soil [Puran Singh, 1915]. However, Sreenivasaya and Rangaswamy, 1931 are of the opinion that sandal growing on rocky soil and in association with xerophytic conditions having higher proportion of soil bearing heartwood than the one thriving on fertile soil enjoying good rainfall and nourished by vigorous hosts, are not comparable since in one case growth is exceedingly slow while in the other girth increment is rapid. In Pachamalai forests of Tiruchirapalli forest division the trees on the lower slopes and plains are generally stunted and poor in heartwood while those on the higher slopes and particularly those on the plateau have good growth with better development of heartwood [Bhaskardoss, 1968]. Heartwood formation in sandal trees on the sandy loams of the sea coast of Bhatkal and Honnavar was not as good as on the table land of the North Kanara district [Qureshi, 1955]. But in the forest college campus, where the soil is shallow and has pebbles

and boulders, the sandal trees of even 30-45 cm girth had little or no heartwood [Nayar, 1974]. Ahir *et al.*, 2014 carried out studies to find the effect of soil type on the growth of Indian Sandalwood (*Santalum album* L.) and observed that survival and overall growth of six month old seedlings for height, collar diameter and survival rate were similar in potting medium having red and yellow soil type.

2.2: Silviculture:

2.2.1: Seed:

Generally, Sandal tree flowers twice a year from March to May and September to November. The fruits are collected during March / April and November / December. Fruits are depulped by rubbing, dried in shade, treated with fungicide and stored in air tight container. Freshly collected seeds are dormant for a period of 2 months and are viable upto 9 months. Germination is about 60% under field condition (ICFRE,1992). Soaking of seeds in 0.05% Gibberellic acid overnight and sowing ensures uniform germination upto 70% in 60 days [Nagaveni and Srimathi, 1980; 1981a]. About 6000 seeds weigh a kilogram. Rai and Kulkarni (1986) have reported that dibbling of seeds in bushes and sowing of seeds on the mounds in the trench-mound method were the most commonly followed in the past, success rate was normally around 30 - 40%. In sandal seeds, the duration of germination is much prolonged after the dormancy period. It starts in 25 days and reaches hardly 50% in 90 days with 0.05% GA_3 soaking for 16 hours (Das and Tah, 2013).

2.2.1.1: Planting of container raised seedlings:

Transplanting of seedlings raised in the nursery is one of the commonly used methods for raising plantations. This method is costly, however, high success rate offsets the cost factor. Watt (1893) had described a method for raising sandal seedlings in the tile cylinders. Initially sandal seedlings alone were grown in baskets or bamboo or tile cylinders. Later, as an improvement of the techniques, host seeds were also introduced in the container. This method was also not successful due to high mortality of seedlings. Narasimhan (1930) reported that mortality is due to attack by fungi, *Phytophthora* sp. and *Rhizoctonia* sp. Nayar *et al*., (1980) noticed that the death of the seedlings was due to attack by a combination of fungi and nematodes. Keeping this in view, a comprehensive method for raising and management of disease free seedlings was developed [Sivaramakrishnan *et al.*, 1984].

2.2.1.2: Cultural Operations:

Nayanna (1949) suggested the some subsidiary operations on natural sandal forests and prescription of tending in plantations.

All Sandal trees should be tended once in 4 years. Tending is better done from June to November, as far as possible it should be done along with extraction of Sandal. In case of seedlings and saplings, shrubs and plants useful as hosts are retained and other unwanted growths like Lantana should be removed to provide more space for development of Sandal.

2.2.2: Vegetative Propagation:

Vegetative propagation of sandal is done through air layering or through root suckers (adventitious roots). The later method, however, showed greater success [Rao and Srimathi, 1977; Vijayakumar *et al.,* 1981]. Cleft grafting method adopted for clonal multiplication using 8 to 12 month old seedlings gave 60% success [Srimathi, 1983]. A method of vegetative propagation through root cuttings was developed by Uniyal *et al.*, (1985). Success rate is upto 60% in this method.

2.2.2.1: Tissue Culture Technique:

Yeast extract was found to initiate and stimulate the proliferation of sandal endosperm. However, for a satisfactory proliferation an auxin (2-4 D) and a kinin (Kinetin) in conjunction with yeast extract are required [Rangaswamy and Rao, 1963]. Studies in culturing of lateral buds, root tips and haustoria of sandal were also carried out [Srimathi and Sreenivasaya, 1963b]. Induction of embryonal proliferation in sandal was studied and it was found that similarity existed in the morphogenetic potentialities of the embryo of sandal and other angiospermic parasites [Rao, 1965]. Somatic embryogenesis in seedling callus of sandal has been observed by Bapat and Rao (1979). Lakshmi Sita *et al*., (1982) induced sandalwood somatic embryogenesis from shoot callus cultures derived from 20-25 year old trees. Lakshmi Sita (1986) and co-workers made exhaustive studies in tissue culture of sandal using different types of tissues. Rathore *et al* (2007) described micro propagation methods through axillary shoot proliferation have high potential for rapid and mass production of Clonal planting material of *S. album* from plus trees. Joshi *et al* (2014) conducted field trial of micropropagated plants of *S. album* and found that the survival is 70% by the end of six months. Mamatha and Rathore (2014) studied the effect of sucrose, agar-agar concentration and pH of the media on somatic embryo induction, maturation and germination from the explants of the mature trees and found that during maturation, size of the somatic embryos increased with increase in the

concentration of sucrose in the medium favoring adventitious shoot induction and embryo creaking.

2.2.3: Heartwood Formation:

Cameron (1894) reported that the tree attains commercial maturity at 27-30 years and at this period the heartwood is well developed at a depth of 5 cm below the surface. Ranganathan and Wilson (1934) and Mitchell (1941) observed that trees extracted from open fields or edges of plantation yield more heartwood than those of comparative size extracted from adjoining forests. Rama Rao(1911) from his investigations inferred that hosts influence heartwood formation also, in addition to growth and development. Srimathi and Kulkarni (1980) were of the view that heartwood formation is dependent on genetic factors of the individual tree and the phenotypic factors play only a secondary role.

2.2.4: Growth and Yield:

Sandal is considered as a slow growing tree under forest conditions. Kushalappa (1995), Rai (1990), Nasi and Ehrhat (1997) reported that Sandal responses well to lime application. Application of biofertilizers to trees will greatly improve Sandal growth (Harley & Smith, 1983). Rajagopal Shetty (1977a) reported that growth rate of sandal in Javadis is 1 cm girth at breast height per annum (0.33 cm DBH). Similar growth behavior had also been reported by Ranganathan and Wilson (1934). More or less the same growth rate was observed on the trees in plantations also [Srimathi and Kulkarni, 1980, 1983]. The mean annual diameter increment in trees each from Andhra Pradesh (Horslekonda, Ananthpur district) and Tamil Nadu (Sanamavu R. F., Salem North) was found to be around 0.287 and 0.195 cm respectively [Sarma and Rai, 1986]. Venkatesan (1980) has reported that though earlier studies had indicated a growth rate of 1.23 cm. girth per year, it could vary from 1 to 5 cm. per year. The relationship between DBH (X) and yield of scented heartwood (Y) per tree in different DBH classes of sandal at Belgaum-Karnataka is expressed in the form of a power curve, $Y = 0.001476 X (.X^{3.3564})$ [Rai and Sarma, 1986b]. Karnataka Forest Department also computed expected weight of actual sandalwood (Heartwood) at various girth of sandal trees [Anon, 1985]. Studies indicate that a healthy Sandalwood tree growing under ideal conditions show an increment of 1.0 kg per year with a girth of 1.5 cm (Rai, 1990). Growth reported by Lahiri (2010) from Ballavpur in Mohammad Bazar Range of Birbhum Forest Division that sandalwood trees attained 60 cm bhg (over bark) in 21 years and height is 7.0 m. and heartwood girth at breast height is 26 cm. Somashekar et al (2014) studied the field performance of tissue

culture raised sandalwood plants as Agro-forestry models and found that tissue culture through axillary proliferation & somatic embryogenesis offers highest clonal propagation efficiency. It was also observed that from 1st to 4th year the plants are growing vigorously attaining height 5.5m & collar girth 34 cm. at the end of 4th year.

2.3: Physiology:

Scott (1871) first reported the parasitic nature of sandal. Barber made detailed investigations on parasitic nature of sandal [Barbar, 1903; 1906]. Rama Rao (1911) in his experiments on extent of root parasitism found that sandal seedlings were incapable of growing beyond one year without haustoria. It has been noticed that the roots of sandal had travelled a length of nearly 40 m and attacked the roots of a large *Pterocarpus marsupium* tree [Venkata Rao, 1938]. Rama Rao (1910) stated that sandal haustoria have a selective power and attack good hosts extensively and bad hosts very sparingly. Venkata Rao (1938) opined that good and bad hosts of sandal can only be differentiated when grown individually with host and differed, on the basis of selective tendency of haustorium [Rama Rao, 1911].

Iyenger (1955) felt that parasitism is also said to be the condition of life, normal and necessary to an organism for nourishment at the expense of another (the host) which, however, is not destroyed in this process. The possibility of absorbing some material from the host is not excluded, particularly at the early stage of development of parasite. Subsequent to the findings of the parasitic habit in sandal by Scott (1871), Barber (1907) made a number of observations on the structure of the haustoria beginning with the formation of cushion like bodies from sandal roots to complete penetration inside the host root and establishing intimate attachment between them. The haustorial connection proceeds in two stages, in the first stage, ruptures and then penetration of the host root till it reached the woody portion. In the next stage, a channel of communication between haustoria and vessels of the sandal root is formed.

Sreenivasaya Rao (1933c) reported that the osmotic pressure in the tissues in sandal is higher compared to that in the tissues of the host plant. This ensure unidirectional flow of nutrient from host to the parasitic sandal. The cation exchange capacity of the white succulent root in the young seedling of sandal was, however, reported to be at a slightly low level [Kunda S. Deval *et al*., 1971]. Venkata Rao (1924) and Srimathi and Srinivasaya (1963a) have reported that certain principles of the host viz. the bitter principle in *Nux vomica* and *Azadirachta indica* were translocated to the sandal leaves. Srimathi *et al*., (1961) found that in leaves of sandal plants, not associated with host, the basic amino acids were practically absent. However, when

grown with leguminous plants the sandal leaves showed concentration of basic amino acids. The authors concluded that for its supply amino acids, sandal depends on its hosts.

Sandal haustorium was reported to contain auxin [Srimathi and Sreenivasaya 1962a]. Occurrence of endopolyploidy in sandal haustoium was also noted [Srimathi and Sreenivasaya 1962b]. They mentioned that the spectacular increase in the rate of growth of the Sandal was related to the increase in number and size of chromosomes and the endopolyploidy was associated with most of the secretion of glands as well as haustoria.This organ contains IAA and other phytohormones. Polyploidy is widely acknowledged as one form of breeding in plants. Polyploid plants usually have larger cells and plants are often larger, thicker shoots, larger leaves and fruits and a higher nutritional content, etc. In order to increase oil content and economic benefits from *S. album*, it was decided to induce polyploidy in this tree species (Zhang et al., 2010).

Brandis (1903) observed that sandal derives part of its nutrition from soil and does not exhibit host specificity. Iyengar (1965) and Bhatnagar (1965) also reported wide range of hosts. While Iyengar (1965) reported that plants belonging to Annonaceae are not parasitized by sandal. Anantapadmanava *et al.,* (1988b) reported that sandal raised with *Annonus squamosa* performed well at Srinivasapura (Karnataka).

2.3.1: Germination & Dormancy

In *Santalum album* germination is sporadic & takes 4 – 12 weeks time to complete germination [Srinivasan *et. al.,* 1992 & Srimathi *et al.,*1995]. Srinivasan *et al.,* (1992) recommended nursery bed of sand and soil in the ratio of 1:3 for seed germination and seed density of 500g/m^2 bed.

Pretreatment of seeds with GA_3 500ppm for 16 hours resulted in 60% germination under field conditions (Nagaveni *et al*. ,1989).Traditionally the seedlings at 4 – 6 leaf stage are transferred to poly-bags of 1500 cc. capacity with a potting mixture of sand, soil & FYM in 2:1:1 ratio with *Cajnus cajan* as a pot host. Plantation seedling of 30 cm height with dark brown stem can be produced in 6 – 8 months period (Rai, 1990).

Germination of Sandal seeds are found profuse from the bird droppings in the forest floor as well as in the village yards & bunds of the agricultural fields. Sandal is also found growing wild in some farmlands, homesteads and wastelands in Hirbundh block of Bankura District. This indicates the potential of growing the tree in the farmlands. The hemi–parasitic

nature of sandal is not fully understood and silvicultural techniques to establish it are not fully known. Ananthapadmanabha *et al*., (1984) reported that sandal plants established haustorial connections with the secondary hosts (e.g. *Pongami*a). Though sandal plants can survive without host, their experiment has proved beyond doubt that the host plants are absolutely necessary for the better growth of sandal plants. Very slow growth of sandal and the long rotation period is another disincentive for sandal cultivation.

However, germination of seeds are very low (15-20%) when the seeds are sown in mother bed (sand beds) after hot & cold water treatment due to its hard seed coat & dormancy. Sandal seeds have been found to germinate fast when the seed coat is completely removed, or seeds are soaked in 0.05% gibberelic acid for 12-16 hours [Nagaveni & Srimathi,1981]. Gunaga *et al* (2014) found that overnight soaking of seeds in GA_3 solution @300ppm (68%) and 500ppm (63%) resulted in better germination over control (38%). They observed that germination of bird dispersed seeds achieved highest seed germination within short time as compared to depulped seeds.

2.3.2: Host –Sandal Plant Parasitism:

Sandal is a hemi – root parasite, was first reported by Scott,(1871), that requires a primary host at nursery stage (Annapurna *et al.,* 2006) & secondary long term host in the field. Being hemi – parasite the Silvicultural requirements are unique and there is no adequate understanding of the same. Its regeneration & establishment has been problematic because of the poor understanding of host – parasite relationships (Surendran *et al.,* 1998). Sandal plants in agro- forestry or forestry systems may have to tolerate varying levels of competition & complementary interactions from the component crops or plants. So, an understanding of the complementary & competitive influence of the host on sandal is necessary for successfully growing of sandal. When host is introduced in the pot at the early phase there is possibility of competition for soil moisture & nutrient between sandal & host. Most of the research in India on sandal has been focused on spike disease and host species selectively. However, little work has been carried out on nourishing sandal in the nursery with organic, inorganic & bio-fertilizers. The plant with a haustorial adaptation on its own roots which parasitise the roots of other tree, but without major harm to its hosts. This plant forms a non-obligate relationship with a number of other plants like *Pongamia pinnata* and *Casuarina equisetifolia* (Nagaveni & Vijayalakshmi,2003).

Sandal can be parasite over 300 species of host plants found in nature from grasses to leguminous trees. This species shows different growth patterns with different host species. Lack of understanding of the host plants relationship cause the failure of sandal seedling production. Srinivasan *et. al*.(1992), Surata et. al. (1995) and Fox *et. al*. (1996) have all reported that *Cajanus cajan* is the best host plants for sandal in nursery. Four different host species, which were the best as reported by different scientists, were selected by Kala *et al.* (2007) as secondary host plants for the main field. These were *Cynodon dactylon* (Kushalappa, 1995); *Albizzia saman* (Surrendran *et al.*, 1999); *Casuarina equisetifolia* (Rai, 1990, Taide *et al.*,1994 and Srivastava, 2003); *pongamia pinnata* (Nagaveni & Vijayalakshmi, 2003).

According to the findings of Rangaswamy *et al*., (1986) and Ananthapadmanatha *et al*., (1988) sandal cannot be grown normally without a host plant. If depends on its host for P, K. & Mg. Tennakoon *et al*., (2000) reported that perennial host is the best for sandal growth. Sekar *et al.,* (2000) opined that combined application of Azospirillum, Phosphobacteria & VAM fungi provide better growth in sandal by improving the nutrient uptake under nursery condition.

Mosse (1973) & Hayman (1986) emphasized that Vesicular Arbuscular Mycorrhizal (VAM) fungi enhance plant mineral nutrition especially phosphorus. Other than their influence on plant nutrition, their interaction with plant pathogens such as fungi, bacteria and nematodes may lead to the reduction in severity of disease (Schenck, 1981, Schonbeck and Dehne, 1981).

Venkata Rao (1938) opined that good and bad hosts of Sandal plants could only be differentiated when grown individually with host Parthasarathy *et. al*., (1974) observed the parasitism with different host by cation exchange capacity (CEC) and recognized 3 categories of good, medium and poor. Ananthapadmanabha *et al*., (1988), Nagaveni & Vijayalakshmi (2004) concluded that host is necessary for good growth of Sandalwood plants and further they categorized host plants as good, medium and poor from pot culture studies based on growth, biomass, nutrient level, haustorial connections etc. Nagaveni and Vijayalakshmi (2007) studied on resistance of sandal to determine the bio-protective effect of arbuscular mycorrhizal fungi in sandalwood plant infected with wilt causing pathogen *Fusarium oxysporum.* They also studied the differential response in the haustorial formation an growth of sandalwood plant (*Santalum album* Linn.) in respect to different host. Rocha *et al* (2014) conducted 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 route became almost a single physiological unit catering to the nutritional requirement of sandalwood tree. Their study

with P^{32} radio tracer technique suggested that the host plans 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.

2.4: Tree Improvement

The number of chromosomes in sandal root tip is 2n = 20 (Iyengar, 1937; Rao, 1942a; Darlington and Wylie, 1955). However, in the haustorium forty chromosomes could be counted in many of the cells. A two to five fold increase in size of the chromosomes was also observed. This was attributed to endopolyploidy (Srimathi and Sreenivasaya, 1962a). The variation in the magnitude of standard error from tree to tree suggests that they are governed by genetic factors (Bagchi and Veerendra, 1985).

Studies on seeds of selected trees have shown that germination and percentage of survival is (i) lower than 45%, (ii) are genetically controlled, (iii) are governed by separate genes and (iv) are independent in nature and some genotypes exhibit staggered germiniation (Bagchi and Kulkarni, 1985). A study of six anatomical characters of apical stem portion of eight trees has shown that there are genotypic differences in the population studied. A method of scoring for ascertaining the higher oil content genotype was developed (Veerendra and Bagchi, 1986)

In order to evolve spike disease resistant strains, several varieties of sandal were screened. Foliar variations were found to be important taxonomic character indicators that are discernible even at the seedling stage (Venkata Rao and Badami, 1930). Variations in leaf length and area were subject to biometrical analysis, Second degree quadratic equations were computed. The derived equations confirmed the occurrence of six biotypes in sandal. For delimiting different type of sandal it was suggested that results of biometric analysis of leaf morphology would be helpful (Kulkarni and Srimathi, 1982). Variations in leaves, flowering behavior, germination and 3 pheno-types have also been reported (Srimathi et al., 1977; Srimathi and Kulkarni, 1983).

Seedling of the above species did not survive for more than a year except in case of *S. austro-calidonicum*, two seedling of which survived for three years (Anon, 1987). After an exhaustive survey 79 plus trees mainly from the States of Karnataka, Tamil nadu and Kerala were selected (Anon, 1987). One seed stand (3 ha) at Anchalpatty (Marayoor, Kerala) has been converted into seed production area (Anon, 1987).

Two clonal seed orchards based on a computerized design development for the purpose (Sekar et al., 1984) have been estsblished at Nallal (Karnataka) and Tirupati (Adhra Pradesh). Clonal material required for establishing such orchards were supplied to Forest Departments of Karnataka and Tamil Nadu (Anon, 1987).

Progeny trials : Progenies of selected plus trees and morphologically different phenotypes were raised. Three half sib progeny trial plots with 16, 19 and 28 plus tree families have been established at Nallal (Anon, 1987). The seedlings in progeny trials exhibited segregation, pleiocotyly, variation and albinism. Twin and triplet seedlings were also observed (Srimathi and Kulkarni, 1982).

It is reported that in sandal not only the type and concentration of particular growth regulator but also the composition of basal medium influences growth and development of plantlets *in vitro*, confirming that a low mineral nutrition is important for development of plantlet (Lakshmi Sita, 1986).

Bapat and Rao (1984) undertook investigations for clonal multiplication of elite disease free trees. They observed that (1) basal portion of hypocotyls was more regenerative, (2) age of hypocotyls had effect on bud formation, (3) polarity was an important factor in determining bud formation, (4) size of explants did not determine the extent of shoot bud formation as evidenced by bud formation even in thin discs and (5) among several plant growth regulators, IAA stimulated remarkably emryogenesis followed by biammonium phosphate (BAP). Othere hormones were ineffective.

Bapat et al., (1985) have shown that protoplasts of sandal that protoplasts of sandal leaf mesophyll, stem and hypocotyl callus under certain experimental conditions, can be manipulated to regenerate into whole plants. Somatic embryogenesis was induced from shoot callus cultures derived from 20-25 years old trees. Embryoids subsequently developed into plants. This technique can be used for propagation of selected superior varieties (Lakshmi Sita *et al*., 1982).

Breeding for resistance to spike disease is one of several control measures suggested. It has been reported that there is no natural resistance to spike disease (Iyengar, 1955). The apparent resistance is likely to be due to absence of adequate spike inoculums and other climatic factors.

Mathews, 1961 recommended that (1) trials of treatment of seedlings and of different potting composts, (2) Vegetative propagation from selected trees and raising cuttings for testing in nursery and field trials and (3) identification of parent trees which transmit resistance to their progenies and production of seedling from them for raising future sandal plantations. A programme for evolving sandal by controlled hybridization and induced mutation was suggested [Venkatesh and Kedarnath, 1963]. Although it is generally believed that sandal has no natural resistance to spike disease, it is possible to obtain some resistant strains by selection and screening [Srimathi *et al*., 1980, 1982].

Clonal material of few plus trees from Karnataka and Tamil Nadu which were disease free and apparently disease resistant succumbed when grafted on with spiked material [Nayar, 1986]. Rao et al., 2007 have estimated the levels of genetic diversity in 19 populations in Southern India and also mapped the distribution of sandal population in the country. Arun Kumar and Joshi, 2007 identified the spike resistant genotypes and other breeding causes for tree improvement. Kulkarni and Srimathi, 2007 reported a new sandal variety based on fruit shape named 'Anchetty sandal variety'. Balasundaran and Suma, 2007 pointed out the relative magnitude of genetic differentiation among the eight sub-population was 0.78 i.e. 78% of the diversity was between provenances and 22% within provenances. Jagadish et al., 2007 conducted the nursery experiment to understand the variation in seed germination and to select the best seed source for mass collection programmes. Joshi and Arun Kumar, 2007 studied to determine optimum seed moisture content and storage temperature to prolong the viability of *Santalum album* seeds during storage. The ideal conditions for storage of sandal seeds are 9.2% seed moisture content and 5°C storage temperature. Vijendra Rao *et al.,* 2007 suggested the species improvement is possible only when wood science aspect is understood and implemented. Ansari *et al.,* 2007 emphasized that isozyme or RADP markers are used for diversity and genetic distance analysis of Indian sandalwood. Arun Kumar *et al.,* 2014 studied on heartwood oil content variation in *Santalum album* with clonal germplasm bank of different accessions having uniform aged trees and growing in identical conditions and observed that there is a significant variability among the different accessions.

2.5: Cultivation :

Annapurna et al., 2007 studied to optimize different factors like seed source, seed pretreatment, germination medium, stage of transfer of seed ling, type of container, potting mixure, supplementary nutrition, Biofertilizer, host species to be used and stage of introduction of host for quality seedling production. Sawyer B, 2014 described that Western Australia has wooden gold in the form of wild Sandalwood (*Santalum spicatum*) unlike mineral gold is a renewable resource. From 2011 to 2013, the FPC experimented with mechanized processes for wild Sandalwood seeding & future generation will be able to harvest wild trees with heartwood oil that will slowly accumulate over 150 years in a wild environment. Gogoi *et al.,* 2014 opined that *Santalum album,* the Indian Sandalwood is one of the most valuable trees in the World, is being cultivated in Assam for its better economic prospect and its luxuriant growth proves that the geo-environmental conditions is suitable for this species. Sudhakar *et al.,* 2014 conducted experiment for 2 decades on Indian Sandalwood to standardize nursery technology and their results indicated that treating the seeds with GA_3 25ppm & IAA 100ppm can be recommended for better germination & production of vigorous seedlings. They prescribed *Casuarina* as the best host followed by *Terminalia, Albizia*, *Dalbergia* and *Pongamia.* They also opined that Sandalwood can take up elements like Ca, S & P directly from soil and a small fraction of these is obtained from host. Mattinson, 2014 pointed out that Santanol developed a host-tree free system for sustainable production of Indian Sandalwood in Ord Valley Western Australia using legume mulch crops and areal application of fertilizer. Ananthapadmanabha., 2014 opined that Agro-forestry systems/models 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-storey crops. Das and Tah, 2014 conducted experiment in different soil environment of South West Bengal both in nursery and field condition after transplantation of sandalwood saplings with different hosts singly & in combination of hosts and found that Arhar (*Cajanus cajan*) is the best host followed by Arhar & Tulsi (*Ocimum sanctum*) combination followed by Tulsi singly though sandalwood plants survive without host but the girth & height growth is much better with the hosts. Binu *et al.*, 2014 opined that the nutrient status of the sandal seedlings inoculated with Arbuscular Mycorrhizal Fungi (AMF) was higher compared to the non-inoculated seedlings. They also seen that the colonization of the roots was higher for the seedlings inoculated with *Glomus mosseae* (average root colonization of 68%), however the host species did not show any

significant influence on the growth of Sandalwood seedlings. Viswanath *et al.,* 2014 suggested the best growth of Sandalwood was recorded with Mango host under intensively managed condition and least was with Amla host under slightly less intensively managed conditions. Their study also reveal that under managed conditions in agroforestry, it is possible to attain mean annual increment in excess of 4cm in a year. Nagaveni and Vijayalakshmi, 2014 observed the symbiotic relationship of Sandalwood plants with that of AM fungi revealed that plants growing in different places showed diverse AM species association and the intensity of colonization was higher in Sandalwood roots than the host. Kala *et al.,* 2007a have taken into consideration to standardize the nutrition for nursery establishment of sandal. Vijayakumar et al (2007) studied the influence of soil moisture regimes and stage host introduction seedling growth of sandal provenances in a pot experiment. Ashokan and Krishnambika., 2007 emphasized the growing demand and the dwindling supply of sandalwood, there exist great potential for raising sandal not only in forest area but also in home garden and other agroforestry system. Chauhan and Aggarwal 2007 explained the growth which are extensively used in the forestry sector to provide prediction about the growth and yield of plantation which maximizes the revenue and other benefits. Viswanath *et al.,* 2007 suggested sandal block plantation with a rotation period of 15 years gives the highest return from selling sandalwood which is substantial compared to the expenditure incurred. Hanumantha *et al.,* 2014 conducted studies pertaining to phenology and natural regeneration of Sandalwood (*Santalum album*) under different plantations like Bamboo, Eucalyptus, Acacia, medicinal plants garden and natural forest where several birds are involved in dispersal of seeds and their result showed that the overall regeneration was highest in medicinal plants garden followed by natural forest and bamboo plantation. Kala *et al.*, 2007b investigated that the nutrition treatment to standardize the nutrition for field establishment of sandal. Sundararaj and Muthukrishnan, 2007 undertook studies to identify the paste complexes of sandal and their host range in South India. Singh *et al.,* 2014 found that height, collar diameter, crown size, clear bole and survival of *S. album* trees were greater with *Citrus aurantium* as compared to *Casuarina equisetifolia* and *Punica granatum* hosts. Veerendra, 2014 studied germination patter and seedling weight in *Santalum album* from 12 provenances and found that first emergence varies from a minimum of 18 days to a maximum of 39 days indicating existence of seed polymorphism in Sandal. He also opined that root length is strongly positively correlated with time of emergence whereas shoot length & total height were negatively correlated indicating that longer the time for germination, seedling establishment will be better in forest floor.

2.6: Disease and Pest:

2.6.1: Disease :

Deficiency of lime in the spiked leaves was observed by Coleman, 1917 but the same could not be traced to deficiency of the element in the soil. It has also been found that the disease is not due to want of soil aeration [Dorairaj, 1958]. Relationship between soil nutrients and incidence of the spike disease was studied by Iyengar (1960a). Hence, it was viewed that calcareous nature and low amount of available nutrients in the soil may serve as predisposing factors for the onset of the disease [Khan and Yadav, 1962]. Parthasarathi *et al*., 1973b made the similar study in sandal bearing areas of Karnataka to see whether deficiency of any major or minor elements in soils would serve as a predisposing factor for the onset of the disease. In Hosur plantation of Tamil Nadu, red sandy soil overlies the granite boulders and even though altitude are 300-500 m with consequent low temperature favourable for growth of pathogen, the spike disease is absent or rare, perhaps due to heat released by granites [Nayar, 1974]. Sandal is a good soil binder and requires very little moisture for its survival and growth [Venkatesan and Srimathi, 1981]. As sandal can stand pruning, shading in the field can also be regulated [Venkatesan, 1979]. According to Lushington (1916), the exact date when the disease appeared in the adjoining North Coimbatore is uncertain. Howard and Howard, 1919 and Hole 1918 believed that the disease is caused due to the unbalanced sap circulation. While Rao, 1965 felt that the disease is not infective and questioned the theory of insect transmission, Kunkel, 1926, McKinley, 1923 and Smith, 1931 suggested that the infective principle is an ultra-microscopic organisms which confirmed Coleman's earlier theory. Norris, 1930 and Venkata Rao, 1935 suspected that the associated rank vegetation of sandal plays decisive role in the spread of disease in nature. Even in abandoned holdings, incidence of spike is more due to herbaceous undergrowth which confirms Kabir's, 1937 observations. Even presence of *Lantana. camera* was considered to be predisposing factor to spike disease [Tireman, 1917; Hart and Rangaswamy, 1926; Venkataramaiah, 1937; Sreenivasaya, 1930a,b, 1931, 1932, 1933a,b,c, 1934]. Nayar and Sreemathi, 1968 confirmed that *Lantana* is a symptomless carrier. External symptoms of spike have been reported on *E. tereticornis, E. citriodora, Ocimum* sp. MLO has also been reported on *Sesamum indicum, Arachis hypogea*, Cowpea, Ppigeon pea, *Argemone mexicana* and sunhemp [Muniappa *et al*;., 1980; Ghosh, 1976; Ghosh and Raychoudhuri , 1972; Ghosh *et al*., 1985].

2.6.1.1: Pollen Theory:

Hart and Rangaswamy, 1926 observed that spike disease spreads in East to North Eastern direction towards Salem district in Tamilnadu corresponding to the general direction of the south west monsoon. They also observed that pollen from partially spiked trees is the causal entity which gives the impression that sandal under nature conditions has never become spiked before flowering. However, it was felt that the pollen theory could not explain adequately the initial attack of spikes on further no experimental transmission by pollen could yield successful results.

2.6.1.2: Physiology of Spiked Sandal :

The onset of spike disease in sandal results in a number of physiological changes. Some of the prominent changes are: increase in levels of carbohydrate, particularly starch [Iyengar, 1928a], total nitrogen, phosphorus [Rama Rao & Sreenivasaya, 1928], Nitrate content [Parthasarathi *et al*., 1962], Phenolic bodies [Parthasarathi and Ramaswamy, 1961], Tannins [Iyengar, 1937a], Acidity [Iyengar, 1938a] and Ascorbic acid [Parthasarathi *et al*., 1963], and a lowering in levels of ash, potash and lime levels [Iyengar, 1928b] and iron content [Parthasarathi and Rao, 1962a].

2.6.2: Pests:

Many species are serious pests of cultivated crop plants and forest trees. Some species inject toxic materials into the plant while feeding and some transmit disease organisms and a few heteropterans are vectors of diseases of warm-blooded vertebrates [Triplehorn and Johnson,2005]. Earlier, Mathur & Singh, 1961 reported that 17 species of hemipterans and Varshney, 1992, 2002 reported that two species of scales and mealy bugs infesting Sandal. Remadevi *et al.*, 2005 reported that eight species of sucking pests infesting Sandal in nurseries. Sundararaj et al., [2006a] reported the occurrence of 23 species of scales and mealy bugs on Sandal. Sundararaj et al., [2006b] in their review indicated the presence of 411 species of hemipterans under 43 families in Sandal ecosystem, which included phytophagous insects, predators & casual visitors and 18 species of Thysanoptera under 4 families infesting Sandal.

Ascotis selenaria imparata Walker (Geometridae: Lepidoptera) is a serious pest in irrigated plantations. There are 5 generations in Northern India and 6 generations in Southern India [Chatterjee,1935].

The insect stem borers play a major role in the damage of Sandalwood. These stem borers include *Indarbela quadrinotata* (Lepidoptera:Indarbelidae), *Zeuzera coffeae* (Lepidoptera:Cossidae) and *Aristobia octofasciculata* (Coleoptera:Cerambycidae) in South India. Trees infested by these borers show poor growth and poor quality timber. Sandal Kotis in South India, showed sandal logs with hollowed heartwood and an average logs of 198.6 kg of heartwood was found lost to every tonne of timber produced by these trees [Remadevi *et al.*,1998]. Beeson, 1941, Mathur & Singh, 1961 and Brown, 1968 recorded that *A. octofasciculata* boring small branches and stem of saplings of sandalwood.

2.7: Chemistry and Utilization

Sandal bark is one of the raw materials which has not been put to any use so far. Benzene extract of powdered bark on repeated chromatography over alumina gave a new triterpene solid ester (yield 0.3%) which has been identified as urs–12–en–3–beta–yl–palmitate (Shankaranarayana et al., 1980a]. The compound is a chemosterilant and an insect growth inhibitor too [Shankaranarayana et al., 1979a]. Sandal bark also contains small amounts of betasitosterol, fatty acids and 14% tannins (Shankaranarayana et al., 1980b). Seeds contain 50 to 60% of a drying oil composed of 80% santalbic, 2.5% stearolic and 10% oleic acids. The seed oil is a polyunsaturated fatty oil comprising of acetylenic glycerides – santalbic and stearolic. Seeds of all members of santalaceae possess santalbic acid which is a characteristic feature of the family [Hatt and Schoemfeld, 1956]. Sandal oil has been studied by many works for its physico – chemical properties, chemical compositions and structure of constituent molecules. [Iyer,1935; Sreenivasaya and Narayanna,1936; Madhurnath and Manjunath, 1938; Manjunath and Siddappa, 1943; Gunstone and McGee, 1954; Gunstone and Russell, 1955; Hatt *et al*., Morris and Marshall, 1966 and Hopkins *et al*., 1969].

Deoiled seed meal prepared from decoated of sandal contains 52.5% protein (rich in essential amino acid) and 5% mineral matter (rich in N, P, K, Ca, Mg). The status of protein, amino acids and minerals in comparison with that of common feed material (cotton seed, guinea grass, oat hay, sorghum hay, wheat hay) indicates its potential use as a feed for farm animals [Shankaranarayana and Parthasarathi, 1985a].

Seeds from young trees show their potential use as rich proteinoid and nutritive source even at the young stage of the sandal plant [Shankaranarayana *et al*., 1990]. Further, it has been found that nonviable sandal seeds contain slightly larger amounts of fatty oil but less amounts of protein compared to viable seeds [Ananthapadmanabha et al., 1989b].

Apart from its importance as a supremely satisfying source of fragrance, it finds use in medicine as an antiseptic, antipyretic, ant scabietic, diuretic, expectorant, stimulant and for treatment of bronchitis, dysuria, gonorrhoea and urinary infections [Handa *et al*., 1951; Okasaki and Oshima, 1953; winter, 1958; Dastur, 1962; Jain, 1968]. However, its use as a base of fragrance has far outweighed its use in medicine.

Sandal oil is nearly colourless to golden yellow, viscous liquid, ref. ind. 1.449 – 1.506, sp.gr. 0.962 – 0.985, solubility in 70% alcohol – 1:5 volumes, opt. rot - 19^0 to 20^0 , acid value 1.9 – 2.2, ester value 13 -16, ester value after acetylation 210 -215, ester content 1.6 – 5.4%, alcohol content (Santalols) > 90%. Sandal oil has been extensively studied for chemical constituents, their isolation, synthesis and quantitative evaluation [Guha and Bhattacharya, 1944; Balakrishnan *et al.,* 1956; Dasgupta *et al*., 1956; Ghatgey and Bhattacharya, 1956; Karawya and Wahba, 1962; Kishore, 1962; Nigam and Devi, 1962; Kamat *et al*., 1967; Walker, 1968; Bhati, 1970; Kumar and Kartha, 1974; Chaurasia *et al*., 1975; Demole *et al*., 1976; Brunke, 1981a; Yadav and Bisarya, 1982].

Gairola et al, 2007 stated that the current harvest of sandal wood and international demand for its oil exceeds supply, and prices continue to rise. Currently, sandal wood oil is sold in the international market at the rate of Rs. 70,000/- to 1,00,000/- per kg. Singh and Shankar, 2007 explained that the world market demand of sandalwood is around 5000-6000 tonnes. Of this demand, more than two-third is for Indian sandalwood. Production and export of sandalwood and its products have shown a steep decline in India. Sandalwood production in the country has fallen from about 4000 tonnes per annum in 1960s to 2000 tonnes during 1990 and 1000 tonnes in 2000. This gap in demand and supply has led to an increase in price has in turn, led to massive smuggling. Kumaravelu et al , 2007 attempted to extent the tree beyond its natural confines were accompanied by poor aroma or absence of aroma in the heartwood. In its natural habitat, the tree flourishes from sea level up to an altitude of 180 m and in a rainfall zone of 300 to 2540 mm, but good heartwood formation is obtained at an altitude between 600 and 900 m and rainfall range of 850 to 1350 mm. Trees growing on poor, gravelly soil are characterized by better fragrance and high oil yield, despite their smaller dimensions. Being a

partial root parasite, it always occur as a mixed species and is never found in pure patches. The hosts of sandal have been classified as good and bad depending upon the host parasite haustorial connections. Dhanya and Viswanath, 2007] made an opinion that India accounts for 85% of the $1billion international sandal market as the foremost producer and consumer of sandalwood. They highlighted the lacuna in existing laws that hamper private initiative in sandal cultivation.

Shivanna *et al.,* 2014 conducted a field study to no stomata movements which regulate the amount of water loss from the transpiration alone. Their study showed that the amount of water loss was highest in the morning and least in the evening. They concluded that the sandalwood tree growth is very slow in almost all ecological systems with minor growth differences and the transpiration is the vital physiological process that eventually controls the plant growth. Arti Rani *et al.,* 2014 studied on molecular approaches to understand/decode oil production in sandalwood and found that the principle chemical constituents are sesquiterpenoid compounds mainly α – santalol (40-55%) and β – santalol (12-27%) which constitute > 90% of the distilled oil. Nesari, 2014 explained that anti-hyperglycaemic and anti-oxidant potentials of α – santalol & sandalwood oil, anti-microbial & anti-oxidant properties possibly attributed to sesquiterpenoids, shikimic acid, etc. Gupta, 2014 studied on vibrational spectroscopy of Indian Sandalwood oil and explained that almost 90% of the total alcohols are santalol, around 2-4% of santalol are present as esters. Mohan *et al.,* 2014 advocated that the species has been categorized as "Vulnerable" by International Union for Conservation of Nature (IUCN). Adulterating an essential oil is relatively easy, forms of adulteration may include introducing an alcohol, producing synthetic products, substituting different and cheaper oils and synthetic chemicals and passing them off as natural oils. Adulteration radically changes or reduces the perfumery and therapeutic properties valued oil.

2.8: USES

Its wood known commercially as 'East Indian Sandalwood' and essential oil from it as 'East Indian Sandalwood Oil' are among the oldest known perfumery materials. Both wood and oil are used in incense, perfumes and in medicine and are of great commercial importance. Sandalwood being closely grained and amenable to carrying, is some of the finest woods for the purpose. It is used for making idols, boxes and other curios of exquisite beauty [Srinivasan *et al,* 1992]. Power of heartwood upon steam distillation yields the East Indian Sandalwood oil which is rated very high for its sweet fragrant, persistent, spicy, warm, woody note, non-

varying composition and fixative property. Apart from it importance as a supremely satisfying source of fragrance, it finds use in medicine as an antiseptic, antipyretic, antiscabietic, diuretic, expectorant, stimulant and for treatment of bronchitis, dysuris, gonorrhea and urinary infections [Handa *et al*., 1951; Okasaki and Oshima, 1953; Winter, 1958; Dastur, 1962; Jain, 1968]. However, its use as a base of fragrance has far outweighed its use in medicine. Indian Sandalwood is highly valued for its fragrant heartwood, which consists of the highest oil (upto 6%) as well as santalol (α & β 90 %) contents in oil as compared to other species of the genus Santalum [Srinivasan *et al,*1992]. Sandalwood oil is used in world – class perfumes due to its excellent fixative properties & attars in Indian perfumes [Anonymous,1972].

During 1918, Shastri a renowned chemist who studied intricacies of soap manufacturing at Landon, started experimenting natural sandal oil use in soap industry. In these experiment, sandal oil maintained its original fragrance & properties intact. The protecting, smoothening, moisturizing, hydrating and skin anti-wrinkling properties of sandal oil are praiseworthy even in the form of soap. **S**andalwood 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. Essential oil of Sandal is formed by the plant cells and reservoir of solar healing power. It is described as lifeblood of the plant. Marcel Lavabre, a French Aroma Therapist, went one step ahead and rightly said "essential oils are the ultimate manifestation of a plant's enjoyment of life''. When one smells the fragrance, it is the tiny droplets of air borne essential oil of sandal, which triggers a response in a olfactory epithelium or smell sensors in roof of the nose. From here it is just one nerve synapse to the limbic system of the brain, which regulates motor activities, primary drives, emotions and memories. Impulses are then transmitted to the hypothalamus, which regulates bodily functions like temperature, thirst, hunger, blood sugar level, growth, sleep and wake patterns, sexual arousal and the emotion. Ultimately, the pituitary is stimulated next, which activates the endocrine system which in turn controls digestion, emotional and sexual behavior, responses to stress and all metabolic process. Bhat and Prajapathi, 2007 described medicinal and cosmetic uses of sandal in the context of ancient literature. Madhu *et al.,* 2014 opined that 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 artefacts and intrinsic carvings and its oil is used in manufacturing perfumes, incense sticks and in medicines.

2.8.1: Medicinal Uses

Ayurveda translates into English as the **Science of Life (Ayur - life, veda - science)**. Ayurveda is the oldest and most developed life science of natural healing in the world. Life is the outcome of the union of **body (Sharir), sense organs (Indriya), Psyche (Mana)** and **Soul (Atma)**.

Ayurveda is not merely a system of Healing, but an entire way of life that aims to bring about the perfect balance of the entire personality - body, mind and spirit. Ayurveda is based on theory of tridosha of the three Biological forces - Vata, Pitta and Kapha. Disease arises when there is an imbalance among the three Doshas and aim of the therapy is to bring about the required equilibrium.

AyurvedaTravelMall.com offers us an opportunity to combine a Tropical vacation along with Ayurveda healing or rejuvenation. We offer you a wonderful selection of Ayurveda health resorts in Kerala, India to choose from. **And a word about Kerala : National Geographic magazine chose Kerala as one of the 50 must see places on earth.**

Kairali is one of its kind unique and exclusive Ayurvedic Health Resort at Palakkad, Kerala, South India, where one could stay in a paradise like atmosphere and experience various Ayurvedic Therapies. Kairali Ayurvedic Health Resort is spread across 50 acres of lush green and beautifully landscaped garden with 30 independent villas designed distinctively different from each other and having luxurious, comfortable and with modern facilities.

Kairali is designed to retain traditional values yet contemporary to suit modern days living. Kairali is the one and only exclusive Ayurvedic Health Resort practicing Panchakarma treatments for rejuvenation, detoxification and treatments for various ailments including Yoga and Meditation practiced under the supervision of highly qualified and experienced Doctors.

Other features of Kairali Resort are swimming pool, indoor recreations, astrologer & palmist on request, full fledged restaurant, which serves delicious and nutritious food, library and conference hall with a seating capacity of 80 people.

Packages at Kairali Resort:

- Kairali's Special Herbal Oil Massage Therapy.
- Kairali's Special Treatment for Arthritis & Spondylitis.
- Kairali's Special Weight Loss Programme.

- Kairali's Special Panchkarma Therapy.
- Kairali's Special Holistic Treatment for Rejuvenation & Detoxification.
- Kairali's Special Ayurveda - Yoga - Meditation & Astrology package.
- Kairali's Special Eye care treatment.
- Kairali's Special Beauty treatment.

Good News to kidney stone patients:

The pain of kidney stones when becomes unbearable, you start finding remedies, and suddenly think of removing it, by surgically or ESWL or pcnl. Even after going through any one of them, you start feeling severe pains within two three months or two three years, because the formation process re-mains on.

This is my experience that, those who eat specially the junk food, they get hard calcium oxalates (hard to hammer also). And those who have followed *Regional Traditional Food Culture*, not gone to any doctors till now. There are four types of kidney stones, Calcium Oxalates, Uric Acid, Struvite and Cystine. 60% to 70% of the kidney stones patients are of Calcium Oxalates.

Now a days this is widely seen that the young generation is getting more affected from this kidney stones disease, due to unhealthy food. And those who eat junk food, specially the biscuits, cookies, bread (yeast added), rusk, deep oil fried, roasted, baked, fridge items like chilled water, soft drinks, ice creams, are also getting affected their health, by one or the other issues.

'*Health is Wealth*' - the meaning of this can be understood, only when the pain starts, and the person starts seeking permanent solution for this disease.

There are so many systems of medicine, among them all, Ayurveda assures you long term relief for the kidney stones relief, but the thing is you have to get addicted to your own Regional Traditional Food Culture, be punctual for your food, drink water only whenever you feel thirsty, that too the quantity you actually needed. Don't suppress the urge of urination and stool - increases toxins in the body. It is always wise and better to keep sufficient gap between two meals, to digest well.

The medicine, which has got more than 35 years' experience, relieved pain and starts dissolving the kidney stones, for rare people the stones have come out, otherwise, the stones get dissolved inside only.

Effective Ayurvedic treatment for back pain, knee joint pain, asthma, diabetes infertility, hair regrowth, knee pain, dandruff, paralysis, obesity, pimples, migraine, hair loss, hair fall, skin diseases, fibroids, piles, weight loss, constipation, acidity, osteoarthritis, cholesterol, jaundice, sciatica, osteoporosis, haemorrhoids, gastric problems, spondylitis, cough, insomnia, psoriasis, rheumatoid arthritis, PCOS , sinusitis etc...

[On-line free Consultancy: http://www.krishnenduayur.com/contact.html].

Used internally in chronic bronchitis, a few drops on sugar giving relief; also in gonorrhoea and gleet; in chronic cystitis, with benzoic and boric acids. Much used as a perfume for different purposes. The wood is used for making fancy articles and is much carved.

Fluid extract, 1 to 2 drachms. Oil, 5 to 20 drops.

Adulterants---Castor oil is often added, and on the Continent oil of cedar, made by distilling the chips remaining from the manufacture of lead pencils.

Other Species---*Pterocarpus santalinus* or *Santalum rubrum* (Red Sandalwood), solely used for colouring and dyeing. Other varieties come from the Sandwich Islands, Western Australia and New Caledonia.

Allergens

Allergen help from Maharishi Ayurveda; Allergens: The Ayurvedic solution; Spring does not have to be synonymous with Allergens; It is helpful for respiratory immunity.

Amrit Protection

Perfect balance in a jar; The inside story of a powerful Ayurvedic Rasayana; A wonderful Gift from Nature; A packet of Nature's inteliigence; An intelligence compound that helps cells function normally; The best generalized antioxidant one can take.

Aroma therapy

Ayurvedic aromatherapy; aromatherapy for perfect balance in every season; using essential oil properly; aromatherapy oils: the scent of perfection.

Ayurveda experts suggestions for

Balanced weight; children's health; Detoxification; Digestion; Energy; Eyes and Ears; Food and beverages; Hair care; Immunity; Joints and muscles; mind and body spirit; Skin care; Good sleep; No retention of stress.

Aurvedic Beauty

Simple, sparkling beauty; a unique paradigm of beauty; How to look more beautiful; anyone can have beautiful hair; Ayurvedic cure for varicose veins; The healing bath as a therapeutic activity.

Aurvedic Diet

Ayurvedic comfort foods; Don't skip breakfast: the ayurvedic perspective; The Importance of astringent and bitter taste for balance nutrition; The ayurvedic view on drinking milk; Super fruits: an ayurvedic view on fruits; Lightening up: balancing Pitta Dosha; Vata-Pacifying Nuts; Stay cool: balancing Pitta Dosha; Embracing pure foods.

Aurvedic Food Tips

Allergy fighters: cilantro and coriander; Simple ways to minimize acid indigestion;

Balalanced Weight Control

Vata-related weight imbalances; The Ayurvedic approach to weight management: tips for pitta-related weight imbalances; Enhancing the fire elements: a unique approach to kapha-related weight gain; FAQ: body type, weight gain and obesity.

Emotional Support

- Beating the Blues: Ayurvedic Insights into Emotional Health.
- A little something for your mood?
- Ten ways to beat Blues: Ayurvedic Recommendations for Emotional Health.
- Keep your spirits up a down economy.

Exercise

- Wiping away fatigue.

- Recharge, restore, rejuvenate! The Ayurveda way to feeling young at any age.
- Are you fighting fir?
- From fighting fatigue to fighting fit: A Practical Ayurvedic Guide.

Heart Health

- Seven common sense Ayurvedic ways with white sandal solution to keep Heart Healthy.
- Ayurveda for a Healthy Heart.
- Heave a Healthy Heart.
- Your Heart and Secret of Ojas.
- Your Magnificent Heart.
- A new look at cholesterol.
- The wisdom of a Healthy Heart.
- The secret Heart of the rose.

Digestion and Metabolism

- The Maharshi Ayurvedic Approach to Balancing Cholesterol.
- Strengthen digestion to enhance immunity.
- The facts about cholesterol.
- How can you tell if you have ama?
- The remarkable qualities of Tri Phala – a famous and revered Ayurvedic formula along with a pinch of white sandal dust.
- Taking care of toxins.
- Nourish the liver to live better.
- Ayurvedic liver support.
- Digestion's hidden power : supporting transformation.
- Use rejuvenation therapy to restart digestion.
- Give thanks to your digestion.
- Happiness starts in the stomach.
- Digestion and balanced Health.
- Nine essential to support Digestion.
- Upgrading to an Ayurvedic Diet: Five secret for good digestion.

- Herbs digestion along with white sandal powder (a needle area only).
- The importance of strong digestion for healthy living.

Immunity

- Stay sniffle free this winter.
- Turning the heat up on the common cold.
- Ways to boost immunity this winter.
- Keys to respiratory immunity from Maharshi Ayurveda.
- You can stay healthy this winter.
- Sinus help is on the way.
- Children's health: stronger immunity through digestion.
- Prepare for flu season with Ayurvedic purification. With white sandal mixture.
- Insight into immunity.
- Five defenses against white sandal Ayurvedic medicines.
- Understanding the six stages of diseases.
- Immune-boosting winter foods and drinks
- Enjoy your youth with a rational harmony.

Joints

- Joint health: flexible for fall.
- Improving joint flexibility using sandal paste or lotion.
- Ayurvedic help for Achy of Joints.
- Use Maharshi Ayurveda medicine for osteoporosis, tennis albow, ortho-artharitis (in shoulder joint), femer bone pain etc. to keep your health in good condition through yoga and free hand exercise in a regular manner.

Massage

- Maintain Ayurvedic foot care.
- Use Sesame oil: Revered in Ayurveda for its Healing properties.
- Use special type of Ayurvedic sandal massage.
- The story of the Next Generation of Skin Care: Youthful Skin Massage.
- Use Abhyanga – the Ayurvedic daily massage.

- How to do an Ayurvedic Spa Treatment in your Own Home – follow the advice of any good Ayurvedic/uninani/allopathy/ homeopathy medical practitioner.

Menopause

Menopause relief; Menopause can be comfortable – the Ayurvedic perspective; Relief from hot flashes; the Ayurvedic way; Prepare a healthy menopause; Managing menopause naturally with Ayurveda; Menopause re-defined.

Prostrate Health

A powerful approach to Prostrate health; A Ayurvedic view on Prostrate health; Maintaining Prostrate health; Prostrate protection: For Men of a Certain Age; Ayr Vedic Approach to Prostrate health.

Miscellaneous

Rose Halva and Cashew cookies; Balance vata Dosha with carrot milk; Cook an Ayurvedic Thanks giving Feast; Ayurvedic recipes for heart; Recipes for fall cleaning; and Celestial Cilantro Chutney; Pumpkin Soup and Party Mix; Food and Holiday Ojas; Cooking with Rose; An Ayur Vedic Lunches; Ayurvedic Rose Petal Spread Recipes; Vegetable Khichari; Spring Recipes.

Jahan and Rahman (2014) explained that sandal dissolves inflammation and tumours and stabilizes palpitation. Sandalwood is used as a disinfectant in bronchial and genitourinary tract infection. 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, diarrhoea, leucorrhoea, menorrhagia and sore throat. It is one of the potential anti-ulcer drug used in Unani system of medicine. Various uses mentioned in Ayurveda system about sandalwood are in treatment of various other ailments like diarrhoea with bleeding, intrinsic haemorrhage, bleeding piles, vomiting, poisoning, hiccoughs, initial phase of pox, urticaria, eye infections and inflammation of umbilicus (Benencia and Courreges, 1999; Desai et al,1991). α-santalol, an active principle of Sandalwood oil, has been studied for its skin cancer preventive efficacy in murine models of skin carcinogenesis, employing human epidermoid carcinoma cells. It was assessed whether α- santalol at concentrations of 25-75 μml resulted in a concentrations and a time dependant decrease in a cell number, which was largely due to cell death. Dwivedi *et al* (2014) enumerated that both the sandalwood powder and its essential oil have been used in Ayurveda for curing genitor-urinary disorders, gastric irritability, dysentery, excessive sweating,

high blood pressure, heart pain, inducing sleeping, cleaning wounds, respiratory disorders, fever and different skin diseases.

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2.8.2: Religious Uses

Sandalwood is often used for rituals or ceremonies in Hinduism. Sandalwood is considered in alternative medicine to bring one closer with the divine. Sandalwood essential oil, very expensive in its pure form, is used primarily for Ayurvedic purposes and treating anxiety. In Buddhism, sandalwoods are considered to be of the Padma (lotus) group and attributed to the Bodhisattva Amitabha. It is believed that the sandalwood scent helps to transform one's desires and maintained a person's alertness during meditation. Sandalwood is also one of the most popular scents used for incense used when offering incense to the Buddha.

2.8.3: Domestic uses

Sandalwood's main component β-santalol (90%) has antimicrobial properties. It is used in aroma therapy and to prepare soaps. Due to this antimicrobial activity, it can be used to clear skin from spots and blackheads, but it must always be properly diluted with carrier oil.

Sandalwood paste is used as an embalming paste in temples on idols. The bindi dot is sometimes created from sandalwood paste used on forehead during worship.

The essential oil extracted from sandalwood is beneficial for toning up the skin as well as healing skin disorders when applied externally. To treat the infected areas on the skin dilute a few drops of diluted sandalwood oil in water and soak the affected area with the solution directly. This will not only help in healing the skin infection but also tone up the epidermis. Sandalwood together with agarwood is the most popular and commonly used incense material by the Chinese and Japanese in worship and in various ceremonies. It has also extensive uses in Indian incense, religiously or otherwise.

2.8.4: Industrial Uses

The great value of this species is its heartwood and oil, which are widely used in cosmetic, perfume, medicine and aroma therapy industries [Srinivasan et al. 1992; Kim et al. 2006]. Sandal bark is one of the raw materials for the industry. Benzene extract of powered bark on repeated Chromatography over alumina gave a new triterpene solid ester (yield o.3%) which has been identified as urs-12-en-3-beta-yl-palmitate [Shankaranarayana et al, 1980b]. The compound is a chemosterilant and insect growth inhibitor too [Shankaranarayana et al, 1979a,b]. Seeds contain 50-60% of a drying oil composed of 80% santalbic, 2.5% stearolic and 10% oleic acids.

Santalum album L. is a small to medium-sized, evergreen semi parasitic tree of family Santalaceae [Fox 2000, Chaudhary *et al.* 2016]. *S. album* commonly known as Indian Sandalwood is one of the oldest and precious sources of natural fragrance with immense medicinal and commercial significance [Burdock & Carabin 2008, Hansda 2009, Bajpai *et al.* 2016]. The species is recognized due to its fragrance and significant social and economic values [Brandis, 1978; Shiddamallayya et al. 2015; Felicity Rusakanika and Munyarads Stray, 2015]. The word sandal has been derived from Chandana (Sanskrit) and Chandan (Persian). It is called Safed Chandan in Hindi, Srigandha, Gandha in Kannada, Sandanam in Tamil, Chandanamu in Telugu. Historical review reveals that sandalwood has been referred to in Indian mythology, folklore and ancient scriptures. It is generally accepted that sandal is indigenous to peninsular India as its history of recorded occurrence dates back to at least 2500 years. Historical review reveals that sandalwood has been referred in Indian mythology, folklore and ancient scriptures. Certain cultures place great significance on its fragrant and medicinal qualities. Its main component *'Santalol'* of Sandal wood has antimicrobial property and used in aromatherapy. A

bulk of it is used in the perfume and toiletries industry. Traditionally, sandalwood oil used to treat skin diseases, acne, dysentery, and in number of other conditions. In traditional Chinese medicine, its oil is considered an excellent painkilling agent, alleviate itching and inflammation, cools, calms and cleans the blood. The medicinal properties of sandalwood exist in the oil, which can either be pressed from the wood or extracted with alcohol or water. It relieves fever, thirst, burning sensation and stops sweating. It is good for fever or rejuvenates the skin to natural state harmed by overexposure to the sun, and it awakens the intelligence. Besides these, it is used in heart care, anti-dandruff shampoo, anti-wrinkle cream, baby cream, baby powder and chayvanprasha. The heartwood of Sandalwood is also used for making wood crafts and decorative furniture [Bisht et al., 2019]. The sandal is known for its oil which is pronounced as the most famous East Indian sandal wood oil which is produced from the heartwood of sandal on distillation mainly for perfumery industries and pharmaceutical industries [Shankaranarayana *et al.,* 1998]. Sandalwood oil is esteemed all over the world and is highly prized in perfumery and cosmetics. The highest yield of sandalwood oil is from roots and lowest from the sap wood. In addition to oil, the wood and its powder are used for religious, cultural and medicinal purpose. Both wood and oil are used in incense, perfumes and in medicine and are of great commercial importance. It is used for making idols, boxes and other curios of exquisite beauty [Srinivasan *et al,* 1992]. Powder of heartwood upon steam distillation yields the East Indian Sandalwood oil which is rated very high for its sweet fragrant, persistent, spicy, warm, woody note, non-varying composition and fixative property. However, the yield and quality of oil varies depending on the locality, age of the tree and distillation method.

There are two main commercial species of Sandalwood in the world: Australian Sandalwood (*Santalum spicatum*) and Indian Sandalwood (*Santalum album*). Annual global demand of Sandalwood was estimated to be 6,000 tons in 2006 [Shankaranarayana, 1998]. To fulfil this demand, Western Australia exports about 2000 tons annually [Shankaranarayana, 1998]. The extremely high demand and reduced supply of Sandalwood is driving its price up all around the world. Sandalwood from Mysore region of southern India is generally considered to be of the highest quality available. The price of Indian Sandalwood fetches two third better prices than Australian Sandalwood. Other species are found in the Pacific region and Australia. The natural resource of Pacific sandalwood species has been heavily exploited since the early 19th century [Shineberg, 1967], and on some islands, the resource has been practically exhausted [Nor, 1982; Neil, 1986; Barrance, 1989]. Some confusion exists over the taxonomy of these species due to variations in appearance and habit. For example, *S. insulare* from French Polynesia and *S. marchionense* from the Marquesas may be varieties of the same species [Neil,

1986]. Sandalwood has not enlisted as endangered flora by CITES but IUCN and the Government of India have included Indian Sandalwood trees in the list of endangered species in recent Years. The government of Indian has attempted to curb its possible extinction through limiting the exportation of sandalwood. Therefore, export of timber from India is totally banned except for handicraft pieces of Sandalwood up to 50g weight [Brandis, 1978].

2.9: PLANT DESCRIPTION

S. album is a small evergreen tree, a partial root parasite, attaining a height of 12 to 13 meters and girth of 1 to 2.4 meters with slender drooping as well as erect branching. Leaves are opposite and decussate, and sometimes show whorled arrangement. Flowers are purplish brown, unscented and are borne in axillary or terminal cymose panicles. Flowers are tetra or pentamerous. The ovary is semi inferior and unilocular. The tree starts flowering at an early age of 2 to 3 years. Generally, trees flower twice a year from March to May, and September to December. Sometimes the two flushes of flower production may overlap each other so that the same tree may show all stages of development of flower initiation to mature fruits at one time. Fruit is a drupe, purplish when fully matured and single seeded. Seeds are naked, lack testa and are dried and stored in polybags or gunny bags [ICFRE, 1972]. The species is spread rapidly through seed dispersal by birds, which feed on the outer fleshy pericarp. Viable seed production occurs when the tree is 5 years old.

2.10.2: Habitat and Distribution

The sandal family is distributed between 30^0N and 40ºS from Indonesia in the West to Juan Fernandez Island in the north to New Zealand in the South. In India *Santalum album* is found all over the country, with over 90% of the area in Karnataka and Tamil Nadu covering 8300 sq. kms. In Karnataka, it grows naturally in the southern as well as western parts over an area of 5000 sq. kms. In Tamil Nadu, it is distributed over an area of 3000 sq. kms. and dense population exists in North Arcot (Javadis and Yelagri hills) and Chitteri hills. The other states where sandal trees are found are Andhra Pradesh, Kerala, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, Bihar and Manipur. The tree flourishes well from sea level up to 1800 m altitude in different types of soil like sandy, clayey red soils, lateritic, loamy and even in black cotton soils. Trees growing on stony or gravelly soils are known to have more highly scented wood. It grows best where there is moderate rainfall of 600 to 1600 mm. It

grows well in early stages under partial shade but at the middle and later stages shows intolerance to heavy overhead shade[3]. It also grows on low lateritic cliffs above the beach. The tree is actually an obligate hemi parasite plant on various hosts, *Cassia siamea, Pongamia glabra* and *Lantana acuminata*. It is now also planted in China, Sri Lanka, Nepal, Malaysia, the Philippines and Northern Australia.

2.11:Cultivation and Harvesting

The sandalwood trees are cultivated mainly by showing the seeds. When sandalwood tree plants are 15 to 20 years old then in august to march the seeds are collected from the sandalwood. The collected seeds are then well treated and dried in sunlight before seminate on nursery beds. Two types of seed beds i.e. sunken and raised beds are available in the nursery for the showing of sandalwood seeds. After 7 to 8 months, a seedling grows up to 30 to 35 cm on nursery beds and they are ready for the transfer in the main field. The pit size is digged 45×45×45 cm for planting the sandalwood seedlings and is kept 10 feet plant to plant distance.

Sandalood tree grows well and matures after 30 years from planting so, it will be ready for harvesting. In the latest technology there are many tree cutting instruments available in the market so farmers can use any instrument for harvesting sandalwood trees. The heartwood of sandalwood trees are transferred tnto the mill and soft woods are removed. By using some machine this hard sandalwood is transferred into powder. This sandalwood powder is soaked in water for 2 days after it is used for making oil and other cosmetic products.

2.12: PRODUCTS

Food: Fruits are edible.

Fodder: Trees are sometimes lopped for fodder; the foliage of S. album is palatable to grazing animals such as rabbits, sheep, goats, cattle, pigs, horses and camels.

Fuel: The wood has been used as a fuel but is generally considered too valuable for this purpose.

Timber: S. album is mainly grown for its timber, which weighs 870 kg/cubic m, is durable and strong. Its close grained heartwood is used for ornamental and carving work.

Tannin or dyestuff: The bark contains about 12-14% tannin and has good potential in the tanning industry.

Seeds yield an oil that can be used in the manufacture of paint.

Essential oil: A valuable oil, 'the sandal oil', is distilled from the heartwood (yield varies from 4-10%) and is used in perfumery, soap making and medicines. The roots contain maximum quantity of oil and hence are more valuable.

Other products: Powder from the heartwood is used to make incense sticks, burnt as perfumes in houses and temples, or is ground into a paste and used as a cosmetic.

2.13: Traditional uses

In the Indian traditional medicine system Ayurveda, white sandalwood (=*Chandana*) has largely been used as a demulcent, diuretic, and mild stimulant [Bhat,2006]. Sandalwood oil has been traditionally used for treatment of common colds, burns, headaches, bronchitis, fever, infection of the urinary tract, inflammation of the mouth and pharynx, liver and gallbladder complaints and other maladies. The oil finds use in Ayurveda as antiseptic, cooling, diaphoretic, antipyretic, antiscabietic, diuretic, expectorant, stimulant, expectorant, carminative, cicatrisant, antiphlogistic, antiseptic, antispasmodic, aphrodisiac, astringent and in the treatment of bronchitis, psoriasis, palpitations, sunstroke, urethritis, vaginitis, acute dermatitis, herpes zoster, dysuria, urinary infection, gastric mucin augmenting activity, and gonnorheal recovery as it contains antibacterial and antifungal principles [Paande, 1977; Handa et al., 1951; Okazaki and Oshima, 1953; Winter, 1958; Dastur, 1962; Jain, 1968; Dikshit and Hussain, 1984]. Sandalwood oil along with other plant mixtures has been used to cure stomach illnesses, in treatment of elephantiasis and lymphatic filariasis [Battaglia, 2007]. The hydrolyzed exhausted sandalwood powder (HESP) on pharmacological screening demonstrated antiremorogenic, antiinflammatory, anti-mitotic, antiviral, anticancerous, hypotensive, antipyretic, sedative, ganglionic 89 blocking, and 90 insecticide properties [Rohadi et al., 2004; Shankarnarayanan and Venkatesan, 1981; Desai et al., 1991].

Venous and lymphatic stasis such as varicose veins and swollen lymph nodes of the lymphatic system were traditionally treated with sandalwood oil, where the therapeutic potential was attributed to santalols that have antiinflammatory effect [Brunke et al., 1995]. In

the traditional Chinese medicine (TCM), sandalwood (=*Tan Xiang*) was used by herbalists to treat skin diseases, acne, dysentery, gonorrhea, anxiety, cystitis, fatigue, frigidity, impotence, nervous tension, immune-booster, eczema, stomachache, vomiting and stress. According to Chinese medicine, sandalwood acts in case of any type of chest pains, originating either from lungs or hearts. The regulating and dispersing action of the oil is curative of the angina pain. Sandalwood also earns a mention in Discorides' De Materia Medica. Furthermore, the German Commission E monograph suggests 1/4 teaspoon (1–1.5 g) of the sandalwood oil for the supportive treatment of urinary tract infections [Holmes, 1989] as well as for pains, fevers and strengthening the heart. The sandalwood oil is used as a flavouring substance in food products such as frozen dairy desserts, candy, pan masala, baked food, gelatine, puddings and also in alcoholic and non-alcoholic beverages. US Food and Drug Administration, Flavour and Extract Manufacturers Association Council of Europe and Joint FAO/WHO Expert Committee has approved sandalwood oil for use as food additives. Besides, its uses in medicine and beverages it is also used in making idols and inlay ivory work. Such work is done on cottage industry scale. Many more items prepared from sandalwood such as rosary from seeds, garland from chips, soaps, perfumes, inscense sticks, powder etc. is long back industry of the people of ancient time. The wood used to make cabinets, caskets, jewel boxes and deed cases. The rich Hindus place pieces of sandalwood in funeral pile [Bluementhal 1998]. In Karnataka, the Government has taken lot of interest for the improvement of handicraft industries. They are supplying wood to the carvers at about 25% of the original price and the rest is borne by the Industries department so as to encourage and keep alive the skill and craft and also to earn foreign exchange for the country [Krishna Bahadur, 2019].

2.14: Religious Importance

2.14.1: Hinduism

Indian Sandalwood is very sacred in the Hindu Ayurveda and is known in Sanskrit as *Chandana.* The wood is used for worshipping the God Shiva, and it is believed that Goddess Lakshmi lives in the sandalwood tree. The wood of the tree is made into a paste using sandalwood powder and this paste is integral to rituals and ceremonies, to make religious utensils, to decorate the icons of the deities, and to calm the mind during meditation and prayer. It is also distributed to devotees, who apply it to their foreheads or the necks and chests. Preparation of the paste is a duty fit only for the pure, so is entrusted in temples and during ceremonies only to priests [Purohit, 2018].

2.14.2: Buddhism

In some Buddhist traditions, sandalwood is considered to be of the *padma* (lotus) group and attributed to Amitabha Buddha. Sandalwood scent is believed by some to transform one's desires and maintain a person's alertness while in meditation. It is also one of the most popular scents used when offering incense to the Buddha and the guru [Purohit, 2018].

2.14.3: Sufism

In *sufi* tradition, sandalwood paste is applied on the *sufi*'s grave by the disciples as a mark of devotion. It is practiced particularly among the Indian Subcontinent disciples. In the Tamil culture irrespective of religious identity, sandalwood paste or powder is applied to the graves of sufis as a mark of devotion and respect [Purohit, 2018].

2.14.4: Jainism

Sandalwood use is integral part of daily practices of Jainism. Sandalwood paste mixed with saffron is used to worship *tirthankar* Jain deities. Sandalwood powder is showered as blessings by Jain monks and nuns (*sadhus* and *sadhvis*) to their disciples and followers. Sandalwood garlands are used to dress the body during Jain cremation ceremonies. During the festival of Mahamastakabhisheka that is held once in every 12 years, the statue of Gommateshwara is then bathed and anointed with libations such as milk, sugarcane juice, and saffron paste, and sprinkled with powders of sandalwood, turmeric, and vermilion [Purohit, 2018].

2.14.5: Chinese, Korean, and Japanese religions

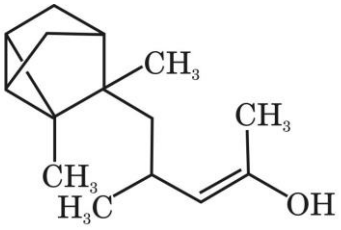
Sandalwood, along with agarwood, is the most commonly used incense material by the Chinese and Japanese in worship and various ceremonies. However, some sects of Taoists, following the Ming Dynasty Taoist Manual, do not use sandalwood (as well as benzoin resin, frankincense, foreign produced) incense and instead either use agarwood, or better still *Acronychia pedunculata*, in worship. In Korean Shamanism, sandalwood is considered the Tree of Life [Purohit, 2018].

2.14.6: Reported Phytochemicals in Sandalwood

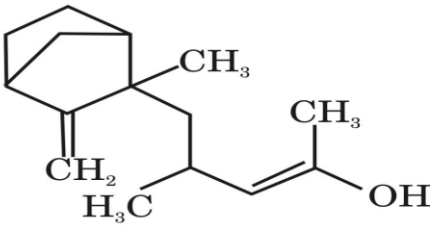
Sandalwood oil has been extensively studied for the chemical constituents and their isolation, synthesis and quantitative estimation. The volatile oil extracted from *Santalum album* L derived from the roots and heartwood is colorless to yellowish, viscous (ref. index-1.499–1.506, specific gravity 0.962–0.985 optical rotation -19–20º) liquid with peculiar heavy sweet odor, the chief constituents of the oil is santalol (90% or more) a mixture of two primary sesquiterpene alcohols, C15H24O like, α-santalol (b.p. 166–167ºC) and β-santalol (b.p. 177–178ºC) α-santalol is major components [www.enredlist.org/details/31852/0 cited on 25/07/2019]. More than hundred constituents of sandalwood oil [Anonymous, 1979; Benecia and Coureges, 1999; Desai et al., 1991] in categories of tannins, terpenes, resins and waxes have been reported which include such as hydrocarbons- santene(C_9H_{14}), nor-tricyclo-ekasantalene ($C_{11}H_{18}$), α and β- santalenes ($C_{15}H_{24}$), alcohols-santenol (C9H16O), teresantalol $C_{10}H_{16}O$), aldehydes- nor-tricyclo-kasantalal ($C_{11}H_{16}O$) and the acids α-and β- santalic acids ($C_{15}H_{22}O_2$) and teresantalic acids ($C_{10}H_{14}O_2$) [Guenther, 1952]

The fragrant parts of sandalwood oil α- and β-santalols were separated in pure form and a 0.5–0.8% higher yield in sandalwood oil was obtained by extracting wood powder with benzene [36]. Two minor components namely cyclosantalal (0.21–2.26%) and isocyclo-santalal (0.11–1.47%) new sesquiterpene aldehyde were reported. Also a new acid – ketosantalic (as methyl ester) and gamma – L – glutamyl-S-(trans-1-propenyl)-L-cysteine sulfoxide, an interesting natural sulfoxide diastereoisomers, have been isolated from sandal. Some authors also report the presence of Tricyclosantalal, α-santalene, trans-β-bergamotene, β-santalene (S & E), α-curcumine, α- santalol, beta-santalol (S&E), nuciferol, α-santalal and β-santalal in Santalum album (Ranibai *et al.*, 1986; Brunke *et al.*, 1995).

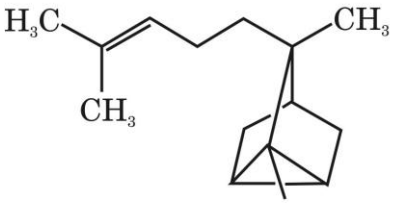
Sandalwood oil was also applied to Nardenisation- a technique to separate terpenic components by shaking with two immiscible solvents, the polar solvent dissolving oxygenated and non-polar holding the non-oxygenated one without santalenes[37]. The hydrolysis of non-steam volatile matter of the spent sandalwood powder with methanolic hydrochloric acid provides a new essential oil of Hydrolysed Exhausted Sandalwood Powder (HESP) (Nadkarni, 1954), which is demonstrated to have anti-inflammatory, anti-pyretic, mildly sedative, ganglionic blocker/hypotensive agent or blood pressure depressant and insecticide in controlling forest pests [Benencia and Couneges, 1999].



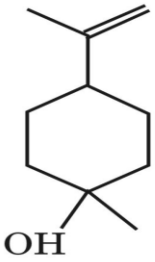
α-Santolol



β-Santolol

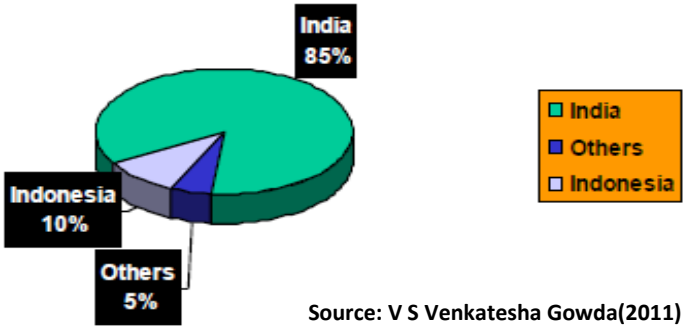


α-Santalene



Cis β- terpinol

The Global production Details of Santaum Album & Oil Production



Source: V S Venkatesha Gowda(2011)

2.14.7: PHARMACOLOGY

A number of pharmacological investigations on sandalwood and its oil have reported various biological effects ranging from aromatherapy, antibacterial to anticancer. The reported pharmacological activities of sandalwood as well as its oil are summarized here under:

Cosmetics and Beauty Therapy

There is a wide range of medicinal properties of sandalwood that makes it the best and most reliable of home remedies for face and all types of skin conditions like eczema, psoriasis and ringworm rash treatment.

Anti-tanning Property – Sandalwood paste is one of the best clear skin remedies that can be used to sooth harsh sunburns and clear skin tanning. The natural oils in sandalwood naturally clear skin complexion and add a healthy glow to it.

Anti-aging Property – The toning effect of sandalwood helps in shrinking skin pores that provides an even skin texture and prevents sagging and aging skin. It tightens the drooping skin tissues in order to provide a supple and youthful appearance to the skin.

Skin Softening Effect – One of the most effective sandalwood oil benefits is ensuring baby soft skin. Sandalwood oil can either be used by itself or infused with other natural oils and massaged into the skin to get best results.

Pimple and Acne Treatment – The powerful antibacterial properties of sandalwood work effectively in fighting the bacteria and fungi and prevents the breakout of pimples and acne.

Itch Relief -Skin itching and infections can be relieved within 30 minutes of application of sandalwood on the skin. It also helps in subsiding inflammation, skin redness and sore skin.

Prickly heat Solution – Excessive heat and sweating during summer season often result in itchy and painful prickly heat. The cooling astringent property of sandalwood helps in cooling the skin and curing prickly heat naturally.

Clear Complexion – Dark and dull complexion can make you unappealing and unattractive. Topical application of sandalwood mixed with other natural ingredients clear skin naturally without any side-effects. Best Sandalwood Remedies for Skin**.** Skin is a delicate organ, and it should be treated with special care. Although, there is a wide range of over the counter skin creams and lotions, but the harsh chemicals present in these products take a toll on the skin and damage it permanently. Therefore, it is best to opt for natural solutions. Here we give you a few sandalwood home remedies for healthy skin that you can prepare in your home. The best thing about these remedies is that only natural ingredients are used in them that are readily available in your kitchen.

Sandalwood Remedy for Pimples

Excessive oil and sebum deposited on skin attracts dirt and impurities and clogs the skin pores that lead to acne and pimple breakouts. Sandalwood is the best homemade treatment for acne and pimple breakouts. Make a paste by mixing 1 tbsp of sandalwood powder with ½ tbsp of turmeric powder and 1 tbsp of rose water. Apply a coat of this paste on your face and keep for about 20 minutes and then wash it off with water. By doing this, you can reduce your pimples and also you can feel your skin happy.

Source: Indian Ayurvedic Council web-site.

Sandalwood Remedy for Skin Spots

Liver dysfunction, exposure to sun rays and increasing age results in the formation of age spots and pigmentation. Take sandalwood powder and turmeric powder in equal quantity and make a paste of milk. Add a pinch of camphor powder to it. Massage your face with the paste and leave it for the night. It not only gives you a cool feeling but also cleans away the skin marks.

Sandalwood Remedy for Soft Skin

With progressing age and constant exposure to environmental pollution, the skin loses its softness. Take equal measures of sandalwood powder, turmeric powder or holy powder and lemon juice to make a paste and

apply it on your face. Rinse with cool water after 30 minutes. It would make your skin not just soft but also marks free.

Source: Indian Ayurvedic Council web-site.

Sandalwood Remedy for Open Pores

Open skin pores enhances the secretion of sebum and provides an uneven appearance to the skin. Make a paste of sandalwood powder and rose water and apply it on your face. Wash after 15 minutes. For the ones with oily skin, this paste prevents pimples and for others it cleanses your pores.

Source: Indian Ayurvedic Council web-site.

Sandalwood Scrub

Exfoliation is an important part of daily skin care that removes the layer of dead cells and deposits from skin, soften heels and cracked skin and add a natural glow to the skin of the body. Mix sandalwood powder and black chickpea powder in equal quantity either of milk or rose water; apply the paste to your face and massage in soft circular motion for 5 minutes. Leave it on for

another 30 minutes and wash off with water. This is an effective scrub for exfoliating the skin and removing dead cells, dirt and impurities.

Source: Indian Ayurvedic Council web-site.

Sandalwood Remedy for Clear Complexion

Even the brightest of complexion can be dull and lifeless due to the harmful effects of free radicals and oxidative stress. Sandalwood is one of the best natural remedies which might very well be the answer to the question of how to get a clear face in a week. Mix 1 tbsp of sandalwood powder with 1 tbsp of almond paste with 1/2 tsp each of honey and milk. Mix well and apply on face and neck. Wait for 1 hour and wash off with water. Applying this remedy 3 to 4 times every week helps in lighting skin tone.

Source: Indian Ayurvedic Council web-site.

Sandalwood Remedy for Anti-tanning

A day out in the beach or a picnic in the park can be fun and full of enjoyment, but it takes a harsh toll on the exposed skin causing severe skin tanning. But, sandalwood is the ultimate solution to the question of how to protect our face from the sun.

Procedure:

Mix one teaspoon of sandalwood powder with 1 teaspoon of sour curd and ½ teaspoon of honey. Blend it well and apply on face, hands and other tanned areas of the body. Leave it on for 1 hour and wash off with water. It not only add natural glow to skin but alsoremoves skin tan.

Sandalwood Remwedy for Anti-aging

Progressing age and continuous cellular damage caused by free radicals lead to the appearance of wrinkles, fine lines and furrows. But it can be prevented and controlled with regular consumption of anti aging fruits and juices and use of sandalwood remedies.

Procedure:

Mix 2 teaspoon of sandalwood powder with 1 egg yolk and 1 teaspoon of honey. Apply the pack evenly on face and nech. Wait for 1 hour and wash with water it helps in increasing the elasticity of sagginf and drooping skin.

Sandalwood Remedy for Prickly Heal

The summer season brings with it sweat and heat that often causes irritating prickly heat.

Procedure:

Mix 2 teaspoon of sandalwood powder with 2 teaspoon of water to turn it into a thick paste. Apply this paste on the affected areas on face, arms, neck, chest and back. Wait for 1 hour and wash it off with water. This helps in soothing and cooling the irritation and burn caused by prickly heat and excessive sweating. It is safe remedy for children. Rather, it is better to use it since childhood to turn their skin glossy and free from any skin disease or skin scarcinosis.

Source: Indian Ayurvedic Council web-site.

Sandalwood Remedy for Rashes and Allergies

Sensitive skin is prone to rashes, infection and allergies.

Procedure:

Mix 1 teaspoon of sandalwood powder with a pinch of powder camphor, add some water to it to make a paste of thick consistency. Apply the paste evenly on the skin allergy and rashes. Let it dry of for 1 hour and then wash iy away with cold water. This is one of the best natural ways to treat psoriasis, eczema, allergies and burns.

No side effect from Sandalwood

Sandalwood is being used for centuries now. Mostly, it is used in Ayurveda. It relieves from any kind of cuts of wound or ulcerates and improvises your skin. As it is natural substance, routine use of sandalwood will not show any side effects. Tips of clear skin are incomplete without the inclusion of sandalwood into it.

Additional benefits of sandalwood:

Apart from the ones mentioned above, sandalwood remedies for skin have many more assets. Here, we go with few additional benefits of using this sandalwood.

Source: Indian Ayurvedic Council web-site.

- Sandalwood has the anti-bacterial trait and hence it is used as an herbal antiseptic. Hence, it is used for curing bruises, scotches and also burns.

- If any part of skin senses any itching or burning sensation make a paste of sandalwood powder, turmeric powder and lemon juice and apply it on the affected area. It will reduce not only the itch, but also the the ruddiness caused due to it.

- Sandalwood oil is proved effective in moisturizing dry skin. Swelling and itch caused by an insect bite can also be reduced by applying a paste of sandalwood powder.

- Not just these, the use of sandalwood in any form is beneficial, be it oil or soap.

- Sandalwood balances the mechanism of your body, improves your digestion process, respiratory process and strengthens your nervous system.

Sandalwood Remedies for Skin: Sandalwood oil

Sandalwood oil is a widely popular essential oil extracted from sandalwood through steam distillation of the chips and billets of the heartwood. It contains 90% of sesquiterpenic alcohols of which 60% is tricyclic alfa santalol and 25% is beta santalol. Sandalwood essential oil has amazing nedicinal properties, and it works effectively as an antiseptic, anti-inflammatory, disinfectant, carminative and sedative. There are three varieties of sandalwood – Indian sandalwood, Hawaiian sandalwood and Australian sandalwood of which Indian sandalwood is considered as best. The excellent cleansing, astringent and toning properties of sandalwood oil make it a common ingredient in facial oils, soaps creams and lotions. Sandalwood oil is especially effective for curing inflamed, chapped and sensitive skin.

Sandalwood oil is considered to be one of the best and natural sandalwood remedies for skin. This oil can reduce tan on skin of human body.

Procedure:

- Take 5 teaspoon of coconut oil, 2 teaspoon of almond oil and 4 teaspoon of sandalwood powder and make a paste. Apply this oil on the tanned part of skin for 10 days. You can see the tan fade off.

- If you sweat a lot then apply the paste of sandalwood powder on your body for 15 days before having a bath. This is an effective natural solution to the question of how to get rid of excessive sweating and body odour that also gives your body a wonderful fragnance. You can also use sandalwood for preparing homemade face packs for healthy skin.

- Sandalwood oil can be mixed with other carrier oils and applied to de-hydrate and aging skin to gain back vitality and youthfulness of skin.

- Regular application of sandalwood oil soothes and softens skin and reduces the appreance of wrinkles, fine lines and blemishes.

- Sandalwood oil can be used topically to treat eczema, inflammation, itching and scars.

- The calming and soothing properties of sandalwood oil help in relieving anxiety, tension and stress and ensures restful sleep.

Remarkable Note: If you want to maintain and have a clear skin then sandalwood remedy is the best option. These sandalwood remedies for skin, work only if perform your activity for a couple of weeks on a regular basis.

Selection and storage of Sandalwood oil

Being a expensive essential oil, it is often adulterated with other oils and therefore, it is important to select and store this oil carefully for enjoying its wholesome benefits.

Source: Indian Ayurvedic Council web-site.

- Sandalwood oil can be diluted with other essential oils like copaiba oil, amyris oil or Atlas cedar fractions. These oil added to the oil to increase the quantity.

- Real sandalwood oil must be aged for six months for full maturity with leads to the development of a sweet woody aroma.

- The fragrance of sandalwood oil continues to increase with age, so it is best to store the oil in a dark, airtight glass container.

  Sandalwood is the ultimate solution for all types of skin problems and one of the best natural ways to clear the skin of impurities. People with all skin types – oily, dry, normal and combination can treat their skin problems using the above mentioned solutions and write back to us in the form of comments or emails about their experience to the author.

Industrial Uses

The great value of this species is its heartwood and oil, which are widely used in cosmetic, perfume, medicine and aroma therapy industries (Srinivasan et al. 1992; Kim et al. 2006). Sandal bark is one of the raw materials for the industry. Benzene extract of powered bark on repeated Chromatography over alumina gave a new triterpene solid ester (yield o.3%) which has been identified as urs-12-en-3-beta-yl-palmitate (Shankaranarayana et al, 1980b). The compound is a chemosterilant and insect growth inhibitor too (Shankaranarayana et al, 1979a,b). Seeds contain 50-60% of a drying oil composed of 80% santalbic, 2.5% stearolic and 10% oleic acids.

Materials used for the work:

1. Sandalwood seeds: Seeds of *Santalum album* L. were collected from Hirbundh mouza of Hirbundh Range under Bankura (South) Forest Division during the month of November-December and May-June of 2011 and 2012 for experimentation. Simultaneously, seeds of *S. album* were also procured from Institute of Wood Science and Technology, Bangalore in the month of February, 2012 for the same experimentation purposes.
2. Chemicals : Gibberellic acid (GA_3)
3. Apparatus : Container, Markin cloth, Polypots, Hycopots.
4. Miscellaneous: Soil samples (for analysis), Sandalwood Samples (for oil and santalol content analysis), Sand, Bricks, Seive, FYM, Water, etc.

2.14.8: Aromatherapy Uses [kuttan et al., 1974]

2.14.8.1: Body:

Sandalwood is recognized as having a pronounced effect on the genito-urinary tract and therefore is useful in urinary tract infections including cystitis (with bergamot and tea tree) and gonorrhea. Sandalwood is also a good pulmonary antiseptic and great for coughs, dry persistent ones in particular, as well as chronic bronchitis and sore throat. Good accompanying oils might include myrtle, frankincense, ravensara, thyme linalool or lemon. Sandalwood's relaxing properties mean that is particularly effective at night as it can help a cougher sleep better. Due to sandalwood's low toxicity level, this is an appropriate oil to use topically, in the bath, or as an inhalant. Sandalwood is also considered to be a digestive aid: blended with, for example, ginger, the spice oils or peppermint, it can help alleviate heartburn, nausea, diarrhea and vomiting. Lastly, but certainly not in importance, is sandalwood's role as a sexual tonic. Besides its relaxing, calming properties, sandalwood, along with jasmine, may possibly have a hormonal effect as well. It is an outstanding aphrodisiac, equally useful in cases of frigidity and impotence.

2.14.8.2: Mind and Spirit:

Sandalwood is calming and useful as an aid to meditation. It is excellent for the stresses of a hectic life as it helps reduce tension, confusion, fear and obsessions. It is also widely known

to be an excellent aphrodisiac and anti-depressant. Sandalwood helps us cut past ties, and move through and past grief, isolationist feelings, ego-centrism, and aggression. It opens us, allowing us to receive love, warmth and understanding. Sandalwood has the ability to bring us back to ourselves, to connect with the earth, to still the mind and allow creativity and our higher consciousness to flower. Sandalwood is one of the oldest and best known of all aromatics, having been in continuous use for over 4000 years. It runs like a common thread throughout many of the world's major religions: in Buddhism, Hinduism and Islam, sandalwood forms the heart of their aromatic aspects, helping to realize and bring the divine within. It has long been considered an important meditation aid. Sandalwood powder has also been used throughout the medical systems of the world: Ayruvedic, Chinese and Tibetan. Sandalwood is also used in death rituals, especially in India. Ideally, one is immolated on a pyre of pure sandalwood and the ashes cast into the Holy Ganges, the Mother of India.

2.14.8.3: Skincare:

Sandalwood is good for all skin types, in particular dry and oily skin and acne. Even as it has moisturizing properties, it is a mild astringent and antiseptic. Sandalwood is also soothing for cracked, chapped and irritated skin. It is also recommended for mature and tired skin as well as stretch mark and scars.

2.14.8.4: Perfumery:

Sandalwood is extremely useful in high-class perfumery for its wonderful ability to blend almost any notes. It is a very popular fixative, deep and rich, yet unobtrusive, soft and sweet. Its long, lingering and subtle aroma makes it a perfect base note. Sandalwood is the utmost in complimentary notes.

2.14.9: Chinese Medicine:

Sandalwood is cooling, decongesting and astringent. It is indicated, therefore, for problems of a hot, inflammatory and catarrhal nature, most often for problems of the intestines, lungs or genito-urinary tract. Examples are diarrhoea, burning cystitis, and a harsh painful cough. Mentally, it will work best when a cooling action is needed against hot and agitated mental states. Commonly, Sandalwood is ground and used as a powder rather than an oil.

2.14.10: Ayruvedic Medicine:

Used for conditions of Pitta, heat, fire, as a cooling agent. Antifebrile, Anti-inflammatory and anti-infectious, here again Sandalwood is used ground to a paste.

2.15: Prolong Human Hair Growth

A team of researchers led by Ralf Paus of the University of Manchester **(19 September 2018, by Bob Yirka)** has found that applying sandalwood to the scalp can prolong human hair growth. In their paper published in the journal *Nature Communications*, the group describes experiments they conducted with the synthetic material and human skin samples. The research built on prior work by a team that had found that a receptor cell in skin called OR2AT4 was sensitive to chemicals in synthetic sandalwood—sandalwood application stimulated growth of keratinocytes. Because skin healing and hair growth are closely related, the researchers wondered if applying synthetic sandalwood might also stimulate new hair growth. The researchers tested their idea by soaking skin samples in a synthetic sandalwood solution for six days and then observing the skin for changes to hair follicles. They report that the treated hair follicles survived longer than those that went untreated, and also produced more growth factor. The researchers verified that it was the synthetic sandalwood interacting with the receptor OR2AT4 that caused the change by blocking the receptors, and noting that doing so inhibited the change from occurring [Solanki et al., 2014].

2.16: Anti-inflammatory and Antioxidant activity sandalwood album Oil (SAO)

SAO is known to mediate its anti-inflammatory properties in vitro through multiple mechanisms. The oil inhibits the oxidative enzyme 5-lipoxygenase and has DPPH radical scavenging activity and in vivo, SAO was able to protect mouse livers from damage resulting from oxidative stress and the formation of reactive oxygen species [Yirka, 2018]. Sandalwood oil when demonstrated in vivo showed increased glutathione S215 transferase (GST) activity and acid soluble sulfhydryl (SH) levels in the liver of adult male Swiss albino mice in oral doses of 5 and 15 μL in 10 and 20 days, respectively [www. Ncbi.nlm.nih.gov// S. album oil as a botanical therapeutic in dermatology]. Enhanced GST activity and acid-soluble SH levels were suggestive of a possible chemo preventive action of sandalwood oil on carcinogenesis through a blocking mechanism. Similarly, methanolic extracts of sandalwood demonstrated acetyl cholinesterase inhibitory (180 μg mL-1) and DPPH and super oxide free radical

scavenging activities (IC50 values of 160-191 µg mL-1) in albino mice, there by indicating potential to tackle dementia and memory loss, associated with Alzheimer's disease. Recently, we demonstrated the *in vivo* anti-hyperglycaemic and antioxidant potential of sandalwood oil (1 g/kg BW) and its major constituent α-santalol (100 mg/kg BW) in alloxan- and D-galactose mediated oxidative stress induced diabetic male Swiss albino mice models, respectively [42]. Additionally anti-inflammatory activity in skin was reported to rely on the activation of the enzyme 11b-HSD1, which plays a role in cortisol synthesis by keratinocytes [Yirka, 2018; Banerjee et al 1993].

2.17: Anti-microbial and Anti-viral property

The anti-microbial efficacy of Santalum album was demonstrated by 3 different methods like Microtiter well plate-based broth dilution assay, the disc diffusion assay and the agar spot assay. Microtiter well plate-based broth dilution assay results revealed that the Gram-negative bacterium Pseudomonas fluorescens and the Gram-positive bacterium Micrococcus flavus were resistant to sandalwood oil. The highest MIC_{70} was recorded against Alcaligenes faecalis at >40 µg ml $^{-1}$. The lowest MIC_{50} values were observed against Salmonella typhimurium (0_078 µg ml $^{-1}$) and the highest MIC_{50} against Enterobacter cloacae (10 µg ml^{-1}). The lowest MIC_{90} value was observed against Staphylococcus aureus (0_0625 µg ml $^{-1}$) and the highest MIC_{90} was against Klebsiella aerogenes (10 µg ml $^{-1}$).

The disc diffusion assay results revealed the highest microbial susceptibility index (MSI) against Ent. Cloacae (100%) and Ps. fluorescens (100%). The lowest MSI was obtained for Arthrobacter nicotiana and Kl. aerogenes (both, 0%). The highest activity was recorded for sandalwood oil (93.75%) and the lowest for both callus and young tree leaves' extracts at 25%. The highest sensitivity to sandalwood oil was observed against A. nicotine, while somatic embryo extracts displayed highest activity against Staph. aureus.

From the agar spot assay results, it was revealed that the lowest MSI was demonstrated by Acinetobacter calcaemic and Ps. fluorescens (both, 0%), both Gram-negative strains, thus rendering them the most resistant strains, whereas the highest MSI was observed against Pseudomonas aeruginosa (100%). Among the Gram-positive bacterium, the highest MSI was observed for A. nicotiana (80%) and the lowest for M. flavus (0%). The highest activity was observed for sandalwood oil (92.85%) and the lowest for old tree leaves' extract (14.28%),

thus making them the most and the least bioactive extracts used in this investigation [Misra and Dey, 2013a].

In an *in vitro* study sandalwood oil demonstrated antiviral activity against herpes simplex viruses (HSV)-1 and 2 in a dose-dependent manner through inhibition of viral replication. It was further assumed that sandalwood oil helped the cells protect themselves by modulating the liver's gluthatione S-transferase and levels of acid-soluble sulfhydryl [Anonymous, 1979]. Sandalwood oil has also been shown to be used in prevention and treatment of warts, skin blemishes and other viral induced tumors on skin [Misra and Dey 2012a]. Additionally, sandalwood oil and santalol derivatives were claimed for use in treating cold sores and herpes (Singh and Nulu, 2010).

2.18: Antifungal Activity

Sandalwood oil is reported to possess anti-fungal activity against *Microsporum canis, Trichophyton mentagrophytes* and *T. rubrum*. Sandalwood oil was found to be effective against human pathogenic fungal strains *Microsporum canis, Trichophyton mentagrophytes* and *T. rubrum* but was ineffective against *Candida albicans, Aspergillus niger* and *A. fumigates* [Haque and Haque, 2000].

2.19: Tetranychus Urticae Repellent Effect of Santalol from Sandalwood Oil

Thirty-four essential oils were screened for their repellent activities against the two spotted spider mite, *Tetranychus urticae* at 0.1% concentration level using choice and no-choice laboratory bioassays. Of these, 20 essential oils showed significant repellencies against *Tetranychus urticae* in the choice tests. In subsequent no-choice tests using these 20 essential oils, only sandalwood oil showed significant repellence against *Tetranychus urticae* [Kumar et al., 2015].

2.20: Apoptotic Effects of α-Santalol in Inhibiting the Growth of Human Prostate Cancer Cells

The a-santalol-induced apoptotic cell death and activation of caspase-3 was significantly attenuated in the presence of pharmacological inhibitors of caspase-8 and caspase-9. α-Santalol, a derivative of sandalwood oil, induces apoptosis in human prostate cancer cells [Roh etal., 2012].

2.21: Insect Growth Inhibitor from Bark of *S. Album*

Triterpenoid- urs-12-en 3 b-yl palmitate (m.p 115-116º, (a) D 24 +200, C46H80O2) has been isolatedfrom sandalwood. The tropical application of triterpenoiod on fresh pupae of forest insects viz: *Atteva fabriciella, Eligma narcissus, Eupterote geminate* etc produced morphologically defective adults indicating growth inhibition activity of the compound. Also observed the chemosterilant activity on freshly emerged moths of*Atteva fabricella* [Bommareddy et al., 2012].

2.22: Effect on Nervous System

Santalols have been reported to have central nervous system (CNS) depressant effects such as sedation, and they affected sleep-wake cycle in sleep-disturbed rats, such as decreased walking time and increase in non-rapid eye movements. Results suggested action of santalols via circulatory system by adsorption into the blood through respiratory mucosa, hence demonstrating implication in patients having sleep related difficulty [Shankarnarayana et al., 1980]. Alpha and Beta-santalols significantly increased the levels of homovanillic acid, 3, 4-dihydroxyphenylaceticacid and/or 5-hydroxyindoleacetic acid in the brain of mice upon intragastric and intracerebroventricular routes of administration [Ohmori et al., 2007]. Alpha-santalol was shown to be a strong antagonist of dopamine D2 and serotonine 5-HT2A receptor binding. Furthermore, the effect of alpha-santalol, was the same as that of chlorpromazine as an antipsychotic [Okugawa et al., 1995]. Alpha-santalol caused significant physiological changes such as relaxing and sedative effects, whereas sandalwood oil provoked physiological deactivation but behavioral activation after transdermal absorption [Okugawa et al., 2000]. Furthermore, we have recently reported that TLC254 bioautographic assays indicated that alpha-santalol, the major constituent of the oil, is a strong inhibitor of both tyrosinase and cholinesterase *in vitro*, and hence there is a great potential of this essential oil for use in the treatment of Alzheimer's disease, as well as in skin-care [Hongratanaworakit et al., 2004].

2.23: Antineoplastic effects of α-santalol on estrogen receptor-positive and negative breast cancer cells

Anticancer efficacy and the mechanism of action of α-santalol was investigated in human breast cancer cells by using p53 wild-type MCF-7 cells as a model for estrogen receptor (ER)-positive and p53 mutated MDA-MB-231 cells as a model for ER-negative breast cancer. α-santalol inhibited cell viability and proliferation in a concentration and time dependent manner in both cells regardless of their ER and-or p53 status. However, α-santalol produced relatively less toxic effect on normal breast epithelial cell line, MCF-10A. It induced G2/M cell cycle arrest and apoptosis in both MCF-7 and MDA-MB-231 cells. Cell cycle arrest induced by α-santalol was associated with changes in the protein levels of BRCA1, CHK1, G2/M regulatory cyclins, cyclin dependent kinases (CDKs), cell division cycle 25B (Cdc25B), Cdc25C and Ser-216 phosphorylation of Cdc25C. An up-regulated expression of CDK inhibitor p21 along with suppressed expression of mutated p53 was observed in MDA-MB-231 cells trated with α-santalol. On the contray, α-santalol did not increase the expression of wild type p53and p21 in MCF-7 cells. In addition, α-santalol induced extrinsic and intrinsic pathways of apoptosis in both cells with activation of caspase-8 and caspase-9. It led to the activation of the executioner caspase-6 and caspase-7 in α-santalol treated MCF-7 cells and caspase-3 and caspase-6 in MDA-MB-231 cells along with strong cleavage of poly(ADP-ribose) polymerase (PARP) in both cells. Taken together, this study for the first time identified strong neoplastic effects against both ER-positive and ER-negative breast cancer cells [Misra and Dey, 2013c].

2.24: Hepatoprotective activity

Hydro-alcoholic Extract of the leaves of *Santalum album* Linn. was carried out to determine the hepatoprotective activity in experimentally induced liver injury by carbon tetrachloride and paracetamol. The levels of serum marker enzymes, bilirubin, total protein and antioxidant status were determined by measuring lipid peroxidation, glutathione, superoxide dismutase and catalase activity. Total wet weight and histopathological study of isolated liver was also carried out. The oral pre-treatment with hydroalcoholic extract of the leaves of *S. album* (200 and 400 mg/kg) showed significant hepatoprotective activity against CCl4 and paracetamol induced hepatotoxicity by decreasing the activities of serum marker enzymes, bilirubin and lipid peroxidation, and significant increase in the levels of glutathione, superoxide dismutase, catalase and protein in a

dose dependent manner, which was also confirmed by the decrease in the total weight of the liver and histopathological examinations [Santha et al., 2013].

2.25: Anti-tyrosinase and Anti-cholinesterase potentials of sandalwood oil

The anti-tyrosinase and anti-colinestrase potentials of sandalwood oil were probed by TLC-bioautographic and colometric methods. Results obtained from colorimetric assays indicated that sandalwood oil is a potent inhibitor of tyrosinase (IC50 = 171µg/ml) and cholinesterase (IC50 = 4.8-58µg/ml), in comparison with the positive controls used in the assays, kojic acid and physostigmine, respectively. The TLC-bioautographic assays indicated that α-santalol, the major constituent of the oil, is a strong inhibitor of both tyrosinase and cholinesterase. These in vitro results indicate that there is a great potential of this essential oil for use in the treatment of Alzheimer's disease, as well as in skin care [Hedge et al., 2014].

2.26: Olfactory Receptor Neuron Profiling

The mammalian olfactory system can discriminate between volatile molecules with subtle differences in their molecular structures. Efforts in synthetic chemistry have delivered a myriad of smelling compounds of different qualities as well as many molecules with very similar olfactive properties. One important class of molecules in the fragrance industry are sandalwood odorants. Sandalwood oil and four synthetic sandalwood molecules were selected to study the activation profile of endogenous olfactory receptors when exposed to compounds from the same odorant family. Dissociated rat olfactory receptor neurons were exposed to the sandalwood molecules and the receptor activation studied by monitoring fluxes in the internal calcium concentration. Olfactory receptor neurons were identified that were specifically stimulated by sandalwood compounds. These neurons expressed olfactory receptors that can discriminate between sandalwood odorants with slight differences in their molecular structures. This is the first study in which an important class of perfume compounds was analyzed for its ability to activate endogenous olfactory receptors in olfactory receptor neurons [Misra and Dey, 2013].

2.27: Effects on genitourinary system

Genitourinary tract infections such as cystitis and gonorrhea have been treated by sandalwood oil for years owing to the astringent properties of the oil and its effect on the mucus membranes of genitourinary tract; helps remove mucous congestion, restore mucous membrane and minimize the risk of infections such as herpes virus [Stephane et al., 2004; Holmes, 1989; Mojav, 1956]. These traditional uses make sandalwood oil suitable for anti-ageing skin care, for toning effects and to prevent skin from ugly scars in modern cosmeceutical applications.

2.28: Antihyperglycemic and antihyperlipidemic activity

Treatment of *S.album* in streptozotocin induced diabetic rats for 60 days demonstrated reduction in blood glucose level. Metformin treated group also showed a decrease in blood glucose as against an increase in diabetic control group. Total cholesterol (TC), low density lipoprotein (LDL) and triglyceride (TG) levels were also decreased in treated diabetic rats whereas, cardioprotective, high density lipoprotein (HDL) were increased. In case of metformin, the values were 11, 29 and 15% respectively, while HDL increased. Significant improvement in atherogenic index was observed in treated rats that led to the conclusion that *S. album* is effective in curing antihyperglycemic and hyperlipidemic activity [Davis, 1999].

2.29: Anti-Ulcer activity

Anti-ulcer activity has been reported in Hydro-alcoholic extract of *S. album* stem (SASE) at a dose of 5000 mg/kg. Two test doses of SASE (250 and 500 mg/kg) were subjected to screening of anti-ulcer activity by three *in-vivo* models namely – water immersion - restrain stress, ethanol and indomethacin induced gastric ulceration models in albino wistar rats. A proton-pump inhibitor, Omeprazole 10 mg/kg and H2 receptor antagonist, Ranitidine 50 mg/kg were employed as standard drugs. The results revealed an increase in gastric protection as a significant decrease ($p < 0.001$) in average number of ulcers, severity of ulcers and cumulative ulcer index test groups. Histopathological evidences supported the above findings. The observed anti-ulcer effect of SASE at 500 mg/kg was comparable to that of standard drugs used in the experiments indicating significant anti-ulcer potential especially at higher concentration [Kulkarni et al 2012].

2.30: Antipyretic Effect

The anti-inflammatory effect of sandalwood oil as well as HESP oil was investigated against yeast induced pyrexia in albino rat in dose of 200 mg/kg using 0.2% of tween 80 as control and 100 mg/kg paracetamol as standard. A significantly high antipyretic effect observed in case of sandalwood oil and HESP [Ahmed et al., 2013; Shankarnarayana and Parthasarathi, 1985].

2.31: Anti Spasmodic:

Being a relaxant and sedative in nature, this oil works great against spasm too. It relaxes nerves, muscles and blood vessels and hence ends spasm or contraction. Thus it is helpful in treating problems associated with spasm, such as cramps, aches, coughs etc [Sivaramkrishnan and Shankarnarayana, 1990].

2.32: Astringent:

Although very mild, still sandalwood oil has some astringent properties which induce contraction in gums, muscles and skin. This proves beneficial in terms of strengthening hold of gums on teeth, strengthening of muscles, tightening of skin etc [Sivaramkrishnan and Shankarnarayana, 1990].

2.33: Anti Septic:

Essential Oil of Sandal Wood is very good as an anti septic. It is safe for both internal and external applications. It ingested, it helps protect internal wounds and ulcers from infections. Similarly, when applied on skin, it protects wounds, sores, boils, pimples etc. from infections and from getting septic [Sivaramkrishnan and Shankarnarayana, 1990].

2.34: Homemade remedies of *Santalum album*

2.34.1: Sandalwood remedy for Insect Bite and Prickly Heat

Sandalwood paste help to get rid of prickly heat, and heal insect bites. The soothing and cooling effects of sandalwood paste, makes it an ideal remedy for prickly heat. Similarly, due to its antiseptic and anti-inflammatory properties, it can be used for treating minor burn,

cut and insect bites. Just add turmeric powder (another herbal antiseptic) and milk to sandalwood powder and make a paste to apply on the affected area [Sivaramkrishnan and Shankarnarayana, 1990].

2.34.2: Sandalwood remedy for skin care

For skin care Sandalwood powder and rose water can be mixed to make a thick paste to apply on skin. It can be effective in removing acne and acne scar. Just apply the paste on the affected are of the skin and leave for about half an hour. Then use lukewarm water to wash it off.

Turmeric and sandalwood paste is effective for removing Pimples, just to do is to mix equal quantity of sandalwood powder and turmeric and then add some water to it. Now mix them properly to make a fine and thick paste. Apply this paste on the pimples and leave overnight. On the next morning, you can wash it off with lukewarm water. This paste will not only help you to get rid of pimples, but also from acne scars [Sivaramkrishnan and Shankarnarayana, 1990].

2.34.3: Sandalwood remedy for Fair and Smooth Complexion

Sandalwood powder or paste is widely used to lighten skin complexion and treat sunburnt skin. To get a radiant complexion, mix sandalwood powder with coconut oil. You can also add a small amount of almond oil to it. Mix all these ingredients to make a paste and apply it on your face. Leave for about half an hour and then wash with lukewarm water. It will remove sun tan and make your complexion even [Sivaramkrishnan and Shankarnarayana, 1990; Tah, 2019].

2.34.4: Sandalwood remedy for anti-aging

Progressing age and continuous cellular damage caused by free radicals lead to the appearance of wrinkles, fine lines and furrows. But it can be prevented and controlled with regular consumption of anti aging fruits and juices and use of sandalwood remedies. Mix 2 teaspoon of sandalwood powder with 1 egg yolk and 1 teaspoon of honey. Apply the pack evenly on face and neck. Wait for 1 hour and wash with water it helps in increasing the elasticity of sagging and drooping skin [Bhowmik et al., 2016].

Chapter –3

Materials

Homemade remedies of *Santalum album*:

i) Pretreatment by soaking in water:

Sandalwood seeds were soaked in water for 24- 36 hours before sowing. Seeds were sown in sand bed (6 mm deep). Germination started after 60 days. In-between 61 to 100 days, only 3-4% germination is obtained.

ii) Pretreatment by boiling water:

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

iii) Pretreatment by alternate wetting & drying:

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

iv) Pretreatment by Gibberellic Acid:

Matured seeds were collected from the sandalwood trees of Hirbandh Block in November- December, depulped, dried in sun and stored in polybags for germination test. 10 samples each of 300 sandalwood seeds were taken and tied in markin cloth. 5 containers (1 liter each) were taken for four different concentrations (100 ppm, 300 ppm, 500 ppm, 1000 ppm) of gibberellic acid and one for control. 2 seed samples were dipped in each container for 16 hours & 24 hours soaking. The treated sandalwood seeds were then sown in the sand bed. The sand beds were watered twice daily in the morning & afternoon. First germination was started after 26 days of seed sowing. The number of seeds germinated in each treatment was recorded and the germination was continued upto 90 days after sowing. The results were shown in the Table-VI to VIII. The germinated seedlings were

transplanted in polypot (8″x4″ & 9″x 5″) and 300 cc hycopots in nursery at 3 to 4 leaf stage.

Sandal seeds have a post drop dormancy of two months due to presence of hard seed coat or due to presence of chemical substances in the seed coat which are impervious to water and gases. Germination of Sandal seeds are found profuse from the bird droppings in the forest floor as well as in the village yards and bunds of the agricultural fields. Sandal is also found growing wild in some farmlands, homesteads and wastelands in Hirbundh block of Bankura District, Arabari forests of Midnapur District and Ausgram forests of Burdwan District. This indicates the potential of growing the tree in the farmlands.

However, germination of seeds are very low (10-15% within 60 days) when the seeds are sown in mother bed (sand beds) after hot and cold water treatment or alternate wetting & drying due to its hard seed coat and dormancy. Sandal seeds have been found to germinate faster when the seed coat is completely removed, or seeds are soaked in 500ppm gibberelic acid for 12-16 hours (Nagaveni and Srimathi, 1981). In sandal seeds, the duration of germination is much prolonged after the dormancy period. It starts in 27 days after sowing and reaches hardly 50% in 90 days with 500ppm GA_3 soaking for 16 hours, (Das and Tah, 2013). Germination study also conducted in Hirbundh & Kamalpur nurseries of Bankura (South) Division in 2011, 2012 & 2013 where seeds are soaked in different concentration (100 ppm, 300 ppm, 500 ppm, 1000 ppm) of gibberellic acid for 16 hours & 24 hours respectively and sown in sand beds of nursery. The germinated seedlings are pricked out from sand bed and planted in polypot & hycopot beds of nursery at 3 to 4 leaf stage and kept in nursery without & with host (*Cajanus cajan*).

Photo 7: Sand bed for germination of sandal seeds

Photo 8: Shifting of seedlings to hycopot

Photo 9: Shifting of seedlings to polypot

Photo 10: Nursery stock ready for planting

Source: Ph.D. thesis, SC Das, Burdwan University, 2014.

Sandal and Host-Parasite Study in Field:

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

Efforts are taken to cultivate sandalwood seedlings in two Joint Forest Management Committee (JFMC) areas viz. Bagaldhara FPC & Rangamati FPC of Hirbundh -I Beat in 2011 for protection with the help of community. It was also planted in some Beat/Range office compounds in laterite tract of South - West Bengal during 2012 & 2013, Table-III. As it is a hemi-(root) parasite, it needs host (non-specific) plant to grow in the initial stage. Host plants like Arhar (*Cajanus cajan*), Tulsi (*Ocimum sanctum*), Nayantara (*Catheranthus roseus*), Akand (*Calotropis procera*), etc. were planted along with sandal seedlings (6 month old seedlings) singly as well as in combination of hosts in the field.

Pits of size 60cm x 45cm x 45cm were dug in the field in March-April for planting of the potted seedlings. The pits were filled with soil and 500 gms of cowdung manure in the month of May-June after a good premonsoon shower. The potted seedlings (6 month old) were planted in the field in July after getting a good rain at a spacing of 2.5m x 2.5m. After planting, a host plant (Arhar, Tulsi, Nayantara, Akand) was planted at the side of the sandalwood sapling singly as well as in combination of hosts. Some sandalwood saplings were allowed to grow without host. Growth parameters (basal girth & plant height) were measured after 1 year, 2 year & 3 year.

Table – IV. Plantation of Sandal plant in different forest gardens in South-West Bengal

Sl. No.	Location	Year of Planting	No. of seedlings Planted
1	Rangamati-Bhubandihi FPC, Hirbundh-I Beat	2011	100
2	Bagaldhara FPC, Hirbundh-I Beat	2011+2012	150+ 200
3	Kamalpur Range office compound	2012	50
4	Khandari Beat compound, Panagarh Range	2012	100
5	Beliatore Range office Compound	2013	100

Source: Ph.D. thesis, SC Das, Burdwan University, 2014.

Growth Study with and without host :

Height and girth growth of sandalwood is studied both with and without host plant in different forest locations of Bankura and Burdwan Districts mainly in lateritic belts viz. Rangamati and Bagaldhara in Hirbandh block, Kamalpur in Chhatna block, Beliatore in Barjora Block of Bankura district and Khandari in Ausgram block of Burdwan. Growth data were collected at the end of 1st, 2nd and 3rd year and presented in Table.

Photo 11: Plantation of 2011 at Bagaldhara

Photo 12: Plantation of 2012 at Bagaldhara

Photo 13: Plantation of 2011 at Rangamati

Photo 14: Plantation of 2012 at Kamalpur

Photo 15: Plantation of 2012 at Khandari

Photo 16: Plantation of 2013 at Beliatore

Further in between 2005 and 2008, about 10 sandalwood trees were cut and removed by smugglers, which were partly recovered, though 2 gunmen were posted alongwith forest staff to guard the trees during night in

Hirbundh Beat office. In the year 2009, an enumeration of sandalwood trees was done and 51 trees were marked which attained breast height girth (b.h.g) 50cm & above taking permission from the higher authority. Those trees were felled and their measurements were taken for yield calculation. To study the growth, sandal trees which were planted from time to time in forest areas and coming up naturally were considered and their height and girth were measured and recorded along with 51 felled trees and presented herein.

Materials for Experiment- 1:

i) Sandalwood seeds: Seeds of *Santalum album* L. were procured from Hirbandh Range under Bankura South Forest Division during the month of November- December and May- June of 2015 and 2016 respectively for experimentation. Simultaneously, seeds of *S. album* L. were also collected from Mukberia village, Midnapore East, West Bengal, India.

ii) Chemicals: Gibberelic acid (GA-3)

iii) Apparatus: Container, markin cloth, polypots, hycopots, modern nursery cage

iv) Sand, bricks, sieve, Farm Yard Manure (FYM), irrigation and other agronomical infrastructure.

v) Meteorological informations

Information of sites:

Abbreviation	Full name	Total
L	Location	5
P	Plantation	4
T	Treatment	9
Y	Year	3

Name of Locations:

Location no	Location name
L_1	Rampur, Nepal
L_2	Malangwa, Nepal
L_3	Kamalpur, India

L_4	**Bardibas, India**
L_5	**Biratnagar, Nepal**

Information of Treatments:

No. of Treatments	Host(s) Composition
T_1	Arhar
T_2	Tulsi
T_3	Arhar + Tulsi
T_4	Akand
T_5	Arhar + Akand
T_6	Ghantu
T_7	Arhar + Ghantu
T_8	Nayantara
T_9	Tulsi + Nayantara
Arhar = Cajanus cajan; Tulsi = Ocimum sanctum; Akand = Calotropis procera; Ghantu = Clerodendron sp.; Nayantara = Vinca rosea, Syn. Catheranthus roseus.	

Information of plantation:

No. of plantation	Year
Y_1	2015
Y_2	2016
Y_3	2017
Y_4	2018

Growth parameters:

i) Plant height (cm),
ii) Basal girth (cm),
iii) Branch no,
iv) Leaf length (cm)
v) Leaf breadth (cm)

Lay-out Design for the plantations of *Santalum album* L. :

Temperature regime (Degree Cel.) in Bankura, W.B, India:

Month	2016		2017		2018		2019	
	Max	Min	Max	Min	Max	Min	Max	Min
Jan	27	09	27	09	27	09	27	09
Feb	32	11	34	09	32	09	32	11
Mar	39	14	38	15	37	16	39	14
Apr	43	20	42	19	38	18	43	20
May	44	24	45	22	43	21	44	24
Jun	39	24	37	22	41	23	39	24
Jul	38	24	37	25	35	25	38	24
Aug	35	23	34	24	35	24	35	23
Sep	34	24	36	24	35	22	34	24
Oct	34	16	35	20	34	18	34	16
Nov	32	11	32	13	32	16	32	11
Dec	32	11	32	13	32	16	32	11
	429	211	429	205	421	217	429	211

Temperature regime (Degree Cel.) in Nepal:

Month	**2016**		**2017**		**2018**		**2019**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
Jan	26	05	27	04	24	02	24	01
Feb	30	07	34	06	29	03	29	04
Mar	37	10	38	13	34	09	34	07
Apr	41	20	38	09	35	12	35	11
May	42	24	39	20	40	18	40	17
Jun	37	24	35	18	38	20	38	21
Jul	36	24	34	17	32	22	32	21
Aug	33	23	31	16	31	23	31	23
Sep	32	24	33	15	30	22	30	24
Oct	31	16	32	14	29	21	29	21

Nov	30	11	30	12	26	19	26	18
Dec	27	10	26	08	22	02	22	02

Monthly rainfall in the district of the site (Deg. Cel.), Bankura, WB, India

Month	Normal	2016	2017	2018	2019
JAN	17	20	03	07	16
FEB	12	13	40	15	12
MAR	19	07	09	04	19
APR	27	04	57	66	27
MAY	65	52	76	77	65
JUN	198	213	247	183	198
JUL	272	331	255	471	272
AUG	293	332	445	386	293
SEP	246	358	139	384	246
OCT	122	18	95	00	122
NOV	15	99	00	00	15
DEC	03	06	00	00	03
TOTAL	**1289**	**1453**	**1366**	**1687**	**1289**

Monthly rainfall in the district of the site (Deg. Cel.), Nepal

MONTH	Normal	2016	2017	2018	2019
JAN	20	40	03	42	08
FEB	19	33	40	35	45
MAR	28	17	09	19	15
APR	42	09	57	11	62
MAY	69	182	76	184	81
JUN	299	211	247	214	252
JUL	292	539	355	541	359
AUG	339	412	445	412	449
SEP	366	438	139	476	143
OCT	222	118	95	129	104
NOV	105	29	10	43	51
DEC	203	96	00	101	00
Total	**2824**	**2124**	**1467**	**2207**	**1569**

Soil samples:

Collection of soil samples	Drying of soil samples
	

Experiment - 2

Introduction

Santalum album is a small evergreen tree that grows to a height of 20 m; girth of up to 2.4 m, with slender drooping branchlets. It is a part of Indian culture and heritage(Ral 1990). Bark is tight, dark brown, reddish, dark grey or nearly black, smooth in young trees, rough with deep vertical cracks in older trees, red inside. Leaves thin, usually opposite, ovate or ovate elliptical, 3-8 x 3-5 cm, glabrous and shining green above, glaucous and slightly paler beneath; tip rounded or pointed; stalk grooved, 5-15 cm long; venation noticeably reticulate (Nurochman et al. 2018). White sandal (Santalum album L.), belonging to the family Santalaceae, is one of the most important economic tree species indigenous to peninsular 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 Hawaiian Archipelago in the north to New Zealand in the south. It is a small to medium-sized hemi parasitic tree, distributed rather widely in India. The populations are more concentrated in the southern region, especially Karnataka, Tamil Nadu and Kerala (Kumar et al., 2012). Sandalwood is growing and regenerating naturally under favourable conditions in India. S. album grows in a wide range of soils but is most common in sandy or rocky red soil zones. The species is not found on black soil but luxuriant growth is noticeable in moist soils such as garden loam and well-drained deep alluvium (Kumar, Joshi, and Ram 2012). It is part of the indigenous vegetation and has been spreading in its distribution. However, several factors now threaten the important status of sandalwood(Ral, 1990). Most of the ecological distribution and population studies have been conducted for the sandalwood species growing in the Australian and Pacific regions of the

world. The reason may be due to the interest of the scientists living in the same regions and USA. The other reason of having many studies completed in the Pacific region could be the presence of the threatened or very rare sandalwood species in that particular region, especially in Hawaii Islands. Comparatively a little amount of ecology and distribution research has been done on S. album, commercially the most important species of all sandalwoods which is naturally growing in India, Sri Lanka and Indonesia (Subasinghe, 2013). It is characteristically a hemi-parasite and requires host plant in the early stages for the better growth and development. It was reported that sandal seedlings were incapable to grow beyond one year without haustoria and confirmed its selectivity for host as although almost all plants in its surroundings may be attacked but the better growth was observed in association with Pongamia pinnata, Albizia lebbeck, Tectona grandis etc(Jassie, A et al., 2018). Though the plant grows naturally in wide agroclimatic conditions like warm desert of Australia, dry and monsoon climate of India, Vanuatu, eastern Indonesia, subtropical climate of Hawaii and New Caledonia where receives almost uniform rainfall but in India the plant is mostly restricted in southern part only. Presently, there are a few patches in one or two districts of West Bengal with white sandal plants, but it can be introduced in many more areas of West Bengal because it can adapt to various soils although prefers light to medium and well-drained soil (Ral et al. 2017). Several environmental factors may drive selection of a specific oil phenotype including abiotic factors (temperature, rainfall, soil composition) and biotic factors [(such as age of the trees, vegetation structure, host species and the presence of pathogens) (Jassie, A et al. 2018)]. Ecologically sandal has adapted various agro - climatic and soil conditions for in situ regeneration with an exception of waterlogged areas and very cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain et al., 1998). The provenances vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of Santalum album in India (Yadav, Mukhopadhyay, and Tah 2018; Jadav et al, 2017). In India, Sandal is distributed throughout the country, but more than 90% of the growing stock lies in Karnataka and Tamil Nadu. Other states where sandal trees are less common are Andhra Pradesh, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Uttar Pradesh, Bihar and Manipur (Jain, Arya, and Kumar 2007).

Experiment-2

Materials (i) Viable seeds of Santalum album L., (ii) distilled water, (iii) Petridishes, (iv) Mercuric chloride, (v) tap water, (vi) Incubator for germinantion, (vii) field for plantation, (viii) all agronomic facilities in the farming site etc.

Methods –

(i) A Randomized Block Design Field (RBD) having 12 ‘ X 15’ plant spacing, (ii) Provide uniform agronomic cultures in both the forest gardens, (iii) collection of data (Plant height, branch number, leaf number) in regular manner, (iv) biometric calculations followed by Tah, 2018.

Study area:

This study was conducted in Khandari (Burdwan), Basudevpur (Bankura), Bagaldhara (Bankura), and Rangamati (Bankura)

Experiments – 3

Introduction

White sandal Santalum album L. is a tropical hemi parasitic plant. White sandal wood plant (Santalum album L.) is widely distributed and very much economically important plant. It renders its service to the human society by providing precious timber and medicinal properties since hum over the world. It has also been used in the pharmaceuticals as well as cosmetic industries since ancient era. The plant is very valuable for its essential oils and medicinal uses. In India Santalum album L. mainly grow in Maharashtra, Andhra Pradesh, Kerala etc. According to Das and Tah, (2013) a small population of white sandal also developed at Bankura & Burdwan and Midnapore District of West Bengal. Various host plants are needed for the establishment, proper growth and development of the sandal saplings. White sandal can make association with many angiosperms as its hot plant. In nature germination of white sandal seeds is 10 – 15% which is not adequate for mass propagation at a time in any agro zone.

Recently we have undertaken the venture of artificial seed germination by applying different concentration of GA3 which has given us a positive indication to undertake the seed propagation program in this location. Ecologically sandal has adapted various agro - climatic and soil conditions for regeneration with an exception o cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of Santalum album in India (Srinivasan Sandal (Santalum album L.) was tried in various locations of South West

Bengal since nineteen sixties. The area has predominantly laterite soil having rainfall from 1200mm to 1600mm with maximum temperature 45C0 and minimum temperature 7C0. To ensure protection, Sandal was grown in various forests Range & Beat Office compounds located in the district of Bankura, Birbhum, Burdwan, Purulia and West Midnapur bringing quality seeds from Institute of Wood Science and Technology (IWST), Bangalore time to ti Sandal is one of the very few tree species in which research has been carried out for more than a century.

The demand for Sandalwood and Oil is increasing and the gap between demand and supply is widening. To bridge the gap between demand and supply, afforestation and plantation programme should aim at increasing the productivity of plantations. In sixties Sandalwood trees were also planted in Hirbundh Beat Office compound under Khatra Range of Bankura District. Trees started flowering after 10-12 years and lot of natural regeneration has started coming up in Hirbundh Block both in forest areas and in the adjoining non-forest areas of the Block. But very few records of growth and yield of white sandals grown in South West Bengal is available. An attempt was being taken in 2009-10 to study growth & yield of sandal trees grown in Hirbundh Beat office compound of Khatra Range in Bankura (South) Division (Das, 2013). Some hindrances and problems for its propagation were observed by various workers in these areas. Keeping all these views in mind we are going to undertake the venture for its mass propagation through seeds and its cultivation with their agronomical maintenance properly. The collected were analysed for the study of correlation and coefficient for the comparative study over the locations.

Experiments – 3

Materials

1. Seed materials collected from (I) Bankura, (II) Burdwan,(III) Mokrampur

2. i) Chemicals: Gibberelic acid (GA3),

ii) HgCl2

Miscellaneous: Distilled Water, Petridishes, Compost manure, Beakers, Conical flasks, measuring cylinder, Chemical weigh balance (digital), Hycopots, Note book, pen etc. Seeds of white sandal (Santalum album L.) were grown in nursery bed to rage the seedlings of the plant. The six months seedlings were planted in the different locations having 15x12 feet plant spacing in the garden. The randomized block design (RBD) having three replications was

followed for the plant populations in each locations . The Uniform agronomic measures were provided for the proper growth and development in each locations. The metrical characters were studied annually in each garden. After 5th year the plant population was observed and the metrical characters were analyzed in correlation and coefficient model of Panse and Sukhatme 2005. On the contrary the soil samples were also taken from each locations at least 20 sample annually and analysed it in the laboratory properly . All those data were calculated properly and tabulated it in table no. 1 and 2.

No. of Location Name of the location L-1 Hetauda L-2 Biratnagar L-3 Duhabi, sunsari

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

Experiment-4

Introduction

Sandalwood (White Sandal) is the fragrant heartwood of some species of genus *Santalum*. The widely distributed and economically important *Santalum* genus belongs to family Santalaceae, includes 30 genera with about 400 species, many of which being completely or partially parasitic (John,1947). The word Sandal has been derived from Chandana (Sanskrit), Chandan (Persian), Savtador (Greek) and Santal (French). There are references of Sandalwood in Indian mythology, folklore and ancient scripts. „Chandana" the Sanskrit name ascribed to *Santalum album* L. was known and used in India from the earliest historic times and is frequently mentioned in the ancient Sanskrit writings, some of which dated before Christian era. Kautilya"s Arthashastra (320 B.C.) considered Sandal as one of the important forest products to increase royal revenue. Charaka Sanhitha, the major text book of internal medicine in Ayurveda (300 B.C.) quotes uses of Sandal over 160 time in the entire text. In treatment of major diseases like fever, piles, hemorrhagic conditions, diabetes, dropsy, mental disorders, management of poisons & skin disorders widespread uses of sandal is seen. Susrutha Samhita (150 B.C.) a great text on Indian wisdom on surgical procedures, equally preferred sandal for the management of wounds. Sandal fumigation is indicated in warding off evils and organisms, which contaminate the wounds. Such fumigations hasten the wound healing & surgical wards remain aseptic. Dusting of wounds with sandal for early healing is common. In the Amarkosha

(Lexicon 3rd or 4th Century A.D.) sandal is mentioned and it is said that „Vina-malayam anyathra chandanam vivarditha‟ [Majumdar, 1941].

The extraction and disposal of sandal came under the Forest Department in 1864 in Mysore state [Adkoli, 1977]. In Karnataka (formerly Mysore) the forest working plan for sandal extraction were prepared for Hunsur Talik in 1910, Heggadadevanakote in 1920 and Narasimharajapura in 1926. In 1871, the parasitic nature of sandal was reported by John Scott. Watt (1893) described the technique of raising sandal seedlings in tile pots in the nurseries and planting in the field. McCarthy (1899) first noticed the spike disease of sandal in Coorg. Brandis (1903) suggested that though sandal is a root parasite, it may derive part of its nutrition from the soil as well. Barber (1905) noted that haustoria formation occurred only on certain roots of sandal and not on all of them. This plant forms a non-obligate relationship with a number of host plants (Nagaveni & Vijayalakshmi,2004).

There is atleast 3 kinds of Sandal namely White Sandal (*Santalum album)* called „Sweta Chandana‟, Red Sandal (*Pterocarpus santalinus)* called „Rakta Chandana‟ and interior Sandal Ku-chandana (*Adenanthera pavonina).* These plants belong to different species and families and have different properties as evidenced from their synonyms. Sandal is a moderate sized evergreen large shrubs or small trees (*S. spicatum*) to tall trees of 12-15 m. in height (*S. album* in India and *S. paniculatum* in Hawaii) and the girth of 1.0 -2.4 m. (Sen Sarma, 1982). The species (*S. album)* is distributed from Indonesia in the West to Juan Fernandez Islands in the East and from Hawaiian Archipelago in the North (30o N) to New Zealand in the South (40o S). It is believed that Sandal was introduced to India from Timor in Indonesia (Shetty, 1977).

Ecologically sandal has adapted various agro - climatic and soil conditions for *in situ* regeneration with an exception of waterlogged areas and very cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain *et al*., 1998). The provenances vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of *Santalum album* L. in India (Srinivasan *et al*., 1992).

Materials

1. Sandalwood seeds: Seeds of *Santalum album* L. were collected from Hirbundh mouza of Hirbundh Range under Bankura (South) Forest Division during the month of November-December and May-June of 2011 and 2012 for experimentation. Simultaneously, seeds of *S. album* were also procured from Institute of Wood Science and Technology, Bangalore in the month of February, 2012 for the same experimentation purposes.

2. Chemicals : Gibberellic acid (GA3)

3. Apparatus : Container, Markin cloth, Polypots, Hycopots**.**

4. Miscellaneous: Soil samples (for analysis), Sandalwood Samples (for oil and santalol content analysis), Sand, Bricks, Seive, FYM, Water, etc.

5. Meteorological Informations of Bankura District.

Table-I: Temperature regime (Degree Cel.) in Bankura, W.B, India.

Month	2016		2017		2018		2019	
	Max	Min	Max	Min	Max	Min	Max	Min
JAN	27	09	27	09	27	09	27	09
FEB	32	11	34	09	32	09	32	11
MAR	39	14	38	15	37	16	39	14
APR	43	20	42	09	38	18	43	20
MAY	44	24	45	22	43	21	44	24
JUN	39	24	37	22	41	23	39	24
JUL	38	24	37	25	35	25	38	24
AUG	35	23	34	24	35	24	35	23
SEP	34	24	36	24	35	22	34	24
OCT	34	16	35	20	34	18	34	16
NOV	32	11	32	13	32	16	32	11
DEC	32	11	32	13	32	16	32	11
TOTAL	429	211	429	205	421	217	429	211

Table-II: Monthly rainfall in the district of the site (Deg. Cel.), Bankura, WB

Month	Normal	2016	2017	2018	2019
JAN	17	20	03	07	16
FEB	12	13	40	15	12
MAR	19	07	09	04	19
APR	27	04	57	66	27
MAY	65	52	76	77	65
JUN	198	213	247	183	198
JUL	272	331	255	471	272
AUG	293	332	445	386	293
SEP	246	358	139	384	246
OCT	122	18	95	00	122

NOV	15	99	00	00	15
DEC	03	06	00	00	03
TOTAL	**1289**	**1453**	**1366**	**1687**	**1289**

Table-III: Temperature regime (Degree Cel.) in Nepal

MONTH	2016		2017		2018		2019	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
JAN	26	05	27	04	24	02	24	01
FEB	30	07	34	06	29	03	29	04
MAR	37	10	38	13	34	09	34	07
APR	41	20	38	09	35	12	35	11
MAY	42	24	39	20	40	18	40	17
JUN	37	24	35	18	38	20	38	21
JUL	36	24	34	17	32	22	32	21
AUG	33	23	31	16	31	23	31	23
SEP	32	24	33	15	30	22	30	24
OCT	31	16	32	14	29	21	29	21
NOV	30	11	30	12	26	19	26	18
DEC	27	10	26	08	22	02	22	02
Total	**402**	**198**	**397**	**152**	**370**	**172**	**370**	**170**

Table- IV: Monthly rainfall in the district of the site (Deg. Cel.), Nepal

MONTH	Normal	2016	2017	2018	2019
JAN	20	40	03	42	08
FEB	19	33	40	35	45
MAR	28	17	09	19	15
APR	42	09	57	11	62
MAY	69	182	76	184	81
JUN	299	211	247	214	252
JUL	292	539	355	541	359
AUG	339	412	445	412	449
SEP	366	438	139	476	143
OCT	222	118	95	129	104
NOV	105	29	10	43	51
DEC	203	96	00	101	00
Total	**2824**	**2124**	**1467**	**2207**	**1569**

Six types of this genus taken for the experiment:

Pecularities were observed in leaf shape, leaf size, colour, thickness, texture and flowering seasons. The seadling planted in different forest gardens have been shown foliar variations. Leaves are opposite, and opposite decussate, sometimes show whorled arrangement. The leaf shape varies from lanceolate to ovate or elliptical (Kulkarni and Srimathi 1982). Two consipicuous types of white sandal trees are observed where from the seeds were collected in Hirbandh forest garden which are as follows:

Table II: Morphogenetic peculiarities of *S album* L.

S.No.	Characterstics	Observation-1	Observation-2
1st Type	Leaf shape	lanceolate	Ovate
2nd Type	Leaf Length	5.5cm	5.5cm
3rd Type	Leaf Width	1.7cm	2.7cm
4th Type	Leaf colour	Light green	Deep green
5th Type	Leaf thickness	Less thick	More thick
6th Type	Leaf texture	Less glossy	More glossy

Chapter -4

Methods

Experiment- 1:

Methods

i) Sandalwood seeds: Seeds of *Santalum album* L. were procured from Hirbandh Range under Baankura South Forest Division during the month of November- December and May- June of 2015 and 2016 respectively for experimentation. Simultaneously, seeds of *S. album* L. were also collected from Mukberia village, Midnapore East, West Bengal, India.

ii) Chemicals: Gibberelic acid (GA-3)

iii) Apparatus: Container, markin cloth, polypots, hycopots, modern nursery cage

iv) Sand, bricks, sieve, Farm Yard Manure (FYM), irrigation and other agronomical infrastructure.

v) Meteorological informations

Information of sites:

Abbreviation	Full name	Total
L	Location	5
P	Plantation	4
T	Treatment	9
Y	Year	3

Name of Locations:

Location no	Location name
L_1	Rampur, Nepal
L_2	Malangwa, Nepal
L_3	Kamalpur, India
L_4	Bardibas, India
L_5	Biratnagar, Nepal

Information of Treatments:

No. of Treatments	**Host(s) Composition**
T_1	Arhar
T_2	Tulsi
T_3	Arhar + Tulsi

T_4	Akand
T_5	Arhar + Akand
T_6	Ghantu
T_7	Arhar + Ghantu
T_8	Nayantara
T_9	Tulsi + Nayantara
Arhar = Cajanus cajan; Tulsi = Ocimum sanctum; Akand = Calotropis procera; Ghantu = Clerodendron sp.; Nayantara = Vinca rosea, Syn. Catheranthus roseus.	

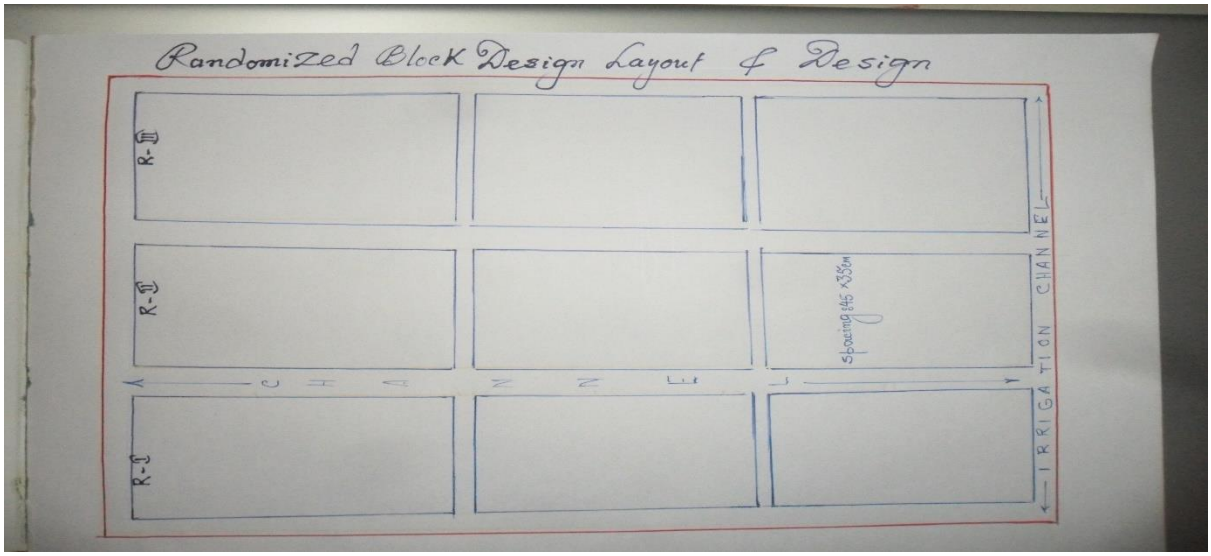
Information of plantation:

No. of plantation	Year
Y_1	2015
Y_2	2016
Y_3	2017
Y_4	2018

Growth parameters:

i) Plant height (cm),
ii) Basal girth (cm),
iii) Branch no,
iv) Leaf length (cm)
v) Leaf breadth (cm)

Lay-out Design for the plantations of *Santalum album* L. :



Temperature regime (Degree Cel.) in Bankura, W.B, India:

Month	2016		2017		2018		2019	
	Max	Min	Max	Min	Max	Min	Max	Min
Jan	27	09	27	09	27	09	27	09
Feb	32	11	34	09	32	09	32	11
Mar	39	14	38	15	37	16	39	14
Apr	43	20	42	19	38	18	43	20
May	44	24	45	22	43	21	44	24
Jun	39	24	37	22	41	23	39	24
Jul	38	24	37	25	35	25	38	24
Aug	35	23	34	24	35	24	35	23
Sep	34	24	36	24	35	22	34	24
Oct	34	16	35	20	34	18	34	16
Nov	32	11	32	13	32	16	32	11
Dec	32	11	32	13	32	16	32	11
	429	211	429	205	421	217	429	211

Temperature regime (Degree Cel.) in Nepal:

Month	**2016**		**2017**		**2018**		**2019**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
Jan	26	05	27	04	24	02	24	01
Feb	30	07	34	06	29	03	29	04
Mar	37	10	38	13	34	09	34	07
Apr	41	20	38	09	35	12	35	11
May	42	24	39	20	40	18	40	17
Jun	37	24	35	18	38	20	38	21
Jul	36	24	34	17	32	22	32	21
Aug	33	23	31	16	31	23	31	23
Sep	32	24	33	15	30	22	30	24
Oct	31	16	32	14	29	21	29	21
Nov	30	11	30	12	26	19	26	18
Dec	27	10	26	08	22	02	22	02

Monthly rainfall in the district of the site (Deg. Cel.), Bankura, WB, India

Month	**Normal**	**2016**	**2017**	**2018**	**2019**
JAN	17	20	03	07	16
FEB	12	13	40	15	12
MAR	19	07	09	04	19
APR	27	04	57	66	27
MAY	65	52	76	77	65
JUN	198	213	247	183	198
JUL	272	331	255	471	272
AUG	293	332	445	386	293
SEP	246	358	139	384	246
OCT	122	18	95	00	122

NOV	15	99	00	00	15
DEC	03	06	00	00	03
TOTAL	**1289**	**1453**	**1366**	**1687**	**1289**

Monthly rainfall in the district of the site (Deg. Cel.), Nepal

MONTH	Normal	2016	2017	2018	2019
JAN	20	40	03	42	08
FEB	19	33	40	35	45
MAR	28	17	09	19	15
APR	42	09	57	11	62
MAY	69	182	76	184	81
JUN	299	211	247	214	252
JUL	292	539	355	541	359
AUG	339	412	445	412	449
SEP	366	438	139	476	143
OCT	222	118	95	129	104
NOV	105	29	10	43	51
DEC	203	96	00	101	00
Total	**2824**	**2124**	**1467**	**2207**	**1569**

A. **Germination Study in Nursery**:

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

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

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

iv) Pretreatment by Gibberellic Acid: Matured seeds were collected from the sandalwood trees of Hirbandh Block in November- December, depulped, dried in sun and stored in polybags for germination test. 6 samples each of 300 sandalwood seeds were taken and tied in markin cloth. 3 containers (1 liter each) were taken for 3 different concentrations (0.0125%, 0.025%, 0.05%) of gibberelic acid. 2 seed samples were dipped in each container for 16 hours & 24 hours soaking. The treated sandalwood seeds were then sown in the sand bed. The sand beds were watered twice daily in the morning & afternoon. First germination was started after 24 days of

seed sowing. The number of seeds germinated in each treatment is recorded and the germination is continued upto 90 days after sowing. The germinated seedlings were transplanted in polypot (8″x4″ & 9″x 5″) and 300 cc hycopots in nursery at 3 to 4 leaf stage.

B. Soil Testing Methods:

(i) Soil pH The pH of the soil was determined with the help of a pH meter in 1: 2.5 soil: water suspension ratio as described by Jackson (1973).

(ii) Oxidizable Organic Carbon Organic carbon was determined by oxidizing soil with 1 (N) potassium dicromate $K_2Cr_2O_7$ in presence of concentrated H_2SO_4 and back titrating the remaining $K_2Cr_2O_7$ with ferrous ammonium sulphate solution using diphenylamine indicator, following the wet digestion method of Walkley and Black as described by Jackson (1973).

(iii) Available nitrogen (N) The available nitrogen (N) of the soil was estimated through the hot alkaline potassium permanganate method as suggested by Subbiah and Asija (1956).

(iv) Available phosphorus (P) Available phosphorus (P) of soil is determined by using Olsen's method. In this method, the extractant is 0.5M $NaHCO_3$ solution adjusted to pH 8.5 with 10% NaOH.

(v) Available potassium (K) Available potassium content of the soil was determined by flame photometer after extraction with neutral normal ammonium acetate solution as described by Jackson (1973).

(vi) Available Zinc(Zn), Copper(Cu), Manganese(Mn) & Iron(Fe) The method developed by Lindsay and Norvell (1978) using DTPA (Diethylene Triamine Penta Acetic Acid) for separating soils into deficient and non-deficient categories for Zn, Cu, Mn & Fe is useful and adopted in this Laboratory analysis.

Extracting Solution:

To prepare 1 litre of DTPA extracting solution, dissolve 13.1 ml reagent grade TEA, 1.967 g DTPA (AR grade) and 1.47 g of $CaCl_2$ in 100 ml of glass distilled water. Allow sometime for the DTPA to dissolve and dilute to approximately 900 ml. Adjust the pH to 7.3 + .05 with 1:1 HCl while stirring and dilute to 1 litre. Addition of approximately 4 ml of IN HCl will bring the pH of the solution to 7.3. This solution is stable for several months.

Extraction and Determination:

Weigh 10 grams of air dried soil in a 125 ml conical flask or polypropylene bottle. Then add 20 ml of the DTPA extracting solution. Cork the bottles or flask and place them upright on a horizontal shaker. Shake for two hours with a speed of 120 cycles per minute. Filter the suspension through Whatman no 42 filter paper. Keep the ilrate in polypropylene bottles to be analysed for Zn, Cu, Mn and Fe with an atomic absorption spectrophotometer. Analyse the

sample as described above under standard curve. When samples need dilution before measurement, they should be diluted with DTPA solution to maintain a constant matrix. Experimental condition such as shaking time. DTPA concentration, pH and temperature during shaking influence the amount of Zn, Cu, Mn and Fe extracted vy DTPA. The most suitable pH of extracting solution is 7.3, shaking time 2 hours and temperature during shaking 25 + 10C. The values of the nutrient extracted will change if these precautions are not followed. Increase in shaking time and temperature markedly enhance the extractability of Zn, Cu, Mn and Fe. The increase in pH from neutral (7.0) to 7.9 had no effect on Zn and Cu while extractability of Fe and Mn was increased markedly.

Zinc Standard Solution: Dissolved 0.439 g AR grade Zinc sulphate ZnSO4.7H2O in 200ml of glass distilled water in a beaker. Added 5 ml of 1:5 H2SO4. Transfer to a litre measuring flask and made volume to the mark to have a standard solution of 100 ug Zn/ml (100 ppm). Transfer 10 ml of this standard solution to 100 ml volumetric flask and diluted to the mark with DTPA extracting solution to have a stock solution of 10 ug Zn/ml (10ppm). For preparing working standard, transfer 1,2,4 and 6 ml of stock solution(10 ug Zn/ml) to a series of clean 100 ml volumetric flask and each to the mark with DTPA extracting solution. Volume of stock Zn solution taken : 0 1 2 4 6ml Concentration of Zn now in solution : 0 0.1 0.2 0.4 0.6ug/ml (ppm)

Iron Standard Solution: Dissolved 0.702g of AR grade ammonium ferrous sulphate (NH4)2SO4FeSO4.6H2O in 300 ml deionized or galss distilled water in a beaker. Added 5 ml of 1:5 H2SO4. Transfer to a litre measuring flask and made volume to the mark. This is a standard solution of 100 ug Fe/ml (100 ppm). To prepare working standards, transfer 1,2,4 and 6 ml of stock solution and diluted each to the mark with DTPA extracting solution. Volume of stock Fe solution taken : 0 1 2 4 6ml Concentration of Fe in solution : 0 1 2 4 6ug/ml (ppm)

Manganese Standard Solution: Dissolved 0.288 g potassium permanganate (KMnO4) AR grade in 300 ml deionized water in a breaker. Added 20 ml concentrated H2SO4 warm to about 600 C and added oxalic acid solution dropwise to make the solution colour less. Cool and transfer to a litre measuring flask and made volume to the mark. This solution contains 100 ug Mn/ml (100 ppm). To prepare working standards, transfer 1,2,4,6 and 8 ml of the standard solution to a series of clean 100 ml volumetric flask and diluted each to the mark with DTPA extracting solution. Volume of stock Mn solution taken : 0 1 2 4 8 ml Concentration of Mn in solution : 0 1 2 4 8ug/ml (ppm)

Copper Standard Solution: Dissolved 0.392 Copper sulphate (CuSO4 .5H2O) of AR grade in 400 ml glass distilled water in a beaker. Transfer to a litre measuring flask and made volume to the mark with glass distilled water. This is a standard solution containing 100 ug Cu/ml. To

prepare the working standards, transfer 1,2,4 and 6 ml of stock solution to a series of clean 100 ml volumetric flask and diluted each to the mark with DTPA extracting solution. Volume of stock Cu solution taken : 0 1 2 4 6 ml Concentration of Cu in solution : 0 1 2 4 6ug/ml (ppm)

(vii) Analysis for Available Molybdenum (Mo): Ammonium oxalate (pH 3.3) or Grigg's reagent is considered to be the best one for the determination of available Mo. Further, this extractant is easy to prepare, have sufficient buffering capacity to prevent any material change in the pH of the soil extract and forms stable complexes with Mo (MoO3.C2H2O4 and (MoO3)2. C2H2O4) Molybdate absorbed on soil colloids and clay is presumably replaced by the oxalations. This exchange is made irreversible by the formation of strong Mo-oxalic acid complexes to make a single extraction effective.

Extracting Solution: To prepare ammonium oxalate (pH 3.3), dissolve 24.9 g AR ammonium oxalate and 12.6 g oxalic acid per litre of solution, adjusted to pH 3.3.

Standard Solution: Prepare a solution containing 100 ug Mo/ml by dissolving 0.150 g AR grade MoO3 in 100 ml of 0.1N NaoH solution rendering it acidic with HCl and make the volume to 1 litre. Take 10 ml of this stock solution in one litre volumetric flask and make the volume to the mark to get a working standard of 1 ug Mo/ml. To make working standards, transfer 0.5,1.0,2.0,3.0 and 4.0 ml of 1 ug Mo/ml solution to series of clean 125 ml separatory funnels.

(vii) Analysis for Available Molybdenum (Mo)

Ammonium oxalate (pH 3.3) or Grigg's reagent is considered to be the best one for the determination of available Mo. Further, this extractant is easy to prepare, have sufficient buffering capacity to prevent any material change in the pH of the soil extract and forms stable complexes with Mo ($MoO_3 \cdot C_2H_2O_4$ and $(MoO_3)_2 \cdot C_2H_2O_4$) Molybdate absorbed on soil colloids and clay is presumably replaced by the exhalations. This exchange is made irreversible by the formation of strong Mo-oxalic acid complexes to make a single extraction effective.

Extracting Solution

To prepare ammonium oxalate (pH 3.3), dissolve 24.9 g AR ammonium oxalate and 12.6 g oxalic acid per litre of solution, adjusted to pH 3.3.

Standard Solution

Prepare a solution containing 100 ug Mo/ml by dissolving 0.150 g AR grade MoO_3 in 100 ml of 0.1N NaoH solution rendering it acidic with HCl and make the volume to 1 litre. Take 10 ml of this stock solution in one litre volumetric flask and make the volume to the mark to get

a working standard of 1 ug Mo/ml. To make working standards, transfer 0.5,1.0,2.0,3.0 and 4.0 ml of 1 ug Mo/ml solution to series of clean 125 ml separatory funnels.

Extraction and Determination of Molybdenum

Twenty five gram soil is taken in a 500 ml corning or pyrex glass conical flask. To this 250 ml ammonium oxalate of pH 3.3 is added. The contents of the flask are shaken over an end to end horizontal shaker for 10 hours and filtered through Whatman filter paper no 50. Then, 200 ml of the filtrate is taken in a 250 ml breaker and evaporated to dryness on a water bath. The contents of the breaker are headed at high temperature (500^0C) in a furnace for 5 hours to destroy organic matter and oxalates.

Contents of the breaker are then digested with 5 ml of diacid (HNO_3 – $HclO_4$ 4:1) after keeping it overnight, then with 10 ml of 4N H_2SO_4 and H_2O_2 every time taking to dryness. Then 10 ml of 0.1N HCl is added to the breaker and filter paper washed with another 10 ml. The filtrate is stored in corked plastic reagent bottles for estimation of available Mo by the procedure described above under standard curve.

(viii) Analysis for Available Boron (B)

Out of several methods devised to assess the level of available B in soil, the hot water soluble B method of Berger and Troug (1939) has been most widely accepted. Recent description of this method include some changes (Keren and Bingham 1985, Sippola and Ervco 1987), but the basic procedure remains the same. Throughout boron analysis, use of borosilicate glassware should be avoided even for storage of chemicals. Plastic containers or corning pyrex glassware should be used.

Standard Solution

To prepare the standard stock solution, dissolve 0.570 g boric acid (H_3BO_3) AR grade in a litre distilled water to obtain a stock solution of 100 ug B/ml. Take 5 ml of the stock solution in a 100 ml volumetric flask and dilute to the mark. This solution contains 5 ug B/ml.

Extraction and Determination of Boron

A 25 gm soil sample, 50 ml of water and about 0.5 g of activated charcoal is boiled for 5 minutes in a quartz flask and filtered immediately through Wahtman filter paper No. 42. 5 ml of the extract is taken in a 25 ml volumetric flask and 4 ml of buffer masking solution and 4 ml of azomethine –H regent solution is added. The colour is allowed to develop for 1 hour, and

the volume is made to the mark**.** Intensity of colour is measured spectrophotometrically at 420 mm, and the B concentration read off from standard curve described above.

E) Statistical Models :

Statistical Models and methods were done as followed by Singh & Chaudhary (1995 ?) and Panse & Sukhatme (2005); Tah, 2018.

Experiment-2

Methods

Data collection Data collection included: morphological characteristic of sandalwood tree, trees composition, edaphic factor, number of leaves, number of branches, tree height etc. Size-class structure data were collected from the assistance of supervisor and colleagues.

1. A comprehensive account of growth parameters of Santalum album L. in terms of plant height, girth and number of branches per plant have also been presented here to reflect the differences (if any) in its growth pattern across these locations.

2. Data analysis Quantitative data of sandalwood were obtained by calculating the CF, TSS, RSS, TRSS and ESS for all locations with the variation in leaves number, plant height and number of branches.

Experiments – 3

Methods

First of all sandal seeds were sun dried for about two weeks. A desire number of seeds were then counted for each location and measured their weight by weigh balance before pouring it in the chemical treatments. Three types of seeds viz. (i) natural scarified (ii) non-scarified (iii) randomly selected seeds were considered for the experiment. These were treated in three treatments. Before going through treatments, three kinds of treatments were made viz i) control (Distilled water), ii) 500 ppm GA3 solution, iii) 700 ppm GA3 solution. Seed were treated with each treatment for about 72 hours. Seeds were pretreated with HgCl2 (0.001%) for surface sterilization for 30 minutes. After 72 hours of soaking in chemical treatments, seeds were removed from the solutions, blot their surface and again measured their weight. There after seeds were taken to the nursery field for sowing. Date viz.: (i) plant height, (ii) stem girth,

(iii) branches/plant (no.), (iv) leaf length (cm) and (v) leaf breadth (cm) were considered or analyzing after five years of plant age. All these data calculated following bivariate correlation regression as per Singh and Chaudhary (2005) for measuring the trend of correlation and its increments. Soil testing methods was followed by IARI soil testing kits for measuring N,P, K….. Mean data of five observations were considered in the correlation table for one average observation. Likewise 20 observations were noted in the correlation table following the models of correlation coefficient (Pansa and sukhatme 2005). We calculated the coorelation value(r) in each bivariate correlation study in each location which have been cited in the table 1. All the soil components as measured in the laboratory have been cited in the table 2.

Experiment-4

Methods

Methods

Statistical calculations done as follow by Sharma (1995) for the Genotypic Environmental Interaction analyses based on means: first, Comstock and Robin's Model, and second, Wricke's Models of Ecovalance.

Lay-out and Design: Randomized Block Design (RBD) Lay-out and design was followed as laid down by Panse and Sukhatme (2005).

Soil Test: As recommended by IARI Soil Testing Kits.

Chapter-5

RESULTS

Experiment-1

Results:

Soil Parameters Study Six soil samples were collected from the different forest gardens of Bankura and Burdwan district, viz. Bagaldhara, Rangamati, Kamalpur, Beliatore & Hirbandh of Bankura and Khandari of Burdwan. The soil samples were tested for pH, Organic carbon, available N, P and K and presented in Table-III. The result show that Bagaldhara has highest macronutrient content and lowest is Kamalpur.

Table - I : Soil Test Reports of Macronutrients

Location	pH	OC (%)	Available N_2 (Kg ha-1)	Available N_2 (PPM)	Available K (PPM)	Available P (PPM)
Rampur	5.71	0.51	234.6	106.63	57.6	8.2
Malangwa	5.70	0.47	221.3	100.59	51.8	7.9
Kamalpur	5.57	0.34	198.8	90.36	49.8	5.7
Bardibas	4.95	0.35	211.3	105.51	50.5	5.6

Micronutrient analysis was done for 4 soil samples, viz. Bagaldhara, Rangamati, Kamalpur and Hirbandh and reffected in Table-XV. It is evident from the results that the micronutrient (Cu,Zn,Mn,Fe,Mo & B) content is lowest in Bagaldhara, Cu content is maximum in Rangamati, Zn & Fe content is highest in Kamalpur, Mn content is highest in Hirbandh. In all the cases B content is below the critical level (0.3 ppm) and Mo content is below detection level (BDL).

Table - II: Soil Test Report of Micronutrients

Sl. no	Test parameter	Critical levels of micronutrients (mgkg-1or PPM)	Results			
			Hirbandh	Kamalpur	Rangamati	Bagaldhara
1	Copper (Cu)	0.6	0.67	1.08	1.38	0.50
2	Zinc (Zn)	0.2	0.32	0.86	0.46	0.19

3	Manganese (Mn)	2.0	73.72	45.89	69.50	25.89
4	Iron (Fe)	4.5	8.66	17.15	7.96	2.25
5	Molybdenum (Mo)	0.05	BDL	BDL	BDL	BDL
6	Boron (B)	0.3	0.14	0.17	0.17	0.17

Experiment-2

Results:

L = Location, L1 = Khandari (Bardwan), L2 = Basudevpur (Bankura), L3 = Bagaldhara (Bankura), L4 = Rangamati (Bankura)

Table 1. Total number of leaves of *S. album* in different study sites Leaf Number

Location	R I	R II	R III	R IV	∑
L -1	1780,17900,350, 280,16600 ∑=52930 x̄ = 10586	19200,800,1200, 13600,19500 ∑=54300 x̄ = 10860	18800,16900,6000, 8600,17500 ∑=62400 x̄ =12480	14800,16200,10900, 9300,14100 ∑=65300 x̄ = 13060	46986
L -2	12500,14600,10800 8600,16500 ∑=63000 x̄ =12600	11300,13400,6000, 9600,12000 ∑=52300 x̄ =10460	7600,9800,4200, 8100,9600 ∑=39300 x̄ = 7860	6300,8100,4600, 9000,8600 ∑= 36600 x̄ = 7320	38240
L -3	20200,16400,18900, 4200,4600 ∑= 64300 x̄ =12860	10200,9000,12500, 16900,14600 ∑= 62700 x̄ = 12540	10700,6000,14100, 7200,7800 ∑= 45800 x̄ =9160	9300,8200,7100, 4600,3800 ∑= 33000 x̄ =6600	41160
L -4	16700,8500,3200, 4500,7100 ∑=40000 x̄ =8000	16800,9700,7400, 9000,9500 ∑=52400 x̄ = 10480	8900,7200,8300, 7600,9600 ∑= 41600 x̄ = 8320	8200,9100,9600, 6100,7500 ∑= 40500 x̄ = 8100	34900
∑	44046	44340	37820	35080	GT= 161286

Calculations: [CF = (161286)2/80 =325164672.45 TSS = 10094500900- 325164672.45 = 9769336227.55 RSS = (6567044516/ 4)- 325164672.45 = 1316596456.55 TRSS = (6582137396/4)- 325164672.45 = 1320369676.59 ESS = 9769336227.55-(1316596456.55+1320369676.59) = 7132370094.45]

ANOVA of Table - 1

SV	Df	SS	MSS	F
Rep	3	1316596456.55	438865485.516	0.5537^{ns}
Treat	3	1320369676.59	440123225.516	0.5553^{ns}
Error	9	7132370094.45	792485566.05	

Table 2. Plant height (cm) of S. album in different study sites

Location	R I	R II	R III	R IV	∑
L-1	30,35,5,5.8,3,30, 35.2,5.9,5.9,30.6 ∑=107.6 x̄ = 21.5	30.5,5.9,6.9,24.5, 33,20,18,22,26,28 ∑=105.3 x̄ = 21.06	23.8,28.7,9.8,12,30. 6 ∑= 104.9 x̄ = 20.98	23,25.7,16.9,14,18 ∑= 97.6 x̄ = 19.52	83.06

L-2	10.8,13.6,8,12.1 ,25.3 ∑= 69.8 x̄ =13.96	18,16.7,9,8.8,10.9 ∑= 63.4 x̄ = 12.68	9.7,11.4,8.6,12.4, 12.6 ∑= 54.7 x̄ = 10.94	10.8,12.7,9.8,11.8, 12.1 ∑= 57.2 x̄ = 11.44	49.02
L-3	10,10,12,12,11,10. 9, 0.7,12,14.6,16.7 ∑= 64.9 x̄ = 12.98	8,7.7,10.8,14.1,11. 2 ∑= 51.8 x̄ = 10.36	13.7,9.9,18,11.3,10. 7 ∑= 63.6 x̄ = 12.72	14.3,15.2,11,10, 4.9 ∑=59.9 x̄ = 11.98	48.04
L-4	10.6,9.9,8.6,9,14.6 ∑=52.7 x̄ = 10.54	12.3,10.9,11,14,10. 3 ∑= 58.5 x̄ = 11.7	10.9,11.2,12,11,14. 4 ∑= 59.5 x̄ = 11.9	11.6,12.3,12.2,9.8,1 0 ∑= 55.9 x̄ = 11.18	45.32
∑	58.98	55.8	56.54	54.12	GT=225.4 4

Calculations:

[CF= (225.44)2/80 = 635.28 TSS = (30)2 + (3.5)2 + (5.9)2 + (5.9)2 + (30.6)2 ……..……...+ (10)2 - CF = 19361.08 – 635.28 = 18725.8 RSS = {(58.98)2 + (55.8)2 + (56.54)2 + 954.12)2}/ 4– 635.28 = (12718.02)/4 – 635.28 = 2544.42 TRSS = {(83.06)2 + (49.02)2 + (48.04)2 + (45.32)2}/ 4- CF = 3415.9-635.28 = 2780.635 ESS = TSS- (RSS + TRSS) = 18725.8- (2544.22 + 2780.63) = 13400.95]

ANOVA of Table - 2

SV	**Df**	**SS**	**MSS**	**F**
Rep	3	3 2544.22	848.07	0.5695 ^{ns}
Treat	3	2780.635	926.87	0.6224 ^{ns}
Error	9	13400.95	1488.99	

Table 3. Total number of branches of S. album in different study sites

Location	**R I**	**R II**	**R III**	**R IV**	∑
L-1	85, 27,15,14,18 ∑=159 x̄ = 31.8	44,10,8,12,19 ∑= 93 x̄ = 18.6	15,18,7,21,14 ∑= 75 x̄ = 15.0	21,33,25,6,18 ∑= 103 x̄ = 20.6	86.00
L-2	8,9,12,23,10 ∑= 62 x̄ = 12.4	12,8,6,12,7 ∑= 45 x̄ = 9	6,28,12,14,18 ∑= 78 x̄ = 15.6	27,19,11,7,16 ∑= 80 x̄ = 16	53.00
L-3	16,25,30,22,24 ∑= 120 x̄ = 24	4,4,11,9,7 ∑= 35 x̄ = 7	22,18,25,19,17 ∑= 101 x̄ = 20.2	11,25,19,8,18 ∑=81 x̄ = 16.2	67.40
L-4	8,2,4,15,25 ∑= 54 x̄ = 10.8	19,9,6,12,8 ∑= 54 x̄ = 10.8	19,23,15,6,18 ∑= 81 x̄ = 16.2	34,10,6,9,14 ∑= 73 x̄ = 14.6	52.4
∑	79.00	45.40	67.00	67.40	GT= 258.80

Calculations:

[CF= (258.8)2/80 = 837.218 TSS = 30934- 837.218 = 30096.782 RSS = (17333.92/4) - 837.218 = 3496.262 TRSS = (17493.52/4) - 837.218 = 3536.162 ESS = 30096.782 – (3496.262+3536.162) = 23064.35]

ANOVA of Table - 3

SV	Df	SS	MSS	F
Rep	3	3496.262	1165.42	0.4547 ^{ns}
Treat	3	3536.162	1178.72	0.4599 ^{ns}
Error	9	23064.35	2562.7	

Experiment-1

Results:

Soil Parameters Study Six soil samples were collected from the different forest gardens of Bankura and Burdwan district, viz. Bagaldhara, Rangamati, Kamalpur, Beliatore & Hirbandh of Bankura and Khandari of Burdwan. The soil samples were tested for pH, Organic carbon, available N, P and K and presented in Table-III. The result show that Bagaldhara has highest macronutrient content and lowest is Kamalpur.

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Kamalpur	5.57	0.34	198.8	90.36	49.8	5.7
Bardibas	4.95	0.35	211.3	105.51	50.5	5.6

Micronutrient analysis was done for 4 soil samples, viz. Bagaldhara, Rangamati, Kamalpur and Hirbandh and reffected in Table-XV. It is evident from the results that the micronutrient (Cu,Zn,Mn,Fe,Mo & B) content is lowest in Bagaldhara, Cu content is maximum in Rangamati, Zn & Fe content is highest in Kamalpur, Mn content is highest in Hirbandh. In all the cases B content is below the critical level (0.3 ppm) and Mo content is below detection level (BDL).

Table - II: Soil Test Report of Micronutrients

Sl. no	Test parameter	Critical levels of micronutrients (mgkg-1or PPM)	Results			
			Hirbandh	Kamalpur	Rangamati	Bagaldhara
1	Copper (Cu)	0.6	0.67	1.08	1.38	0.50
2	Zinc (Zn)	0.2	0.32	0.86	0.46	0.19
3	Manganese (Mn)	2.0	73.72	45.89	69.50	25.89
4	Iron (Fe)	4.5				
5	Molybdenum (Mo)	0.05				
6	Boron (B)	0.3				

Experiment-2

Results:

L = Location, L1 = Khandari (Bardwan), L2 = Basudevpur (Bankura), L3 = Bagaldhara (Bankura), L4 = Rangamati (Bankura)

Table 1. Total number of leaves of *S. album* in different study sites

Leaf Number

Location	R I	R II	R III	R IV	∑
L -1	1780,17900,350, 280,16600 ∑=52930 x̄ = 10586	19200,800,1200, 13600,19500 ∑=54300 x̄ = 10860	18800,16900,6000, 8600,17500 ∑=62400 x̄ =12480	14800,16200,10900, 9300,14100 ∑=65300 x̄ = 13060	46986
L -2	12500,14600,10800 8600,16500 ∑=63000 x̄ =12600	11300,13400,6000, 9600,12000 ∑=52300 x̄ =10460	7600,9800,4200, 8100,9600 ∑=39300 x̄ = 7860	6300,8100,4600, 9000,8600 ∑= 36600 x̄ = 7320	38240
L -3	20200,16400,18900, 4200,4600 ∑= 64300 x̄ =12860	10200,9000,12500, 16900,14600 ∑= 62700 x̄ = 12540	10700,6000,14100, 7200,7800 ∑= 45800 x̄ =9160	9300,8200,7100, 4600,3800 ∑= 33000 x̄ =6600	41160
L -4	16700,8500,3200, 4500,7100 ∑=40000 x̄ =8000	16800,9700,7400, 9000,9500 ∑=52400 x̄ = 10480	8900,7200,8300, 7600,9600 ∑= 41600 x̄ = 8320	8200,9100,9600, 6100,7500 ∑= 40500 x̄ = 8100	34900
∑	44046	44340	37820	35080	GT= 161286

Calculations: [CF = (161286)2/80 =325164672.45 TSS = 10094500900- 325164672.45 = 9769336227.55 RSS = (6567044516/ 4)- 325164672.45 = 1316596456.55 TRSS = (6582137396/4)- 325164672.45 = 1320369676.59 ESS = 9769336227.55- (1316596456.55+1320369676.59) = 7132370094.45]

ANOVA of Table – 1

SV	Df	SS	MSS	F
Rep	3	1316596456.55	438865485.516	0.5537^{ns}
Treat	3	1320369676.59	440123225.516	0.5553^{ns}
Error	9	7132370094.45	792485566.05	

Table 2. Plant height (cm) of S. album in different study sites

Location	R I	R II	R III	R IV	∑
L-1	30,35,5,5.8,3,30, 35.2,5.9,5.9,30.6 ∑=107.6 x̄ = 21.5	30.5,5.9,6.9,24.5, 33,20,18,22,26,28 ∑=105.3 x̄ = 21.06	23.8,28.7,9.8,12,30. 6 ∑= 104.9 x̄ = 20.98	23,25.7,16.9,14,18 ∑= 97.6 x̄ = 19.52	83.06
L-2	10.8,13.6,8,12.1 ,25.3 ∑= 69.8 x̄ =13.96	18,16.7,9,8.8,10.9 ∑= 63.4 x̄ = 12.68	9.7,11.4,8.6,12.4, 12.6 ∑= 54.7 x̄ = 10.94	10.8,12.7,9.8,11.8, 12.1 ∑= 57.2 x̄ = 11.44	49.02
L-3	10,10,12,12,11,10. 9, 0.7,12,14.6,16.7 ∑= 64.9 x̄ = 12.98	8,7.7,10.8,14.1,11. 2 ∑= 51.8 x̄ = 10.36	13.7,9.9,18,11.3,10. 7 ∑= 63.6 x̄ = 12.72	14.3,15.2,11,10, 4.9 ∑=59.9 x̄ = 11.98	48.04
L-4	10.6,9.9,8.6,9,14.6 ∑=52.7 x̄ = 10.54	12.3,10.9,11,14,10. 3 ∑= 58.5 x̄ = 11.7	10.9,11.2,12,11,14. 4 ∑= 59.5 x̄ = 11.9	11.6,12.3,12.2,9.8,1 0 ∑= 55.9 x̄ = 11.18	45.32
∑	58.98	55.8	56.54	54.12	GT=225.4 4

Calculations:

[CF= (225.44)2/80 = 635.28 TSS = (30)2 + (3.5)2 + (5.9)2 + (5.9)2 + (30.6)2 …….……...+ (10)2 - CF = 19361.08 – 635.28 = 18725.8 RSS = {(58.98)2 + (55.8)2 + (56.54)2 + 954.12)2}/ 4– 635.28 = (12718.02)/4 – 635.28 = 2544.42 TRSS = {(83.06)2 + (49.02)2 + (48.04)2 + (45.32)2}/ 4- CF = 3415.9-635.28 = 2780.635 ESS = TSS- (RSS + TRSS) = 18725.8- (2544.22 + 2780.63) = 13400.95]

ANOVA of Table – 2

SV	**Df**	**SS**	**MSS**	**F**
Rep	3	3 2544.22	848.07	0.5695 ^{ns}
Treat	3	2780.635	926.87	0.6224 ^{ns}
Error	9	13400.95	1488.99	

Table 3. Total number of branches of S. album in different study sites

Location	**R I**	**R II**	**R III**	**R IV**	∑
L-1	85, 27,15,14,18 ∑=159 x̄ = 31.8	44,10,8,12,19 ∑= 93 x̄ = 18.6	15,18,7,21,14 ∑= 75 x̄ = 15.0	21,33,25,6,18 ∑= 103 x̄ = 20.6	86.00
L-2	8,9,12,23,10 ∑= 62 x̄ = 12.4	12,8,6,12,7 ∑= 45 x̄ = 9	6,28,12,14,18 ∑= 78 x̄ = 15.6	27,19,11,7,16 ∑= 80 x̄ = 16	53.00
L-3	16,25,30,22,24 ∑= 120 x̄ = 24	4,4,11,9,7 ∑= 35 x̄ = 7	22,18,25,19,17 ∑= 101 x̄ = 20.2	11,25,19,8,18 ∑=81 x̄ = 16.2	67.40

L-4	8,2,4,15,25 ∑= 54 x̄ = 10.8	19,9,6,12,8 ∑= 54 x̄ = 10.8	19,23,15,6,18 ∑= 81 x̄ = 16.2	34,10,6,9,14 ∑= 73 x̄ = 14.6	52.4
∑	79.00	45.40	67.00	67.40	GT= 258.80

Calculations:

[CF= (258.8)2/80 = 837.218 TSS = 30934- 837.218 = 30096.782 RSS = (17333.92/4) - 837.218 = 3496.262 TRSS = (17493.52/4) - 837.218 = 3536.162 ESS = 30096.782 – (3496.262+3536.162) = 23064.35]

ANOVA of Table – 3

SV	**Df**	**SS**	**MSS**	**F**
Rep	3	3496.262	1165.42	0.4547 ^{ns}
Treat	3	3536.162	1178.72	0.4599 ^{ns}
Error	9	23064.35	2562.7	

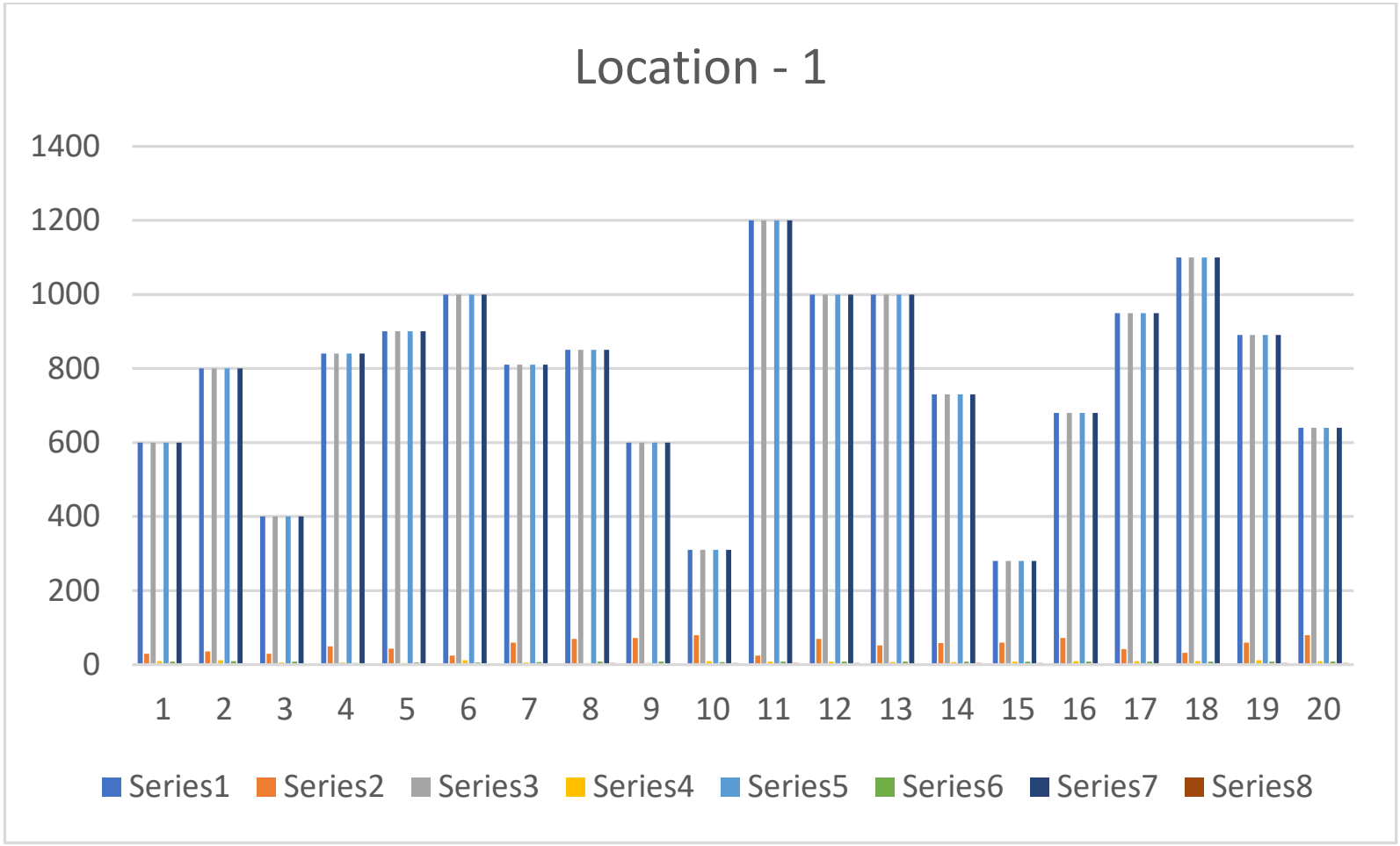
Experiment-1

Results-

Table 1: Statement of Correlation coefficients of White sandal (*Santalum album* L.) from three locations of Nepal

s. no1 vs2	Location -1								Location - 2								Location - 3							
	1vs 2		1vs 3		1vs 4		1vs 5		1vs 2		1vs 3		1vs 4		1vs 5		1vs 2		1vs 3		1vs 4		1vs 5	
1	600	30	600	9	600	8.0	600	2.5	550	14.1	600	4	600	8	600	2.5	1200	36.0	600	3	600	3.3	600	2.2
2	800	36	800	12	800	9.0	800	2.5	350	9.1	800	5	800	7	800	2.4	1100	37.0	800	2	800	3.9	800	.23
3	400	30	400	6	400	8.0	400	2.5	410	8.4	400	6	400	9	400	2.5	1250	48.0	400	2	400	4.2	400	2.7
4	840	50	840	6	840	5.0	840	2.6	590	11.6	840	7	840	8	840	2.5	1400	47.0	840	2	840	4.1	840	2.8
5	900	43	900	5	900	6.0	900	2.7	520	17.0	900	4	900	7	900	2.5	1450	50.0	900	2	900	4.7	900	2.5
6	1000	25	1000	12	1000	6.0	1000	2.4	380	16.0	1000	3	1000	9	1000	3.4	1450	42.0	1000	2	1000	2.9	1000	2.6
7	810	60	810	6	810	7.0	810	2.8	460	15.5	810	7	810	6	810	2.5	1500	50.2	810	2	810	3.2	810	2.1
8	850	70	850	5	850	8.0	850	3.8	500	14.9	850	3	850	8	850	2.4	1500	52.0	850	2	850	3.0	850	1.9
9	600	72	600	5	600	8.0	600	3.7	490	13.7	600	4	600	7	600	2.9	1510	58.0	600	2	600	2.6	600	3.0
10	310	80	310	10	310	7.0	310	4.1	440	12.6	310	5	310	9	310	2.5	1500	59.0	310	2	310	3.7	310	2.9
11	1200	25	1200	8	1200	8	1200	4.0	560	11.9	1200	2	1200	6	1200	2.5	1600	60.0	1200	2	1200	4.1	1200	2.6
12	1000	70	1000	8	1000	8.3	1000	4.0	510	12.0	1000	3	1000	8	1000	2.4	1600	61.0	1000	2	1000	3.6	1000	2.2
13	1000	52	1000	7	1000	8.0	1000	3.5	430	13.0	1000	4	1000	7	1000	2.4	1620	53.0	1000	2	1000	3.5	1000	2.3
14	730	58	730	7	730	8.2	730	4.0	490	14.9	730	3	730	7	730	2.5	1610	54.0	730	2	730	3.8	730	2.1
15	280	60	280	8	280	8.0	280	3.9	390	16.6	280	4	280	7	280	2.5	1580	56.0	280	2	280	4.0	280	2.0
16	680	72	680	9	680	8.1	680	2.5	380	16.0	680	5	680	6	680	2.4	1570	31.0	680	2	680	4.1	680	2.4
17	950	42	950	9	950	8.2	950	3.7	530	13.7	950	2	950	9	950	2.5	1590	39.0	950	2	950	4.3	950	2.5
18	1100	32	1100	10	1100	8.4	1100	2.6	560	14.8	1100	2	1100	8	1100	2.5	1625	44.0	1100	3	1100	4.4	1100	2.4
19	890	60	890	12	890	8.0	890	4.1	570	15.7	890	3	890	8	890	2.4	1638	49.0	890	4	890	3.9	890	2.1
20	640	80	640	10	640	8.1	640	3.8	590	17.3	640	2	640	7	640	2.3	1670	68.0	640	2	640	4.6	640	2.0
r - value	1.051		0.186		0.088		-0.050		0.185		0.309		0.045		0.283		0.496		0.027		0.001		-0.217	

1 vs 2= plant height vs. stem girth (cm), 1 vs. 3= plant height vs. branch/plant (no), 1 vs. 4= plant height vs. leaf length (cm) and 1 vs. 5= plant height vs. leaf breadth (cm)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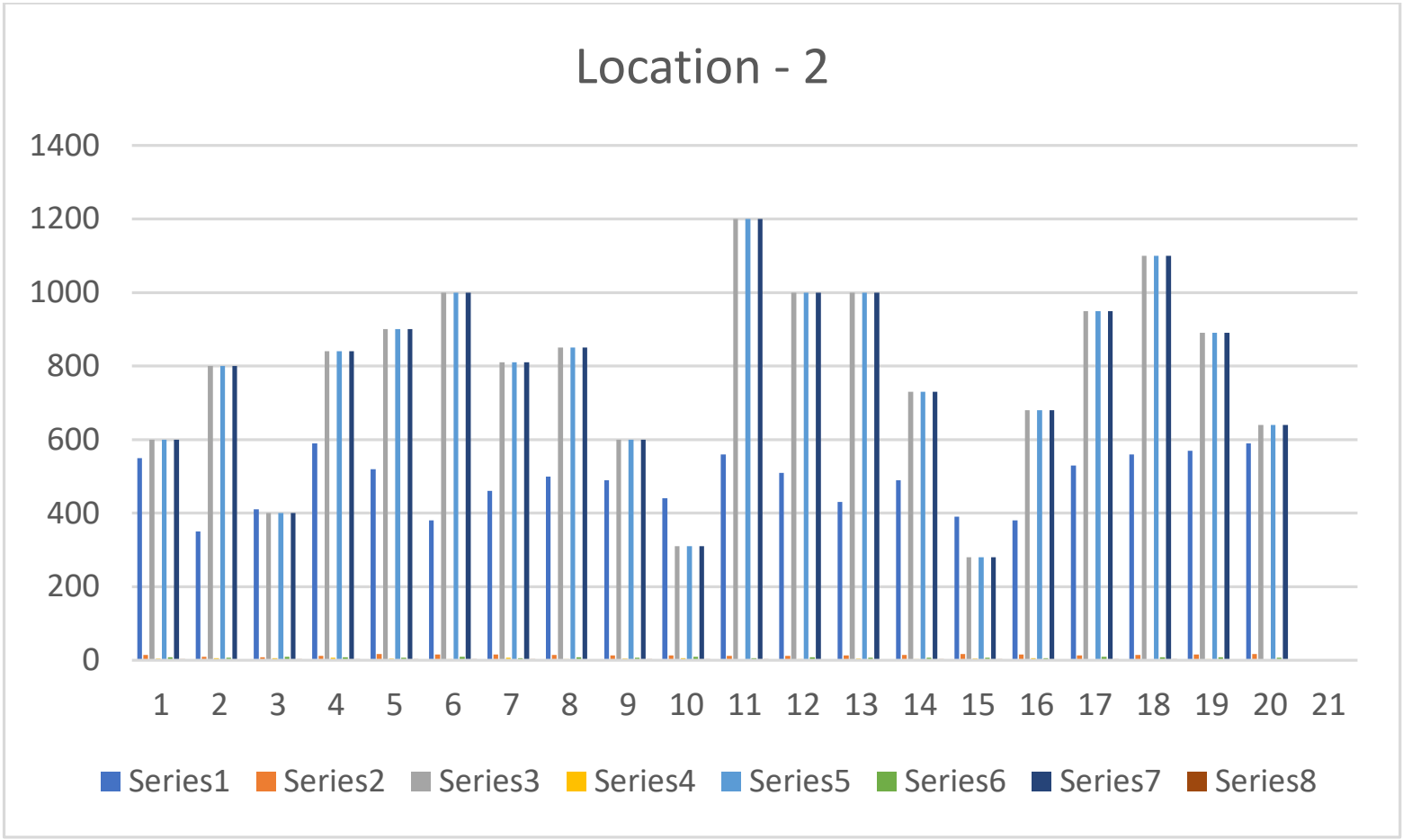
Series1 Series2 Series3 Series4 Series5 Series6 Series7 Series8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1000
800
600
400
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0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Series1 Series2 Series3 Series4 Series5 Series6 Series7 Series8

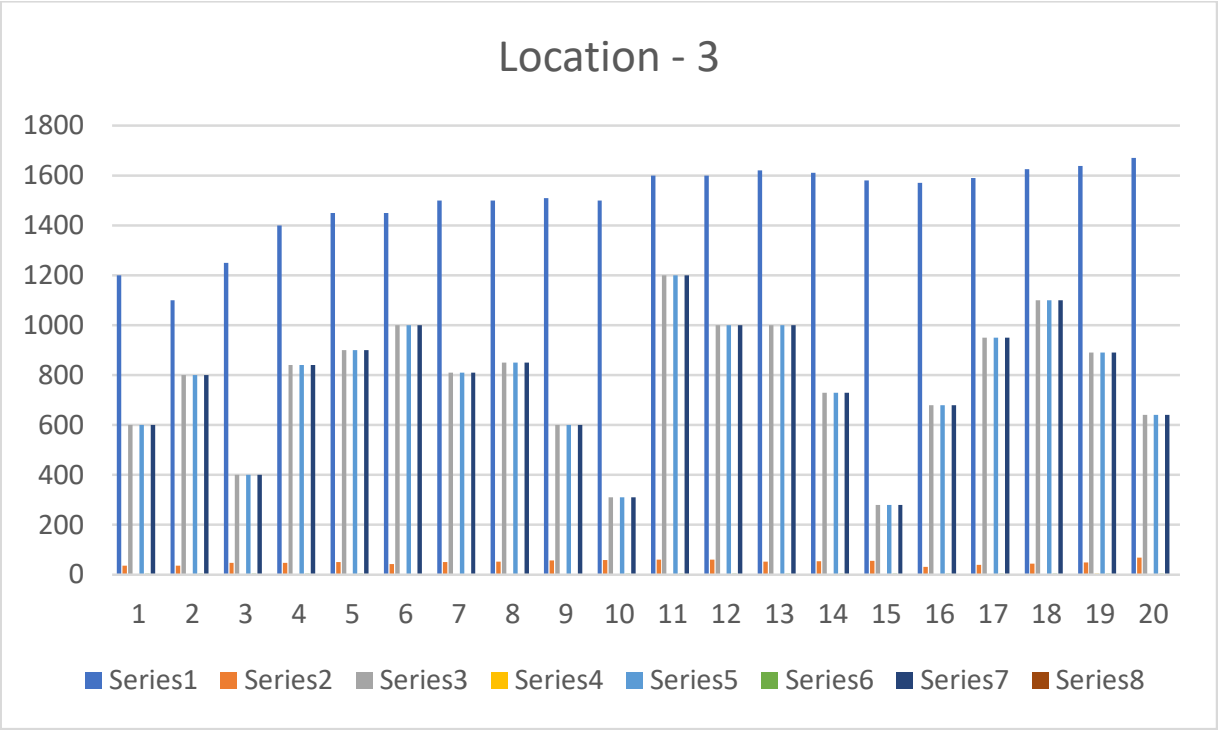


Table 1: Soil analyses of the soil samples taken from the field of White sandal (*Santalum album* L.) from three locations of Nepal

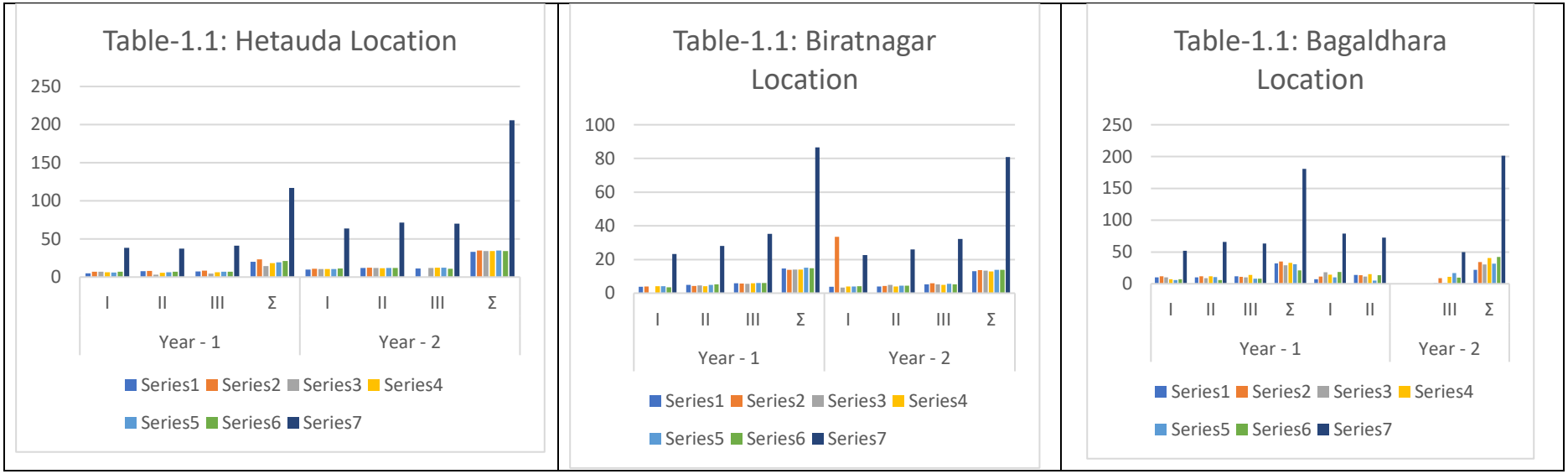
Components	**Location - 1**	**Location -2**	**Location- 3**
Phosphorous	Very high	Very high	High
Potassium	High	High	High
Ammoniacal nitrogen	Low	Low	Very low
Carbon	Dark	Slightly dark	Faint
pH	6.9	6.8	6.5

Experiment- 4

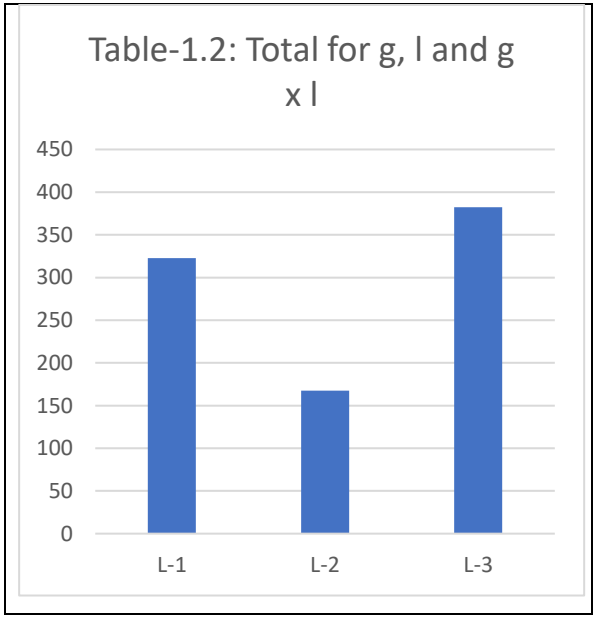
Table -1.1: Plant height (m) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

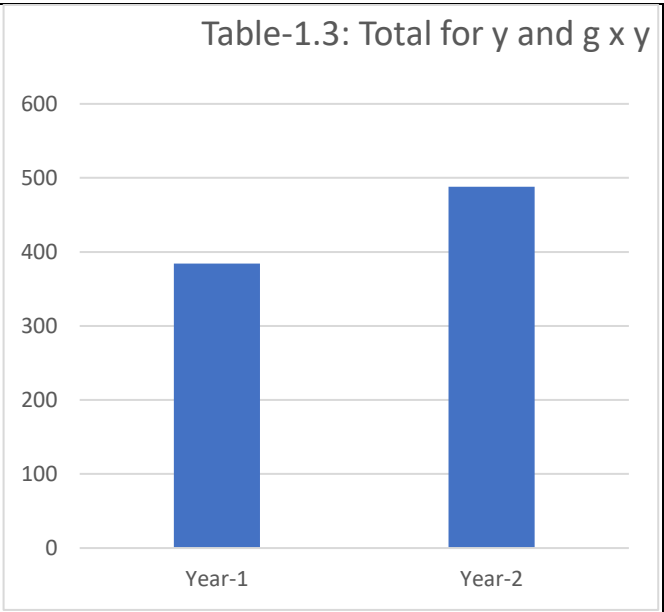
T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year - 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	5.0	7.7	7.5	20.2	10.0	12.0	11.1	33.1	3.8	4.9	5.9	14.6	3.8	4.0	5.3	13.1	10.0	10.0	12.0	32.0	7.0	14.0	1.0	22.0
2	7.0	8.0	8.4	23.4	11.0	12.4	11,5	34.9	3.9	4.3	5.7	13.9	33.5	4.3	5.9	13.7	12.0	12.0	11.0	35.0	11.2	13.7	9.0	34.0
3	7.0	3.0	4.5	14.5	10.5	11.8	12.0	34.3	3,8	4.6	5.6	14.0	3.3	4.9	5.2	13.4	10.0	9.0	10.1	29.1	18.0	11.3	1.07	30.37
4	6.5	5.5	6.4	18.4	10.4	11.5	12.3	34.2	4.1	4.1	5.9	14.1	4.0	3.9	5.0	12.9	7.0	12.0	14.0	33.0	14.3	15.2	11.0	40.5
5	6.0	6.3	7.2	19.5	10.7	11.9	12.4	35.0	4.2	5.0	6.0	15.2	3.9	4.5	5.5	13.9	6.0	10.7	8.0	30.7	10.0	4.9	16.9	31.8
6	7.0	6.9	7.1	21.0	11.3	12.0	10.8	34.1	3.5	5.2	6.1	14.8	4.1	4.4	5.3	13.8	7.0	6.0	8.0	21.0	18.6	13.6	9.8	42.0
Σ	38.5	37.4	41.1	117.0	63.9	71.6	70.1	205.6	23.3	28.1	35.2	86.6	22.6	26.0	32.2	80.8	52.0	65.7	63.1	180.8	79.1	72.7	49.67	201.17

$TR_1 = 279.4$,$TR_2 = 301.5$, $TR_3 = 291.37$, GT= 872.27



Tables >	1.2: Total for g, l and gxl			1.3: Total for y and gxy			1.4: Total for lxy			
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	**Σ**
A	TAL1= 53.3	TAL2=27.7	TAL3= 54.0	A	TAY1= 66.8	TAL2= 68.2	1	GT1= 117.0	GT2= 205.6	**T11= 322.6**
B	TBL1=58.3	TBL2 =27.6	TBL3= 69.8	B	TB Y1= 72.3	TBL2 = 83.4	2	GT3= 86.6	GT4= 80.8	**T12= 167.4**
C	TCL1= 48.8	TCL2=27.4	TCL3= 59.47	C	TC Y1= 57.6	TCL2= 78.07	3	GT5= 180.8	GT6= 201.17	**T13= 381.97**
D	TDL1= 52.6	TDL2=27.0	TDL3= 73.5	D	TD Y1= 65.5	TDL2= 87.6	**Σ**	**384.4**	**487.57**	**871.97**
E	TEL1= 54.5	TEL2=29.1	TEL3= 62.5	E	TE Y1= 65.4	TEL2= 80.7				
F	TFL1= 55.1	TFL2=28.6	TFL3= 63.0	F	TF Y1= 56.8	TFL2= 89.9				
Σ	**322.6**	**167.4**	**382.27**	**Σ**	**384.4**	**487.87**				





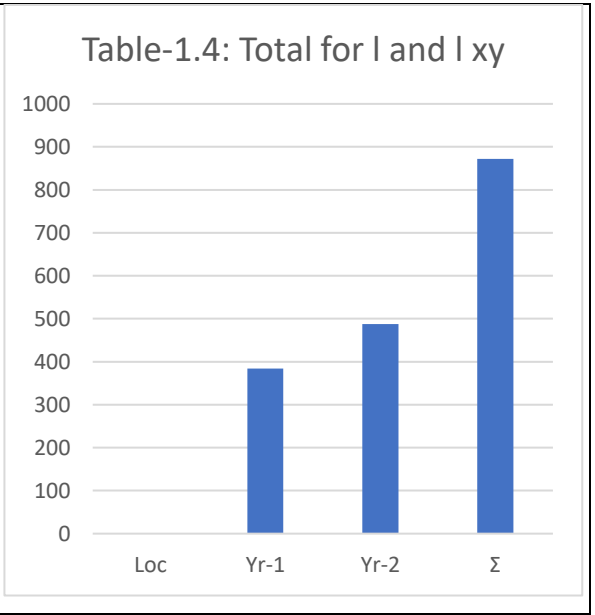
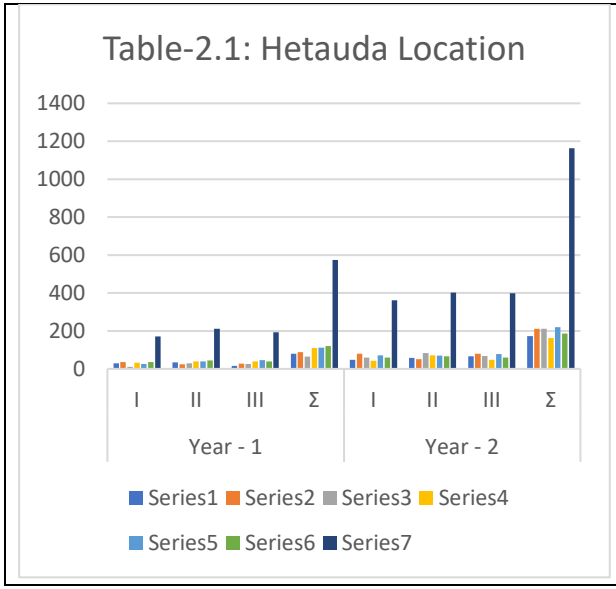
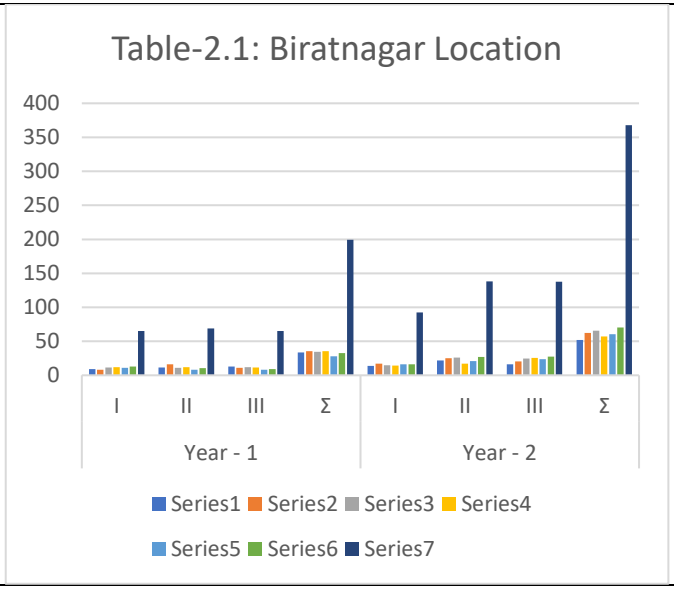


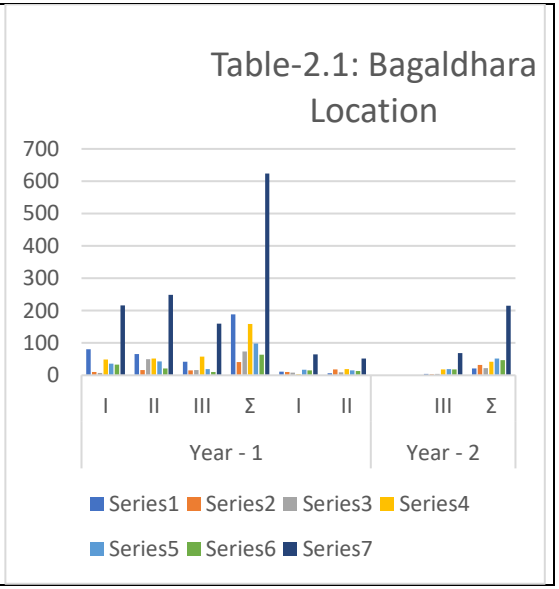
Table – 2.1: Basal Girth of Plant (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year - 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	30.0	34.0	16.0	80.0	48.0	58.0	66.0	172.0	9.1	11.5	13.0	33.6	14.0	22.0	16.0	52.0	80.3	66.1	42.0	188.4	10.8	6.5	4.3	21.6
2	36.0	25.0	27.5	88.5	80.0	52.0	80.0	212.0	8.4	16.0	11.1	35.5	17.0	25.0	20.2	62.2	9.8	16.0	15.2	41.0	9.8	18.6	3.5	31.9
3	10.0	29.9	25.9	64.9	60.0	82.5	68.5	211.0	11.6	10.9	11.9	34.4	15.0	26.0	24.5	65.5	7.6	50.0	15.8	73.4	7.8	9.2	4.8	21.8
4	32.0	39.0	38.7	109.7	42.0	72.0	48.0	162.0	11.9	11.8	11.6	35.3	14.5	17.0	25.7	57.2	48.6	52.3	58.0	158.9	3.7	19.6	18.6	41.9
5	26.0	40.0	45.5	111.5	72.0	70.5	77.5	220.0	11.0	8.4	8.4	27.8	16.0	21.0	23.5	60.5	36.3	42.9	18.8	98.0	17.3	14.8	19.3	51.4
6	36.5	44.5	39.5	120.5	60.0	66.5	59.5	186.0	13.0	10.5	9.1	32.6	16.0	27.0	27.5	70.5	33.2	21.0	9.8	64.0	15.4	13.2	18.0	46.6
Σ	170.5	211.5	193.1	575.1	362.0	401.5	399.5	1163.0	65.0	69.1	65.1	199.2	92.5	138.0	137.4	367.9	215.8	248.3	159.6	623.7	64.8	51.9	68.5	215.2

TR_1 = 970.6 ,TR_2 = 1150.3, TR_3 = 1023.2, GT= 3144.1







Tables >	2.2: Total for g, l and gxl of *S. album* L.			2.3: Total for y and gxy of *S. album* L.			2.4: Total for lxy of *S. album* L.			
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	**Σ**
A	TAL1= 252	TAL2=85.6	TAL3=21.0	A	TAY1= 188.4	TAL2= 245.6	1	GT-1= 575.1	GT2= 1163.0	**T11= 1738**
B	TBL1= 300.5	TBL2= 97.7	TBL3=72.9	B	TB Y1= 165.0	TBL2= 306.1	2	GT3= 199.2	GT4= 367.9	**T12= 567.1**
C	TCL1= 275.9	TCL2= 99.9	TCL3=95.2	C	TC Y1= 172.7	TCL2= 298.3	3	GT5= 623.7	GT6215.2	**T13= 838.9**
D	TDL1= 271.7	TDL2= 92.5	TDL3=200.8	D	TD Y1= 303.9	TDL2= 261.1	**Σ**	**1398.0**	**1746.1**	**3144.1**
E	TEL1= 331.5	TEL2= 88.3	TEL3=149.4	E	TE Y1= 237.3	TEL2= 331.9				
F	TFL1= 306.5	TFL2=103.1	TFL3=110.6	F	TF Y1= 217.3	TFL2= 303.1				
Σ	**1738.1**	**567.1**	**838.9**	**Σ**	**1398.0**	**1746.1**				

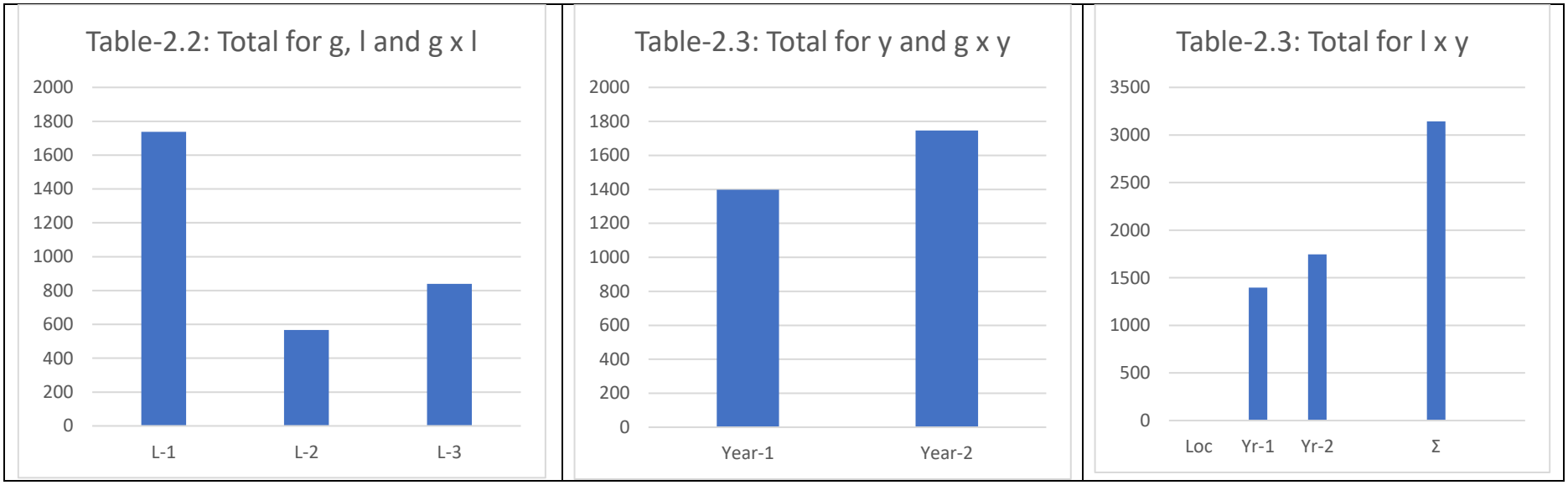
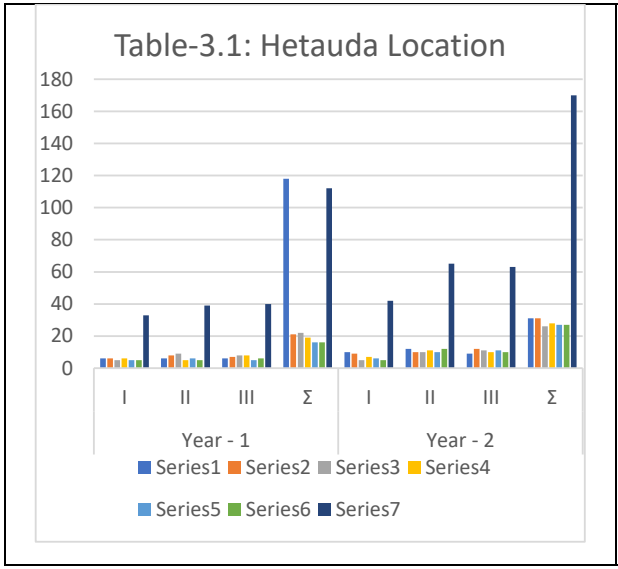
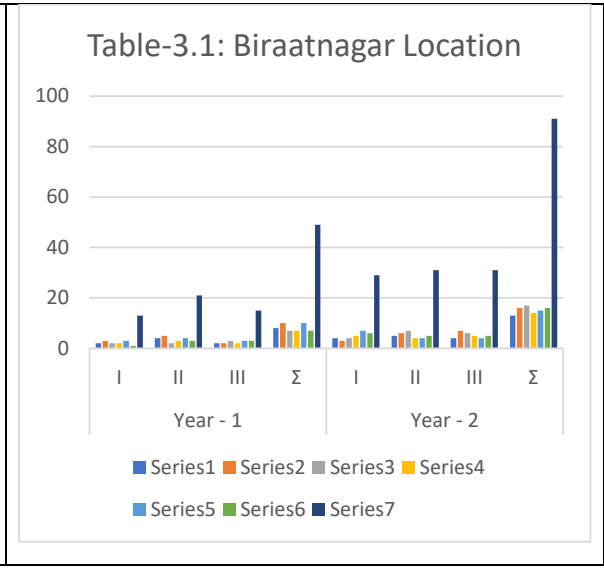


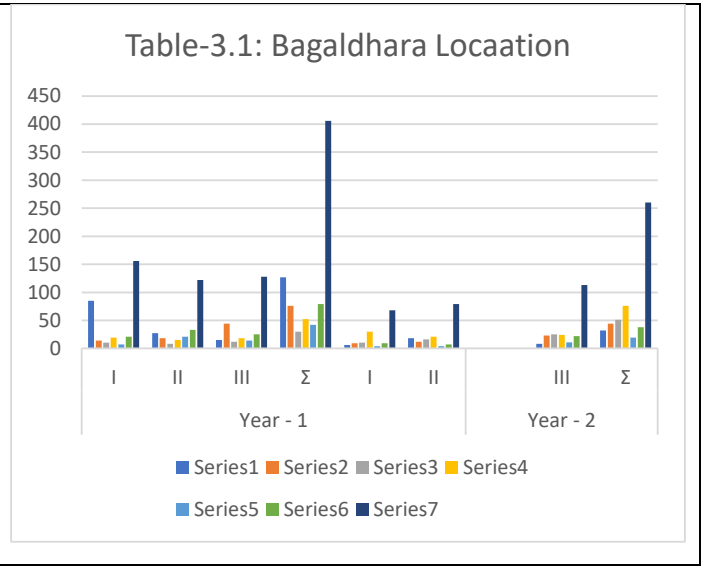
Table – 3.1: Branches/Plant (no) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year - 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	6	6	6	118	10	12	9	31	2	4	2	8	4	5	4	13	85	27	15	127	6	18	8	32
2	6	8	7	21	9	10	12	31	3	5	2	10	3	6	7	16	14	18	44	76	9	12	23	44
3	5	9	8	22	5	10	11	26	2	2	3	7	4	7	6	17	10	8	12	30	10	16	25	51
4	6	5	8	19	7	11	10	28	2	3	2	7	5	4	5	14	19	15	18	52	30	21	24	76
5	5	6	5	16	6	10	11	27	3	4	3	10	7	4	4	15	7	21	14	42	4	4	11	19
6	5	5	6	16	5	12	10	27	1	3	3	7	6	5	5	16	21	33	25	79	9	7	22	38
Σ	33	39	40	112	42	65	63	170	13	21	15	49	29	31	31	91	156	122	128	406	68	79	113	260

TR_1 = 341.0 , TR_2 = 357.0 , TR_3 = 390.0 , GT= 1088.0







Tables >	3.2: Total for g, l and gxl			3.3: Total for y and gxy			3.4: Total for lxy			
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	**Σ**
A	TAL1= 49.0	TAL2= 31.0	TAL3= 159.0	A	TAY1= 153.0	TAL2= 76.0	1	GT1= 112.0	GT2= 170.0	**T11= 282.0**
B	TBL1= 52.0	TBL2= 26.0	TBL3= 120.0	B	TB Y1= 107.0	TBL2 = 91.0	2	GT3= 49.0	GT4= 91.0	**T12= 140.0**
C	TCL1= 48.0	TCL2= 24.0	TCL3= 81.0	C	TC Y1= 59.0	TCL2= 94.0	3	GT5= 406.0	GT6= 260.0	**T13= 666.0**
D	TDL1= 47.0	TDL2= 24.0	TDL3= 128.0	D	TD Y1= 78.0	TDL2= 118.0	**Σ**	**567.0**	**521.0**	**1088,0**
E	TEL1= 43.0	TEL2= 25.0	TEL3= 61.0	E	TE Y1= 68.0	TEL2= 61.0				
F	TFL1= 43.0	TFL2= 23.0	TFL3= 117,0	F	TF Y1= 102	TFL2= 81.0				
Σ	**282.0**	**143.0**	**666.0**	**Σ**	**567**	**521.0**				

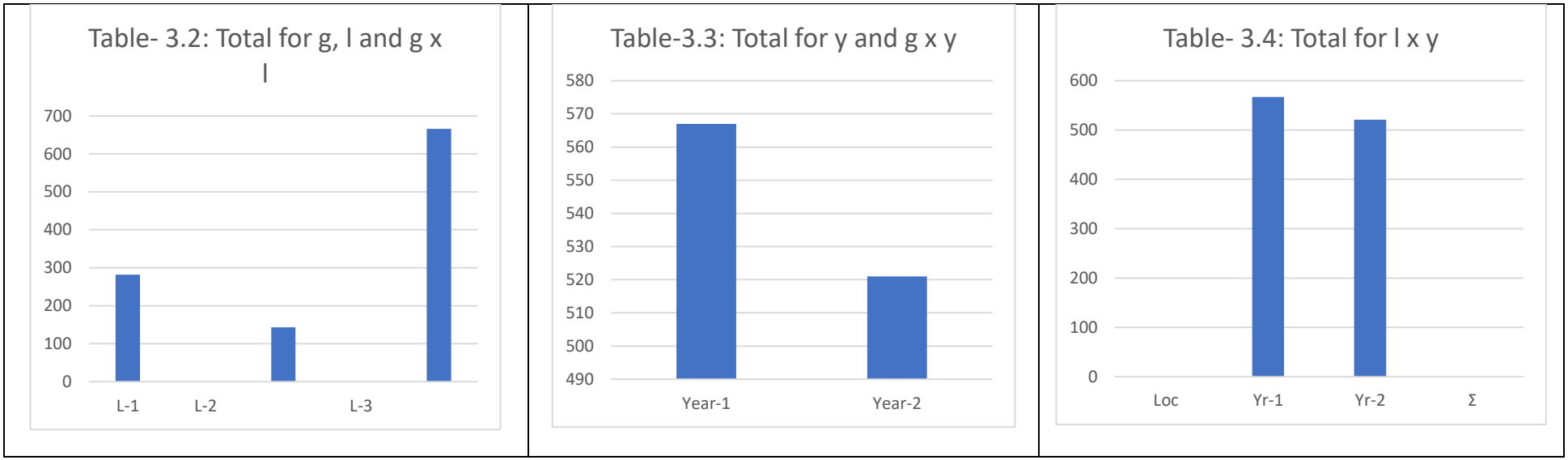
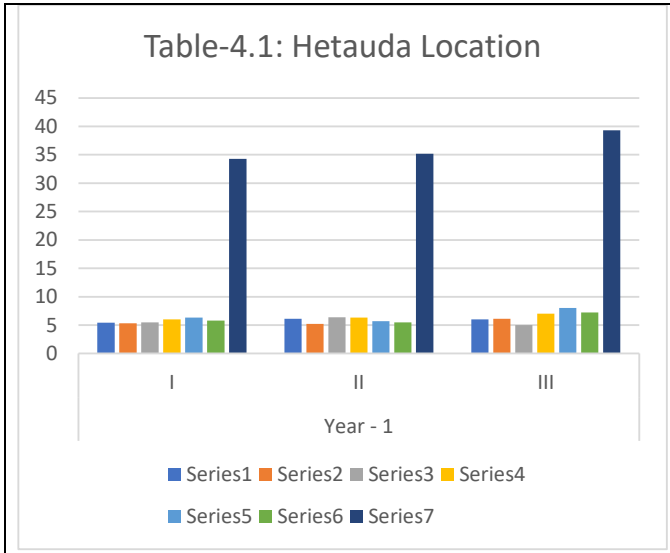
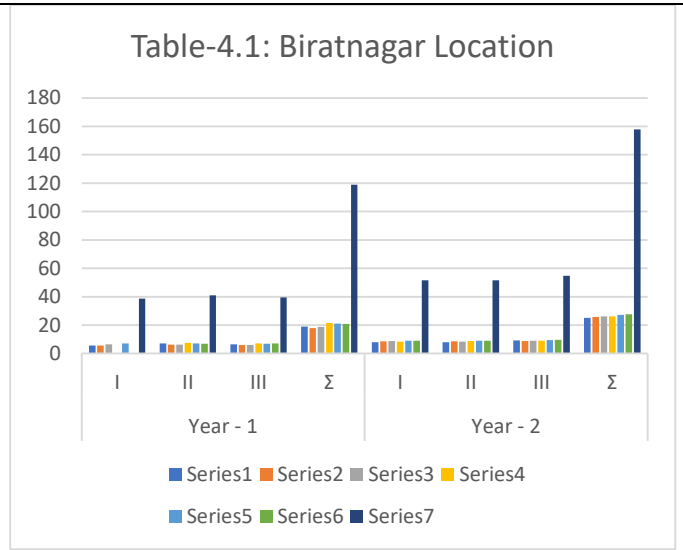


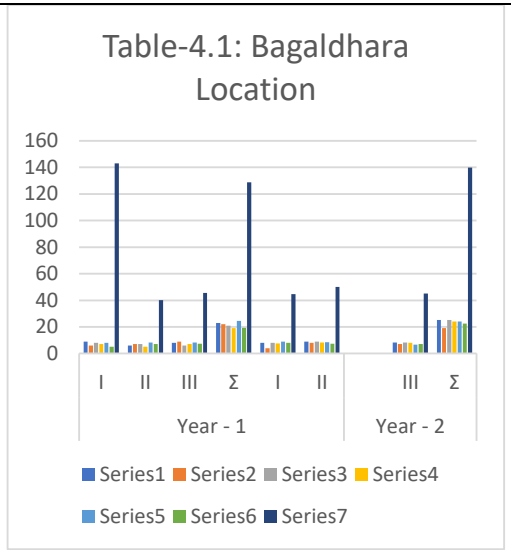
Table - 4: Leaf length (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year - 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	5.4	6.1	6.0	17.5	8.0	8.2	9.0	25.2	5.5	7.0	6.5	19.0	8.0	8.0	9.1	25.1	9.0	6.0	8.0	23.0	8.0	9.0	8.3	25.3
2	5.3	5.2	6.1	16.6	9.0	8.4	8.5	25.9	5.6	6.2	6.0	17.8	8.5	8.5	8.7	25.7	6.0	7.0	9.0	22.0	4.0	8.0	7.0	19.0
3	5.5	6.4	5.0	16.9	8.5	8.0	7.0	23.5	6.5	6.3	6.0	18.8	8.8	8.4	9.0	26.2	8.0	7.0	6.0	21.0	8.0	9.0	8.2	25.2
4	6.0	6.3	7.0	19.3	7.0	8.2	8.0	23.2	7,0	7.5	7.0	21.5	8.4	8.7	9.0	26.1	7.0	5.0	7.0	19.0	7.6	8.3	8.1	24.0
5	6.3	5.7	8.0	20,0	8.3	8.1	8.4	24.8	7.1	7.1	6.9	21.1	8.9	8.9	9.3	27.1	8.0	8.2	8.3	24.5	9.0	8.4	6.6	24.0
6	5.8	5.5	7.2	18.5	8.2	8.3	8.3	24.8	7,0	6.8	7.0	20.8	9.0	9.0	9.7	27.7	5.0	7.0	7.3	19.3	8.0	7.4	7.0	22.4
Σ	34.3	35.2	39.3	108.8	49.0	49.2	49.2	147.4	38.7	40.9	39.4	119.0	51.6	51.5	54.8	157.9	143.0	40.2	45.6	128.8	44.6	50.1	45.2	139.9

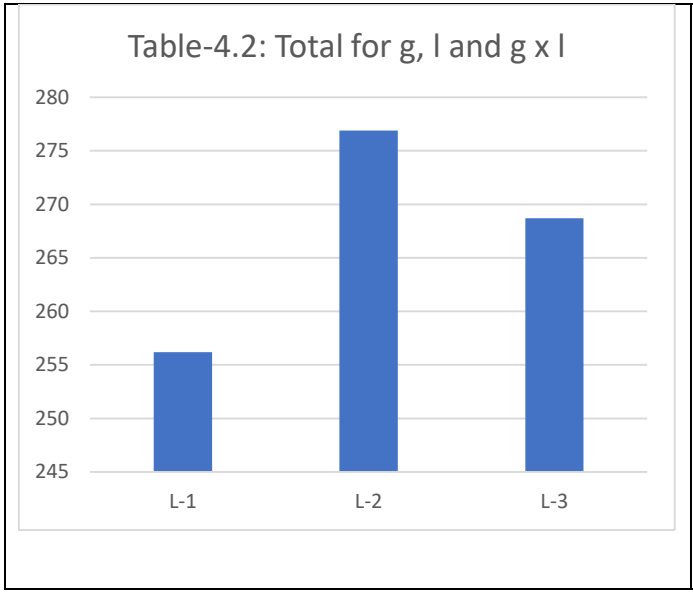
$TR_1 = 361.2$, $TR_2 = 267.1$, $TR_3 = 273.5$, GT= 901.8

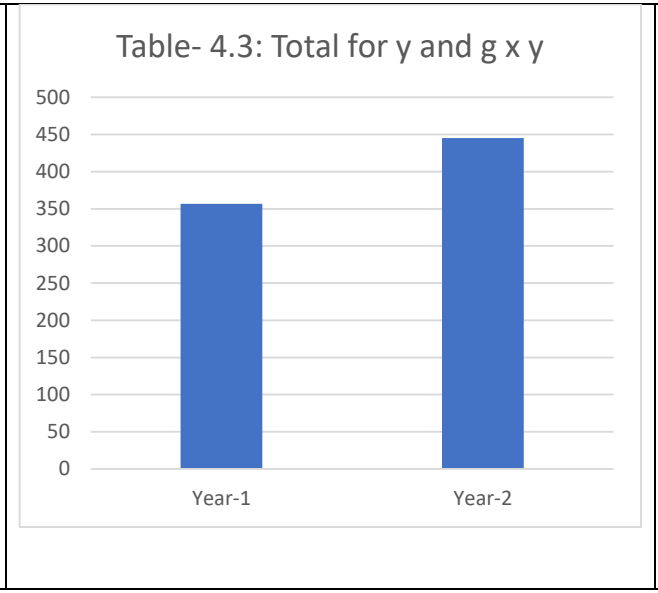






Tables >	4.2: Total for g, l and gxl			4.3: Total for y and gxy			4.4: Total for lxy			
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	**Σ**
A	TAL1= 42.7	TAL2= 44.1	TAL3= 48.3	A	TAY1 = 59.5	TAL2= 75.6	1	GT-1= 108.8	GT2= 147.4	**T11= 256.2**
B	TBL1= 42.5	TBL2 = 43.5	TBL3= 41.0	B	TB Y1 = 56.4	TBL2= 70.6	2	GT3= 119.0	GT4= 157.9	**T12= 276.9**
C	TCL1= 40.4	TCL2= 45.0	TCL3=46.2	C	TC Y1= 56.7	TCL2= 74.9	3	GT5= 128.8	GT6= 139.9	**T13= 268.7**
D	TDL1= 42.5	TDL2= 47.6	TDL3=43.0	D	TD Y1 = 59.8	TDL2= 73.3	**Σ**	**356.6**	**445.2**	**801.8**
E	TEL1= 44.8	TEL2= 48.2	TEL3= 48.5	E	TE Y1 = 65.6	TEL2= 75.9				
F	TFL1= 43.3	TFL2= 48.5	TFL3=41.7	F	TF Y1 = 58.6	TFL2= 74.9				
Σ	**256.2**	**276.9**	**268.7**	**Σ**	**356.6**	**445.2**				





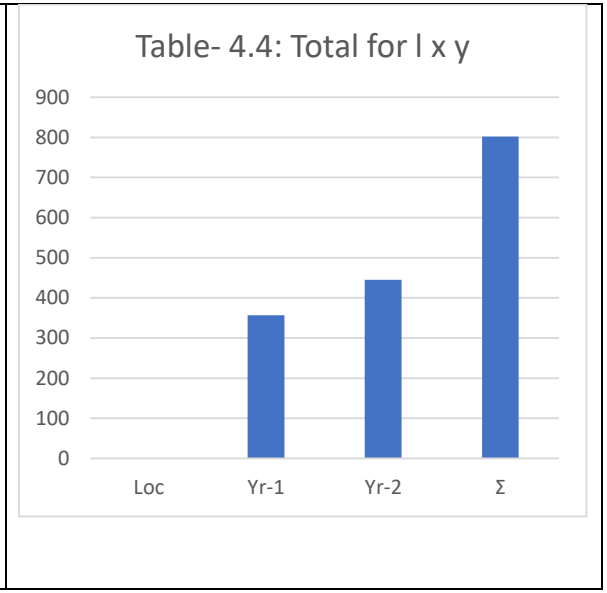
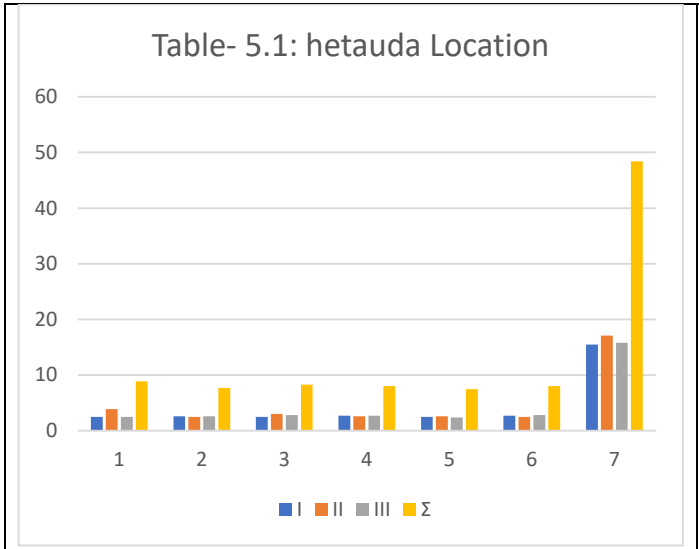
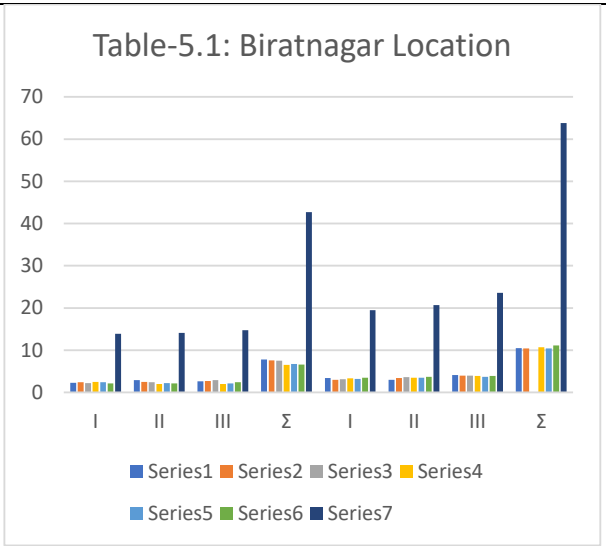


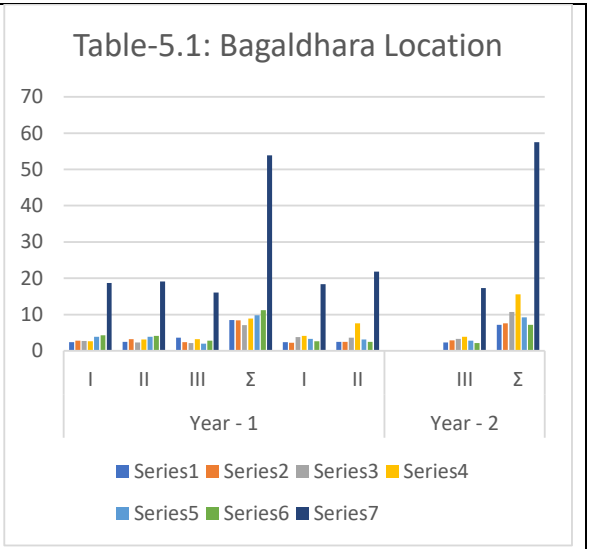
Table – 5.1: Leaf breadth (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year - 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	2.5	3.9	2.5	8.9	2.8	4.1	4.2	11.1	2.3	2.9	2.6	7.8	3.4	3.0	4.1	10.5	2.4	2.5	3.6	8.5	2.4	2.5	2.3	7.2
2	2.6	2.5	2.6	7.7	3.1	3.8	4.1	10.9	2.4	2.5	2.7	7.6	3.0	3.4	4.0	10.4	2.8	3.2	2.4	8.4	2.2	2.5	2.9	7.6
3	2.5	3.0	2.8	8.3	3.5	4.0	4.4	11.9	2.2	2.4	2.9	7.5	3.1	3.6	4.0	10,7	2.7	2.3	2.1	7.1	3.8	3.6	3.3	10.7
4	2.7	2.6	2.7	8.0	3.3	3.9	4.5	11.7	2.5	2.0	2.0	6.5	3.3	3.5	3.9	10.7	2.6	3.1	3.2	8.9	4.1	7.6	3.9	15.6
5	2.5	2.6	2.4	7.5	3.4	3.7	4.6	11.7	2.4	2.2	2.1	6.7	3.2	3.5	3.7	10.4	3.9	3.9	2.0	9.8	3.3	3.1	2.8	9.2
6	2.7	2.5	2.8	8.0	3.7	4.0	4.9	12.6	2.1	2.1	2.4	6.6	3.5	3.7	3.9	11.1	4.3	4.1	2.8	11.2	2.6	2.5	2.1	7.2
Σ	15.5	17.1	15.8	48.4	19.7	23.5	26.7	69.9	13.9	14.1	14.7	42.7	19.5	20.7	23.6	63.8	18.7	19.1	16.1	53.9	18.4	21.8	17.3	57.5

$TR_1 = 105.7$, $TR_2 = 116.3$, $TR_3 = 114.2$, GT= 336.2







Tables >	5.2: Total for g, l and gxl			5.3: Total for y and gxy			5.4: Total for lxy			
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	**Σ**
A	TAL1= 20.0	TAL2= 18.3	TAL3= 15.7	A	TAY1= 25.2	TAL2= 28.8	1	GT-1= 48.4	GT2= 69.9	**T11= 118.3**
B	TBL1= 18.6	TBL2= 18.0	TBL3= 16.0	B	TB Y1= 23.7	TBL2= 28.9	2	GT3 42.7	GT4= 63.8	**T12= 106.5**
C	TCL1= 20.2	TCL2= 18.2	TCL3= 17.8	C	TC Y1= 22.9	TCL2=33.3	3	GT5= 53.9	GT6= 57.5	**T13= 111.4**
D	TDL1=19.7	TDL2= 17.2	TDL3= 24.5	D	TD Y1= 23.4	TDL2= 38.0	**Σ**	**145.0**	**191.2**	
E	TEL1= 19.2	TEL2= 17.1	TEL3= 19.0	E	TE Y1= 24.0	TEL2= 31.3				
F	TFL1= 20.6	TFL2= 17.7	TFL3= 18.4	F	TF Y1= 25.8	TFL2= 30.9				
Σ	**118.3**	**106.5**	**111.4**	**Σ**	**145.0**	**191.2**				

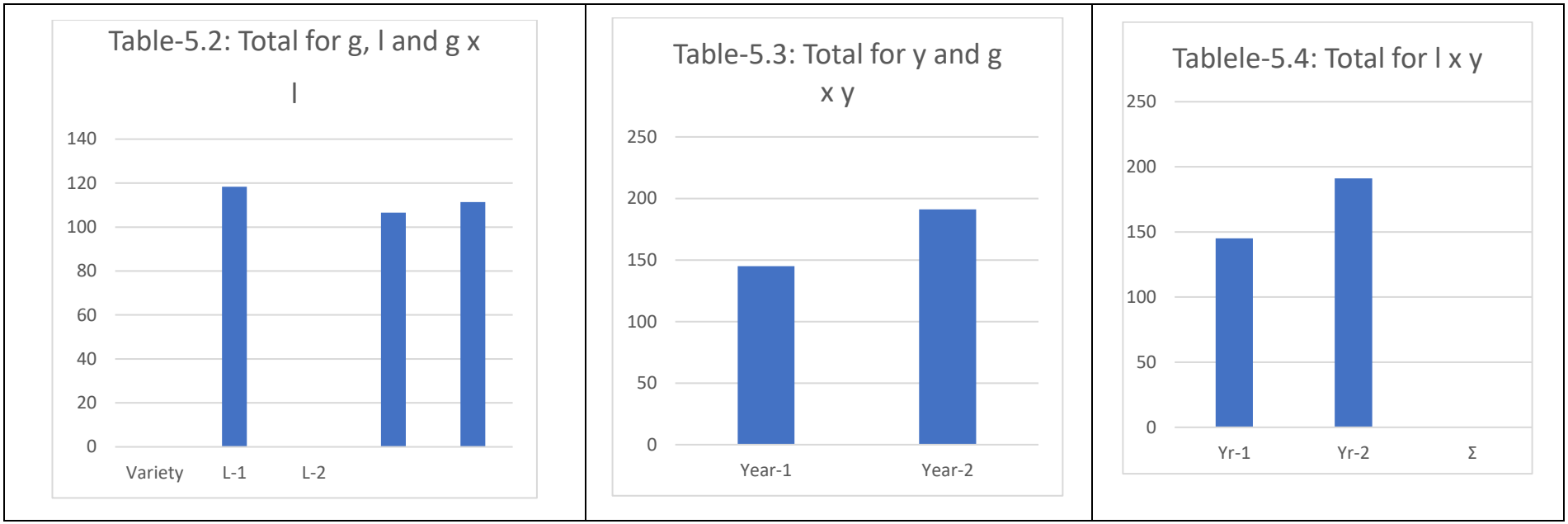


Table-6: ANOVA for GXE interaction

S.V.	df	SS	MSS	Expectations
Rep(r)	r-1	RSS	RMS	--
Loc (l)	l-1	LSS	LMS	---
Year(y)	y-1	YSS	YMS	---
L x y	(l-1)(y-1	LYSS	LYMS	---
Gen (g)	(g-1)	GSS	GMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl+rl\delta^2gy+rly\delta^2eg$
G x l	(g-1)(l-1)	GLSS	GLMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl$
G x y	(g-1)(y-1)	GYSS	GYMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl+rl\delta^2gy$
Gxlxy	(g-1)(l-1)(y-1	GLYSS	GLYMS	$\Delta^2 e+r\delta^2gly$
Error(e)	(r-1)(gly-1)	ESS	EMS	$\Delta^2 e$
Σ				

Table-7: ANOVA for GXE interaction (calculated value)

S.V.	df	MSS				
		X_1	X_2	X_3	X_4	X_5
Rep(r)	2	3.399	237.09	17.34	76.79	0.875
Loc (l)	2	341.74	10433	2068.71	-785.68	0.97
Year(y)	1	99.13	1121.97	19.59	-1504.72	19.76
L x y	2	62. 50	6952.32	345.68	795.78	2.90
Gen (g)	6	4.116	110.03	83.27	-314.23	0.50
G x l	12	2.932	284.57	61.47	158.61	0.65
G x y	6	6.421	409.41	88.47	315.90	0.94
Gxlxy	12	22.166	219.201	119.08	-153.97	0.87
Error(e)	42	4.900	69.45	58.88	-1.96	0.39
Σ	**85**					

Table-8: Estimates of variance components and h^2

Esti mate	X_1	X_2	X_3	X_4	X_5
$\delta^2 g$	-1.52	-44.61	-10.32	-35.26	-0.10
$\delta^2 e$	4.11	69.45	58.88	-1.96	0.39
$\delta^2 gl$	-3.20	10.89	-9.60	52.09	-0.03
$\delta^2 gy$	-1,74	21.13	-3.40	52.20	0.007
$\delta^2 gly$	5.75	49.19	20.06	-50.67	0.160
$\delta^2 p$	-0.59	-6.50	-89.46	-8.82	-0.018
h^2_{BS}	2.54	6.86	2.07	3.99	6.053

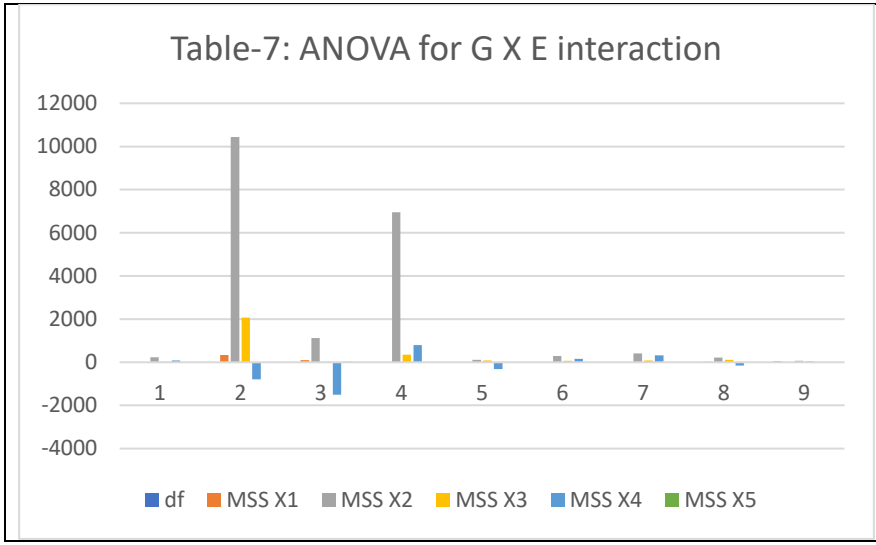


Table-7: ANOVA for G X E interaction
12000
10000
8000
6000
4000
2000
0
-2000
-4000
1
2
3
4
5
6
7
8
9
df
MSS X1
MSS X2
MSS X3
MSS X4
MSS X5

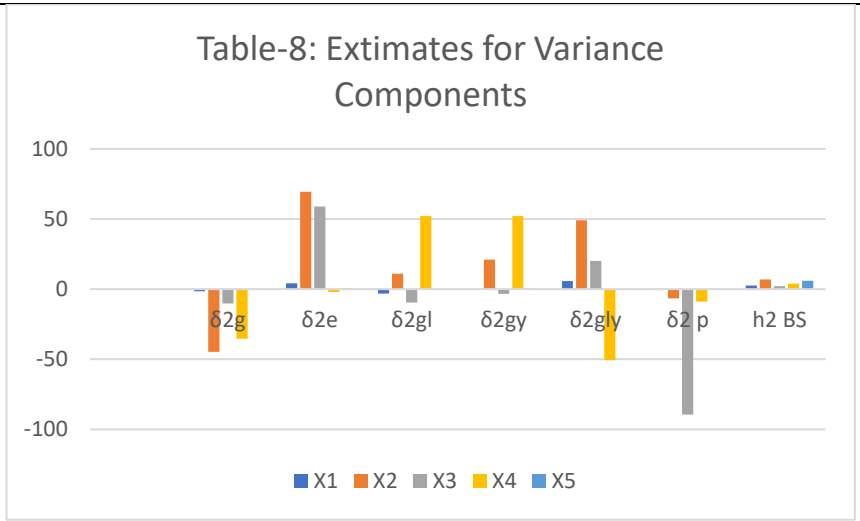


Table-8: Extimates for Variance Components
100
50
0
-50
-100
δ2g
δ2e
δ2gl
δ2gy
δ2gly
δ2 p
h2 BS
X1
X2
X3
X4
X5

Chapter-6

DISCUSSION

Experiment-1

Discussion

Germination of Sandal seeds

In sandal seeds, the seed germination is common problem. It has been observed that in sandal seeds, the duration of seed germination is much prolonged after its dormancy period. It starts in 30th day and persist upto 90 days giving 50% germination. Afterwards the germination rate become very slow & it may extend over 140 -150 days. But, it is notable, in this period some other factors like fungus, nematodes and rodents may invade into the seeds through embryo, thereby create hindrances for germination capacity. Indeed, also such delayed germination affects nursery management and misguide the gardener by increasing sapling cost. Therefore, in order to get maximum germination in shortest possible period, pretreatment should be allowed to the Sandal seeds.

In *Santalum album* L. the germination is sporadic and takes 4 -14 weeks time to complete germination (Srinivasan et al,1992; Srimathi et al,1995). Srinivasan et al (1992) recommended nursery bed in the ratio of 1:3 for seed germination and seed density of 500g/m^2 nursery bed. It is also reported that the enforced dormancy of seeds are due to presence of hard seed coat or due to presence of unknown chemical substances in the seed coat which are impervious to water and gases. Ananthapadmanabha et al (1988) have reported that treatment with dilute hydrochloric acid or gibberellic acid can remove the dormancy principle from the seeds. Early and quick germination in a short time (15 days) by breaking the false seed coat, indicate the presence of inhibitory principle in seed coat Srimathi & Rao (1969). Pretreatment of seeds with GA_3 in 500ppm for 16 hours imbibition resulted in 60% germination under normal field condition (Nagavani et al, 1989). Sandal seeds have been found to germinate fast when the seed coat is completely removed or seeds are soaked in gibberellic acid (Nagaveni & Srimathi, 1981a). Germination accelerated by complete removal of hard shell covering the seeds of sandal (Srimathi & Rao,1969).

Ovcharov (1977) observed that grading seeds by floatation method on water or different % of ammonium sulphate makes it possible to eliminate immature, injured and infected seeds as a result of which germination % may increase. It was also experimented by Nagaveni & Srimathi (1981) with the sandal seeds to test for viability and germination %. Masev & Kutacek (1966) have used Zinc sulphate to accelerate germination in certain hard coated seeds. In an experiment Nagaveni & Srimathi (1980) had proved that dormancy could be broken and germination may be hastened by using 0.05% GA_3. It has been found by Chatterjee (1960) that the chemicals like Indole Acetic Acid (IAA) and Indole Buteric Acid (IBA) has a role of germination acceleration in certain hard coated seeds like *S.album*. Villers & Wireing (1960) found that the chemicals like hydrogen per oxide has role to stimulate or hasten the germination by leaching out the inhibitory substances present on the seed coat.

Micronutrient analysis was done for 4 soil samples, viz. Bagaldhara, Rangamati, Kamalpur and Hirbandh and reffected in Table-XV. It is evident from the results that the micronutrient (Cu,Zn,Mn,Fe,Mo & B) content is lowest in Bagaldhara, Cu content is maximum in Rangamati, Zn & Fe content is highest in Kamalpur, Mn content is highest in Hirbandh. In all the cases B content is below the critical level (0.3 ppm) and Mo content is below detection level (BDL).

Experiment-2

Discussions

The average number of leaves found in different geographical regions of our study showed L1 (46986), L2 (38240), L3 (41160), L4 (34900). The average height of plants as in the study site was found to be 83.06, 49.02, 48.04 and 45.32 feet respectively for L1, L2, L3 and L4. Similarly, the average branch number were in the order of 86,53, 67.4 and 52.4 as shown in the table above. Sandalwood (Santalum album L.) is a partial root parasite, small evergreen tree attaining a height of 12 to 15 metres and a girth of 1 to 2.4 metres with slender drooping as well as erect branching. FAO, 1995

published a bulletin on Flavours and Fragrances of Plants origin which is very much related tantalum album L. This plant has been rendering its performance properly for the sake of human beings since ancient time of civilization. There was no existence of sandal plant in West Bengal in national map. Recently, Das and Tah (2014) reported its existence in West Bengal in an international forum. A few plants were grown by forest executive in undivided Bankura Forest Division. It was felt by present workers that there is certainly some scientific lacuna for its seed propagation and also adaptation due to specific edaphic factors and less germination percentage. Keeping all these views in mind, this venture was undertaken to find out any reason behind this problem.

Experiments – 3

Discussion

Discussion correlation study: Three locations were allotted to study in this location.

Observations after one year were considered bi-variate correlation co-efficient analysis. The calculated r-values were presented in Table -127. The r-values against each treatment are lying in-between 0.149 – 0.839 in first set experiment, 0.383 – 0.882 in second set of experiment and 0.086 – 0.867 in third set of experiment respectively which are most acceptable in biometrical view point. Das and Tah (2013) experimented on the effect of seed germination of Sandal plant and thereafter observed the adaptability on this crop with different host plant species in varied edaphic factors in South Bengal. Batabyal and Tah (2014), Batabyal et al. (2014) studied the variation of seed morphology of different sources and its contribution to seed germination of S. album and germination parameter by means of artificial seed germination and its responses of some phyto-hormones for vegetative propagation of this ancient crop species. Das and Tah (2014) reconfirmed the stability parameters of S. album through different silviculture programmes. Batabyal et al., (2014) have been exercised lot experiments in this problem. Das et al., (2015) vividly studied on frequency distribution on

the growth of Santalum album L. Karmaker et al., (2017) observed an extensive study on “Germination behaviour and morphological activities of white sandal” whereas Jadav et al. (2017) showed the “Role of edaphic factors over seed production and rate of seed germination of white sandal (Santalum album L.).

Ananthapadmanava et al (1984) stated that though the sandal plant can survive without host, but it has proved beyond doubt that the host plants are absolutely necessary for the better growth of sandal plant. He also published his work on survival % and mean height growth of sandal plants following standard error (SE) model. Indeed, there is no reference of frequency distribution model and correlation co-efficient model on sandal plant. Some other workers like Barber (1903); Rama Rao (1903); Rao (1942); Scott (1871) gave the evidence of hemi root parasite and parasitic nature of sandal which revealed that the presence of haustoria in sandal roots. Nagaveni &Srimathi (1985) studied haustoria less sandal plants and their growth and yield attributes. Other workers like Barber (1906, 1903); Fischer (1922); Govinda (1916,1922); Hole [VOLUME 5 I ISSUE 4 I OCT.– DEC. 2018] E ISSN 2348 –1269, PRINT ISSN 2349-5138 652 IJRAR- International Journal of Research and Analytical Reviews Research Paper (1918); Lushington (1903,1918); Rao (1942); Rama Rao (1918); Scott (1871); Srinivasaya (1933a,1948); Varadaraja (1965); Venkata (1924); Venkata Rama (1918) described the hemi-parasites as they have green leaves which are photosynthetically active and the presence of haustoria which act as an organ of attachment to draw nutrients from the host plants. Ananthapadmanava et al (1988) clearly carified the classification of host as poor, medium and good for the growth of sandal plants. Rangaswamy et al (1986a), Venkata Rao (1938) and Rangaswamy and Griffith (1939) worked on the effect of association of different hosts of sandal. Venkata Rao (1939) enumerated that the sandal plant may drain the nutrient completely and may kill it in course of time. Nair and A. Padmanava (1974) studied the bio-assey of tetracycline which helps to indicate that such reverse process can occur in sandal plants also. Nagaveni and Vijoylakshmi (1989) studied on

the response in the haustoria formation and growth of sandalwood plant. Rangaswamy & Griffith (1939) expressed the effect on association of different host plant. Parthasarathi et al (1974) focused the parasitism with different host by cation exchange capacity (CEC) and accepted three categories of good, medium and poor host plants for sandal plant. Nagaveni and Vijoylashmi (2004) also accepted that the host is necessary for good growth of sandalwood plant and recognized three categories of host plant as good, medium and poor hypothesis. Radomiljac et al. (1998) also experimented S. album with different hosts in field experiment.

Timber wood production is expressed by its timber volume. It is measured by the plant height and basal girth. In this case we have observed the plant height and basal girth of the plant in each treatment location-wise which have been exhibited in bi-variate correlation Tables (Table-62 – 122). These individual Tables were calculated as followed by Panse & Sukhadme, 2005. Year-wise plantation of sandal plants having all possible treatments in each location, r-values have been exhibited in Tables at a glance (Table-123 to 128).

From the Table-123, it has been found that r-values against each treatment year-wise of 1st plantation are lying in this Table. After 1st year the correlation values have been calculated which were lying between 0.76 – 0.94 in positive manner. Similarly, the correlation values after 2nd year have calculated which are ranging from 0.43 – 0.85. Similarly, after 3rd year all the r-values are positive and which are ranging from 0.08 – 0.97.

The second time sandalwood plantation was done in Bagaldhara forest area under Bankura (S) Forest Division in the year 2012. After one year interval the plant height and basal girth data were taken for correlation co-efficient studies. Seven treatments were applied at second time sandal plantation. Treatment-wise data were taken from the plant population and calculated properly following Panse & Sukhadme, 2005 for r-values. These r-values both the years (1st year & 2nd year) have been exhibited in a Table at a glance. This combined Table of r-values reflected all positive r-values. In the first year the positive r-values ranging between 0.42 – 0.89 and in the

second year the positive r-values ranging between 0.69 – 0.96. It is very remarkable venture for this location where no negative correlation values have been found.

Simultaneously similar venture was undertaken for another location, i.e Rangamati location. Six treatments including control treatment were applied during sandal plantation in this location. In an interval of one year, growth parameters were studied. The plant height and the basal girth were taken into consideration for calculating the r-values of each treatment. All these r-values have been accumulated at a glance in Table-125. From this Table, it has been observed that all the r-values are positive and within the range of 1.0 which indicates most suitable positive r-values. The r-values from first year population are exhibiting in a range of 0.49 – 0.97. The range of correlation values in the second-year population were lying in-between 0.75 – 0.93. As in observation from the third-year r-values, it was a very befitting range from 0.78 – 0.94.

Another venture was undertaken for sandal plantation in a protected forest garden in Kamalpur under Bankura (S) Forest Division in the year 2012. No host plant is considered for this experimentation. Indeed, more than 50% mortality in the first year and more than 60% mortality have been occurred. However, the survived plant population presented the best class value out of all plantation of sandal plant population in these two forest Divisions. The calculated correlation values were positively significant in both the years which are 0.86 and 0.95 respectively.

In the last year, sandalwood plantation was done in Beliatore forest garden under Bankura (N) Forest Division. Three treatments were allotted to study in this location. Observations after one year were considered bi-variate correlation co-efficient analysis. The calculated r-values were presented in tabulated form.The r-values against each treatment are lying in-between 0.64 – 0.89 which are most acceptable in biometrical view point.

Ananthapadmanava et al (1984) stated that though the sandal plant can survive without host, but it has proved beyond doubt that the host

plants are absolutely necessary for the better growth of sandal plant. He also published his work on survival % and mean height growth of sandal plants following standard error (SE) model. Indeed, there is no reference of frequency distribution model and correlation co-efficient model on sandal plant. Some other workers like Barber (1903); Rama Rao (1903); Rao (1942); Scott (1871) gave the evidence of hemi-root parasite and parasitic nature of sandal which revealed that the presence of houstoria in sandal roots. Nagaveni & Srimathi (1985) studied houstoria less sandal plants and their growth and yield attributes. Other workers like Barber (1906, 1903); Fischer (1922); Govinda (1916,1922); Hole (1918); Lushington (1903,1918); Rao (1942); Rama Rao (1918); Scott (1871); Srinivasaya (1933a,1948); Varadaraja (1965); Venkata (1924); Venkata Rama (1918) described the hemi-parasites as they have green leaves which are photosynthetically active and the presence of houstoria which act as an organ of attachment to draw nutrients from the host plants. Ananthapadmanava et al (1988) clearly carified the classification of host as poor, medium and good for the growth of sandal plants. Rangaswamy et al (1986a), Venkata Rao (1938) and Rangaswamy & Griffith (1939) worked on the effect of association of different hosts of sandal. Venkata Rao (1939) enumerated that the sandal plant may drain the nutrient completely and may kill it in course of time. Nair & A. Padmanava (1974) studied the bio-assey of tetracycline which helps to indicate that such reverse process can occur in sandal plants also. Nagaveni and Vijoylashmi (1989) studied on the response in the haustorial formation and growth of sandalwood plant. Rangaswamy & Griffith (1939) expressed the effect on association of different host plant. Parthasarathi et al (1974) focused the parasitism with different host by cataion exchange capacity (CEC) and accepted three categories of good, medium and poor host plants for sandal plant. Nagaveni and Vijoylashmi (2004) also accepted that the host is necessary for good growth of sandalwood plant and recognized three categories of host plant as good, medium and poor hypothesis. Radomiljac et al (1998) also experimented *S. album* with different hosts in field experiment.

Useful part of sandalwood

The trunk of sandalwood tree is used to extract the highly aromatic sandalwood paste and powder. Sandalwood is well known for its many health benefits, and it is used for its antiseptic properties. Sandalwood essential oils are used in the preparation of soaps, incense, powders, perfumes, and other cosmetics. Sandalwood essential oils have medicinal uses and sandalwood aromatherapy can be used for relaxation. Pure sandalwood oil is very expensive and is considered a rare commodity. It is indigenous to India and is used extensively in the Indian subcontinent as well as in China. This evergreen tree thrives well in the hot and wet climate of Southern India.

Nutritional Information and Properties

Pure sandalwood contains a lot of chemical compounds that help remove infection from your body. Sandalwood oil is usually used as a flavoring agent in foods. In China, however, sandalwood is used for medicinal purposes as well. It is recommended that you consume sandalwood medications only after discussing it with your doctor. Sandalwood aromatherapy can be used to treat stress-related disorders. The oil is also healthy for your skin and can be used to treat various skin conditions including dryness, eczema, itchiness, and rashes. Sandalwood has pheromone-like properties and is therefore used in manufacturing perfumes and deodorants. Sandalwood oil can also be used as an aphrodisiac.

Health Benefits and Therapeutic Uses

Apart from its fragrance, sandalwood is also used for its many health benefits and therapeutic uses.

- Perfumes with sandalwood are used for their aphrodisiac properties. These perfumes also have pheromone-like properties that make them a highly desirable additive to perfumeries and perfumed cosmetics.
- The wood, bark, and sandalwood oils are also used for their healing properties. They have been used in Chinese medication for healing of

abdominal pains and other gastric problems. Sandalwood has an anti-microbial action and can be used to treat internal infections such as those in the alimentary canal.

- Being an antiseptic agent, sandalwood can be used externally to treat inflammation of the genital organs, urinary bladder, cystitis, and other urinary infections. It can also help in reducing inflammation caused from sexually transmitted diseases like gonorrhoea.
- Sandalwood paste is great for the skin. It can be used to improve skin texture, soothe burnt skin, and treat eczema and rashes. It can also be used to soothe prickly heat.
- Sandalwood powder, though expensive, can be a great addition to your daily skin care routine. Using sandalwood paste on your skin can help remove any microbes, reducing the risk of skin infections and acne.
- Sandalwood essential oil can be used in aromatherapy to reduce stress, hypertension, and emotional negativity. The compounds in this volatile oil can trigger off the production of serotonin in the brain, increasing overall happiness and contentment.
- Sandalwood essential oil can also be used for healing wounds and treating skin blemishes. The oil itself is very potent, so it should be used in very small quantities only after mixing with some carrier oil.
- Sandalwood has been found to be an antispasmodic agent. It helps to relax the nerves, blood vessels, and muscles. Regular use of sandalwood oil can stop muscle contractions and spasms.
- It also has slight astringent properties, and this makes it excellent for gums. This can help tighten the hold of the gums on your teeth, preventing natural teeth loss.
- Sandalwood also acts as an expectorant and can help treat chronic or severe cough. For this, sandalwood can be used both internally and externally.
- It can be a healthy tonic for growing children. It is also soothing for the child's stomach and abdomen.

Experiment-4

Discussion

The following data of the phenotypic characters were observed and tabulated In the following tables:

1. Plant Height (cm) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 1.1]
2. Branches / plant (no) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 2.1]
3. Basal girth (cm) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 3.1]
4. Leaf length (cm) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 4.1]
5. Leaf breadth (cm) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 5.1]

Similarly all the tables [Table 1.2 to Table 5.7] towards anova for G*E, total for g, l and g*l, total y and g*y, total l*y, ANOVA for GxE interaction estimates of variance components and heritability .

Table 6: Soil tests reports and macronutrients (Soil Samples**)**

Location	**PH**	**OC %**	**Available ammo. N_2**	**Available N (PPM)**	**Available K(PPM)**	**Available P(PPM)**
Hetauda, Nepal	7.1	High	Medium	High	Very	Normal
Biratnagar, Nepal	6.9	High	Low	High	Very high	Blank
Bagaldhara, India	7.0	Medium	Low	Normal	High	Blank

Quality Assessment (oil content) of sandalwood

Quality of sandalwood depends on the oil and alcohol (Santalol) content of the heartwood. The oil content of the sandalwood very much dependable on the components available in the soil where the plant was grown in our case. In our case the oil content of sandalwood was estimated collecting wood samples from the stand/ stock of Hirbandh forest range office, Bankura south division, India and the standing stock wood samples from Hetauda and Biratnagar gardens in Nepal. These wood samples were analyzed in the institute of wood science and technology (IWST), Bangalore, India. The results show that the heartwood contents α- santalol=59.40% and β-santalol= 30.25% in Hirbandh, India and α-santalol= 60.1% and 59.9% ; β-santalol= 30.5% and 30.9% from the wood sample of Hetauda and Biratnagar, Nepal respectively (Das and Tah 2014). The quality of the heartwood of sandal have been cited in a table given below:

Table 7: Quality Assessment (oil content) of sandalwood

Sl.no	Name of Chemical	Content%
Hetauda	α- santalol	60.1%
	β-santalol	30.5%
	Total Santalol	90.6%
	Oil content	4.2%
Biratnagar	α- santalol	59.9%
	β-santalol	30.9%
	Total Santalol	90.8%
	Oil content	4.1%
Bagaldhara	α- santalol	59.40%
	β-santalol	30.25%
	Total Santalol	89.65%
	Oil content	4.0%

Discussion:

In this context, it has been found that the total replication value over the location was found to be greater in case of Biratnagar location than the second position location was Bagaldhara. In case of total g, l and gxl (table 1.2, 2.2, 3.2 4.2 and 5.2), it has been found that the location three was the highest adaptive zone but, location 1 and location 2 were the 2nd and 3rd position of locations. According the phenotypic data the plant height played an important major role. That's why we considered plant height as the constant phenotypic character in all cases. Considering all the characteristics features it has been summarized as follows:

Bagaldhara, India > Hetauda, Nepal > Biratnagar in regard to stem girth. But, in case of plant height it has been observed that Bagaldhara, India > Biatnagar, Nepal > Hetauda, Nepal.

However, in context to the calculation of all the locations, there were a mixed model of tendencies in regard to growth and development at this stage. Indeed, after 20 to 25 years there might be a nice observations to complete each and every location but, Bagaldhara has a specific constant steady role for growth and development in a regular manner.

There are some relevant references on this aspect viz. Zhang and Zhou (2010) who worked on Salicylic acid in plant disease resistance over the locations. Bent et al (1994) worked on *Arabidopsis thaliana* for the repeat class of plant disease resistance genes and its establishment and variations over the locations. Once again Zipfel et al (2004) observed the bacterial disease resistance in *Arabidopsis thaliana.* Lawton et al (1996) enumerated the Benzothiadizole induces disease resistance. Bruce at el (2014) found out the new hypotheses on seed-to-seed growth and development on *Arabidopsis thaliana* and their physiological growth of patterns over the locations. Yetisen et al (2011) published a new assay study on pollen tube germination. Abbott and Gomes (1989) focused the population genetics structure and out-crossing root of *Arabidopsis thaliana.* Das (2013), Das and Tah (2014, 2015 and 2016) also observed the locational variation and the effect of different edaphic factors on white sandalwood in different forest garden of West Bengal.

Chapter-7

Comment

Experiment-1

Comment

Santalum album is a prized gift of the plant kingdom woven into the culture and heritage of India. With more than 200 constituents, the essential oil is emergent as an interesting and biologically valuable active source of phytochemicals. Therapeutic potentials associated with this plant and its active chemical ingredients promise future healthcare applications, as shown by above mentioned pharmacological investigations, such as the roles of santalols in combating cancer, tumour, viral diseases, microbes, oxidants, as well as anti-ulcer, skin nourishing agent and as its dietary factors, thus supporting its traditional uses. The aim of this review is comprehended and put forth, available information on biological activities of this plant from a pharmacological point of view for future directions in clinical applications. This review also deals with some cosmetics and beauty therapy as well the global oil production details. India is in the first position in the export of raw materials of *Santalum album* and it must be in the first position in future, therefore, we have to increase the area of healthy Sandalwood plantations, protect them and government should give priority for the Research and Development of the *Santalum album* to increase export of the quality raw material.

Experiment-2

Comment

The productivity of timber plants is measured by analysing the plant height and breast height girth (b.h.g) in specific unit area. In this case four locations are distributed in both the Forest Divisions, Bankura (South & North). The plant height and basal girth were measured critically as much as it was possible out of 700 of S. album plants, grown in Forest gardens. The yield of heartwood varies from locality to locality and with the age of the tree. In India, trees of 100cm girth have been reported to yield between 85kg and 240kg of heartwood according to the area from which they come (FAO,1995). Timber wood production is expressed by its timber volume. It is

measured by the plant height and basal girth. Jahan and Rahman, 2014 explained that sandal dissolves inflammation and tumours and stabilizes palpitation. Sandalwood is used as a disinfectant in bronchial and genitourinary tract infection. Das and Tah (2013) observed the effect of concentration of GA3 on seed germination of sandal (Santalum album L.). Das and Tah (2014) vividly experimented on Silvicultural practices for its adaptability with different host species and natural regeneration in south-West Bengal in different forest gardens in Bankura and Burdwan Forest Divisions in South Bengalas and Tah (2015) studied the soil nutrients for the growth of white sandal (Santalum album L.) in southern part of West Bengal. Batabyal et al., (2014, 2015 and 2017) experimented on different seed-sources on germination parameters by means of artificial seed germination of Santalum album L ., different seed bed materials and GA3 on seed germination of Santalum album L. and Characterization of Bacillus cereus Symbiotic to Hemi-parasitic Plant Santalum album L. Yadav et al., 2018 took up a venture on the Study of Edaphic Factors of the Location for the Growth of White Sandal (Santalum album L.) in Indo-Nepal Border. A paste of the wood is applied in burns, fever and headache. It relieves thirst. Sandalwood is often used for rituals or ceremonies in Hinduism. Sandalwood is considered in alternative medicine to bring one closer with the divine.

Experiments – 3

Conclusion

It is evident that the soil components viz; Phosphorus, potassium, Ammonical nitrogen, carbon, PH of soil etc. have their specific individual or combined role for the growth and development of the plant population. On the contrary, the meteorological activities has specific action upon the plant population for their morpho-phisiological performances towards survivalibility over the location.

Experiment-4

Comment

There are a few rumours that sandal wood plants may grow in any soil environment prevailing in any climatic condition. If grows, those plants will not bear α- and β- santalol. Our laboratory tests have proved beyond doubt that the plants which are grown in these areas prevailing in all these edaphic factors contain adequate chemical properties (α- santalol : 59.25% and β- santalol : 30.40%).

From the experiment, it has been revealed that combination of host plants is always found to be better than that of single host treatment. *Arhar (Cajanus cajan*) + Tulsi (*Ocimum sanctum*), Tulsi (*Ocimum sanctum*) + Nayantara (*Catharanthus roseus*) gave best result for the sandal growth and development during treatment period.

It has also been found that Arhar *(Cajanus cajan*) is the best single host plant over Tulsi (*Ocimum sanctum*), Akand (*Callotropis procera*) and Nayantara (*Catharanthus roseus*) host plants.

It has also revealed that Sandal plants may grow without support of any host plant. Reasons behind this might be the presence of rhizo-mycorrhisal or AM fungus in the soil of Sandal Garden, though it is a chance factor and needs further study.

A uniform agro-measure and techniques were provided for the proper growth and development in for all the plants in all locations. After attaining its heartwood maturity, we collected the heartwood samples from each location and estimated the santalol following standard distillation method.

The aims and object of this experiment were to study the growth index i.e., quantitative assessment and determining the percentage of santalol present in the heartwood for its qualitative. assessment. All these peculiarities and the recorded data have been put forth in this paper for a clear explanation.

It has been found that the edaphic factors are congenial for the physiological growth and development of white sandal (*Santalum album* L.) in all these areas where those experimental plants were grown. Indeed, it might be better in special private farming technology than forest areas where to take any special care is never possible in general.

The productivity of timber plants is measured by analysing the plant height and breast height girth (b.h.g) in specific unit area. In this case four locations are distributed in both the Forest Divisions, Bankura (South & North). The plant height and basal girth were measured critically as much as it was possible out of 700 of S. album plants, grown in Forest gardens. The yield of heartwood varies from locality to locality and with the age of the tree. In India, trees of 100cm girth have been reported to yield between 85 kg and 240 kg of heartwood according to the area from which they come (FAO,1995). Timber wood production is expressed by its timber volume. It is measured by the plant height and basal girth. Jahan and Rahman, 2014 explained that sandal dissolves inflammation and tumours and stabilizes palpitation. Sandalwood is used as a disinfectant in bronchial and genitourinary tract infection. Das and Tah (2013) observed the effect of concentration of GA3 on seed germination of sandal (*Santalum album* L.). Das and Tah (2014) vividly experimented on Silvicultural practices for its adaptability with different host species and natural regeneration in south-West Bengal in different forest gardens in Bankura and Burdwan Forest Divisions in South Bengalas and Tah (2015) studied the soil nutrients for the growth of white sandal (*Santalum album* L.) in southern part of West Bengal. Batabyal et al., (2014, 2015 and 2017) experimented on different seed-sources on germination parameters by means of artificial seed germination of *Santalum album* L., different seed bed materials and GA3 on seed germination of *Santalum album* L. and Characterization of Bacillus cereus Symbiotic to Hemi-parasitic Plant *Santalum album* L. Yadav et al., 2018 took up a venture on the Study of Edaphic Factors of the Location for the Growth of White Sandal (*Santalum album* L.) in Indo-Nepal Border. A paste of the wood is applied in burns, fever and headache. It relieves thirst.

Sandalwood is often used for rituals or ceremonies in Hinduism. Sandalwood is considered in alternative medicine to bring one closer with the divine.

It is evident that the soil components viz; Phosphorus, potassium, Ammonical nitrogen, carbon, PH of soil etc. have their specific individual or combined role for the growth and development of the plant population. On the contrary, the meteorological activities has specific action upon the plant population for their morpho-physiological performances towards survivalibility over the location.

Precautions:

- Stagnant water in the field is strictly prohibited.
- Must provide at least one host for the growth and development of white sandal plant.
- Host plant should be provided upto three years (atleast).
- Never depend on chemical fertilizer, always use organic manure.
- Never neglect root part of the tree, it is also more precious than shoot portion.

Chapter-9

FUTURE PLAN

Future Prospects

There is lot of scope of future study on the various aspects of Sandalwood. Sandalwood resource in India particularly the wild populations are threatened mainly because of illicit felling, forest fire and spike disease coupled with heavy domestic and international demand. The following topics are highlighted for future study to increase the dwindling population of Sandalwood.

- Performance of Sandalwood plants with association of Arbuscular Mycorrhizal fungi.
- Standardization of manures and fertilizer application for proper growth of Sandal in field.
- Performance of Sandalwood under different Agro-forestry conditions.
- Study of root rhizosphere of Sandalwood for its better survivility and establishment.
- Study on Genetic Improvement in Heartwood quality of *Santalum album* L.
- Study on Anti-logging devices for protection of Sandalwood Plantations.

Chapter-10

REFERENCES

REFERENCES

Abbott RJ, Gomes MF (1989). "Population genetic structure and outcrossing rate of Arabidopsis thaliana (L.) Heynh". Heredity. **62**(3): 411–418. doi:10.1038/hdy.1989.56.

Adkoli, N. S. [1977]. Sandalwood in Karnataka. *Retrospect and prospect – Proceedings of the All-India Sandal Seminar*, Bangalore, 86-94.

Adkoli, N. S. [1977]. Sandalwood in Karnataka. *Retrospect and prospect – Proceedings of the All-India Sandal Seminar*, Bangalore, 86-94.

Ahir C., M.Chotaliya, D.Ghori (2014). Effect of soil type on the growth and survival of seedlings of Indian sandalwood (*Santalum album* L). Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 32.

Ahmad N, Khan MSA, Jais AMM, Mohtaruddin N, Ranjbar M, Amjad et al. Anti-ulcer Activity of Sandalwood (Santalum album L.) Stem Hydroalcoholic Extract in Three Gastric-Ulceration Models of Wistar Rats. Bol Latinoam Caribe Plant Med Aromat, 2013; 12(1): 81-91.

Ananthapadmanabha H.S (2014). Sandalwood plantations in agro-forestry systems: different growth models with host species. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 21.

Ananthapadmanabha H.S., C.R. Rangaswamy, C.R. Sarma, H.C. Nagaveni, S.H. Jain, K.R. Venkatesan and H.P. Krishnappa 1984. Host requirement of sandal (Santalum album L.). Indian Forester 110(3): 264 – 68.

Ananthapadmanabha H.S., C.R.Rangaswamy, C.R. Sarma, H.C.Nagaveni, S.H. Jain, K.R. Venkatesan and H.P. Krishnappa (1984). Host requirement of sandal (*Santalum album* L.). Indian Forester 110(3): 264 – 68.

Ananthapadmanabha H.S., H.C. Nagaveni and K. Parthasarathi (1986). Differential effect of exogenously applied gibberellic acid on the amylase activities in germinating sandal seeds. Science and Culture 52: 58 - 59.

Ananthapadmanabha H.S., H.C. Nagaveni and S.N. Rai.(1988b). Influence of host plants on the growth of *sandal*. Myforest 24(2):154-160.

Ananthapadmanabha H.S., H.C. Nagaveni and S.N. Rai.1988b. Influence of host plants on the growth of sandal. Myforest 24(2):154-160. Barber, C.A.1903. Report on spike disease of sandalwood trees in Coorg. Indian Forester, 29: 21-31.

Ananthapadmanabha H.S., K.H. Shankaranarayana and H.C. Nagaveni (1989b) Compositional changes in sandal seeds on storage. Ind. J. of Forestry 22: 157 – 158.

Annapurna, D., T.S. Rathore and G. Joshi. (2004). Effect of container type and size on the growth and quality of seedlings of Indian Sandal wood (*Santalum album* L.). Australian Forestry, 67(2): 82- 87.

Annapurna, D., T.S. Rathore and G. Joshi. (2005). Refinement of potting medium ingredients for production of high quality seedlings of sandalwood (*Santalum album* L.) Australian Forestry 68(1): 43-48.

Annapurna, D., T.S. Rathore and G. Joshi. (2007). Integrated nursery practices for mass production of quality planting stock of *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 67-73.

Annapurna, D., T.S. Rathore and G. Joshi.(2006). Modern nursery practices in the production of quality seedling of Indian Sandalwood (*Santalum album* L.) – stage of host requirement and screening of primary host species. Journal of Sustainable Forestry. 22 (3/4): 33 – 55.

Anon (1985). Proceeding of the Govt. of Karnataka G.O. No. FFD 76 FSW 85, 12.121985.

Anon (1987). Research Highlights, 1977 -1987. Sandal Research Center, Bangalore.

Anon, [1972]. *Santalum*. Wealth of India. Raw Materials Rh-SO-9, pp 208-224. Publication and Information Directorate, CSIR, New-Delhi.

Anonymous. (1979). The Wealth of India, *Santalum* (Indian Academy of Sciences,CSIR, New Delhi), pp. 208–224.

Anonymous. The Wealth of India. Vol.9th., New Delhi; Council of Science and Industrial Research: 2003, pp. 208-211.

Ansari, S. A., C. Narayanan and P. Kumar (2007). Molecular marker analysis of Indian sandalwood (*Santalum album* L.). Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 78-81.

Arti Rani, P. Ravi Kumar and A.Kush (2014). Molecular approaches to understand/decode oil production in sandalwood. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 54.

Arun Kumar, A. N. and G. Joshi (2007). Tree improvement in sandal-retrospect and prospect, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 32-37.

Arun Kumar, A. N., G. Joshi and Y.B.Srinivasa (2014). Heartwood and oil content variation in *Santalum album* – implications in tree improvement. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 42.

Ashokan, P. K. and N. Krishnambika (2007). Growing sandal in home garden and other agroforestry systems – potentials and problems. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 143-152.

Bagchi, S. K. and H. C. S. Veerendra (1985). Study on intra-tree and inter-tree variations in leaves of *Santalum album* L. Myforest, 21: 33-39.

Bagchi, S.K. and H.D. Kulkarni (1985). Germination of open pollinated seeds and survival of seedlings from selected trees of *Santalum album* L. Myforest, 21: 221-224.

Balakrishnan, V.K., S. Dasgupta and S.C. Bhattacharya (1956). Quantitative evaluation of sandal oil through I.R.

Balasundaran, M. and T. B. Suma (2007). Variation in genetic diversity and seedling survival of sandal provanances, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 40-46.

Banerjee, S., Ecavade, A., and Rao, A.R. (1993). Modulatory influence of sandalwood oil on mouse hepatic glutathione S-transferase activity and acid soluble sulfhydryl level. *Cancer Letters, 68,* 105-109.

Bapat, V.A. and P.S. Rao (1979). Somatic embryogenesis and plantlet formation in tissue culture of sandalwood (*Santalum album* L.). Annals of Botany, 44 : 624 – 630.

Bapat, V.A. and P.S. Rao (1984). Regulatory factors for *in-vitro* multiplication of sandal (*Santalum album* L.) wood. Shoot Bub regeneration and somatic embryogenesis in hypocotyls culture. Proc. Ind. Acad. Sci. (Plant Science), 93: 19-27.

Bapat, V.A., Ravinred Gill and P.S. Rao (1985). Regenaration of somatic embryos and plantlets from stem callous. Protoplast of sandalwood tree (*Santalum album* L.), Curr. Sci. 54: 978-982.

Barber, C.A. 1903. The mature houstorium. Ibid J. Pt. 4: 149. Barber, C.A.1906. Studies in root parasitism: The haustoria of *Santalum album* L. Mem Dept. Agri. Ind Bot. Ser.,1 Pt. 1: 1-26

Barber, C. A. [1902]. The natural history of sandal trees. Ind.For. 28: 340-41

Barber, C. A. [1903] The mature houstorium. Ibid J. Pt. 4 : 1-49.

Barber, C.A. [1903]. Report on spike disease of sandalwood trees in Coorg. *Indian Forester*, 29: 21-31. Barber, C.A. [1903]. Studies in root parasitism – the houstorium of *Santalum album* L. 1. Early stages upto penetration. Mem. Dept. Agri,Ind. Bot.Soc.I., Pt. 1:1-26.

Barber, C.A. [1905]. The haustoria of sandal roots. *Indian Forester* 31: 189.

Barber, C. A.[1905]. The haustoria of sandal roots. *Indian Forester* 31: 189.

Barber, C.A. [1906]. Studies in root parasitism: The haustoria of *Santalum album* L. *Mem Dept. Agri. Ind Bot. Ser* 1 Pt. 1: 1-26

Barber, C.A. [1907]. Studies of root parasitism: the haustoria of *Santalum album* L. *Mem Dept. Agri. Ind Bot. Ser* 1 Pt., 11: 1-58.

Barber, C.A.1903. Studies in root parasitism – the houstorium of *Santalum album* L. 1. Early stages upto penetration. Mem. Dept. Agri, Ind. Bot. Soc., I., Pt. 1:1-26.

Baskardoss, P. (1968). Working plan for Tiruchirapalli Forest Division 1969-70 to 1978-79. Office of the Chief Conservator of Forests, Madras. 1-59.

Batabyal Siuli, Tinkari Dalal and Jagatpati Tah. 2015. Effect of different seed bed materials and GA3 on seed germination of Santalum *album* L. - National Seminar on 'Contemporary Progress in Plant Sciences' orgd by Department of Botany, BU during March 20-21, 2015, pp. 40.

Batabyal, S. Dalal, T. and Tah, J. 2014. White sandal (*Santalum album* L.): problems and solutions of its silvicultural practices, Asian Plant Science Conference, Bhairawaha, Siddharnagar, Nepal: pp-5

Batabyal, S. Dalal, T. and Tah, T. 2014. Effect of different seed-sources on germination parameters by means of artificial seed germination of Santalum album L. –. International Journal of Pure & Applied Bioscience 2(2): 149-152. Das, S.C. 2013. Growth and yield of white sandal (Santalum album L.) in South West Bengal. Indian Forester, 139 (2): 109-112.

Batabyal, Siuli, Priyanka Mukhopadhyay, Soumendranath Chatterjee, Jagatpati Tah and Nimai Chandra Saha. 2017. - Characterization of Bacillus cereus Symbiotic to Hemi-parasitic Plant Santalum album L. - Biotechnology Journal International 17(2): 1-8, Article no. BJI.29582. [Previously known as British Biotechnology Journal ISSN: 2231-2927, NLM ID: 101616695] SCIENCEDOMAIN International. www.sciencedomain.org

Batabyal, Siuli, Tinkari Dalal and Jagatpati Tah, 2014. Effect of different seed-sources on germination parameters by means of artificial seed germination of Santalum album L. –. International Journal of Pure & Applied Bioscience 2(2): pp. 149-152.

Batabyal,S. and Tah, J. 2014 . Variation of seed morphology of different sources and its contribution to seed germination of Santalum album L., International Journal of Science and Research (IJSR). Vol. 3.(4): 882-885.

Batabyal,S.Dalal, T. and Tah, J. 2014. Responses of some phyto-hormones for vegetative propagation of an ancient precious wood plant Santalum album L., Bioscience Discovery, 5(2): 170-174.

Battaglia, S. (2007). The Complete Guide to Aromatherapy, The International Centre of Holistic Aromatherapy, Brisbane pp. 263.

Beeson, C.F.C. (1941). Ecology and Control of forest insects of India and the neighbouring countries. Vasant Press, Dehradun.

Beeson, C.F.C. and B. N. Bhatia (1939). On the biology of the Cerambycidae, Coleoptera. Indian Forest records (New Series). Entomology V(1) Govt. of India Press, New Delhi, p235.

Benencia F, Courreges M. C. (1999). Antiviral activity of Sandalwood oil against Herpes Simplex Viruses 1 & 2, Phytomedicine, 6(2): 119 - 123.

Benencia, F. and Courreges, M.C. (1999). Antiviral activity of sandalwood oil against Herpes simplex viruses. *Phytomedicine,* 6(2): 119–123.

Bent AF, Kunkel BN, Dahlbeck D, Brown KL, Schmidt R, Giraudat J, Leung J, Staskawicz BJ (September 1994). "RPS2 of Arabidopsis thaliana: a leucine-rich repeat class of plant disease resistance genes". Science. **265** (5180): 1856–60. Bibcode:1994Sci...265.1856B. doi:10.1126/science.8091210. PMID 8091210.

Berger, K.C. and E.Troug (1939). Boron determination in soils and plants. Ind. Eng. Chem. Anal. Ed. 11: 540-545

Bewley, J.O. and M. Black (1978). Physiology and Bio-chemistry of Seeds. Springer – Verlag, Berlin, 262.

Bhat HR. A field guide to Medicinal Plants of Devarayanadurga State of Forest. Bangalore; The Deputy Conservator of forest`s Karnataka Forest Department: 2006, pp. 133.

Bhat, S. and R. C. Prajapathi (2007). Sandal in ancient India – medicinal and cosmetic uses. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 192-95.

Bhati, A. (1970). Recent development in the chemistry of sandal oil. Flvour Industry, 1: 5.

Bhatnagar, S.P. (1965) Studies in Angiospermic Parasites (No. 2) *Santalum album* – The sandalwood tree. National Botanical Gardens, Lucknow, India, Bull. No. 112.

Binu N.K, P.K. Ashokan, M. Balasundaran, Rajesh S.K, N.Nishant (2014). Responses in nutrition status of Sandalwood (*Santalum album* L.) seedlings to shade, host and mycorrhizal association. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 23.

Bisht SS, Ravindra M & Gayathri DN (2019) Variability in yield and composition of oil from Indian Sandalwood (*Santalum album* L.) trees grown in homogeneous conditions. *Tropical Plant Research* 6(1): 31–36.

Blumenthal, M., Busse, W.R., Goldberg, A. (1998). The Complete Commission E Monographs: Therapeutic Guide to Herbal Medicines. Integrative Medicine Communications, Boston, MA, USA, pp. 199.

Bob Yirka: Synthetic sandalwood found to prolong human hair growth (2018, September 19).

Bommareddy, A., Rule, B., VanWert, A.L., Santha, S. and Dwivedi, C. (2012). a-Santalol, a derivative of sandalwood oil, induces apoptosis in human prostate cancer cells by causing caspase-3 activation. *Phytomedicine,* 19(8–9): 804–811.

Brandis C. (1903). Treatment of the sandal tree. Indian For. 29: 3–6.

Brandis, D. [1903]. Treatment of the sandal tree. *Indian Forester*, 29: 3-6.

Brown, E. A. (1968). Pests and diseases of forest plantation trees. Clarendon Press, Oxford, p1330.

Bruce M., Busse, James S., Stankovic, Bratislav (2014) Seed-to-Seed-to-Seed Growth and Development of Arabidopsis in Microgravity. Astrobiology Vol. 14: Issue. 10: Pages. 866-875 doi:10.1089/ast.2014.1184.

Brunke, E. J. (1981a). New constituents from sandal oil. Perfu. And Cosmet (German) 62: 78.

Brunke, E.J., Vollhardt, J., and Schmaus, G. (1995). Cyclosantal and epicyclosantalal new sesquiterpene aldehydes from East Indian sandalwood oil. *Flavour and* Fragrance *Journal, 10, 211* 219.

Cameron, J. (1894). Forest trees of Mysore and Coorg. Mysore Govt. Central Press, Bangaloure.

Chatterjee S.K. (1960) Effect of Presowing treatments of tung (*Aleuritus fordis* Homse). Science & Culture, 29(3): 130-131.

Chatterjee, N.C. (1935) Entomological investigations on the spike disease of sandal (25); Lepidoptera. Indian Forest Records, Ent. I(10) New Series, 185 - 204.

Chauhan, S. S. and P. Aggarwal (2007). Growth models for *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 153-157.

Chaurasia, L. O., K. N. G. Nair and T. V. Mathew (1975). Semi-micro method for the estimation of free santalol in sandal wood oil. Ind. Perfu., 19: 19.

Clarke, M. 2006. Australia's Sandalwood Industry: An overview and analysis of research needs. A report for the Rural Industries Research and Development Corporation, RIRDC Publication No. 06/131.

Coleman, L. C. [1917]. Spike disease of sandal. *Department of Agric., Mysore Mycology Series Bull.* No. 3, 1-52.

Comstock, R.E. and Robinson, H.F. (1952a). Genetic parameters, their estimation and significance. Proc. Sixth Intern. Grasslands Congr.284-291.

Comstock, R.E. and Robinson, H.F. (1952b). Estimation of average dominance of genes. In: Heterosis (ed. J. W. Gowen), Iowa State College Press, Imes, Iowa, 494-516.

Darlington, C.D. and A.P. Wylie (1955). Chromosome atlus of plants. 2nd Edition. George Ayen Unwis Ltd, London.

Das Sudhir Chandra and Jagatpari Tah.2014. White Sandal (Santalum album L.): Silvicultural practices for its adaptability with different host species and natural regeneration in south-West Bengal _ Asian Plant Science Conference, Bhairawaha, Siddharnagar, Nepal during October 28-30, pp. 115.

Das, S.C and J. Tah (2014). Sandalwood (*Santalum album* L.): its adaptability with different host species in varied edaphic condition of South-West Bengal. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 22.

Das, S.C and J. Tah (2014). Sandalwood (*Santalum album* L.): its adaptability with different host species in varied edaphic condition of South-West Bengal. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 22.

Das, S.C and J. Tah 2014. Sandalwood (Santalum album L.): its adaptability with different host species in varied edaphic condition of South-West Bengal. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 2628, 2014) pp 22.

Das, S.C. (2013). Growth and yield of white sandal (*Santalum album* L.) in South West Bengal. *Indian Forester*, ***139*** (2): 109-112.

Das, S.C. and J. Tah (2013). Effect of GA_3 on seed germination of sandal (*Santalum album* L.). *International Journal of Current Science* 2013, 8: E 79-84.

Das, S.C. and J. Tah (2013). Effect of GA_3 on seed germination of sandal (*Santalum album* L.). *International Journal of Current Science* 2013, 8: E 79-84.

Das, S.C. and J. Tah 2013. Effect of GA3 on seed germination of sandal (Santalum album L.). International Journal of Current Science 2013, 8: E 79-84.

Das, S.C. and J. Tah 2014, White Sandal (Santalum album L.): Silvicultural practices for its adaptability with different host species and natural regeneration in south-West Bengal, Asian Plant Science Conference, Bhairawaha, Siddharnagar, Nepal: pp-115.

Das, S.C., Das, S., and J. Tah 2015. Frequency distribution study on the growth of *Santalum album* L. in West Bengal, International Journal of Scientific Research. Vol 4(7): pp. 11-15.

Das, Sudhir Chandra and Jagatpati Tah. 2015. Study of soil nutrients for the growth of white sandal (*Santalum album* L.) in West Bengal 2015. – National Seminar on 'Contemporary Progress in Plant Sciences' orgd by Department of Botany, BU during March 20-21, pp. 34.

Das, Sudhir Chandra; Suddhasuchi Das and Jagatpai Tah Frequency Distribution Study on the Growth of Santalum Album L. in west Bengal. IJSR - INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH, Volume: 4 | Issue : 7 | July 2015 • ISSN No 2277 - 8179

Dasgupta, S., K.K.Chakravarti and S.C. Bhattacharya (1956). I. R. Spectra of compounds containing cyclo-propane ring and its applications to quantitative evaluation of sandal oil. Ind.Soap J. 21:217

Dastur, J. F. (1962). Medicinal plants of India and Pakistan. D.B. Taraporevala Sons & Co. Pvt. Ltd. Bombay-1.

Dastur, J.F. (1962). Medicinal plants of India and Pakistan. Taraporevala, D.B., Sons and Co. Pvt. Ltd. Bombay, India.

Davis, P. (1999). Aromatherapy: An A-Z. 2nd edn. Daniel, C.W. Company Limited, Great Britain.

Debjit Bhowmik, Dipak Biswas and K.P.Sampath kumar. Recent aspect of ethnobotanical application and medicinal properties of traditional Indian herbs *Santalum album*. 2016. 21-27

Delaney TP, Uknes S, Vernooij B, Friedrich L, Weymann K, Negrotto D, Gaffney T, Gut-Rella M, Kessmann H, Ward E, Ryals J (November 1994). "A central role of salicylic Acid in plant disease resistance". Science. **266** (5188): 1247–50. Bibcode: 1994Sci... 266.1247D. doi:10.1126/science.266.5188.1247. PMID 17810266.

Demole, E., C. Demole and P. Enggist (1976). Chemical Investigation of the volatile constituents of sandal oil. Helv. Chim. Acta. , 59: 737.

Desai V.B., Rakesh, K. Sindhu, Upma, A.Kumar, S.Arora. (1991) Pharmacological screening of HESP and Sandalwood oil. Indian Perfumer, 35(2): 69-70.

Desai, V.B. and K.H. Shankaranarayana(1990). On the utilization aspects of sandal seed oil. Research and Industry, 35: 232 -233.

Desai, V.B., Hiremath, R.D., Rasal, V.P., Gaikwad, D.N. and Shankarnarayana, K.H. (1991). Pharmacological screening of HESP and sandalwood oil. *Indian Perfumer,* 35(2): 69–70.

Desai, V.B., Hiremath, R.D., Rasal, V.P., Gaikwad, D.N., and Shankarnarayana, K.H. (1991). Pharmacological screening of HESP and sandal oils. *Indian Perfumer, 35,* 69, 70.

Dhanya, B. and S. Viswanath (2007). Policy and legal issue governing sandal (*Santalum album* L.) conservation Southern India: A comparative analysis. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 207-219.

Dhanya, B., S. Viswanath and S. Purushothman (2010). Sandal (*Santalum album* L.) conservation in southern India: A review of policies and their impacts. Journal of Tropical Agriculture 48 (1–2): 1–10, 2010.

Dijkstra, J. and T. S. Le, [1969]. Presence of mycoplasma-like bodies in the phloem of sandal affected with spike disease. *Neth. J. Pl. Path.*, 75: 374-378.

Dikshit, A., and Hussain, A. (1984). Antifungal action of some essential oils against animal pathogen. *Fitoterapia, 55,* 171 176.

Dorairaj, K. (1958). Working Plan for the Salem South Forest Division, Chief Conservator of Forests, Madras, 12 -18.

Dwivedi, N.K., A.Indiradevi, R.A.Nair and A.Suma (2014). Ethnomedicinal uses, collection and conservation of sandalwood (*Santalum album* L.) germplasm. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 50.

Effendi, M. 1994. Selection of Sandalwood (*Santalum album* L.) candidate plus trees in Timor Tengah Selatan District. Sandalwood Research Newsletter 3: 3-4.

FAO, (1995). *Flavours and fragrances of plant origin*. Chapter – VI, p 1-8.

FAO. 1995 Non wood Forest Products on Flavours and Fragrances of Plants origin. Food and Fragrances Bulletin No.: 11 Agriculture Organization of the United Nations.

Ferl RJ, Paul AL (April 2010). "Lunar plant biology--a review of the Apollo era". Astrobiology. **10** (3): 261–74. Bibcode:2010AsBio.10..261F. doi:10.1089/ast.2009.0417. PMID 20446867.

Fischer, C. E. C. [1938]. Entomological investigations on the spike disease of sandal(7). Genus Exocentus (Ceramycidae). *Indian Forest Records*, 18: pt. 4.

Fischer, C.E.C. (1922). The spike disease of sandal. Ind. For., 48:156-160.

Fischer, C.E.C. 1922. The spike disease of sandal. Ind. For., 48:156-160 Govinda Menon, K 1916. A possible cause of Spike in sandal. Ind. For, 42(9):4-6

Fischer, C.E.C. (1928). The original home of *Santalum album* L. J. Indian Bot. Soc., 7: 12 -13.

Fox, J., A. I. Doronila, D. R. Barrett and K. Surata,1996. *Desmanthus Virgatus* L. Wild – *An efficient intermediate host for the parasitic species Santalum album* L. *in Timor, Indonesia. Journal of Sustainable Forestry, 3:13-23.*

Gairola, S., G. Ravikumar and P. Aggarwal (2007). Status of production and marketing of sandal wood (*Santalum album* L.), Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 1-8.

Ghani N. Khazainul Advia. New Delhi; Aijaz Publishing House: 2007, pp. 932-933.

Ghani N. Khazainul Advia. New Delhi; Aijaz Publishing House: 2007, pp. 932-933.

Ghatgey, B. B. and J. C. Bhattacharya (1956). Isolation of Santalenes from sandalwood oil. Perfu. Ass. Oil Rec., 47: 35.

Ghosh, R.C. (1976). Handbook of afforestation technique No. P.F.R.I. 168.

Ghosh, S.K. and S.P. Raychoudhuri (1972). Mycoplasma I, the new Chapter in plant pathology. Current. Sci., 4 : 235-241.

Ghosh, S.K., M. Balasundaran and M.I. Mohamed Ali (1985). Studies on the spike disease of sandal. Kerala Forest Research Institute, Peechi, Report, 37: 56 pp.

Gildemeister and Hoffman. Die Atherischen Ole. 3rd ed. Vol. II, 50B in Guenther 1952.

Gogoi R, R.Rahman and R.K.Boruah (2014). Sandalwood cultivation in Karbi Anglong district of Assam, India: A study from Geo-Environmental perspective. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 12.

Goodwin, T.W. and E.I. Mercer (1975). Introduction to Plant Bio-chemistry, Pergamon Press, Oxford, 335.

Govinda Menon, K (1916). A possible cause of Spike in sandal. Ind. For, 42(9):4-6

Govinda Menon, K (1922). Sandalwood- its parasitic habit and spike. Ind. For, 48(6) : 344.

Guenther, E. (1952). Oil of sandalwood East Indian. *The Essential Oils,* 5: 173–187.

Guha, P.C. and S. C. Bhattacharya (1944). Seperation of santalols and santalins. J. Ind. Chem. Soc. 21:261.

Gunaga R.P., M. Hanumantha, S.S. Narkhede (2014). Seed germination studies in Sandalwood (*Santalum album* L.): problems and solution. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 27.

Gunstone, F.D. and M.A.McGee (1954). Structure of santalbic acid. Chem. & Industr.,1112.

Gunstone, F.D. and W. Russell (1955). Constitution and properties of Santalbic acid.,J.Chem. Soc.,3782.

Gunther, E. (1952) The Essential oils, D. van Nostrand Comp. Inc. Londan, 5 : 173 -194.

Gupta, B.S. (2014). Vibrational spectroscopy of Indian Sandalwood oli- a short review. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 60.

Handa, K.L., Kapoor, L.D., and Chopra, I.C. (1951). Present position of crude drugs used in indigenous medicine. *Indian Journal of Pharmaceutical Sciences, 13,* 29 48.

Handa, K.L., L.D. Kapoor, I.C. Chopra and Somnath (1951). Present position of crude drugs used in the indigenous medicine. Ind. J. Pharm, 13 : 28.

Hanumantha M., R.P.Gunaga, R.S.Patil, G.B.Shahapurmath, Nagaraja (2014). Phenological variation and natural regeneration in (*Santalum album* Linn.): implication for management. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 33.

Haque, M.H., and Haque, A.U. (2000). Use of sandalwood oil for the prevention and treatment of warts, skin blemishes and other viral-induced tumors. US Patent 6132756.

Harisetijono and S. Suriamihardja. 1993. Sandalwood in Nusa Tenggara Timur. **In:** Sandalwood in the Pacific Region. McKinnell, F.H. (ed), Proceeding of a symposium held on 2 June 1991 at the XVII Pacific Science Congress, Honolulu, Hawaii. Canberra ACIAR Proceeding 49: 39-43.

Harley, J.L. and S.E.Smith. (1983). Mycorrhizal symbiosis. Academic Press, London, p75.

Hart, N.C. and Rangaswamy, S. (1926), Preliminary investigation into the cause and cure of the spike disese in sandal in North Salem Division. Indian Forester, 52 : 373 -390.

Hatt, H.H. and F. Schoemfeld (1956). Some seed fats of Santalaceae family. J. Sci. Food Agri., 7: 130 -133

Hatt, W.C., A.C.K. Triffett and P.C. Wailes (1959). Acetylenic acids from seed fats of santalaceae and Oleanceae. Aust. J. Chem., 12: 190.

Hayman, D.S. 1986. Mycorrhizae of nitrogen – fixation legumes; MIRCEN J.Appl. Microbial Biotechnol. ***2***: 121 -145.

Hegde K, Deepak TK, Kabitha KK, Hepatoprotective Potential of Hydroalcoholic Extract of *Santalum album* Linn. Leaves. *International Journal of Pharmaceutical Sciences and Drug Research* 2014, 6(3), 224-228.

Heggadadevanakote, (1920). Earch in zapmetaseaarch.com

Hewson, H and A. George. 1984. Santalaceae. Flora of Australia (George, A. ed.). Australian Govt. Publishing Service, Canberra, pp 29-66.

Hole, R.S. (1918). Spiked disease of sandal. Indian Forester, 44: 325 -54.

Hole, R.S. 1918. Spiked disease of sandal. Indian Forester, 44: 325 -54.

Holmes, P. (1989). The energetic of western herbs Vol II, Artemis Press, USA.

Homfray, C.K. (4th Edition) and K.C. Roychoudhury (5th Edition), (1960). Nursery and Plantation Notes for West Bengal, p 219-222.

Hongratanaworakit, T., Heuberger, E., and Buchbauer, G. (2004). Evaluation of the fects of East Indian sandalwood oil and alpha-santalol on humans after transdermal absorption. *Planta Medica, 70,* 3-7.

Hopkins, C.Y., M.J. Chisholm and W.J. Cody (1969). Fatty acid components of some Santalaceae seeds oils. Phytochemistry, 8 : 161-165.

Howard, A. and C.L.C. Howard (1919). The spike disease of Peach tree, an example of unbalanced sap circulation. Indian Forester, 45 : 611-617.

http://en.wikipedia.org/wiki/Sandalwood_album cited on 25/07/2019)

http://ijrar.com/ Cosmos Impact Factor 4.236 Research Paper IJRAR-International Journal of Research and Analytical Reviews 653

Hull, R., T. W. Horne and R. M. Nayar [1969]. Mycoplasma-Like bodies associated with sandal spike disease. *Nature*, 224 (5224): 1121-1122.

Hunsur Talik (2010). Sandal seed: Its extraction and Utility. hehimalayantimes.com/opinion/sandalwood-seeds.

IARI Soil Testing Kits, Pusa Campus, New Delhi – 110 001.

Ibne Sina. Al-Qanoon Fil Tib (Urdu Translation by GH Kantoori). 2006. Vol 2nd. New Delhi; Idara Kitabus Shifa: (YNM): 433.

ICFRE (1992). SANDAL (*Santalum album* Linn.*).* Institute of Wood Science & Technology, Indian Council of Forestry Research & Education, 10pp.

Indian Council of Forestry Research and Education, Dehradun. Sandal (*Santalum album Linn.*). Dehradun, Forest Research Institute. 2006. 9p

Iyengar, G. S. (1937). Life history of *Santalum album* L. J. Indian Bot. Soc. 16: 175-195.

Iyenger, A.V.V.(1928a). Contributions to the study of spike disease of Sandal – Analysis of leaves from healthy and spiked trees. J. Ind. Inst. Sci., 11A: 97-102.

Iyenger, A.V.V. (1928b). Contributions to the study of spike disease of Sandal – Part 3, Physico-chemical study of leaf sap. J. Ind. Inst. Sci., 11A: 103.

Iyenger, A.V.V. (1937a). Contribution to the Study of spike disease of sandal (*Santalum album L.)*- some factors relating to the normal accumulation of carbohydrates in diseased tissues. J. Ind. Inst. Of Sci., 20:1-14.

Iyenger, A.V.V. (1937b). Stop influence of spike disease on the mineral metabolism of sandal. Curr. Sci. 6(6): 278-279.

Iyenger, A.V.V. (1938a). Lime in relation to spike disease of sandal. Chronica Botanica, 4: 205-206.

Iyenger, A.V.V. (1955). The physiology of the spike disease of Sandal, Rev. App. Micology, 34:254.

Iyenger, A.V.V. (1960a). The relation of soil nutrients to the incidence of spike disease in sandalwood (*Santalum album L.)*. Ind. For. 86:220-229.

Iyenger, A.V.V. (1965). The physiology of root parasitism in sandal (*Santalum album L.). Indian Forester,*91:246-256,341-344,423-437.

Iyer,Y.V.S.(1935). Characteristics of sandal seeds and seed oil. Analyst,60:319-320.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd.;

Jadab, P., Karmakar,A. Goswami, N. and Tah. J. 2017, Role of edaphic factors over seed production and rate of seed germination of white sandal (*Santalum album* L.), World Journal of Pharmacy and Pharmaceutical Sciences, ISSN 2278-4357. Vol: 7, Issue-1, pp. 723-733, 20177 [Impact Factor: 6.647].

Jadab, Paban Nirupama Goswami and Jagatpati Tah. 2017. ROLE OF EDAPHIC FACTORS OVER SEED PRODUCTION AND RATE OF SEED GERMINATION OF

WHITE SANDAL (SANTALUM ALBUM L.) –World Journal of Pharmacy and Pharmaceutical Sciences ISSN 2278-4357. Vol.: 7, Issue-1, pp. 723-733, [Impact Factor: 6.647].

Jagadish, M. R., S. M. Ahmed, K. S. Madhu, S. Viswanath and T. S. Rathore (2007). Effect of seed source collection time in *Santalum album* L. on germination parameters, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 47-51.

Jagadish, M. R., S. Muyeed Ahmed, K. S. Madhu, S. Viswanath and T.S.Rathor (2007). Effect of seed source and collection time in *Santalum album L* on germination parameters. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 47-51.

Jagatpati Tah. (2017). White sandal (*Santalum album* L.), a precious medicinal and timber yielding plant: A short review. Volume 6, Issue 6, 616-634

Jahan Rahaman. 2018. Amazan Publications, USA

Jahan,N. and K.Rahman (2014). Medicinal value of Sandalwood and its oil in Unani system of medicine. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 65.

Jaime A Teixeira da Silva, Tikam Singh Rana, Diganta Narzary, Nidhi Verma, Deodas Tarachand Meshram, Shirish A RanadePomegranate biology and biotechnology: A review. Scientia Horticulturae.Vol. 160. Pp. 85-10, Elsevier. 2016.

Jain, S. H., Ranjana Arya and Hemant Kumar. 2007. Distribution of Sandal (Santalum album L.), Current Growth Rates, Predicted Yield of Heartwood and Oil Content and Future Potential in Semi-arid and Regions of Rajasthan, India. "Forest Trees and Livelihoods 17(3): 261-66.

Jain, S.H., V.G. Angadi, A.N. Rajeevalochan, K.H. Shankaranarayana, K.S Theagarajan and C.S. Rangaswamy. (1998). *Identification of provenances of Sandal in India* for genetic Conservation. *In*: *Sandal and its prodncts*, Raomiljac A.M., H.S.A padmanabha, R.M. Welbourn and K.S. Rao (eds.), Proceedings of an International Seminar held at bangalore, India. 18-19 December, 1997. Canberra, ACIAR Proceedings, 84 :117 – 120.

Jain, S.H., V.G. Angadi, A.N. Rajeevalochan, K.H. Shankaranarayana, K.S Theagarajan and C.S. Rangaswamy.(1998). Identification of provenances of Sandal in India for genetic Conservation. In: Sandal and its prodncts, 1998. Canberra, ACIAR Proceedings, 84 :117 – 120.

Jain, S.H., V.G.Angadi and K.H.Shankaranarayana,(2003). *Edaphic, environmental and genetic factors associated with growth & adaptability of Sandal (Santalum album L.) in provenances*. Sandalwood Research Newsletter ***17***: 6 – 7.

Jain, S.K. (1968). Medicinal Plant. National Book Trust, New Delhi, pp. 123 125.

Jain,S.H., C.R.Rangaswamy and C.R.Sharma (1988). Soil properties and their relationship to the growth of sandal *(Santalum album L.)* in three study areas in Karnataka. Myforest, 24:141-146.

Jain,S.H., C.R.Rangaswamy and C.R.Sharma (1988). Soil properties and their relationship to the growth of sandal *(Santalum album L.)* in three study areas in Karnataka. Myforest, 24:141-146.

Jassie Moniodis, A. et al. 2018. “Genetic and Environmental Parameters Show Associations with Essential Oil Composition in West Australian Sandalwood (Santalum spicatum).”: 48-58.

Jayaraman,V.(1973). Working Plan of Central Coimbatore Forest Division,1972-1982.

John, H. (1947). The history, present distribution and abundance of sandalwood on Oahu, Hawaiian Islands. Hawaiian Plant Studies Pacific Science. I: 5- 20.

John, H. (1947). The history, present distribution and abundance of sandalwood on Oahu, Hawaiian Islands. Hawaiian Plant Studies Pacific Science. I: 5- 20.

Joshi, G. and A. N. Arunkumar (2007). Standardization of optimum conditions for storage of *Santalum album* L. seeds for *ex-situ* germplasm conservation, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 52 -54.

Joshi, G., K.Vignesh, T.S.Rathore (2014). Hardening and field trial of micropropagated plants of *Santalum album.* Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 47.

Kabir, S.A. (1937). The role of undergrowth in the spread of the spike disease of sandal. Quar. Jour. Mys. For. Dept., 6: No. 1.

Kala, S., K. K. Suresh, K. Kumaran and M. G. Rao (2007b). Standardization of nutrition for field establishment of *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 106-110.

Kala, S., K. K. Suresh, T. Kalaiselvi and T. M. Raj (2007a). Standardization of nutrition for quality seedling production in *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 55-58.

Kamat, S. Y., K. K. Chakravarthi and S. C. Bhattacharya (1967). Synthesis of Santalene, Santalol and Santalbic acid. Tetrahedron, 23: 4487.

Karawya, M. J. and S. K. Wahba (1962). Chromagraphic analysis of sandal oil, Egypy Pharm. Bull., 44: 23.

Karmakar, A. Goswami, N. and Tah. J. 2017, Germination behavior and morpho-physiological activities of white sandal (Santalum album L.) - Asian Journal of Science and Technology, 08: pp 6877-6883, 2017.

Keren, R. and F.T. Bingham (1985). Boron in water, soils and plants. Adv. Soil Sci. 1: 229-276

Khan, M.A. W. and J.S.P. Yadav (1962). Preliminary investigation on soils in relation to the occurrence of spike in sandal (Santalum album L). Indian Forester, 88: 219-225.

Khan, M.S. (1957). *Santalum album* (Sandal) in Hyderabad State. Indian Forester, 83: 23 – 25.

Kim, Sung-yong, Jinrong Wan, Xue-Cheng Zhang, David Neece, Katrina, Ramonell, M., Steve Clough, Minviluz,G. and Garry Stacey (2006). A LysM Receptor-like Kinase plays a critical role in Chitin signaling and fungal resistance in Arabidopsis. Published online before print in February,2008; The Plant Cell,2:471-481.

Kirtikar KR, Basu BD. Indian Medicinal Plants with Illustrations. Vol 3rd., 2nd ed., Dehradhun; Inter National Book Distributor: 2008, pp. 2185-2188.

Kirtikar, K.R. and B.D.Basu (1987). Indian Medicinal Plants. International Book Distributors, Dehra Dun.

Kishore, I. (1962). Hot pyridinic phthalation method for estimating primary alcohol in essential oils. Soap Perfu. Cosmet.., 35: 446.

Krishna Bahadur KC. Status and distribution of Sandalwood (*Santalum album*) in Nepal: A study of Pyuthan district. *Species*, 2019, 20, 13-23.

Krishnamurthy, R., S. Kondas, A. Sekaranandam and P. Krishnamurthy. (1983). A Study on the performance of Sandal in the soils of Talamalai Range. Indian J. of Forestry, 6 : 17-23.

Krishnappa, H.P. (1972). Sandal tree,a dollar earning parasite. Myforest, 8 :1-5.

Kristensen, H. R. [1960]. The sandal spike disease, *FAO, ETAP Report of Government of India*, No. 1229: 1-31.

Kulkami, H.D. and Srimathi, R.A. 1980. Variations in the foliar characteristics in sandal. A biometric analysis. Proceedings of the National Symposium on Improvement of Forest Biomass. Himachal Pradesh Department of Forestry. Krishi Vishva Vidhyalaya, Oachaghat (Solan), Section II Cytology. Genetic variation and Breeding of Trees.

Kulkarni CR, Joglekar MM, Patil SB, Arvindekar AU, Antihyperglycemic and antihyperlipidemic effect of *Santalum album* in streptozotocin induced diabetic rats. *Pharmaceutical Biology,* 2012; 50: 360-365.

Kulkarni, H.D. and R.A. Srimathi (1982). Variation in foliar characteristics in sandal – Biometric analysis in Improvement of forest Biomass. P.K. Khosla (Eds.), International Book Distributors, Dehra Dun. 63 -69.

Kulkarni, H.D. and R.A. Srimathi (2007). Anchetty variety of sandal, *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 38-39.

Kumar A. N. Arun and Geeta Joshi are in the Institute of Wood Science and Technology, 18th Cross, Malleswaram, Bengaluru 560 003, India; H. Y. Mohan Ram is in Shriram Institute for Industrial Research, 19 University Road, Delhi 110 007, India.

Kumar, S. and A. R. S. Kartha (1974). Estimation of total alcohols and phenols in essential oils. Ind. J. Agri. Sci., 44: 79.

Kumaravelu, G., R. K, Bharathi, A. Jainaludeen and V. C. Balraj (2007). Resurrection of the rare aromatic *Santalum album* population in Tamil Nadu, India, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 14-22.

Kunda S. Deval, V.N. Vasantharajan and J.C. Bhat (1971). Low cation exchange capacity (CEC) of roots of the root parasite *Santalum album* L. Curr. Sci., 40 : 662.

Kunkel, L. O. (1926). Virus diseases of plants. Chapter IX of Filterable Viruses. Ed. By T. M. Rivers. Vailliera Tindol and Coy, London.

Kushalappa, K.A. (1995). Sandal in social forestry. In: Recent Advances in Research and Management of Sandal (*S. album* L.) in India. Srimathi, R.

A., H. D. Kulkarni and K. R. Venkatesan (eds.), Associated Publishing Company, New Delhi, pp206-209.

Kuttan, R., Nair, N.G., Radhakrishnan, A.N., Spande, T.F., Yeh, H.J. and Witkop, B. (1974). The isolation and characterization of g-L glutamyl S-(trans –1- propenyl)-L-cysteine sulfoxide from sandal (*Santalum album L)*: An interesting occurrence of sulfoxide diastereoisomers in nature. *Biochemistry,* 13(21): 4394–400.

Lahiri, A.K. (2010). Note on Performance of *Santalum album* in South Bengal. *Indian Forester*, 136(7) : 999-1000.

Lakshmi Sita, G. (1986). Sandalwood (*Santalum album* L.), Bio- technology in agriculture and forestry Vol. I Trees. Ed. Y.P.S. Bajaj. Springer-Verlag Berlin, 363.

Lakshmi Sita, G. C.S. Vaidyanathan and T. Ramakrishnan (1982). Applied aspects of plant tissue culture with spiecal reference to tree improvement. Curr. Sci., 51 : 88-92.

Lawton K, Friedrich L, Hunt M (1996). "Benzothiadizaole induces disease resistance by a citation of the systemic acquired resistance signal transduction pathway". The Plant Journal. **10** (1): 71–82. doi:10.1046/j.1365-313x.1996.10010071.x. PMID 8758979.

Lindsay , W.L. and W.A. Norvell (1978). Development of a DTPA soil test for Zinc, Iron , Manganese and Copper. Soil Sci. Soc. Amer. J. 42: 421- 428

Lushington, A.W. (1903). Treatment of the Sandal trees. Indian Forester, 29 : 113-114.

Lushington, A.W. 1903. Treatment of the Sandal trees. Indian Forester, 29: 113-114.

Lushington, P.M. (1916). Note on spike disease in sandal. Indian Forester, 42(2) : 61.

Lushington, P.M. (1918). Progress of spike investigation in the Southern Circle, Madrass Presidency during 1917-18. Indian Forester, 44(10) : 439-460.

Madhu S., A.Srivastava, A.Kanfade (2014). History, traditional values, uses of the Sandalwood in the current scenario and approaches to revive the lost

glory of a precious paragon. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 16.

Madurnath, M.K. and B.C. Manjunath (1938). Chemical examination of the oil from seeds of sandal. J. Ind. Chem. Soc., 15 : 389.

Majumdar, G. P. [1941]. The white sandal. *Science and Culture*, 6: 492-495.

Majumdar, G. P. [1941]. The white sandal. *Science and Culture*, 6: 492-495.

Mamatha, R. and T.S. Rathore (2014). Effect of sucrose, agar-agar concentrations and pH on somatic embryogenesis in *Santalum album* L. from the leaf of mature trees. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 49.

Manjunath, B.L. and S. Siddappa (1943). On the constitution of Santalbic Acid from sandal. J. Mys. Uni., 4B : 167.

Mapa, R.B, Somasiri, S. and Nagaraja S. 1999. Soils of the wet zone of Sri Lanka. Soil Science Society of Sri Lanka. Wijerama Mawatha, Colombo.

Masev N. and N. Kutacek (1966). The effect of Zinc on the bio-synthesis of Tryptofan, Indole Auxins and Gibberelins in Barley. Biol. Plant. Acad.Sci., Biochem., 8 (2) : 142-151.

Mathews, J. D. (1961). Breeding for resistance of spike disease of Sandal. Report to Govt. of India No. 1349, FAO, Rome.

Mathur, R. N. and B. Singh. (1961). A list of insect pests of forest plants in India and the adjacent countries. Indian Forest Bull. (New Series) Entomology. FRI, Dehradun. No.171(8), Part 9:1-86.

Mattinson S (2014). A non-conventional approach to Indian Sandalwood production. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 20.

McCarthy, C. [1899]. Progress Report of Forest Administration in Coorg for 1898-1899.

McKinley E.B. (1923). Filtarable viruses and Ruksetta disease. Philipp. Jour. Sci., 39 : 1-416.

Mishra BB, Dey S. TLC-bioautographic evaluation of in vitro anti-tyrosinase and anti colinesterase potentials of sandalwood oil. Nat Prod Commun. 2013;8(2):253-256.

Misra, B.B., and Dey, S. (2012a). Comparative phytochemical analysis and antibacterial efficacy of *in vitro* and *in vivo* extracts from East Indian sandalwood tree (*Santalum album* L.). *Letters in Applied Microbiology, 55,* 476-486

Misra, B.B., and Dey, S. (2013a) Shikimic acid (tamiflu precursor) production in spension cultures of East Indian sandalwood (*Santalum album*) in air-lift bioreactor. *Journal of Postdoctoral Research 1*, 1-9.

Misra, B.B., and Dey, S. (2013c) TLC-bioautographic evaluation of in vitro anti-tyrosinase and anti-cholinesterase potentials of sandalwood oil. *Natural Product Communications 8*, 253-256.

Mitchell, J.E.M. (1941). Sandalwood problems, factors affecting heartwood and oil content in sandalwood. Proc. 5th Silvi. Conference, Dehra Dun, 1939.

Mohan,S.,S.H.Jain, G.Ravikumar & S.Naithani (2014). Adulteration of Sandalwood oil – detection and purity evaluation. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 59.

Mojay, G. (1996). Aromatherapy for healing the spirit. Hodder and Stoughton.

Morris, L.J. and M.C. Marshall (1966). Occurrence of stearolic acid in Santalaceae seed oils. Chem. & Industr., 460.

Mosse, B. 1973. *Advances in the study of vesicular arbuscular mycorrhiza*. Annu. Rev. Phytopathol **11** : 171-196.

Muniyappa, V. , N. Vijayakumar, M. Subbarao and K.A. Kushalappa (1980). Studies on the sandal spike disease in the forests of Karnataka state, Part I, Univ. of Agril. Sci., Hebbal, Bangalore, p254.

N.S. Solanki, C.S. Chauhan, B. Vyas, Deepak Marothia(2014). Santalum album Linn: A Review Int.J. PharmTech Res.2014-2015,7(4),pp 629-640.

Nadkarni KM. Indian Materia Medica. Vol 1st., 3rd ed., Mumbai; Popular Prakashan Private Limited: 2010, pp. 1098-1102.

Nagaveni, H.C & H.S.Ananthapadmanabha (1986). Seed polymorphism and germination in *Santalum album* L. Van Vigyan 24 : 25-28.

Nagaveni, H.C & H.S.Ananthapadmanabha and S.N. Rai (1989). Effect of different chemicals on germination of sandal seeds. Myforest 25 : 311-313.

Nagaveni, H.C & R.A. Srimathi. (1980). Studies on germination of the Sandal Seeds, *Santalum album* L. II. Chemical stimulant for germination. Indian Forester, 106 (11) : 792 -799.

Nagaveni, H.C & R.A. Srimathi. (1981). Sandal seeds, viability, germination and storage. Second All India Sandal Seminar, Salem. Tamil Nadu Forest Dept. 9-10, May.

Nagaveni, H.C & R.A. Srimathi. (1981a). Studies on germination of the Sandal *Santalum album* L. Pretreatment of sandal seeds. Indian Forester, 107 (6) : 348 – 354.

Nagaveni, H.C & R.A. Srimathi. (1985). A note on haustoria less sandal plants. Indian Forester, 111 : 161-162.

Nagaveni, H.C & R.A. Srimathi. 1985. A note on haustoria less sandal plants. Indian Forester, 111: 161-162.

Nagaveni, H.C. and G. Vijiyalakshmi (2007). Performance of sandalwood plants with association of mycorrhizal fungi and their resistance to Fusarium wilt disease. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 130-136.

Nagaveni, H.C. and G. Vijiyalakshmi (2014). Combined function of Arbuscular Mycorrhizal Fungi and haustoria in growth of Sandalwood plants. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 25.

Nagaveni, H.C. and G. Vijiyalakshmi, (1989). Differential response in the haustorial formation and growth of sandalwood plant (*Santalum album* L) with respect to different hosts. Myforest, 25: 137- 142.

Nagaveni, H.C. and G. Vijiyalakshmi, (2002). Effect of VAM and *AZOTOBACTOR* inoculation on growth and biomass production in forestry species. Ind. Jour. Of Forestry, 25(3): 286-290.

Nagaveni, H.C. and G. Vijiyalakshmi, (2004). Growth performance of Sandal (*Santalum album* L) with different leguminous & non-leguminous host species. Sandalwood Research Newsletter, 18: 1-4.

Nagaveni, H.C. and G. Vijiyalakshmi, (2004). Growth performance of Sandal (*Santalum album* L) with different leguminous & non-leguminous host species. Sandalwood Research Newsletter, 18: 1-4.

Nagaveni, H.C. and G. Vijiyalakshmi, 1989. Differential response in the haustorial formation and growth of sandalwood plant (Santalum album L) with respect to different hosts. Myforest, 25: 137- 142. [VOLUME 5 I ISSUE 4 I OCT. – DEC. 2018] e ISSN 2348 – 1269, Print ISSN 2349-5138

Nagaveni, H.C. and G. Vijiyalakshmi, 2004. Growth performance of Sandal (Santalum album L) with different leguminous & non-leguminous host species. Sandalwood Research Newsletter, 18: 1-4.

Nair, R.M. and H. S. Ananthapadmanabha (1974). Bio assay of tetracycline uptake in spiked sandal (*Santalum album*). J. Ind.Acad. wood Sci.,5: 108-112.

Nair, R.M. and H. S. Ananthapadmanabha 1974. Bio assay of tetracycline uptake in spiked sandal (Santalum album). J. Ind. Acad. wood Sci.,5: 108-112.

Nanayyya, K. M. (1949). Sandal forests in Coorg. Ind. For., 75: 87-90.

Narasimhan, J.J. (1930). Studies in the genus phytophthora in Mysore. Phytopath 20: 201-204.

Narasimhanrajapura (1926). Studies in the genus phytophthora in Mysore. Phytopath 20: 201-204.

Nasi, R. and Y. Ehrhart. (1997). Sandalwood a perfume of property – Part II plantations. Bois et Forests des Tropiques,1996, No. 248: 5-16.

Nayar, R. (1984). Contral of seedling disease of sandal. J Ind. Acad. Wood Sci., 15 : 60 – 54.

Nayar, R. (1986). Natural resistance of *Santalum album* L. to spike disease. J. Ind. Acad. Wood Sci.,17: 111-114.

Nayar, R. (1974). Role of ecological factors in the incidence of spike disease and heartwood formation in sandal. J. Ind. Acad. Wood Sci., 5 : 108 -112.

Nayar, R. and R.A. Srimathi (1968). A symptomless carrier of sandal spike disease. Curr. Sci. 37: 567 – 568.

Nayar, R., H. S. Ananthapadmanabha and K.R. Venkatesan (1980). Seedling disease of Sandal. Ind. J. Forestry, 31: 24-25.

Nayar, R., H.S.Ananthapadmanabha and K.R. Venkatesan (1980a). Rot in stored sandal logs. Eur. J. For. Path., 2: 136 -138.

Nesari, M. (2014). Sandalwood in Ayurvedic perspective. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 55. New Delhi. Pp. 498-.

Nigam, I. C. and L. Devi (1962). GLPC of sesquiterpenic compounds. Can J. Chem., 40:2083

Norris, R.V. (1930). Spike disease of sandalwood. Nature (London), 126:311

Nurochman, Deden, Juang Rata Matangaran, Gunawan Santosa , Didik Suharjito , Rita Kartika Sari. 2018 Autecology and morphological properties of sandalwood (Santalum album L.) in Pidie District, Aceh, Indonesia. Vol 19 no.: 2 pp 406-412. ISSN: 1412-033X. E-ISSN: 2085-4722. DOI: 10.13057/biodiv/d190207

Ohmori, A., Shinomiya, K., Utsu, Y., Tokunaga, S., Hasegawa, Y., and Kamei, C. (2007). Effect of santalol on the sleep-wake cycle in sleep-disturbed rats. *Nihon Shinkei Seishin Yakurigaku Zasshi, 27,* 167-171.

Okasaki, K. and S. Oshima (1953). Antimicrobial effect of essential oils. J. Pharm. Soc. Japan, 73 : 344.

Okazaki, K., and Oshima, S. (1953). Antibacterial activity of higher plants XXV: Antibacterial effect of essential oils VI. *Journal of the Pharmaceutical Society of Japan (Japan), 73,* 344 347.

Okugawa, H., Ueda, R., Matsumoto, K., Kawanishi, K., and Kato, A. (1995). Effect of _- santalol and _- santalol from sandalwood on the central nervous system in mice. *Phytomedicine, 2,* 119 126.

Okugawa, H., Ueda, R., Matsumoto, K., Kawanishi, K., and Kato, K. (2000). Effects of sesquiterpenoids from "Oriental incenses" on acetic acid-induced writhing and D2 and 5-HT2A receptors in rat brain. *Phytomedicine, 7,* 417-422.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bycarbonate. USDA Circular, 939. U.S Government Printing Office, Washington D.C.

Ovcharov, K.E. (1977). Physiological basis of seed germination. Amerind Publishing Co. Pvt. Ltd. New Delhi, 179.

Ovcharov, K.E. (1977). Physiological basis of seed germination. Amerind Publishing Co. Pvt. Ltd. New Delhi, 6 - 19.

Panabokke, C.R. 1996. Soils and Agro-Ecological Environments of Sri Lanka. Sri Lanka: Natural Resources Energy and Science Authority Press, Maitland place, Colombo 07.

Pande, M.C. (1977). Medicinal oils and their importance. *Medicine and Surgery, 17,* 13 16.

Panse, V.G. and P.V. Sukhatme (1995). Statistical Methods for Agricultural Workers. Published by I.C.A.R., Anusandhan Bhavan, Pusa, New Delhi,110012.

Panse, V.G. and P.V. Sukhatme (1995). Statistical Methods for Agricultural Workers. Published by I.C.A.R., Anusandhan Bhavan, Pusa, New Delhi,110012.

Parimala Varadaraj and K.H. Shankaranarayana (1986). Antibacterial activity of sandal bark tanning against Staphylococcus aureus. Van Vigyan, 24: 121-122.

Parthasarathi, K. and M.N. Ramaswamy (1961). The role of phenolic bodies in the metabolism of Sandal (*S. album* L.) in health and disease. J. Sci. Ind. Res. 20C: 273-275.

Parthasarathi, K. and P. S. Rao [1962]. Studies on Sandal spike: Physiological significance of disturbed iron balance in the spike disease of Sandal (*S. album* L.). Proc. Ind. Acad. Sci., 55B: 99-106.

Parthasarathi, K., C.R. Rangaswamy and V.G. Angadi (1985). Leaf peroxidase, malate dehydrogenase and esterase isoenzyme pattern in ten sandal (*Santalum album* L.) types showing variations in leaf pattern. Indian Forester, 111: 441- 449.

Parthasarathi, K., P.K. Ramaiah and. S. Rao [1963]. Studies on sandal spike; Ascorbic acid in the metabolism of Sandal (*S. album* L.) in health and disease. *Proc. Indian Acad. Sci.*, 57B: 68-71.

Parthasarathi, K., P.K. Ramaiah, T.R. Manjunatha and P. S. Rao [1962]. Studies on Sandal spike. Part 3. The nitrate reductase activity in the normal and pathochemical states of Sandal. Proc. Ind. Acad. Sci., 55B: 285-289.

Parthasarathi, K., S. K. Gupta and A.N. Rajeevalocha and P.S. Rao (1973b). Studies on sandal spike. Incidence of the spike disease versus the major and minor nutrient status of the soils of sandal growing regions. Indian Forester, 99: 645 – 650.

Parthasarathi, K., S. K. Gupta and P. S. Rao [1971]. Studies on sandal spike, Part –IX Cation exchange Capacity of Sandal (Santalum album L.) in health and disease. Curr. Sci. 23: 640 - 641.

Parthasarathi, K. Rangaswamy, C.R and Angadi, V.G. 1985. Leaf peroxidase, malate dehydrogenase and esterases isoenzyme pattern in ten sandal (*Santalum album* L.) types showing variation in leaf pattern. Indian Forester. 111(6): 441-449

Parthasarathy, K., S. K. Gupta and P.S. Rao. 1974. Differential response in the cation exchange capacity of the host plants on parasitization by Sandal. Current Science, 43: 20.

Parthasarathy, K., S. K. Gupta and P.S. Rao. 1974. Differential response in the cation exchange capacity of the host plants on parasitization by Sandal. Current Science, 43: 20.

Puran Singh (1911). Memorandum on the oil value of sandal woods from Madras. Forest Bull. No. 6, F.R. I & Colleges, Dehra Dun.

Puran Singh (1915). A further note on the oil value of some sandalwoods from Madras. Indian Forester, 41: 123 -129.

Purohit, P. M. (2018): Reviving the royal tree *Santalum album* Linn.: Santalaceae. Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand, Gujarat, India 273-276.

Qureshi, I.M. (1955). A note on the distribution, geology, etc. of sandalwood in Bombay State. Indian Forester, 81: 318 -319.

Radomiljac, A.M., J. a. McComb and S.R. Shea (1998). Field establishment of (*Santalum album* L) – the effect of the time of introduction of a pot host *Alternanthera nana* R. Br. For. Ecol. Manage, 111: 107-118.

Radomiljac, A.M., J. A. McComb and S.R. Shea 1998. Field establishment of (Santalum album L) – the effect of the time of introduction of a pot host Alternanthera nana R. Br. For. Ecol. Manage, 111: 107-118.

Rai, S.N. 1990. *Status and cultivation of sandalwood in India*. In: Proceeding of the Symposium on Sandalwood in the Pacific. Hamilton L. & C.E. Conrad, (eds), USDA Forest Service General. Technical Paper PSW -122, Honolulu, pp 66-71.

Rai, S.N. and C.R. Sarma (1986b). Study of diameter growth in sandal. J. of Tropical Forestry, 2: 202-206.

Rai, S.N. and H.D. Kulkarni (1986). Sandal wood plantation. In Plantation Crops. Vol. I, Opportunities and constraints. Ed. Srivastava et. al., Oxford and IBH unblushing Co., 295 -300.

Rajagopal Shetty, H. (1977). Growth rate of sandal in Javadis. Proc. All India Sandal seminar, Karnataka Forest Department, Bangalore, 66-67.

Rajagopal Shetty, H. (1977a). Spread and yield of sandal in Javadis. Proc. All India Sandal seminar, Karnataka Forest Department, Bangalore, 68-72.

Rajagopal Shetty, H. (1981) Working Plan for Vellore Forest, 1974 -1984.

Rakesh Kumar* Nishat Anjum and Y.C. Tripathi (2015). PHYTOCHEMISTRY AND PHARMACOLOGY OF *SANTALUM ALBUM* L.: A REVIEW. Volume 4, Issue 10, 1842-1876.

Ral, Shobha N. 1990. A Text Book. "Status and Cultivation of Sandalwood in India 1." : 66–71.

Rama Rao, D.A. and M. Sreenivasaya (1928). Contributions to the study of spike disease of Sandal (*S. album* L.) Part IV- chemical composition of healthy and spiked Sandal stems. J. Ind. Inst. Sci., 11A: 241-243.

Rama Rao, M. (1903). Root parasitism of sandal tree. Ind. For. 29: 386-389.

Rama Rao, M. (1908b) Sandal wood at sea level. Indian Forester, 34: 151 -153, 406 -407.

Rama Rao, M. (1910). Germination and growth of sandal seedlings. Indian Forest Records, 2 (3): 137 -157.

Rama Rao, M. (1911) Host plants of the sandal tree. Indian Forest Records, 2 (4) : 159 -207.

Rama Rao, M. (1918) Host plants of the Santalum album. Indian Forester, 44 : 58

Rama Rao, M. 1903. Root parasitism of sandal tree. Ind. For. 29: 386-389. Rama Rao, M. 1918 Host plants of the Santalum album L. Indian Forester, 44: 58.

Ranganathan, C.R. and C.L. Wilson (1934). Working plan for the North Salem Forest Divn. Madras, 116.

Rangaswamy, C.R., H.S.Ananthapadmanabha, S.H. Jain and H.C. Nagaveni (1986b). Nutrient uptake and host – requirement of sandal. Van Vigyan, 24: 75 -79.

Rangaswamy, C.R., S.H. Jain and K.Parthasarathi,(1986a). *Soil properties of some Sandal bearing areas*. Van Vigyan. 24: 61-68.

Rangaswamy, C.R., S.H. Jain and K. Parthasarathi,1986. *Soil properties of some Sandal bearing areas*. Van Vigyan. 24: 3 – 4.

Rangaswamy, C.R., S.H. Jain and K. Parthasarathi,1986a. Soil properties of some Sandal bearing areas. Van Vigyan. 24: 61-68.

Rangaswamy, M.N. (1956c). Letter to Editor. Indian Forester, 82 : 266 -267

Rangaswamy, N.S. and P.S. Rao (1963). Experimental studies on *Santalum album* L. Establishment of tissue culture of endosperm. Phytomorphology, 13 : 450 -454.

Rangaswamy, S. and Griffith, A.L. 1939. Host plants and the Spike disease of Sandal. Ind.for., 65: 335-345.

Rangaswamy,S. and A.L.Griffith (1939). Host plants and the Spike disease of Sandal. Ind.for., 65: 335-345.

Rao, L.N. (1942). Parasitism in Santalaceae. Annals of Botanty. N. S. 6(2): 131-149.

Rao, L.N. 1942. Parasitism in Santalaceae. Annals of Botanty N.S. 6(2): 131-149.

Rao, M. N., G. Ravikanth, K. N. Ganeshaiah, T. S. Rathore and R. Uma Shanker (2007). Assessing threats and identified the ecological niche of sandal resources to identify hot-spots for *in-situ* conservation in Southern India, Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 23-31.

Rao, P.S. (1965). In vitro induction of embryonal proliferation in *Santalum album* L.. Phytomorphology, 15 : 165 -167.

Rao, P.S. (1965). The Scientific study of sandal: Physiological and pathological aspects. Advancing Frontiers in the Chemistry of Natural Products. Hindusthan Publishing Corp., Delhi, 237 -250.

Rao, P.S. and R.A. Srimathi (1977). Vegetative propagation of sandal (*Santalum album* L.). Current Sci. 46: 276.

Rao, R.V., T.R. Hemavathi, M. Sujatha and S. Shashikala, (2007). Status on Wood structure, heartwood formation, age, gaps and research needs in *Santalum album* L. *Proceedings of National Seminar held in Institute of Wood Science & Technology (ICFRE)*, Bangalore, 12-13 December, 2007, pp 165-171.

Rathore, T. S., B. Goyal, A. K. Dubey and P. S. Rao (2007). In-vitro cloning of sandalwood (*Santalum album* L.) through axillary shoot proliferation and evaluation of genetic fidelity. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 85-91.

Remadevi, O. K., H. C. Nagaveni and R. Muthukrishnan. (2005). Pests and diseases of sandal wood plants in nurseries and their management. Working papers of the Finnish Forest Research Institute 11:69-74.

Remadevi, O. K., R. Muthukrishnan and L.N. Santhakumaran (1998). Incidence, damage potential and biology of wood borers of *Santalum album* L.. In : Sandal and its Products, Radomiljac, A.M., H.S.A. Padmanabha, R.M. Welbourn and K.S. Rao (eds.). Proceedings of an International Seminar held at Bangalore, India, 18 – 19 Dec., 1997. Canberra, ACIAR Proceedings, 84: 192 -19.

Remadevi,O.K., and R. Muthukrishnan (2006). Incidence of *Aristobia octofasciculata* Aurivillus (Cerambycidae : Coleoptera), the heartwood borer pest of sandalwood trees. J.Ind. Acad. Wood Sci. (N.S.) 32(2):42.

Robinson, J. (1952a) The Rate of Interest and Other Essays, London:

Robinson, J. (1952b) The model of an expanding economy, Economic Journal.

Rocha D., P.K. Ashokan, A.V.SantoshKumar, E.V.Anoop, P.SureshKumar (2014). Anatomy and functional status of haustoria in field grown sandalwood tree. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 28.

Roh, H.S., Park, K.C. and Park, C.G. (2012). Repellent effect of santalol from sandalwood oil against Tetranychus urticae (Acari: Tetranychidae). *J. Econ. Entomol.,* 105(2): 379–85.

Rohadi, D., Aryani R.M., Belcher, B., Perez, M., and Widnyana, M. (2004). Can sanndalwood in East Nusa Tenggara survive? Lessons from the policy impact of resource sustainability. *Sandalwood Research Newsletter, 10,* 3 6.

Saeed M. Hamdard Pharmacopeia of Eastern Medicine. 2nd ed., New Delhi; Sri Satguru Publications: 1997, pp. 455-460.

Salio, G.L. and Bagyaraj, D.J. (2003). Bio. Agri. Hort., 2003: 20(4)

Santha S, Bommareddy A, Rule B, ET AL. Antineoplastic effects of α-santalol on estrogen receptor-positive and estrogen receptor-negative breast cancer cells through cell cycle arrest at G2/M phase and induction of apoptosis. PloS One.2013;8(2):e56982.

Sarma, C.R. and S.N. Rai (1986). Periodic annual diameter increment in saldal. Van vigyan, 24 : 69 – 74.

Sarma, C.R. and S.N. Rai (1986). Periodic annual diameter increment in saldal. Van vigyan, 24: 69 – 74.

Sastry, S.G. (1994). Oil of sandalwood East Indian. *J. Sci. Industry Research,* 3(2): 173–187.

Sawyer B (2014). Renewing the wooden gold of Western Australia. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 11.

Schenck, N.C. 1981. Can mycorrbiza. Centrol root disease? Plant Disease, 65 : 230-234.

Schonbeck, F. and H.W Dehne (1981). Mycorrhiza and plant health; Gesunde Pflanz. 33: 186-190.

Scott, J. (1871). Notes of horticultural in Bengal. No. 2, Loranthceae, the mistletoe order, their germination and mode of attachment, J. Royal Hort. Soc. India, 2: 287.

Scott, J. (1871). Notes of horticultural in Bengal. No. 2, Loranthceae, the mistletoe order, their germination and mode of attachment, J. Royal Hort. Soc. India, 2: 287.

Scott, J. (1871). Notes of horticultural in Bengal. No. 2, Loranthceae, the mistletoe order, their germination and mode of attachment, J. Royal Hort. Soc. India, 2: 287.

Sekar, I., K. K. Suresh, V.M. Srinivasan, and K.S. Neelakandan. 2000. *Response of biofertilizer on the growth & development of Sandal.* Newsletter, Tamil Nadu Agricultural University, Coimbatore.

Sen Sarma, P.K. (1982). Insect vectors of sandal spike disease. Eur. J. For. Path., 12: 297 - 299.

Sen Sarma, P.K. 1982. *Sandalwood – Its cultivation and utilization*. In : Cultivation and utilization of Aromatic plants. Atal, C.K. and B.M. Kapur (eds.), Regional Research Laboratory, CSIR, Jammu Tawi. 395-495.

Shankaranarayana, K.H. (1979b). Partial hydrogenation of sandal seed oil. J. Oil Tech. Assn. India, 11: 96 – 97.

Shankaranarayana, K.H. (1985a). Nutrient composition of deoiled seed meal-minerals and amino acids. JAOCS.,62:1386-87.

Shankaranarayana, K.H. (1988a). Removal of unsaponifiables from sandal seed oils and fatty acid composition of seed coat. Van Vigyan, 26: 43.

Shankaranarayana, K.H. and G.S. Krishna Rao (1982). Sodium santalbate – dimethyl sulphate inclusion complex. JAOCS. 59: 240 – 241.

Shankaranarayana, K.H. and K. Parthasarathi (1984a). Compositional differences in Sandal oils from young and mature trees and in oils undergoing colour change on standing. Ind.Perfu., 28: 138-141.

Shankaranarayana, K.H. and K. Parthasarathi (1987a). On the content and composition of oil from heartwood of different levels in sandal. Ind.Perfu., 31: 211-214.

Shankaranarayana, K.H., and K. Parthasarathi (1986). Surface active products from sandal seed oil. JAOCS., 63: 1473 – 1474.

Shankaranarayana, K.H., Ayyar, K.S. and Rao, G.S.K. (1980). Insect growth inhibitor from the bark of Santalum album. *Phytochemistry,* 19: 1239–1240.

Shankaranarayana, K.H., K.S. Ayyar and G.S. Krishna Rao (1980a). Insect growth inhibitor from the bark of *Santalum album* L. Phytochemistry, 13: 239-240.

Shankaranarayana, K.H., K.S. Ayyar and G.S. Krishna Rao (1980b). Chemical constituents of the bark of *Santalum album* L. Curr. Sci. 49: 198 – 199.

Shankaranarayana, K.H., S.H. Jain and B.S. Kamala (1990). Fatty acid and mineral composition of seed from young and mature sandal trees. Ind. J. Forestry, 13: 250 – 251.

Shankaranarayana, K.H., Sivaramakrishnan,V.R, Ayyar, K.S. and Sen Sarma,P.K (1979a). Isolation of a compound from the bark of sandal and its activity against some Lepidopterous and Coleopterous insects. J. Entomol Res. 3:116-118.

Shankaranarayana, K.H., V.G. Angadi, A.N. Rajeevalochan, K.S. Theagarajan, C.R. Sarma and C.R. Rangaswamy (1997). A rapid method of estimating essential oil content in heartwood of *Santalum album* L. Current Sci. 72(4): 241-242.

Shankaranaryana, K.H. and Kamala, B.S. (1989). Six new essential oils from waste plant material. *Indian Perfumer,* 33(1): 40–43.

Shankaranaryana, K.H. and Parathasarthi, K. (1985). KESP: A new essential oil from the acid hydrolysis of spent sandalwood. *Perfumer and Flavorist,* 10: 60.

Shankaranaryana, K.H., and Venkatesan, K.R. (1981). Rectification 633 of benzene extract: A simple method for extracting sandal oil in higher yield. *Indian Perfumer, XXV,* 31 34.

Sharma, J.R. (1995). Principals and Practice of Plant Breeding. Tata Mc Graw-Hill, New Delhi.

Shetty, J. B. (1977). Proposals for the adoption of adequate legal measures for the protection of Sandalwood. In: Proceedinds of All India Sandal Seminar, 7-8th Feb, Karnataka Forest Department, 198-204.

Shetty, J. B. (1977). Proposals for the adoption of adequate legal measures for the protection of Sandalwood. In: Proceedinds of All India Sandal Seminar, 7-8th Feb, Karnataka Forest Department, 198-204.

Shivanna H, P. Surendra, R. L. Chavan (2014). Stomatal regulation – a growth attribute for transpiration and gas exchange in sandalwood (*Santalum album* L.) – vital process in plant metabolism. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 30.

Sindhu RK, Upma, Kumar A, Arora S. Santalum album Linn: A review on morphology, phytochemistry and pharmacological aspects. International Journal of PharmTech Research, 2010; 2(1): 914-919.

Sindhu Veerendra H. C. (2014). Variation in seedling emergence time and its contribution to seedling morphology and early establishment in provenances of Santalum *album* L. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 34.

Singh B, T. S. Rathore and G. Singh (2014). The effect of long-term hosts species on *Santalum album* L. growth under agroforestry in semi-arid condition of North Gujarat, India.

Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 26.

Singh, B. K. and P. Shankar (2007). Status of sandalwood (*Santalum album* L.) in Karnataka). Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 9-13.

Singh, R.K. and Chaudhary, B.D. 1995 Biometrical Methods in Quantitative Genetic Analysis, Kalyani Publishers, New Delhi, 110002.

Singh, R.K.and Chaudhary,B.D.(1995) Biometrical Methods in Quantitative Genetic Analysis, Kalyani Publishers, New Delhi, 110002.

Sinhdu Veerendra H.C. (2014). Variation in seedling emergence time and its contribution to seedling morphology and early establishment in provenances of *Santalum album* L. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 34.

Sivaramakrishnan, V.R. and Shankaranarayana, K.H. (1990). Investigation on the insecticidal properties of plant extractives-I testing of new medicinal oils, HESP from spent sandalwood powder on insects. *Science and culture*, 56(03): 124–127.

Sivaramakrishnan, V.R., H.S. Ananthapadmanabha, B. Ramanujam, M. Subramany and R. Smith (1931). Virus diseases of plants and their relationships with insect vectors. Biol. Rev. 6: 302 – 345.

Sivararnakrishnan, V.R., Nagaveni, H.C. and Raja Muthukrishnan 1987. Poor seed-setting on sandal (Santalurn album L.). Myforest 23 (34): 101-103,343-344.

Smith, K.M. (1931). Virus diseases of Plants and their relationships with insect vector. Biol. Rev 6: 302-345.

Somashekar P.V, T.S. Rathore, K.T. Chandrashekar and M. Srinivasa Rao (2014). Field performance of tissue culture raised Sandalwood plants as Agro-forestry models. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 36.

Sothers, D.B. (1928). Revised Working Plan for the Teak pole and sandalwood forests of Nagargali and Khanapur (including sandalwood areas of Gunjal range), Belgaum Divn. Karnataka: 1 – 14.

Sreenivasa Rao, Y.V. (1933c). Contributions of the physiology of sandal *(Santalum album* L.*)*. Influence of host plants on the nitrogen metabolism of sandal. J. Ind. Inst. Sci., 16A: 167 -178.

Sreenivasaya, M. (1930b). Contribution to the study of spike disease of sandal. Part – 11, New method of disease transmission and significance. J. Ind. Inst. Sci., 13A: 113 – 117.

Sreenivasaya, M. (1930c). Occurrence of mannitol in spike disease of sandal *(Santalum album L.)*. Nature, London, 126: 346.

Sreenivasaya, M. (1931). A quantitative study of the transmission of spike disease of sandal. Proc. Ind. Sci. Cong., 18: 283.

Sreenivasaya, M. (1932). Present position of the problem of spike disease. Curr. Sci., 1: 126 – 127.

Sreenivasaya, M. (1933a). Present position of the problem of spike disease. Indian Forester,59; 123 – 125.

Sreenivasaya, M. (1933b). Pollarding in the control of spike. Indian Forester, 59: 263 – 265.

Sreenivasaya, M. (1933c). Quinquennial survey of investigations on spike disease of sandal Part. 1. Lab. Results found applicable to silvicultural conditions (Extr.) Indian Forester, 59: 473 – 478.

Sreenivasaya, M. (1934). Insect transmission of spike disease. Extracts found from Ind. Inst. Sci. Indian Forester, 60: 504 – 505.

Sreenivasaya, M. (1948). Spike disease of Sandal. Curr. Sci., 17: 141.

Sreenivasaya, M. 1933a. Present position of the problem of spike disease. Indian Forester,59; 123 – 125. Sreenivasaya, M. 1948. Spike disease of Sandal. Curr. Sci., 17: 141.

Sreenivasaya, M. and N. Narayana (1936). Sandal seed, its oil and protein. J.Ind. Inst. Sci. 16A: 1.

Sreenivasaya, M. and S. Rangaswamy (1931). Contributions to the study of spike disease of sandal (*Santalum album L.).* Part XII. Ecology of sandal. J. Ind. Inst. Sci., 14A : 59 – 65.

Srimathi, R.A (1983). Breeding of sandal, a tropical hardwood tree. Tree symposium on Advances in tree Science, F.R.I., Dehre Dun.

Srimathi, R.A and H.D. Kulkarni (1980). Preliminary findings of the heartwood formation in Sandal (*Santalum album* L.). Paper presented in second Forestry Conference held at Dehra Dun.

Srimathi, R.A and H.D. Kulkarni (1982). Progeny trials on selected trees in *Santalum album* L. variations in seedlings. In improvement of forest biomass. Ed. P.K.Khosla, International Book Distributors, Deharadun,119-130.

Srimathi, R.A and H.D. Kulkarni (1983). Sndal in dry zone afforestation. III Silviculturists Conference, Madurai, Tamil Nadu.

Srimathi, R.A and P.S. Rao (1969). Accelerated germination of sandal. Ind For. 95 : 158 -159.

Srimathi, R.A, H.D. Kulkarni and K.R. Venkatesan (1977). Variation pattern in *Santalum album* L. Mycoplasma diseases of trees. Ed. S. P. Roychoudhury Associated Pub Co., New Delhi.

Srimathi, R.A, H.D. Kulkarni and K.R. Venkatesan (1980). Selection of sandal (*Santalum album* L.) foe spike resistance and other qualities Ind. J. Forestry 3 : 303 – 305.

Srimathi, R.A, H.D. Kulkarni and K.R. Venkatesan (1983). Phenotypes of sandal. J. Bom. Nat. Hist. Soc., 80: 245 – 246.

Srimathi, R.A. and M. Sreenivasaya (1962a). Occurrence of endopolyploidy in the haustorium of *Santalum album* L. Curr. Sci., 31: 69 – 70.

Srimathi, R.A. and M. Sreenivasaya (1962b). Occurance of auxins in the haustoria of *Santalum album*. J. Sci. Ind. Res. 21c : 131.

Srimathi, R.A. and M. Sreenivasaya (1963a). Occurrence and significance of phenolic body in the leaves of *Santalum album* L. Curr. Science., 32 : 11.

Srimathi, R.A. and M. Sreenivasaya (1963b). Studies on the culture of lateral buds, root tips and tissue and organ culture haustoria of *Santalum album* L. A symposium Mc Graw Hill publication, Ed. A. Maheswari and N.S. Rangaswami, p.57.

Srimathi, R.A., D.R.C. Babu, and M. Sreenivasaya (1961). Influence of host plant on the amino acid make up of *Santalum album*. Curr. Science, 30.

Srimathi, R.A., H.D. Kulkarni and K.R. Venkatesan. 1995. Recent advances in research and management of Sandal (*S. album* L.) in India. Associated Publishing Co., New Delhi, pp 416.

Srinivasan, V.V., V. R. Sivaramakrishnan, C. R. Rangaswamy, H.S. Ananthapadmanabha and K.H. [1992]. Sandal – *Santalum album* Linn. Indian Council of Forestry Research and Education. Publsd. ICFRE, Bangalore.

Srinivasan, V.V., V. R. Sivaramakrishnan, C. R. Rangaswamy, H.S. Ananthapadmanabha and K.H.1992. Sandal – *Santalum album* Linn. Indian Council of Forestry Research and Education. Publsd. ICFRE, Bangalore.

Srinivasan, V.V., V. R. Sivaramakrishnan, C. R. Rangaswamy, H.S. Ananthapadmanabha and K.H. [1992]. Sandal – *Santalum album* Linn. Indian Council of Forestry Research and Education. Publsd. ICFRE, Bangalore.

Srivastava, K., R. Rajee and K. Srivastava (2003). Mortality rate and regeneration status in different age groups of *Santalum album* L under some species hosts. Ind. For., 129:999-1008.

Stephan Bieri, Katherine Monastyrskaia, and Boris Schilling. (2004). Olfactory Receptor Neuron Profiling using Sandalwood Odorants. Chem. Senses 29: 483–487

Subbarao, N.S., D. Yadav, Ananthapadmanabha, Nagaveni, C.S. Singh and S.K. Kavimandan (1990). Nodule haustoria and microbial features of Cajanus and Pongamia parasitized by Sandal (Sandal wood). Plant and Soil, 128: 249- 256.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Science, 25: 259-260.

Sudhakar K., N.K,Binu, P.K.Ashokan (2014). Two decades of Sandalwood research at College of Forestry, Kerala Agricultural University, Thrissur, Kerala. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 19.

Sundararaj, R. and R. Muthukrishnan (2007). Sucking paste complexes of sandal and their host range in South India. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 111-120.

Sundararaj,R., G. Sharma and L. R. Karibasavaraja. (2006a) Insects associated with Sandal – a checklist. Annals of Forestry 14(1): 121-168.

Sundararaj,R., L. R. Karibasavaraja, G. Sharma and Raja Muthu Krishnan. (2006b). Scales and mealybugs (Coccoidea: Hemiptera) infesting sandal. Entomol., 31(3):239-241.

Surata, I.K, H. Tijona and M. Sinaga. 1995. *Effect of interopping on growth of sandalwood (Santalum album L.)*. Forestry Abstracts, CAB Publications,1997.

Surendran, C., K.L. Parthiban, C.Bhunaneshwaram and M. Murugesh. 1998. Silvicultural stategies for augmentation of sandal regeneration. **In**: *Sandal & its products*, Radomiljae, A.M., H.S. A. Padmanabha, R.M. Welbourn and K.S. Rao (eds.). Proceeding of an International Seminar held at Bangalore, India, 18-19 December, 1997, Canberra, ACIAR Proceeding, 84: 69 -73.

Swain, D. (1999). Eucalyptus – Bane (or) Boon. Indian Forester 123(5):440.

Taide, Y. B., L. C. Babu and C. C. Abraham. (1994). Influence of host species on the initial growth and development of sandal (*S. album* L.). Indian J. of Forestry,174: 288-292.

Tennakoon, K.U., S.P. Ekanayake and L. Etampawala. 2000. *An introduction and current status of sandalwood research in Sri Lanka*. International Sandalwood Research Newsletter, 10: 1-4.

Thirawat, S. (1955). Spike disease of sandal. Indian Forester, 81: 804.

Thungappa, B.K. [1977]. Economic potential of sandalwood. A challenge to forester. *Proc. All India Sandal Seminar*, Karnataka Forest Department, Bangalore: 111-119.

Tireman, H. (1917). Experiments to test the effect of removing of Lantana on the incidence of spike disease attack. Proc. Conference of the spike disease in Sandal.

Triplehorn, C.A. and N.F. Johnson. (2005). Borrer and De Long's Introduction to the study of insects. Thomson Books Cole Publishers, Canada, p864.

Troup, R.S. (1921). The silviculture of Indian trees, Clarendon press, Oxford, 3: 817.

Uniyal, D.F., R.C. Thapliyal and M.S. Rawat (1985). Vegetative propagation of Sandal by root cuttings. Indian Forester, 111:145.

Varadaraja Iyengar, A.V. 1965. The physiology of root parasitism in Sandal (Santalum album L). Ind. For. 91: 246, 341 & 423.

Varadaraja Iyengar,A.V. (1965). The physiology of root parasitism in Sandal (*Santalum album*). Ind. For. 91: 246, 341 & 423.

Varshney, R. K. (1992). A checklist of the scale insects and mealybugs of South Asia. Records of Zoological Survey of India, Occassional Paper, No. 139, p152.

Varshney, R. K. (2002). A checklist of the scale insects and mealybugs of South Asia (Part-2). Records of Zoological Survey of India, Occassional Paper, No. 191, p1-147.

Veerendra, H.C.S.and S.K. Bagchi (1986). Analysis of inter-tree variability in anatomical characters of *Santalum album* L. Ind. For. 112:80-84.

Veerendra, H.CS and Bagchi, S.K. 1986. Analysis of intertree variability in anatomical characters of Santalum album. Indian Forester 112: 80-84.

Venkata Rao, M.G. (1924). Virus disease: Strychnine in sandal. Indian Forester, 50: 456 – 458.

Venkata Rao, M.G. (1935). The role of undergrowth in the spread of the spike disease of sandal. Indian Forester, 61: 169 – 188.

Venkata Rao, M.G. 1924. Virus disease: Strychnine in sandal. Indian Forester, 50: 456 – 458. Venkata Rao, M.G. 1938. The influence of host plants on Sandal spike disease. Indian Forester, 64: 656 -669.

Venkata Rao, M.G. 1938. The influence of host plants on Sandal spike disease. Indian Forester, 64: 656 -669.

Venkata Rao, M.G. and K. Badami (1930). A preliminary note on varieties of *Santalum album* L. Mysore Sandal spike Investigation Committee Bull. No.1

Venkatarama Ayyer, K.R. (1918). Is Spike disease of Sandal (*Santalum album* L) due to an unbalanced circulation of sap. Indian Forester, 44 (7): 316-324.

Venkatarama Ayyer, K.R. 1918. Is Spike disease of Sandal (Santalum album L) due to an unbalanced circulation of sap. Indian Forester, 44 (7): 316-324.

Venkataramaiah, N. (1937). Spike disease of sandal in Hassan district. Qrtly. Jour. Of Mysore Forest Dept., 5: 13.

Venkatesan, K.R. (1979). A note on the use of sandal in social forestry. Unpublished note of Sandal Research Centre, Bangalore.

Venkatesan, K.R. (1980). A fresh look at the management of Sandal. Proc. of Second Forestry Conference, F.R.I. & Colleges, Dehra Dun.

Venkatesan, K.R. and R.A. Srimathi (1981). Environment – A role of sandal. Proc. of Seminar on Forest & Environment, Karnataka Forest Department, Bangalore, 217 -220.

Venkatesan, K.R. and S. Kedarnath (1963). Breeding Sandal for resistance to the spike disease. World consultation of forest genetics and tree improvement, Stockholm, Section V, 69:1-9 (FAO FORGEN,63 6a/5, 9, 1963).

Verma A., V. V. Chenulu, S. P. Raychaudhuri, Nam Prakash and P. S. Rao [1969]. Mycoplasma like bodies in tissues infected with sandal spike and brinjal leaf. *Indian Phytopath.*, 22: 289-291.

Vijayakumar, H., J. Hiremath and P. K. Ashokan (2007). Influence of soil moisture regimes and stage of host introduction on seedling growth of sandal provenances. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 59-66.

Vijayakumar, N., M.M. Khan, V. Muniyappa and K.A Kushalapaa (1981). Studies on clonal propagation of sandal (*Santalum album* L.) by cuttings Report, University of Agri. Sci. Bangalore.

Vijendra, Rao R, T. R. Hemavathi, M. Sujatha and S. Shashikala (2007), Status on wood structure, heartwood formation, age, gaps and research needs in *Santalum album* L. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 165-177.

Villers, T.A. and P.F. Wareing (1960). Interaction of growth inhibitor and a natural germination stimulator in the dormancy of *Fraxinus excelsior* L., Nature, Lond. 185: 112-114. Viswanath, S., B. Dhanya and T. S. Rathore (2007). Financial viability of sandal (*Santalum album* L.) cultivation practices. Proceedings of National Seminar in IWST, Bangalore (December 12-13, 2007) pp 158-162.

Viswanath, S., S.M.Ahmed, K.S.Madhu, N.P. Kumar, C.Sowmya, S.C.Arade, M. Adhikari (2014). Performance of Sandalwood based agroforestry models with horticulture crops as secondary hosts in Karnataka. Abstracts of International Seminar on Sandalwood: Current Trends and Future Prospects in IWST, Bangalore (February 26-28, 2014) pp 24.

Walker, G. T. (1968). Chemistry of sandalwood oil. Perfu. Ess. Oil Rec., 59: 778.

Watt, J. S. [1893]. *Economic products of India*.

Wesley, D.G. (1970). Revised Working Plan for the sandal areas of Sirsi-Siddapur taluks of Sirsi Division, Sirsi, 1, (Karnataka),1

Winter, A,G. (1958). Significance of volatile oils for treatment of urinary passage infections. Planta Medica, 6: 306.

Winter, A.G. (1958). Significance of volatile oils for treatment of urinary passage infections. *Planta Medica, 6,* 306.

www.iucnredlist.org/details/31852/0 cited on 25/07/2019

www.ncbi.nlm.nih.gov// S.album oil as a botanical therapeutic in dermatology.

Yadav Roshan Kumar, Subrata Mukhopadhyay and Jagatpati Tah. 2018. Study of Edaphic Factors of the Location for the Growth of White Sandal (Santalum album L.) in Indo-Nepal Border. Asian Journal of Applied Science and Technology. Vol. 2(3). pp 115-126.

Yadav, V. K. and S. C. Bisarya (1982). Synthetic Aspects of Santalols in Santalenes. J. Sci. Indust. Res. 41: 650

Yetisen AK, Jiang L, Cooper JR, Qin Y, Palanivelu R, Zohar Y (May 2011). "A microsystem-based assay for studying pollen tube guidance in plant reproduction". J. Micromech. Microeng. **25**.

Zhang J, Zhou JM (September 2010). "Plant immunity triggered by microbial molecular signatures". *Molecular Plant.* **3** (5): 783–93. doi:10.1093.

Zhang1 Xin-Hua, Jaime A., Teixeira da Silva and Guo- Hua Ma (2010). Caryologia,63 (2): 142-148.

Zipfel C, Robatzek S, Navarro L, Oakeley EJ, Jones JD, Felix G, Boller T (April 2004). "Bacterial disease resistance in Arabidopsis through flagellin perception". Nature. **428** (6984): 764–7. Bibcode:2004Natur.428..764Z. doi:10.1038/nature02485. PMID 15085136.

Chapter-11

PUBLISHED PAPERS

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1. Assessment of Santalol oil of White Sandalwood (*Santalum Album* L.) in different locations of Nepal - Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. International Journal of current Science (IJCSPUB), Volume 13, Issue 2, May 2023, Page No_ 375 -385. Paper ID- IJCSP23B1159.
2. Santalol oil of Sandalwood (white) grown in different edaphic factors in West Bengal , India. Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. World Journal of Advanced Research and Reviews (WJARR), 19(01), 1404-1413, 2023.
3. 3. GEI Study on White Sandalwood (*Santalum album* L) from the Nepal and India. Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. International Journal of Current Advanced Research ISSN: O: 2319-6475, Available Online at www.journalijcar.org Volume 9; Issue 01 (A); January 2020 DOI: http://dx.doi.org/10.24327/ijcar.20
4. 4. Comparative study of Correlation Co-efficients of white sandal (*Santalum Album* L .) from three locations in Nepal. Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. Internation Journal of Current Research (IJCR). ISSN-0975833X Quarterly.
5. 5. A short Review on white sandalwood (*Santalum Album* L .) . Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. International Journal of Scientific Research and Reviews (IJSSR), 2019, Vol. 8, Issue-4, P. 73-136.
6. Factors Associated for the growth and development of White Sandal (*SANTALUM ALBUM* L.) plants in Bankura and Burdawan forest divisions. Registration Id; IJRAR_ 206223, Roshan Kumar Yadav, Jagatpati Tah, Subrata Mukhopadhayay, International Journal of Research and Analytical Reviews (IJRAR). June, 2018, Vol. 06, Issue-2, p.29-37.
7. Study of Edaphic factors of the locations for the growth of white sandalwood (*Santalum Album* L .) in Indo-Nepal border. Roshan Kumar Yadav, Subrata Mukhopadhyay and Jagatpati Tah. Asian Journal of Applied Scienceand Technology (AJAST), Vol. - 2, Issue – 3, P. 115-126 July-September, 2018.