The Sacred Dutjahn Tree

Western Australian Sandalwood essential oil & nut oil: a sustainable source of an ancient aromatic medicine

PART 1 ~ ECOLOGY & CUSTODIANSHIP
PART 2 ~ PHARMACOLOGY & THERAPEUTICS

Dr Kelly Ablard
Gabriel Mojay

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PART 1 ~ ECOLOGY & CUSTODIANSHIP

Dr Kelly Ablard

Taxonomy

Santalum spicatum, commonly referred to as *Western Australian sandalwood* or *dutjahn* by the Aboriginal desert Martu, belongs to the family Santalaceae, and is recognised as a 'true' sandalwood.

Santalaceae is a widely distributed family of flowering plants recognised for their partially parasitic behaviour on host plants, and for their aromatic wood.

Recognised synonyms of *Santalum spicatum* include *Santalum cygnorum* Miq., *Eucarya spicata* (R.Br.) Sprague & Summerh., *Fusanus cignorum* Kuntze, *F. spicatus* R.Br., F. *spicatus* var. frutescens Hochr., and *Mida cignorum* (R.Br.) Kuntze (RBGK, 2021).

FAMILY	Santalaceae
BINOMIAL	*Santalum spicatum*
SYNONYMS	*Santalum cygnorum* *Eucarya spicata* *Fusanus cignorum; F. spicatus* *Fusanus spicatus* var. *frutescens* *Mida cignorum; M. spicata*
ABORIGINAL	*Dutjahn* (Martu) *Waang* (Noongar)

Biology

Santalum spicatum occurs across a wide range of environmental conditions from Western Australia to South Australia. Its original habitat, currently over 50 million hectares, is located deep in the Gibson desert, northeast of Kalgoorlie, and is recognised under Australian Native Title as the *Dutjahn Homelands.* [Figs. 1 & 2]

Santalum spicatum is a root hemiparasitic tree that requires nutrients and water from host trees to survive, yet is capable of photosynthesis. Suitable hosts include nitrogen- fixing trees from the Acacia, Cassia, Casuarina, and Eremophila genera. Certain host species are commonly referred to by the Wongi and Martu peoples as a *water tree,* and *gidgee tree* (Smith, 2019; D. Farmer, personal communication, April 27, 2021).

Fig. 1: *Santalum spicatum* (Western Australian sandalwood)

Santalum spicatum grows slowly, reaching heights of 3-10 m tall. Trees are single- or multi-stemmed, and flower during years when there is consistent rainfall between January and April (Kealley, 1991). This varies between the species' two ecotypes— the arid and the semi-arid ecotype (Byrne et al, 2003a). In the semi-arid areas in the south, where there is relatively more rainfall, the species has larger leaves and nuts, higher chlorophyll content, generally thicker stems, and a lower concentration of essential oil than species in the arid northern areas (Loneragan, 1990; Fox & Band, 1993). The semi-arid ecotype can produce fragrant heartwood from age 5-10 years, while the arid ecotypes require a longer period of growth before they are capable of yielding viable quantities of essential oil (FPC, 2017).

Santalum spicatum has a preferentially out-crossing, or out-breeding, mating system, but is also capable of self-fertilisation under extreme conditions. A red-brown fruit with leathery skin develops from the flower when germination is successful. However, the survival rate of germinated seeds is as low as 20% in plantations and 1-5 % in cultivated plots (Kealley, 1991).

It is understood that the mating system of populations in the north have higher levels of genetic diversity than those in the south (Byrne et al, 2003b).

Conservation

There are currently 19 accepted species of Santalum, the majority of which have been classified as Threatened or Near Threatened, or as Extinct. Six of these accepted species occur in Australia - *Santalum spicatum*, *S. lanceolatum, S. acuminatum, S. murrayanum, S. obtusifolium* and *S. album*.

The top threats to *Santalum* species include climate change, habitat destruction, pathogens, illegal harvesting, and overexploitation with little or no sign of regeneration, (WCMC, 1998; Das and Pullaiah, 2021; IUCNa, IUCNb, 2021; RBGK, 2021).

The Threatened species subject to the greatest exploitation is *Santalum album,* traded for its scented heartwood and essential oil in local, regional and international markets (Das & Pullaiah 2021). Yet most of the world's demand for sandalwood essential oil is supplied from Western Australian sandalwood (*Santalum spicatum*) due to chemical-olfactory similarity (Shea et al, 1998; Burnes et al, 2003a; Pullaiah & Swamy, 2021). In contrast to *S. album, S. spicatum* is not as vulnerable to extinction. Commercial demand, however, continues to grow (Lingard and Perry, 2018), as it has done steadily since 1845 (Loneragan, 1990).

Sustainable management of this species is therefore imperative. The urgency of this fact was recognised in 1926 when Professor EH Rennie, in his presidential address to the Australian Association for the Advancement of Science, said, *"every precaution should be taken to provide against a complete extinction of this valuable tree"* (Williams, 2010).

When informed by Indigenous wisdom, conservation as a concept urges the current generation to make decisions for the benefit of children seven generations into the future. Making this principle a guiding one, Airmid Institute tailored five sustainability standards to essential- and carrier oil-bearing plants and their environment, to strengthen communities and foster ongoing success. The five overlapping standards are: social, environmental, cultural, economic, and distribution labelling.

Meeting these standards entails enhancing the quality of the environment and its natural resources— through implementing renewable resources efficiently, developing financial stability, and through fostering local and global community outreach and engagement, research and education. Success also requires collaboration between, for example, scientists and Indigenous peoples. This is especially important when dealing with a species for which biology and cultivation is delicate and complicated, and for which regeneration is required after harvesting.

Extraction of essential and seed oil from plant material must also be carefully carried out, and in a timely fashion. Distillations should be efficient, and should integrate renewable resources into the process. Chemical analysis should be performed on batches of essential oil regularly, and the data made available for public consumption. Quality-control checks of the laboratory and distillation equipment should be integral— while the implementation of these standards throughout the supply chain of *S. spicatum,* an internationally traded oil-bearing plant, is critical.

Corporate dedication to the sustainable management of *S. spicatum* according to the five pillars of sustainability is demonstrated by Australian-based Dutjahn Sandalwood Oils (DSO), a company brought to life by Dutjahn Custodians. Dutjahn Custodians are Traditional Gibson Desert 2nd contact Aboriginal desert nomads of Wongi and Martu heritage who have been sustainably harvesting *dutjahn* since 1977. [Fig. 3]

Fig. 2: *Santalum spicatum* (Western Australian sandalwood) plantation

Dutjahn Custodians Clinton Farmer, Chairman of Kutkabbuba Aboriginal Corporation, and Darren Farmer, Dutjahn Director, were instrumental in winning a landmark Native Title settlement over their homelands in 2014. They carried out the vision of their ancestors to establish the DSO company so that it could be a successful example of socio-economic independence for other Aboriginal communities in their homeland. Their initiatives gained further momentum in 2017 when the Aboriginal desert nomads partnered with the founders of Australia's largest *S. spicatum* plantation company. The collaboration is rooted in the ancestral knowledge of, and respect for, wild *dutjahn*, together with modern knowledge of Western Australian sandalwood oil production. The five sustainability standards help to ensure a sustainable and quality resource of essential and carrier oil for future generations.

Social sustainability

Social sustainability means: enriching and preserving communities through social engagement, community investment, equal access to social resources, equal opportunity, and community-based education while respecting social diversity and community members as well as implementing practices that will benefit future generations.

Community

- DSO was the first Australian company to be awarded the United Nations Equator Prize. Recipients of this award are recognised for their exemplary work in developing sustainable environmental solutions to the impacts of climate change in collaboration with local and Aboriginal communities. [Fig. 4]

- A percentage of DSO profits are allocated to community-based Aboriginal educational and training programmes.

Collaboration

- DSO and the K.Farmer Dutjahn Foundation (KFDF), a separate not-for-profit foundation, have collaborated on health projects designed to protect Aboriginal communities against Covid-19, and are in the process of developing further projects focused on education, and environmental and cultural protection. DSO is committed to contributing AUD$200,000 to KFDF to support these projects and the Aboriginal people.

- DSO has many clients who request specific grades of essential oil to meet a chosen odour and/or chemical profile. Collaborative work is conducted internally and externally to advance special research and development projects for mutual benefit.

Environmental sustainability

Environmental sustainability means: the ongoing management of a physical environment that supports and enriches the biodiversity, protection and preservation of natural resources, and that balances the needs of communities to benefit future generations.

Ancestral cultivation

- Aboriginal desert nomads work closely with Nature to preserve *dutjahn* (D. Farmer, personal communication, April, 27, 2021). They are the tree's master cultivators and caretakers. This mastery comes from ancestral knowledge passed down through hundreds of generations, and is the result of a deep connection to the environmentm and an understanding of its ecology. With their deep respect for Nature, the Martu have an abiding dedication to caring for the plants they are responsible for.

- Aboriginal knowledge of *dutjahn* pollination biology, flowering times, and outcrossing rates is comprehensive. A high level of genetic diversity is key for the survival of many plants such as *dutjahn* that are sustaining impacts of climate change. Dutjahn Custodian Darren Farmer explains that climate change is a significant problem for *dutjahn* cultivation because it is causing longer periods of drought. He recently witnessed the longest dry season in 40 years (personal communication, April 27, 2021). *Dutjahn* caretakers rely on rain as their only source of water, and turn to their cultural plant wisdom for answers regarding this dilemma. One solution is genetic diversification through selective regeneration and genetic reinforcement of seeds from trees that appear straight in form, are healthy (i.e. disease-free), show strong annual growth, and respond well to micro-climatic changes.

- Seeds are planted by hand when the weather permits; the timing of germination needs to be exact. Without the right host for this hemiparasitic plant, *dutjahn* will not grow properly, nor will the essential oil be of good quality. Host trees are not planted by the Aboriginal caretakers, so they must be able to identify and choose the right host for each *dutjahn* seed. Limiting factors such as location, host plant health, water availability, and micro-climatic conditions can make finding a suitable match for a *dutjahn* plant a challenge. High-quality essential oil is a post-indicator of an efficient Western Australian sandalwood (*Santalum spicatum*) plantation host match. To the untrained, achieving a successful outcome would appear to require decades. However, timely success lies with the Aboriginal caretakers' intuitive decisions guided by their ancestral plant wisdom.

Natural resources

- Natural resources are the only resources utilised by the Aboriginal caretakers.

Pest control

- Aboriginal caretakers are readily able to identify *dutjhan* pathogens, and rely on ancestral knowledge of their life cycles in place of agrochemicals to control them naturally.

Sustainable sourcing

- The Western Australian Forest Products Act 2000 established the Forest Products Commission (FPC) to manage *S. spicatum* harvesting and supply (Forest Products Act 2000; Biodiversity Conservation Act 2016). The FPC mission is to support an *"environmentally sustainable and commercially viable forest products industry"* (FPC, 2017). Dutjahn Custodians were granted a supply contract in recognition of their commitment to environmental and social sustainability. In addition to obtaining wood from Native Title Lands, DSO also source from Western Australian Plantations Pty Ltd., and purchase wood from Aboriginal harvesters in the Kuktabubba Aboriginal Community and in the region surrounding Wiluna, Western Australia.

- DSO is now a Provisional Member to UEBT Union for Ethical Biotrade (https://www.ethicalbiotrade.org/about- uebt) and aims to become a full member with verified certification by the end of 2021.

- Western Australian Sandalwood Plantations Pty Ltd. currently manages, in addition, over 13,000 hectares of sandalwood plantations— at which harvesting began in 2015 and will continue over the next 25 years.

Sustainable harvesting

- DSO harvest teams are compromised of 80-100 per cent Aboriginal people. Dutjahn harvesters are known for their great dedication, travelling some 600 km into the bush to set up base camp. Setting out early to harvest whole trees, they debark the precious timber and load it onto trucks for processing and distillation. For each tree that is removed, 10-15 seeds are planted.

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Cultural sustainability

Cultural sustainability means: ensuring that educational and cultural initiatives respect and preserve traditional and Indigenous traditions, customs, beliefs and practices.

Education and engagement

- DSO employs a Cultural Liaison professional whose remit is to develop cultural and education programmes for DSO staff, clients and stakeholders generally—fostering cultural understanding and sensitivity.

- Training programmes, designed to provide instruction for Rangers on Indigenous practice, have been developed for various DSO projects.

Indigenous involvement

- What makes DSO unique is its partnership with the Dutjahn Custodians and Aboriginal peoples. It is well documented that, within the industry, other institutions often did little to consider Aboriginal knowledge and concerns and learn their ways. Organizations were all too often failing to prioritise long-term economic opportunities for Aboriginal communities (Lingard and Perry, 2018). DSO has proved itself to be a notable exception, indeed a model for a successful Indigenous enterprise (Mozley, 2019). Moreover, the strong relationship between DSO and the Aboriginal communities has delivered high employee retention rates and a firm foundation for the future growth of DSO.

- DSO is strongly influenced by Martu and Wongi culture. Aboriginal culture impacts and fosters executive business decisions, community engagement, educational programmes and community gatherings (D. Farmer, personal communication, April 27, 2021).

- 50% of DSO Directors are represented by Aboriginal people, and 17% of the workforce on the production end is Aboriginal.

Spiritual practice

Indigenous beliefs and community rituals reflect the deep spiritual culture of Australia's Aboriginal desert nomads. *Dutjahn* plays an important part in that spiritual culture— in terms of its symbolic ritual role and ethnopharmacology as well as its economic importance. In this way, *dutjahn* is at the heart of Martu and Wongi spiritual practice (D. Farmer, personal communication, April 27, 2021).

Distribution and labelling sustainability

Sustainability of distribution and labelling means: accurate, truthful public disclosure of information; transparency and integrity in distribution and recycling; and effective policies of conservation and reuse. These guidelines are in addition to trading within legal parameters and with the necessary permits.

Transparency

- New products are developed within transparent commercial guidelines to ensure adherence to Access and Benefit Sharing and with Prior and Informed Consent with Indigenous Australians.

Fig. 3: Dutjahn Custodians and harvesters in the bush alongside a *dutjahn* (*Santalum spicatum*) and host tree

Fig. 4: DSO was the first Australian company to be awarded the United Nations Equator Prize.

Renewable materials

- DSO rolled out a new system of environmentally friendly packaging options in July 2021.

Distillation

- Essential oil from sustainably wild-harvested green and dead plant material, and sustainably managed green plantation wood, is extracted using steam distillation in a stainless steel still. The first fraction of the crude essential oil is removed and set aside. The second fraction undergoes further refinement via a proprietary process.

- Hydrosol, the more mild-scented aqueous by-product of distillation, is used in cosmetic applications and as an addition to wood powder for incense manufacture.

Quality control

- Quality assurance measures are in place throughout the manufacturing process, from wood lot verification, crude and purified oil production to blending of oils. Detailed records are kept, weights are measured, identities verified, and batch quality validated.

- *Santalum spicatum* essential oil production is quality controlled physically, chemically and organoleptically. Each crude batch of essential oil is tested for its Refractive Index, Optical Rotation, Acid Value and Gas Chromatograph with Flame Ionization (GCFID). The chemical analysis of each crude lot assists in the final blending of the finished batches. Most DSO oil is produced to meet ISO specification for *Santalum spicatum* essential oil unless otherwise requested. For example, refined oils from different provenances and/or tree parts can be blended to create DSO grades of essential oil to customer specification.

Transportation

- To help reduce greenhouse gas emissions, DSO and their suppliers consolidate shipments with larger transport vehicles. This allows the harvest crews to spend many weeks in remote areas collecting significant tonnage of wood before its transport to the processing facilities.

Economic sustainability

Economic sustainability means: practices that support long-term economic growth and fair and adequate compensation without compromising social, environmental, and cultural sustainability.

- DSO is 50% Aboriginal-owned.

- DSO Directors started the company with experience, cultural respect and monetary investment, investing the seed money to grow the business. Since its inception the DSO Board, with its years of financial experience, has ensured the business has grown responsibly. It has managed the company's material and human capital expansion sustainably, avoiding excessive debt and undue risk. Financial stability came from wise investments and good business practice as well as assured partnerships with key customers who recognized DSO's unique business model. Givaudan and the Estee Lauder Companies are foundational partners in DSO's success, buying product at a fair and equitable price and committing to ordering timeframes. Relationships are the key to DSO's success.

- DSO is developing a line of Aboriginal-inspired products that will come with stories told by the communities who will sell them.

Traditional uses

Dutjahn has long been used as a traditional medicine, as a protective aid, and in cultural practices and ceremonies by the Martu and Wongi Nations for centuries.

Traditional medicine

- The moist inner lining of *dutjahn* bark is placed directly onto an area of the body that is afflicted or wounded to help reduce inflammation and infection, and to help accelerate healing.

- The hard outer lining of *dutjahn* bark, its crushed leaves, and its nuts can be heated over a fire and used externally to reduce muscle pain, prevent infection, and accelerate healing of an external or internal injury.

- The cream from the *dutjahn* nut is often used to moisturise the skin and to help combat skin ailments within the communities.

Protection

- *Dutjahn* is a symbol of protection. This is reflected, for example, in the practice of burning *dutjahn* bark to ward off snakes. It can provide a natural barrier between humankind and evil spirits, and protects families camped out in the bush.

- The bark is also burned to ward off mosquitoes. Interestingly, research conducted on a sesquiterpene alcohol derived from *S. spictaum* (*dutjahn*) was determined to be a prime candidate for use as a mosquito abatement (Spafford, 2007).

Cultural practices

There is a cultural expectation to confer a gift when visiting custodians on territory outside your homeland. The gifts are given to gain trust and to be allowed the freedom to enter restricted areas. A gift of *dutjahn* wood, a boomerang, or an offerring of meat would be considered acceptable and indeed generous.

Cultural ceremonies

The smoke from burning *dutjahn* bark is used in community ceremonies for ritual cleansing, and to enhance the private practice of meditation. Objects used as part of these ceremonies are frequently made from *dutjahn* wood. Ceremonies are still practised today using the bark and other parts of *dutjahn* that are considered too sacred to disclose (D. Farmer, personal communication, 27.04.21).

In summary

When sourcing a precious aromatic material such as essential oil of sandalwood, for both its fine fragrance and promising therapeutics – the subjects of Part 2 of *the Sacred Dutjhan Tree,* 'Pharmacology & Therapeutics', it is essential to be guided by principles of sustainability in all its forms. It is incumbent upon us as professionals to understand and respect the importance of its modern and traditional use within Indigenous communities. *Doing so will help to foster sustainable, ethical sources of medicinal and aromatic plants for generations to come.*

References

Arunkumar AN, Dhyani A, Joshi G. *Santalum album.* The IUCN Red List of Threatened Species: e.T31852A2807668.https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS T31852A280766en. Accessed July 2022.

Barstow M. *Santalum austrocaledonicum.* The IUCN Red List of Threatened Species: e.T177878A1499004. https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T177878A1499004 en. Accessed July 2022.

Biodiversity Conservation Act. Western Australian. Version 00-d0-01. 2016. www.legislation.wa.gov.au.

Byrne M, Macdonald B, Brand J. Phylogeography and divergence in the chloroplast genome of Western Australian sandalwood (*Santalum spicatum*). *Heredity.* 2003, 91, 389-395.

Byrne M, Macdonald B, Broadhurst L, Brand J. Regional genetic differentiation in Western Australian sandalwood (*Santalum spicatum*) as revealed by nuclear RFLP analysis. *Theor Appl Genet.* 2003, 107, 1208-1214.

Das SD, Pullaiah T. Sustainable use, threats, and conservation of sandalwood. In: Pullaiah T, Bapat VA, Reddy VD, Das SC, Swamy MK; Murthy KSR (Eds.), *Sandalwood: Silviculture, Conservation and Applications.* (267-277). Springer, 2021.

Fox JED, Brand JE. Preliminary observations on ecotypic variation in *Santalum spicatum* 1. Phenotypic variation. Mulga Research Centre Journal. 1993, 11, 1-12.

Forest Products Commission (FPC). Native sandal--wood industry strategy for Western Australia: Six steps for a valuable, sustainable industry in regional WA, Western Australian Government. 2017 https://www.wa.gov.au/government/publications/fpc-native-sandalwood-industry-strategy.

Gowland, K. 2021. *Santalum spicatum.* The IUCN Red List of Threatened Species: e.T172724199A172724334 https://dx.doi.org/10.2305/IUCN.UK.20213.RLTS.T172724199A172724334.en. Accessed July 2022.

Grave E, Kroessig T. *Santalum paniculatum*. 2020. The IUCN Red List of Threatened Species:e.T116996583A120702770.https://dx.doi.org/10.2305/IUCN.UK.20201.RLTS.T116996583A120702770en. Accessed July 2022.

International Union for Conservation of Nature (IUCN). Regional Red List. August 2021. https://www.iucnredlist.org.

Kealley IG. The management of sandalwood. Wildlife Management Program. 1991, 8, 1-137. Department of Environment and Conservation. Western Australian Parliament.

Lingard K, Loneragan OW. Historical review of sandalwood (*Santalum spicatum*): research in Western Australia. Research Bulletin No. 4. 1990. Department of Conservation and Land Management, Perth.

Mozley S. Dutjahn sandalwood oils becomes first Australian business to win UN equator prize. *National Indigenous Times.* 2019. https://nit.com.au/dutjahn-sandalwood-oils-becomes-first-australian-business-to-win-un-equator-prize/

Perry M. An assessment of the regulatory framework of the Western Australian sandalwood industry. Australian Forestry. 2018. https://doi.org/10.1080/00049158.2017.1420455.

Pullaiah T, Swamy MK.Sandalwood: The green gold. In: Pullaiah T, Bapat VA, Reddy VD, Das SC, Swamy MK; Murthy KSR (Eds.), *Sandalwood: Silviculture, Conservation and Applications.* (267-277). Springer, 2021.

Royal Botanic Gardens Kew (RBGK). Plants of the world online. 2022. http://www.plantsoftheworld online.org/ Accessed July 2022.

Shea SR, Radomiljac A, Brand J, Jones P. An overview of sandalwood and the development of sandal in farm forestry in Western Australia. In: Radomiljac AM, Ananthapadmanabho HS, Welbourn RM, Satyanarayana RK (Eds.). *Sandal and its Products.* ACIAR: Canberra. 9-15. 1985.

Smith PA. Stimulation of Western Australian sandalwood (*Santalum spicatum*) oil production using multiple treatments. Edith Cowan University. 2019. https://ro.ecu.edu.au/theses/2202/

Spafford H, Jardine A, Carver S, Tarala K, van Weiss M, Weinstein, P. Laboratory determination of efficacy of a *Santalum spicatum* extract for mosquito control. *J Eur Mosq Control.* 2007, 22(3), 304-311.

Victoria State of Government. Santalum lanceoletum. Department of Environment, Land, Water and Planning list of rare and threatened plants. 2014. https://www.delwp.vic.gov.au/

World Conservation Monitoring Centre (WCMC). *Santalum fernandezianum.* IUCN Red List of Threatened Species 1998. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T30406A9544750.en. Accessed August 2021.

Williams C. *Medicinal Plants of Australia.* Vol. 1, *Bush Pharmacy.* Rosenberg Publishing. 2010.

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The Sacred Dutjahn Tree

Western Australian Sandalwood essential oil & nut oil: a sustainable source of an ancient aromatic medicine

PART 2 ~ PHARMACOLOGY & THERAPEUTICS

Gabriel Mojay

Introduction: the Sacred Dutjahn Tree

The Santalaceae family consists of 29 genera composed of approximately 400 species, 19 of which belong to the Santalum genus (Harbaugh et al, 2010). Indian sandalwood (*Santalum album*) has long held a prominent position culturally and economically in India and throughout the world, while Western Australian sandalwood (*Santalum spicatum*) has been an important timber crop since the 1850s, valued for its fragrant heartwood, essential oil and nut oil. [Figs. 1 & 5]

Western Australian sandalwood (*S. spicatum*), known as dutjahn by the Indigenous Martu, the tree's ancestral guardians, is one of six Santalum species endemic to the Continent. *S. spicatum* is concentrated in the arid and semi-arid areas of western and southern Australia (Harbaugh, 2007).

Sandalwood is a root hemiparasite that draws water and nutrients from host trees through *haustoria*— root-like structures that grow into or around another plant structure in order to absorb moisture and nourishment. Capable of photosynthesis, hemiparasitic plants do not necessarily have a negative influence on their host (Loveys & Tyerman, 2002).

Hemiparasites such as Santalum produce large, nutritious fruits which help to sustain other species; thus, the tree functions ecologically to redirect nutrients from the host important to the survival of other organisms (Watson, 2009; Watson et al, 2011).

Due to their hemiparasitic nature, sandalwood trees are found in habitats suited primarily to their hosts, from fertile meadows to granite cliffs. Acacia trees are the most common hosts, though species of Eucalyptus, Casuarina and other shrubs are also seen.

FAMILY	Santalaceae
BINOMIAL	*Santalum spicatum*
SYNONYMS	*Santalum cygnorum* *Eucarya spicata* *Fusanus cignorum; F. spicatus* *Fusanus spicatus* var. *frutescens* *Mida cignorum; M. spicata*
ABORIGINAL	*Dutjahn* (Martu) *Waang* (Noongar)

Fig 1: *S. spicatum* (Western Australian sandalwood) fruit

Biology

Australia is home to six species of Santalum, which ranges as a genus from India and Papua New Guinea to the Pacific Islands (Harbaugh & Baldwin, 2007). The six species occurring in Australia – S*antalum spicatum, S. lanceolatum, S. leptocladum, S. acuminatum, S. murrayanum* and *S. obtusifolium* - are distributed widely across the Continent.

Species of the genus Santalum have been heavily exploited for centuries, resulting in the fact that the 19 species listed in TABLE 1 are classified globally or nationally as follows:

- **Vulnerable** (6 species incl. *S. album* and *S. spicatum*)
- **Near Threatened** (1 species: *S. austrocaledonicum*)
- **Endangered, or Imperiled** (10 species)
- **Critically Endangered** (1 species: *S. macgregorii*)
- **Extinct** (1 species: *S. fernandezianum*)
- **Not listed:** (1 species: *S. papuanum*)

The long-standing commercial exploitation of the oil-rich fragrant heartwood has resulted in a deep reduction in the biodiversity of the genus as a whole. Together with the effects of climate change on natural resources, the situation is one that requires – indeed, *has* required - effective action to preserve what is left of remnant native and wild species.

Today, much of the world's demand for sandalwood essential oil is met by West Australian sandalwood (*S. spicatum*) due to the similarity of chemical composition and fragrance it shares with Indian sandalwood (*S. album*) (Pullaiah & Swamy, 2021).

To reduce pressure on wild stands, Western Australian sandalwood is often harvested from stands on plantations established on former agricultural land. The potential exists for the significant improvement of *S. spicatum* plantations through selecting trees with desirable growth characteristics and chemical constituent profiles. The sustainable development of this species – a species adapted to the arid biosphere of Western Australia - will advance conservation goals as well as improve the essential oil's commercial potential (Moniodis et al, 2017).

Sandalwood essential oil is commonly produced through the steam distillation of the chipped heartwood, over 40-70 hours. Oils are also produced through hydrodistillation, steam-hydrodistillation, microwave hydrodistillation and supercritical carbon dioxide (CO2) extraction. The oil is generally colorless to pale-yellow, and slightly viscous. (Kusuma & Mahfud, 2016).

The essential oil of *Santalum album* develops in the heartwood and root of the tree over a 10-15 year period. Trees require 60-80 years to produce essential oil considered by those in the industry to possess the finest aroma. The average yield by weight of *S. album* oil is 4.5-6.25%, with the greatest concentration occurring in the roots, at proportions of up to 10% by weight (Baldovini, 2011). Similarly, essential oil is produced in the heartwood of *S. spicatum* trees 10 years and older.

Compositon

Sandalwood extracts consist of a complex mixture of sesquiterpenoids with a distinct chemical make-up apparent across species, and frequently observable within species (Moretta, 2001). More than 230 constituents belonging to different chemical classes have been identified in the heartwood of *S. album.* While these are mainly terpenoids, the tree is also rich in saponins, phenolics and tannins (Misra & Day, 2012).

Of the many chemical constituents that have been identified in *S. album* essential oil, the sesquiterpenic geometric isomers α-santalol and β-santalol (C15H24O) are the most abundant. α-Santalol and β-santalol consist of a bicyclic ring system covalently linked to an aliphatic unsaturated chain containing a hydroxyl functional group. They are the principal molecules responsible for sandalwood oil's fragrance as well as its biological activities. [Figs. 2 & 3] [TABLES 2 & 3]

α-Santalol is a sesquiterpenic alcohol with a molecular weight of 220.35 g, a boiling point of 166° C, and density of 0.9770 g/cm3. α-Santalene, α-santalal, β-santalal, epi-β-santalal, α-santalol, β-santalol, (E)-β-santalol, α-bergamotol and spirosantalol have been identified as key odour components in sandalwood oils (Nikiforov et al, 1988; Howes et al, 2004).

α-Santalol contributes a mild sweet-woody scent, while β-santalol is more responsible for the oil's characteristic, widely admired smooth, creamy, sweet-woody, musky-diffusive fragrance (Baldovini et al, 2011). In terms of established international essential oil trade standards, *S. album* should contain between 41%–55% α-santalol and 16%–24% β-santalol (Dwivedi et al, 2003).

Heartwood extracts of *S. spicatum* contain over 100 individual sesquiterpenes. Many of these compounds have demonstrated a fungicidal action, one which protects the tree against wood-rotting fungal pathogens due to their high concentration in the heartwood.

The most abundant compounds in *S. spicatum* essential oil are α- and β-santalol, farnesol, nuciferol, α- and β-bisabolol, bergamotol and lanceol, together with a variety of minor compounds including olefins such as the santalenes, bergamotene and curcumenes (Brophy et al, 1991; Valder et al, 2003).

TABLE 1: SANTALUM SPECIES

SPECIES	HABIT	ORIGIN	CHEMISTRY	IUCN STATUS
Santalum spicatum West Australian sandalwood *dutjahn* (Martu); *waang* (Noongar)	shrub	southwest Australia	***ess oil:*** (Z)-α-santalol (25-40%), (Z)-β-santalol (8-15%) ***nut oil:*** ximenynic acid (35%)	Vulnerable
Santalum album Indian sandalwood *chandana* (Sanskrit); *chandan* (Sanskrit)	tree	India, Sri Lanka, eastern Indonesia, northern Australia	***ess oil:*** (Z)-α-santalol (46-60%), (Z)-β-santalol (20-29%)	Vulnerable
Santalum acuminatum desert quandong; sweet quandong *guwandhang* (Wiradjuri); *wolgol* (Noongar)	shrub	central & southern Australia	***ess oil:*** No santalols. ***nut oil:*** ximenynic acid (32-46% of total fatty acids)	Vulnerable (TPWC Act)
Santalum austrocaledonicum Coral Sea sandalwood *sandalwud* (Vanuatu); *bois de santal* (French)	tree	New Caledonia & Vanuatu	***ess oil:*** (Z)-α-santalol (46-50%), (Z)-β-santalol (18-25%)	Near Threatened
Santalum boninense Bonin Islands sandalwood *muninbakudan* (Japanese)	shrub	Ogasawara-shoto, Japan	[not extracted]	Endangered: Japan
Santalum ellipticum coastal sandalwood *ʻiliahialoʻe* (Hawaiian)	tree	Hawaiian Islands	[not extracted]	Imperiled (NatureServe)
Santalum fernandezianum Chile sandalwood *sándalo de Juan Fernandez* (Spanish)	tree	Juan Fernández Islands, Chile	[not extracted]	Extinct
Santalum freycinetianum forest sandalwood, Freycinet sandalwood *iliahi* (Hawaiian)	tree	Hawaiian Islands	[not extracted]	Endangered
Santalum haleakalae Haleakala sandalwood *ʻiliahi* (Hawaiian)	tree	East Maui volcano Maui, Hawaii (slopes of Haleakalā)	[not extracted]	Vulnerable
Santalum insulare Polynesian sandalwood *puahi* (Marquesas Islands, French Polynesia)	tree	eastern Polynesia	[not extracted]	Endangered
Santalum involutum Involute sandalwood *ʻiliahi* (Hawaiian)	tree	Hawaiian Islands (Kauaʻi)	[not extracted]	Endangered
Santalum lanceolatum desert quandong, northern sandalwood bale bush, *dumbuyumbu* (Marra; Alawa)	shrub	eastern & northern Australia	***ess oil:*** (Z)-α-santalol (0.6-2.6%), (Z)-β-santalol (2-4.3%), Z-lanceol (20–90%)	Endangered: Northern Australia
Santalum macgregorii Papua New Guinea sandalwood *botto* (Motu)	tree	Papua New Guinea	***ess oil:*** (Z)-α-santalol (0.5-51%), (Z)-β-santalol (>24%), (Z)-lanceol (0–72%)	Critically Endangered
Santalum murrayanum bitter quandong *coolyar* (Noongar)	tree	southern Western Australia	[not extracted]	Endangered: Australia
Santalum obtusifolium blunt sandalwood southern sandalwood; scrub sandalwood	shrub	eastern Australia	***nut oil:*** ximenynic acid (72%), oleic acid (14%)	Vulnerable: Australia
Santalum paniculatum mountain sandalwood, Hawaiian sandalwood, *ʻiliahi* (Hawaiian)	tree	Hawaiian Islands	***ess oil:*** (Z)-α-santalol (35-40%), (Z)-β-santalol (11-16%)	Vulnerable
Santalum papuanum ba bu ya tan xiang (Chinese)	tree	New Guinea	[not extracted]	[not listed]
Santalum pyrularium Kauaʻi forest sandalwood	tree	Kauaʻi, Hawaiian Islands	[not extracted]	Endangered
Santalum yasi yasi; yasi dina (Fijian)	tree	Fiji, Tonga, Niue	[not extracted]	Endangered

A study of the heartwood cores of 87 *Santalum spicatum* trees from 12 different sites in Western Australia revealed that levels of α- and β-santalol can vary from 3%–67%, and E,E-farnesol from 5%–30%, across the entire distribution range (Moretta, 2001).

Western Australian sandalwood nut oil is produced through cold expression of the kernel to produce an oil rich in the monounsaturated omega-9 oleic acid, and the polyunsaturated acetylenic fatty acid ximenynic acid. Ximenynic acid has demonstrated anti-inflammatory, antiproliferative, proapoptotic, anticancer activities (Cai et al, 2016) as well as an antidiabetic effect. (Zhang et al, 2021) [TABLE 4].

Traditional and scientific therapeutics

Sandalwood essential oil possesses a milky-musky, sweet-woody fragrance consistent in psycho-energetic terms with its ability to calm the mind and soothe, center and uplift the spirit.

Warmly aromatic yet soft and 'neutral', its unimposing fragrance nature has contributed to its status as a classic perfume fixative. It is this same unique quality that makes sandalwood essential oil intrinsic to the production of traditional aromatic oils in Kannauj, India, in which it provides flowers such as champaka and jasmine with a luxuriously diffusive solvent base to produce an often floral *attar* (from the Arabic for 'perfume, essence').

For centuries in the Indian subcontinent, the benefits of sandalwood's uniquely potent phytochemistry have been exploited in the form of pastes, emulsions, decoctions and powders as well as through the essential oil and traditional attar.

From an Ayurvedic perspective, sandalwood was considered *Sattvic*— corporeally and spiritually pure; beneficial for both mind and body, innately virtuous and healing. This special quality it has to instil purity – the heartwood itself protects and regenerates - is reflected in its remarkable antioxidant, anti-inflammatory, antimutagenic and anticancer activities (Santha & Dwivedi, 2013; 2015).

Sandalwood is used in the traditional Tibb-Unani system of medicine to treat gastric ulcers and diverse disorders including those of a cardiac, neurological, hepatic and dermal nature (Kausar et al, 2014). In Oriental medicine, sandalwood extracts are used to treat inflammatory skin disorders, dyspepsia and gastritis, genitourinary infections, and chronic anxiety (Misra & Dey, 2013).

Sandalwood's ancient reputation as a medicine for the body and mind, able to restore vitality as well as instil serenity, has been coupled with its widespread use in ritual space since time immemorial. A key temple incense and meditation aid, it gained over time an almost magical status— indeed, one of sanctity and transformation, throughout Asia and in Aboriginal Australia.

Sandalwood essential oil exerts an anti-inflammatory action in keeping with its ancient reputation as a cooling, soothing herbal paste and aromatic extract. Its anti-inflammatory activity combines with its antioxidant action to give it its remarkable chemopreventive, protective faculty.

In clinical aromatherapy, sandalwood essential oil is employed in aromatic formulae to relieve chronic nervous tension, anxiety and depression, depending on the precise condition of the individual (Setzer, 2009).

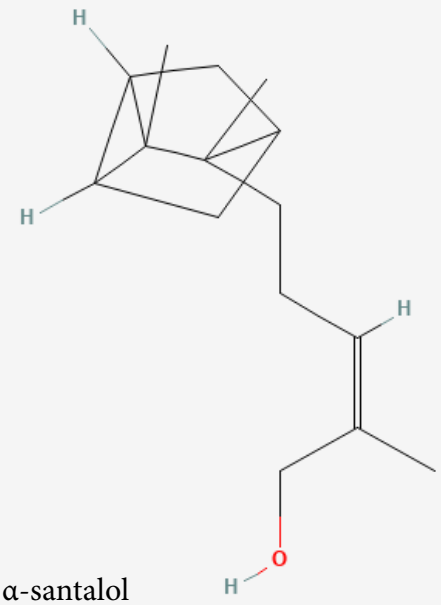


Fig 2: α-santalol

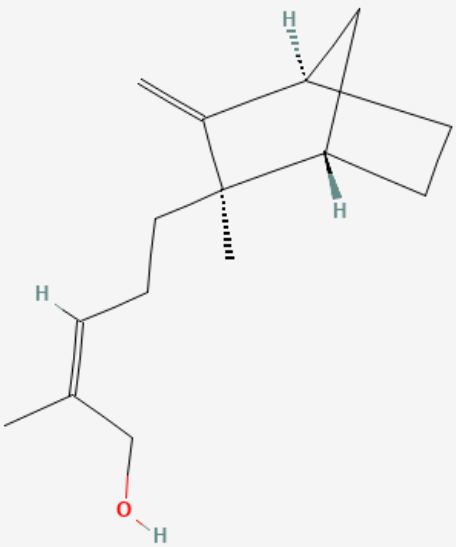


Fig 3: β-santalol

TABLE 2: INDIAN SANDALWOOD (*SANTALUM ALBUM*) ESSENTIAL OIL KEY CONSTITUENTS

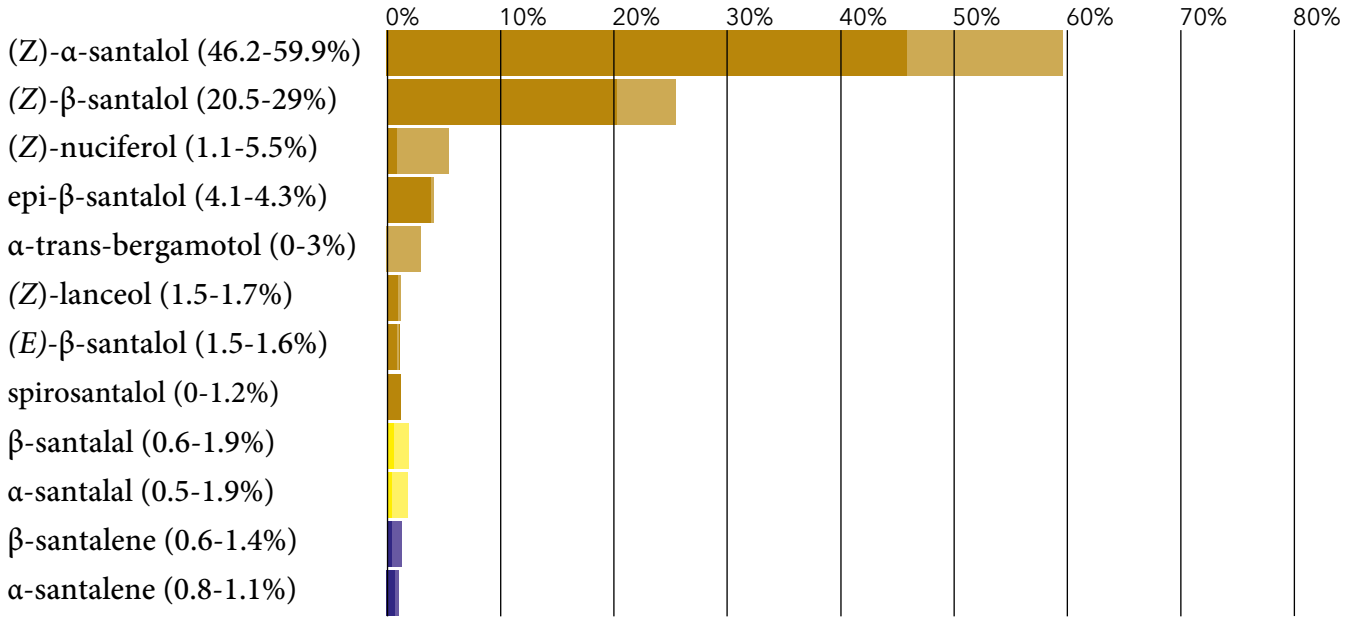


TABLE 3: WESTERN AUSTRALIAN SANDALWOOD (*SANTALUM SPICATUM*) ESSENTIAL OIL KEY CONSTITUENTS

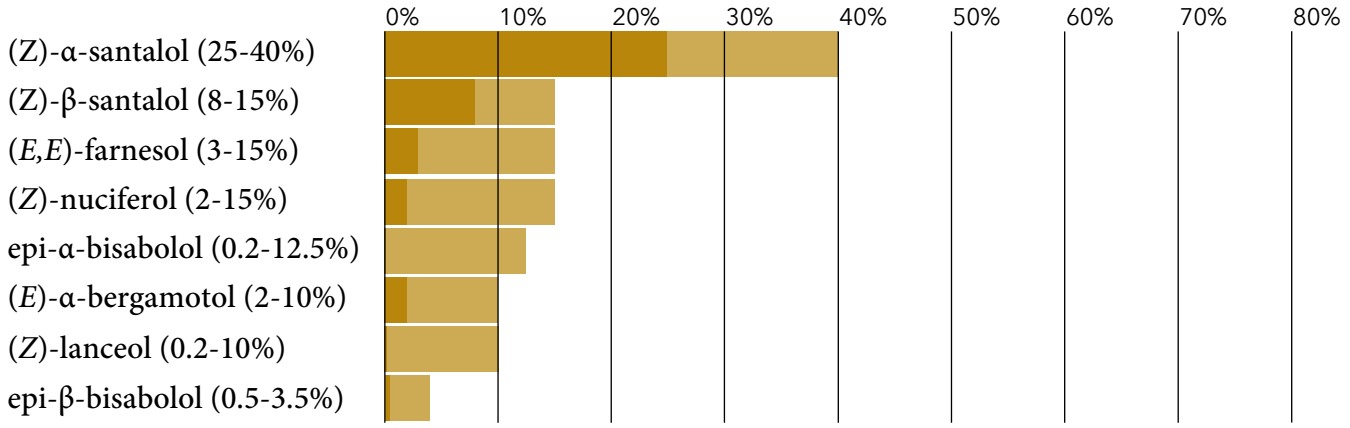
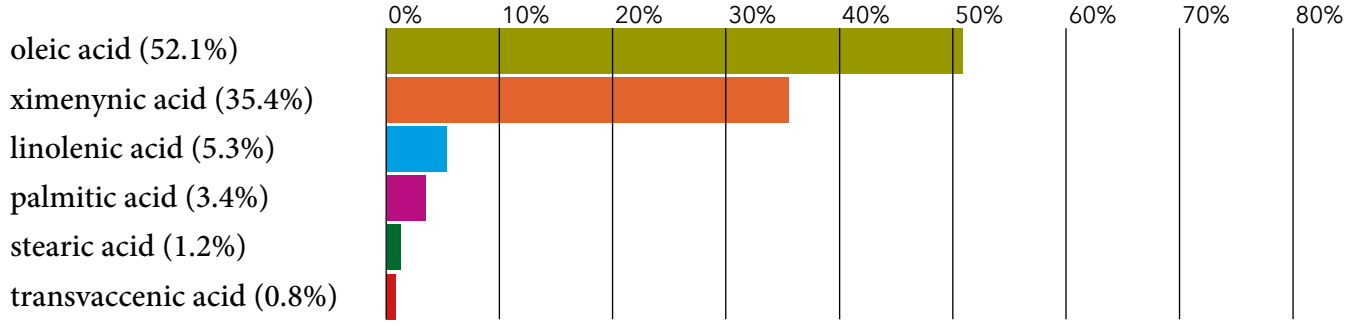


TABLE 4: WESTERN AUSTRALIAN SANDALWOOD (*SANTALUM SPICATUM*) NUT OIL KEY CONSTITUENTS



Key to functional group:

- sesquiterpenol
- aldehyde
- sesquiterpene
- monounsaturated omega-9 fatty acid
- polyunsaturated acetylenic fatty acid
- polyunsaturated omega-3/6 fatty acid
- C16 saturated fatty acid
- octadecanoic saturated fatty acid
- trans-unsaturated fatty acid

Possessing central nervous system depressant, neuroleptic and bronchial-dilating effects, the essential oil encourages improved sleep hygiene and a more restful night's sleep. α-Santalol in particular has been shown to be readily absorbed into the blood via the circulatory system through the pulmonary mucosa (Ohmori et al, 2007).

In terms of palliative care, too, the results of a pilot study to evaluate the effectiveness of daily aromatherapy interventions support the observation that sandalwood essential oil, applied either transdermally or via olfaction-inhalation, is effective in reducing anxiety in palliative and end-of-life care (Kyle, 2006).

In terms of dermatology, sandalwood essential oil has been utilized topically for centuries in both Ayurvedic and traditional Oriental medicine.

Many skin conditions and diseases are characterized by inflammation, infection and *hyperplasia*; swelling and thickening. In general pathological terms, hyperplasia is enlargement of an organ or tissue resulting from an increase in cellular reproduction rate— often an initial stage in the development of cancer. Sandalwood essential oil and its key constituents have been shown to exert an antiproliferative, anti-inflammatory action in keeping with its Oriental-energetic function of clearing Damp-Heat, thereby reducing swelling and thickening.

In clinical trials investigating its pharmacological mechanisms of action, sandalwood essential oil has been shown to be effective and safe in treating acne, psoriasis, eczema and common warts (Moy & Levenson, 2017). Its favourable safety profile and ease of topical use make it increasingly employed in the field of dermatology [TABLE 5].

Anticancer activities

According to the World Health Organization (WHO), cancer is the second leading cause of death in Europe and the United States, and accounting for one in every four or five deaths, and second only to heart disease. In Europe, cancer is the main cause of premature death in 28 of the 53 countries in the region (WHO, 2012).

Among all forms of cancer, skin cancer including basal cell carcinoma and squamous cell carcinoma is the most common form of cancer in the USA, with more than one million cases diagnosed yearly.

The widespread prevalence of cancer has led to a growing interest in developing chemopreventive agents to address cutaneous malignancies, including an interest in agents of a natural origin, due to their typically low risk of adverse reactions and side effects.

Many plants synthesize compounds that possess anticancer activities, and so numerous anticancer drugs in current use have been isolated from plants (Santha & Dwivedi, 2015). With no more than 10% of the world's biodiversity having been investigated for biological activity, many more useful natural lead compounds are doubtless waiting to be discovered (Dias et al, 2012).

Plants were the sole source of pharmaceutical medicines for thousands of years. Their longstanding importance for the development of new drugs arises from the fact that plants, immobile and thus vulnerable to herbivores, produce secondary metabolites to defend themselves. Plants have therefore evolved a complex chemical defence system that relies on the biosynthesis of numerous chemically diverse compounds (Cragg et al, 2012).

Correspondingly, thousands of plant compounds have shown anticancer chemopreventive activities, and hundreds of these are the subject of ongoing scientific research.

α-Santalol is one such essential oil compound — a phytochemical with a low toxicity profile and promising chemopreventive properties that address carcinogenesis of the skin, breast, mouth, head and neck, prostate, bladder, and lung, as evidenced by in vivo, ex vivo and in vitro studies.

Both α-santalol and sandalwood essential oil have undergone extensive testing as potential chemopreventive agents for skin cancer in particular [TABLE 5].

Let us remember that essential oils are readily absorbed through the human skin due to their lipid solubility and very low molecular size and weight— together with the lipophilic nature of the dermal interface.

Matsuo and Mimaki (2010, 2012) showed that α-santalol possesses tumor-specific cytotoxicity - in other words, it selectively kills human cancer cells - and that, central to this activity, it induces *apoptosis. Apóptōsis,* from the ancient Greek ἀπόπτωσις, literally meaning "falling off" – as leaves from a tree or petals from a flower - is a form of programmed cell death occurring in multicellular organisms.

Biochemical events and metabolic processes in the living body lead naturally to morphological cell changes and over time to death. Changes including cell shrinkage, nuclear fragmentation, DNA fragmentation and mRNA decay are due to apoptosis, and together result in the natural process of ageing. Apoptosis results in the average human adult losing 50-70 billion cells every day of their life.

TABLE 5: *Santalum* • RESEARCHED ACTIVITIES

ACTIVITY	DF RD	SUMMARY	AUTHORS
Oncology			
cytotoxic proapoptotic anticancer *(leukemia; lung adenocarcinoma)*	HE VT	***Santalum album*** heartwood extract demonstrated the cytotoxic activity of lignans against HL-60 human promyelocytic leukemia cells and A549 human lung adenocarcinoma cells mediated through the induction of apoptosis. **Note:** Lignans are polyphenols found in numerous plants; they are precursors to phytoestrogens, and defend plants and seeds against herbivores.	Matsuo & Mimaki, 2010
cytotoxic proapoptotic anticancer *(leukemia)*	EC VT	**α-Santalol** derivatives from *Santalum album* heartwood extract had a potent cytotoxic activity against HL-60 human promyelocytic leukemia cells and TIG-3 normal human diploid fibroblasts through inducing apoptosis. Among these derivatives, (9S,10E)-9-hydroxy-α-santalal, demonstrated significant tumor-selective cytotoxicity.	Matsuo & Mimaki, 2012
cytotoxic anticancer *(leukemia; lung adenocarcinoma; oral cancer)*	EC VT	**α- & β-Santalols** and derivatives were evaluated for their cytotoxic activity against HL-60 human promyelocytic leukemia cells, A549 human lung adenocarcinoma cells, HSC-2 and HSC-4 human oral squamous cell carcinoma cell lines, and TIG-3 normal human diploid fibroblasts. cis-β-santalol and β-santaldiol induced apoptotic cell death in HL-60 cells.	Matsuo et al, 2014
cytotoxic anticancer *(oral cancer; HNSCC)*	EC VT	**α- & β-Santalols** interact with tubulin to inhibit microtubule polymerization, similar to chemotherapeutic agents, but without the potency and toxicity of agents that interact directly with tubulin. This activity is clinically relevant to head and neck squamous cell carcinoma (HNSCC), 6th most common cancer.	Lee et al, 2015
cytotoxic proapoptotic antiangiogenic anticancer	EO EC SR	***Santalum album*** **EO** and **α-Santalol** are safe and promising cancer chemopreventive/therapeutic agents with potential to target various pathways involved in carcinogenesis. Mechanisms of action include proapoptotic, antiproliferative, antiangiogenic, antioxidant and anti-inflammatory activities.	Santha & Dwivedi, 2015
Dermatology			
chemopreventive antiproliferative anticancer *(skin cancer)*	EO VV	***Santalum album*** **EO** demonstrated chemopreventive effects on 7,12-dimethyl--benz(a)anthracene-(DMBA)-initiated and 12-O-tetradecanoyl phorbol-13-acetate(TPA)-promoted skin papillomas. Papilloma incidence decreased by 67%, multiplicity by 96%, and TPA-induced ODC activity by 70%.	Dwivedi & Abu-Ghazaleh, 1997
chemopreventive antiproliferative anticancer *(skin cancer)*	EC VV	**Topical α-Santalol** significantly prevents papilloma development during promotion phase of 7,12-dimethylbenz(a)anthracene-TPA carcinogenesis protocol in both CD-1 and SENCAR mice, possibly by inhibiting TPA-induced ornithine decarboxylase (ODC) activity and DNA synthesis.	Dwivedi et al, 2003
chemopreventive antiproliferative anticancer *(skin cancer)*	EC VV	**Topical α-Santalol** treatment (1.25% & 2.5% conc.) significantly reduced the TPA-induced ODC activity and incorporation of [3H]thymidine in DNA in the epidermis of CD-1 mice. There was no significant difference in the effects of 1.25% & 2.5% concentrations of α-santalol on tumour incidence, multiplicity, epidermal TPA-induced ODC activity, or DNA synthesis in CD-1 mice.	Dwivedi et al, 2005
chemopreventive anticancer *(skin cancer)*	EC VV	**Topical α-Santalol** (5% conc.) significantly ($p < 0.05$) decreased DMBA- and TPA-induced tumor incidence and multiplicity in mice, suggesting its chemopreventive efficacy against UVB radiation-caused tumor initiation.	Dwivedi et al, 2006
chemopreventive antiproliferative anticancer	EC VV	**α-Santalol** (5% conc.) significantly ($p < 0.05$) delayed skin tumor development for 25 weeks, reduced tumor multiplicity, and inhibited lipid peroxidation in skin and liver microsomes, preventing UVB-induced skin tumor development.	Bommareddy et al, 2007
chemopreventive antiproliferative anticancer *(skin cancer)*	EC VT	**Topical α-Santalol** inhibited human epidermoid carcinoma A431 cell growth and human melanoma UACC-62 cells *in vitro* through G2/M phase arrest; its effects on cell cycle arrest and other signal pathways *in vitro* and *in vivo* are needed to further elucidate the mechanism(s) of chemopreventive action.	Zhang et al, 2010

KEY • DF: dose form; **EO:** essential oil; **EC:** essential oil constituent; **HE:** herbal extract; **SO:** cold-pressed nut oil; **RD:** research design; **VT:** *in vitro* study; **VV:** *in vivo* study; **EV:** *ex vivo* study; **SR:** systematic review; **CT:** clinical trial.

chemopreventive proapoptotic anticancer *(skin cancer)*	**EC VV**	**α-Santalol** has been shown to prevent skin cancer development in both chemically and UVB-induced skin cancer in CD-1, SENCAR and SKH-1 mice. In this study, pre-treatment with α-santalol 1 hour prior to UVB exposure significantly ($p < 0.05$) reduced tumor incidence and multiplicity, and caused a significant ($p < 0.05$) increase in apoptosis proteins, caspase-3 and -8 levels and tumor suppressor protein, p53, suggesting it prevents skin cancer development by inducing proapoptotic proteins via an extrinsic pathway and increasing p53.	Arasada et al, 2008
anti-inflammatory antioxidant *(vitiligo vulgaris)*	**EC VV**	**α-Santalol** upregulated the key transcription factor nuclear factor E2–related factor 2 (Nrf2) and the downstream genes NAD(P)H:quinone oxidase-1 (NQO-1), γ-glutamyl cystine ligase catalytic subunit (GCLC), and γ-glutamyl cystine ligase modifying subunit (GCLM) in the lesional epidermal skin of subjects with vitiligo vulgaris. Phase II detoxification pathways have now been identified as being central to the regulation of epidermal skin homeostasis.	Natarajan et al, 2010
chemopreventive antiproliferative proapoptotic anticancer	**EC VV**	**Topical α-Santalol** (10%, wt/vol in acetone) caused a reduction in tumor incidence, multiplicity and volume. Its action against UVB-induced photocarcinogenesis was associated with inhibition of inflammation and epidermal cell proliferation, cell cycle arrest and induction of apoptosis.	Santha & Dwived, 2013
anti-tyrosinase anti-hyperpigmentation	**EC VT**	**α-Santalol,** through LC-bioautographic assays, strongly inhibited both tyrosinase and cholinesterase, indicating its potential application in skin care and as a chemopreventive and therapeutic adjunct in Alzheimer's disease.	Misra & Dey, 2013
antiproliferative proapoptotic anticancer *synergistic*	**EC VV**	**α-Santalol**, honokiol and magnolol decreased tumor multiplicity up to 75% compared to control, as individual compounds in SKH-1 mice. The combination decreased cell viability, proliferation, and enhanced apoptosis compared to the compounds alone in human epidermoid carcinoma A431 cells.	Chilampalli et al, 2013
chemopreventive antikeratotic anticancer *(skin cancer)*	**EO VT**	***Santalum album* EO** demonstrated a chemopreventive activity resulting from a blockade of cell cycle progression in pre-treated HaCaT keratinocytes as well as an inhibition of UV-induced AP-1 activity, two cellular effects known to drive skin carcinogenesis, inhibiting pre-cancerous cells associated with actinic keratosis (AK) progressing into skin cancer.	Dickinson et al, 2014
anti-inflammatory antioxidant radioprotective	**EO CT**	***Santalum album* and *Curcuma longa* EOs** prevented radiodermatitis in patients with head and neck cancer undergoing radiation therapy, and reduced the occurrence of Grade 3 dermatitis to a statistically significant degree.	Palatty et al, 2014
Gynecology			
selectively genotoxic antiproliferative anticancer *(breast adenocarcinoma)*	**EC VT**	**α-Santalol** inhibited cell viability and proliferation in a concentration and time-dependent manner in p53 wild-type MCF-7 cells (functioning as a model for estrogen receptor (ER)-positive) and p53 mutated MDA-MB-231 cells (functioining as a model for ER-negative breast cancer). α-Santalol produced a less toxic effect on normal breast epithelial cell line MCF-10A.	Santha et al, 2013
selectively genotoxic antiproliferative anticancer *(breast adenocarcinoma)*	**EC VT**	***Santalum album* EO** showed selective genotoxic effects in breast adenocarcinoma (MCF-7) and nontumorigenic breast epithelial (MCF-10A) cells at noncytotoxic concentrations. The main constituents reported in the essential oil were (Z)-α-santalol (25.34%), (Z)-nuciferol (18.34%), (E)-β-santalol (10.97%), and (E)-nuciferol (10.46%). *Santalum album* EO was shown to be selectively genotoxic: capable of inducing DNA single- and double-strand breaks in MCF-7 cells. There is evidence that the EO promotes the production of epoxides that induce DNA damage, halting the cell cycle. Stopping cell cycle progression is crucial to prevent replication of damaged DNA and to activate the machinery needed for DNA repair.	Ortiz et al, 2016
chemopreventive proapoptotic anticancer *(breast adenocarcinoma)*	**EC VT**	**α-Santalol** has been shown to inhibit cancer cell growth *in vitro* by inducing apoptosis. In this study, α-santalol induced apoptosis in cultured MCF-7 (estrogen receptor ER-positive and wild-type p53) and MDA-MB-231 (ER-negative and mutant p53) breast cancer cells. Treatment of breast cancer cells for 6 and 9 hrs with α-santalol (20, and 40 μM) resulted in statistically significant concentration-dependent downregulation of survivin. Survivin, a member of the apoptosis inhibitor family, is associated with the activation of various cell survival signaling cascades. Overexpression correlates with tumor recurrence and therapeutic resistance.	Bommareddy et al, 2015

chemopreventive antiproliferative *(breast adenocarcinoma)*	**EC VT VV**	**α-Santalol formulations** (cream, solution and microemulsion) were developed and assessed for their *in vitro* permeability using excised animal (porcine and rat) and human breast skin/ mammary papilla (nipple). Breast cancers typically originate from epithelial cells lining the milk ducts in the breast. *In vivo* biodistribution and efficacy studies were conducted in female rats. Transdermal delivery of α-santalol significantly reduced the tumor incidence, multiplicity, and size. *In vivo d*elivery of α-santalol through the entire breast (breast skin and nipple) in rats resulted in a significantly higher concentration in the mammary gland compared to transdermal delivery through the breast skin or nipple. Phospholipid based α-santalol microemulsion showed the highest penetration through the nipple and breast skin.	Dave et al, 2017
chemopreventive proapoptotic anticancer *(breast adenocarcinoma)*	**EC VT**	**α-Santalol** has been shown to inhibit breast cancer cell growth *in vitro* by inducing apoptosis. In this study, we demonstrate that α-santalol targets the Wnt/β-catenin pathway to inhibit migration of cultured breast cancer cells. Exposure of MDA-MB 231 and MCF-7 cells to α-santalol significantly reduced their migratory potential and wound healing ability. α-Santalol inhibits the migration of breast cancer cells by targeting the Wnt/β-catenin pathway.	Bommareddy et al, 2017
Male Reproductive			
chemopreventive proapoptotic anticancer *(prostate cancer)*	**EC VT**	**α-Santalol** *in vitro* treatment of prostate cancer cells induced apoptosis as evidenced by DNA fragmentation and nuclear staining of apoptotic cells by DAPI, a fluorescent dye that binds selectively to double-stranded DNA and forms strongly fluorescent DNA-DAPI complexes with high specificity. α-Santalol treatment also resulted in activation of caspase-3 activity and poly ADP ribose polymerase (PARP) cleavage. PARP is a major substrate of activated caspase-3.	Bommareddy et al, 2012
chemopreventive antiangiogenic proapoptotic anticancer *(prostate cancer)*	**EC EV VV**	**α-Santalol** administration significantly inhibited the proliferation, migration, invasion, and tube formation of human umbilical vein endothelial cells (HUVECs) and prostate tumor cells (PC-3 or LNCaP) *in vitro.* The effect indicated that α-santalol inhibited tumorigenesis by targeting angiogenesis, inhibiting *ex vivo* and *in vivo* angiogenesis as evident by rat aortic and sponge implant angiogenesis assay. α-Santalol significantly reduced the volume and the weight of solid tumors in prostate xenograft mouse model, reducing cell viability and inducing apoptosis in PC-3 cells.	Saraswati et al, 2013
chemopreventive proapoptotic anticancer *(prostate cancer)*	**EC VT**	**α-Santalol** (20, 40 μM) treatment of prostate cancer cells resulted in the down-regulation of survivin and p-AKT (s-473) expression as well as a statistically significant reduction in total survivin levels. α-Santalol induced apoptotic cell death as determined by cell viability, cellular morphology, active caspase-3 activity and expression of polymerase (PARP) cleavage	Bommareddy et al, 2020
chemopreventive proapoptotic autophagosomic anticancer *(prostate cancer)*	**EC VT**	**α-Santalol** has been shown to inhibit the growth of cultured human prostate cancer cells and PC-3 prostate cancer xenografts *in vitro*. α-Santalol targets the serine/threonine kinase 1 (AKT) pathway to induce apoptosis. Treatment of LNCaP and PC-3 cells caused an autophagic response, including the formation of acidic vesicular organelles, and the recruitment and cleavage of microtubule-associated protein 1 light chain 3 (LC3) to autophagosomes. α-Santalol further suppressed phosphorylation of activated AKT and mTOR, critical regulators of autophagic responses.	Walters et al, 2021
Urinary			
anti-inflammatory selectively genotoxic proapoptotic anticancer *(bladder cancer)*	**EO VT**	***Santalum album* EO** (16,000–7,000 dilutions) (v/v) and ***Boswellia carterii* EO** (1,400–600 dilutions) (v/v) reduced cell viability in human bladder cancer J82 cells, which were more sensitive to the proapoptotic effects of Boswellia EO than were immortalized normal bladder UROtsa cells. Santalum EO also suppressed the viability of both J82 and UROtsa cells. While both EOs activated common pathways such as inflammatory interleukins (IL-6 signaling), each had a unique molecular action on human bladder cancer cells. Heat shock proteins and histone core proteins were activated by Boswellia EO, while negative regulation of protein kinase activity and G protein-coupled receptors were activated by Santalum EO. Boswellia EO elicited selective cancer cell death via NRF-2-mediated oxidative stress; Santalum EO induced non-selective cell death via DNA damage and cell cycle arrest.	Dozmorov et al, 2014

Endocrine			
antihyperglycemic hyperlipidemic cardioprotective antidiabetic (type 2 diabetes)	**EO VV**	**Oral *Santalum album* EO** (10 µg/kg body weight 2 times daily for 60 days) lowered blood glucose level by 140 mg/dl. Total cholesterol, low density lipoprotein and triglyceride levels were decreased by 22%, 31% and 44% respectively in treated diabetic rats; cardioprotective high density lipoprotein increased by 46%. Significant improvement in atherogenic index from 267% to 139% was observed in treated rats. *Santalum album* demonstrated an antihyperlipidemic activity that can help in overcoming insulin resistance.	Kulkarni et al, 2012
antihyperglycemic hyperlipidemic antioxidant antidiabetic *synergistic* (type 2 diabetes)	**EO EC VV**	**Intraperitoneal administration of α-santalol** (100mg/kg body weight) and *Santalum album* EO (1g/kg body weight) for 7 days restored parameters incl. body weight, blood glucose, serum bilirubin, liver glycogen, and lipid peroxides contents to normoglycemic levels in alloxan-induced diabetic mice. Similarly, intraperitoneal administration of α-santalol (100mg/kg body weight) and *Santalum album* EO (1g/kg body weight) for14 days modulated parameters incl. serum aminotransferases, alkaline phosphatase, bilirubin, superoxide dismutase, catalase, free sulfhydryl, protein carbonyl, nitric oxide, liver lipid peroxide contents, and antioxidant capacity in D-galactose mediated oxidative stress-induced mice. The biological activities of α-santalol were differentially amplified by other constituents present in the whole essential oil, thus indicating a corresponding synergistic activity.	Misra & Dey, 2012
antihyperglycemic antioxidant antidiabetic (type 2 diabetes)	**HE VT**	Traditional Indian and Australian medicinal plant extracts were investigated to determine their therapeutic potential to inhibit key enzymes in carbohydrate metabolism, relevant to the management of hyperglycemia and type 2 diabetes. Antioxidant activity was determined by measuring (i) the scavenging effect of plant extracts against 2, 2-diphenyl-1-picryl hydrazyl (DPPH) and 2, 2'-azinobis-3-ethylbenzothiazoline-6-sulfonate (ABTS) and (ii) ferric reducing power. Total phenolic and flavonoid contents were also determined. Of the 12 ethanol extracts evaluated, the highest inhibitory activity against both α-amylase and α-glucosidase enzymes was exhibited by ***Santalum spicatum*** and *Pterocarpus marsupium* extracts, with IC50 values of 5.43 µg/ml and 0.9 µg/ml, and 5.16 µg/ml and 1.06 µg/ml, respectively.	Gulati et al, 2012
antihyperglycemic antioxidant antidiabetic (type 2 diabetes)	**HE VT**	12 ethanol extracts (7 Australian Aboriginal and 5 Indian Ayurvedic) were investigated for glucose uptake and adipogenesis in murine 3T3-L1 adipocytes. Only ***Santalum spicatum*** and *Acacia kempeana* extracts stimulated glucose uptake in adipocytes, demonstrating an antidiabetic activity.	Gulati et al, 2015
antihyperglycemic hyperlipidemic anti-inflammatory hepatoprotective antidiabetic (type 2 diabetes)	**SO VV**	***Santalum spicatum* nut oil** significantly attenuated glucose intolerance, hyperglycaemia, obesity, and hepatic lipid accumulation in 50 high-fat/high-sucrose diet (HFHSD)-induced insulin resistant male Sprague-Dawley rats. The nut oil reduced the serum levels of pro-inflammatory factors IL-6, IL-1β and TNF-α compared to control, activated the PI3K/AKT insulin signaling pathway, and down-regulated the JNK/NF-κB inflammatory signaling pathway in the liver. Ximenynic acid-rich *Santalum spicatum* nut oil ameliorated the effect on insulin resistance by reducing hepatic inflammation and thereby preventing disruption of the insulin signaling pathway.	Zhang et al, 2021
Gastrointestinal			
antibacterial antiulcerogenic (peptic ulcer)	**EO EC VT**	***Santalum album* EO**, **(Z)-α-santalol** and **(Z)-β-santalol** demonstrated a strong antibacterial activity against *Helicobacter pylori,* incl. antibacterial activity against a clarithromycin-resistant strain (TS281) among other strains.	Ochi et al, 2005
anti-diarrhoeal antispasmodic hypotensive (diarrhoea)	**HE VV**	***Santalum album* methanol extract** (200, 400 and 800 mg/kg) showed significant antidiarrhoeal activity in models of castor oil-induced diarrhoea compared to control. It inhibited gastric emptying and small intestinal motility in mice in which small intestinal hyperfunction was induced by neostigmine. The extract inhibited the spontaneous contraction of rat-isolated jejunum in dose-dependent manner ranging from 0.02 to 0.4 mg/mL, relaxing ACH-induced, 5-HT-induced and K(+)-induced contractions. The methanol extract reduced calcium channel Ca(2+) concentration-response times to a level comparable with the calcium channel blocker verapamil (0.025 mM).	Guo et al, 2014

Antioxidant		
antioxidant **proapoptotic** **antiproliferative** **hepatoprotective**	**EO** **EC** **VV**	**Oral *Santalum album* EO** (5 and 15 microliters) administered daily for 10 and 20 days exhibited an increase in glutathione S-transferase (GST) activity in a time- and dose-responsive manner. Enhancement of GST activity and acid-soluble sulphydryl levels in the liver suggest a chemopreventive action on carcinogenesis through a blocking mechanism. Glutathione S-transferases (GSTs) determine intracellular concentrations of 4-Hydroxy-2-trans-nonenal (4HNE), a key signaling molecule which maintains a balance between the formation and exclusion of core cellular processes: higher concentrations of 4HNE promote apoptosis; lower concentrations promote proliferation. Just as reactive oxygen species (ROS) are by-products of oxidative stress, so too are secondary intermediates such as 4-hydroxy-2-nonenal (4-HNE) and malondialdehyde (MDA). As a product of lipid peroxidation, 4-HNE is also considered a biomarker of oxidative stress.	Bannerjee et al, 1993
antioxidant **proapoptotic** **chemopreventive** **neuroprotective** **geroprotective** *(Parkinson's disease)*	**EO** **EC** **VT**	***Santalum album* EO** and **α- & β-Santalol** demonstrated a pronounced antioxidant and antiapoptotic activity capable of extending the lifespan of 6-OHDA-intoxicated *Caenorhabditis elegans,* inhibiting the generation of reactive oxygen species (ROS) and promoting germline cell apoptosis. Additionally, α- and β-santalol reduced 6-OHDA- and α-synuclein-induced Parkinson's disease-related pathologies and improved neurological function.	Mohankumar et al, 2018
antioxidant **anti-aggregative** **neuroprotective** **geroprotective** *(dementia, Alzheimer's disease, Huntington's disease)*	**EC** **VV**	This study sought to identify the anti-aggregation and antiaging mechanisms of **α- and β-santalol** using the genetic tractability of *Caenorhabditis elegans* as an *in vivo* model. The results showed that α- and β-santalol retard aging, improve health span, and inhibit the aggregation of toxic amyloid-β (Aβ1-42) and polyglutamine repeats (Q35, Q40, and HtnQ150) in *Caenorhabditis elegans* models of Alzheimer's disease and Huntington's disease, respectively. Gene expression analysis revealed that α- and β-santalol selectively regulate SKN-1/Nrf2 and EOR-1/PLZF transcription factors through the RTK/Ras/MAPK-dependent signaling axis which controls the expression of several antioxidants and protein aggregation inhibitory genes that extend longevity and minimize age-induced protein oxidation and aggregation. *"We believe that these findings will further promote α- and β-santalol to become next-generation prolongevity and anti-aggregation molecules for longer and healthier life."*	Mohankumar et al, 2020
anti-inflammatory **neuroprotective** **geroprotective** *(dementia, Alzheimer's disease)*	**EO** **VT**	Neuroinflammation is an inflammatory response in the nervous system associated with various neurological diseases incl. Alzheimer's disease. ***Santalum album* EO** attenuated polyinosnic-polycytidylic acid (PolyI:C)-induced neuroinflammatory response in human neuroblastoma cells. Treatment of cells with *Santalum album* EO extract indirectly affected the expression of interferons and other pro-inflammatory cytokines in the SH-SY5Y human neuroblastoma cell line.	Suganya et al, 2021
Nervous & Psychological		
sedative **soporific** **neuroleptic** *(insomnia, hypomania, bipolar disorder)*	**EO** **EC** **VV**	***Santalum album* (Byakudan in Japanese) extracts** (benzene, chloroform, methanol and water extraction methodologies) were tested for CNS activity through intraperitoneal administration. Potentiation of hexobarbital sleeping time together with alterations in body temperature and antinociceptive and spontaneous motor activity confirmed prior evidence of a sedative effect. The results demonstrated that α- and β-santalol resemble the pharmacologically neuroleptic activity of chlorpromazine.	Okugawa et al, 1995
sedative **neuroleptic** *(insomnia, hypomania)*	**EC** **VV**	**α-Santalol** was the most potent antagonist among 6 aromatic compounds of dopamine D2 and serotonin 5-HT2A receptor binding. Its action as an antipsychotic agent was compatable to that chlorpromazine, if less potent.	Okugawa et al, 2000
sedative **soporific** *(insomnia)*	**EC** **VV**	**Inhaled α-santalol** was investigated for its effect on the sleep-wake cycle in sleep-disturbed rats. It caused a significant decrease in total waking time and an increase in total non-rapid eye movement (NREM) sleep time. Further tests revealed that α-santalol acts via the circulatory system rather than the olfactory system, being absorbed into the blood through the respiratory mucosa. Therefore α-santalol may be useful for those experiencing sleep hygiene without being affected by subjective differences in fragrance preference.	Ohmori et al, 2007

Apoptosis is a highly regulated process which brings with it distinct biological advantages to the life cycle of an organism. In contrast to *necrosis* – which is a form of traumatic cell death arising from acute cellular injury - apoptosis is a process that is essential and indeed intrinsic to life.

The separation of fingers and toes in the developing human embryo, for example, takes place because the cells between the digits undergo apoptosis. And in contrast to necrosis, apoptosis produces cell fragments called apoptotic bodies which phagocytes are able to engulf and remove before the contents of the cell can damage surrounding cells (Alberts et al, 2022).

Defective processes of apoptosis have been implicated in a broad range of diseases. Excessive apoptosis results in atrophy; however, an insufficiency of apoptotic mechanisms leads to conditions of uncontrolled cell proliferation such as cancer.

Chemotherapeutic agents in general exert a cytotoxic action through processes that often trigger cell apoptosis. This therapeutically desirable activity, however, also triggers side effects — the result of the severe damage that conventional cytotoxic drugs do to normal host cells.

According to WHO, "Prevention, as well as treatment, is an effective measure to reduce the premature mortality from diseases of the circulatory system and cancer. Prevention is the only measure to reduce the impact of diseases for which no effective treatment is yet available."

As can be seen from TABLE 5, various *in vitro, ex vivo* and *in vivo* studies have demonstrated wide-ranging chemopreventive, anticancer effects exerted by *Santalum spp.* essential oil and its major chemical constituent α-santalol, without resulting in observable side-effects. It is non-mutagenic and has low acute oral and dermal toxicity (Burdock & Carabin, 2008).

The proapoptotic, antiproliferative, antiangiogenic, antioxidant and anti-inflammatory activities of sandalwood essential oil work in tandem to exert an essentially chemopreventive effect against cancers of the skin, breast, and prostate, in particular.

Energetic and scientific therapeutics

Sandalwood's essential oil's quintessentially sweet-woody fragrance energy settles and calms the mind and comforts the spirit, quelling the overthinking and worry which in terms of Oriental medicine are psychological indicators of a disharmony of the Spleen-pancreas and Earth Element.

Fig 4: *Santalum album* (Indian sandalwood) trees. *"A paste is made from the wood for applying to the forehead in a variety of symbolic markings indicating to which religious sect a person belongs. Its cooling and soothing properties when applied in this manner are said to direct a persons attention towards contemplation of the mystery of life... The connection between fragrant plants and spirituality as practiced in India is profound. Sandalwood holds the preeminent place amongst them. It was the material of transformation and elevation."* **Christopher McMahon**, *Sacred Sandalwood ~ The Divine Tree* (2003)

TABLE 6: WESTERN AUSTRALIAN SANDALWOOD (*SANTALUM SPICATUM*) ORIENTAL-ENERGETIC ACTIONS

Fragrance energy: sweet-woody; milky, musky, urinous, animalic – *calming, pacifying, restoring*

Energy: *cooling, moistening, draining*

Systemic actions:

- ***Clears Heat, protects and regulates the Essence, reinforces the Yang:*** oxidative stress and redox imbalance, chronic inflammation, neuroinflammation, type 2 diabetes, mutagenesis; leukemia, skin cancer, breast cancer, oral cancer, head and neck squamous cell carcinoma, prostate cancer, bladder cancer, lung cancer; chemopreventive; radioprotective.

Organ system actions:

- ***Tonifies Spleen-Qi, regulates homeostasis, drains Damp-Heat, pacifies the Yi*** **(Intellect):** chronic lethargy, mental fatigue, overthinking and worry, migraine, irritable bowel syndrome, colitis, acute diarrhea [**suppl***], type 2 diabetes [**suppl***].

- ***Clears Heat and Damp-Heat, cools the Blood, benefits the skin, restrains infection:*** dermatitis, eczema, psoriasis, urticaria, acne, rosacea, shingles, genital herpes, vitiligo vulgaris, actinic keratosis, skin cancer chemopreventive.

- ***Regulates Heart-Qi, cools Heart-Fire, clears Heart Phlegm-Fire, sedates the Shen*** **(Mind):** chronic nervous tension, insomnia and poor sleep hygiene, overthinking and worry, restlessness, 'workaholic' syndrome, nervous exhaustion, neurasthenia†, hypomania, bipolar disorder, Parkinson's disease [**suppl**], dementia [**suppl**].

- ***Cools Lung-Heat, expels Wind-Heat and Lung Phlegm-Heat, supports Lung-Yin:*** cough (accompanied by sticky yellow sputum), acute and chronic bronchitis, extrinsic asthma, pharyngitis, laryngitis.

- ***Supports Kidney-Qi and-Yin, drains urogenital Damp-Heat:*** leucorrhea, vaginal candidiasis, genital herpes, squamous intraepithelial lesion (SIL).

* **suppl** = strictly supplementary intervention.

† ***neurasthenia*** is a 19th century term implying "weakness of the nerves". When used in psychology, it describes a condition characterized by chronic lethargy, mental fatigue, mild depression, poor concentration, loss of appetite, and insomnia. Further possible symptoms include headache, dizziness, myalgia, weight loss, restlessness, anxiety, excessive sweating, irritability, and tachycardia.

Sandalwood essential oil's action on the Spleen-pancreas organ and Earth Element is physically tonifying and mentally pacifying and harmonizing. Its ability to tonify the Qi of the Spleen-pancreas and Earth Element is reflected in its antihyperglycemic, antihyperlipidemic, antidiabetic activities (Gulati et al, 2012; Kulkarni et al, 2012; Misra & Dey, 2013a; 2013c; Gulati et al, 2015). These are benefits that are shared with ximenynic acid-rich cold-pressed *Santalum spicatum* nut oil (Zhang et al, 2021).

Moreover, the fact that sandalwood essential oil tonifies the Spleen-pancreas and clears Damp-Heat (in Ayurvedic terms, Kapha and Pitta) from the body makes it indicated generally for those presenting with symptoms that can include chronic lethargy, mental fatigue and anxiety, 'overthinking' and worry, gastritis, colitis, and inflammatory conditions of the musculoskeletal system and the skin [TABLE 6].

Sandalwood essential oil's healing, harmonizing effect on the Spleen-pancreas supports and, is coupled with, a gently sedating action on the and central nervous system, making it a first-class evidence-based tranquilizing soporific— deliverable through olfactory, respiratory, dermal, and if required, oral routes.

The fact that both sandalwood essential oil and α-santalol have an action comparable to first generation neuroleptics (Okugawa et al, 1995; Okugawa et al, 2000) reflects its pronounced capacity to calm the *Heart-Shen*. The *Shen* in Oriental medicine refers to the essential

functions of consciousness including cognition, imagination, mood and memory. In turn, the pivotal role of the Heart with respect to mental-emotional equilibrium is the result of the fact that it provides a functional-energetic 'residence' – a mind-body interface - for the *Shen* itself.

Known in traditional Chinese herbal medicine by its Mandarin name, *Tan Jiang, S. album* heartwood, administered herbally in the form of a decoction or powder, is utilized in energetic-functional terms to move the *Qi* – primarily in the chest and abdomen - and so to relieve pain (Bensky & Gamble, 1993).

The essential oil can be combined with that of *Lavandula angustifolia* (true lavender) to relieve stagnant *Qi-energy* of the Heart and its associated symptoms of chronic nervous tension, insomnia and poor sleep hygiene, and a feeling of constriction and anxiety in the chest.

Sandalwood's age-old cultural reputation as a versatile medicament, ritual aromatic and spiritual aid gave it a special status in ancient times tantamount to a substance that one might refer to alchemically as an *elixir* or, therapeutically, as a *panacea.*

One reads debate about the criteria necessary for a botanical remedy to be considered an *adaptogen:* a natural agent that actively aids the body to adapt to stress, and which exerts a normalizing effect on bodily functions.

Sandalwood essential oil protects the body from the oxidative stress leading to the breakdown in normal function which results in dysfunction and, potentially, in mutagenesis. It exerts this faculty through modulating the immunogenetic interface responsible for expressing the very blueprint of the body's biological integrity. Hence, on the basis of the available scientific evidence, I would argue that *Santalum spicatum* essential oil meets the essential criteria for the descriptor, *adaptogen.*

The essential oil is able to provide this biological protection by supporting biochemically the process most vital to the cycle of life: paradoxically, the natural ability to die, and so to "die into life": apoptosis… the 'falling of the leaves from the trees', 'the flowers from the petals'... life's eternal round of decline and renewal.

In this way, in terms of traditional Oriental medicine, sandalwood essential oil possesses one of the most vital energetic medicinal plant actions of all: to *protect the genetic Essence* (*Jing*)— our constitutional strength as well as our capacity to resist disease.

TABLE 8: Example aromatic formulae

SOOTHING ANTIPRURITIC-ANTIDERMATITIC-ANTI-ECZEMATOUS FORMULA FOR SKIN APPLICATION

Indications: itching, dermatitis, eczema

Dose form: non-aqueous ointment

Container: 2 oz (or 60 ml) glass jar

EO concentration: approx. 0.5%

Formulation:

Beeswax (*Cera alba*) (pastilles)	12 g
Calendula officinalis herbal oil	15 ml
Rosehip (*Rosa rubiginosa*) oil	15 ml
Santalum spicatum nut oil	15 ml
Santalum spicatum EO	120 mg (≈4 drops)
Matricaria recutita EO	60 mg (≈2 drops)
Lavandula angustifolia EO	60 mg (≈2 drops)

Application: Apply to the affected area 2-4 times per day.

NURTURING CHEMOPRVENTIVE FORMULA FOR BREAST (NIPPLE) APPLICATION

Indications: chemopreventive use in clinical context according to indvidual risk factors and lifestyle

Dose form: non-aqueous ointment

Container: 2 oz (or 60 ml) glass jar

EO concentration: approx. 4%

Formulation:

Beeswax (*Cera alba*) (pastilles)	12 g
Santalum spicatum nut oil	15 ml
Calendula officinalis herbal oil	15 ml
Rosehip (*Rosa rubiginosa*) oil	15 ml
Santalum spicatum EO	1.2 g (≈40 drops)
Pelargonium graveolens EO	0.3 g (≈10 drops)
Rosmarinus officinalis CO2 ext.	0.3 g (≈10 drops)

Application: Apply a small volume (≈1 g) to each nipple once per day.

CALMING ANXIOLYTIC-SOPORIFIC FORMULA FOR CLINICAL DIFFUSION AND INHALATION

Indications: nervous tension, anxiety, restlessness, insomnia

Dose form: nebilized diffusion

Container: direct administration into diffuser

EO concentration: N/A

Formulation:

Lavandula angustifolia EO	40%
Citrus bergamia EO	20%
Citrus sinensis EO	20%
Santalum spicatum EO	20%

Application: Diffuse for 20-30 minutes 2-4 times per day.

The Essence (*Jing*) in Oriental medicine is our genetic foundation, akin scientifically to DNA— understood since ancient times to be formed at conception from the uniting of the Essence of each of our parents. It 'governs' – i.e. modulates - the growth, reproduction and development of the individual throughout life. A normal, healthy condition of the Essence, relying in particular on the health of the Kidneys, ensures normal cycles of development, maturation and aging.

Sandalwood essential oil shields and protects the genetic Essence (*Jing*) from dysfunction and decline through protecting the body's cells and nucleic acids from mutagenesis— and therefore from cancer and numerous other diseases common in Western societies.

Sandalwood has long been venerated in India in particular for its therapeutically and spiritually 'cooling' faculty. Applying sandalwood paste to the forehead was, and remains, a ubiquitous practice in Hinduism and Buddhism, and reflects the aromatic's ability to 'cool' and therefore calm and quiesce the Mind. [Fig. 4]

In traditional Oriental medicine, conditions of excess Yang and pathogenic Fire generate Heat and Fire in the Heart which in turn disturbs the mind and *Shen*. Therapeutically cooling remedies with an affinity for the nervous system cool the pathogenic Fire that agitates the mind and which frequently results in mental anxiety, hypomania and low mood.

Sandalwood essential oil, as reflected in its sweet-woody fragrance nature, cools as well as settles and sedates the mind, imparting a serenity consistent with feeling "cool, calm and collected"— better able experience that which in Buddhism is known as presence, or fully-present and -focused being.

In summary

Essential oil and nut oil of Western Australian sandalwood (*Santalum spicatum*), obtained from sustainably-managed sources, is capable of delivering – like other therapeutically major essential oils - a number of very significant evidenced-based biological functions. Chief among those is a chemopreventive action which, together with sandalwood oil's antioxidant and anti-inflammatory activities, corresponds in Oriental-energetic terms to representing a potent natural protector of the genetic Essence and DNA— of the source of life itself.

~ *Santalum* ~

The *Rājanighantu*, a lexicon
of healing plants, from rose to cardamom,[1]
in sage times mentioned precious sandalwood
as being through many names understood.

Its most ancient name, *chandana*, relates
to *cāntu,* meaning 'rub into a paste'.
The term *chandana* is also defined
as the most superlative of its kind.

White sandal paste was applied to the brow
to cool the mind and devotion avow,
to draw down Shiva and awaken Shakti,
to enrich one's bliss and deepen bhakti.

The scented wood's Pure Land[2] perfection fueled
its rise as one of the 'seven jewels
of the emperor', a true Sattvic[3] tree
imparting the power of divinity.

Its purity made it a 'piece of fortune',
śrīkhanda, a sweet curd saffron portion:
a cold, light paste with a creamy perfume
known by the Devas[4] as the 'scent of the moon'.

Its sweet cool aroma was regarded
by the serpents that entwined and guarded
sacred sandal trees on Mount Malaya
as *priya*,[5] as enticing as a raga.[6]

Chandana was thus praised in Ayurvedic verse
for cooling passions that all minds can curse,
for dispersing the Fire that sears and clouds,
inflames the limbs and lucidity shrouds.

Distilled from the heartwood, the tree's essence,
Gandhasarna[7] scented gem presence,
clears and stills the mind, fragrances the breath,
guards against, surrenders to, blesses Death.

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1 The *Rājanighantu*, compiled by Narahari, is a 14th century Ayurvedic medical lexicon (*nighantu*) concerning 698 drugs of plant, animal and mineral origin.
2 Pure Land: the celestial realm of a buddha or bodhisattva in Buddhism, offering respite from karmic transmigration; adorned with flowers, fruits and wish-granting trees.
3 Sattvic: possessing the nature of *Sattva,* one of the three *gunas* (qualities or attributes) in Hindu philosophy; the quality of balance, harmony, serenity, purity and goodness.
4 Devas: celestial beings in Hinduism and Buddhism.
5 *Priya*: 'dear'; 'beloved'.
6 *Raga*: a traditional melodic pattern or mode in classical Indian music.
7 *Gandhasārana*: from *gandha* - a kind of perfume; *sarana* - 'jewel'.

References

Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. *Chapter 18 Apoptosis: Programmed Cell Death Eliminates Unwanted Cells. In: Molecular Biology of the Cell* (7th ed). Garland Science; 2022.

Arasada BL, Bommareddy A, Zhang X, Bremmon K, Dwivedi C. Effects of alpha-santalol on proapoptotic caspases and p53 expression in UVB irradiated mouse skin. *Anticancer Res.* 2008 Jan-Feb;28(1A):129-32.

Baldovini N, Delasalle C, Joulain D. Phytochemistry of the heartwood from fragrant Santalum species: a review. *Flavour Frag J.* 2011, 26:7-26.

Ballabh B, Chaurasia OP, Ahmed Z, Singh SB. Traditional medicinal plants of cold desert Ladakh-used against kidney and urinary disorders. *J Ethnopharmacol.* 2008 Jul 23;118(2):331-9. doi: 10.1016/j.jep.2008.04.022.

Banerjee S, Ecavade A, Rao AR. Modulatory influence of sandalwood oil on mouse hepatic glutathione S-transferase activity and acid soluble sulphydryl level. *Cancer Lett.* 1993 Feb;68(2-3):105-9.

Bensky D, Gamble A. *Chinese Herbal Medicine Materia Medica.* Eastland Press, Seattle; 1993.

Bommareddy A, Hora J, Cornish B, Dwivedi C. Chemoprevention by alpha-santalol on UVB radiation-induced skin tumor development in mice. *Anticancer Res.* 2007 Jul-Aug;27(4B):2185-8.

Bommareddy A, Rule B, VanWert AL, Santha S, Dwivedi C. α-Santalol, a derivative of sandalwood oil, induces apoptosis in human prostate cancer cells by causing caspase-3 activation. *Phytomedicine.* 2012 Jun 15;19(8-9):804-11.

Bommareddy A, Crisamore K, Fillman S, Brozena S, Steigerwalt J, Landis T, Vanwert AL, Dwivedi C. Survivin down-regulation by α-santalol is not mediated through PI3K-AKT pathway in human breast cancer cells. *Anticancer Res.* 2015 Oct;35(10):5353-7.

Bommareddy A, Knapp K, Nemeth A, Steigerwalt J, Landis T, Vanwert AL, Gorijavolu HP, Dwivedi C. Alpha-Santalol, a component of sandalwood oil inhibits migration of breast cancer cells by targeting the β-catenin pathway. *Anticancer Res.* 2018 Aug;38(8):4475-4480.

Bommareddy A, McGlynn D, Lewis M, Lockus L, Seward J, Hong KL, VanWert AL, Dwivedi C. Akt/survivin pathway inhibition enhances the apoptotic cell death-induced by alpha-santalol in human prostate cancer cells. *Fitoterapia.* 2020 Jun;143:104552.

Brophy JJ, Fookes CJR, Lassak EV. Constituents of *Santalum spicatum* (R.Br.) A. DC. wood oil. *J Essent Oil Res.* 1991, 3, 381–385.

Burdock GA, Carabin G: Safety assessment of sandalwood oil (*Santalum album* L.). *Food Chem Toxicol.* 2008, 46: 421-432.

Cai F, Li J, Liu Y, Zhang Z, Hettiarachchi DS, Li D. Effect of ximenynic acid on cell cycle arrest and apoptosis and COX-1 in HepG2 cells. *Mol Med Rep.* 2016 Dec;14(6):5667-567.

Chilampalli C, Zhang X, Kaushik RS, Young A, Zeman D, Hildreth MB, Fahmy H, Dwivedi C. Chemopreventive effects of combination of honokiol and magnolol with α-santalol on skin cancer developments. *Drug Discov Ther.* 2013 Jun;7(3):109-15.

Cragg G, Kingston D, Newman D. *Anticancer Agents From Natural Products.* Boca Raton: CRC Press; 2012.

Dave K, Alsharif FM, Islam S, Dwivedi C, Perumal O. Chemoprevention of breast cancer by transdermal delivery of α-santalol through breast skin and mammary papilla (nipple). *Pharm Res.* 2017 Sep;34(9):1897-1907.

Dias DA, Urban S, Roessner U. A historical overview of natural products in drug discovery. *Metabolites.* 2012 Apr 16;2(2):303-36.

Dickinson SE, Olson ER, Levenson C, Janda J, Rusche JJ, Alberts DS, Bowden GT. A novel chemopreventive mechanism for a traditional medicine: East Indian sandalwood oil induces autophagy and cell death in proliferating keratinocytes. *Arch Biochem Biophys.* 2014 Sep 15;558:143-52.

Dozmorov MG, Yang Q, Wu W, Wren J, Suhail MM, Woolley CL, Young DG, Fung K, Lin H. Differential effects of selective frankincense (*Ru Xiang*) essential oil versus non-selective sandalwood (*Tan Xiang*) essential oil on cultured bladder cancer cells: a microarray and bioinformatics study. *Chin Med.* 2014, 9:18.

Dwivedi C, Abu-Ghazaleh A. Chemopreventive effects of sandalwood oil on skin papillomas in mice. *Eur J Cancer Prev.* 1997 Aug;6(4):399-401.

Dwivedi C, Guan X, Harmsen WL, Voss AL, Goetz-Parten DE, Koopman EM, Johnson KM, Valluri HB, Matthees DP. Chemopreventive effects of alpha-santalol on skin tumor development in CD-1 and SENCAR mice. *Cancer Epidemiol Biomarkers Prev*. 2003 Feb;12(2):151-6.

Dwivedi C, Maydew ER, Hora JJ, Ramaeker DM, Guan X. Chemopreventive effects of various concentrations of alpha-santalol on skin cancer development in CD-1 mice. *Eur J Cancer Prev.* 2005 Oct;14(5):473-6.

Dwivedi C, Valluri HB, Guan X, Agarwal R. Chemopreventive effects of alpha-santalol on ultraviolet B radiation-induced skin tumor development in SKH-1 hairless mice. *Carcinogenesis.* 2006 Sep;27(9):1917-22.

Fox JED, Brand J. Preliminary observation on ecotype variation in *Santalum spicatum. Mulga Research Centre Journal.* 1993;11:1-12.

Gulati V, Harding IH, Palombo EA. Enzyme inhibitory and antioxidant activities of traditional medicinal plants: potential application in the management of hyperglycemia. *BMC Complement Altern Med.* 2012 Jun 19;12:77.

Gulati V, Gulati P, Harding IH, Palombo EA. Exploring the anti-diabetic potential of Australian Aboriginal and Indian Ayurvedic plant extracts using cell-based assays. *BMC Complement Altern Med.* 2015 Feb 5;15:8.

Guo H, Zhang J, Gao W, Qu Z, Liu C. Anti-diarrhoeal activity of methanol extract of *Santalum album* L. in mice and gastrointestinal effect on the contraction of isolated jejunum in rats. *J Ethnopharmacol.* 2014 Jul 3;154(3):704-10.

Harbaugh DT. A taxonomic revision of Australian northern sandalwood (*Santalum lanceolatum*, Santalaceae). *Aust Syst Bot* 20:409–416.

Harbaugh DT, Baldwin BG. Phylogeny and biogeography of the sandalwoods (Santalum, Santalaceae): repeated dispersals throughout the Pacific. *Am J. Bot.* 2007; 94(6):1028-1040.

Harbaugh DT, Oppenheimer HL, Wood KR, Wagner WL (2010) Taxonomic revision of the endangered Hawaiian red-flowered sandalwoods (*Santalum*) and discovery of an ancient hybrid species. *Syst Bot.* 35:827–838.

Howes MJ, Simmonds MS and Kite GC: Evaluation of the quality of sandalwood essential oils by gas chromatography-mass spectrometry. *J Chromatogr A.* 1028: 307-312, 2004.

Kausar H, Jahan N, Ahmed K, Aslam M, Ahmed P, Ahmed S: Unani perspective and recent studies of sandal safed (*Santalum album* Linn.): a review: *World J Pharm Pharmaceut Sci* 3: 2133-2145, 2014.

Kulkarni CR, Joglekar MM, Patil SB, Arvindekar AU. Antihyperglycemic and antihyperlipidemic effect of *Santalum album* in streptozotocin induced diabetic rats. *Pharm Biol.* 2012 Mar;50(3):360-5.

Kusuma HS, Mahfud M. The extraction of essential oil from sandalwood (*Santalum album*) by microwave air-hydrodistillation. *J Mater Environ Sci.* 2016, 7(5):1597-1606.

Kyle G: Evaluating the effectiveness of aromatherapy in reducing levels of anxiety in palliative care patients: results of a pilot study. *Complement Ther Clin Pract,* 12: 148-155, 2006.

Lee B, Bohmann J, Reeves T, Levenson C, Risinger AL. α- and β-santalols Directly interact with tubulin and cause mitotic arrest and cytotoxicity in oral cancer cells. *J Nat Prod.* 2015 Jun 26;78(6):1357-62.

Loveys BR, Tyerman SD. Effect of different host plants on the growth of the root hemiparasite *Santalum acuminatum* (quandong). *Aust J Exp Agric.* 2002, 42(1), 97-102.

Matsuo Y, Mimaki Y. Lignans from *Santalum album* and their cytotoxic activities. *Chem Pharm Bull* (Tokyo). 2010 Apr;58(4):587-90.

Matsuo Y, Mimaki Y. α-Santalol derivatives from *Santalum album* and their cytotoxic activities. *Phytochemistry.* 2012 May;77:304-11. Erratum in: *Phytochemistry.* 2012 Sep;81:175.

Matsuo Y, Sakagami H, Mimaki Y. A rare type of sesquiterpene and β-santalol derivatives from Santalum album and their cytotoxic activities. *Chem Pharm Bull* (Tokyo). 2014;62(12): 1192-9.

Misra BB, Dey S. Evaluation of *in vivo* anti-hyperglycemic and antioxidant potentials of α-santalol and sandalwood oil. *Phytomedicine.* 2013a Mar 15;20(5):409-16.

Misra BB, Dey S. TLC-bioautographic evaluation of *in vitro* anti-tyrosinase and anti-cholinesterase potentials of sandalwood oil. *Nat Prod Commun.* 2013b Feb;8(2):253-6.

Misra BB, Dey S: Biological activities of East Indian sandalwood tree, *Santalum album. Peer J Pre Prints,* 96v1, 2013c.

Mohankumar A, Shanmugam G, Kalaiselvi D, Levenson C, Nivitha S, Thiruppathi G, Sundararaj P. East Indian sandalwood (*Santalum album* L.) oil confers neuroprotection and geroprotection in *Caenorhabditis elegans* via activating SKN-1/Nrf2 signaling pathway. *RSC Adv.* 2018 Oct 3;8(59):33753-33774.

Mohankumar A, Kalaiselvi D, Thiruppathi G, Muthusaravanan S, Nivitha S, Levenson C, Tawata S, Sundararaj P. α- and β-Santalols delay aging in *Caenorhabditis elegans* via preventing oxidative stress and protein aggregation. *ACS Omega.* 2020 Dec 10;5(50):32641-32654.

Moniodis J, Jones CG, Renton M, Plummer JA, Barbour EL, Ghisalberti EL, Bohlmann J. Sesquiterpene Variation in West Australian Sandalwood (*Santalum* spicatum). *Molecules.* 2017 Jun 6;22(6):940.

Moretta P. Extraction and variation of the essential oil from Western Australian sandalwood (*Santalum spicatum*). PhD Thesis, Univ of Western Australia, Perth, Australia, 2001.

Moy RL, Levenson C. Sandalwood album oil as a botanical therapeutic in dermatology. *J Clin Aesthet Dermatol.* 2017 Oct;10(10):34-39.

Natarajan VT, Singh A, Kumar AA, Sharma P, Kar HK, Marrot L, Meunier JR, Natarajan K, Rani R, Gokhale RS. Transcriptional upregulation of Nrf2-dependent phase II detoxification genes in the involved epidermis of vitiligo vulgaris. *J Invest Dermatol.* 2010 Dec;130(12):2781-9.

Nikiforov A, Jirovetz L, Buchbauer G, Raverdino V. GC- FTIR and GC-MS in odour analysis of essential oils. *Mikrochim Acta.* 1988, 11:193-198.

Ochi T, Shibata H, Higuti T, Kodama KH, Kusumi T, Takaishi Y. Anti-*Helicobacter pylori* compounds from *Santalum album. J Nat Prod.* 2005 Jun;68(6):819-24.

Ohmori A, Shinomiya K, Utsu Y, Tokunaga S, Hasegawa Y, Kamei C. [Effect of santalol on the sleep-wake cycle in sleep-disturbed rats]. *Nihon Shinkei Seishin Yakurigaku Zasshi.* 2007 Aug;27(4):167-71. Japanese.

Okugawa H, Ueda R, Matsumoto K, Kawanishi K, Kato A. Effect of α-santalol and β-santalol from sandalwood on the central nervous system in mice. *Phytomedicine.* 1995 Oct;2(2):119-26.

Okugawa H, Ueda R, Matsumoto K, Kawanishi K, Kato K. Effects of sesquiterpenoids from "Oriental incenses" on acetic acid-induced writhing and D2 and 5-HT2A receptors in rat brain. *Phytomedicine.* 2000 Oct;7(5):417-22.

Ortiz C, Morales L, Sastre M, Haskins WE, Matta J. Cytotoxicity and genotoxicity assessment of sandalwood essential oil in human breast cell lines MCF-7 and MCF-10A. Evid Based Complement Alternat Med. 2016;2016:3696232.

Palatty PL, Azmidah A, Rao S, Jayachander D, Thilakchand KR, Rai MP, Haniadka R, Simon P, Ravi R, Jimmy R, D'souza PF, Fayad R, Baliga MS. Topical application of a sandalwood oil and turmeric based cream prevents radiodermatitis in head and neck cancer patients undergoing external beam radiotherapy: a pilot study. *Br J Radiol.* 2014 Jun;87(1038):20130490.

Pullaiah T & Swamy MK (2021). *Sandalwood: The green gold.* T. Pullaiah, VA.

Santha S, Dwivedi C. α-Santalol, a skin cancer chemopreventive agent with potential to target various pathways involved in photocarcinogenesis. *Photochem Photobiol.* 2013 Jul-Aug;89(4):919-26.

Santha S, Bommareddy A, Rule B, Guillermo R, Kaushik RS, Young A, Dwivedi C. 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.
Santha S, Dwivedi C. Anticancer effects of sandalwood *(Santalum album). Anticancer Res.* 2015 Jun;35(6):3137-45.

Saraswati S, Kumar S, Alhaider AA. α-Santalol inhibits the angiogenesis and growth of human prostate tumor growth by targeting vascular endothelial growth factor receptor 2-mediated AKT/mTOR/P70S6K signaling pathway. *Mol Cancer.* 2013 Nov 22;12:147.

Setzer WN: *Essential oils and anxiolytic aromatherapy. Nat Prod Commun* 4: 1305-1316, 2009.

Suganya K, Liu QF, Koo BS. *Santalum album* extract exhibits neuroprotective effect against the TLR3-mediated neuroinflammatory response in human SH-SY5Y neuroblastoma cells. *Phytother Res.* 2021 Apr;35(4):1991-2004.

Valder C, Neugebauer M, Meier M, Kohlenberg B, Hammer--schmidt F-J, Braun NA. Western Australian sandalwood oil. New constituents of *Santalum spicatum* (R.Br.) A. DC. (Santalaceae). *J. Essent. Oil Res.* 2003, 15, 178–186.

World Health Organization (WHO). Leading causes of death in Europe: fact sheet. The European Health Report 2012. WHO Regional Office for Europe, 2012. http://data.euro.who.int/hfadb.

Walters C, Reed M, Bartholomew S, Bommareddy A. Autophagy induction by α-santalol in human prostate cancer cells. *Anticancer Res.* 2021 Mar;41(3):1197-1202.

Watson DM. Parasitic plants as facilitators: more Dryad than Dracula? *J Ecol.* 2009, 97(6), 1151-1159.

Watson DM, McGregor HW, Spooner PG (2011). Hemiparasitic shrubs increase resource availability and multi-trophic diversity of eucalypt forest birds. *Func Ecol.* 2011, 25(4), 889-899.

Zhang X, Chen W, Guillermo R, Chandrasekher G, Kaushik RS, Young A, Fahmy H, Dwivedi C. Alpha-santalol, a chemopreventive agent against skin cancer, causes G2/M cell cycle arrest in both p53-mutated human epidermoid carcinoma A431 cells and p53 wild-type human melanoma UACC-62 cells. *BMC Res Notes.* 2010 Aug 3;3:220.

Zhang H, Gao X, Li K, Liu Y, Hettiarachichi DS, Sunderland B, Li D. Sandalwood seed oil ameliorates hepatic insulin resistance by regulating the JNK/NF-κB inflammatory and PI3K/AKT insulin signaling pathways. *Food Funct.* 2021 Mar 15;12(5):2312-2322.

Fig. 5: *Santalum spicatum* (Western Australian sandalwood)

Authors

Dr. Kelly Ablard RA®,EOT®, MIFPA,PhD holds a Doctor--ate in Biology, an MSc in Conservation, a BSc in Biology (*cum laude*), and is a certified clinical aromatherapist. As founding CEO of California-registered non-profit Airmid Institute - https://airmidinstitute.org - Kelly is dedicated to the global education, research, and conservation of medicinal and aromatic plants (MAPs).

Kelly has long been passionate about lecturing on botany, ethnobotany, conservation aromatherapy™, and the relation--ship between MAPs and the Animal Kingdom. She has explored these relationships as a community scientist for Science World, as founder of the Vancouver Community College Urban Apothecary Learning Garden, and as Co-Principal of Essence of Thyme College of Holistic Studies.

Kelly has authored many peer-reviewed articles in the fields of conservation, chemical ecology, evolutionary biology, genetics, behavioral ecology and ethnobotany. Her work has taken her the world over, including the UK, Germany, Malaysia, Peru, Ecuador, Costa Rica, and Bahía de los Ángeles, discovering firsthand the pivotal role that chemical communication plays in the natural world, and the importance and uses of medicinal plants within Indigenous cultures.

Kelly investigated the traditional uses of over 60 Peruvian MAPs; made the novel discovery of how wasps rely on chemical signatures to mediate their mating ritual (featured in *Canadian Geographic*); and identified potential toxins in the Critically Endangered slow loris (*Nycticebus javanicus*), (featured on BBC TV). She reported too on the ingenuity of tool use by Endangered orangutans (*Pongo pygmaeus*)—part of Kelly's ongoing research into the link between sociality and olfactory communication in mammals.

Kelly has lectured for professional associations including NAHA, IFPA, AIA, CAOA, ICAA, and ICAN. She has also been featured on podcasts including *An Aromatic Life, Aromatic Plant Wisdom, Aromatic Chat, LabAroma* and *Maria's Aromatic Café.* Kelly received the Canadian Alliance of Aromatherapists (CAOA) Achievement of Excellence Award, and has been awarded multiple grants for her research. She served on the CAOA Board for over adecade and on the Executive Board of United Plant Savers (UPS) for a term.

Currently Kelly, working with three Shipibo communities, is conducting research on Endangered rosewood (*Aniba rosaeodora*) in central Peru, and is working with the Quechua on *Minthostachys*, including the popular minty herb *muña,* in southern Peru. She is also working on programs in support of the sustainable and legal trade of white sage (*Salvia apiana*).

GabrielMojay LAc,CertEd,FIFPA is an author-researcher, edu--cator and practitioner in the scientific and Oriental-energetic aspects of medicinal and aromatic plant extracts. He has practiced clinical herbalism, aromatic medicine, and acupuncture since 1987. Gabriel was born in England, grew up in Maryland, has spent most of his career in London, and now lives in the Bay Area, north of San Francisco.

Gabriel Mojay first studied natural medicine in 1978, initially training in Shiatsu Therapy and Oriental Medicine. He later became a registered member of the Shiatsu Society. In 1988 he completed four years of training in Traditional Chinese Medicine and Acupuncture, and became a member of the British Acupuncture Council.

While at acupuncture school Gabriel trained in both Western and Chinese herbal medicine with Michael McIntyre, among others; and in scientific and clinical aromatherapy with Pierre Franchomme and Daniel Pénoël MD, Prof. Dietrich Wabner, Rhiannon Lewis and Peter Holmes, among others.

From 1990-2020 Gabriel was Principal of the Institute of Traditional Herbal Medicine and Aromatherapy (ITHMA), based in central London. In 1990 he founded the Register of Qualified Aromatherapists, a UK professional association that in 2002 merged to form the International Federation of Professional Aromatherapists (IFPA), which has some 2000 members in about 50 countries. He is a Fellow of IFPA and ICAN, and a member of the AHG, AIA and NAHA.

Gabriel has lectured at conferences hosted by IFPA, the Tisserand Institute (UK), National Association for Holistic Aromatherapy (USA), Alliance of International Aromatherapists (USA), Pacific Institute of Aromatherapy (USA), Canadian Alliance of Aromatherapists, Canadian Federation of Aromatherapists, Czech Association of Aromatherapists, and the Botanica international conference series. He has given seminars in Japan, Korea, China, Hong Kong, Australia, Ireland, Mexico and Brazil.

Gabriel was founding Co-Editor of IFPA's professional journal, *In Essence,* and was Associate Editor of the *International Journal of Clinical Aromatherapy* (based in France) from 2014-2019. He is co-author of *Shiatsu - the Complete Guide* (HarperCollins), and author of *Aromatherapy for Healing the Spirit* (Healing Arts Press/ Fragrance Journal), which outlines a holistic energetic approach to working with the mental-emotional benefits of essential oils according to the body-mind relationships of Oriental Medicine and the Five Elements. It has been translated into several different languages.