Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.11, No.13, 2021

Ecology, Status and Uses of Osyris Quadripartita (African Sandalwood) in Southern Ethiopia: A Comprehensive Review

Kedir Erbo* Gizawu Bejigo
Forest and Range land plant department, Hawassa biodiversity center, Hawassa, Ethiopia

Abstract
Osyris quadripartita (Africa sandalwood) is an evergreen root hemiparasite plant and belongs to the Santalaceae family which is most ordinarily referred to as African sandalwood. It's a culturally and commercially important species that are used for herbal medicine, religious activities, and thus the perfumery refining industry. The species grows 1 m to 7 m tall counting on the soil type, climate, and genetic variation. The tree occurs on rocky ridges and mountain slopes with an altitude between 900 m to 2550 m above sea level. Regarding to geographic distribution species commonly found in the humid highland and semi-arid ecosystem of Ethiopian. The population structure were an inverted J-shape distribution form and therefore the plant habitats were mostly grouped under Acacia-Rhus-Terminalia community types. Regard to yield quality, it's concluded that sandalwood populations vary substantially within the stock and quality of oil which can be produced. In terms of oil stock the root system is superior to shoot system in quality aspects. Therefore, the main review of this paper was to admission the latest Osyris research and its importance and standing in Ethiopia in order that the knowledge are often used as an honest reference resource for researchers, students, conservationist and NGOs working in Ethiopia within the area of oil crops generally and Osyris in specific.
Keywords: Osyris quadripartita, Sandalwood, population structure, Oil crop, Ethiopia
DOI: 10.7176/JBAH/11-13-02
Publication date: July 31st 2021

1. INTRODUCTION

Natural forests in Ethiopia are declining rapidly because of their conversion to farmlands joined without careful consideration and excessive utilization caused by increasing increase. This result had continued to possess serious consequences on several ecosystems in Ethiopia (Kitessa Hundera, 2010). From the immemorial time, people started exploiting the natural environment because the source of their livelihoods specifically, different wild plant species are used as sources of food, medicine, clothing, firewood, and source of various household utensils (Dereje and Desalegn, 2013). Wild plants still play a key role within the livelihood of an outsized proportion of the world's population. This was mainly true in developing countries, where wild-collected food and medicine have an extended and never-ending history of use (Koduru et al., 2007).

Osyris quadripartita (Africa sandalwood) is an evergreen root hemiparasite plant. It's a culturally and commercially important species that are used for herbal medicine, religious activities, and therefore the perfumery refining industry (Subasinghe et al., 2013). In recent times, market demands in Asia and Europe shop center have amplified for sandalwood oil products (CITES Cop 16) and therefore the plant products sell have inadequate benefit for lower community groups. Although, Sandalwood trade African was uncontrollable because the woods were collected from natural stands and there was a weak domestication program for the species (Mukonyi et al., 2011). Furthermore, the misuse of this species for herbal medicine has increased which resulting in a declining in population in natural stands (Githae et al., 2011). Arising from this concern, Sandalwood was now listed as threatened species under USF & WS (United State Forest and Wildlife Service, 2013). The difficulty of decline resource where similarly an equivalent with Ethiopia sandalwood particularly in southern Ethiopia. Currently, the markets of sandalwood and its products are increasing while the resource has been declining (Rai and Sarma, 1990; Srinivasan et al., 1992; Coppen, 1995). 40 (forty) years ago sandalwood oil was under US$100/kg; now it's over US$2,000/kg reflecting the constraint to provide (Source: HTTP: //www.intracen.org/ Market information of sandalwood oils). The expansion in demand and attractive prices offered for the wood, oil and its products have increased the pressure on this sandalwood resource base (Rai and Sarma, 1990). The massive value and scarcity of the resource within the natural environment have led to over-exploitation (Mukonyi et al., 2011).

Generally, Loss of forest cover and biodiversity due to anthropogenic factors was rising concern in many parts of the world and in Ethiopia (Feyera Senbeta and Demel Teketay, 2003). Particularly, in Southern Ethiopia parts excess, unsustainable harvesting of Osyris quadripartita plants resources for production perfume oils in Ethiopia lead to a population under great pressure (SNNPR, EPFA reports, 2017). Although, the population status and distribution of particular plant species are not well documented earlier. So, such key species reviews in the literature were essential. Besides this, the generation of scientific knowledge through comprehensive reviews of different literature on specific species is crucial for well-organized management and conservation practices.

2. LITERATURE REVIEW

2.1 The taxonomy and Habitat of the species

Osyris quadripartita Salzm. ex Decne synonyms with; *O. abyssinica* Hochst. ex A. Rich, *O. lanceolata* Hochst & Steudel, *O. arborea* Wall. ex A.DC., *O. densifolia* Peter, *O. laetaPeter*, *O. oblanceolate* Peter, *O. parvifolia* Baker, *O. rigidissima* Engl. *O. tenuifolia* Engl., *O. urundiensis* De Wild., *O. wightiana* Wall. ex Wight (also known as Nepalese sandalwood), *O. wightiana* var. stipitata (Lecomte) P.C. Tam (Global Plants, 2016). The species belongs to the ***Santalaceae*** family, is most commonly known as **sandalwoods** Global Plant List (2016). The species are mostly root hemi-parasitic, meaning although they can survive and grow by themselves; they are also opportunistically tap into the root systems of nearby plants and parasitize them (Irving LG and Cameron DD, 2009).

Osyris quadripartita is a shrub/small tree that grows 1 m to 7 m in height depending on the soil type, climatic conditions, and genetic variation (Bekele et al., 2019). The tree occurs on rocky ridges and mountain slopes with an altitude between 900 m to 2550 m above sea level (Giathi et al., 2011). The plant is indigenous to East and South African regions and has a wide geographic distribution in Africa from Algeria to Ethiopia and Kenya to South Africa, Europe (Iberian peninsula and The Balearic Islands), Asia (India to China), and Socotra (Giathi et al., 2011; Gathara et al., 2014; Global Plants, 2016).

The gallery forest of African sandalwood was *Juniperus procera, Podocarpus falcutus, Combretum-Terminalia,* and *Dodonaea* woodland, Erica scrub, *Acacia nilotica, Commiphora-Africana* scrubland, on rocky slopes, degraded woodland, dry evergreen and semi-desert of Ethiopian region; throughout Africa, southern Asia to China (Mwang'ingo et al., 2005).

2.2 Morphology and Growth Season of the species

Osyris quadripartita is an evergreen, root hemiparasitic, dioeciously shrub/trees. Branches of the shrub/trees were angular (sharp-edged) and strongly branched. Leaves alternate and linear to broadly elliptic shapes. Leaf type is blade grayish-green, which about 1.2-1.6 is cm length and 0.6 -2 cm width. The leaves are leathery, occasionally rogues on both shells with dense glands. The leaves' base gradually narrowed or obtuse, and apex acute to cuspidate or rounded (Hedberg I., and Edwards S., 1989). The male inflorescences are 5-13 in number flowery; peduncle to 11 mm diameter, whereas; female inflorescences 1-3 in number flowered; bracts minute, caducous. Male flowers are pedicel 4-8 mm in diameter; perianth concave, 4 mm in diameter, 3 lobes yellow or green, sometimes flushed brown, concave 1.5 mm. Stamens 3, filaments very short, disk fleshy; sterile ovary very small, at the center of the disk. Female flowers usually solitary, sometimes to 4 in sub-umbel; pedicel to 25 mm, enlarged at apex; bracteoles 2, linear-spatulate concave, as long as ovary, soon caducous, disk and stamens as in male but stamens sterile. The bi-sexual flowers similar to females but with fertile stamens and the stigmas contain three in numbers. The fruit's color drupe orange changed to red when ripened, drying soft blackish, having a partial globular form or pear-shaped, 4.5-10 mm in diameter (Hedberg and Edwards, 1989). The flowering period lasts for nearly 6 months (March-September) for females and nearly the entire year for males, with a peak in May-June for both sexes. Also, the interval between anthesis and fruit ripening is quite variable (range from 13-54 weeks) due to within-plant variance in developmental rates. As a consequence, ripe fruits are produced throughout the year, with a major peak in winter and a minor one in spring. As well, the growth season encompasses the period November-August for females and virtually the entire year for males (Herrera, 1988).

2.3 Geographic distribution of the species

The species distributed in African countries such as Tanzania and Kenya and is frequently found in arid to semiarid areas, primarily on stony and rocky soils (Kokwaro, 2009), or occasionally in rocky sites and along the margins of dry forests, evergreen bush land, savanna, and abundant at an altitude range of 900-2250 m above sea level (Giathi et al., 2011). However, large trees can occur in humid climates, preferentially in low soil pH and sufficient soil nitrogen (Mwang'ingo et al., 2003). The plant also grows naturally in the arid and semi-arid areas which receive a mean annual rainfall of 500-700 mm per year (Giathi et al., 2011).

In Ethiopia the species commonly found in the humid highland and semi-arid ecosystem of southern Ethiopian region (Teshome et al., 2004; Gemedo et al., 2005). The species were potentially abundant in Gamo Gofa (Mirab Abaya, Arba Minch Zuria, Bonke woreda), South Omo (Banne Tsemay, Hammer, Malle), and Borena (Yabello & Dirre woreda). Although the species rarely occurred in Derashe Special Woreda, Konso Special Woreda, in South Omo (Dasenech, South Ari, and North Ari woreda), in Gamo Gofa (Kemba, Zala, Dermalo & Uba Debratsehay woredas), in Borena (Arero, Dhas, Dubuluk, Gomole &Taltalle woredas), in Guji (Abaya, Galana, Dugda Dawa, Bule Hora, Sero Berbado, Wadera, Shakiso) and other woredas far apart from main routes in Guji zone (Bekele et al., 2019; Erbo et al.,2020).

2.4 Population structure of the species

According to Erbo et al. (2020), species population structure acknowledged the variability of population

dynamics within the vegetation of the world. The Stem density, and DBH-class of Osyris plants structure examines have shown that there are decreasing in similar trends by stem density and diameter sizes (Erbo et al., 2020). The population structure comparable reported by Tesfaye et al. (2000) studies on Dodonaea angustifolia in Afro-montane forest of Ethiopia and Shrubland vegetation studies by Belete Kebede (2012).

The stem density of the species increases with decreasing number of individual species. So, the overall pattern of DBH classes are an inverted J-shape distribution form (Erbo et al., 2020). Inverted J-shaped pattern shows high distribution of people of a species within the lower diameter classes and a gradual decrease towards the upper classes (Erbo et al., 2020). In other words, population structure of the species indicated the absence of people in DBH class ≥ 30 cm. Therefore, the results clearly defined the occurrence of high disturbance in matured tree of the forest by cutting of trees for fragrance, firewood, house construction, and fencing in the southern part of Ethiopia.

2.5 Plant Community type and Associated host species

Generally, from the reviewed literatures in Southern Ethiopia *Osyris quadripartita* population distribution potential larger could been dispersed in *Acacia-Rhus-Terminalia* community type. Those species listed in this community are; *Acacia hockii, Acacia mellifera, Acacia seyal, Acalypha fruticose, Commiphora confuse, Dichrostachys cinerea, Euclea divinorum, Maytenus senegalensis, Osyris quadripartita, Rhus natalensis and Terminalia laxiflora* (Erbo et al., 2020). *Acacia hockii* is the characteristic species of the community type and is found between 1380 - 1762 m a.s.l. of an altitudinal range (Erbo et al., 2020). This community have high slope natures of the sites were not easily accessible by local people to disturbed the vegetation which may also influence the richness of the species in the areas. Therefore, the highest population of Osyris species recorded at sloppy and hillside topography.

Osyris quadripartita might be hooked in to over 300 species of plants from herbaceous weeds, grass, multi-stem shrubs, and trees. Usually, it's found in association with various host plants like like Dodonaea anguistifolia, Euclea schimperi, Gardenia ternifolia, Rhus tenuinervis, Acacia hockii, Tecomaria capensis, Catha edulis, Apodytes dimidiata, Brachytegia spiciforms, Rhus natalensis and Casuarina equisetifolia (Mwang'ingo et al., 2010)

According to Erbo et al. (2020) the most dominant associated trees/shrubs with Osyris quadripartita are; Acacia hockii & Acacia Senegal (Girar in amharic), Euclea divinorum (dedaho), Euclea racemose (kurkura), Dodonaea angustifolia (kitkita), Combretum molle (Abalo), Olea europea (Weira), Rhus natalensis (Miste Aybelash), Terminalia laxiflora and Terminalia schimperiana (Woyiba) in the southern Ethiopia. Those species were more exposed to human interference in the form of selective woody tree cutting for household purpose.

2.6 Utilization techniques and harvesting practice

Regard to harvest raw materials, all of the woody portion of sandalwood are pulled from the bottom at harvest, the upper limbs are cut and bark removed. Logs are then dig billets which are either processed or exported directly (Loneragan, 1990). Usual downstream processing involves grinding the wood into a fine powder and processed into incense or joss sticks. These are utilized in many Asian ceremonies and non-secular events (Loneragan 1990; Rai and Sarma 1990). The groundwood is additionally distilled by either hydro or steam distillation to supply the neat oil, often used as a fixative for several perfumes.

Despite to the present, Sandalwood are being a renewable plant resource, and it's affected by significant decline in India, Indonesia, the South Pacific and Australia. This was mainly because of over- harvesting and illegal thieving of native stands, or by biological interruption from grazing animals or sandal spike disease (Loneragan 1990; Rai and Sarma 1990). camwood (Osyris lanceolata Hochst & Steud.) was among the Osyris species known for producing fragrant-scented wood from which sandalwood volatile oil is extracted (Ruffo et al., 2002). Sandalwood oil were utilized in the assembly of varied luxurious cosmetics, perfumes and fragrances (Sharmeen et al., 2021). The superb blending and antiseptic properties of the oil makes it valuable as a fixative for other fragrances (Srinivasan et al., 1992; Coppen, 1995). Sandalwood oil was also popular as a sedative in oriental medicine and thought of to possess narcoleptic effect. It a chemo-preventive effect and thus utilized in treating inflammatory and eruptive skin diseases, bronchitis, dysuria, gonorrhea, and urinary infection (Dwivedi et al., 1997).

The species has been of little importance, until recently when it had been captured within the limelight because of its overexploitation to satisfy the international demand for its perfumery and medicinal products within the treatment of hepatitis. The character of it exploitation raises concern on its survival within the wild because it involves uprooting of the full tree (destructive harvesting). The products increased in demand resulting in overexploitation, to an extent that its survival in natural habitats is severely threatened (William, 2012). The threatened population of Osyris might be convalesced through propagation mechanisms. The normal mode of propagation is by seed or root suckers (Kokwaro, 2009). Also, propagation by seeds is difficult because of a limited supply and availability of seed at the proper time (being a dioecious species), the spatial distribution

of trees affects the reproductive outcome (Mwang'ingo et al., 2008), storage difficulties and thus poor germination (Mbuya et al., 1994). Therefore, several interventional measures are required to conserve this species.

2.7 Product use of species in local area

The *Osyris quadripartita* species is synonym with *Osyris lanceolata* and therefore the plants used for huge purposes in locally. Those uses like food, medicine, timber, volatile oil, tannin, fragrance and fuel wood products. Food: Roots and bark are used for tea and as a tonic in soup. Fruits are edible; ripe fruits are eaten raw, with the seed discarded; only as an emergency food, especially by children or herdsmen (Addis et al., 2013). Medicine: A root decoction is employed to treat diarrhea in Kenya; a decoction of the bark and heartwood is employed to treat sexually transmitted diseases and anaemia in Tanzania (Orwa et al., 2009). It's also reported to treat stomach aches, tonsils, diarrhoea, ulcers, snakebites and rashes (Mohamed and Musya, 2005). Extracts from the plant can cure certain diseases, including the killer Hepatitis. Local's people are reported to use its bark powder to heal wounds.

Timber: The wood is extremely hard, strong and heavy. It's used for carvings, grain mortars, pestles, pegs, and for building poles and bedsteads. Essential oils: Roots and wood are scented and used to make cosmetics and perfume; and has a lucrative market in Germany, India, Indonesia and South Africa (Orwa *et al.,* 2009). Tannin or dyestuff: The bark was used for tanning leather by the voortrekkers while the root gives a strong red dye. Fibre: The root fibres are used in basketry. Fuel: also used as a source of firewood the most necessary woods in Southern part of Ethiopia (Erbo *et al.* 2020). Also, used for fragrances culturally in Borena area and Traditional healers have long used plants to prevent or cure infectious disease.

2.8 Marketable importance of the species

African sandalwood oil extracted from the heartwood and roots of the sandalwood tree is one of the most valuable essential oils, valued by perfumers for its woody notes, providing a deep rich base note to perfumes and acting as a natural adhesive (Gowda V.S, 2011). In addition to acting as a feedstock for essential oil production, wood is also valued for carving and furniture making. At an industrial level, wood and bark oils are reportedly used to extract highly valued perfumes and other cosmetics (Mohamed and Musya, 2005). It is also used as an ingredient for quality lotions and rare soaps. The local communities highly valued the plant for its medicinal properties, providing income generation to herbalists (Pamplona and Rogers, 2000).

Rising demand and very high prices for both wood and essential oil, a slow-growing tree that takes 30 to 60 years to give a crop, a destructive harvest to get the roots and heartwood with unsustainable harvesting options, and the scene is set for wild and illegal harvesting by the destruction of the natural resource (Gowda, 2011). Before 40 years ago sandalwood oil was under US$100/kg; now it is over US$2,000/kg reflecting the constraint to supply (Gowda, 2011).

In Ethiopia, Osyris quadripartita resources has been used as traditional means for a long time. Besides this, commercial contribution of the species to the livelihood of rural communities of our country was not known yet elsewhere (Ashenafi Ayenew, 2015). Since, 2012 utilization demands of *Osyris quadripartita* resources raised due to begin of Indian Company in our country to harvest plant for oil extraction. The agreement has signed between Ethiopian Biodiversity Institute (EBI) and DOCOMO Plc., USA based Company to harvest plant from wild (open access forest) and extract oil from heart wood of plants (Ashenafi Ayenew, 2015). This evidence implies that the resource were depleted from others neighboring East Africa Countries especially in Tanzania and Kenya (CITES Cop 16). Moreover, essential oils companies are attention in Ethiopian to invest/extract oils from this plants (EBI report, 2017).

2.9 Overall implication and Conservation measures

In Ethiopia, most *Osyris quadripartita* populations occur on public lands where there's little government control in terms of harvesting and management. Therefore, special strategies got to be developed to help its management and conservation. Perhaps the participatory management approach for state forest that's currently being developed in various parts of our country Ethiopia where local communities become key partners within the management, utilization, and conservation of the natural resources could prove useful. Efficient management and conservation of Osyris quadripartita in its natural habitats must also consider inclusions of other commercially important species. The tiny proportion of *Osyris quadripartita* (maximum basal area contribution is 6.75%) in most of the populations can hardly justify its management as single species (Erbo et al., 2020).

3. SUMMARY AND CONCLUSION

The review result shows some populations of Osyris quadripartita in Ethiopia are stable despite to this, with in few years free exploitation happened. the stableness is however not the results of controlled harvesting but, the actual fact that the bulk of the studied populations were little or not touched, being considered inferior or

uneconomical to reap in terms of quantity obtained and overall transportation cost to processing centers.

When consider yield quality, it's concluded that sandalwood populations vary substantially within the stock and quality of oil which will be produced. The standard of wood was poorly correlated to the climate and soil characteristics of the location. Perhaps, genetic factors, alone or together with the environmental play a big role in controlling the standard of the oil. There's no evidence to suggest that the basis system is superior to the shoot system in quality aspects. However, portions near the bottom level in both root and shoot system have more and better quality oil compared to those further away. It's recommended that harvesting of the species needs care, as populations with quality sandalwood seem to be few. Uprooting the species for any reason should be discouraged as this might interfere with natural vegetative regeneration. There's a requirement to include more populations of Osyris quadripartita in quality assessments to work out yield content and quality of oil. Other useful chemical compounds identified within the oil of Osyris quadripartita need fully exploration of their utilization to widen its use and market potential.

Finally, Osyris quadripartita is the most useful plant that needed attention for future research and the conservation. The present commercially harvesting was of the species influenced the population structure, a population number and the regeneration status of this species. Therefore, the management and conservation strategies are essential to be put in situ to save lots of the species from species list.

4. ACKNOWLEDGEMENT

We are grateful to Almighty Allah who helped us to accomplish this study. Our gratitude also goes to our families who encouraged and supported us in any aspect of our life and in the work of the present review.

REFERENCES

Ashenafi Ayenew, 2015. Current status of access genetic and benefit sharing implementation in Ethiopia reports. January 2015, Copenhagen.

Bekele T, Seifu A, Ayenew A, 2019. Status of Osyris quadripartita in Borana and West Guji zones, Oromia region, Ethiopia. Biodiversity International Journal. 2019; 3(2):79–83. DOI: 10.15406/ bij.2019.03.00131.

Butaud J-F, Rives F, Verhaegen D, JM Bouvet, 2005. Distribution of chloroplastic micro-satellite diversity in Santalum insulare across the South east Pacific archipelagos.

CITES, Cop 16. 2013. Sixteenth meeting of the Conference of the Parties, Bangkok (Thailand), 3-14 March 2013. Convention on International Trade in Endangered Species of Flora and Fauna. CoP16 Prop.69: pp. 1-10.

Coppen, J.W, 1995. Flavors and Fragrances of Plant Origin. Food and Agriculture Organization of the United Nations, Rome, Italy. 101p.

Dereje D. and Desalegn D. 2013. Abundance and use of *Vepris dainellii* (Pichi-Serm.) Kokwaro, an Ethiopian endemic plant, in Melokoza woreda, Southern Ethiopia. *Ethiopian Journal of Education & Science*. 8(2), pp.1-10.

Dwivedi C. and Abu-Ghazaleh A. 1997. Chemo preventive effects of sandalwood oil on skin papillomas in mice. *Eur J Cancer Prev.* Doi: 10.1097/00008469-199708000-00013.

EBI, 2017. Ethiopia Biodiversity Institute ABS directorate, Current status and benefit sharing from *Osyris quadripartita* field Monitoring and Evaluation report, 2017. Addis Ababa, Ethiopia.

Erbo K, Tolera M, & Awas T, 2020. Distribution, Association and Population Structure of Osyris Quadripartita (African Sandalwood) in a Dry Woodland Forest, Southern Ethiopia. Glob J Agric Health Sci 9:101. Doi: 10.35248/2319-5584.20.9.101

FAO, 2012. Global State of the world's forests, 2012. Rome, Italy.

Feyera Senbeta and Demel Teketay, 2003. Diversity, community types and population structure of woody plants in Kimphee Forest, a virgin Nature Reserve in Southern Ethiopia. *Ethiop. J. Biol. Sci.* 2(2):169-187.

Gathara, M. et al. 2014. Prediction of *Osyris lanceolata (Hochst & Steud*.) site suitability using indicator of plant species and edaphic factors in Kenya forests. *J. of Horticulture and Biodiversity,* Vol. 6(11), pp.99-106.

Gemedo, D., Brigitte L. M., and Johannes I., 2005. Plant Biodiversity and Ethnobotany of Borana Pastoralists in Southern Oromia, Ethiopia. *Economic Botany*, 59(1), pp.43-65.

Getachew Addis, Zemede Asfaw and Zerihun Woldu, 2013. Ethnobotany of Wild and Semi-wild Edible Plants of Konso Ethnic Community, South Ethiopia. *Ethnobotany Research & Applications* 11:121-141

Githae EW, Gachene CKK, Odee DW, 2011. Implications of in situ conservation of indigenous species with special reference to *Coffea arabica L.* population in Mount Marsabit Forest, Kenya. Trop. Subtrop. Agroecosyst, 14, pp.715-722.

Global Plants, 2016. The Plant List with literature. Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow.

Gowda V.S. 2011. Global Emerging Trends on Sustainable Production of Natural Sandalwood. Sandalwood oils export market data report 2011.

Habibur R., Abu Sayed A.K, Bishwajit R., Jannatul F., 2011. Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh. *Journal of Forestry Research*, 22(4), pp.551-559.

Hedberg I., and Edwards S., 1989. *Flora of Ethiopia, Vol.3 Pittosporaceae to Araliaceae*. The National Herbarium, Addis Ababa University, AA and Uppsala.

Herrera, C. M. 1988. The fruiting ecology of *osyris quadripartita:* individual variation and evolutionary potential: *Journal of Ecology,* 69(1). pp. 233-249

Herrera, C.M. 1984b. The annual cycle of *Osyris quadripartita*, a hem-parasitic dioecious shrub of Mediterranean scrublands. *Journal of Ecology*, 72, pp.1065-1078.

Herrera, J. 1985. Flower and fruit biology in southern Spanish Mediterranean shrub lands. *Journal of Botany*, 90, pp.113-127.

Irving LG, and Cameron DD, 2009. You are what you eat: interaction between root parasitic plants and their hosts. Advanced Botany Res. 50 pp.87-138.

IUCN, 1999. Biological Diversity of Drylands, Arid, Semiarid, Savanna, Grassland and Mediterranean Ecosystems. IUCN, the World Conservation Union.

Kitessa Hundera, 2010. Status of Indigenous Tree Species Regeneration under Exotic Plantations in Belete Forest, South West Ethiopia. *Ethiopian Journal of Education and Science*. 5(2), pp.19-28.

Koduru, S., Grierson, S.D., Afolayam, J.A. 2007. Ethnobotanical information of medicinal plants used for treatment of cancer in the Eastern Cape Province, South Africa. *Current Science*. 92 (7).

Kokwaro, J.O. 2009. Medicinal Plants of East Africa 3rd edit, Kenya Literature Bureau, Nairobi.

Loneragan, O.W. 1990. Historical Review of Sandalwood (*Santalum spicatum*) Research in Western Australia. Research Bulletin 4, Department of Conservation and Land Management, Como.

Mohamed A. M. and Musya D. K., 2005. The status of Osyris lanceolata Hochst. & St. the money tree: An overexploited medicinal plant in southern Drylands Kenya. A preliminary report presented to National project coordinator (NPC) -Natural Forests, KEFRI.

Mukonyi KW, Kyalo S, Lubia IK, Leitoro E, Mbaka RM, Lusweti AM, Mutwiri FM, 2011. Status of *Osyris lanceolata* in Kenya. Kenya Wildlife Service Report.

Mwang'ingo PL, Kibodya G, Mngong o AR, 2010. Oil yield and quality variation between sexes in *Osyris lanceolata* (African Sandalwood) and its value as a fodder plant in Tanzania. *Forests. J.* For. Sci. 72: pp. 69-74.

Mwang'ingo PL, Teklehaimanot Z, Hall JB, Lulandala LL, 2003. African Sandalwood (*Osyris lanceolata*): resource assessment and quality variation among populations in Tanzania. *South Afr. Forest. J.* 199: pp.77-88.

Mwang'ingo PL, Teklehaimanot Z, Lulandala LL, Mwihomeke ST, 2005. Host plants of *Osyris lanceleota* (African Sandalwood) and their influence on its early growth performance in Tanzania. *South Afr. Forest. J.* 203: pp.55-65

Newton AC. 2007(a). Forest ecology and conservation: a handbook of techniques. Oxford: Oxford University Press.

Newton AC. 2007(b). Biodiversity loss and conservation in fragmented forest landscapes. The forests of montane Mexico and temperate South America. Wallingford: CABI

Orwa C, A Mutua, Kindt R , Jamnadass R, S Anthony. 2009. Agroforestree Database: a tree reference and selection guide version 4.0.

Pamplona G. D. and Roger M. D., 2000. Plants for the stomach. Encyclopedia of medicinal plants, *Vol 2.*

Peters, C. M. 1996. The Ecological and Management of Non -Timber Forest Resources. World Bank Technical Paper 322, ISBN 0-8213-3619-3. Washington.

Rai, S.N. and Sarma, C.R., 1990. Depleting sandalwood production and rising prices. *Indian Forester*, 116: pp.348-355.

Ruffo, C.K, Birnie, A. and Tengnas, B. 2002. Edible wild plants of Tanzania. Region Land Management Unit Technical Handbook series 27. RELMA/ (SIDA), Nairobi, Kenya.

Sharmeen, Jugreet B.; Mahomoodally, Fawzi M.; Zengin, Gokhan; Maggi, Filippo. 2021. "Essential Oils as Natural Sources of Fragrance Compounds for Cosmetics and Cosmeceuticals" Molecules 26, no. 3: 666. https://doi.org/10.3390/molecules 26030666.

Srinivasan, V.V., Sivaramakrishnan, V.R., Rangaswamy, C.R., Ananthapadmanabha, H.S. and Sankaranarayana, K.H., 1992. Sandal (*Santalum album*.). Indian Council of Forestry Research and Education, Dehra Dun, India. 233p.

Subasinghe, U., Gamage, M., Hettiarachchi, D.S. 2013. Essential oil content and composition of Indian sandalwood (*Santalum album*) in Sri Lanka. *J. Forestry Research,* 3(01):pp.1-8.

Teshome S., Demel T., & Sebsebe D. 2004. Ecological study of vegetation in Gamo Gofa zone, South Ethiopia. *Tropical Ecology,* 45 (2): pp.209-221

Tshisikhawe MP, van Rooyen MW, Bhat RB. 2012. An evaluation of the extent and threat of bark harvesting of medicinal plant species in the Venda Region, Limpopo Province, South Africa. *Int. J. Experiment Botany*, 81: pp.89-100

USF and WS, 2013. US Forest and Wildlife Service notice to the world import/export community on changes in CITES species listings. Inspector, US Department of F the Interior. Fish and Wildlife Service.

William O. O., 2012. A very useful plant, *Osyris lanceolata*, is at risk of extinction due to over exploitation. *Kew News*. Kew Botanical Gardens. Retrieved 14 December 2012.

Woodall GS, and Robinson CJ (2003). Natural diversity of Santalum spicatum host species in south-coast river systems and their incorporation into profitable and biodiverse revegetation. Australian Journal of Botany 51, 741–753.