Assessment of Standing Stock, Distribution, Harvesting, Processing, Trade, Control and Monitoring of *Osyris lanceolata*in Selected Sites in Tanzania

Dr Abel Malyango Masota
Tanzania Forest Service

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Executive summary

Introduction

East African Sandalwood (*Osyris lanceolata*) is among the species known for producing fragrant-scented wood from which sandalwood essential oil used in perfumery, fragrance and medicinal industry is extracted. Apart from its use in the fragrance industry, sandalwood oil finds its use in medicine, and is considered to have narcoleptic effect. On the other hand, sandalwood tree also yields edible berries (fruits), used extensively as a dietary supplement in dry lands areas of Tanzania where it is mostly found.

Sandalwood resource in Tanzania has ever been declining since its identification in 1900s as an important source of the oil. Pressure to overexploit the resource increased further in 1990s following a serious decline in the resource base of Indian sandalwood (*Santalum album*), a species known to yield the best sandalwood oil in the world. For example, a study done in 17 districts in 2006 revealed that there was hardly enough sandalwood in Tanzania to support industrial investment as a result, harvesting of the species was banned to date.

However, unless efforts to manage the species are done, the natural populations alone can no longer meet the industrial requirement of the species. Nevertheless, before embarking to the management of sandalwood it is important that population size and standing stock is largely known. Such information will facilitate sustainability of the current off-take levels, propose/recommend the allowable harvesting quantities, and propose appropriate management activities. However, any management recommendations require information on the current stock and distribution of the species in a country. It is against this background that this study was carried out to assess the standing stock and distribution of *Osyris lanceolata* in Tanzania and propose appropriate management of the species.

Objective

The main objective of this study to assess the standing stock and distribution of *Osyris lanceolata* and propose appropriate management of the species in Tanzania.

Specific objectives

Specifically, this study intends to:

i. Estimate total per ha volume and basal area for the different populations of *O. lanceolata* and look-alikes.
ii. Propose management activities, production and harvesting quotas.
iii. Produce biomass distribution maps of O. lanceolata and look-alikes.
iv. Carry out botanical survey of *O. lanceolata* in the selected study sites providing information/data species distribution, natural stands, natural regeneration, and stocks.
v. Propose/develop strategies for the conservation of these tree species.

Methodology

Selection of sites

Literature review and direct communication with different private and government offices assisted to provide informed information regarding the sites where *O. lanceolata* is found. This information guided the selection of sites to carry our inventory. The districts identified to have a

population of *O. lanceolata* were Babati, Hanang, Kondoa, Lushoto, Handeni, Kilindi, Ludewa, Makete, Mbarali, Manyoni, Mufindi; Iringa rural, Kilolo, and Karatu.

Due to limited financial resources, we selected three districts for surveying (Babati, Kondoa and Hanang) to carry out forest inventory. These districts were selected because they support the growth of the best quality *O. lanceolate* in terms of santalol content (32 %) in Tanzania. With help from DFO, DNRO, local communities and DCO, we selected locations and forests with high concentration of *O. lanceolata* outside protected areas since harvesting in these areas is likely to be allowed.

Study design

In each selected forest, transects of 10 m width and different length depending on the size of the forest were laid out. The transects were parallel to each other and spaced at a distance of at least 250 m. Within each transects, plots with a radius of 3 m were laid at every instance of encountering the *O. lanceolata* when traversing in the transect. The number of plots depended on the frequency of encountering *O. lanceolata*. The plots aimed to collect data from the encountered *O. lanceolata* (regeneration and larger tree) and its associate tree species found within the plot area.

Data collection

The following measurement was taken in each plot:

a. For *O. Lanceolata* with dbh>1 cm:
    i. Diameter at beast height (Dbh); and
    ii. The Dbh and tree identity of all tree species within a radius of 3 m.
b. Regeneration counts of all *O. lanceolata* with dbh< 1 cm.

In addition, for forests with no information of forest area, we estimated the forest area

Data analysis

Stand parameters of interest which were computed were the number of stems, basal area (G), volume (V), and biomass (B) per ha. Stand parameters were computed for *O lanceolata* exceeding Dbh of 1 cm. below that, the species were considered to be regenerant. In addition, stand parameters of the associate tree species were computed and identified the common tree species associated with *O. lanceolata*.

Data from the National Forest Resources Monitoring and Assessment (NAFORMA) was the only source which was able to provide the distribution of *O. lanceolata* at national level. In this case, NAFORMA data may not give the status of the species since about nine years has elapsed since the assessment. A lot may have happened. However, NAFORMA data provides indication of potential sites with *O. lanceolata* for future in-depth assessment in these sites.

Main findings

Stand density of O. lanceolata

The highest stand density of O. *lanceolata*was found in Babati and Hanang ranged from 6 to 103. Forests in Kondoa were found to have relatively lower stem density compared to the former districts ranging from 1 stems/ha to 12 stems/ha. Overall, the basal area and the AGB ranged from 0.0001 to 0.096 m^2/ha and from 0.001 to 0.231 tones/ha, respectively.The total standing AGB in Babati, Hanang and Kondoa is estimated to be 110.1, 183.38 and 45.9 tons respectively. A survey carried out earlier, URT (2005) reported sandal wood standing biomass of 29, 62 and 1 tons in Babati, Hanang and Karatu districts respectively. It seems the ban on harvesting the species has helped stock build up significantly.

Diameter distribution of O. lanceolata

The distribution of number of stems per ha by diameter classes in most of the studied village forests indicated active regeneration as expected in a natural forest, i.e., large number of stems for lower diameter classes that decreased with the increase of diameter.

Regeneration

This study considered regeneration as a tree with a Dbh of less than 1 cm. Few studied village forests were found to have promising regeneration mainly from coppicing stumps following removal of the main stem. These forests include Duru (19 stems/ha), Gidagewong (24 stems/ha), Gubali (28 stems/ha) and Kolo (8 stems/ha) Table 4. The remaining forests had at most 6 stems/ha. Poor regeneration of *O. lanceolata* is possibly caused by high forest degradation (mostly extraction of firewood and charcoal; and grazing) as observed during field work campaigns and therefore reduce stocking of associate tree species.

Associate tree species

Tree species which appeared in all studied village forests were *Rhus natalensis* and *Combetum mole*. These were followed by *Jubelnadiaglobiflora, Vachelliahockii, Catunaregum spinosa, Eucleadivinorum, Brachystegiaspiciformis, Canthiumoligocarpum, Dombeya rotundifolia* and *Senna singuena* which show up in at least in four studied forests. Similar observations of associate species were reported in earlier surveys.

Biomass distribution in the country

The primary data collected from the field campaign were not adequate to provide useful information on the distribution of *O. lanceolata* at national level. Available secondary source which is NAFORMA database is over 9 years which might not be reliable to provide the status of *O. lanceolata*. However, this source is crucial since it is the only available that indicate hotspot sites with significant population of *O. lanceolata*. NAFORMA data show that *O. lanceolata* is mainly found in five districts namely Lushoto, Mbalali, Manyoni, Njombe and Ludewa. The good news is that most of the plots except for Lushoto district fall outside the protected areas and therefore potentially available for harvesting. The findings from NAFORMA database show that large number of plots with *O. lanceolata* were found in Lushoto having the largest stand parameters (i.e., G = 16.9 m^2/ha; V = 87.2 m^3/ha). This was followed by Njombe region (Ludewa and Njombe districts). The district with the least value of stand parameters was Mbarali and Manyoni.

Management activities, production and harvesting quotas

Existing management of O. lancelata

Currently no management per se is instituted on *O. lancelata*. Although the ban to harvest the species was placed its enforcement was weak in some districts. In the surveyed districts there was evidence of tree cut and removals. Also holes in the soil indicating uprooting of the species were detected. This may indicate illegal harvesting to feed the industry in Babati.

Harvesting potential

The minimum harvesting sizes for different tree species are specified by the Government in the Fourteenth Schedule of Forest Regulations of 2017 (URT 2017). Unfortunately, there is no mention of *O. lanceolate* making it difficult to conclude whether the available stems have reached harvestable sizes or not. However, given the fact that the species can reach Dbh of 24 cm, it appears the maximum size of 11 cm found in the studied sites are still juvenile. Nonetheless, as observed harvesting ban instituted on *O. lanceolate* seems to have helped stock build up despite evidence of illegal harvesting. According to URT 2005, the lowest capacity of a sandal wood processing factory is 30 tonnes per month, and hence 360 tons per year. The estimated total biomass of sandal wood currently growing in Babati, Hanang and Kondoa districts is 339 tons including small tree down to 1 cm Dbh. It is clear that this amount is inadequate to feed the Babati factory even for 1 year. It is therefore premature to think of any harvesting of the species currently.

Propose/develop strategies for the conservation of these tree species

Given the current status of *O. lanceolate*, we propose the following conservation strategies;

- Strengthening law enforcement to control illegal harvesting; and
- Establishment of research trials to propagate and domesticate *O. lanceolata.*

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1. Introduction

1.1 Background

East African Sandalwood (*Osyris lanceolata*) is among the species known for producing fragrant-scented wood from which sandalwood essential oil used in perfumery, fragrance and medicinal industry is extracted. The oil is famous as an incense in various religious functions like Buddhism and Hinduism. The excellent blending and antiseptic properties of sandalwood oil makes it valuable as a fixative for other fragrances. Apart from its use in the fragrance industry, sandalwood oil finds its use in medicine, and is considered to have narcoleptic effect. It is used in treating inflammatory and eruptive skin diseases, bronchitis, gonorrhoea, and urinary infection and chronic mucus infections (Dwivedi and Zhang, 1999). On the other hand, sandalwood tree also yields edible berries (fruits), used extensively as a dietary supplement in dry lands areas of Tanzania where it is mostly found. Wild fruits are known to play a significant role in human nutrition, especially as source of vitamins C and minerals. Fruits are important source of nutrient in many parts of the world, and offer advantages over dietary supplements because of low cost and wide availability.

Sandalwood resource in Tanzania has ever been declining since its identification in 1900s as an important source of the oil. Pressure to overexploit the resource increased further in 1990s following a serious decline in the resource base of Indian sandalwood (Santalum album), a species known to yield the best sandalwood oil in the world (Srinivasan et al., 1992). Throughout the years, the natural populations have been the only supplier of the raw material, leading to rapid decline of the resources (Ruffo et al., 2002). As availability of the resources continued to decline, harvesting practices which involved root excavation and debarking emerged (Ruffo et al., 2002; Mwang'ingo and Mwihomeke, 1997) hence leading to overexploitation. For example, a study done in 17 districts in 2006 revealed that there were hardly enough sandalwood in Tanzania to support industrial investment (MNRT, 2006). As a result, harvesting of the species was banned to date. There are two processing industries in Tanzania located in Babati and Mombo towns. These industries import their raw materials from South Sudan and Uganda (Mr. Ali Majid, TFS licensing officer: personal communication).

However, unless efforts to manage the species are done, the natural populations alone can no longer meet the industrial requirement of the species. Nevertheless, before embarking to the management of sandalwood it is important that population size and standing stock is largely known. Such information will facilitate sustainability of the current off-take levels, propose/recommend the allowable harvesting quantities, and propose appropriate management activities. However, any management recommendations require information on the current stock and distribution of the species in a country. It is against this background that this study was carried out to assess the standing stock and distribution of *Osyris lanceolata*in Tanzania and propose appropriate management of the species.

1.2. Objective

The main objective of this study to assess the standing stock and distribution of *Osyris lanceolata* and propose appropriate management of the species in Tanzania.

1.3. Specific objectives

Specifically, this study intends to:

vi. Estimate total per ha volume and basal area for the different populations of *O. lanceolata* and look-alikes.
vii. Propose management activities, production and harvesting quotas.
viii. Produce biomass distribution maps of O. lanceolata and look-alikes.
ix. Carry out botanical survey of *O. lanceolata* in the selected study sites providing information/data species distribution, natural stands, natural regeneration, and stocks.
x. Propose/develop strategies for the conservation of these tree species.

2. Methodology

2.1. Selection of districts

Literature review and direct communication with different private and government officesassisted to provide informed information regarding the sites where *O. lanceolata* is found. Table 1 presents districts where the species is found and source of information.

Table 1. Districts with *O. lanceolata*

Region	District	Source of information
Manyara	Babati, Hanang	DFO; DFC; URT, (2005); et al
Dodoma	Kondoa	DFO; DFC; URT, (2005); et al
Tanga	Lushoto, Handeni, Kilindi	DFO; DFC; URT, (2005); et al, *NAFORMA data base
Njombe	Ludewa, Makete	NAFORMA data base; URT, (2005)
Mbeya	Mbarali	NAFORMA data base
Singida	Manyoni	NAFORMA data base
Iringa	Mufindi; Iringa rural, Kilolo	URT, (2005)
Arusha	Karatu	URT, (2005); et al,

DFO: District Forest Officer
DFC: District Forest Conservator
*NAFORMA: National Forest Resources Monitoring and Assessment of Tanzania (URT, 2015)

2.2. Selection of sites

Some of the sites with the studied species was in protected area. This includes several sites in Lushoto, Babati, Ludewa and Handeni. We selected three districts for surveying (Babati, Kondoa and Hanang).These districts were selected because they support the growth of the best quality *O. lanceolate* in terms of santalol content (32 %) in Tanzania (Mwangingoet al 2003). The quality of this species is based on santalol content. With help from DFO, DNRO, local communities and DCO, we selected locations and forestswith high concentration of*O. lanceolata* outside protected areas since harvesting in these areasis likely to be allowed.Most of these areas were Village Land Forests. Table 2 presents selected sites within the three districts

2.3. Study design

In each selected forest, transects of 10 m width and different length depending on the size of the forest were laid out. The transects were parallel to each other and spaced at a distance of at least 250 m. In forests which were bordered by the main road, the transects were laid out perpendicular to the road. Depending on the size of the forest area, the number of transects ranged from 2 to 6. Within each transects, plots with a radius of 3 m were laid at every instance of encountering the*O. lanceolata*when traversing in the transect. The plot center was the location of the *O. lanceolata* stem. The number of plots depended on the frequency of encountering *O. lanceolata*. The plots aimed to collect data from the encountered *O. lanceolata*(regeneration and larger tree) and its associate tree species found within the plot area.The use and efficiency of this approach have been reported by different scholars (e.g. Buckland et al., 2007; Munishi et al., 2010; Peres, 1999).

Table 2. Selected sites in Babati, Hanang and Kondoa districts

Region	District	Village	Forest	Estimated area (ha)	Number of transects	Number of Plots????
Manyara	Babati	Ayasanda	Warimbu	50	2	
	Babati	Duru	Duru	1400	5	
	Babati	Gidimu	Haisamu	180	4	
	Babati	Riroda	Ayatlaa	30	2	
	Babati	Riroda	Gedagerere	1200	5	
	Hanang	Barjomot	Gidagewong	720	6	
	Hanang	Gabadau	Gabadau	230	4	
	Hanang	Gendabi	Sebas	40	4	
Dodoma	Kondoa	Gubali	Gubali	900	6	
	Kondoa	Hachwi	Hachwi	1503	5	
	Kondoa	Kolo	Kolo	1030	5	

2.4. Data collection

The following measurement was taken in each plot:

c. For *O. Lanceolata* with dbh>1 cm:
   i. Diameter at beast height (Dbh); and
   ii. The Dbh and tree identity of all tree species within a radius of 3 m.
d. Regeneration counts of all *O. lanceolata* with dbh< 1 cm.

In addition, for forests with no information of forest area, we estimated the forest area

2.5. Data analysis

2.5.1. Stand parameters of *O.lanceolata*

Stand parameters of interest were the number of stems, basal area (G), volume (V), and biomass (B) per ha. The equations below wasused to compute the stand parameters of the study species. Similar equation 1 were used to compute stand parameters for the associate tree species.

$$Y = \frac{\sum_i^k y}{a_j} \Big/ m \qquad (1)$$

Where:*Y* is basal area, volume or number of stems per ha; *y* is the tree basal area, volume, biomass or number of a tree (*y* =1) of tree the*i*thtree of *k* trees in the plot or transect; and *a* is the area of the transect or plot*j*; and *m* is the total number of transects or plots.

The volume and biomass equation for miombo woodlands developed by (Mauya et al., 2014) and (Mugasha et al., 2013), respectively were applied to estimate the individual stem above ground volume and biomass.

2.5.2. Regeneration of *O. lanceolata*

Since in each plot and transect the regeneration was counted, equation (1) was used to estimate the number of regenerants per ha. The *y*'s in equation (1) corresponds to one for each instance of encountering the regenerant in the particular transect or plot.

2.5.3. Associate tree species

Stand parameters for the associate tree species were computed as described in Section 2.5.1. It is important to document the stand density in which the *O. lanceolata* occur. To ascertain the common tree species associated with *O. lanceolata*, the frequency of occurrence of each associate tree species was calculated for each forest and to the overall data set. Tree species which had at least two occurrences were presented.

2.5.4. Distribution of *O. lanceolata in* Tanzania

Data from the National Forest Resources Monitoring and Assessment (NAFORMA) was the only source which was able to provide the distribution of *O. lanceolata* at national level. In this case, NAFORMA data may not give the status of the species since about nine years has elapsed since the assessment. A lot may have happened. However, NAFORMA data provides indication of potential sites with *O. lanceolata*for future in-depth assessment in these sites.For each identified site, stand parameters, i.e., stems (N) and basal area (G), were computed and presented.

3. Preliminary Results and Discussion

3.1. Stand density of *Osyris lanceolata*

Stand level parameters in term of number of trees (N), basal area (G), and biomass (B) are presented in Table 3. The stem density of *O. lanceolata* in Babati and Hanang ranged from 6 to 94 stems/ha (highest in Haisamu and lowest in Gedagerere village forests) and from 7 to 103 stems/ha(highest in Gidagewong and lowest in Sebas village forests). Forests in Kondoa were found to have relatively lower stem density compared to the former districts ranging from 1 stems/ha in Hachwito 12 stems/ha in Gubalivillage forests. Basal area and the AGB followed the same trend as the number of stems per ha ranging from 0.0001 to 0.096 m^2/ha and from 0.001 to 0.231 tones/ha, respectively.

Table 3. Stand parameters of *O. lanceolata*

District	Forest name	code	Forest Area	Amount per ha			Total amount available		
				Stem	G (m^2)	AGB (tones)	Stems	AGB (tones)	Total AGB in the district (tones)
Babati	Warimbu VLFR	0	50	12 - (9)	0.008 - (0.006)	0.019 - (0.016)	647	0.96	110.1
	Duru VLFR	0	1400	25 - (3)	0.015 - (0.002)	0.032 - (0.005)	35,548	45.45	
	Haisamu VLFR	0	180	94 - (44)	0.096 - (0.052)	0.28 - (0.184)	16958	50.4	
	Ayatlaa VLFR	0	30	45	0.022	0.048	1363	1.45	
	Gedagerere VLFR	0	1200	6 - (3)	0.004 - (0.001)	0.01 - (0.003)	8151	11.84	
Hanang	Gidagewong VLFR	0	720	103 - (31)	0.09 - (0.022)	0.231 - (0.058)	74480	166.05	183.38
	Gabadau VLFR	0	230	39 - (17)	0.029 - (0.014)	0.073 - (0.039)	8991	16.82	
	Sebas VLFR	0	40	7 - (1)	0.006 - (0.001)	0.013 - (0.002)	303	0.51	
Kondoa	Gubali VLFR	0	900	12 - (5)	0.006 - (0.003)	0.014 - (0.006)	10944	12.31	45.9
	Gubali VLFR	1	900	2	0.001	0.001	1902	1.09	
	Hachwi VLFR	0	1503	6 - (1)	0.004 - (0.001)	0.01 - (0.004)	9856	14.39	
	Hachwi VLFR	1	1503	1	0.0001 -	0.001	1233	1.32	
	Kolo VLFR	0	1030	8 - (5)	0.006 - (0.005)	0.016 - (0.014)	8494	16.79	
Total biomass in three districts									339.4

In brackets are the standard error; Code 0: Male; Code 1: Female.

The total standing AGB in Babati, Hanang and Kondoa is estimated to be 110.1, 183.38 and 45.9 tons respectively. A survey carried out earlier, URT (2005) reported sandal wood standing biomass of 29, 62 and 1 tons in Babati, Hanang and Karatu districts respectively. It seems the ban on harvesting the species has helped stock build up significantly.

3.2. Diameter distribution of *O. lanceolata*

The distribution of number of stems per ha by diameter classes in most of the studied village forests indicated active regeneration as expected in a natural forest, i.e., large number of stems for lower diameter classes that decreased with the increase of diameter except for Kolo, Gubali, Gedagerere and Sebas village forestsFigure 1. Forests which did not comply to this expected pattern suggest having poor recruitmentstrend and therefore jeopardize the sustainability of*O. lanceolata.*

Of 11 studied village forests, only Kolo, Haisamu and Gidagewong forests have trees in largest diameter class. The other forests had no tree in the largest diameter class, i.e., >8 cm. the maximum Dbh attained in the studies forests was 11.6 cm. Based on the NAFORMA data base, the Dbh of *O. lanceolata* can potentially reach24 cm. This impliesthat for most of the studiedvillage forests, *O. lanceolata* is in the regrowth phase suggesting that harvesting took place in past as reported earlier URT (2005). This was also confirmed by local communities claiming that there had been illegal harvesting of *O. lanceolata* in the past. In addition, most of the identified stems of *O. lanceolata* originated from coppices following tree cut.

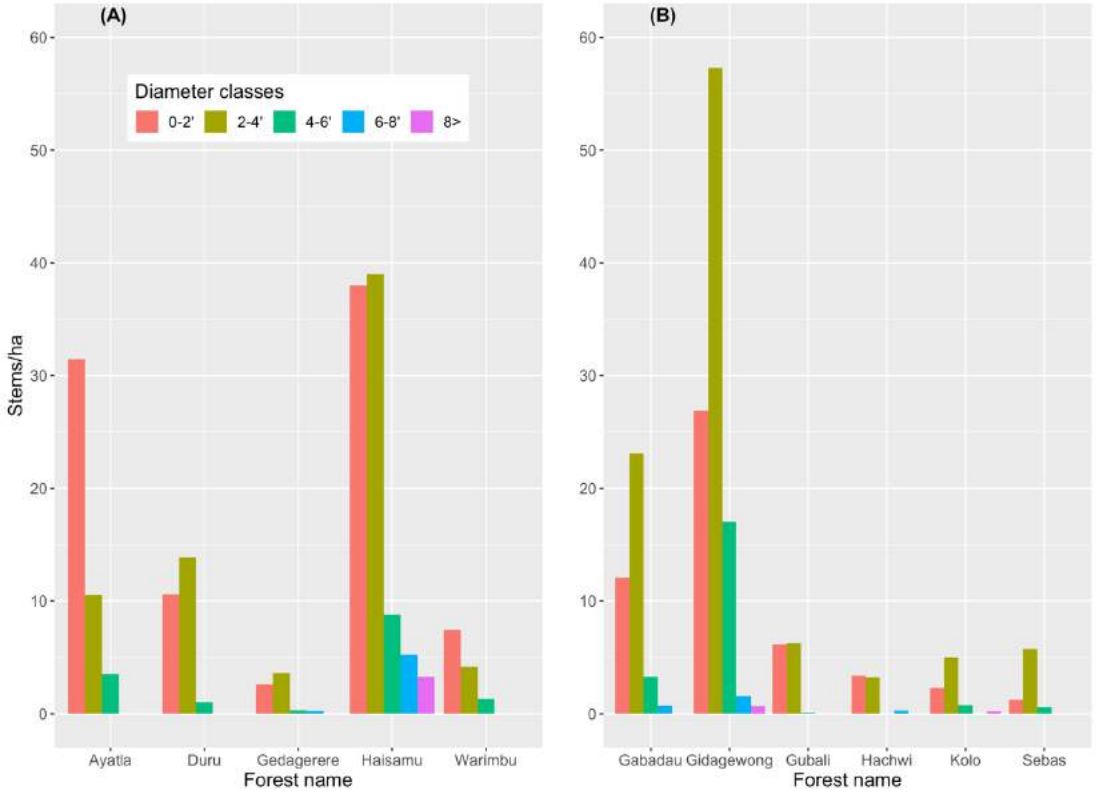

Figure 1. Distribution of the number of stems per ha by diameter classes for each studied village forests

3.3. Regeneration

This study considered regeneration as a tree with a Dbh of less than 1 cm. Few studied village forests were found to have promising regeneration mainly from coppicing stumps following removal of the main stem. These forests include Duru (19 stems/ha), Gidagewong (24 stems/ha), Gubali (28 stems/ha) and Kolo (8 stems/ha)Table 4. The remaining forests had at most 6 stems/ha. Poor regeneration of *O. lanceolata* is possibly caused by high forest degradation (mostly extraction of firewood and charcoal; and grazing) as observed during field workcampaigns and therefore reduce stocking of associate tree species.Tree species which have been found often to be associated with *O. lanceolata* are presented in subsequent Section.

Table 4. Regeneration of*O. lanceolata*

District	Village	Forest	Code	Stems/ha
Babati	Ayaasanda	Warimbu VLFR	0	3.3
Babati	Duru	Duru VLFR	0	19.4
Babati	Gidimu	Haisamu VLFR	0	6.0
Babati	Riroda	Gedagerere VLFR	0	4.1
Hanang	Barjomot	Gidagewong VLFR	0	24.0
Hanang	Gabadau	Gabadau VLFR	0	4.9
Kondoa	Gubali	Gubali VLFR	0	28.3
Kondoa	Gubali	Gubali VLFR	1	1.1
Kondoa	Hachwi	Hachwi VLFR	0	4.6
Kondoa	Hachwi	Hachwi VLFR	1	1.5
Kondoa	Kolo	Kolo VLFR	0	8.3

Code 0: Male; Code 1: Female.

3.4. Associate tree species

Tree species appearing in association with *O. lanceolata*in at least two forests is presented in

Table 5. Tree species which appeared in all studied village forests were *Rhus natalensis* and *Combetum mole*. These were followed by *Jubelnadiaglobiflora, Vachelliahockii, Catunaregum spinosa, Eucleadivinorum, Brachystegiaspiciformis, Canthiumoligocarpum, Dombeya rotundifolia* and*Senna singuena* which show up in at least four studied forests. Similar observations of associate species were repoterd in earlier surveys (URT 2005)

The findings suggest that *O. lanceolata* have broad geographical ranges from lowland forests (Gidagewong and Gabadauforests in Hanang district) to miombo woodlands (the remaining studied forests). Some of the associate tree species such as *Rhus natalensis, Vachelliahockii, Combetum mole, Catha edulis, and Dodonaeaviscos*a were also common in both cover types suggesting their strong association with *O. lanceolata*(Appendix 1). Nevertheless, it is apparent that some of the associated tree species had higher frequency at forest level due to cover type and site condition differences. For example, associated tree species which were found in at least 50% of the plots at forest level were *Carissa edulis*(Haisamu forest); *Rhus natalensis*(Duru, Gedagerere and Gidagewong, Sebas and Warimbu forests); and *Jubelnadiaglobiflora*(Hachwi and Kolo forests)(References

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Appendices

Appendix 1. These findings suggest that site conditions and type of cover is important since it decide what tree species should be associated with *O. lanceolata*. Therefore, efforts towards domestication of *O. lanceolata*should take consideration of these factors.

Table 5. Frequency of occurrence and percentage of plots with associate tree species

Local name	Botanical name	Average percentage of plots with associate species in all forests	Number of forests with associate species
Sirongi, Datrii	*Rhus natalensis*	48	11
Nafumo, Mhangala	*Jubelnadiaglobiflora*	41	4
Warfi	*Catha edulis*	29	3
Titiwi	*Carissa edulis*	25	3
Gendaii, Gendaamo	*Combetummolle*	24	11
Hhatsmo, Slontli	*Apodytesdimidiata*	23	2
Hhewasi	*Brachystegiamicrophylla*	23	4
Fitsitoo	*Vachelliahockii*	23	8
Getalongo	*Catunaregum spinosa*	23	5
Sirongi	*Rhus vulgaris*	21	2
Pararaamo	*Schreberatrichoclada*	20	3
Pararaamo	*Schreberaalata*	20	2
Miningiti	*Eucleadivinorum*	19	6
Tsilenaii, Mtarima	*Lanneaschimperi*	18	4
Mhasa	*Euphorbia candelabrum*	17	4
Bermi	*Dodonaeaviscosa*	17	6
Tsapenai	*Flacourtia indica*	17	4
Seese	*Vernonia exserstiflora*	17	3
Barang'u	*Vangueriainfausta*	16	3
	Rytigyniaschumanii	15	3
Nistiay	*Omorcarpumkirkii*	15	3
Irocktum	*Protea rochetiana*	14	2
Mwirela	*Brachystegiaspiciformis*	12	4
Frankii	*Canthiumoligocarpum*	11	4
Gudaati	*Dombeya rotundifolia*	10	4
Msisivili	*Albizia harvey*	10	2
Miningiti	*Eucleanatalensis*	10	2
Irocktum	*Protea angolensis*	9	2
Daraa'ghw	*Senna singuena*	9	4

3.5. Biomass distribution in the country

The primary data collected from the field campaign werenot adequate to provide useful information on the distribution of *O. lanceolata* at national level. Available secondary source which is NAFORMA database is over 9 years which might not be reliable to provide the status of *O. lanceolata*. However, this source is crucial since it is the only available that indicate hotspot sites with significant population of *O. lanceolata*. NAFORMA data show that *O. lanceolata*is mainly found in five districts namely Lushoto, Mbalali, Manyoni, Njombe and Ludewa (Figure 2). It is apparent that the species is found elsewhere (Table 1). The good news is that most of the plots except for Lushoto district fall outside the protected areas and therefore potentially available for harvesting. The narrow distribution of the species in NAFORMA data is attributed to the lowsampling intensity applied by NAFORMA reducing chances of its detection in the field. In addition,NAFORMA sampling design intentionally favoured areas with high wood biomass

while *O lanceolate*prefers stony hill side sites with often poor vegetation cover (Mwangingo et al 2003).

The findings from NAFORMA database show that large number of plots with *O. lanceolata* were found in Lushoto having the largest stand parameters (i.e., G = 16.9 m^2/ha; V = 87.2 m^3/ha) except for number of stems per ha. This was followed by Njombe region (Ludewa and Njombe districts). The district with the least value of stand parameters was Mbarali and Manyoni.

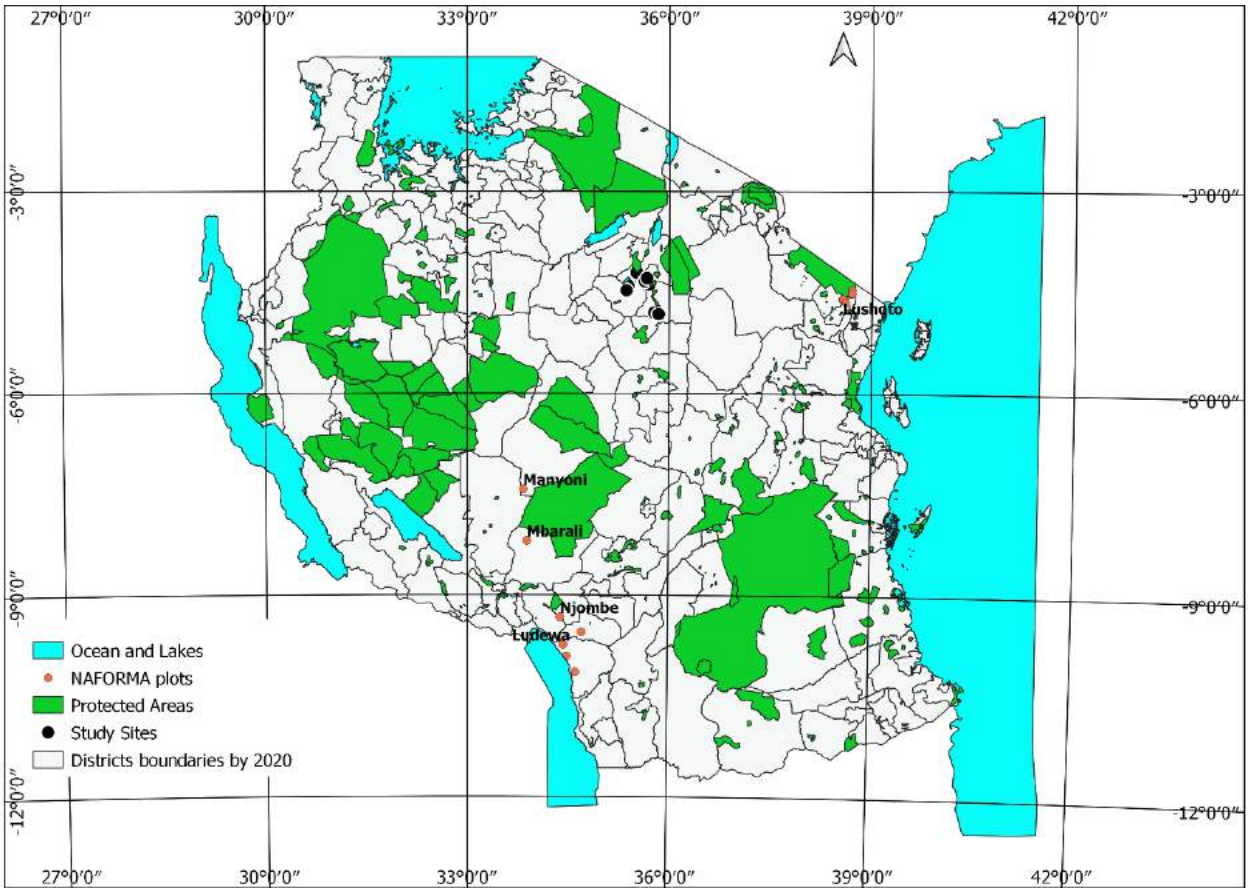

Figure 2. Study sites and NAFORMA plots where *O. lanceolata* was encountered

Table 6. Stand parameters of *O. lanceolata* based on NAFORMA data

Region	District	Number of plots	Diameter (cm)			G (m2/ha	Stems/ha	Biomass (tones/ha)	V (m^3/ha)
			Min.	Max.	mean				
Njombe	Njombe	3	10.4	14.5	12.5	15.0	1193.7	66.9	68.6
Njombe	Ludewa	8	5	13	7.8	8.5	1591.5	32.4	33.5
Mbeya	Mbarali	1	10.5	10.5	10.5	6.9	795.8	27.8	28.7
Singida	Manyoni	3	6.4	7.7	6.9	9.1	2387.3	30.2	31.3
Tanga	Lushoto	18	5	24	12.8	16.9	1101.8	85.4	87.2

3.6. Management activities, production and harvesting quotas

3.6.1 Existing management of *O. lancelata*

Currently no management per se is instituted on *O. lancelata*. Although the ban to harvest the species was placed its enforcement was weak in some districts. In the surveyed districts there was evidence of tree cut and removals. Also holes in the soil indicating uprooting of the species were detected. This may indicate illegal harvesting to feed the industry in Babati.

3.6.2 Harvesting potential

The minimum harvesting sizes for different tree species are specified by the Government in the Fourteenth Schedule of Forest Regulations of 2017 (URT 2017). Unfortunately, there is no mention of *O. lanceolate* making it difficult to conclude whether the available stems have reached harvestable sizes or not. However, given the fact that the species can reach Dbh of 24 cm it appears the maximum size of 11 cm found in the studied sites are still juvenile.Nonetheless, as observed in Section 3.1 the harvesting ban instituted on *O. lanceolate* seems to have helped stock build up despite evidence of illegal harvesting.

According to URT 2005, the lowest capacity of a sandal wood processing factory is 30 tonnes per month, and hence 360 tons per year. The estimated total biomass of sandal wood currently growing in Babati, Hanang and Kondoa districts is 339 tons including small tree down to 1 cm Dbh. It is clear that this amount is inadequate to feed the Babati factory even for 1 year. It is therefore premature to think of any harvesting of the species currently.

3.6.3 Propose/develop strategies for the conservation of these tree species

Given the current status of *O. lanceolate*, we propose the following conservation strategies;

- Strengthening law enforcement to control illegal harvesting; and
- Establishment of research trials to propagate and domesticate *O. lanceolata*

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Appendices

Appendix 1.Occurrence of associate tree species in the studied forests

District	Forest name	Local name	Botanical name	Number of sub-plots	Plots with associate species	Percent
Babati	Warimbu VLFR	Sirongi, Datrii	*Rhus natalensis*	16	8	50
Babati	Warimbu VLFR	Nafumo, Mhangala	*Jubelnadiaglobiflora*	16	6	38
Babati	Warimbu VLFR	Hhewasi	*Brachystegiamicrophylla*	16	5	31
Babati	Warimbu VLFR	Gendaii, Gendaamo	*Combetummolle*	16	4	25
Babati	Warimbu VLFR	Tsilenaii, Mtarima	*Lanneaschimperi*	16	3	19
Babati	Warimbu VLFR	Tsapenai	*Flacourtia indica*	16	2	13
Babati	Warimbu VLFR	Frankii	*Canthiumoligocarpum*	16	2	13
Babati	Warimbu VLFR	Mwirela	*Brachystegiaspiciformis*	16	2	13
Babati	Warimbu VLFR	Ang'kwi	*Vernonia subligera*	16	2	13
Babati	Duru VLFR	Sirongi, Datrii	*Rhus natalensis*	35	25	71
Babati	Duru VLFR	Hhewasi	*Brachystegiamicrophylla*	35	8	23
Babati	Duru VLFR	Gendaii, Gendaamo	*Combetummolle*	35	6	17
Babati	Duru VLFR	Irocktum	*Protea rochetiana*	35	5	14
Babati	Duru VLFR	Frankii	*Canthiumoligocarpum*	35	4	11
Babati	Duru VLFR	Bermi	*Dodonaeaviscosa*	35	3	9
Babati	Duru VLFR	Ghambalangw	*Allophylus calophyllus*	35	2	6
Babati	Duru VLFR	Getalongo	*Catunaregum spinosa*	35	2	6
Babati	Duru VLFR	Ghambalangw	*Allophylus africana*	35	2	6
Babati	Duru VLFR	Fitsitoo	*Vachelliahockii*	35	2	6
Babati	Duru VLFR	Daraa'ghw	*Senna singuena*	35	2	6
Babati	Duru VLFR	Barang'u	*Vangueriainfausta*	35	2	6
Babati	Duru VLFR	Baraghumo	*Vangueriavolkensii*	35	2	6
Babati	Duru VLFR	Girwang	*Dichrostachys cinerea*	35	2	6
Babati	Duru VLFR	Munughumo	*Zanhaafricana*	35	2	6
Babati	Haisamu VLFR	Titiwi	*Carissa edulis*	21	11	52
Babati	Haisamu VLFR	Warfi	*Catha edulis*	21	10	48
Babati	Haisamu VLFR	Hhatsmo, Slontli	*Apodytesdimidiata*	21	7	33
Babati	Haisamu VLFR	Bermi	*Dodonaeaviscosa*	21	7	33
Babati	Haisamu VLFR	Sirongi, Datrii	*Rhus natalensis*	21	7	33
Babati	Haisamu VLFR	Sirongi	*Rhus vulgaris*	21	6	29
Babati	Haisamu VLFR	Mumui	*Mytenus senegalensis*	21	5	24
Babati	Haisamu VLFR	Sakwenay	*Warburgiastuhlmanii*	21	5	24
Babati	Haisamu VLFR	Pararaamo	*Schreberatrichoclada*	21	4	19
Babati	Haisamu VLFR	Daetewi	*Maesa lanceolata*	21	3	14
Babati	Haisamu VLFR	Irocktum	*Protea rochetiana*	21	3	14
Babati	Haisamu VLFR		*Dissotis rotundifolia*	21	3	14
Babati	Haisamu VLFR	Irocktum	*Protea angolensis*	21	3	14
Babati	Haisamu VLFR	Gudaati	*Dombeya rotundifolia*	21	2	10

District	Forest name	Local name	Botanical name	Number of sub-plots	Plots with associate species	Percent
Babati	Haisamu VLFR	Gendaii, Gendaamo	*Combetummolle*	21	2	10
Babati	Ayatlaa VLFR	Fitsitoo	*Vachelliahockii*	3	2	67
Babati	Ayatlaa VLFR	Getalongo	*Catunaregum spinosa*	3	2	67
Babati	Ayatlaa VLFR	Maa'yangu	*Ximenia caffra*	3	2	67
Babati	Gedagerere VLFR	Sirongi, Datrii	*Rhus natalensis*	31	21	68
Babati	Gedagerere VLFR		*Rytigyniaschumanii*	31	9	29
Babati	Gedagerere VLFR	Hhewasi	*Brachystegiamicrophylla*	31	9	29
Babati	Gedagerere VLFR	Miningiti	*Eucleadivinorum*	31	8	26
Babati	Gedagerere VLFR	Gendaii, Gendaamo	*Combetummolle*	31	6	19
Babati	Gedagerere VLFR	Tsapenai	*Flacourtia indica*	31	5	16
Babati	Gedagerere VLFR	Bermi	*Dodonaeaviscosa*	31	4	13
Babati	Gedagerere VLFR	Sirongi	*Rhus vulgaris*	31	4	13
Babati	Gedagerere VLFR	Fitsitoo	*Vachelliahockii*	31	3	10
Babati	Gedagerere VLFR	Manenehhi	*Cussoniaholstii*	31	3	10
Babati	Gedagerere VLFR	Barang'u	*Vangueriainfausta*	31	3	10
Babati	Gedagerere VLFR	Daraa'ghw	*Senna singuena*	31	3	10
Babati	Gedagerere VLFR	Gudaati	*Dombeya rotundifolia*	31	2	6
Babati	Gedagerere VLFR	Irku	*Brachystegia utilis*	31	2	6
Babati	Gedagerere VLFR	Nistiay	*Omorcarpumkirkii*	31	2	6
Hanang	Gidagewong VLFR	Sirongi, Datrii	*Rhus natalensis*	47	24	51
Hanang	Gidagewong VLFR	Fitsitoo	*Vachelliahockii*	47	14	30
Hanang	Gidagewong VLFR	Gendaii, Gendaamo	*Combetummolle*	47	12	26
Hanang	Gidagewong VLFR	Warfi	*Catha edulis*	47	10	21
Hanang	Gidagewong VLFR	Bermi	*Dodonaeaviscosa*	47	10	21
Hanang	Gidagewong VLFR	Gudaati	*Dombeya rotundifolia*	47	8	17
Hanang	Gidagewong VLFR	Daraa'ghw	*Senna singuena*	47	7	15
Hanang	Gidagewong VLFR	Tsilenaii, Mtarima	*Lanneaschimperi*	47	6	13
Hanang	Gidagewong VLFR	Titiwi	*Carissa edulis*	47	6	13
Hanang	Gidagewong VLFR	Hhatsmo, Slontli	*Apodytesdimidiata*	47	6	13
Hanang	Gidagewong VLFR	Miningiti	*Eucleadivinorum*	47	5	11
Hanang	Gidagewong VLFR		*Rytigyniaschumanii*	47	4	9
Hanang	Gidagewong VLFR	Pararaamo	*Schreberaalata*	47	3	6
Hanang	Gidagewong VLFR	Tsaati	*Tecleatichocarpa*	47	3	6
Hanang	Gidagewong VLFR	Nistiay	*Omorcarpumkirkii*	47	2	4
Hanang	Gabadau VLFR	Sirongi, Datrii	*Rhus natalensis*	23	9	39
Hanang	Gabadau VLFR	Fitsitoo	*Vachelliahockii*	23	7	30

District	Forest name	Local name	Botanical name	Number of sub-plots	Plots with associate species	Percent
Hanang	Gabadau VLFR	Gendaii, Gendaamo	*Combetummolle*	23	6	26
Hanang	Gabadau VLFR	Miningiti	*Eucleadivinorum*	23	5	22
Hanang	Gabadau VLFR	Warfi	*Catha edulis*	23	4	17
Hanang	Gabadau VLFR	Bermi	*Dodonaeaviscosa*	23	3	13
Hanang	Gabadau VLFR	Emoroo'gi	*Dovyalismacrocalyx*	23	3	13
Hanang	Gabadau VLFR	Titiwi	*Carissa edulis*	23	2	9
Hanang	Gabadau VLFR	Pararaamo	*Schreberatrichoclada*	23	2	9
Hanang	Gabadau VLFR	Tsilenaii, Mtarima	*Lanneaschimperi*	23	2	9
Hanang	Gabadau VLFR	Gudaati	*Dombeya rotundifolia*	23	2	9
Hanang	Sebas VLFR	Sirongi, Datrii	*Rhus natalensis*	3	3	100
Kondoa	Gubali VLFR	Fitsitoo	*Vachelliahockii*	38	11	29
Kondoa	Gubali VLFR	Sirongi, Datrii	*Rhus natalensis*	38	9	24
Kondoa	Gubali VLFR	Gendaii, Gendaamo	*Combetummolle*	38	7	18
Kondoa	Gubali VLFR	Nafumo, Mhangala	*Jubelnadiaglobiflora*	38	7	18
Kondoa	Gubali VLFR	Msisivili	*Albizia harvey*	38	4	11
Kondoa	Gubali VLFR	Miningiti	*Eucleadivinorum*	38	4	11
Kondoa	Gubali VLFR	Miningiti	*Eucleanatalensis*	38	4	11
Kondoa	Gubali VLFR	Mwirela	*Brachystegiaspiciformis*	38	3	8
Kondoa	Gubali VLFR		*Mystoxylonaethiopicum*	38	3	8
Kondoa	Gubali VLFR	Frankii	*Canthiumoligocarpum*	38	2	5
Kondoa	Gubali VLFR		*Ochna holstii*	38	2	5
Kondoa	Gubali VLFR	Fitsitoo	*Vachelliamyrifera*	38	2	5
Kondoa	Gubali VLFR	Daraa'ghw	*Senna singuena*	38	2	5
Kondoa	Gubali VLFR	Manenehhi	*Eucleaschimperi*	38	2	5
Kondoa	Gubali VLFR	Mhasa	*Euphorbia candelabrum*	38	2	5
Kondoa	Hachwi VLFR	Nafumo, Mhangala	*Jubelnadiaglobiflora*	34	17	50
Kondoa	Hachwi VLFR	Sirongi, Datrii	*Rhus natalensis*	34	12	35
Kondoa	Hachwi VLFR	Gendaii, Gendaamo	*Combetummolle*	34	11	32
Kondoa	Hachwi VLFR	Miningiti	*Eucleadivinorum*	34	8	24
Kondoa	Hachwi VLFR	Mwirela	*Brachystegiaspiciformis*	34	6	18
Kondoa	Hachwi VLFR			34	6	18
Kondoa	Hachwi VLFR	Mhasa	*Euphorbia candelabrum*	34	5	15
Kondoa	Hachwi VLFR	Bermi	*Dodonaeaviscosa*	34	4	12
Kondoa	Hachwi VLFR	Hhewasi	*Brachystegiamicrophylla*	34	3	9
Kondoa	Hachwi VLFR	Miningiti	*Eucleanatalensis*	34	3	9
Kondoa	Hachwi VLFR		*Rytigyniaschumanii*	34	3	9
Kondoa	Hachwi VLFR	Niimo, Ijoviya	*Commiphora edulis*	34	3	9
Kondoa	Hachwi VLFR	Getalongo	*Catunaregum spinosa*	34	3	9
Kondoa	Hachwi VLFR	Gulgurchandi	*Sclerocaryabirrea*	34	2	6

District	Forest name	Local name	Botanical name	Number of sub-plots	Plots with associate species	Percent
Kondoa	Hachwi VLFR		*Ochna macrocalyx*	34	2	6
Kondoa	Kolo VLFR	Nafumo, Mhangala	*Jubelnadiaglobiflora*	20	12	60
Kondoa	Kolo VLFR	Getalongo	*Catunaregum spinosa*	20	5	25
Kondoa	Kolo VLFR	Sirongi, Datrii	*Rhus natalensis*	20	5	25
Kondoa	Kolo VLFR	Miningiti	*Eucleadivinorum*	20	4	20
Kondoa	Kolo VLFR	Gendaii, Gendaamo	*Combetummolle*	20	4	20
Kondoa	Kolo VLFR	Mhasa	*Euphorbia candelabrum*	20	3	15
Kondoa	Kolo VLFR	Frankii	*Canthiumoligocarpum*	20	3	15
Kondoa	Kolo VLFR	Mwirela	*Brachystegiaspiciformis*	20	2	10
Kondoa	Kolo VLFR	Niimo, Ijoviya	*Commiphoraafricana*	20	2	10
Kondoa	Kolo VLFR	Mkomu	*Rothmaniamanganjae*	20	2	10
Kondoa	Kolo VLFR		*Dalbergia nitidula*	20	2	10
Kondoa	Kolo VLFR	Msisivili	*Albizia harvey*	20	2	10
Kondoa	Kolo VLFR	Seese	*Vernonia exserstiflora*	20	2	10

CITES TREE SPECIES PROGRAMME

SUB CONTRACT 2.7

ADOPTION OF APPROPRIATE SILVICULTURE PRACTICES IN MANAGEMENT AND DOMESTICATION OF *OSYRIS LANCEOLATA*

By Dr. Stephen M. Maduka (Expert)

Tanzania Forestry Research Institute,
P.O. Box 1854,
MOROGORO.

Phone : +255 23 2603725/2604499
E – Mail : tafori@taforitz.org
Website : www.taforitz.or.tz

1.0 Introduction

Osyris lanceolata (Sandalwood) is an economic tree species that can spur income growth to the community. Previous, trading of *O. lanceolata* which involved uprooting of roots and in some cases debarking the stem lead to habitat destruction and decline of its populations in natural forests. It is projected that, the Sandalwood is going to contribute significantly to global Sandalwood oil trade in the coming 5-10 years. Basing on these demands, decrease of wild population and ban of exploitation of Sandalwood from natural forests, domestication of Sandalwood could be the viable solution for increasing its population and meeting this demand. Domestication of Sandalwood can reduce pressure on wild populations, increase its population while providing markets with sustainable stocks and improving livelihoods. However, domestication of this species is still constrained by inadequate knowledge on appropriate silvicultural practices for seedlings' raising. Several attempts have been done in Tanzania on artificial propagating for *O. lanceolata* which include air layering, complete removal of the seed coat and soaking in hot water, sowing without pre-germination treatments and nicking at the base of the seed. These pre-treatments improved germination up to 60%. These propagation techniques have not been widely implemented for massive seedlings production to enhance domestication of *O. lanceolata*.

Hence, Tanzania Forestry Research Institute (TAFORI) mandated in conducting forest research in the country was assigned by CITES Tree Species Programme (Tanzania chapter) to develop a protocol for adoption of appropriate silviculture practices for domestication of *O. lanceolata* in a selected area.

2.0 Objectives of the assignment

Developing a propagation protocol and facilitating the adoption of appropriate silviculture practices for domestication and sustainable management of Sandalwood by public and private actors.

3.0 Approach and Methodology

3.1 Field reconnaissance survey in Babati in Manyara and Kondoa in DodomaRegions

3.1.1 Development of selection criteria and identification of one pilot production site

Reconnaissance survey was carried out to identify location, availability and phonological status of *O. Lanceolata* from 31st August 2020 to 3rd September 2020. It was initiated by visiting Tanzania Forest Service Agency (TFS) for the introduction of the programme and getting contact person for forest surveys.

In collaboration with Beleku Forest Reserve guards, survey was carried out in Beleku Forest Reserve where the guards assisted to locate and identify Sandalwoods. According local communities around, Sandalwood was locally categorized as Male (in Kiswahili known as *Dume*) and female (in Kiswahili known as *Jike*).The Male has bulged leaves at its centre, while female has narrower leaves (Plate 1).

Plate 1: *Osyris lanceolata* branches, Male **(left)** with flowers **and** Female **(right) with** fruit

The Male tree roots was reported as not aromatic as for Jike tree. However, during trading all trees were harvested. During this period, Male trees were observed to have more flowers than Female. During this period, most of *O. lanceolata* trees were flowering and some had mature seeds (Plate 1). Through, literature, it was also realised that, the tree species tend to flower throughout the year. Therefore, it was necessary to make agreement between the Team and Beleku Forest Reserve guards (Plate 2) to carry out seeds collection exercise in order to match with the growing season. It was further agreed that, Forest guards at Beleku Forest Reserve to identify more areas with flowering Sandalwoods that will be used for collection of seeds after

maturing. In the absence of expert, field guards were asked to monitor phenology status, especially on flowering and fruiting trends at two weeks intervals and communicate with the expert on the status for planning of fruits collection.

Plate 2: Forest survey Team with Forest Guards

The Team also visited Duru Haytemba Forest Reserve which is under the village Authority. The survey in this forest didn't locate any *O. lanceolata* despite the presence of associated species. The team was informed on the absence of intensive management in this Forest Reserve like those present in National Forest Reserve (Central Government) since it was under Local Authority management. This management could have probably resulted into species local extinction of this tree species from this forest.

The Team also visited Salanga Forest Reserve which is in Kondoa where males and female Sandalwoods with some flowers and some with few mature fruits existed. Field guards and Forest supervisors were requested to conduct a thorough survey to identify more potential areas that can be used for collection of planting materials and do monitoring to identify at what period fruits/seeds can be mature.

During reconnaissance survey in all forest reserves in Beleku and Salanga, geographical positioning was recorded with GPS, associates species and *O. lanceolata* specimens were collected for further identification and references. During this period also, one pilot production

site was identified for *ex-situ* conservation and two pilot sites for seedlings production were selected from private and government nurseries.

3.2 Propagation of *Osyris lanceolata* through seeds

3.2.1 Fruits collection of *Osyris lanceolata* at Beleku forest reserve

Seeds collection was carried out in Beleku Forest Reserve (pilot site for planting materials collection) by Forest Guards from September 2020 to January 2021 which was found to be the peak season for seed maturation. This site was selected because it is closer to the processing industry and most of people are aware on the importance of the tree species which may make them adopt easier.

Even though it was the peak season for seed collection, it was found that, ripening of *O. Lanceolata* seeds don't occur at the same time, at least one up four seeds was found to mature per tree. It was therefore proposed to collect mature seeds existing in each tree and keep them for some days to become ripe (Plate 3). However, it was realised that, after few days, most of seeds kept loosed viability and as their germination was poor.

Plate 3: Collected fruits for *Osyris lanceolata*

From this observation, it was agreed with Team formed to pick only ripe fruits (Plate 4), extract seeds and sow immediately at Private Nursery at Bisoma Village Boay and some delivered to Tanzania Forest service agency (TFS) in Babati (pilot sites for planting materials production).

The Team was also instructed to collect and handle seeds as was difficult for the expert to make frequent visit due to budget constraint. Also, selection of these nursery sites was done basing on accessibility of the community to these nurseries especially for the private nursery as well as using the facilities and experience of nursery management owned by TFS. Facilities for nursery establishment especially for the private nursery such as hoe, sieves, rake, potting materials, polythene tubes and watering can were mobilized.

During this collection period, mature seeds were hand-picked and extraction of seeds conducted within 48 hours after harvesting (Plate 4). Mature Sandalwood seeds were observed to have a white firm endosperm while immature ones have milky content. Thus, seeds were extracted from pulp by rubbing in the wire mesh sieve (4 mm) (Plate 4), rinsed with water, and dried under shade. They were also treated with fungicide before being sown to control fungi infection and preserve them for shorter period. Before sowing, flotation test was conducted by immersing extracted seeds in water to identify the viable seeds. Viable seeds would normally sink while unviable seeds will float.

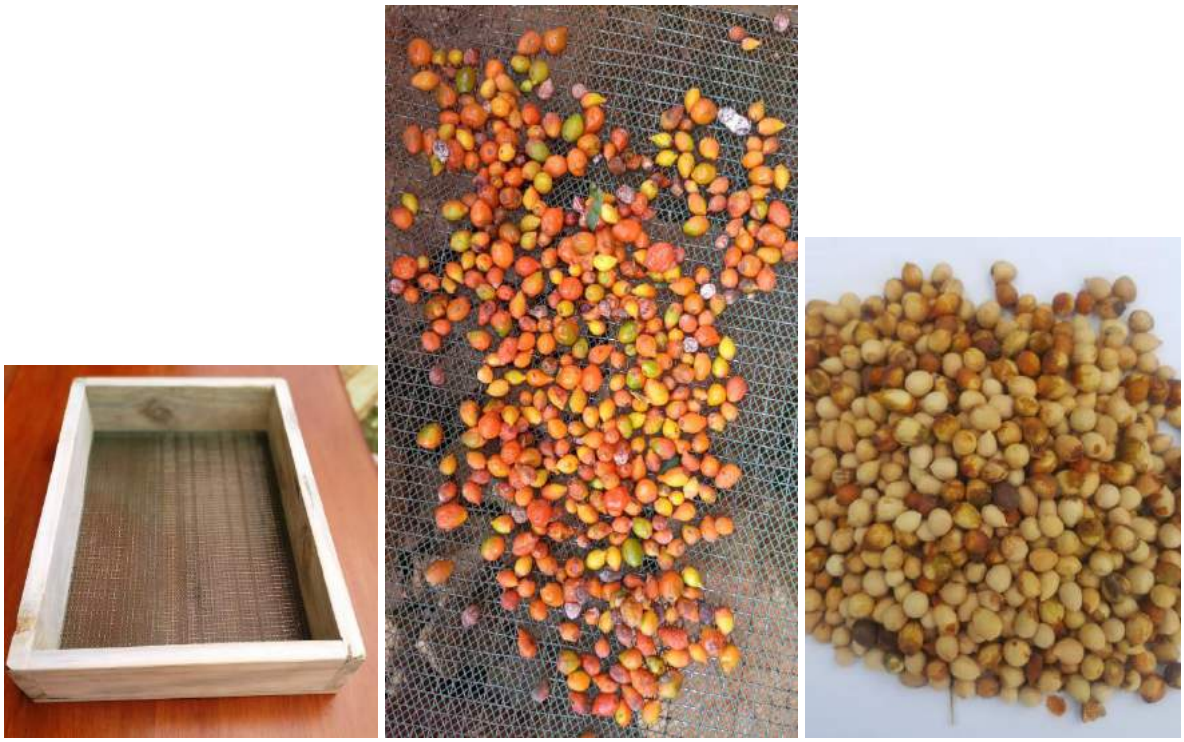

Plate 4: Sieve (left), freshly collected (middle) and extracted seeds (right)

After identification of viable seeds, they were sown in 5 cm diameter polythene tubes and to the soil seed bed both at private and TFS nursery (Plate 5). Polythene tubes and soil bed were filled with potting material composing of top forest soil, decomposed cow-dung manure and

sand at the ration of 4:1:1 v/v. After sowing, sown seeds were managed by watering and weeding.

Plate 5: Seeds sown in the polythene tubes (left) and soil seed bed (right)

At these nurseries, 500 seeds were sown in the polythene pots and 500 seeds to the soil bed to evaluate which bed can be suitable for seedlings rising. Both seedbeds were covered with grasses for moisture conservation and managed as per nursery management standards. After germination, seedlings from the direct soil seed bed were pricked out while had three leaves and transplanted onto the 5 cm diameter polythene tubes filled with a growth media composing of top forest soil, sand and decomposed cow dung manure at the of 3:1:1 v/v. Normally, seedlings pricking was done while have 3 – 4 leaves. At these nurseries, supervisors were trained on how to manage and collect germination data.

3.2.2 Seed germination

After 6 weeks (47 days) of sowing, germination of seeds commenced at both beds and ended after 37 days (Plate 6). It has been noticed that, germination of Sandalwoods is sporadic, i.e. germination occurs at irregular intervals. Thus, germination of 32.4% has been attained in the polythene tube bed and 36.8% in soil bed. However, establishment and survival for the pricked out seedlings from the soil bed have been challenging. Even though seedlings were pricked out when they had three leaves as per mostly done with other species, about 60% of them died after 3 days of their pricking. Hence, a closer follow up is required to understand at what period seedlings should be pricked out to improve their survivals. Further, it was also found that, survived seedling after pricking, some of them wilted and died after 14 days (at least 3 – 4 cm high) maybe due root rot. Further study is required to understand if fungal infection may exist to seed or to soil causing root rot (Plate 7).

Plate 6: Germinated seedlings polythene tube (left) and soil seed bed (right)

Plate 7: Potted pots Polythene tube with wilted seedlings (left) and dead seedling

3.3 Propagation of *Osyris lanceolata* through stem cuttings and saplings

Following these challenge, stem cuttings and saplings were collected from the field and set in the polythene tubes on 16th of February 2021. 320 stem cuttings and 36 saplings were set at TFS and 400 saplings at Bisoma-Boay Village private nursery in Babati Manyara. After 2

months, out of 320 cuttings and 36 saplings set at TFS, 81.2% and 95.8% were surviving respectively and 100% saplings were surviving at private nursery (Plate 8). Some of investigated surviving cuttings and saplings have been reported to provide shoots and roots. Basing on these preliminary results, *O. lanceolata* can be propagated using stem cuttings and saplings.

Plate 8: Stem cuttings (left) set in the potted polythene pots (TFS nursery) and performance of suckers (middle) at TFS and Boay (left) after 2 months of setting

Currently, there is ongoing study of assessesing rooting potential of *O. lanceolata* using stem cuttings and rooting hormone by managing relative humidity to enhance more rooting and shorten rooting period. Also, there is ongoing study at TAFORI of assessing the effect of tree association in improving the growth and survival *O. lanceolata* seedlings.