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Sandalwood (*Santalum album*) growth and farming success strengthen its natural conservation in the Timor Island, Indonesia

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Abstract. *Seran YN, Sudarto, Hakim L, Arisoesilaningsih E. 2018. Sandalwood (*Santalum album*) growth and farming success strengthen its natural conservation in the Timor Island, Indonesia. Biodiversitas 19: 1586-1592.* Sandalwood (*Santalum album* L.) is a unique plant of the East Nusa Tenggara (NTT) Province of Indonesia and locally known as the unity symbol woody fragrance (*hau meni*). The study aimed to compare growth quality of trees grown in plantations and forests in the districts of North Central Timor (TTU) and South Central Timor (TTS). Vegetation analysis was held by purposive sampling in eight sites comprising 87 plots. Plots sizes were 20x20 m^2 for trees, 10x10 m^2 for poles, and 5x5 m^2 for saplings. Variables observed in each plot included density, trunk diameter, height, crown quality, and vitality. Data were analyzed by descriptive and multivariate statistics. The results showed that the growth of sandalwoods varied spatially in all study sites and was classified into five groups. Two plantations in TTS District showed better trees growth quality compared to those in TTU. Higher saplings and poles density were found in two sites, a plantation and a forest in TTU plantation, and in a forest in TTS. However higher vitality were found in two plantations, each one in TTS and TTU. Inferior growth was observed in Nununamat plantation. Farmers had a significant role in strengthening sandalwood conservation in two districts as shown by their successful farming and trees growth quality that was similar to those in the forests.

Keywords: Forest, growth quality, NTT, plantation, sandalwood

INTRODUCTION

East Nusa Tenggara (*Nusa Tenggara Timur*, NTT), Indonesia is a dry climate area and rich with deciduous tropical plants. A prolonged dry season is a great constraint in the agricultural sector in NTT. Therefore, local farmers cultivate various drought resistant commodities, one of them is the endemic plant of NTT, namely sandalwood (*Santalum album* L.). Sandalwood tree grows naturally in the forests or cultivated by the local people for a long generation using traditional farming due to its high economic, social, and cultural values. In addition, sandalwood is also well known as a symbol of unity, producing fragrance (*hau meni*) and livelihood for the families (Tallo 2001). Since 1986 the sandalwood was established as the mascot of NTT (Suripto 1992). The sandalwood highly contributed to the Local Government Revenue (*Pendapatan Asli Daerah,* PAD) of NTT per year, so the government determined sandalwood as one of the main commodities to support the NTT local revenue. Therefore according to the Forestry Regional Office of NTT, from 1986 to 1998, sandalwood had played an important role as the primary PAD source of NTT, reached 28.20% to 47.60% of the revenue. Meanwhile, the contribution of sandalwood for the PAD of the South Central Timor (TTS) and North Central Timor (TTU) Districts was around 50% per year (Banoet 2001). This contribution was possible due to a high density of sandalwood in East Nusa Tenggara, Indonesia.

According to Widyatmika (2000), in the past, sandalwood in NTT naturally grew in the forests, and its distribution was largely found in Timor, Alor, Sumba, Solor, Lembata and Flores Islands. However, in 1987 its natural distribution significantly reduced, then sandalwood population in the forest and field was only found in Timor and Sumba Islands. In 1997, the sandalwood population continued being decreased and remained in only four districts in Timor Island, namely TTU, TTS, Belu, and Kupang.

TTU has a total area of 266,970 hectares, among which 40.18% was the habitat of sandalwood. Data from 2006 revealed that the natural population of sandalwood in TTU was 33,678 trees, a reduction of 98.82% compared to that from 1997 (Forestry Office of TTU 2007). Meanwhile, the population of sandalwood in TTS based on inventory conducted in 2010 was 1,426 trees or reduced by 79.03% compared with those conducted in 1997 of 112,710 trees (Forestry Office of TTS 2010). These population reductions due to overexploitation caused sandalwood status to become rarer in the local, national, and even regional markets (Butarbutar 2008). The production of sandalwood in NTT, especially in Timor Island, had not met the demand for the timber, and now the trees are extremely rare. Following the survey from 1999 to 2003, the harvesting of sandalwood trees in the two regions had been stopped, and the supply of sandalwood in the market had been provided from other regions. The main reason for the rarity and low regeneration of sandalwood were exploitation activities that exceeded the tree reproduction capacity, the high annual logging rate of the tree, forests degradation, conversion of sandalwood forests into agricultural and residential areas, and forest fires. These problems occurred not only in Timor Island but also in regional and worldwide levels. This significant reduction in sandalwood population changed the world conservation status of the plant from "not threatened" (Walter and Gillet 1998) into "vulnerable" (IUCN 2016).

Recovery efforts have been conducted by the local government to conserve the sandalwood species, among them is the NTT Province Regulation Number 2, Year 1999 on the conceding of sandalwood ownership to the district government and farmers; the TTS Regional Regulation Number 25 Year 2001, and the TTU Regional Regulation Number 2 Year 2004 on sandalwood (Raharjo 2013). These policies favor the local people because they guarantee the ownership of sandalwood trees cultivated as the belonging of the farmer. The provision of incentives and sandalwood seedlings to the local people has promoted their interest to re-cultivate sandalwood in the plantations and home gardens. More farmers actively cultivate sandalwood in the garden, sustaining the species conservation effort and supporting the economic growth.

The success of sandalwood planting is determined by many factors such as the plant survival success; life cycle completion (vitality); density, diameter, canopy quality, height, and branchless trunk height of the tree. Besides, the economic value of sandalwood depends on their hearth wood growth. Therefore, the growth quality analysis using trunk diameter is an important tool for the evaluation of sandalwood growth. The growth of trunk diameter and height will be more significant in open areas compared to that in covered ones. Riswan (2001) stated that after growing 20 to 30 years old, sandalwood tree height can reach 12 to 15 m, with a trunk diameter of around 20 to 35 cm. Tree diameter increases if the net photosynthesis output exceeds the energy needed for respiration, reproductive activities, leaf change, and root and trunk height growth (Husch et al. 2003; Charles 2011). Unfortunately, the growth of sandalwood in plantation and forest has not been reported yet.

The availability of data regarding the growth quality of sandalwood trees grown in both forests and plantations by local people in TTS and TTU becomes very important after 15 years' implementation of the new provincial policies. This study aimed to evaluate the growth quality of sandalwoods in the plantations and compare it to that in the forests in TTS and TTU districts. The farming success of sandalwood in plantations in comparison to those in its natural habitat, will not only strengthen the availability of mother trees and seedling sources but also increase the favorable growth habitat for sandalwood conservation effort, as well as support the master plan for sandalwood conservation in the Province of East Nusa Tenggara (NTT), Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in Timor Tengah Selatan (TTS) and Timor Tengah Utara (TTU) Districts, Province of East Nusa Tenggara (NTT), Indonesia. The study sites were in forests and plantations. Naturally, sandalwoods grow symbiotically with wild plants of Timor Island such as *Acacia auriculiformis* A.Cunn ex Benth, *Acacia leucophloea* (Roxb.) Willd, *Tamarindus indica* L., *Eucalyptus alba* Rein.ex Blume., *Timonius amboinicus* Boerl, *Alstonia scholaris* (L.) R.Br, *Pittosporum timorence* Blume, *Lantana camara* L., *Pterocarpus indicus* Willd, and *Zizyphus timorensis* DC. The determination of observation and sampling sites was based on the base map of sandalwood distribution (Figure 1), as well as the initial survey, and consideration of the location's accessibility.

The study location in TTS consisted of five observation stations: two stations in the forest, namely the forest of Tetaf (SFTe) (868,8 m asl., 9°50′ 26.3″S-124°25′ 41.3″E, hilly topography, slope 20%), and the forest of Karang Siri (SFKs) (962,8 m asl., 9°49′ 38.9″S-124°15′ 46.4″E, undulating topography, slope 30%); and three stations in the plantation of Binaus (SPBi) (972,7 m asl., 9°47′ 10.9″S-124°16′ 51.6″E, hilly topography, slope 20%), Oelbubuk (SPOe) (1038 m asl., 9°46′ 01.3″S-124°16′ 34.7″E, steep topography, slope 40%), and Nununamat (SPNu) (727,9 m asl., 9°59′ 04.3″S-124°30′ 35.6″E, very steep topography, slope 60%). The study location in North Central Timor (TTU) consisted of three observation stations: one station in the plantation of Upfaon (UPUp) (398,3 m asl., 9°22′ 55.7″S-124°40′ 45.6″E, hilly topography, slope 20%); and two stations in the forests, namely the forest of Banamlaat (UFBa) (383,8 m asl., 9°30′ 38.5″S-124°31′ 53.1″E, plain topography, slope 15%) and Oinbit (UFOi) (534,8 m asl., 9°26′ 34.2″S-124°43′ 07.9″E, undulating topography, slope 30%). The average temperature in the study site 11-35°C, humidity 65-90% and soil pH 6.3-8.07. The study was conducted from September 2015 to June 2016.

Procedures

Data collection for the growth quality of sandalwood trees in both the forests and plantations in TTS and TTU used a vegetation analysis method of purposive nested sampling approach. The samplings were done at 8 stations using 87 square-shaped observation plots of 20x20 m^2 for trees, 10x10 m^2 for poles, and 5x5 m^2 for saplings (Figure 2). The sampling was done based on the combination of various treatments of population, slope, and temperature. Variables observed in each plot included sandalwood density, trunk diameter, tree height, canopy quality, and vitality. Data collection was done by recording the number of individuals per plot for each growth stadium, such as the plant height, saplings height, trunk diameter, branch-free trunk height, density, and vitality. The sandalwood growth stadia were classified as follows: (i) trees including plants with a height of over 10 m, and

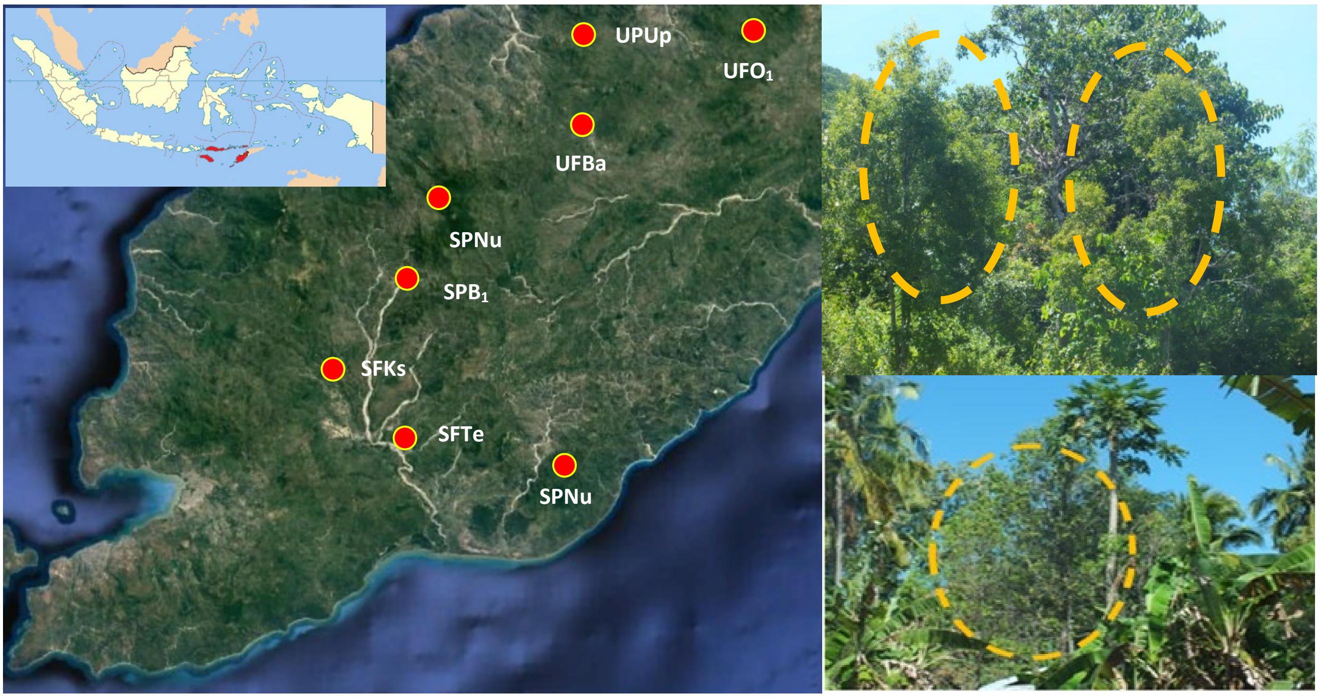


Figure 1. A. Map of the study area in Timor Tengah Selatan (TTS) and Timor Tengah Utara (TTU) Districts, Province of East Nusa Tenggara (NTT), Indonesia; B. Sandalwood Forest; C. Sandalwood Mixed-Plantation. Dashed lines indicate of sandalwood plant

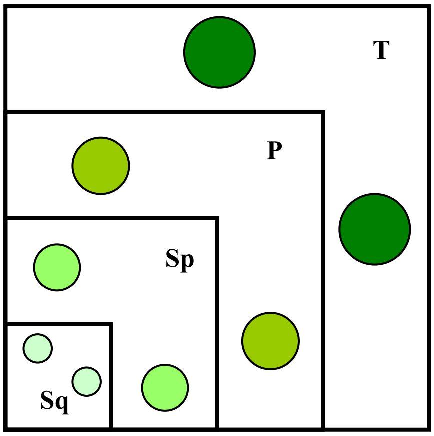


Figure 2. Nested plots. Note: T: *Trees*: 20 x 20 m^2 plot, P: *Poles*: 10 x 10 m^2 plot, Sp: *Saplings*: 5 x 5 m^2 plot, Sd: Seedlings: 2 x2 m^2 plot. Circle patches represent for sampling of sandalwood plant

trunk diameter >20 cm; (ii) poles or small trees stage including plants with a height of 5-10 m, and trunk diameter of 10-19 cm; (iii) saplings or younger growth stage comprising plant with 1.5-5 m in height, and less than 10 cm in trunk diameter; and (iv) seedlings consisting of germinated seedlings up to ones with a height of 1.5 m (Rohadi 2002; Michael and Bashir 2011; Subasinghe 2014). The sandalwood tree canopy was classified according to Daubenmire cover classes standard: Class 1 (0-5% canopy cover), class 2 (5-25% cover), class 3 (25-50% cover), class 4 (50-75% cover), class 5 (75-95% cover), class 6 (95-100% cover). Finally, the vitality of the sandalwood trees was scored and classified as follows: Score 1, the highest vitality in which all plant stages, seedlings, saplings, poles, trees are present and complete life cycle; score 2, a high vitality, in which the plant life cycle is complete but irregular; score 3, a medium vitality in which the life cycle is rarely complete, trees, poles, and saplings are present but seedlings are absent; score 4, a low vitality, in which the life cycle is sometimes complete but only comprises some sprouts and rarely survive (Nuhamara et al. 2001).

Data analysis

Data analysis was conducted using descriptive qualitative and multivariate statistics with Biplot and Cluster using Euclidean distance of PAST 3.0 to compare the variation and similarity among the growth parameters of sandalwood trees The parameters included the canopy cover, trunk diameter, DBH, height, and vitality of parent trees as a whole according to the spatial variation among locations and variation in forests and plantations of every growth strata (Glaser 2010).

RESULTS AND DISCUSSION

Crown quality variation of sandalwood trees and poles

The result of this study indicated that crown qualities of sandalwoods in all study sites were highly varied both in the plantation and forests (Figure 3.A). Sandalwoods growing naturally in the forests or cultivated in the plantations in TTS showed slightly higher crown quality and homogenous crown variation compared with those in TTU. Viewing the difference in crown quality value of sandalwood at the study site, it was at level 3 of the crown quality (25-50%). It means that growth quality of sandalwood canopy cultivated in the plantation was similar with one grown in the forest. This result indicated that farmers in the two districts had successfully cultivated sandalwoods using agroforestry system. The sandalwood crown size would highly affect the photosynthetic and respiration rate of the tree. Tree with a large crown cover had a larger capability in photosynthesis; thus it would produce more carbohydrate for synthesizing and maintaining tree's biomass (Sitompul 2002). The crown quality of the sandalwood poles was relatively similar to one another among the study sites (Figure 3.B), ranging from 25% to 50% (level 3). The crown quality of the poles in the forests was also similar to those grown in the plantations in both TTS and TTU. Sandalwoods cultivated in plantations generally showed a lower shading level; thus, this caused the higher biomass accumulation compared to trees grown in forests where the shading level was higher. Anderson and Belanger (1987) suggested that a significant improvement in crown quality would affect sandalwood's growth quality.

Trunk diameter variation of sandalwood of trees, poles, and saplings in forest and plantation

The result of this study showed that trunk diameters of sandalwoods slightly varied among the study sites (Figure 4.A). Sandalwoods grown in the plantations in TTU and TTS showed larger trunk diameters than those found in the forests. Sandalwood trees in the forests in TTU and TTS had similar trunk diameters to one another. (Figure 4.B showed) that trunk diameters of sandalwood poles were similar among all the study sites, both in the forests and plantations.

Trunk diameters of sandalwood saplings in all the locations in TTU and TTS districts were similar to one another (Figure 4.C). Overall, growth variations in trunk diameter as shown in Figure 4.A-C indicated that cultivated sandalwoods in the plantations showed similar diameters compared with those found in the forests. Our present study also concluded that farmers in both TTS and TTU districts have succeeded in cultivating sandalwood in the plantations by implementing agroforestry system in locations with different characteristics. Although Anderson and Belanger (1987) reported that there was a correlation between a tree's crown quality and its trunk diameter, in which the higher the crown cover, the higher the increase in trunk diameters, our study revealed a weak correlation between both variables.

Varied sandalwood trunk diameters of all the study sites indicate that techniques used by sandalwood farmers in both districts are selective in choosing good seeds, qualified parent trees; effective in maintaining the seedlings as well as managing the pests and diseases. These practices positively contribute to the sandalwood's trunk diameter. Previous studies suggest that diameter growth will increase if the need for photosynthesis product for respiration, leaf change, root growth and plant height is in a stable condition (Husch et al. 2003; Charles 2011; Sumardi et al. 2014).

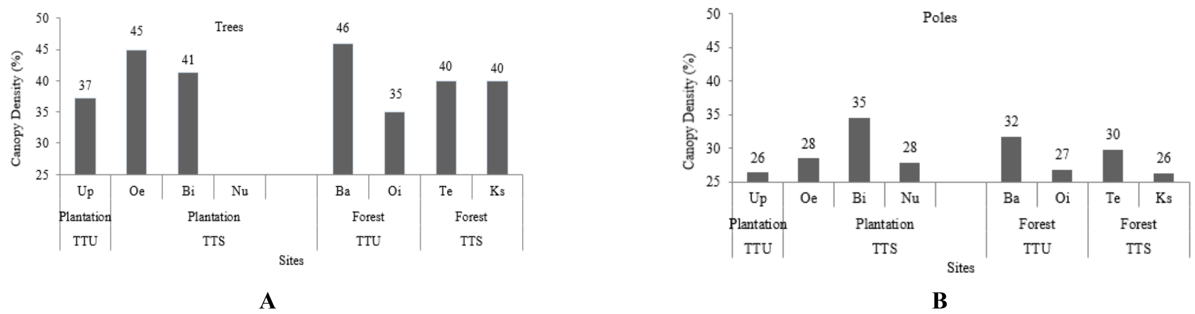


Figure 3. Canopy density of sandalwood (a) trees, and (b) poles. Note: Up = Upfaon, Oe = Oelbubuk, Bi = Binaus, Nu = Nununamat, Ba = Banamlaat, Oi = Oinbit, Te = Tetaf, Ks = Karang Siri stations

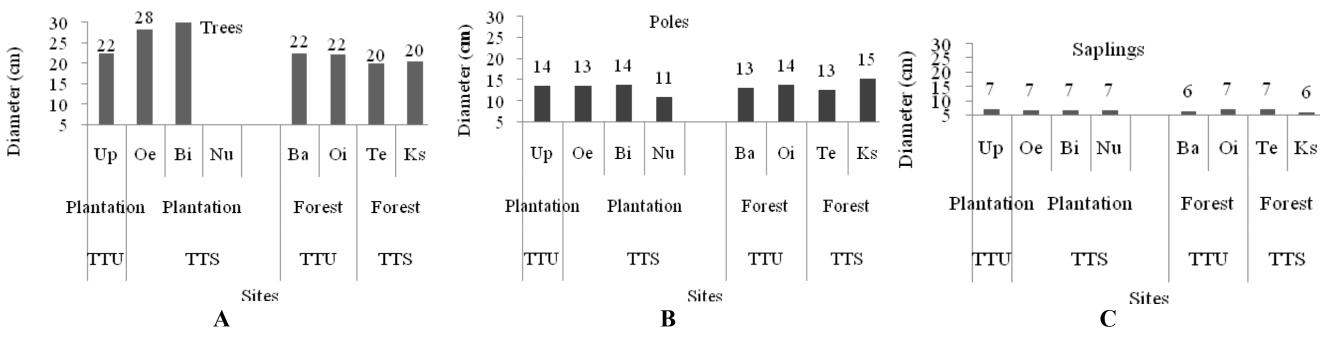
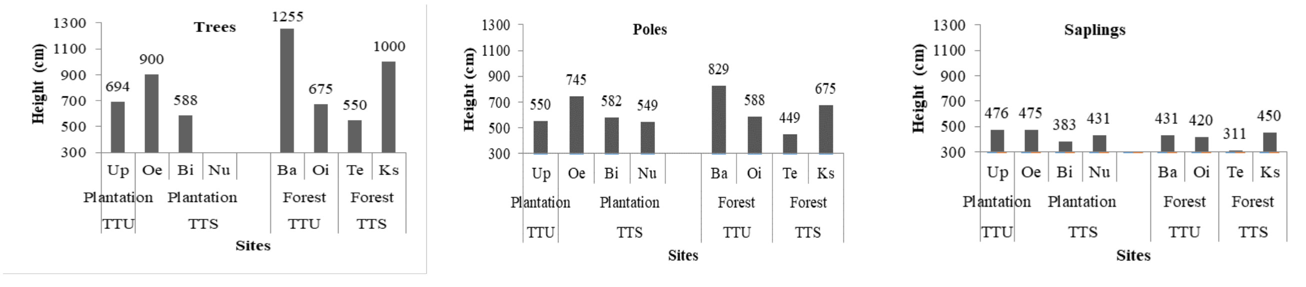


Figure 4. Mean trunk diameter of sandalwood (A) trees, (B) poles, and (C) saplings. Note: Up: Upfaon, Oe: Oelbubuk, Bi: Binaus, Nu: Nununamat, Ba: Banamlaat, Oi: Oinbit, Te: Tetaf, Ks: Karang Siri stations



A B C

Figure 5. Mean height of sandalwood (A) trees, (B) poles, and (C) saplings. Note: Up = Upfaon, Oe = Oelbubuk, Bi = Binaus, Nu = Nununamat, Ba = Banamlaat, Oi = Oinbit, Te = Tetaf, Ks = Karang Siri stations

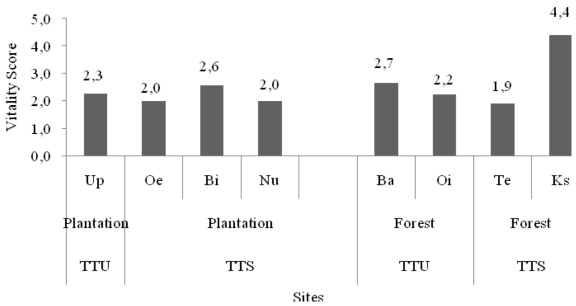


Figure 6. Sandalwood vitality in all study sites. Note: Up: Upfaon, Oe: Oelbubuk, Bi: Binaus, Nu: Nununamat, Ba: Banamlaat, Oi: Oinbit, Te: Tetaf, Ks: Karang Siri stations

Height variation of sandalwood of trees, poles, and saplings in forest and plantation

Heights of sandalwood trees were highly varied among study sites (Figure 5). Same sandalwood trees grown in the forests were taller than those in the plantations of both districts. Interestingly, sandalwoods in TTU District were higher than that in TTS. Heights of sandalwood poles and saplings found in the forests and plantations were similar to each other. Figure 5.A-C, showed that plant height variation was more affected by the plant age and plantation condition. Kurniawan (2012) showed that densely shading increased sandalwood trees and poles height, but a moderately or lightly shading inhibited saplings and seedlings tall. Although sandalwood trees and poles were spatially varied in sandalwood heights among the study sites, but sapling ones were almost equal. This variation increased with age. This finding supports Riswan report (2001) that after 20-30 years old, sandalwood trees could reach a height of 12-15 m and trunk diameter of 20-35 cm. Observation and deep interview with farmers in the study site also suggested that most sandalwoods grown in the plantations were 10-20 years old. Moreover, Orwa et al. (2009) showed that sandalwood trees in Timor Island were higher than those in Australia but still lower than those in India.

Vitality of sandalwood in forest and plantation

Sandalwoods in the forests and plantations showed a slight vitality variation other (Figure 6). Generally, the vitality scores of sandalwoods ranged from level 2 to level 3 indicating that the life cycle (trees, poles, saplings, and or seedlings) were often complete but irregular. This vitality also indicated the fertility and or survival rate of a plant in its life cycle as a response toward environment (Doberrtin 2005). A study by Ramya (2010) suggests that depletion of sandalwood life cycle can be attributed to several factors, both natural and anthropogenic. The limiting factor to low vitality an natural regeneration of sandalwoods in forests included the annual fires, illegal logging, long dry season, and seedlings pest and disease attacks. These factors decreased regeneration and vitality in the forest areas and reduced the seed stock.

Principal Component Analysis of sandalwood growth qualities using Biplot and Cluster

Principal Component Analysis (PCA) showed two principal components of sandalwood growth quality. The first principal component had Eigenvalue 3.8 and variance value 52.60%. The second principal component had Eigenvalue 2.569 with a variance value of 36.71%. Therefore, the cumulative contribution of growth quality variables in the plantations and forests toward the formation of two principal components were 89.30%. Based on the relationship value between the seven growth quality variables, we obtained the first principal component comprising the trees crown quality (Tcrown), vitality (vitality), trees diameter (Tdia), and poles diameter (Pdia). The second principal component comprising the poles density (PD), saplings diameter (Sdia) and saplings density (SD).

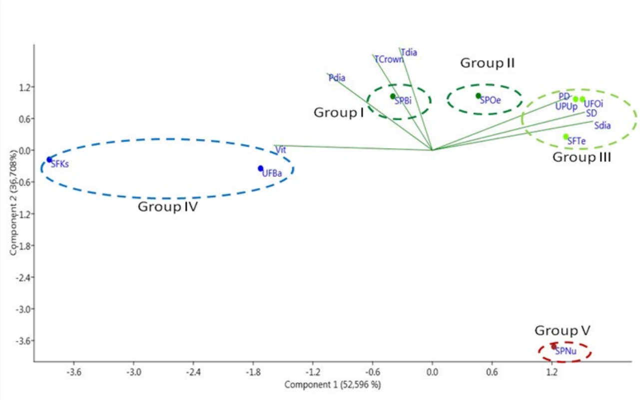


Figure 7. Biplot diagram of growth quality variation of sandalwood plant. Note: SPNu: Soe Plantation Nununamat, UFOi: Kefa Forest Oinbit, UPUp: Kefa Plantation Upfaon, SFTe: Soe Forest Tetaf, SPOe: Soe Plantation Oelbubuk, SPBi: Soe Plantation Binaus, UFBa: Kefa Forest Banamlaat, SFKs: Soe Forest Karang Siri stations

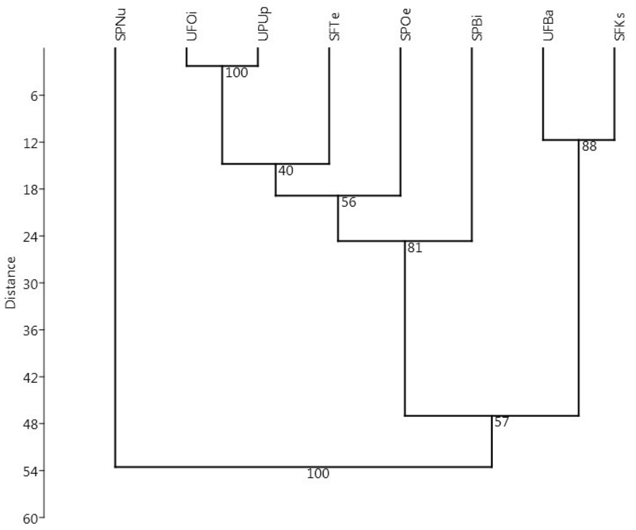


Figure 8. Grouping of observation stations based on common growth quality of sandalwood by using Euclidean distance index. SPNu: Soe Plantation Nununamat, UFOi: Kefa Forest Oinbit, UPUp: Kefa Plantation Upfaon, SFTe: Soe Forest Tetaf, SPOe: Soe Plantation Oelbubuk, SPBi: Soe Plantation Binaus, UFBa: Kefa Forest Banamlaat, SFKs: Soe Forest Karang Siri stations

Biplot analysis (Figure 7) showed that the sandalwood growth was spatially varied in all study sites. Best sandalwood growth was found in a TTS plantation namely station SPBi (Group I), and followed by SPOe (Group II). High-density poles and saplings were found in the plantations and forests of TTU District and the forest of TTS District (Group III). Sandalwoods in the plantations showed a better vitality compared with those in the forest (Group IV). Lowest sandalwood growth quality was found in Nununamat of TTS District (Group V). Therefore, it revealed that sandalwoods farmers in TTU and TTS districts had successfully cultivated sandalwood in plantations as shown by the similar growth quality of the tree population to those found in the forests. The grouping of sandalwood growth quality was also held based on the cluster analysis by using Euclidean distance (Figure 8). The cluster analysis revealed that five groups with similarity value over 40. Group I consists of observation station SPBi (*Soe Plantation Binaus*); Group II consists of observation station SPOe (*Soe Plantation Oelbubuk*); Group III comprises observation station UPUp (*Kefa Plantation Upfaon*), UFOi (*Kefa Forest Oinbit*), and SFTe (*Soe Forest Tetaf*); Group IV consists of observation station SFKS (*Soe Forest Karang Siri*) and UFBa (*Kefa Forest Banamlaat*); and Group V includes observation station SPNu (*Soe Plantation Nununamat*).

In conclusion, the growth quality of sandalwood trees in TTU and TTS were spatially varied in all study sites. Trees growth quality of two plantations in TTS District (Binaus and Oelbubuk) was better than to those in TTU. Moreover, higher saplings and poles density were found in two sites of TTU plantation and forest or a TTS forest. However higher vitality was found in plantation of TTS or TTU. The inferior growth was observed in Nununamat plantation. It revealed that farmer in two districts successfully cultivated sandalwood in plantation shown by similar growth quality with those of forest trees.

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