Pot host and media treatments towards kayu papi’s 
(Exocarpus latifolius R.Br) growth

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Abstract. Kayu papi or shrub sandalwood (Exocarpus latifolius R.Br.) is a hemiparasitic plant, member of Santalaceae family which incorporated host plant on their nutrient absorption. Kayu papi is a fragrant wood that can mimic and perhaps substitute sandalwood (Santalum album Linn.). Many studies recorded that exocarpic acid derived from kayu papi is also beneficial as a tuberculosis remedy. However, the information on silvicultural techniques has only been investigated just a few times. This study aimed to examine the effect of host plants and media combination on kayu papi’s growth under the nursery condition. Kayu papi seedlings were planted with five different hosts and control (without host plant) on six different media. The parameters are the height and diameter of the seven-month kayu papi seedlings. The result indicates that host plants significantly affected kayu papi’s growth. The interaction between the host plant (Alternanthera spp.) and media combination latosol soil and manure also significantly promoted the height of kayu papi. While kayu papi grown in grumusol with Saorupus androgynous host showed the highest diameter on average. In conclusion, kayu papi seedlings indicate that host plant presence and particular media optimized their growth.

1. Introduction
Kayu papi or shrub sandalwood (Exocarpus latifolius R.Br) is a fragrant wood belonging to the Santalaceae family that is also known as Female sandalwood (Timor Island), Patiboga (Flores Island), Ndailingga and Marologe (Sumba Island) [1], Ant-sandalwood/Cendana semut (Indonesia), Agsum, Kamiing, Uksur (Philippines) [2]. Kayu papi is a small evergreen tree, up to 10-20 m in height and 0.5 m in diameter [2]. Based on the anatomical wood properties, kayu papi and sandalwood (Santalum album Linn.) have many similarities such as pore form, pore arrangement, pore distribution, parenchyma type, ray type, and ray width [3]. Kayu papi also contains sandalwood oil; thus, kayu papi can mimic and substitute sandalwood, even though its odor is less intense compared to sandalwood oil [4]. Many studies also reported that exocarpic acid derived from kayu papi is beneficial as a tuberculosis remedy [5 - 8]. Because of its benefits, kayu papi could be classified as economically valuable wood and has the potential to be developed. However, information on silvicultural techniques of kayu papi has only been investigated a few times.
Kayu papi is a hemiparasitic plant that requires a host plant in terms of optimizing nutrient absorption. Hemi-parasitic plants characteristically attain water and mineral from host xylem through a specific organ called a haustorium [9, 10]. To date, numerous researches investigating the effect of the host plant to other Santalaceae species such as Santalum album Linn. [11 - 18], S. acuminatum [19, 20], Thesium sp. [21 - 23], have been conducted. There is little information available regarding the effect of pot host to kayu papi growth. Hence, this study focuses on examining the effect of pot host plants and media combination on kayu papi’s growth under the nursery condition. Some plants have been reported to have the potential as a host plant of kayu papi are Canthium spp., Callitris sp., Petalostigma spp., Terminalia sp., and kayu papi itself [2]. In this research, we chose five host plants and six media combinations, which are common or easily found locally (Timor Island). This paper tested the hypothesis that the combination between the host plant and media will accelerate kayu papi growth under nursery conditions.

2. Material and Methods
The research was undertaken in the Nursery of Oil Sonbai Research Station of Environment and Forestry Research Development Institute of Kupang, East Nusa Tenggara, from April to December 2013.

2.1. Plant material
Kayu papi seeds were collected from kayu papi seed exploration activities on Timor Island in 2012 and sown in April 2013. Scarification or pre-treatment was carried out on kayu papi seeds by breaking the seed-coat (mechanical treatment) before sowing them into polybags to improve the germination process.

2.2. Media combination
Kayu papi seeds were sown in six different media combinations (Table 1.) inside polybags. Physical and chemical properties of media combination were analyzed in the Soil Chemistry Laboratory of Nusa Cendana University, Kupang, NTT (Table 2.).

| Media Code | Composition                   |
|------------|-------------------------------|
| I          | Grumusol (black soil)         |
| II         | Latosol (red soil)            |
| III        | Grumusol: Manure (1:1)        |
| IV         | Latosol: Manure (1:1)         |
| V          | Grumusol: Manure: Sand (1:1:1)|
| VI         | Latosol: Manure: Sand (1:1:1)|

| Medium Code | Organic material (%) | N (%) | P2O5 (Olsen method) (ppm) | K (me/100g) | C/N ratio | pH KCL | Sand (%) | Silt (%) | Clay (%) | Texture          |
|-------------|----------------------|-------|--------------------------|-------------|-----------|--------|----------|----------|----------|-----------------|
| I           | 6.88                 | 0.23  | 89.19                    | 1.14        | 17.70     | 6.60   | 48.67    | 22.00    | 29.33    | Sandy clay loam |
| II          | 6.73                 | 0.22  | 101.01                   | 1.02        | 18.06     | 7.07   | 72.67    | 16.00    | 11.33    | Sandy loam      |
| III         | 2.61                 | 0.16  | 72.13                    | 0.78        | 9.57      | 7.20   | 72.00    | 13.33    | 14.67    | Sandy loam      |
| IV          | 9.34                 | 0.32  | 98.11                    | 1.06        | 16.91     | 7.14   | 69.33    | 18.67    | 12.00    | Sandy loam      |
2.3. **Pot host species**
The pot host species were introduced into polybags that contained six weeks old (1.5 months old) *kayu papi* seedlings (Table 3.). *Kayu papi* seedlings and pot host treatments (with or without host species) continued for 26 weeks old (5.5 months old) further in the nursery.

**Table 3.** The pot host species of *kayu papi* applied in the nursery experiment.

| Treatment Code | Pot Host species             | Family           |
|----------------|------------------------------|------------------|
| A (Control)    | -                            | -                |
| B              | *Sauropus androgynus* L. Merr | Phyllanthaceae   |
| C              | *Capsicum* sp.               | Solanaceae       |
| D              | *Cajanus cajan* L. Mill      | Fabaceae         |
| E              | *Alternanthera* spp.         | Amaranthaceae    |
| F              | *Sesbania grandiflora* L. Pers | Fabaceae      |

2.4. **Experiment design**
The experiment used a factorial design with pot host as factor I (6 pot host species) and media combinations as factor II (6 media combinations). In total, it consisted of 36 treatments with each treatment using 25 seedlings.

2.5. **Measurement**
The final assessment of the response of *kayu papi* to the pot host presence and media combination was done by measuring the height and diameter of seven months old seedlings.

2.6. **Data analyses**
Statistical analyses were carried out using the RStudio program, 0.99.903 version. Two-way analysis of variance (ANOVA) was used to investigate the effect of different pot host species and media combinations on *kayu papi* height and diameter. Fisher’s LSD was conducted as a post-hoc analysis to distinguish among treatments.

3. **Result**
3.1. **The effect of pot host and media combinations on the height of kayu papi seedlings**
Pot host and media compositions affected *kayu papi* height tested in this study (Figure 1). ANOVA analysis showed that pot host presence, media compositions, and the interaction between pot host and media have significant effects on the height of *kayu papi* (p < 0.001). Among six-pot host treatments (without pot host and five host species), *Alternanthera* spp. (E), and *Cajanus cajan* (D) have a more significant influence on the height growth of *kayu papi* seedlings. While three other pot host species: *Sauropus androgynus* (B), *Capsicum* sp. (C), and *Sesbania grandiflora* (F) have the same effect on the height of *kayu papi* as control (without pot host).

Considering media treatments, media IV (latosol + manure) was the most suitable media for accelerating the height of *kayu papi* seedlings among the other five media combinations. Moreover, media IV combined with the pot host *Alternanthera* spp (E) and *C. cajan* (D) promoted the tallest and second tallest of the *kayu papi* seedlings with the average height 10.35±0.64 cm and 8.12±0.24 cm respectively. Conversely, the interaction between *S. androgynus* (B) pot host species treatment and media VI (latosol+manure+sand) showed the lowest of the average height of *kayu papi* seedlings (4.75±0.33 cm on average).
In the other five media combinations, the presence of *Alternanthera* spp (E) and *C. cajan* (D) pot host species treatments also indicated positive effects on *kayu papi* height. The average heights of *kayu papi* with *Alternanthera* spp (E) in media I (grumusol) was 6.38±0.26 cm, in media II (latosol) was 6.52±0.27 cm, in media III (grumusol+manure) was 6.54±0.27, in media V (grumusol+manure+sand) was 6.72±0.43, and in media VI (latosol+manure+sand) was 5.79±0.41 cm. Moreover, the average heights of *kayu papi* seedling grown with *C. cajan* (D) in media I, media II, media III, media V, and media VI were 6.88±0.40 cm, 5.24±0.20 cm, 6.61±0.28 cm, 5.72±0.32 cm, and 6.48±0.16 cm respectively. Interestingly, the average heights of *kayu papi* seedlings grown without pot host species treatment had roughly the same value as the average height of *kayu papi* with the *S. androgynus* (B), *Capsicum* sp. (C), and *S. grandiflora* (F) pot host species treatments (around 4 cm up to 6 cm).

![Figure 1](image_url)

**Figure 1.** The average height of *kayu papi* at seven months old seedlings, which were grown without pot host (A) and with pot host: *Sauropus androgynus* L. Merr (B), *Capsicum* sp. (C), *Cajanus cajan* L. Mill (D), *Alternanthera* spp. (E), and *Sesbania grandiflora* L. Pers (F) in the grumusol soils (I), latosol soils (II), grumusol + manure (1:1) mixture soils (III), latosol + manure (1:1) mixture soils (IV), grumusol + manure + sand (1:1:1) mixture soils (V), and latosol + manure + sand (1:1:1) mixture soils (VI). Error bars represent +/-1 Standard Error. Letters on top of bars represent significance grouping tested at P=0.05, within a media combination.

### 3.2. The effect of pot host and media combinations on the diameter growth of *kayu papi* seedlings

Pot host, media combinations, and the interaction between them also significantly influence the diameter growth of *kayu papi* (p<0.001). The most desirable combination for accelerating the diameter growth was the *S. androgynus* (B) pot host species treatment and media I (grumusol), with the average diameter of 1.65±0.05 mm. Furthermore, the *S. androgynus* (B) also provided the highest diameter growth among other pot host species and control treatments in media III (grumusol+manure) with 1.61±0.03 mm on average, and media VI (latosol+manure+sand) with 1.58±0.03 mm.

Followed by the combination of the *Alternanthera* spp. (E) pot host treatment in media IV (latosol+manure) and in media VI (latosol+manure+sand) gave the highest diameter growth among other pot host species (the average of diameter both combinations were the same: 1.51±0.02 mm). While the smallest average diameter was 1.25±0.02 mm, it was *kayu papi* grown with *S. grandiflora* (F) in media V (grumusol+manure+sand). Hence, this study reveals that the combination of the
Alternanthera spp. (E) pot host treatment and media IV (latosol+manure) was preferably promoting the kayu papi growth, both the height and diameter.

Figure 2. The average diameter of kayu papi at seven months old seedlings, which were grown without pot host (A) and with pot host: Sauropus androgynus L. Merr (B), Capsicum sp. (C), Cajanus cajan L. Mill (D), Alternanthera spp. (E), and Sesbania grandiflora L. Pers (F) in the grumusol soils (I), latosol soils (II), grumusol + manure (1:1) mixture soils (III), latosol + manure (1:1) mixture soils (IV), grumusol + manure + sand (1:1:1) mixture soils (V), and latosol + manure + sand (1:1:1) mixture soils (VI).

Error bars represent +/-1 Standard Error. Letters on top of bars represent significance grouping tested at P=0.05, within a media combination.

4. Discussion
In this study, two pot host species significantly increase the height of kayu papi (Alternanthera spp. (E) and C. cajan (D)) and two pot host species that significantly affected diameter growth (S. androgynus (B) and Alternanthera spp. (E)), among six-pot host treatment (five-pot host species and without pot host). On the other hand, the three other pot host species S. androgynus (B), Capsicum sp. (C), and S. grandiflora (F) were poor hosts for increasing height and three other pot hosts (Capsicum sp. (C), C. cajan (D), and S. grandiflora (F)) were inadequate for advancing the diameter growth as well. Thus, not all pot host species used in this experiment performed better on increasing growth levels of kayu papi more than control (without pot host).

Moreover, the experiment showed that among six media composition treatment, the effect of different media compositions on kayu papi growth was various. Seedling height and diameters are the most straightforward morphological parameters to measure seedling quality and to predict the field response [24, 25]. Adding sand and manure was aimed to improve the physical, biological and chemical properties of media growth [26 - 28]. A prior study showed that a type of soil that has a high level of resource availability promoted a high growth rate of the host plant, which then lead to the increase of the hemiparasitic plant growth [29]. Based on their natural habitat in Timor, the physical characteristic of the media combination that was used in this experiment must fulfill the requirement for kayu papi growth, i.e., loamy sand to sandy clay loam [1]. Table 2 shows that media IV (latosol + manure) contained the highest amount of organic materials (9.34%), and N was the most suitable for accelerating height growth. However, media I (grumusol) had the best texture quality among other media, where the proportion of sand, silt, and clay were almost the same (sandy
clay loam) and was the most appropriate media for supporting diameter growth. Therefore, there was no most suitable media for increasing both the height and diameter.

Nevertheless, among six-pot host treatment (without pot host and five pot host species) and six media compositions, the combination of Alternanthera spp. (E) pot host treatment and media IV (litosol+manure) was the most consistent combination for promoting kayu papi growth by increasing both height and diameter. In contrast, the effect of other combinations between six-pot host treatments and six media composition varied on kayu papi growth. Some of the combinations only increased height but did not increase the diameter or vice versa.

While these combinations can improve kayu papi’s growth, other selected combinations between pot host and media could produce lower height and diameter growth than the control (without pot host), i.e., S. androgynus (B) in media VI (litosol+manure+sand) and S. grandiflora (F) in media V (grumusol+manure+sand). Previous studies noted that an inappropriate pot host species could reduce the growth level [21 - 30]. However, this reason is not entirely relevant because kayu papi attached to S. androgynus (B) in media VI (litosol+manure+sand) produced the shortest kayu papi seedlings. However, media I (grumusol) showed the most significant diameter growth. Therefore, the interaction between pot host and media should be considered.

In previous studies, Alternanthera spp. (herbaceous plant, Amaranthaceae family) has been identified to be an ideal pot host species for another Santalaceae species, i.e., S. album [21, 30, 33] and S. album plantation in Timor [34]. Alternanthera spp. also was the most effective pot host for kayu papi among the five-pot host tested. In the second rank was C. cajan, a shrub plant from family Fabaceae. Fabaceae species have been known widely as the Nitrogen-fixing plant, which improves the soil quality [30]. C. cajan also has been recognized as a suitable pot host species [33]. However, it has some disadvantages, such as rapid vegetative growth, thus requiring intensive management (pruning) to reduce light and nutrient competition and increase resistance to pests and fungi [30, 33].

Additionally, S. androgynus was in the third rank of the preferable pot host species for kayu papi. However, S. androgynus affected kayu papi growth inconsistently, only boosting diameter size and not the height. Therefore, in selecting species for the pot host, several requirements should be met including low light competition as a host plant is a potential light competitor [35], low growth level, low level of allelopathic, exceptional root growth [13 , 21], and the species that have economic value or easy to find locally.

5. **Conclusion**

This pot host experiment demonstrated that the most effective pot host species for boosting kayu papi growth was Alternanthera spp. in mixture media latosol and manure (1:1). The two other potential pot hosts were C. cajan and S. androgynus. However, further study is required to provide all aspects of silviculture of kayu papi, from sowing the seed until producing economic value.

**Acknowledgments**

This research was funded by Environment and Forestry Research Development Institute of Kupang, Indonesian Ministry of Environment and Forestry in 2013.

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