Growth performance of *sengon* (*Falcataria mollucana*) and *manglid* (*Magnolia champaca*) at different spacing distance

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Abstract. *Sengon* (*Falcataria mollucana*) has rapid growth, but susceptible to pest and disease, while *manglid* (*Magnolia champaca*) has slower growth compared to *sengon*, but relatively more resistant. Farmers can prevent high losses by interplanting their land with *sengon* and *manglid*. This interplanting technique between *sengon* and *manglid* has not been widely known. The study was conducted in Sodonghilir Village, Tasikmalaya, West Java, from December 2015 - November 2018. Seedlings were planted with minimal height of 30 cm and planted at the beginning of the rainy season, and each seedling was tied to a bamboo stick. One month after planting, plants were given an organic fertilizer TSP (phosphorus) and urea with a ratio of 1:2, 50 gr each plant. The study used split plots design with tree species (*sengon* and *manglid*) as the main factor and spacing as sub-plots (3 x 3 m, 3 x 4 m, 3 x 5 m, and 3 x 6 m). The treatments resulted in 8 combinations with 49 plants as the observation unit with four replications. The total planted area was 1 ha. The results showed that the interaction between species and spacing had a significant effect on the growth of *sengon* and *manglid*. The results showed the highest height was shown by treatment S4 (*sengon*, 3 x 6 m) with a height of 297.48 cm, while the highest diameter by S3 (*sengon*, 3 x 5 m) with a diameter of 52.9 mm. *Sengon* is more productive than *manglid*. However, the local community prefers to plant both species (*manglid* and *sengon*) to overcome the loss of income because *sengon* is more prone to pest and disease compared to *manglid*.

1. Introduction
Woody plant cultivation has become a potential dryland agribusiness. The market of timber from a private forest in Java Island is still wide-open with a promising price. *Sengon* is one of the tree species that is widely common to be planted in private forests. The farmers select *sengon* trees because it is fast-growing, easy to be cultivated, and has high market demand. The contribution of sengon wood to the economic income of farmer households varies [1]. More than that, sengon has high productivity that affects the farmer’s income. According to [2], farmer’s income from sengon wood trade in Pati District ranged between 6% - 22%. Productivity differences have caused income variation. Differences in productivity were affected by seedling quality, the level of nurturing, and also the interference from pests and disease.

*Manglid*, which was planted in a monocultural pattern, has a higher risk of being attacked by pest and disease. [3] revealed that manglid, which was planted monoculturally, had a higher rate of leaf pest attack (39.25%); meanwhile, in mix planting patterns, it only gained 25.75% of attack intensity.
In some locations, early age sengon plantation had a high risk of gall rust disease, reaching 95.5% [4]. Private forest health has three indicators, namely productivity, vitality and site quality [5]. Those indicators can be fulfilled in the condition that the vegetation of the private forest consists of a diverse structure of plants. A diverse vegetation structure will increase the thickness of litter, so it will affect the quality of soil fertility and soil porosity [6]. Mixed forests with at least two types of plants have a more significant advantage in biodiversity, economy and forest health compared to monoculture plants [7]. Mixed plantation forests have a lower risk of drought in soil microbial activity compared to monoculture forests [8].

The changing climate has increased the risk of failure in trees and crop cultivation due to prolonged drought and pest and disease outbreak. A combination of plant species, which are drought tolerant and intermediate shade-tolerant, can be the selection to encounter climate change [9]. One key to success in mix planting is how to regulate the level of competition between species. Some types of woody plants require the initial spacing to be narrow to produce optimal growth. Commonly, in sengon cultivation, the farmers have applied a very close initial spacing but did not practice thinning [10].

Close spacing on sengon stands can reduce tree productivity by inhibiting the tree growth. Besides that, farmers have less interest in cultivating woody plants since it has an extended economic return and less aware of the benefit of the trees [11]. Farmer communities prefer to maintain the existence of annual crops as the main crop so that the land can be managed with broader spacing for tree plants. The effort to bridge the interests of the farmer community to maximize the annual crops yield and cultivate woody plants can be made by widening the spacing of wood species. At the moment, the measurable effect of spacing width on the growth of sengon and manglid has not been widely known. This study aimed to determine the growth of sengon and manglid plants grown in a mixed pattern and to discover the effect of spacing on plant growth.

2. Methodology
2.1 Location and time
This research had been undertaken in Cukangkawung Village, Sodonghilir District, Tasikmalaya Regency. The elevation is 850 m asl, located between 107° 18’ 30” – 108° 25’ 00” E and 07° 04’ 30” – 07° 11’ 00” S. The location was the agroforestry plot area which consists of 1 ha manglid stand, 1 ha sengon stand, and 1 ha mixed stand of sengon and manglid planted in alternate rows. The research was commenced from February 2015 – December 2018. The landscape condition is hilly with the soil type of yellow-red podzolic. The site was unproductive ex-tea plantation with low growth manglid belong to the local community. During the plot establishment, the old tea bushes and low growth manglid were cut and cleared down.

2.2. Materials and tools
Research materials were sengon stand and manglid stand that have been established by the Agroforestry Research Centre. Tree seedlings were made and grown in the Agroforestry Research Centre’s nursery. Tools used consisted of scale for height measurement and caliper for diameter measurement.

2.3. Land preparation and planting activity
Firstly, land clearing had been done to clear the weeds. Planting holes were made with the size of 40 x 40 x 40 cm. Basic fertilizer used was manure with a dose of 1.5 kg per planting hole. Seedlings were planted with a minimum height of 30 cm. Tree planting was undertaken at the beginning of the rainy season. After being planted, each seedling was tied to a bamboo stick. One month after planting, plants were given an organic fertilizer of TSP (phosphorus) and urea with a ratio of 1:2, 50 gr for each plant. Plot maintenance was done by giving organic (1.5 kg manure) and (100 gr NPK) fertilizer once a year for two years. Tree replacements to replace the dead seedlings were done during the first year.
2.4. Experimental design
Split Plot Design was used in this trial with two types of tree species as the main factor, namely sengon (S) and manglid (M). Spacing was designed as the sub-plot consisted of 4 plant spacing (3 x 3 m, 3 x 4 m, 3 x 5 m, and 3 x 6 m). Each treatment consisted of 42 trees, which had four replications, where the total number of trial trees reached 1,344 plants. Observed parameters were height and breast height diameter.

2.5. Data analysis
Observed data were analyzed using analysis of variance (ANOVA) and for further testing, Duncan Multiple Range Test (DMRT) was used if there were significant differences. The data analysis software tool was SPSS 26.

3. Result and Discussion
Interaction among factors significantly influenced plant growth. The result of ANOVA on sengon and manglid growth is described in Table 1 in Appendix I. The result of Duncan post hoc test is presented in Figure 1.

Figure 1. The result of the Duncan test on the effect of treatments on (a) diameter (b) height.
Remark: The average value in the column, followed by the same letter, shows no significant difference in the level of confidence of 95%. S1=Sengon 3x3 m; S2=Sengon 3x4 m; S3=Sengon 3x5 m; S4=Sengon 3x6 m; M1=Manglid 3x3 m; M2=3x4 m; M3=3x5 m; M4=3x6 m.

The optimum growth was significantly reached by sengon (S4 for height and S3 for diameter). Detailed on each species, treatment that reached the highest height was shown by treatment S4 (sengon, spacing 3 x 6 m) and M3 (manglid, spacing 3 x 5 m). While S3 (sengon, 3 x 5 m) and M2 (manglid, 3 x 4 m) reached the highest result for diameter. The result for manglid in line with [12] that 3 x 5 m gained the highest height. This result, however, complements the findings that sengon has the best growth at initial spacing 2 x 3 m [13], while manglid provides the best growth at initial spacing 2 x 2 m [14]. According to [15] that 3 x 3 m is the most common spacing applied in commercial plantation, and there was no evidence that narrow or wider spacing gave higher results than other treatments. [15] discovered that there was no significant effect of closer spacings on height development in early age loblolly pine (Pinus taeda). The height growth depended on initial spacing at
an early age and remained unchanged with age. Table 1 below is showing the highest tree growth as the effect of species and spacing on diameter and height.

| Species | Diameter (mm) | SD   | Spacing (m) | Height (cm) | SD   | Spacing (m) |
|---------|---------------|------|-------------|-------------|------|-------------|
| Sengon  | 52.98         | ±26.45 | 3 x 5       | 297.48      | ± 176.20 | 3 x 6       |
| Manglid | 45.78         | ±15.02 | 3 x 4       | 243.73      | ± 85.21 | 3 x 5       |

Fast-growing species, such as sengon, generally have a higher shoot: root ratio and higher respiration rate compared to slow-growing plants [17]. Sengon grows faster compared to manglid. The sengon root system caused this can grow wider, so it can absorb more nutrients and water. Since sengon grows faster in height, it will get more sunlight and get optimum photosynthesis. This research showed that wider spacing was followed by bigger diameter and height. A study from [18] on the effects of spacing in two hybrid poplar clones in Canada stated that basal diameter increased in line with increased spacing between trees, but for breast height diameter (dbh) can increase or sustained depending on the clone.

![Figure 2](image.png)

**Figure 2.** Growth of sengon and manglid plants at each spacing (a) diameter (b) height.

The diameter and height of the plants are continuously growing each year. Sengon trees had shown faster growth compared to manglid since it reached one year after planting (Fig. 2). The spacing 3 x 5 m showed optimum growth when it reached the age of three. Sengon, as one of the legume trees, can bind N from the surrounding air, tolerant to drought and has a better root development [19, 9]. After passing two years old, sengon and manglid had a faster growth rate. At that age, the plant has better rooting, so it was more resistant to the dry season, absorbing more nutrients and able to compete with weeds. Competition among the trees had been low because the tree canopy has not overlayed yet. [20] mentioned that the effect of the mixture on a tree and stand dynamics is the feedback of interaction between environmental condition (light percentage, soil moisture, air temperature), the function of the system (such as transpiration, photosynthesis, growth), and the generated structure (e.g., stem, canopy,
root). Research from [16] discovered that the growth of Eucalyptus in a mixed planting with a native tree was 75% more productive than the monoculture.

4. Conclusion
The results of our study showed that 3 x 6 m treatment was the optimum spacing for sengon. Meanwhile, the 3 x 5 m treatment was the optimum spacing for manglid in gaining height growth. The 3 x 5 m and 3 x 4 m treatments gave optimum diameter on sengon and manglid, respectively. In mixed planting, sengon showed optimum diameter and height growth compared to manglid. The increase of tree growth (stem size and tree height) is not always a response to the increases in spacing distance or depending on species. It also depended on the interaction between spacing distance and species. Sengon is more productive than manglid. However, the local community prefers to plant both species (manglid and sengon) to overcome the loss of income because sengon is more prone to pest and disease compared to manglid.

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Appendix

Table A. Results of analysis of variance the effect of plant species and plant spacing Sengon and Manglid.

| Source of variance          | Sum of squares | df | Mean Square | F. calculate | Sig.  |
|-----------------------------|----------------|----|-------------|--------------|-------|
| Height                      |                |    |             |              |       |
| Species*Spacing             | 137,471.870    | 3  | 45,823.957  | 2.647        | 0.048 |
| Species*Block              | 201,535.913    | 3  | 67,178.638  | 3.881        | 0.009*|
| Spacing*Block              | 1,082,784.633  | 9  | 120,309.404 | 6.950        | 0.000*|
| Spacing*Species*Block      | 791,778.997    | 9  | 120,309.404 | 6.950        | 0.000*|
| Species                    | 347,100.868    | 1  | 347,100.868 | 20.050       | 0.000*|
| Spacing                    | 66,335.197     | 3  | 22,111.732  | 1.277        | 0.281 |
| Block                      | 343,700.118    | 3  | 114,566.706 | 6.618        | 0.000*|
| Diameter                   |                |    |             |              |       |
| Species*Spacing             | 6,702.449      | 3  | 2,234.150   | 5.489        | 0.001*|
| Species*Block              | 7,181.047      | 3  | 2,393.682   | 5.881        | 0.001*|
| Spacing*Block              | 16,210.330     | 9  | 1,801.148   | 4.425        | 0.000*|
| Spacing*Species*Block      | 13,139.126     | 9  | 1,459.903   | 3.587        | 0.000*|
| Species                    | 2,264.320      | 1  | 2,264.320   | 5.563        | 0.019 |
| Spacing                    | 8,211.749      | 3  | 2,737.250   | 6.725        | 0.000*|
| Block                      | 4,407.500      | 3  | 1,469.167   | 3.610        | 0.013 |

Remarks: *significant different at a 95% level of confidence