Improving the growth of cempaka (*Elmerillia ovalis*) seedlings to accelerate ex situ plantation

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**Abstract.** Cempaka tree (*Elmerillia ovalis*), best known as a multipurpose tree species, is mostly used for the building of luxurious traditional houses of the Toraja and Minahasa Tribe as well as for religious sculptures. Due to the specific qualifications, the cempaka wood demands gradually increase, while the populations in nature drastically decrease. On the other hand, early seedling growth encounters many obstacles such as recalcitrant seeds, slow growth, and sensitivity to leaf disease. This study aimed to improve the quality of the seedling prepared for a higher survival rate when planted in the field. This research was conducted at the nursery of the Bogor Forest Research and Development Centre, Indonesia. The factorial experiment was conducted in a completely randomized design, consisting of two factors: wood vinegar as a growth stimulant and media composition, in three replications. The stimulant factor consisted of two levels: the addition of wood vinegar (1.5 %) and (control), and the media composition factor consisted of four levels: (a) soil 100%, (b) soil: cocopeat rice husks (6: 3: 1), (c) soil: rice husks (1:1), and (d) soil: manure (2:1). The observed parameters were seedling height, diameter, root/shoot ratio, seedling quality index (SQI). The best growth of cempaka seedlings resulted in treatments of wood vinegar in combination with soil media mixed with manure. Seedlings in this treatment height 58.93 cm, 6.8 mm diameter, S/R ratio 3.61, and 1.26 SQI, respectively, better than the others. The best treatment also gives the 12 months seedlings absence of leaf disease.

1. Introduction

One of the identified failure factors in Cempaka (*Elmerillia ovalis* Miq. Dandy) plantation is a very unsatisfactory survival rate of natural regeneration. The early stage of plant growth is the most critical phase determining the successfulness of either at nursery or field plantation. That stage is strongly influenced by both internal and external factors. The main internal obstacles in Cempaka cultivation are recalcitrant seeds, slow growth, and sensitivity to leaf disease. While the main external factors are presumed, mainly environment changing due to the anthropogenic disturbance during uncontrolled timber exploitation.

Among the tribe, especially in South Sulawesi and North Sulawesi, Cempaka wood is the most demanded. It is due to cempaka wood being the prestigious and sacred element for their traditional houses that is unchangeable with any other timber species. Besides for house building, the communities also utilize this timber for various purposes, such as traditional music “kolintang,” boat, furniture (cabinets, chairs, tables), doors, the manufacture of water pipes to replace pipes, wooden bearings, posts, boards, or construction under the roof of buildings [1]. Therefore, this timber is highly commercial wood
which is very popular for these communities. Due to their multi purposes, it is no wonder that Cempaka timber is one of the most desired commercial wood species in North Sulawesi. The Ministry of Forestry of Indonesia classified Cempaka as the fancy timber for their distinctive wood color as light yellow-brown or yellowish-gray, and sometimes there are green spots in between. According to Ramadani (2008), cempaka wood is characterized by its resistance to water and moisture and remains durable when they are placed directly on the ground. [2] Recently the demand for cempaka wood gradually increased from time to time. In contrast, the existence of this species in their natural habitat drastically decreases. Hence the species becomes one of the threats to distinct. This is due to the continually unsustainable exploitation without balanced regeneration effort. Furthermore, the local governments have launched a policy in the cempaka plantation movement in North and South Sulawesi Provinces. Cempaka then is mandatory to be widely planted “ex-situ” in community forests and in the development of plantation forests.

To support the success of the ex-situ plantation program, it needs huge amounts of qualified seedlings. Therefore, this research is aimed to improve the quality of cempaka seedlings for better growth in the nursery as well as to utilize the available resources for the seedlings media to formulate a practicable and applicable technique in producing cempaka seedlings. Hopefully, the better seedlings will be more survive when planted in the field and fulfill the expectations of cempaka wood planters.

2. Materials and methods

2.1. Time and location
This research was conducted in June 2018 – May 2019 at the R&D Centre for Forest nursery, Bogor. Media of seedlings were analyzed at the Soil Laboratory Biotrop, Bogor.

2.2. Materials
Cempaka seedlings (2 weeks age after germination), 12 months age seedlings, wood vinegar, cocopeat, manure, rice husk charcoal, soil (topsoil).

2.3. Methods

2.3.1. Media preparation. Media for seedlings were prepared in four levels; they are is soil (as a control); soil: cocopeat: rice husk charcoal (3:6:1); soil: manure (3 : 1); and soil: rice husk charcoal (1:1). The media were mixed well as the treatment than were placed into polybags with 20x15 cm sizes.

2.3.2. Planting the seedlings. The seedlings were selected with the following criteria: vigorous, having 2-4 leaves, 2-3 cm height, free of pests or diseases. They were estimated to be 14 days old from germination. Maintenance during three months in the nursery was daily watering, weeding, pest controlling.

2.3.3. Soil addition with wood vinegar. This treatment was initiated by preparing a solution of wood vinegar in 1.5% concentration; through a solution of 4.5 ml of wood vinegar into 300 ml of water. The addition was taken place by spraying 10 ml of the solution to each polybag once in two weeks for 12 months. The wood vinegar was distilled from wood waste with pH ± 4.

2.3.4. Design of experiments. The study was conducted in the two factors of completed-randomized design, where the first factor was seedling media and the second was wood vinegar treatment. Seedlings media consist of four levels; that is:
A0 = Soil (as control)
A1 = Soil : Cocopeat
A2 = Soil : Manure : Rice husk charcoal
A3 = Soil : Rice husk charcoal
Wood vinegar consists of 2 levels:
B1 = 0% (control)
B2 = 1.5%

Experiments were arranged in three replications; each treatment consisted of 10 seedlings, hence resulting in 4 x 2 x 3 x 10 = 240 seedlings in total. Total observation time was 12 months.

2.3.5. Growth observations. Height and diameter (weekly), dry weight of roots and shoots, a ratio of shoot/root, as well as the total dry weight and index of seedling qualities, were observed for growth assessment. Whereas the intensity of disease incident was observed to find out the impact of soil addition to seedlings health and vigor.

2.3.6. Height and diameter of seedlings. Height and diameter were measured monthly for 12 months. Heights were observed at the 1 cm distance from the media surface, (as well as the diameter) up to the newest shoot emerged. Rates of growth were calculated by reducing the last with the first measurement.

2.3.7. Shoot dry weight (SDW). Shoots were separated from root parts restricted by media surface (root neck) at the 12 months age of seedlings. Each part was then put in the oven to remove the water contents. After 48 hours the samples have accessed the weight for root and height calculation, total growth biomass, and Shoot/Root ratio.

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\text{S/R} = \frac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}
\]  

2.3.8. Index of seedling quality (ISQ). ISQ was calculated vertically and horizontally based on height, diameter, total dry weight, as the following equation:
Seed quality index [3]:

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\frac{(\text{Shoot dry weight (g)} + \text{root dry weight (g)} \text{ height (cm)})}{\text{Diameter (cm)}} + \frac{\text{shoot dry weight (g)}}{\text{root dry weight (g)}}
\]  

2.3.9. Data analysis. The collected data were then analyzed using ANOVA test, treatments with significant impact then were further analyzed using Duncan’s Multiple Random Test (DMRT) at the level of confidence 95% (\(\alpha = 0.05\)), with the application of SPSS Program 16.0.

3. Result and discussion

3.1. Influence of media composition on the seedling growth
Analysis of variance resulted in a single factor of wood vinegar addition that gave no significant difference. On the other hand, media composition gave a highly significant impact to almost all growth variables, except diameter and S/R (Table 1). Interaction of media composition and the wood vinegar addition had a significant impact to all variables observed in this study (Table 1).

| Treatments | Height | Diameter | SDW | RDW | TDW | S/R | ISQ |
|------------|--------|----------|-----|-----|-----|-----|-----|
| (A)        | **     | ns       | **  | **  | **  | ns  | **  |
| (B)        | ns     | ns       | ns  | ns  | ns  | ns  | ns  |
| A*B        | **     | ns       | **  | **  | **  | **  | **  |
3.2. Height and diameter

Growth performance, as illustrated in Table 2, stated that the most significant growth was given by treatment composition of soil media and manure combined with wood vinegar 1.5% (A3B1). The height of that treatment at the age 12 months was 58.93 cm, whereas the least growth was given by the treatment control (pure soil without wood vinegar addition = A0B0) that had 43.87 cm height at the age of 12 months. The best diameter was given by A2B1 treatment (soil: cocopeat combined with vinegar) by 6.8 mm, while the worst was given by A0B1 (pure soil with vinegar addition) with 5.5 cm. This study is confirmed with the earlier study conducted by Kurniawan (2013), Cempaka seedlings 6 months old with 47 cm height and 4.2 mm diameter were proper to be planted in the field [4].

The result indicated that having vinegar added to the media without organic matter (pure soil) will reduce the growth performance. It can be understood that vinegar having high acidity (pH = 4) then will have a negative impact on the seedlings grown on the soil without organic matter addition. As [5] stated, organic matter can act as a buffer for pH adjustment [5]. When in a low pH condition, organic matter can increase the acidity and vice versa.

Table 2. Growth performance of *Elmerillia ovalis* seedlings 12 months age

| Treatments | Height | Diameter |
|------------|--------|----------|
|            | Media  | B0  | B1  | B0  | B1  |
| A0         | 43.87c | 50.60 abc | 5.8 a | 5.5 a |
| A1         | 47.53 bc | 52.87 ab | 6.10 a | 6.37 a |
| A2         | 48.77 bc | 50.00 bc | 6.33 a | 6.8 a |
| A3         | 45.27 c | 58.93 a | 6.00 a | 5.73 a |

Remarks: values followed by the same letters in the same column indicated non-significant differences at the level of confidence 95%.

However, overall, wood vinegar additions improve the growth of all seedlings (Table 2). Referring to chemical analysis carried out by Komarayati et al., (2011), the main wood vinegar components are acetic acid (21.71–30.05 ppm, methanol 0.44–1.15%, and phenol 45.07–63.62 ppm) [6]. The concentrations of chemical compounds strongly depend on the origin of the wood species processed to become wood vinegar. Wood vinegar in this study indicated a positive influence on the growth of Cempaka seedlings at 12 month age. Yatagai (2002) explained in what ways compounds found in the wood vinegar increased the growth of seedlings [7]. Acetic acid and phenol play an important role in improving plant growth, particularly, by suppressing disease attack; while methanol acts as plant growth improvement [7]. Methanol in wood vinegar is one type of carbohydrate that plays an important role in plant tissue establishment. Study conducted by Edriyanti (2018) showed that the application of 1.5% wood vinegar solution has depleted disease attacks 26.7% to 6.6%; and suppressed the disease intensity 6.67 % to 3.3% [8].

In this study, growth of diameter showed non-significant difference at all treatments (Table 2). It can be assumed that the seedlings (until 12 months of age) are radially growing (where stem and root grow toward up and ground). Hence there is no competition for space due to sufficient growing space laterally. Photosynthate in the assimilation process in the 12 months age of *Cempaka* seedlings are assumed to be utilized for elongation of stem, respiration process, and leaves shifting.
3.3. Response of biomass to the addition of wood vinegar

The success of plant adaptation can be measured through biomass because the parameter is the result of interactions between inner physiological processes with their environment. Biomass of the stand are the total of all living plant tissues at a definitive time [9]. Total dry weight (TDW) is an important parameter because it demonstrates the interactions among environment, genetic traits, and plant physiological processes.

Table 3 showed that the best treatment in improving shoot dry weight, root dry weight, S/R ratio and total biomass is A1B1 (soil: cocopeat with wood vinegar addition) treatments. This treatment has the highest values, (SDW, RDW, TDW) by 4.27; 8.03; and 12.30 gram), respectively. That is a very significant improvement compared to the control (A0B0) which has the least properties. The treatments improve root growth six fold, shoot growth four fold, and total biomass 6 fold from the control.

### Table 3. Biomass performance of Elmerillia ovalis seedlings aged 12 months after treatments with media composition and wood vinegar addition

| Treatments | Root dry weight (g) | Shoot dry weight (g) | Total dry weight (g) |
|------------|---------------------|----------------------|----------------------|
| Media      | B0                  | B1                   | B0                  | B1 | A0   | A1   |
| A0         | 2.60ab              | 3.43 ab              | 5.50 ab             | 6.53 ab     | 8.10 ab | 9.97 a |
| A1         | 2.83ab              | 4.27 a               | 6.03 ab             | 8.03 a      | 8.87 ab | 12.30 a |
| A2         | 1.83 bc             | 2.73ab               | 6.00 ab             | 6.37 a      | 7.83 ab | 9.10 ab |
| A3         | 1.7 bc              | 0.70 c               | 2.83 bc             | 2.03 c      | 4.53 bc | 2.73 c  |

Remarks: values followed by the same letter in the same column indicated as non-significantly different at the level of confidential 95% (α = 0.05)

3.4. Shoot/root ratio and index of seedlings quality

Shoot-root ratio illustrates comparison the growth above and below ground of seedlings, while the seedling quality index demonstrates the physiological attributes of the seedlings (Table 4).

### Table 4. Root/Shoot ratio and Index of Elmerillia ovalis seedlings quality of 12 months old due to composition of media and wood vinegar addition

| Treatments | Root/Shoot Ratio | ISQ |
|------------|------------------|-----|
| Media      | B0               | B1  | B0 | B1 |
| A0         | 2.18 bc          | 2.52 abc | 0.89 abc | 1.05 a |
| A1         | 2.12 bc          | 1.89 bc  | 0.97 ab   | 1.26 a  |
| A2         | 3.20 ab          | 2.29 abc | 0.78 abc  | 0.85 abc |
| A3         | 1.78 c           | 3.61 a   | 0.35 bc   | 0.26 c   |

Remarks: values followed by the same letter in the same column indicated as non-significantly different at the level of confidential 95% (α = 0.05)

Table 4 showed that the best S/R ratio is also given by the treatment A1B1 where the value is close to 1.89. This indicates that the seedlings grow balanced either upward or downward. Hence the seedlings will be the most vigorous. Gardner et al., (1991) stated that S/R demonstrated one indication of seedling’s tolerance to drought [10]. A bigger S/R value indicated bigger drought stress faced by the seedlings. Hardjowigeno (2010) explained that the S/R ratio is the best indication to observe the efficiency of nutrient absorption [11].

A1B1 treatment is the media added with two kinds of organic matter. It is assumed that organic matter plays a critical role in the maintenance of pH, water retention, and cation exchange capacity [11]. Nutrients can be absorbed efficiently when the media have moderate pH and good porosity. Organic matter also can improve the beneficial microbes in the rhizosphere [12], but the weakness of this study is that the data of the rhizosphere community is not available. On the other hand, organic matter have
many benefits to soil fertility as its mineralized to inorganic elements such as N, P, K, Ca, Mg, S, micronutrients, as well as improve the physics traits of soil such as porosity, water holding capacity, moisture, and temperature [11,13].

Index of seedling quality is reflected in various growth variables that ensure they will survive and grow better when transplanted to the field. Table 4. also demonstrated that the best ISQ (1.26) is also given by the A1B1 treatment but has no significance with the control (1.05). Interestingly, A2B1 and A3B1 depleted the ISQ. Komarayati (2011) estimated that those treatments cause pH depletion. Subsequently nutrient absorption was restricted [6]. Utilization of cocopeat to improve the growth media, perhaps, give multiple impacts to the farmers. This is the most available resource, applicable technology, and inexpensive for the farmers to produce more vigorous *cempaka* seedlings. On the other hand, Sulawesi is the island producing lots of coconuts that is exported as coconut powders, called “copra.” Hopefully, the success ex-situ plantation of Cempaka can be realized.

4. Conclusion
It can be concluded that the best media composition in producing *Elmerillia ovalis* seedlings is A1B1 (soil: cocopeat: charcoal rise husk: 3:6:1 combined with 10 ml 1.5% weekly monthly for 3 months). This improved almost all variables of growth, namely height, shoot dry weight, root dry weight, S/R ratio, and total biomass, and the index of seedling quality, except the diameter. This treatment persists until the seedlings at the 12 months age, the most proper for ex-situ transplanting to the field.

Author contribution:
All authors contributed equally in field experiments, data analysis and draft the manuscript.

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