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Short-Communication

Accelerating the Height Increase of Mersawa (*Anisoptera marginata*) Seedlings through Inundation Height with and without Water Treatments

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ABSTRACT

Deforestation on peatlands in Indonesia has become an important issue. To restore the peatland condition, planting native tree species such as mersawa (*Anisoptera marginata*) is required. One of the problems with planting is the frequent occurrence of inundation at planting sites. The study aimed to analyze the inundation height, which accelerated the height increase of mersawa seedlings in acid or neutral water conditions. The method used was experimental research with a factorial completely randomized design. Factors studied were inundation height, consisting of without inundation, inundation at polybag height, inundation between the tips of the polybags and the apices of the plants, and inundation reaching the apices of the plants. The water composition consisted of peat swamp water, peat swamp water mixed with boiler ash from palm oil mill, and peat swamp water mixed with dolomite lime. The treatment of inundation between the tips of the polybags and the apices of the plants led to the highest height growth, while the lowest were the seedlings without inundation. The interaction between the inundation height and the water composition had a survival percentage of 100%, while the seedlings inundated up to the seedling apices with water treatments had a survival rate of 16%.

1. Introduction

Deforestation on peatlands in Indonesia has become an international concern due to the importance of peatland ecosystems in the future. To overcome the problem, a program must be carried out to rehabilitate peat swamplands with local species that can benefit the surrounding community economically and help them grow well in peat swamp conditions. A tree species suitable planted in peat swamp land is mersawa (*Anisoptera marginata*). Mersawa, a part of being used as a source of wood for building materials, can also produce resin or *damar*. The mersawa tree is an indigenous species growing in mixed peat swamp land and in healthy forests at an altitude of 1,200 m (Bayu et al. 2021). In addition, Harlinda et al. (2016) stated that the mersawa tree species is a species that can produce resin for the raw material industry. Still, unfortunately, according to (DLH 2014), the species has been categorized as endangered. Therefore, they should be sustained and cultivated through plantations.

Two problems in planting mersawa species in the peat swamp land are inundation and acid peat swamp water. So, it is essential to study the inundation height that the species can tolerate and the inundation height that can accelerate the growth of mersawa seedlings. Knowing the optimum height growth of the mersawa seedlings will make it easier to find locations for planting the seedlings in peat swamp land based on inundation height. Furthermore, according to Achmad and Bakri (2021), the pH of the peat swamp water is very acidic (pH 3.5), and therefore, it needs to increase.

To increase pH of peat swamp water, Achmad and Bakri (2021) have proven that adding oil palm empty fruit bunches (OPEFB) and dolomite lime was able to increase the pH of the peat swamp water and increase the growth of belangeran (*Shorea balangeran*) seedlings by watering peat swamp water mixed with OPEFB, and dolomite on the seedlings. In addition, Achmad and Bakri (2022) found that the growth of Kalimantan swamp jelutung (*Dyera polyphylla*) seedlings were susceptible to inundation height. Achmad and Bakri (2022) proved that applying dolomite lime was able to increase the survival rate of the Kalimantan swamp jelutung seedlings, especially at the inundation height up to the apices of the Kalimantan swamp jelutung seedlings. However, the treatment of peat swamp water with OPEFB caused the death of all the seedlings used in the study due to OPEFB decomposition in an anaerobic manner (Yunita 2012). For this reason, the present research replaced the OPEFB with boiler ash from a palm oil mill because, based on the pH test results, the boiler ash can increase the pH of the water without further decomposition by microorganisms.

According to the research results of Arianci et al. (2014), boiler ash from palm oil mill contains 30 - 40% K_2O, 7% P_2O_5, 9% CaO, and 3% MgO. It was further stated that the boiler ash is also alkaline and suitable for acidic soil types in plant cultivation. Arianci et al. (2014) also noted that the best treatments for the growth and productivity of soybean in peat soils are 1,45 kg OPEFB + 145 g boiler ash + 2.9 g trichoderma per plot. The treatments increased high in the plant, sped up the age of flowering, and increased the number of pods and dry weight of the soybean plant. According to Elia and Mukhlis (2015), adding boiler ash to ultisol soil can increase soil pH, available P, exchangeable K, and plant P uptake. The pH increased because it was an alkaline material with a pH of 9.9. According to Ichriani et al. (2021), boiler ash mixed with coal fly ash can increase pH, phosphor, and availability of nutrients of the oil palm fruit empty bunch compost in peat soils. Meanwhile, according to Mulyani et al. (2017), boiler ash added to the composting process improved the OPEFB quality through increased pH, humic acids, and macronutrients, and decreased lead (Pb) contents. In detail, the nutrients contained in the boiler ash are silicon dioxide (SiO_2) of 40.0%, potassium oxide (K_2O) of 12.1%, calcium oxide (CaO) of 10.0%, phosphorous pentoxide (P_2O_5) of 8.2%, magnesium oxide (MgO) of 6.4%, aluminum oxide (Al_2O_3) of 6.1%, carbon (C) of 5.4%, iron oxide (Fe_2O_3) of 2.5%, others of 2.0%, and ignition loss of 7.3% (Roselan 2014). Furthermore, Setyawati et al. (2023) have researched the mixture of peat soil with cocopeat, compost, or biochar. The results showed that the treatments significantly increased pH, ash, and nutrients. As a result, the treatments increased the growth of *D. polyphylla* and *S. balangeran* seedlings.

Some researchers have studied the utilization of dolomite lime in peat lands. Krismawati and Latifah (2022) stated that the application of 300 kg/ha urea, 400 kg/ha NPK Phonska, and 4 tons/ha dolomite obtained the highest dry seeds yield of corn 7.68 ton/ha or an increase of 23.87% from the Recommended Rates of Inorganic Fertilizers/RRIF, received the highest net income (profit) IDR 19,580,000 or growth of 25.03% from the RRIF, R/C ratio 2.38, and B/C ratio 1.73. In addition, Pamungkas et al. (2017) concluded that dolomite affected the dry weight of growth and yield of Bogor groundnuts in peat soils.

The research aims to accelerate the height growth of mersawa seedlings based on inundation height with and without water treatments to increase the seedlings' survival rate during the inundation. The results of this study can be of consideration for practitioners in silviculture when planting mersawa in peat swamp lands.

2. Materials and Methods

2.1. Materials

The research was conducted in the greenhouse of the Faculty of Forestry, Lambung Mangkurat University, Banjarbaru. Observations were carried out from July to October 2022. Materials used were 180 mersawa seedlings obtained from the nursery of the Forest Plant Seed Center of the South Kalimantan Province Forestry Service in Banjarbaru, polybags as many as 180 pieces with a size of 17 cm × 12 cm with holes punched in them, peat swamp soil as planting media, peat swamp water as the water used to inundate the seedlings, boiler ash from palm oil mill and dolomite lime as water treatments. The research used equipment such as a thermo-hygrometer for temperature/humidity measurement, ruler/caliper for growth measurement, digital scales for dolomite lime and boiler ash measurement, a pH meter, jerrycans as containers to transport the peat swamp water, basins as containers of peat swamp water and seedlings to determine the height of water inundation.

2.2. Methods

The method used was experimental research with a factorial design that was completely random. Factors studied: Factor A (inundation height) consisted of A0 = no inundation, A1 = inundation at polybag tip height, A2 = inundation at mid-height between polybag tips and seedling apices, and A3 = inundation at seedling apices, and factor B (water composition) consisted of B0 = peat swamp water without treatment/control, B1 = peat swamp water with boiler ash (the amount of boiler ash treatment to reach the pH neutral (pH 7) of the peat swamp water was 1.69 grams per liter of peat swamp water), and B2 = peat swamp water with dolomite lime (the amount of dolomite lime treatment to reach the pH neutral (pH 7) of the peat swamp water was 1.19 grams per liter of peat swamp water). Dolomite lime has long been known to increase soil and water pH, but boiler ash is relatively new based on several studies. If the present study shows that the boiler ash has the same effect as dolomitic lime on plant growth, it means that the boiler ash can be a substitute for dolomitic lime. Boiler ash is a waste from palm oil processing that does not need to be purchased and can even cause air pollution around the palm oil industry. In addition, Vantoai et al. (2001) divided inundation based on crop conditions into two levels: the inundation level, where only plant roots were inundated, and the inundation level, where plant parts were fully flooded. However, in the present study, the inundating was more varied as described, providing more detailed results. The number of seedlings per treatment was 5, repeated 5 times. The total number of seedlings used = 12 treatment interactions × number of seedlings per treatment (5 stems) × 3 replications = 180 seedlings. The experimental design used was a 4 × 3 factorial design in a completely randomized design. An overview of the inundation height is presented in **Fig. 1**.

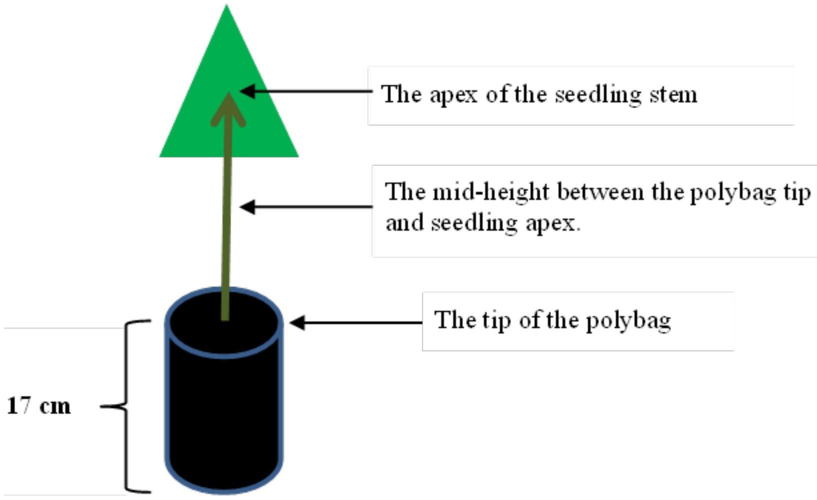

Fig. 1. Inundation height at a seedling.

2.3. Procedure

The working procedure began by putting the seedlings into plastic bags containing 30 seedlings per bag to facilitate transportation from the seedling source. After arriving at the nursery, the seedlings were kept in the shelter for ten days to acclimatize to the new circumstances. Initially, peat compost and husks were used, and the medium was replaced with peat soil. The initial polybags used were too small (8 cm × 9 cm) for four months of seedling growth, so they were replaced with larger polybags measuring 12 cm × 17 cm. Next, peat swamp water (pH 3.77) was put into the basins according to the treatment interaction. The first treatment interaction (peat swamp water without treatment) consisted of four basins, namely the first basin without peat swamp water, the second basin was filled with peat swamp water at the level of the polybags (17 cm), the third basin filled with peat swamp water with an inundation height between the tip of the polybag and the apex of the seedling stem (39 cm), and the fourth basin was filled with peat swamp water at the apex of the seedling (61 cm) on average. The second treatment interaction (peat swamp water mixed with boiler ash) also consisted of four basins with the same inundation height as the first treatment interaction. The third treatment interaction used was (peat swamp water mixed with dolomite lime) with the same inundation height as the previous treatment interactions. During the observation, the seedlings were placed in a greenhouse so rainwater would not disturb the treatment. Measurements were taken at the beginning and end of the study. Tending during the observation included the addition of peat swamp water with and without boiler ash and dolomite lime to maintain the inundation height according to the treatment. In contrast, those not inundated were only watered once a day. Each water composition was stocked in one drum with a capacity of 220 liters to preserve the inundation height according to treatments.

2.4. Variables

The parameters measured were (1) the percentage of seedlings alive was obtained by calculating the number of seedlings alive until the end of the study divided by the number of seedlings studied multiplied by 100% and (2) seedling height measured from 1 cm above the root collar to the tip of the seedling stem. Measurements were taken at the beginning and end of the study.

2.5. Data Analysis

Data were analyzed based on a factorial pattern design in a completely randomized system. Treatments in the analysis of variance table that showed significantly different effects between treatments were analyzed with the Least Significant Difference (LSD) test. Data analysis was carried out using the SPSS program.

3. Results and Discussion

3.1. Survival Rate

The survival rate of mersawa seedlings showed significantly different results from the results of Achmad and Bakri (2022), indicating that the higher the inundation for the Kalimantan jelutung (*Dyera polyphylla*) seedlings, the lower the survival rate. However, the decrease in percentage can be reduced by adding dolomite lime to peat swamp water. The present research showed that the survival rate of mersawa seedlings (*Anisoptera marginata*) was not affected by inundation height (all seedlings were alive), except for the seedlings treated with peat swamp water mixed with boiler ash and dolomite lime at inundation height as high as the apices of mersawa seedlings (only one seedling was alive out of 15 seedlings observed). In this case, the survival rates of the mersawa seedlings were not analyzed using the analysis of variance.

In addressing the problem, the peat swamp water with and without treatments was analyzed, and the results are shown in **Table 1**.

Table 1. Analysis results for pH, Dissolve Oxygen (DO), and ammonia

Components	Water composition		
	PSW	PSW + DL	PSW + BA
pH	3.77	7.83	7.20
DO	5.08	5.46	5.86
Ammonia	0.02	0.08	0.03

Notes: PSW = peat swamp water, DL = dolomite lime, and BA = boiler ash.

Based on **Table 1**, PSW + DL and PSW + BA increased the pH and ammonia. According to Shukla et al. (2018), ash damaged *Mangifera indica* leaves morphologically and physiologically. The dust load and high pH cause physical injury, necrosis, stomata blockage, and reduced photosynthesis. In addition, Sett (2017) stated that alkaline dust that settles on the leaf surface can also cause leaf chlorosis and leaf tissue death through a combination of thick crust and alkali toxicity produced in wet weather. In addition to the pH increase, the death of the seedlings inundated up to the apex of the seedling was presumably due to the influence of the boiler ash and dolomite lime plugging stomata of mersawa leaves.

A reduction in stomatal conductance can cause growth disruption, and it is due to the blocking of stomata on the upper surface of the leaf by dust (Zia-Khan et al. 2015). Amina et al. (2020) stated that the absence of several types of stomata in plants of the same species collected from polluted sites could be related to the ability of cement dust to clog, denature, and destroy plant stomata. Likewise, Kameswaran et al. (2019) stated that dust particulate deposition can cause stomata blockage on the upper and lower surfaces of the vegetation. Clogging the leaf stomata decreases the transpiration rate of carbon assimilation, reduces photosynthesis, and results in stunted growth.

So, it is suspected that the boiler ash and dolomitic lime added to the peat swamp water as treatments to raise the pH of the peat swamp water caused the death of the mersawa seedlings for two reasons, namely that the treatments blocked and even damaged the stomata and because the pH of the peat swamp water became high, causing physical damage, necrosis and chlorosis of the leaves, and tissue death through dust accumulation and alkali toxicity.

3.2. Height Increase of Mersawa Seedlings

Based on the variance analysis (tests of between-subjects effects), the inundation height factor significantly affected the height of mersawa seedlings. In contrast, the water composition factor and its interaction with inundation height did not have a considerable effect. **Table 2** shows the inundation height factor's p-value (sig.) (0.000 < 0.01), while the significance value of the water composition factor (0.12) and its interaction with inundation height (0.36) is greater than 0.05, so it is considered not to have a natural effect on the height of mersawa seedlings.

Table 2. Tests of between-subjects effects for the increase of the mersawa seedling height

Dependent variable: Seedling height increase				
Source	**Sum of squares**	**Df**	**Mean square**	**Sig.**
Inundation height	360.55	2	180.27	0.00
Water composition	50.08	2	25.04	0.12
Inundation height × water composition	51.36	4	12.84	0.36
Error	1,487.39	126	11.80	
Total	1,949.40	134		

Furthermore, to determine the treatment of inundation height, which had a significant effect, a further test was carried out using the Least Significant Difference (LSD) test, with the results shown in **Table 3**.

Table 3. LSD test results of the height increase of mersawa seedlings

Inundation height	**Height increase (cm)**	**Mark**
- Between the tip of the polybag and the apex of the seedling stem	10.94	a
- Inundation is as high as the polybag	8.87	b
- Without inundation	6.94	c
LSD 0.05 = 1.42		

Based on **Table 3**, the seedlings that were given inundation between the tip of the polybag and the apex of the seedling stem had a height increase that was significantly different from the height of seedlings that were given inundation up to the tip of the polybag, and the seedlings without inundation. The finding indicated that the higher inundation, the faster the vertical growth of mersawa seedlings. This also showed that the seedlings of mersawa are more suitable to be planted in inundated locations as high as between the tip of the polybag and the apex of the seedling rather than in muddy or dry areas. The new information will enrich information about the suitable areas for mersawa seedling plantations. For the mersawa trees, Bayu et al. (2021) stated that the mersawa tree (*Anisoptera marginata*) is a forest tree that can grow in the lowlands and drylands. Meanwhile, according to Harlinda et al. (2016), mersawa tree species are among the species that can grow in peat swamps, but the height of the inundation is not known with certainty. The results of the present study indicated that mersawa seedlings could tolerate the inundation of peat swamp water up to the apices of the seedling stems without water treatments for four months during the research.

In terms of the higher inundation (inundation at the middle of the tip of the polybag and the apex of the seedling), there is a sharp increase in seedling height. This conforms to the opinion of Achmad and Bakri (2022), who stated that the growth of the Kalimantan swamp jelutung (*Dyera polyphylla*) experienced a significant increase in height when the inundation height was increased. This may be due to the plant's reaction to inundation, where the plant wanted to leave the inundation quickly. This is analogous to when there are other plants around a plant. The competing plant will activate its sensors and try to accelerate its height growth to win the light competition (Sasidharan et al. 2011). In the case of a sharp increase in seedling height with increasing inundation height, Voesenek and Bailey-Serres (2015) stated that total submersion causes losses as it cuts off the plant's access to the aerial environment and seriously impairs photosynthesis. As with waterlogging, strategies to overcome submergence are geared towards improving aeration. The plan to avoid inundation is for shoot growth to escape the inundation so that there is contact with the atmosphere again (Sasidharan et al. 2013; Van Veen et al. 2013). An energy-consuming escape strategy in deep flooding is unfavorable because plant growth will not result in emergence. In this case, restricted growth is an alternative strategy that conserves reserves for post-flood growth re-establishment (Sasidharan et al. 2013; Van Veen et al. 2013). So, the acceleration of height increases for the seedlings inundated between the tip of polybags and the apices of the seedlings is presumed that the seedlings tried to escape the inundation. Still, the seedlings are inundated until the shoots of seedlings experience difficulties escaping the inundation for two reasons: the seedlings conserve their energy for growth after inundation, and almost all physiological organs do not function properly. Furthermore, Kozlowski (1997) stated that soil inundation stimulates multiple physiological dysfunctions in plants. Photosynthesis and carbohydrate transport are inhabited, and absorption of macronutrients is decreased because of root mortality, mycorrhizae loss, and root metabolism suppression. In addition, many potentially toxic compounds accumulated in inundated soils, such as sulfides, CO_2, soluble Fe, and Mn.

4. Conclusions

The interaction between the inundation height and the water composition had a survival percentage of 100%. The inundation height factor has a very significant effect on the height increase of mersawa seedlings. The higher the inundation, the faster the height of the seedling increases. The treatment of the inundation height at the middle of the tips of polybags and the apices of the seedling stems led to the highest height increase (10,94 cm), while the lowest one was the seedlings that were not given inundation with a height increase of 6.94 cm for four months. Accelerating the height of mersawa seedlings at a nursery can be done with an inundation system with and without treatment to increase the pH of peat swamp water. The seedlings inundated up to the apex of the seedling without peat swamp treatment are all alive, while with water treatment, the seedlings experienced the death of 84%. The death of mersawa seedlings inundated with peat swamp water mixed with dolomite lime or boiler ash as high as the seedling apex needs further studies. The sharp height increase of mersawa seedlings at the middle of the tip of the polybag and the apex of the seedling should also be studied further.

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