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by Triyono Sudarmadji

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Biochar Application on Spodosols Soils Promotes Higher Plant Growth and Survival Rate

Syahrinudin^{1,*} Triyono Sudarmadji¹ Nurman Krisdianto¹ Ibrahim¹ Wahjuni Hartati¹

¹Laboratory for Silviculture Sciences, Forestry Faculty of Mulawarman University, Samarinda, Indonesia

*Corresponding author. Email: syahri@ymail.com

ABSTRACT

Interests in biochar applications for improving soil properties and fertility are increasing worldwide, and numerous production techniques, raw materials, and application options are now available. This research aimed to investigate the effects of biochar application on growth rate (height, stem diameter, leaf number, and survival) performance of *Anthocephalus cadamba* seedling planted on degraded Spodosols on bioassay trial in the nursery. Bioassay trial was carried out in Forestry Faculty of Mulawarman University, Samarinda, Indonesia. It followed Completely Randomized Design (CRD) applying six levels of treatments, i.e., 0, 2, 5, 10, 25, and 100%v of biochar, and three replications. The 100%v biochar treatment was aimed at investigating the potential of applying biochar for primary media in raising seedlings in the nursery as the replacement of the conventional media. Of those six levels of treatments, the 10%v biochar treatment gave the best height growth at $p = 0.05$, and 25%v showed the best stem diameter growth but not statistically significant. Even though it was not statistically significant, low-level biochar application (up to 5%v) on spodosols soils improved plant survival. Based on the results of this preliminary on the effect of biochar application on plant growth and survival on spodosols soils, it is concluded that: (1) the application of biochar on such soils might be promising and (2) the development of biochar as main media for raising seedling in nursery might also be beneficial.

Keywords: Biochar, Spodosols, Growth rate, Plantation media, *Anthocephalus cadamba*

1. INTRODUCTION

The applications' long-term multi-benefits drive the tremendous worldwide increase of interest in biochar application in the last few decades. Regardless the debate on the magnitude, uncertainties and residence time effects, biochar application promotes the improvement of water and nutrient retention [1,2,3,4]; soil microbial biomass, activities and structures [5,6]; fertilizer and nutrient use efficiency [7,8]; soil physical properties [9,10]; immobilization of toxic substances in soils [11,12]; plant growth and productivity [13,14,15,16,17]; plant drought and salinity resistance [18,19,20,21,22]; plant toxicity resistance [11,12,23,24]; plant disease resistance [25,26]; nitrous oxide and methane emission reduction [27,28,29]; and soil carbon pool [30,31,32].

At the COP21 meeting in Paris, 103 countries have set mitigation, and adaptation targets in agriculture and other land uses, including forests and degraded land [33], leading to the '4 per 1000 Initiative'. This

initiative sets an annual global increase of SOC stock at the rate of 0.4% of global anthropogenic emission in all land uses to mitigate the buildup of atmospheric CO₂.

The role of land carbon management needs to be reexamined. Namely, soil organic carbon (SOC) sequestration, afforestation, and reforestation, including tree planting through agroforestry, are the only land-based harmful emissions (i.e., removing CO₂ from the atmosphere) that are readily available at low cost [34]. Soils also carry a significant potential for carbon sequestration, primarily through restoration measures on degraded soils [35]. About 90% of the total technical mitigation potential in agriculture (excluding bioenergy and improved energy use) is based on SOC sequestration options [36,37].

Carbon sequestrations in agricultural soils are essential for atmospheric carbon dioxide mitigation and soil fertility enhancement [4,32]. However, traditional soil organic carbon (SOC) enrichment practices involving incorporation of biomass residues and green

manures not only result in rapid mineralization and release of CO₂ to the atmosphere [38,39,40,41] but also subject to the enhancement of methane and nitrous oxide emission [42] contributing to higher global warming potential. In contrast to traditional organic materials, biochar is a highly carbonized material produced by pyrolysis that consists of many aromatic compounds resistant to biological degradation [43]. It may stay in soils for hundreds to thousands of years [44,45]. Therefore, biochar application is a promising alternative to sequester more C in soils than traditional practices and is rated as the best geo-engineering option for carbon sequestration [46]. Large-scale biochar applications will increase the soil carbon pool contributing to climate change mitigation [47].

Over several decades, studies have demonstrated that improved land use and management can help to sequester organic C in soil and reduce greenhouse gas (GHG) emissions [34,48,49]. This opportunity was the motivation behind the "4 per 1000" initiative, launched at the COP21 meeting in Paris, aiming to increase global soil organic C stocks by four parts per 1000 (or 0.4%) per year as compensation for global GHG emissions from anthropogenic sources. At a world land area of 149 million km², an estimated SOC on average would come to 161 tonnes per hectare or an average sequestration rate to offset emissions at 0.6 tonnes of C per hectare per year. SOC sequestration rates across the world may come to an annual rate of 0.2 to 0.5 tonnes C per hectare [50].

Biochar application to soils leads to dual benefits of long-term carbon sequestration and potentially positive soil amendment [51,52,53]. In particular, the ability of biochar to act as a feasible climate change mitigation technology, implementable at a globally significant scale, is recognized [54], with the potential to sequester the equivalent of up to 12% of anthropogenic greenhouse gas (GHG) emissions [55] in ecologically and economically sustainable systems.

The application of biochar on degraded weathered soils in the tropics would benefit SOC sequestration and crop production. This study was devoted to the evaluation of the possibility of biochar application on Spodosols in East Kalimantan.

2. METHODS

The leaves of *E. pellita* were collected from PT Surya Hutani Jaya, Sebulu, Kutai, East Kalimantan, Indonesia. The sample was prepared to air-dried for 24 h maintaining the integrity of the specifications.

Growth media preparation, including arrangement and tests, was carried out at the Soil Science Laboratory and the Soil and Water Conservation Laboratory, Faculty of Forestry, Mulawarman University, Samarinda. Bioassay test for *Anthocephalus cadamba*

seedlings was carried out at the nursery of the Faculty of Forestry, Mulawarman University.

Spodosols soil used for this research's growth media was collected from nearby degraded Spodosols soil while biochar used was produced based on retort biochar production method [13]. The raw material for the biochar production is derived from adjacent plantation waste of *Vitex pinnata*.

Biochar was ground to powder to pass a 2-mm-sieve before mixing with soils. Biochar application in this research was prepared to comply with the Completely Randomized Design procedure. Six level of biochar application for growth media were arranged, those are: 0%v, 2%v, 5%, 10%v, 25%v and 100%v. Treatment was replicated three times, each consist of 20 seedlings; thus, this research involved 360 seedlings of *Anthocephalus cadamba*. Low-level biochar treatment was established to evaluate biochar treatment's importance in promoting plant growth on degraded Spodosols soils. In contrast, high-level biochar treatment was established to evaluate the possibility of using biochar as major media for plant growth in nurseries.

The effect of biochar treatment on the growth of *Anthocephalus cadamba* seedlings was assessed by incrementing seedlings' height and diameter. The size of seedlings was defined weekly, and the diameter was determined at the end of the research period, three months after replanting. However, the survival of seedlings was also calculated weekly.

Data collected in this research were tested and adjusted to normal distribution before analysis of variance and mean different test with the help of SPSS software.

3. RESULT AND DISCUSSIONS

The importance of biochar on plant survival is mostly driven by plant tolerant on salinity [18, 20,21], resistant on diseases [26,25], drought-resistant [18,19,56,57] and heavy metals and toxic elements resistance [11,12,23,23]. The survival of *Anthocephalus cadamba* seedlings was calculated as the ratio of the number of life seedlings to the number of those at the start of the study. Table 1 shows the survival of seedlings at the end of the study.

Table 1. Survival of seedlings at the end of the study

Treatment	Biochar (%v)	Survival (%)
A0	0,00	96,67
A1	2,00	98,33
A2	5,00	98,33
A3	10,00	93,33
A4	25,00	93,33
A5	100,00	91,67

At the full range of biochar application levels, ranging from 0% to 100%, there is no significant effect of biochar application on the survival rate of seedlings studied. Nevertheless, applying low-level biochar promoted higher survival of seedlings than control, 0% biochar application, but not high-level biochar. However, all treatments gave a high survival rate, more than 90%, including 100% biochar treatment. Biochar application on growth media in the nursery also showed high survival for Dipterocarps seedling [13,58]. This demonstrated that biochar's use as the primary media for raising seedlings in the nursery is of interest.

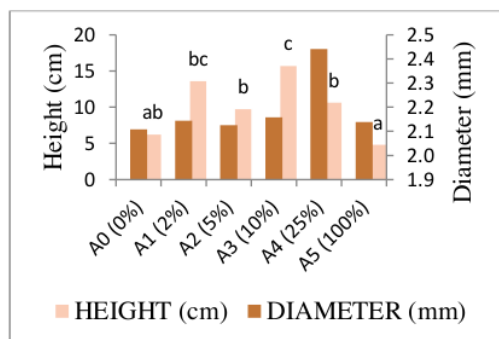


Figure 1 Diameter and height of seedlings at the end of the study

The average plant height increased in line with the plant's age till the end of the observation period (3 months after replanting). The difference in the size of plants among biochar application levels also increased with age. At the end of the observation period, three months after replanting, excluding the height of seedlings planted at growth media of 100% biochar treatment, the average height of plants in all media receiving biochar treatment was higher than that without biochar (Figure 1), application of 10%v biochar gave highest seedlings height, $p < 0.01$. Biochar modifies the environmental conditions of the growing media through the improvement of aeration, water availability [59][60][61], soil reactions, microorganism activity in the soil, and availability of plant nutrients [62][63] to facilitate the optimal utilization of the resources of plant roots environment which in turn will increase plant growth. However, at higher biochar application (25%v

and 100%v), the height growth rate of *Anthocephalus cadamba* seedlings decreased, which may attribute to the nutrient immobilization by microorganism consuming volatile matter in biochar [64,65].

The diameter growth rate of *A. cadamba* seedlings showed a similar manner to that of height growth rate, but less pronounce and higher preference to the biochar application level. At the end of the observation period, three months after replanting, the average diameter of plants in all media receiving biochar treatment was higher than that without biochar (Figure 1). The application of 25%v biochar gave the most increased seedlings diameter but not statistically different. The growth rate of seedling diameter showed a positive response to a wide range of biochar application levels. Even though the diameter growth rate response of *A. cadamba* seedlings to the application of 100% biochar treatment was less pronounced, the growth rate was still higher than that of control. Here again, using biochar for significant plant growth in media in raising seedlings in the nursery is promising.

4. CONCLUSIONS

Application of biochar on such degraded, strongly weathered soils might benefit long-term carbon sequestration and soil amendment. Juveniles gave a positive response to a wide range of biochar applications in such soils. This suggests that biochar development as the primary media for raising seedlings in the nursery might also be beneficial.

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