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Cocoa Pod Husk Biochar Reduce Watering Frequency and Increase Cocoa Seedlings Growth

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Abstract*— *Biochar amount applied in the growing soil medium may decrease water use of cocoa seedling during dry season and hence may increase water use efficiency, thus a polybag experiment was carried out in the Glasshouse Agricultural Faculty, Halu Oleo University, Kendari, Southeast Sulawesi Indonesia in 2016to evaluate the effect of cocoa pod husk (CPH) biochar and watering frequencies on growth of cocoa seedlings.The experiment was arranged in a randomized block design with seven cacao pod husk (CPH) biochar levels (without CPH biochar, 3 g CPH biochar kg^{-1} soil, 6 g CPH biochar kg^{-1} soil, 9 g CPH biochar kg^{-1} soil, 12 g CPH biochar kg^{-1} soil, 15 g CPH biochar kg^{-1} soil dan 18 g CPH biochar kg^{-1} soil) and three watering frequencies (every two days, every four days and every six days) in three replications. Results showed that CPH biochar and watering frequency significantly influenced soil moisture. The rate of CPH biochar amendment determined watering frequency and cocoa seedling growth rate. CPH biochar improved cocoa seedling growth and reduced watering frequency. Cocoa seedlings treated with 9 g CPH biochar kg^{-1} soil and 60 g CPH biochar kg^{-1} soil with every six days of WF increased WUE by 208.8% and 262.22%, respectively, compared to no biochar application.

***Keywords*— biochar, cacao, growth, rate, soil, water.**

I. INTRODUCTION

Increasing cocoa production and improving quality of cocoa seedling is a major target to meet the domestic and export demand since Southeast Sulawesi as a national area center of cocoa development in Indonesia. Cocoa (*Theobroma cacao* L) seedlings require a significant amount of nutrient and water for their proper growth and development. It has been reported that water being essential in growth and development of plants, a specific amount of water is needed for optimum growth and very large amount of water required to sustain seedlings growth is obtained primarily from the soil. [1] regular watering for tree nurseries is necessary to produce good quality seedlings at economic rate.

The amount of water in the soil varies widely over time and almost never is ideal for maximum absorption by roots. Usually there is too much or too little water in the soil, and mostly the latter. The major sources of water for seedlings in the nursery phase are irrigation water. However, a portion of this water is lost by surface run off and some evaporates before it can percolate into the soil. The amount that is lost by evaporation varies with atmospheric conditions and with soil texture, color, and porosity [2]. The big challenges for obtaining high quality of seedling in the nursery growing period during dry season with the current trend of changed weather are limited water resources, therefore, seedling frequently exposed to drought conditions.

Drought is one of the main limiting factors affecting seedling growth in Indonesia. Drought decreases soil moisture content by evaporation and limits water availability to seedling root systems [3]. Seedlings close their stomata during drought and photosynthesis is stopped, resulting in seedling mortality due to“carbon starvation” [4]. This conditions has in a long way discouraged the farmer leading to fall in the level of production of high quality of seedling to be transplated in the field. The possible approach to addressing those constraints to obtain the high quality of seedlings is the application of biochar and regulating water applied. Biochar amendment may be a viable means of mitigating current water shortages on drought-prone soils and future water shortages accompanying climate change [5].

Biochar has been proposed as a beneficial amendment concerning various agricultural and environmental aspects such as increasing soil fertility, retaining water in the soil and enhancing plant growth [6]. Most biochars made from plant materials have a high porosity and surface area [7] and thus a large capacity to hold water at field capacity [8]. Biochar application improves nutrient availability and water holding capacity for supporting plant growth [9,10]. Biochar from cocoa pod husk influenced soil temperature, soil moisture and seedling growth [11]. Research reports have been shown that biochar addition significantly increased the available water contents of the soils by both increasing the amount of water held at field capacity, allowing plants to draw the soil to a lower water content before wilting and increase produktivity in drought-prone regions or reduce the frequency of irrigation [5]. This indicates that biochar applied into the growing soil medium may decrease water irrigation for cocoa seedlings during dry season and may, therefore, increase water use efficiency. Thus, CPH biochar has the potential to be used as a material for improving growth and water use efficiency of cocoa seedlings. It would therefore be important to also study growth of cocoa seedling under different rate of biochar and watering frequencies. The aim of the current study was to investigate the effects of CPH biochar and watering frequencies on growth and water use efficiency of cocoa seedlings.

II. MATERIAL AND METHODS

A polybag experiment was conducted in the Glasshouse of Agricultural Faculty, Halu Oleo University, Kendari, Southeast Sulawesi Indonesia, 2016. The experiment was arranged in a randomized block design with seven levels of cacao pod husk (CPH) biochar (i.e. without CPH biochar, 3 g CPH biochar kg^{-1} soil, 6 g CPH biochar kg^{-1} soil, 9 g CPH biochar kg^{-1} soil, 12 g CPH biochar kg^{-1} soil, 15 g CPH biochar kg^{-1} soil dan 18 g CPH biochar kg^{-1} soil) and three levels of watering frequencies (i.e. every two days (V0), every four days (V1) and every six days (V2)) in three replications. The mean daily temperatures in the glasshouse varied from 22°C to 30°C, and the relative humidity ranged from 68% to 88%.

Biochar was produced from cocoa pod husk (CPH) by using a drum kiln, in which carbonization was done within 4-6 h [12]. The hot biochar produced after pyrolysis was quenched with distilled water, collected, air-dried, crushed and sieved through a 2 mm sieve before being used. The soil for trial was collected from the sandy loam (76% sand, 21% silt and 11% clay) of the experimental farm of Agricultural Faculty, Halu Oleo University.

Cacao seedlings were raised on germination media for 14 days and each seedling was then transplanted into a polybag (25 cm X 30 cm size) seedling madia which have been filled with 5 kg dry soilmixed witha treatment-based rate of biochar from cacao podhusks (0.5 mm particle size) at a planting space 20 cmx 20 cm [11]. The amount of water applied was 200 ml per plant for the three months under glasshouse conditions with a frequency depending on the given treatment. Seedling growth and soil moisture were monitored for three consecutive months. The data collected include: seedling height, number of leaves, leaf area, root dry weight,shoot dry weight and water use efficiency. The soil moisture was monitored with asoil moisture meter (model: PMS-714), while soil temperature with soil thermometer at the depth of 12 cm below the surface every two days at 17.00 pm (before being irrigated). Seedling height, number of leaves and leaf area were measured 90 days after planting. Thereafter, seedlings were removed from the nursery and sent to the laboratory, in order to obtain their dry weight of root and shoot. Dry weight was obtained after drying the material at 85 °C for 48 hours. The WUEwas determined by using the formula: WUE= shoot dry weight (g)/total water use (L) [13]. Data were analyzed by using anova followed by Duncan's multiple test at an error rate of 5% ($P <0.05$).

III. RESULTS AND DISCUSSIONS

As shown in Figure 1, biochar from cocoa pod husk (CPH) and watering frequencies (WF) significantly influenced soil moisture. Soil moisture increased with an increase in CPH biochar rate at different WF. The rate of CPH biochar application determined soil moisture at all WF treatments. Our results showed that CPH biochar maintained soil moisture even at every six days of WF. This indicates that CPH biochar could retain moisture and minimize WF, therefore, less water was required for cacao seedling growth. The application of biochar improves soil structure [8] and improves the soil's ability to retain moisture [14,15]. Further, CPH biochar increases pore aeration and water availability [10]. The significant increase in soil moisture under treatment of CPH biochar was in conformity with the findings that biochar amendment in soils increased the plant available water content [16,17].

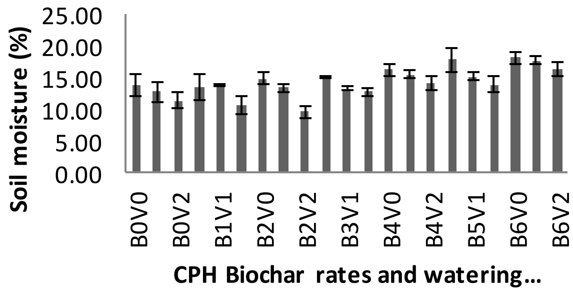

Fig.1: Effects of cocoa pod husk (CPH) biochar rates and watering frequencies on soil moisture. Error bars indicate standard deviations.

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Cocoa seedlings grown on soils treated with 6 g CPH biochar kg^{-1} soil with every four days of watering frequency were higher in dry root weight but insignificantly different from those treated with 3 g CPH biochar kg^{-1} soil with every four and six days of WF and other rates of CPH biochar at different WF (Figure 3a). This indicates that small amount of CPH biochar improved root growth due to the capacity of CPH biochar in increasing water holding capacity. Dose of CPH biochar exceeding 6 g CPH biochar kg^{-1} soil significantly decreased root dry weight due to high soil moisture (Figure 1). This means that CPH biochar greatly influences root growth and root growth may be determined by soil water conditions. Root development is largely influenced by the soil moisture. This strengthens the previous findings that soil water content was a crucial component that influenced root growth [18], with possible affects on leaf growth and cocoa seedling growth as a whole. A positive influence on plant growth and development due to the plant available water content is increased [19].

As shown in Figure 2 and 3, CPH biochar and WF significantly affected seedling height, number of leaves, leaf area, root dry weight and shoot dry weight of cocoa seedling. Cocoa seedlings grown on soils treated with 9 g CPH biochar kg^{-1} soil with every four days of WF were higher in plant height, number of leaves, leaf area and dry shoot weight of cocoa seedling, but insignificantly different from cocoa seedlings grown on soils without CPH biochar with every two days of WF and 9 g CPH biochar kg^{-1} soil with every six days of WF. This clearly indicates that adding CPH biochar can significantly affect cacao seedling growth and reduce WF. It means that CPH biochar increased both cocoa seedlings biomass and water use efficiency (Figure 3 and 4). The application of 9 g CPH biochar kg^{-1} soil increased seedling height, number of leaves, leaf area, and shoot dry weight of cocoa seedling. Similar results were reported by a number of researchers [20,21,22,23] that biochar significantly increased plant growth and biomass. Our results also followed similar trends established in different studies involving application of biochar in increasing WUE. The greatest WUE (1.63 g L^{-1}) was found in the soils treated with 12 g CPH biochar kg^{-1} soil with every six days of WF and the lowest was found in the soils without CPH biochar (0.45 L^{-1}) application. Such a greatest WUE found in the former treatment was, however, not significantly different from cocoa seedlings treated with 9 g CPH biochar kg^{-1} soil with every six days of WF. Cocoa seedlings treated with 9 g CPH biochar kg^{-1} soil and 12 g CPH biochar kg^{-1} soil with every six days of WF increased WUE by 208.8% and 262.22%, respectively, compared to no biochar application. On the other hand, as CPH biochar rates exceeded 12 g, the WUE tended to decrease at different WF. Our study showed that biochar was effective in increasing the WUE of cacao seedlings, however, the rates of biochar application should be considered.

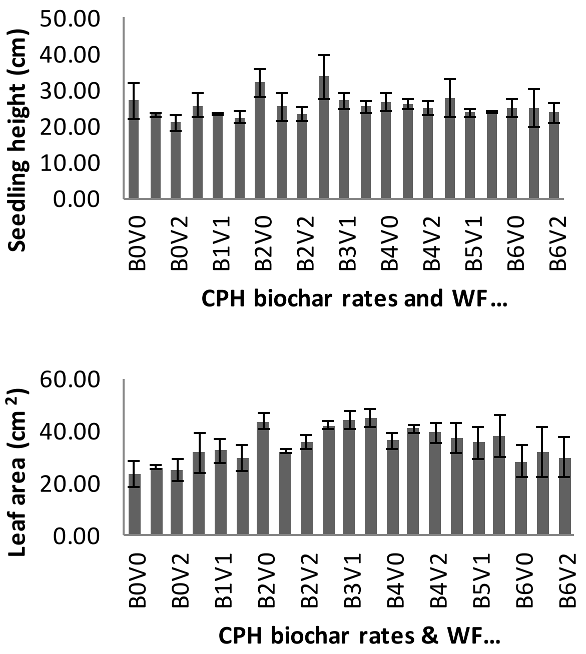

Fig.2: Effects of CPH biochar rates and watering frequencies on seedling height (a) and leaf area (b). Error bars indicate standard deviations.

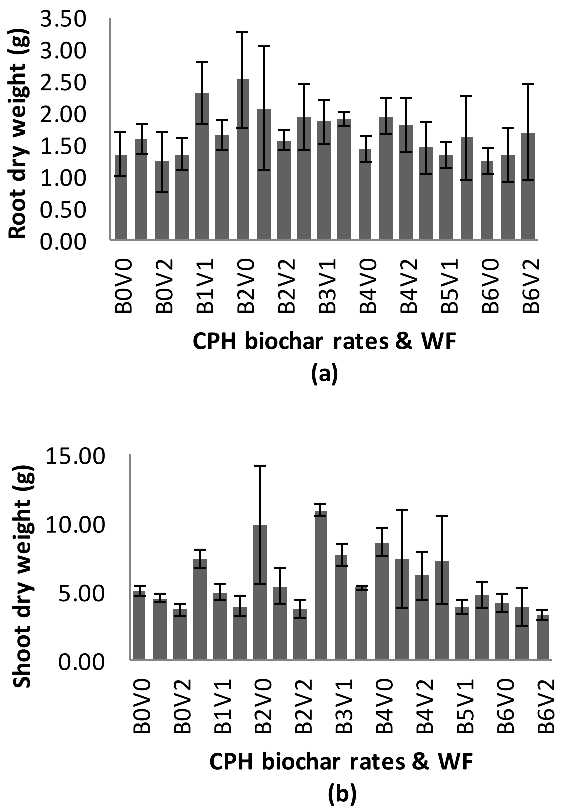

Fig.3: Effects of CPH biochar rates and watering frequencies on root dry weight (a) and shoot dry weight (b). Error bars indicate standard deviations.

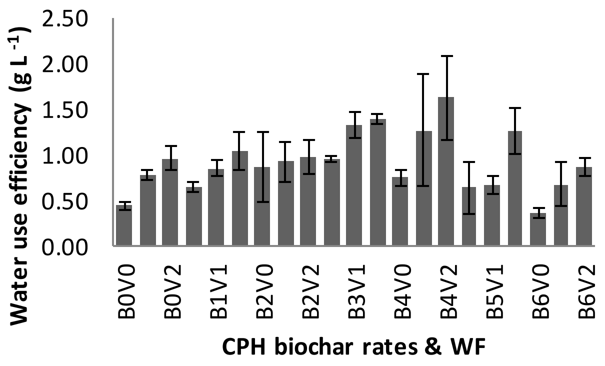

Fig.4: Effects of CPH biochar rates and watering frequencies on water use efficiency. Error bars indicate standard deviations.

In general, the results also showed that the biochar treatment exceeding 9 g CPH biochar kg^{-1} soil significantly decreased seedling growth. The above result has been reported by [11]. However, such a decrease in cocoa seedling growth rate also depended on WF. Interestingly, mean of cocoa seedling growth at a rate of 15 g CPH biochar kg^{-1} soil and 18 g CPH biochar kg^{-1} soil with every six days of WF was higher than those grown on soils treated with CPH biochar and every two days of WF. This is presumably a consequence of the big changes in soil moisture (Figure 1). The decrease in seedling growth may be due to great changes in soil bulk density, restricted aeration or higher soil moisture at a rate of 18 g CPH biochar kg^{-1} soil compared to without biochar and the other treatments (Figure 1). This indicates that roots were exposed to limited oxygen and high water content conditions [11]. Lack of oxygen content in the soils may be damaged of root development[24]. This is similar to findings by [25] who found reduced permeability to water due to poor aeration may cause decreased tree growth.

IV. CONCLUSION

Results showed that CPH biochar and watering frequency significantly influenced soil moisture. The rate of CPH biochar amendment determined watering frequency and cacao seedling growth rate. CPH biochar improved cacao seedling growth and reduced watering frequency. Cacao seedlings treated with 9 g CPH biochar kg^{-1} soil and 12 g CPH biochar kg^{-1} soil with every six days of WF increased WUE by 208.8% and 262.22%, respectively, compared to no biochar application. Application of 9 g CPH biochar kg^{-1} soil and 12 g CPH biochar kg^{-1} soil are recommended for increasing growth and water use efficiency of cocoa seedling.

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