The response of growth rate in different husk biochar application of *Allium cepa* in sandy soil

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Abstract. Shallot (*Allium cepa*) is typically cultivated in Coastal area of Yogyakarta with high input of water and organic fertilizer. This area has sandy soil type with low water holding capacity and low soil fertility. Husk biochar is a potential alternative soil amendment to improve soil quality and may increase crop productivity. The objective of this study is to characterize growth rate of *Allium cepa* under different husk biochar application in sandy soil. Experiment was carried out in growth chamber with four different treatments. The treatments were (1) control; (2) Husk Biochar; (3) Husk biochar and compost (0.5:0.5); and (4) Husk biochar and compost (0.65:0.35). Plant growth and irrigation were monitored every day for 30 days experiment. Daily temperature, relative humidity inside and solar radiation growth chamber were around 30 – 34.5°C, 46.7 – 66.7% and 5.3 – 20.7 W/m² respectively. The results showed that soil amendments treatment in various comparisons affected the growth of shallots (*Allium cepa*). Husk biochar and compost treatment (0.5:0.5) significantly increased plant growth. Moreover, husk biochar treatment has better water use efficiency (WUE) than other treatment (0.09 g/mm).

1. Introduction

Sandy soil on the southern coast area in Yogyakarta, Indonesia has great potential to be developed into agricultural land. This area has some advantages, i.e. wide area, flat, huge amount of sunlight, shallow ground water, and neutral soil pH. However, in utilization as agriculture, coastal sand land has limiting factors related to the physical, chemical and biological properties of soil. These limiting factors include the ability to store low water, high infiltration and evaporation as well as low fertility and organic matter [1]. In addition, on dry land, water stress in plants can occur due to reduced water availability or due to the very high transpiration rate compared to normal conditions [2]. This condition affects the productivity of plants as well as the yields [2, 3]. WUE (water use efficiency) of plants is one of indicator that show comparison between crop productivity and water use by different plants [4].

In addition, some plants species are adaptable to drought stress. Such tolerance in different plants may vary due to different adaptation mechanism [5]. Shallot (*Allium cepa*) is typically cultivated in Coastal area of Yogyakarta. Shallot plants are considered suitable for planting in coastal sand because these plants are very responsive to changes in environmental conditions, especially soil.

There are some soil amendments that will increase plant tolerance to drought as well as WUE. Biochar is an example of amendments that contain about 80% of carbon and has ability to conserve water for plants [2]. Biochar was selected as raw material for soil amendments based on the production of untapped plant residues [6]. Biochar itself is charcoal from agricultural waste such as...
rice husks, corncobs, coconut shells and wood residues. These materials are difficult to decompose which requires incomplete combustion process (pyrolysis) in order to obtain charcoal with activated carbon content to be applied to the soil. Biochar is known as a material that can last long enough in the soil and is relatively resistant to microorganism attack, thus the decomposition process runs slowly [7].

Many studies have investigated the addition of soil amendments on the sandy soil. According to [8], farmer in coastal area Yogyakarta applied clay (0.75 – 1 m³ per 100 m²) and organic fertilizer (20 t/ha) for shallot cultivation. However, there was lack information about biochar application and its impact on plant productivity as well as water use efficiency in sandy soil. This study aims to determine the effect of the addition of husk biochar in sandy soil with a certain ratio to the plant growth rate and water use efficiency (WUE).

2. Materials and Methods
2.1. Site and experiment description
The experiment was conducted in growth chamber Laboratory of Farm Structure Environment Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada. Microclimatic conditions in the growth chamber during the study included temperatures between 30.1-34.5°C, air humidity of 47.67-66.67% and solar radiation 5.3-20.7 W/m².

The experiment was carried out for 30 days from July to August 2019. The plant was shallots (Allium cepa L) and planted in polybags with a 10 cm diameter and 13 cm height. The planting media was sandy soil from Bantul coastal area, D.I. Yogyakarta Province, Indonesia. Each planting media has different treatment, by using different comparison of sand, biochar, and compost as mention in Table 1. All treatment followed complete randomized design with four replications. Shallot was planted by using tubers sliced at the ends to accelerate bud growth. All treatment was irrigated manually by adding water in accordance with shallot water requirement, about 123 mm/day.

Table 1. Comparison of Treatment and Dosage

| No. | Code | Treatment            | Dosage   |
|-----|------|----------------------|----------|
| 1   | P    | Sand (control)       | 1        |
| 2   | PB   | Sand and biochar     | 1 : 1    |
| 3   | PBK1 | Sand, biochar and compost | 1 : 0.5 : 0.5 |
| 4   | PBK2 | Sand, biochar and compost | 1 : 0.35 : 0.65 |

2.2. Measurement and Analysis Data
2.2.1. Soil condition. Disturbed soil samples were collected and mixed with soil amendments as mention in table 1. Soil chemical basic parameters (pH, C-organic, N-total, available K, and P₂O₅) were measured at the beginning of experiment for each treatment. This analysis was conducted in Laboratory of Soil, Institute of Agricultural Technology Yogyakarta. C-organic measurement was conducted by Walky & Black method; N-total by Kjeldahl method; available K by Morgan-Wolf method; and P₂O₅ by Olsen method.

2.2.2. Plant height. The growth of shallot was measured every three days, started from 0 day during vegetative phase. Height was measured from the surface of growing media to the leaf using a ruler. On the 18 days after planting, the plants were collected in order to determine of fresh and dry mass. Dry mass was obtained after dying in an oven (65 °C) for 24 hours.

Data in the form of plant height during the vegetative phase were analyzed to obtain plant growth rate by using monomolecular equation. The monomolecular function explains the progress of a simple first-order irreversible reaction. Assuming a constant and independent growth rate of plant height, the equation is obtained [9]:

\[ \frac{dt}{dt} = -kS \]  \hspace{1cm} (1)
that $k$ is a constant and $S$ is a substrate. If the final substrate condition $S_t = 0$ and substrate changes during growth $S = H_{f} - H$, then it can be substituted into equation (1), resulting in equation (2)

$$\frac{dH}{dt} = k(H_{f} - H)$$

(2)

The integral form of equation (2) is equation (3):

$$\int_{H_{0}}^{H} \frac{dH}{H_{f} - H} = \int_{0}^{t} k dt$$

(3)

The integral form of equation (3) solved into equations (4):

$$\ln\left(\frac{H_{f} - H_{0}}{H_{f} - H}\right) = kt$$

(4)

$H_{0}$ : initial plant height at planting
$H_{f}$ : plant height at harvest
$H$ : plant height at observation day

2.2.3. Water Use Efficiency (WUE). Evapotranspiration in this experiment was measured based on evaporation and transpiration that occur every day by looking at changes in the weight of a polybag (changes in moisture content). To do an analysis of Water Use Efficiency (WUE), the evapotranspiration calculation is done first by using the following equation [10]:

$$ET_{(o)i} = \frac{W_{i} - W_{i-1}}{\rho_{w}A}$$

(5)

$ET_{(o)i}$ : day evapotranspiration (mm)
$W_{i-1}$ and $W_{i}$ : weights (kg) of the polybag at day i-1 and i
$\rho_{w}$ : water density (g cm$^{-3}$)
$A$ : surface area (m$^2$)

Water Use Efficiency (WUE) analysis for each treatment using the equation:

$$WUE = \frac{Y}{ET}$$

(6)

$Y$ : shallot bulb yield (g polybag$^{-1}$)
$ET$ : seasonal evapotranspiration (mm)

3. Result and Discussion

3.1. Soil condition

Soil samples were mixed with different treatment and resulted different soil chemical properties (table 2). PBK2 treatment (biochar sand and compost) with a ratio of 1: 0.35: 0.65 resulted the highest pH value i.e. 7.07 of the four treatments, while PBK1 (sand, biochar and compost) 1: 0.5: 0.5 was 7.03. This result show that the provision of organic material (compost) and soil amendments (biochar / husk charcoal) significantly improved soil pH.

C-organic in the four treatments also has different result, where PBK1 treatment has the highest C-Organic content (5.30 %) compared to other treatments. C-organic in planting media plays an important role in improving soil properties both physically, chemically and biologically. Moreover, total nitrogen of PBK1 also showed highest N-total (0.18%), followed by PBK2 (0.16%). Another parameter is the potassium content in the four treatments obtained the highest K value for the control treatment (sand) while the lowest value in the PBK1 treatment. In the PBK1 treatment the potassium value is quite low because the potassium levels are absorbed by the plants. Potassium nutrients play a role in vegetative growth to strengthen stem stands and increase carbohydrate levels [11]. Furthermore, Phosphorus availability also increase with addition of biochar.
Table 2. Test results of soil chemical properties in various treatments

| No | Test Parameter      | P     | PB    | PBK1  | PBK2  |
|----|---------------------|-------|-------|-------|-------|
| 1  | pH (H₂O)            | 6.52  | 6.94  | 7.03  | 7.07  |
| 2  | C-organic (%)       | 0.60  | 4.53  | 5.30  | 4.06  |
| 3  | N-total (%)         | 0.01  | 0.17  | 0.18  | 0.16  |
| 4  | K available (ppm)   | 95    | 69    | 41    | 64    |
| 5  | P₂O₅ (ppm)          | 70    | 186   | 507   | 791   |

Source: Results of planting media analysis on research in Laboratory of the Soil, Plant, Fertilizer, Water

Soil used in this experiment was sandy soil from tropical condition with neutral pH, low organic carbon, and low total nitrogen availability. Addition of soil amendments (husk biochar and compost) have positive response to soil parameters (table 2). This results has similar trends in different application of biochar by [2,12].

3.2. Effect of Treatment on Plant Growth Rate

3.2.1. Plant growth. Plant height was measured as one of the plant growth parameters. The height was assessed at 0 days after planting to 18 days after planting and plotted into a graph by following monomolecular function (Fig 1). Plants growth rate was higher in PBK1 treatment (sand, biochar and compost; 1 : 0.5 : 0.5) as compared to other treatments. PB (sand and biochar) treatment was lowest plant growth rate. Moreover, control (sand) treatment in this study was resulted higher growth rate than PB and PBK 2. Therefore, addition of husk biochar and compost was found to be more effective than other treatment to increase plant growth rate of shallot.

![Figure 1. Relationship between age to plant height](image)

Addition of husk biochar and compost in sandy soil was positively affected plant growth. Composition of a balanced planting media can support a good aeration process, so that the roots can grow well and optimally absorb nutrients so the plants grow well [13]. Growing media is one of important factor that must be considered in conducting cultivation for plant growth and development. Provision of soil amendments, such as biochar and compost can improve the physical and chemical properties of the soil by improving the structure, texture, water retention ability, aeration and soil nutrient content [14].
3.3. Effect of Treatment on Water Use Efficiency (WUE)
Efficient use of water is the ratio between plant dry weights and water requirements [15] and shows the ability of plants to convert available water into dry matter [16]. Comparison of WUE of control (sand) and other treatment is presented in table 3. Addition of husk biochar in sandy soil significantly increase WUE. Biochar treatment (PB) was resulted highest WUE (0.09 g/mm). Husk biochar together with compost (PBK2 and PBK1) has also improved the WUE (0.04 and 0.05 g/mm respectively). Therefore, husk biochar in sandy soil was proved to be more effective to increase WUE of shallot. Other studies related to the value of WUE in onion plants (Allium cepa L) at harvest time were 0.1169-0.289 g/mm [10]. One significant increase in the value of WUE is influenced by the addition of biochar and organic fertilizer [17].

In the other hand, dry weight of shallot was different result, where control treatment resulted higher dry weight than other treatment. It may be caused by data measurement. In this study, plant growth and dry weight of shallot were measured at the beginning of vegetative phase that would be have impact on the result.

| Treatment | Dry Weight (g) | ET (mm) | WUE (g/mm) |
|-----------|--------------|--------|-----------|
| P         | 0.65         | 30.87  | 0.02      |
| PB        | 0.55         | 6.38   | 0.09      |
| PBK1      | 0.48         | 9.45   | 0.05      |
| PBK2      | 0.43         | 10.95  | 0.04      |

Moreover, evapotranspiration (ET) of shallot was also different between treatment. Control treatment (P) was significantly has highest ET (30.87 mm) with lowest WUE (0.02 g/mm). Husk biochar as well as husk biochar and compost were decreased ET. Previous study by [18] resulted that biochar added to sandy loam increases water-holding capacity and might increase water available for crop use. increasing of water holding capacity of sandy soil will improve water use efficiency of crop in agricultural system.

4. Conclusion
Based on the results of the study showed that the treatment of different growing media in various comparisons affected the growth of shallots (Allium cepa L). In PBK1 treatment, the ratio between sand, biochar (husk biochar) and compost (1:0.5:0.5) positively affected plant growth of shallot. As for the efficient use of water, PB treatment(sandy soil and husk biochar) with a ratio (1:1) was higher than other treatments (0.09 g/mm) as well as lowest value of evapotranspiration (6.38 mm). Therefore, addition of biochar (husk biochar) and compost fertilizer improved plant growth and increased Water Use Efficiency (WUE).

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