Root morphology of several varieties of sorghum (*Sorghum bicolor* (L.) Moench.) on ultisols treated with cocopeat

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Abstract. This research aimed to determine the root morphology of several sorghum varieties on Ultisol soil-medium treated with cocopeat. The research was carried out at the Greenhouse of the Faculty of Agriculture, Universitas Sumatera Utara, Medan, from April 2019 to January 2020. This research used a randomized block design with two factorials and three replications. Factor I was the planting medium (topsoil, Ultisol, Ultisol + 1 kg of Cocopeat, Ultisol + 2 kg of Cocopeat). Factor II was the Sorghum variety (Pahat, Kawali, Samurai 1, and Samurai 2) treatment. The results indicated that there are several differences in the appearances of sorghum plant varieties on the root morphology (root volume and length) of sorghum on Ultisol soil media treated with cocopeat, and there were interaction effects between sorghum plant varieties and Ultisol soil media treated with cocopeat on the root morphology (root length) of sorghum plants.

1. Introduction

Sorghum has great potential to be developed in Indonesia because it has a large area of adaptation [1]. One of the distinctive characteristics of sorghum is that it is tolerant of drought and inundation [2]. The obstacle faced in cultivating sorghum in Indonesia's dry land is the stress of acid soils, because this type of soil is very vast, reaching 99.5 million hectares, which are spread across Kalimantan, Sumatera and Papua. Soil reacts with acid with the main indicator of soil pH less than 5.0 resulting in high solubility of Aluminum (Al) in the soil hence it becomes toxic to plants [3]. Ultisol is one type of acid soil with a pH of less than 5.5 which is widespread in Indonesia. In Sumatera, ultisol has the most widespread distribution that is 14.695 million hectares. Ultisols are acid mineral soils with agricultural crop development potentials, covering an area of 45.8 million hectares or about 25% of Indonesia total land area [4]. Organic matter application is a solution for critical land improvement [5]. One of the organic matters that can be used is Cocopeat, which is a fine powder from the crushing of coconut coir [6]. The nutrient content in cocopeat needed by plants is macro and micronutrients including potassium, phosphorus, calcium, magnesium and sodium. Hold water content and chemical fertilizers and also neutralize soil acidity is ability Cocopeat [7]. Rhizotron is a soil-filled plant planting container with transparent glass on the sides, allowing it for the analysis of root growth [8]. This research was conducted by observing the morphology of the roots to obtain the variability and heritability values as the references of selection.
2. Materials and Methods
This research was carried out at the Greenhouse of the Faculty of Agriculture, Universitas Sumatera Utara, Medan with an altitude of ± 32 m asl. The research started from April 2019 and finished on January 2020.

The materials used were 4 varieties of Sorghum (Sorghum bicolor (L.) Moench), Cocopeat, Ultisol Soil from Simalingkar B - Medan, and Topsoil as Planting Media. The tool used was the Rhizotron as a sorghum planting container.

Randomized block design with two factorials is the used in this research. Factor I was planting medium (topsoil, Ultisol, Ultisol + 1 kg of Cocopeat, and Ultisol + 2 kg of Cocopeat). Factor II was the Sorghum varieties (Pahat, Kawali, Samurai 1, and Samurai 2) treatment. Hence, there were 16 treatment combinations with 3 replications. Each replication had 1 rhizotron per treatment combinations, hence there were 48 plants. The observed parameters were the number of roots (pcs), root length (cm), root volume (cm$^3$), root distribution diameter (cm), flowering age (d), harvest age (d), shoot dry weights (g), root dry weights (g), root wet weights (g), and shoot wet weights (g). The obtained data were analysed using ANOVA, and then continued with DMRT. This research used Microsoft Excel program for the data processing.

3. Results and Discussion
The analysis of variance showed that the cocopeat and strain factors own significant effect on the observed parameter (table 1).

Root length parameters showed significant differences in cocopeat application. The parameters of root volume, shoot wet weights, shoot dry weights, root wet weights, and harvest time showed very significant differences in the variety-treatments.

Cocopeat application had a positive significant effect on plants. This indicates that the added organic matter can improve soil chemical properties and soil structure and also increase soil nutrients [9]. Cocopeat is an ideal medium. Cocopeat is good at storing water, high water absorption, and loosening the soil with a neutral pH. This is beneficial because it will store liquid fertilizer hence the frequency of fertilization can be reduced and it contains nutrients from nature that are very much needed by plants [10]. Soil aggregates water stability depends on organic matter, and it characterizes the soil, independent tillage [11].

| Character                      | Genotype MS | Env MS | GxE MS |
|-------------------------------|-------------|--------|--------|
| diameter of root distribution (cm) | 160.36      | 153.87 | 108.50 |
| root length (cm)              | 169.03      | 283.95*| 211.11*|
| number of root (pcs)          | 58.92       | 171.75 | 360.58 |
| root volume (ml)              | 4.49**      | 0.95   | 0.98   |
| root wet weight (g)           | 0.43*       | 0.20   | 0.05   |
| root dry weight (g)           | 0.64        | 0.14   | 0.18   |
| shoot wet weight (g)          | 50.38**     | 9.06   | 2.37   |
| shoot dry weight (g)          | 5.45**      | 0.31   | 0.81   |
| flowering age (d)             | 0.67        | 0.05   | 0.24   |
| harvest age (d)               | 304.40*     | 145.91 | 82.78  |

Note: * = significantly different $\alpha=5\%$, ** = significantly different $\alpha=1\%$.

Table 2 showed that the highest Root Volume was found in Samurai 1 Variety (V3) which was significantly different from Pahat Variety (V1) and not significantly different from Samurai 2 (V2) and Kawali (V2). The root volume parameter no significant effect on the media treatment.
In the treatment of ultisol + cocopeat 2 kg (M4) planting media, showed the highest root length and was not significantly different from ultisol + cocopeat 1 kg (M3) and topsoil (M1) growing media. However, it was significantly different from ultisol (M2) media.

**Table 2.** Planting medium and variety treatments effect on the root length, root volume, shoot wet weights, shoot dry weights, root wet weights, and root dry weight parameters.

| Treatment            | Root Length (cm) | Root Volume (cm³) | Shoot Wet Weight (g) | Shoot Dry Weight (g) | Root Wet Weight (g) | Root Dry Weight (g) |
|----------------------|------------------|-------------------|----------------------|----------------------|--------------------|--------------------|
| Varieties            |                  |                   |                      |                      |                    |                    |
| Pahat (V1)           | 43.42            | 11.80b            | 20.95b               | 15.06b               | 6.55b              | 20.13              |
| Kawali (V2)          | 45.71            | 14.70ab           | 25.31b               | 17.18a               | 6.93b              | 23.44              |
| Samurai 1 (V3)       | 48.50            | 17.54a            | 39.97a               | 21.32a               | 8.17a              | 25.78              |
| Samurai 2 (V4)       | 52.13            | 16.09a            | 30.70a               | 16.44a               | 7.84a              | 26.19              |
| Planting Media       |                  |                   |                      |                      |                    |                    |
| Topsoil (M1)         | 46.88ab          | 16.15             | 33.70                | 18.35                | 7.99               | 25.24              |
| Ultisol Soil (M2)    | 41.04b           | 13.57             | 26.05                | 16.93                | 7.01               | 22.75              |
| Ultisol Soil 10 kg + Cocopeat 1 Kg (M3) | 49.25b | 14.78 | 26.96 | 17.09 | 6.90 | 22.82 |
| Ultisol Soil 10 kg + Cocopeat 2 Kg (M4) | 52.58a | 15.63 | 30.21 | 17.63 | 7.59 | 24.73 |

Note: The number followed by the same letter in the same column in each treatment showed insignificant different results based on the DMRT at the 0.05 level.

Table 2 explained that shoot wet weight and root wet weight showed the highest significant difference in Samurai 1 (V3) varieties which were not significantly different from Samurai 2 (V4) varieties and significantly different from Pahat (V1) and Kawali (V2) varieties but had insignificant effect on the planting medium. Shoot dry weight was not significantly different for the four varieties and also had no significant effect on the growing medium.

Table 3 showed that the interaction between planting medium and variety treatments had a significant effect on root length parameters. In the treatment of M4 (Ultisol + Cocopeat 2 kg) V4 (Samurai 2) showed a greater response compared to other varieties and was not significantly different from treatment M3 (Ultisol + Cocopeat 1 kg) V4 (Samurai 2). This showed that the cocopeat medium has a cavity that makes it easy for roots to spread and has high water absorption hence it can store water supplies for plants [12].

**Table 3.** Interaction between media planting and some population to the observed parameters.

| Varieties | Root Leght |
|-----------|------------|
|           | M1         | M2         | M3         | M4         |
|           | (Topsoil)  | (Ultisol)  | (Ultisol + Cocopeat1 kg) | (Ultisol + Cocopeat2kg) |
| Pahat (V1)| 40.00^bc   | 42.00^bc   | 43.67^abc  | 48.00^abc  |
| Kawali (V2)| 55.50^ab  | 32.33^c    | 53.00^ab   | 42.00^bc   |
| Samurai 1(V3)| 50.00^abc | 46.33^abc  | 39.33^bc   | 58.33^ab   |
| Samurai 2 (V4)| 42.00^bc | 43.50^abc  | 61.00^a    | 62.00^a    |
3.1. Root morphological characters appearances in several sorghum plant varieties.

3.1.1. Pahat varieties. In the ultisol + cocopeat 2 kg medium, it had more root length, root volume and number of roots than other media. The differences in the root of Pahat varieties (V1) on the planting medium of topsoil, ultisol, ultisol + 1 kg of cocopeat, and ultisol + 2 kg of cocopeat were presented in figures 1 and 2.

![Figure 1](image1.png)

**Figure 1.** The differences in the roots of Pahat varieties in topsoil (M1V1) planting media, ultisol soil (M2V1), Ultisol + 1 kg of cocopeat (M3V1) and Ultisol + 2 kg of cocopeat (M4V1) in Rhizotron.

![Figure 2](image2.png)

**Figure 2.** The differences in the roots of Pahat varieties in the planting medium of topsoil (M1V1), ultisol soil (M2V1), Ultisol + 1 kg of cocopeat (M3V1) and Ultisol + 2 kg of cocopeat (M4V1).

3.1.2. Kawali varieties. The kawali variety had almost the same number of roots and root volume in the planting medium of ultisol + cocopeat 2 kg (M4) and topsoil (M1). However, for the root length in ultisol (M2) planting media, it was shorter than in other media. The differences in root growth were presented in figures 3 and 4.

![Figure 3](image3.png)

**Figure 3.** Root length differences in Kawali varieties on the planting media of Topsoil (M1V2), Ultisol (M2V2), Ultisol + 1 kg of Cocopeat (M3V2) and Ultisol + 2 kg of Cocopeat (M4V2) in Rhizotron.
Figure 4. Root length differences in Kawali varieties on the planting media of Topsoil (M1V2), Ultisol (M2V2), Ultisol + 1 kg of Cocopeat (M3V2) and Ultisol + 2 kg of Cocopeat (M4V2).

3.1.3. Samurai 1 varieties. Samurai 1 variety showed that Ultisol + Cocopeat 2 Kg (M4) had better the number of roots and the root length than the other planting media, but the root volume was almost the same as the Ultisol (M2) planting medium. The differences in root growth were presented in figures 5 and 6.

Figure 5. The differences in the roots of Samurai 1 varieties in topsoil (M1V3) planting media, ultisol soil (M2V3), ultisol + 1kg of cocopeat (M3V3) and ultisol + 2 kg of cocopeat(M4V3) in Rhizotron.

Figure 6. The differences in the roots of Samurai 1 varieties in the plantin medium of topsoil (M1V3), ultisol soil (M2V3), ultisol + 1kg of cocopeat (M3V3) and ultisol + 2 kg of cocopeat (M4V3).
3.1.4. Samurai 2 varieties. Samurai 2 varieties had a higher number of roots, longer roots and a greater volume of roots in Ultisol + Cocopeat 2 Kg planting media than in Topsoil, Ultisol + Cocopeat 1 Kg and Ultisol planting media. The differences in root growth were presented in figures 7 and 8.

![Figure 7](image7.jpg)

**Figure 7.** The differences in the roots of Samurai 2 varieties in topsoil (M1V4) planting media, ultisol soil (M2V4), ultisol + 1 kg of cocopeat (M3V4) and ultisol + 2 kg of cocopeat (M4V4) in Rhizotron.

![Figure 8](image8.jpg)

**Figure 8.** The differences in the roots of Samurai 2 varieties in the planting medium of topsoil (M1V4), ultisol soil (M2V4), ultisol + 1 kg of cocopeat (M3V4) and ultisol + 2 kg of cocopeat (M4V4).

4. Conclusions
Root morphology that had a significant effect was root volume and root length. Interaction on root length characters a significant effect. The varieties that have the best volume of roots in samurai 1 varieties and the best root length in samurai 2 varieties. The Best Medium is Ultisol + 1 kg of cocopeat

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