Relationship Between The Diversity of Mycorrhizal Arbuscule Fungi with The Physic-Chemical of Dystropept Soil

R Suryantini*, S Latifah, and R S Wulandari
Faculty of Forestry, Universitas Tanjungpura, Pontianak, Indonesia

*Corresponding author e-mail: rosa@fahutan.untan.ac.id

Abstract. The one of poor soil in West Kalimantan is the dystropept soil which includes sub ordo of inceptisol. Increasing the dystropept soil quality through the microbial approach is very rare or even may not have been done. As a first step, the purpose of the research was to determine the abundance and diversity of AMF (arbuscular mycorrhizal fungi) and the relationship of dystropepts soil characteristic with AMF diversity. The method consisted of taking soil samples at the location in depth of 0-20 cm, 20-40 cm and 40-60 cm, and location II in depth of 0-20 cm; identifying spore-based on morphology. Analyzing data used the pattern of relative abundance, diversity index, evenness index, and biplot RDA. The results were Glomus was dominant genera with high abundance and low species diversity in all location and uneven distribution of species. This diversity of species positively with excellent sand content, Mg, CEC, N, BS, K, and C.

1. Introduction
The about 80-90% of forest vegetation associated with mycorrhizal fungi (AMF) and form the structure of arbuscule-vesicle mycorrhizae. Therefore, the presence of AMF is an indicator of land quality. The AMF influence plant growth through nutrient acquisition and prevent adverse effects due to drought [1, 2]. In the soil ecosystem, correctly, AMF plays a role in soil aggregation as a result of hyphal activity and glomalin secretion [3]. Generally, AMF with other soil fungi plays a decisive role in the nutrient cycle, nutrient uptake soil structure formation, and ecosystem reclamation [4].

AMF is a group of the Glomeromycota phylum. Wang [5] said that there are six families of AMF that are widely associated with the forest vegetation. They are Glomeromycaceae, Claroideoglomeraceae, Gigasporaceae, Acaulosporaceae, Ambisporaceae, and Archaeosporaceae. The dominant genera found are Glomus and Acaulospora. The host species influence these genera. The host plant growth is closely related to the abiotic soil characteristics, such as soil pH. The soil pH, N, Cu, and Zn influence the AMF community [6].

The ability of AMF in the soil aggregation helps to increase the soil improvement physically, as well as in the nutrient cycle. The symbiosis between plant and AMF improve soil characteristics chemically through the nutrient cycle. Conversely, the activity of AMF influenced by the structure and chemical soil of soil type [7, 8].

The soil dystropepts are the ordo of soil inceptisol that is poor nutrient. This soil is characterized by the content of fine sand > 20 %, base saturation < 30 %, Fe > 10 %. This soil is not yet formed ped, and some of the upper layers are thick litter [9]. Kadarwati [10] explained that the depth of solum is less than 29 cm. in this condition (the minimum plant growth requirements), the plants are difficult or unable to grow well except the pioneer species plant, as well as AMF in soil. This land can be improved using
pioneer plant and fast-growing and associate with AMF species, which has high sporulation and colonization. In these efforts, information is needed about the AMF community to obtain AMF species that are dominant and can survive in the dystropepts soil. This study was to determine the abundance and diversity of AMF and the characteristic soil effect to AMF.

2. Method

2.1. Materials
The materials used was soil samples and fungi. Soil samples obtained in Muan Hamlet, Tunggul Boyok Village, Bonti District, West Kalimantan. Soil samples taken from two sites (vegetation land and grassland) of the production forest area. Soil fungi isolated from soil samples.

2.2. Procedure
Soil samples were taken at five-point at each site with different depth (0-20 cm, 20-40 cm, 40-60 cm). Soil samples at one site were taken at a depth of 0-20 cm because its solum was only up to 20 cm. Sample points at each site and depth were composited to analyze the soil characteristics.

Soil samples also were used to identify AMF species through the extraction of 100 g air-dried soil using wet sieving. Spore collected on filter paper and identified based on spore size, color, ornaments, and cell wall under a dissecting microscope at 40 magnifications. Then spore was mounted in the Melzeir reagent. The identification spore based on AMF spore description [11].

2.3. Analysis data
Data were analyzed using Shannon-Wienner index (H’), Evenness index (E) [13], and Relative abundance (RA) [14]. Value of H’ index and soil characteristics with the ordinary biplot RDA. 

\[ RA = \frac{\text{the number of individual species or genus}}{\text{total}} \times 100\% \]

\[ H' = -\sum_{i=1}^{n} P_i \ln P_i \]

H’ : The Shannon-Wiener index of diversity
P : Proportion of number of the colony in species -i to total of the colony

\[ E = \frac{H'}{\ln S} \]

E : Evenness index
H’ : The Shannon-Wiener index of diversity
S : Number of species

3. Result and discussion
The results of the soil analysis classified based on Balai LPT [12]. The soil characteristics represented the select properties of dystropepts soil, namely the content of fine sand and base saturation (BS) [10]. The other characteristics (Table 1) is the general condition of plant growth.

| Sites | pH (H2O) | C-Org (%) | TN (%) | CEC (mg/100 g) | BS (%) | P2O5 ppm | K (cmol/kg) | Mg (cmolc/100 g) | Fine sand (%) |
|-------|---------|-----------|--------|----------------|--------|----------|------------|----------------|--------------|
| M1    | 3.75    | 0.75      | 0.10   | 4.49           | 15.37  | 9.00     | 0.05       | 0.18           | 50.08        |
| M2    | 4.45    | 0.51      | 0.07   | 3.79           | 14.25  | 12.51    | 0.05       | 0.17           | 56.00        |
| M3    | 4.39    | 0.13      | 0.02   | 3.53           | 14.45  | 9.98     | 0.04       | 0.15           | 50.43        |
| B1    | 4.30    | 0.56      | 0.07   | 3.81           | 14.44  | 17.74    | 0.05       | 0.16           | 48.58        |

Total nitrogen (TN), cation exchange capacity (CEC), base saturation (BS), potassium (K), magnesium (Mg).
Soil samples at M1, M3, and B1 showed very acidic reaction because the pH value was less than 4.5 while M2 was acidic soil because it ranged between 4.5 – 5.5. The content of C-organic at all sites was shallow. N total at M2, M3, and B1 was also meager while M1 was low. The CEC value was deficient because it was less than 5, as well as base saturation. The effect of low base saturation was the low K and Mg content. P content at M1 and M3 was shallow but moderate at M2 and B1.

The characteristics of dystropepts soil determined by fine sand content of more than 20 %, base saturation of less than 30 %, undeveloped soil with Fe content of more than 10 % [9]. According to Kadarwati [10], this soil had low fertility based on CEC and BS. Great fine sand content (48.58-50.53%) caused low surface colloidal soil so that CEC was very low (less than 5 mg / 100 g) [12]. This resulted in low base saturation as well, as evidenced by low base cations (K < 0.6 cmol/kg and Mg < 0.2 cmol/kg).

The P content was related to soil pH. The soil in this location had a very acidic pH, but the P content varied. M1 and M3 had shallow P content, P content at M3 was low, and B1 was moderate. The solubility of Al and Fe also influenced the difference in P content in very acid soils. Besides CEC, BS, and P, the content of N and C was also one of the requirements in plant growth. The high N would increase competition between soil microbes, including the development of AMF spores in the rhizosphere or open land.

3.1. Abundance and diversity of AMF

Identification of soil samples obtained eight genera of Glomus and one genera Gigaspora. In Table 2. showed that Glomus was more dominant than Gigaspora. Some of the studies proved that there was a dominance of Glomus Genera in variant soil conditions [15, 3, 16]. Glomus in this soil had a size between 10.17 – 19.6 µm, and Gigaspora was 16.02 µm. According to Wang et al. [5], Glomus has a small spore size and is easy to produce in a short time. Glomus was genera which were dominant to produce glomalin so it could spur soil aggregation [15] and cosmopolite genera [16].

Figure 1. showed that the abundance of AMF species varied at every site. The highest relative abundance of AMF species at B0 was Glomus sp. 1 (45.83%), Glomus sp. 3 at M3, M2 and M1 (29.03%, 20.59%, and 28.38%). Glomus sp. 8 did not found at B0, but it found on other sites. The species with the highest abundance was Glomus sp. 3 and 1 at a different site.

![Figure 1. The relative abundance of AMF species in dystropepts soil.](image-url)
| Type Spore   | Morphological characteristics                                                                 | Reaksi Melzer’s                        |
|-------------|------------------------------------------------------------------------------------------------|----------------------------------------|
| *Glomus* sp. 1 | Spore is globose, yellow, smooth at spore surface, and it does not have a hyphal attachment, size of 18.65 µm. | It did not react with Melzer’s reagent. |
| *Glomus* sp. 2 | Spores are ellipsoid, reddish-yellow, smooth at spore surface, and it does not have a hyphal attachment, size of 19.5 µm. | did not react with Melzer’s reagent.    |
| *Glomus* sp3  | Spores are globose, brownish yellow, smooth spore surface, do not have hypha attachment. measuring 10.8 µm. | did not react with Melzer’s reagent.    |
| *Glomus* sp4  | Spores are globose, brownish red, smooth spore surface, do not have hypha attachment. measuring 19.6 µm. | did not react with Melzer’s reagent.    |
| *Glomus* sp5  | Spores are ellipsoid, red-black, smooth spore surface, have hypha attachment. measuring 15.35 µm. | did not react with Melzer’s reagent.    |
Table 2. Spore of arbuscule mycorrhizal fungi in dystropepts soil (continuation)

| Fungi          | Morphology                                                                 | Reaction with Melzer’s reagent          |
|----------------|----------------------------------------------------------------------------|----------------------------------------|
| Glomus sp. 6   | Spores are globose, dark white, smooth spore surface, do not have hypha attachment, measuring 10.17 µm. | did not react with Melzer’s reagent     |
| Glomus sp. 7   | Spores are globose, yellow-white, smooth spore surface, measuring 10.6 µm. | reacted with Melzer’s reagent and caused changes in the inside of the spore walls are brown. |
| Glomus sp. 8   | Spores are globose, red dark, smooth spore surface, measuring 22.6 µm. | reacted with Melzer’s reagent and caused changes in the inside of the spore walls are black. |
| Gigaspora sp. 1| Spores are globose, brown, rough spore surface, have bulbus suspensor, measuring 16.02 µm. | reacted with Melzer’s reagent and caused changes in the inside of the spore walls are black. |

The absence of one species (Glomus sp. 8) at B1 affected the richness and diversity of AMF species. The lowest Shanon-Wienner index value proved this at B1 compared to the others (Figure 2). The diversity at locations I and II at all soil depths categorized as low, with the Shanon-Wienner index (H') value of 0.84 (M1), 0.91 (M2), 0.84 (M3) and 0.72 (B1). Evenness at M1, M3 and B1 is less than 0.4 (E = 0.35-0.38) while M2 is more than 0.4 (E = 0.42). Thus the uniformity of AMF species populations in M1, M3, and B1 is low while in M2 is moderate. The categorization of H'/E index followed Zhang et al. [14].
The diversity of AMF spores is inseparable from the soil characteristics. In dystropepts soils, species diversity positively related to excellent sand content, Mg, CEC, N, BS, K, and C (Figure 3). The correlation between the diversity of AMF species and exceptional sand content was stronger than AMF diversity with Mg, CEC, N, BS, K and C. K or Mg addition correlated with AMF colonization and diversity [5]. The positive correlation of K/Mg and AMF diversity in this study can not increase plant colonization by AMF. These because the low K/Mg content (0.07 to 0.09 cmol, kg⁻¹) had not shown increasing of AMF colonization [17]. AMF diversity also depended on soil conditions and the composition of AMF communities and their interactions [18]. Soil chemistry which was a condition for plant growth, was shown to be positively correlated with AMF diversity. Base cations (Mg and K) and BS interrelated with exceptional sand content. As explained earlier that the high content of sand reduced the surface of colloids so that it affected the low content of base cations and BS. Base cations such as Mg and K affected global fungal growth, especially for the genus Glomus [5].

The P content negatively correlated with AMF diversity. Figure 3 indicated that M2 and B1 had the same characteristics. M2 and B1 characterized by relatively the same P content that was low to moderate. On the other sites had a shallow P content. However, these did not indicate that they had the same AMF diversity index. The low P content at M2 showed the highest Shanon-Wiener index compared to M1 and M3, although the H’ values of all sites categorized as low (H’ < 1). At B1 (sites that had a soil depth of 1-20 cm), the H’ index was lowest (0.72) even though P was moderate. Saidi et al. [3] showed that the high P content in agriculture soil had a low AMF diversity. Soil containing high
P impacted on the transduction of P secreted by AMF and would prevent its growth [5]. The species that dominate were usually AMF species that able to develop fast and high sporulation (45-46), such as *Glomus* [20].

The diversity of AMF and their wealth was also related to C and N, as one of the requirements of plant growth. [21, 22] explains that the ability of host plants to distribute C influenced AMF sporulation, growth, and survival. The proportion of C / N ratio illustrated if C is low, then the TN ratio will be high [12]. The high N was negatively correlated with fungi diversity [9, 23] because it increased competition between soil microbes.

4. Conclusion
The abundance and AMF diversity in dystropepts soil were low. Soil characteristics determined the low AMF diversity, especially the content of fine sand, Mg, K, CEC, BS, C, and N. *Glomus* were the dominant genera in dystropepts soil.

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