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Study of Arbuscular Mycorrhizal Fungi population in the rhizosphere of oil palm planted on 4 different soil types in Central Kalimantan Indonesia

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Abstract. Arbuscular mycorrhizal fungi (AMF) are naturally found in the soil. The population of this fungus is influenced by environmental factors such as soil type. Different soil types have different characteristics and will affect the AMF population in the soil. Therefore, this study was carried out to determine the AMF population in the soil based on the number of spores in the rhizosphere of oil palm planted in 4 different soil types, namely Dystrudepts, Paleudults, Haplohumods, and Haplosaprists. Soil samples were taken from each soil type at 4 sample points. At each sample point, soil samples were taken from 5 adjacent oil palm trees. Rhizosphere soil samples were taken at 4 points inside the oil palm circle at a depth of up to 15 cm and 4 points from the outside and then composited to represent 1 sample point for inside and outside the circle. Extraction of AMF spores from soil samples was carried out by the wet sieving method. The results showed that the average number of AMF spores per 50 g of rhizosphere soil from inside and outside the oil palm circle were 66,7 and 53,5 spores for Dystrudepts, 115,5 and 91,5 spores for Paleudults, 27 and 71,8 spores for Haplohumods, and 83,3 and 55 spores for Haplosaprists respectively. In Dystrudepts, Paleudults, and Haplosaprists soil types, the number of spores in the rhizosphere of oil palm inside the circle was higher than outside. On the other hand, for Haplohumods soil types, the number of spores inside the circle was lower than outside the circle.

1 Introduction

Arbuscular mycorrhizal fungi (AMF) are soil fungi that form a mutualistic symbiosis with the roots of almost all types of plants. In this symbiotic relationship, the host plant provides the hydrocarbon compounds needed by the fungus to grow and develop, while the fungus helps the host plant absorb water and minerals from the soil through its extensive network of hyphae in the soil [1, 2]. In addition, other benefits of AMF are also reported to increase crop

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resistance to drought, increase tolerance against toxicities of heavy metals, improve plant water relations and increase plant resistance to diseases [3, 4].

Arbuscular mycorrhiza fungi can be found naturally in the rhizosphere of plants, including oil palm (*Elaeis guineensis* Jacq.). However, the population and the diversity of these fungi in the soil are very diverse, which is influenced by biotic and abiotic factors [5–7]. The suitability of the host plant with AMF species is a biotic factor that determines the success of the symbiosis [8]. Meanwhile, abiotic factors such as soil pH, soil fertility, texture, organic matter content, and soil moisture are believed can affect the success of the symbiosis and subsequently affect the population and the diversity of AMF in the rhizosphere [4, 6]. In cassava, Rini M.V. [6] found that the abiotic factor of organic matter affected AMF population in the soil where the higher AMF population was found in the soil with higher organic matter. In oil palm, a study was carried out in mineral and peat soils [7] and reported that AMF population was affected by the soil type. In Indonesia, oil palm was planted in various type of soil. However, studies on the AMF population in the rhizosphere of oil palm planted on different soil types are still very lacking.

PT Bumitama Gunajaya Agro (BGA) is an oil palm plantation company with a total land area of 180,213.92 Ha, located in three provinces in Indonesia, namely Central Kalimantan (104,807.71 Ha), West Kalimantan (73,106.80 Ha), and Riau (2,299.41 Ha) [9]. In Central Kalimantan, the oil palms are planted in various soil types, such as Dystrudepts, Paleudults, Plinthudults, Haplohemists, Haplohumods, Quartzpsamments, Sulfaquepsts, and Haplosaprist. Different soil types also have different abiotic characteristics [10] that can affect the population and diversity of AMF in the soil. Therefore, the aim of this study was to evaluate the population of AMF spore in 4 different soil types i.e., Dystrudepts, Paleudults, Haplohumods, and Haplosaprists. The information obtained from this study will be very useful in making policies to decide whether AMF application is needed in each of these soil types to get the many benefits of AMF for oil palm.

2 Materials and methods

The study was conducted at PT Bumitama Gunajaya Agro Oil Palm Plantation in Central Kalimantan from September to December 2020. The study was conducted on 4 soil types, namely Dystrudepts, Paleudults, Haplohumods, and Haplosaprists. In each type of soil, soil samples were taken from 4 different blocks with a size of ± 30 hectares per block. In each block, 5 adjacent oil palm trees were chosen as the sample tree in the middle of the block. In each sample tree, the rhizosphere soil samples were taken at 4 points inside the circle and 4 points outside the circle. Soil samples from inside the circle from 5 sample trees were then composited and mixed evenly to represent one sample from inside the circle for one block. Soil samples from outside the circle were also treated in the same way.

2.1 Spore number counting and soil chemical analysis

Soil samples from each block were then brought to the laboratory for determination of the spore number in the sample using the wet sieving method [11]. A total of 50 grams of soil sample was put into a 2 L beaker glass, and then 1 L of water was added. After that, stirring was carried out to ensure that the spores trapped in the soil aggregate were freed into the solution. The solution was then allowed to stand for about 10 seconds to allow large soil particles to settle, and then the solution was poured onto 500 µm and 45 µm micro-sieves (which were arranged in stages with 45 µm on the bottom and 500 µm on the top). The same thing was done 5 times to ensure that no AMF spores remained in the soil sample. The spores retained in the 45 µm and 500 µm sieves were then transferred into a petri dish, observed under a stereo microscope with a magnification of 45 times, then the number of spores in the dish was counted manually. In addition to data on the number of spores, an analysis was also carried out to determine the chemical properties of the soil, such as pH, C-organic, total N, available and total P, exchangeable K, Ca, Mg, and cation exchange capacity. The data obtained are then presented descriptively.

3 Result and discussion

Oil palm is a symbiotic plant with AMF, either naturally [12, 13] or intentionally applied with exogenous AMF [14, 15]. In nature, AMF populations are strongly influenced by vegetation and abiotic conditions of the soil [6, 8]. Based on the results of this study, it can be seen that the highest AMF spore population in the oil palm rhizosphere inside the circle was obtained from Paleudults mineral soils, followed by peat soils (Haplosaprists) and mineral soil Dystrudepts, while the lowest from soils sandy soil Haplohumods (Figure 1). Paleudults soils are characterized by low soil fertility, low pH, and low organic C. However, at PT BGA, chemical fertilizers are used to increase soil fertility. With a higher clay content (belongs to the clayey loam soil texture) [10] than other soils, Paleudults soil has a higher CEC than other soil types in this study. Higher CEC, available P, and higher total P (Table 1) were thought to support the growth of oil palm plants, including root growth. This situation supports AMF symbiosis in oil palm roots and hence spore population in the soil.

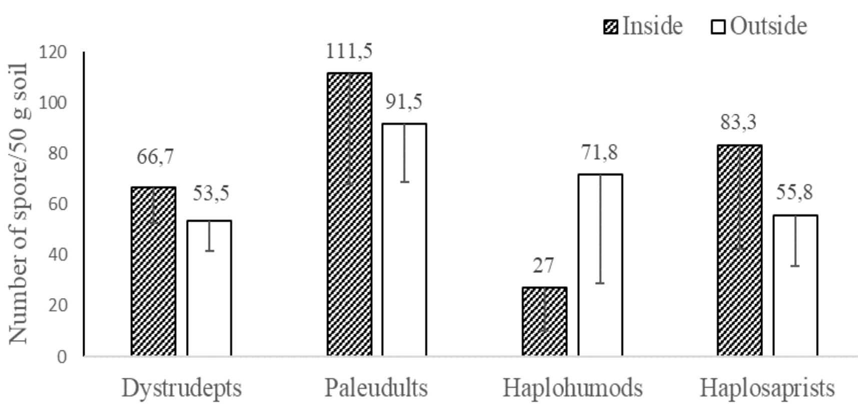

Fig. 1. Number of AMF spores at the rhizosphere of oil palm planted in different soil types.

The chemical properties of the soil in this study can be seen in Tables 1 and 2. Paleudults and Dystrudepts are mineral soils. However, the number of AMF spores in these two soils was different. The number of spores in Paleudults is higher than the number of spores in Dystrudepts. Although these soils are both mineral soils, Dystrudepts soils contain more sand (belongs to the sandy clay loam soil texture) than Paleudults soils [10]. Therefore, it can be seen in Tables 1 and 2 that the values of CEC, available P, and total P in Dystrudepts soils were lower than in Paleudults soils, although soil pH, organic C, total N, and exchangeable K, Ca, and Mg were not different. It is estimated that the lower CEC, available P, and total P in Dystrudepts soils are the main factor that affects the lower AMF population in the soil.

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Table 1. Soil chemical properties (pH, C-Org, N Total, Available P, and P Total) of 4 different soil types.

Soil Type	pH H_2O	C - Org (%)	N Total (%)	Available P (ppm)	P Total (ppm)
Dystrudepts	4,2	0,9	0,2	17,7	104,0
Paleudults	4,0	0,8	0,2	22,1	132,3
Haplohumods	5,1	1,9	0,2	11,1	70,3
Haplosaprists	4,6	35,3	0,4	38,5	155,0

Table 2. Soil chemical properties (exchangeable Ca, Mg, K, and CEC) of 4 different soil types.

Soil Type	Exch. Ca (cmol(+)/kg)	Exch. Mg (cmol(+)/kg)	Exch. K (cmol(+)/kg)	CEC (cmol(+)/kg)
Dystrudepts	1,1	0,2	0,2	16,8
Paleudults	0,9	0,3	0,2	22,3
Haplohumods	1,0	0,3	0,2	8,0
Haplosaprists	1,8	0,7	0,2	47,0

Note: Exch. = Exchangeable

The lowest number of spores was obtained from the rhizosphere of oil palm (inside the circle) planted in Haplohumods soil. This soil contains a high amount of sand (texture class, Sandy Loam) [10]. The high sand content results in a very low soil CEC (Table 2). This soil is also vulnerable to low water availability due to the low water holding capacity of the sand. These conditions were believed to be the main factor that caused low spore numbers in the soil. The low spore number in sandy soil in semi-arid land was reported by [8]. They found that the number of spores was around 5-70 spores per 100 g of soil, depending on the type of host plant. The low AMF spore number in sandy soil was also reported by [16] in South-Western Cape, South Africa.

The number of spores in the Haplosaprist soil was higher than the number of spores in the Dystrudepts and Haplohumods soils (Figure 1). Haplosaprists is peat soil. This soil is characterized by low pH, high organic C content, higher total N content, available P, total P, and CEC compared to other soil types (Table 1 and 2). The chemical properties of this peat soil are better than mineral soil, but the number of spores in the oil palm rhizosphere in this soil is lower than that of Paleudults soil. The high content of organic C in the soil is thought to be a factor limiting the development of mycorrhizae in the Haplosaprists soil [6]. reported that the number of AMF spores was higher in cassava fields containing higher organic C of 1,42% when compared to low organic C of 0,78%. However, the very high organic matter in Haplosaprist soils (35,3%) was suggested does not support root colonization by AMF [15] and leads to low AMF populations in these soils.

The area around the base of the oil palm trunk (circle area) is always cleaned for harvesting and fertilizing activities. For harvesting, the area is cleaned to facilitate the calculation of loose fruit. For fertilization activities, weeds in this area must be controlled to ensure that the fertilizer applied is utilized by the roots of the oil palm. Therefore, the spores obtained inside the circle area were assumed to be produced by AMF hyphae which formed a symbiosis association with oil palm root. The number of spores in the soil can be used to predict hyphae that develop in the soil and further describe hyphae colonization on oil palm roots. The higher the number of spores, the more hyphae that develop in the soil and the more hyphae that colonize oil palm roots.

In Dystrudepts, Paleudults, and Haplosaprist soils, the number of spores outside the circle was lower than the number of spores inside the circle (Figure 1). The soil samples in this study were taken from 13-15 years old oil palms. The palm fronds are already growing to their maximum length and cover the area below the fronds. Under the shade condition, very few weeds and legume cover crops exist in oil palm alley. This condition, together with higher humidity and low light intensity, is thought to lead to a lower AMF population in the soil [17]. reported that AMF colonization was affected by light intensity. The lower the light intensity, the lower root colonization by AMF, and the lower the spore number in the soil. However, in Haplohumods soil, the number of AMF spores outside the circle was higher than inside the circle (Figure 1). We found that the alley of oil palm trees in Haplohumods soil was covered by *Nephrolepis biserrate* intensively. We also checked that the roots of *Nephrolepis biserrate* were colonized by AMF and resulting in a higher AMF spore number in the soil.

4 Conclusions

The highest AMF spore number inside the circle was obtained from the rhizosphere of oil palm planted in Paleudults soils and the lowest from Haplohumods soil. The highest spore number outside the circle was from Paleudults soil and the lowest was from Haplosaprist. The number of spores outside the circle was higher than the number of spores inside the circle in Dystrudepts, Paleudults, and Haplosaprist soils. But, in Haplohumods soil, the number of AMF spores outside the circle was higher than inside the circle.

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