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Identification and Diversity of Mycorrhizae in Several Rhizospheres of Plant Vegetation in Ultisol Land

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Abstract

The poor fertility of ultisol soil hinders the cultivation of food, horticultural crops, and plantation crop nurseries, leading to the abandonment of many lands. Low fertility and productivity levels and high solubility of Al, Mn, and Fe characterize ultisol soil. One effective method to enhance soil properties is by utilizing arbuscular mycorrhiza. Arbuscular Mycorrhizal Fungi (AMF) play a crucial role in improving nutrient and water absorption, thereby enhancing the growth potential of AMF-infected roots and plants. This study aims to identify the types and diversity of mycorrhizae present in the rhizosphere of plants growing in Ultisol soil. The study employed an exploratory approach involving the collection of soil and plant samples, analysing soil, and identifying Arbuscular Mycorrhizal Fungi (AMF) in Ultisol vegetation. The results revealed the presence of AMF in the rhizospheres of various plant species, including Seduduk, Harendong, Kirinyuh, Alang-Alang, and Paku Resam. Three mycorrhizal genera were identified, namely Glomus, Acaulospora, and Gigaspora.

Keywords: Diversity, Identification, Mycorrhiza, Vegetation, Soil Properties

1. Introduction

Andalas University has an experimental garden situated at the base of Karamuntiang Hill in the Limau Manis area, at an altitude of approximately 350 meters above sea level. This experimental garden comprises both dry land and wetlands utilized by students for practical exercises and research purposes. The dry land is typically used for growing food crops, horticulture, and plant nurseries, although many areas remain unused. The primary challenge is the low soil fertility, which hinders plant growth, necessitating enhancements to boost soil fertility. Veldkamp (2020) emphasizes that improving agricultural land involves various factors such as land management, planting, maintenance, and harvesting practices that influence soil properties.

The soil type in the area is Ultisol, a prevalent soil type in Indonesia covering approximately 45,794,000 hectares or about 25% of the country's land area (Syahputra et al., 2015). Ultisol faces issues with low fertility and productivity due to high soil acidity, low organic matter, deficient nutrient levels (N, P, K, Ca, Mg), and elevated solubility of Al, Mn, and Fe (Aryani et al., 2019). These characteristics lead to a decline in soil microbial populations and biodiversity, significantly impacting soil fertility and quality. Maya et al. (2024) highlight the crucial role of soil organisms as decomposers in providing nutrients and enhancing the biological properties of the soil to maintain stability and fertility. One effective method to enhance Ultisol properties is by utilizing arbuscular mycorrhizal fungi to harness soil microorganisms.

Arbuscular Mycorrhizal Fungi (AMF) are organisms from the fungus group that have a mutualistic symbiosis with plant roots, so that they can increase plant growth by increasing nutrient absorption, resistance to drought, protecting the plant rhizosphere from pathogen attacks, and mycorrhiza can also increase plant growth-promoting hormones (Opanida et al., 2020). Mycorrhiza can be associated with almost 90% of plant species, so AMF is found in almost all areas on earth without specific host characteristics. According to Schussler & Walker (2010), the diversity of AMF has been identified as many as 250 types that can interact with various host plants spread across tropical, subtropical and arctic regions.

Mycorrhiza has been proven to form a good symbiosis for plant growth and development, so plants infected by mycorrhiza show a better root system. This is

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thought to be due to mycorrhizal hyphae, which can significantly increase its capacity to absorb water and nutrients in the soil (Zenbua, 2024). AMF is one type of endomycorrhizal mycorrhiza found in almost all ecosystems (Tuheteru et al., 2017). However, not every plant necessarily shows the same or best response to AMF administration. This is influenced by the type of host plant to environmental influences such as humidity, texture and soil pH. According to Rosendahl (2008), the plant type greatly influences each type and population of AMF in an ecosystem. The results of research by Arifin et al., (2022) found four genera of AMF with a total of 235 spores in Entisol soil, and two genera were found in Inceptisol soil with a total of 141 spores.

The research conducted differs from previous studies in that it focuses more on the diversity of arbuscular mycorrhizal fungi (AMF) rather than just identification. The diversity of AMF types is influenced by the soil type, with different types of soil having varying effects on the abundance of AMF. This is supported by the findings of Lica et al. (2022), who identified three genera of AMF with a total of 479 spores in Ultisol soil, where environmental factors accounted for approximately 14.2% of AMF availability.

Research on the types and diversity of mycorrhizae in the plant rhizospheres of the dry land experimental garden at the Faculty of Agriculture, Andalas University, has not been previously conducted. Therefore, it is essential to conduct identification to determine the types of mycorrhizae and the diversity of AMF present in the vegetation of each plant rhizosphere in the experimental garden.

2. Material and Methods

This research was conducted from March to May 2024 at the experimental garden of the Faculty of Agriculture, Andalas University. The height of the research location is ± 200 m above sea level with hilly topography. The location is at coordinates 0 ° 54'50.6 ”S and 100 ° 28'13.1 ”E. Soil and plant root sampling was carried out on each vegetation in the field. Furthermore, sample analysis was carried out at the Plant Physiology Laboratory, Andalas University, Padang.

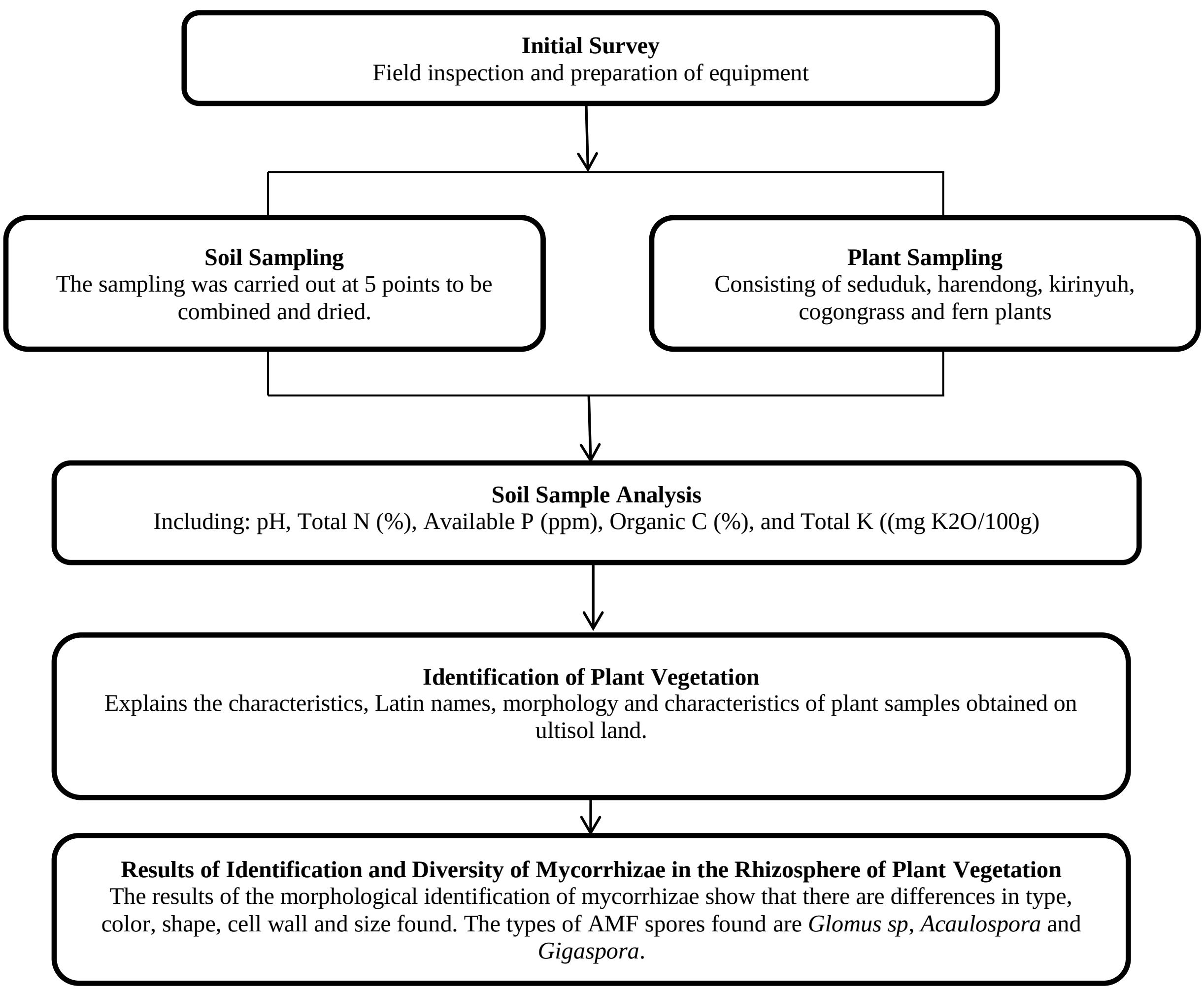


Figure 1. Research flow diagram

The tools used are hoes, knives, scissors, laminating plastic, and labels, bottles, aluminium foil, 1000ml cylinder tubes, aluminium cups, digestion tubes, boiling flasks, test tubes, film bottles, glass slides, cover glasses, cuvettes, Petri dishes, measuring flasks, Erlenmeyers, measuring cups, stencil paper, stirring rods, digital scales, dropper pipes, microscopes, hot plates, analytical scales, and spectrophotometers. The materials used during laboratory analysis are 10% KOH, 2% HCL, glucose and 0.05% trypan blue.

Sampling begins with conducting a field survey first to obtain permission for sampling activities and to ensure that the condition of the observed land has not changed in use during the research period. Furthermore, samples for identifying AMFs that are symbiotic with plants are carried out by taking plant vegetation that grows around the land. Plant samples are taken by pulling them out to the roots then putting them in plastic.

The soil around the roots was taken and put into plastic and labeled. Soil and vegetation samples were taken to the laboratory for soil analysis and AMF identification. The flow diagram of the research implementation can be seen in Figure 1.

Ultisol soil analysis was carried out on each sample that had been taken. Soil analysis was observed, including pH, Total N, Available P, Organic C, and Total K. Mycorrhizal identification was then carried out on the rhizosphere of the obtained plant vegetation. The method was to weigh 50 g of soil sample that had been taken and put it into a bottle. After that the soil sample was mixed with 500 ml of water. The soil and water solution that had been stirred was filtered with a 300 µm, 106 µm, and 45 µm sieve using the wet sieving method according to the method (Brundrett, 1996). The supernatant solution of each sieve size was channeled into a 50 ml glass, each sample extract was taken as much as 5 ml. Then, the 5 ml spore extract results were mixed with 5 ml of 60% glucose and centrifuged at 2500 rpm for 10 minutes. After that, the spores were filtered with a 45 µm sieve. The spores were then observed and counted using a binocular microscope with 100x magnification.

3. Results and Discussion

3.1. Ultisol Soil Analysis Results

The ensuing discourse shall elucidate the findings emanating from the analytical investigation of Ultisol's numerous fundamental soil chemical properties within the experimental garden of the upper land of the Faculty of Agriculture, Andalas University, Padang. The analysis was conducted to evaluate the pH, N-Total, P-Available, C. Organic, and K-Total concentrations. The resulting data are presented in Table 1.

Table 1. Results of Analysis of Several Chemical Properties of Ultisol Soil

No.	Analysis Parameters	Results	Criteria
1.	pH	4.6	Sour
2.	N- Total (%)	0.5	Low
3.	P- Available (ppm)	1.69	Low
4.	C. Organic (%)	1.63	Low
5.	K-Total (mg K2O/100g)	0.3	Low

Table 1 presents the soil analysis results of the study, indicating acidic soil with a pH of 4.6. The analysis also revealed low levels of total N (0.5%), available P (1.69 ppm), organic C (1.63%), and total K (0.3 mg), all falling within the low criteria range. Ultisol soil is characterized by low fertility levels due to its high acidity and low N, P, and organic C levels. The soil exhibits low base saturation, which can hinder plant growth (Fiantis, 2007).

The low total N content in Ultisol soil is attributed to its low organic C content. The soil's limited ability to provide nutrients is influenced by its low organic matter content, with organic C playing a crucial role in N levels. Darlita et al. (2017) suggest that the low organic C levels may be due to N loss through leaching and evaporation. The availability of P is linked to soil acidity (pH), as P originates from mineral weathering in the soil. The analysis indicated relatively low available P levels in Ultisol soil, as the source of weathering from parent soil/mineral materials is generally low (Syahputra et al., 2015). The low total K content in Ultisol soil is attributed to high rainfall, leading to nutrient loss through leaching and runoff.

3.2. Identification of Plant Vegetation on Ultisol Land

The Ultisol soil used in this study came from the experimental garden of the Faculty of Agriculture, Andalas University, Padang. Some vegetation was found around this land, as can be seen in Figure 2.

In Ultisol land, seduduk plants (*Melastoma malabathricum*) are commonly observed. These branched shrubs typically reach a 0.5 - 2 m height, varying based on the habitat. The leaves have a rough and stiff hairy surface with slightly pointed tips. Small white or sometimes pink hairy flowers are clustered at the branch ends, and the fruits resemble decorative glasses with a blackish purple color when ripe (Sandoval and Rodriguez, 2014).

Another vegetation species found in Ultisol land is the harendong plant (*Clidemia hirta* (L.) D. Don). It features stems and leaves with fine thorns resembling hair, shiny green leaf surfaces, and oblong-shaped leaves that are broad and tapered at the ends (Pelu and Djarami, 2021). The harendong plant's stem can grow to less than 1 meter in height, and its round fruits are covered in fine hair, reproducing through seeds.

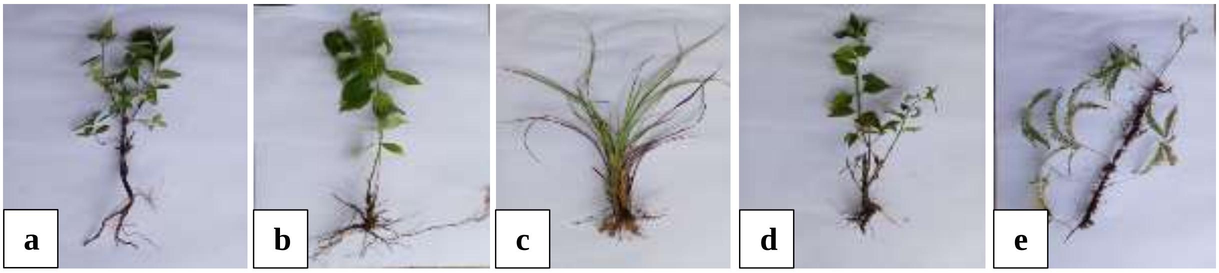


Figure 2. Vegetation of Ultisol land, a) Seduduk (*Melastoma malabathricum*), b) Harendong (*Clidemia hirta* (L.) D. Don), c) Alang-alang (*Imperata cylindrica*), d) Kirinyuh (*Chromolaena odorata*), e) Fern (*Dicramopteris linearis*)

The harendong plant is considered an invasive alien species due to its rapid spread and increased abundance outside its native habitat. It is commonly found on forest edges, riversides, and roadsides.

Cogongrass (Imperata *cylindrica*) is a type of grass found in Ultisol land, with the characteristics of having an upright stem forming one flowering and long-haired nodes. The base of the cogongrass stem shoots consists of several short segments, while the leaf blades grow upright in the form of lines that narrow towards the base. Cogongrass flowers are white grains and oval-shaped seeds, brown with a length of 1-1.5 mm (Damaru, 2011). Cogongrass is easily spread widely through its seeds and strong rhizome roots.

Kirinyuh plants (Chromolaena *odorata*) found on Ultisol land have a large taproot arrangement shaped like a long cone with a yellowish color. Kirinyuh has oval-shaped leaves with a wider lower surface and is increasingly pointed towards the tip. The serrated leaf edges face the base. The stem is round with the direction of the stem growing perpendicularly. Kirinyuh flowers are blue when young and will turn brown when old (Yuliana and Lekitoo, 2018).

The stem of the resam fern (*Dicramopteris linearis*) grows parallel to the ground and is not very visible, because it grows like a root. According to Suryana (2009), some fern leaves are single, some are compound, and some are even doubly pinnate. The roots of the resam fern are rhizome roots called rhizomes, because shoots grow from the pale green rhizome roots covered by black hairs. Each vegetation is identified to see the type of mycorrhiza around the plant's rhizosphere.

Results of Identification and Diversity of Mycorrhizae in the Rhizosphere of Plant Vegetation on Ultisol Land

The results of the morphological identification of mycorrhizae in the rhizosphere of five plant vegetations can be seen in Table 2.

The results of the morphological identification of mycorrhizae in the rhizosphere of plants (Table 2) show that differences in type, color, shape, cell wall, and size were found. The types of AMF spores found are *Glomus sp*, Acaulospora and Gigaspora.

Arbuscular Mycorrhizal Fungi of the *Glomus sp* type are found in the rhizosphere of kirinyuh and cogongrass plants and have round and oval characteristics and thick cell walls of 1-3 layers. The size of Glomus found varies from 45µm-300 µm. The color of the spores found is brownish to black. Spores of the genus Glomus have a high abundance in tropical areas, with a percentage of 52.3%, and can live in soil with high salinity levels (Yakop et al., 2019)

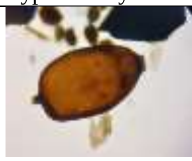
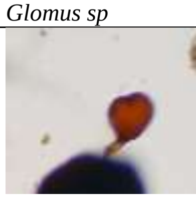
The distinctive characteristics of *Glomus sp*ores are the clearly visible spore walls, and the presence of hyphal tips attached to the surface of the spores. Glomus has a high level of adaptation to various environmental conditions. According to Prayoga and Prasetya (2021), *Glomus sp* has good development and adaptation to acidic soil types, often found in the rhizosphere of yam bean plants (*Pachyrhizus erosus* L.) and weeds. This follows the research results by Armansyah et al. (2019) on Glomus which can adapt and reproduce better than Acaulospora, Gigaspora, and Sclerocystis.

The type of Gigaspora found in the rhizosphere of fern has a round shape with a yellowish color. According to INVAM (2019), This type has a round shape, smooth wall surface, spores produced singly in the soil, and several layers of walls and hyphae from spores that attach to the outermost wall. This genus has a size of 125-600 µm and is found on a 106 πm sieve.

Acaulospora fungi are commonly found in the rhizosphere of seduduk and harendong plants. They have round and oval shapes and come in light yellow (cream), brown, and dark brown colors. According to INVAM (2021), Acaulospora belongs to the family Acaulosporaceae and has spores with a two-layered wall, measuring between 100-400 µm, formed on the side of the neck of the sporiferous saccule. Acaulospora spores develop terminal hyphae and continue to grow.

Acaulospora is the second most dominant spore type after Glomus, accounting for 20.9% of the 250 identified AMF spores. This genus thrives in acidic to neutral soil conditions, with a preference for pH levels below 5. According to Kurnia et al. (2019), Acaulospora and Gigaspora spores are well-suited for sandy soil textures and are more adapted to such environments.

Table 2. Morphology of mycorrhizal identification results in the rhizosphere of plant vegetation in the experimental garden of the Faculty of Agriculture, Andalas University.

No	Types of Mycorrhiza	Information
1	 *Acaulospora*	• Oval shaped • Yellowish brown in color • Has thin cell walls • Found on the 45 πm sieve • Found in the rhizosphere of Seduduk (Melastoma *malabathricum)*
2	 *Gigaspora*	• Round shaped • Has a yellowish color • Has smooth cell walls • Found on the 106 πm sieve • Found on the rhizorfer of Paku Resam (Dicramopteris *linearis)*
3	 *Acaulospora*	• Round oval shape • Yellowish brown in color • Has thin cell walls • Found on the 45 πm sieve • Found in Harendong rhizosphere (Clidemia *hirta* (L.) D. Don)
4	 *Glomus sp*	• Round shaped • Blackish brown in color • Has thick cell walls • Found on the 300 πm sieve • Found in the rhizosphere of kirinyuh (Chromolaena *odorata)*
5	 *Glomus sp*	• Round shaped • Brown in color • Has thick cell walls • Found on the 106 πm sieve • Found on the rhizosphere of Alang Alang (Imperata *cylindrica)*

4. Conclusion

The research conducted indicates that the vegetation in Andalas University's experimental garden, which has ultisol soil type, includes seduduk, harendong, kirinyuh, cogongrass, and fern resam plants. These plants are associated with arbuscular mycorrhizal fungi (AMF) genera such as Glomus, Acaulospora, and Gigaspora. Among these genera, Glomus and Acaulospora are the most dominant.

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