BIODIVERSITAS
Volume 24, Number 8, August 2023
Pages: 4373-4381

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240818

The effect of peat soil and sandy soil on the growth of *Eleutherine palmifolia* and arbuscular mycorrhizal diversity

TITIN APUNG ATIKAH[1], ENY WAHYUNING PURWANTI[2,♥]

[1]Faculty of Agriculture, Universitas Palangka Raya. Jl. Yos Sudarso, Palangka, Jekan Raya, Palangka Raya 74874, Central Kalimantan, Indonesia
[2]Plant Protection Laboratory, Department of Agriculture, Politeknik Pembangunan Pertanian Malang. Jl. DR. Cipto No.144a, Sengkkrajan, Bedali, Lawang, Malang 65215, East Java, Indonesia. Tel.: +62-341-427771, ♥email: enywah17@gmail.com

Manuscript received: 20 January 2023. Revision accepted: 18 August 2023.

Abstract. *Atikah TA, Purwanti EW. 2023. The effect of peat soil and sandy soil on the growth of* Eleutherine palmifolia *and arbuscular mycorrhizal diversity. Biodiversitas 24: 4373-4381.* Arbuscular mycorrhizae as root symbionts is capable of inducing plant growth on marginal lands. It has the potential to be used as fertilizer or soil enhancer. Mycorrhizae are commonly found in peat soils endemic to the island of Borneo. Peat soil contains a lot of organic matter needed by mycorrhizae. The development of plant roots also influences the process of mycorrhizal colonization. Apart from functioning as fertilizer, mycorrhizae is associated with Dayak shallot (*Eleutherine palmifolia* Merr.; syn.: *Sisyrinchium palmifolium* L.) roots can also overcome fusarium wilt disease. This study aimed to explore the potential of peat soil to support the growth of *E. palmifolia* 's and to identify mycorrhizal colonization associated with the plant. Two soil types were used for planting *E. palmifolia*: peat and sand. Parameters observed were plant height, number of leaves, morphospecies and each population of arbuscular mycorrhizae. The plant growth data were tabulated and analyzed with an analysis of variance, and the population of arbuscular mycorrhizae was analyzed for the level of similarity in the structure of species. The results showed that peat soil promoted the growth of *E. palmifolia* better than sandy soil. The similarity value of mycorrhizal species structure was 28.7%. It means that the structure of mycorrhizal species on peat were differed that on sand media. Mycorrhizae successfully explored from sandy soil were 10 morpho-species with a population of 1.441 spores, while mycorrhizae from peat soil contained 6 morphospecies with a population of 462 spores.

Keywords: Arbuscular mycorrhizae, Dayak shallot, fusarium wilt, *Glomus*, morpho-species, peat soil, root symbionts

Abbreviations: AM: Arbuscular Mycorrhizae, AMF: Arbuscular Mycorrhizal Fungi, DAP: Days After Planting, WAP: Weeks After Planting, nMDS: non-Metric Multidimensional Scaling

INTRODUCTION

Mycorrhizae, 'root fungus,' was first used in 1885 to describe the mutualistic relationship between root crops and fungi. Naturally, 80% of mycorrhizal symbiosis with plant roots occurs by an arbuscular mechanism (Bharti et al. 2016). Mycorrhizal spores forming a branching structure of hyphae in the cortex of the host root are often referred to as arbuscular mycorrhizae (Brundett et al. 1994; Harrison 1997). The mycorrhizae' role as symbionts can be divided into four functions. First, mycorrhizae are organisms that play a role in helping plants absorb micro and macronutrients. They can act as catalysts for making nutrients available for plant roots. Second, mycorrhizae also develop a network of external hyphae, which absorb and translocate phosphate and other mineral nutrients from the soil to the roots; this improves plant health and resistance to environmental stress. Third, mycorrhizae can increase resistance to plant pathogens. Fourth, mycorrhizal fungi help in the uptake of water that can not reach plant roots (Pankaj et al. 2019). The accumulated role of Arbuscular Mycorrhizae (AM) in various studies can increase plant productivity by around 25-50% (Bharti et al. 2016; Sun et al. 2017; Rezaei-Chiyaneh et al. 2020).

On marginal lands such as Central Kalimantan, Dayak shallot (*Eleutherine palmifolia* Merr.; syn.: *Sisyrinchium palmifolium* L.) is commonly found and is useful as medicine (Atikah et al. 2017). For years the Dayak people have believed that this introduced plant (from South America) could prevent and treat various diseases, including heart disease and anti-inflammatory (Quadros Gomes et al. 2021). Clinically, the tuber of the *E. palmifolia* has functioned as an immunostimulant to optimize the body's immunity (Fransira et al. 2019; Kamarudin et al. 2020) to increase milk production, treat stroke, breast cancer, hypertension, and sexual disorders (Insanu et al. 2014). Also, it treats infections caused by bacterial (Borges et al. 2020; Fransira et al. 2020; Jiang et al. 2018). It was reported by (Couto et al. 2016; Insanu et al. 2014) that *E. palmifolia* bulbs contain naphthoquinones, anthraquinones, and naphthalenes, which are beneficial for health.

In its development, improper cultivation techniques and pests and diseases decreased the yield of *E. palmifolia* bulbs, so management measures were needed to ensure optimal growth and crop yields. Plant development efforts must be supported by advances in cultivation practices, including various types of fertilization and pest and disease control (Atikah et al. 2017). Control of pathogen attacks

currently relies on synthetic pesticides, which, if used consistently, have negative impacts such as environmental pollution and emergence of toxic residues in medicinal plants which are not good for health. Based on their role, mycorrhizae are mostly found in infertile soil conditions or marginal land, one of which is peat soil (Jiménez-Moreno et al. 2018). Peat ecosystems have different types and densities of AM. Plants cultivated on peatlands have a root system (rhizosphere) that contains various types of AM microorganisms in large numbers (Matysek et al. 2019). Therefore, to find out their types and numbers, it is necessary to study the potential of indigenous AM in peat ecosystems (Koegel et al. 2015). In Central Kalimantan, relatively few studies have been conducted on the potential of indigenous AMF (Arbuscular Mycorrhizal Fungi) in peat and sandy soil habitats. Hence, data on the type and number of AMF microorganisms are still very limited. According to Bharti et al. (2016), the dominant mycorrhizae living on marginal land were *Glomus* sp. and *Gigaspora* sp. Therefore, the potential for colonization of mycorrhizal populations needs to be studied more broadly. Differences in location and rhizosphere result in species diversity and AM population differences. The introduction to the type and abundance of indigenous mycorrhiza can be used as a base studies to develop its applications and formulation, and also the test for its effectiveness in increasing plant growth (Elman Miska et al. 2016). Media factors supporting AM colonization must be investigated as a starting point for AM application in improving soil fertility quality. Biological fertilizers or soil improvement materials are an absolute necessity for the sustainability of agricultural production (Seleiman et al. 2013). The proportion of soils with low fertility quality is increasing due to land conversion practices that ignore ecology and the unique characteristics of the soil. This has encouraged the exploration of biological agents to be used widely for managing soil fertility and increasing plant disease resistance (Feng et al. 2016; Bharti et al. 2016). The objective of this research was to investigate the plant growth with the addition of various nutrient sources and to isolate and identify arbuscular mycorrhizae on peat soil and sandy soil where *E. palmifolia* was previously planted.

MATERIALS AND METHODS

The rhizosphere used was a former *E. palmifolia* plantation. Two planting soil types were peat (G) and sand (P). The peat soil was taken from Kalampangan, Palangkaraya, Central Kalimantan. The sandy soil was taken from Petuk Katimpun, Km 10 Palangkaraya city. Each medium was given a different nutrient source treatment. The treatments included 0 without the addition of nutrient sources, 1 with the addition of organic fertilizer derived from fermented chicken manure and dolomite with a ratio of 13: 3.2: 800. Next, 2 is the addition of NPK compound fertilizer in a ratio of 5.5: 800. Finally, 3 is the addition of organic + dolomite and inorganic fertilizers in a ratio of 13: 3.3: 5.5: 800.

Procedures

Plant growth

Plant materials used 6-10 g/tuber were obtained from local farmers. The research design used was a factorial randomized block design with three replications. Chicken manure obtained from the farm was applied 14 days before planting. Urea was given twice, namely at the time of planting and the age of 30 days after planting (DAP). At the time of planting, SP-36 and KCl fertilizers were also used. The observed growth parameters were plant height and number of leaves at the age of 7 and 11 weeks after planting (WAP). Harvesting of tubers was done at the age of 12 weeks. Soil analysis was carried out at the Analytical Laboratory of the University of Palangka Raya at the beginning of the study, including pH, total N, available P, K, Ca2+, Mg2+, and C-organic.

Mycorrhizal isolation

Mycorrhizal isolation was carried out by wet filtration and glucose gradient centrifuge (Nadeem et al. 2014). For this, 50 g of each planting material was transferred in a container, then mixed with 300 ml of water and leaf for 15-20 seconds. The mixture was then passed through into 600, 180, 106, 75, 63, and 38 µm-sized filters and sprayed with tap water. Next, a 600 µm-sized filter sample was poured in the size 180, 75, 63, and 38 µm sieve into sample. In this way, the last residue was collected from 38 µm sieve. The sample was transfered into the centrifuge tube and then 60% glucose solution was added and centrifuge at 2,500 revolutions per minute (rpm) for 3 minutes. The top liquid (clear) was transferred into a petri dish and poured in a 38 µm sieve. Spray with tap water to remove the glucose solution and observed under the microscope. Schematic of the isolation method is shown in Figure 1.

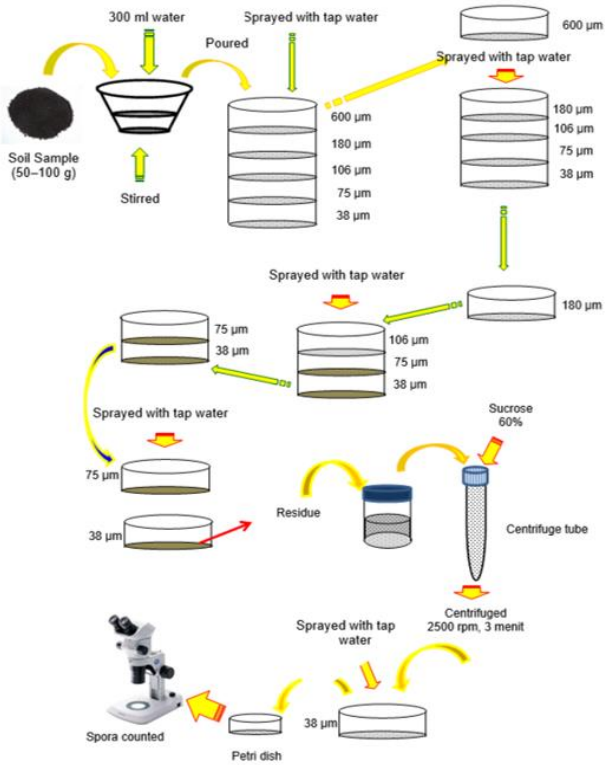


Figure 1. Schematic diagram of mycorrhizal isolation steps

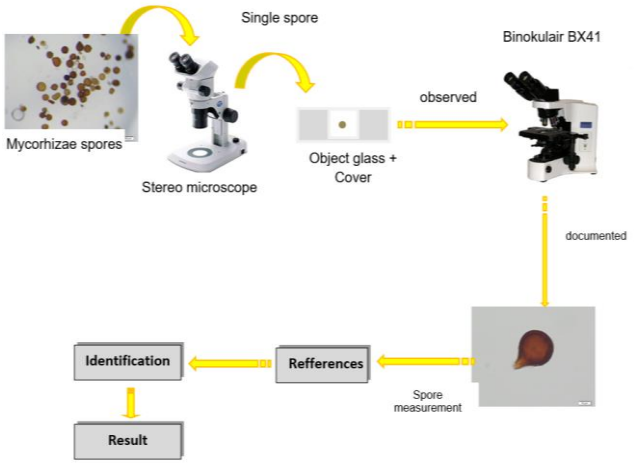


Figure 2. Schematic steps of mycorrhizal identification

Mycorrhizal identification

Identification and characterization of fungal spores were carried out based on the general characteristics of spores, including spore shape, color, number of spore walls, and spore reactions before and after being given Melzer solution, based on the Manual for the Identification of Mycorrhizal Fungi and the International Culture Collection of Vesicular and Arbuscular Mycorrhizal Fungi (INVAM 2014) (Ortas 2015). The population was only counted on the 1st to 3rd largest morpho-species in each soil sample. The schematic working steps of identification are presented in Figure 2.

Data analysis

The plant growth data were analyzed using variance α 5% and 1%. If any difference was found, it was using the 5% level DMRT. Meanwhile, the morpho-species and population of AM identified were analyzed using non-Metric Multidimensional Scaling (nMDS) and similarity (anosim) analysis. The aim of these two analyses were to determine the community structure similarity between peat media and sand planting media. Moreover, the accuracy of plot can be detected through the stress value. Four stress values were used to detect the accuracy of the value of a plot that describes the structure of the sample composition obtained were: (i) Stress value < 0.05 describes a perfect plot, with the possibility of no errors in interpreting it, (ii) Stress value = 0.15 describes a quite accurate plot with a low interpretation error, (iii) Stress value < 0.2 describes the plot as not well used, (iv) Stress value > 0.2 describes very likely to be misinterpreted (Wang et al. 2017).

RESULTS AND DISCUSSION

Plant height

Based on the analysis of variance, it was found that there was an interaction between treatment of the type of nutrient source and the type of soil media on the height of the *E. palmifolia* plant at the age of 7 and 11 WAP. The effect of peat soil (M1) and sandy soil (M2) on plant height in treatments P1, P2, and P3 was statistically different. The highest shallot in peat media was recorded by P1, this may be due to the addition of chicken manure as nutrient source. Meanwhile, the highest one in sandy soil reached by P1 and P3 which both also added by chicken manure. The effect of P0 treatment (without nutrient sources) on plant height was not significantly different between peat and sandy soil media (Table 1).

Table 2 shows that P1 and P3 treatments on peat soil media (M1) had similar effects on plants height at 11 WAP but significantly differed from the P0 and P2 treatments. The P1 treatment had the greatest effect on plant height. On sandy soil media (M2), P1 and P3 treatments had the same effect but significantly differed from those of treatments P0 and P2. While the effect of treatments P0 (without fertilizer) and P2 on peat and sandy soil media was not significantly different, the effect of treatments P1 and P3 on peat and sandy soil media was significantly different, with the peat soil treatment (M1) being superior to sandy soil treatment (M2).

The results for plant growth in the two different types of soil were not the same, but soil acidity and nutrients affect plant growth. According to the results of soil analysis, nutrient content of peat soil is higher than sandy soil, namely N-total 1.06%, P-Bray I 488.55 ppm, K-dd 2.72 me/100 g, Ca-dd 8.77 me/100 g, Mg-dd 2.22 me/100 g, C-organic 49.11% with soil acidity pH H_2O 4.93 (Integrated Laboratory Analysis, University of Palangka Raya 2021). Low soil acidity in sandy soils (pH 4.7) limits plant nutrient availability and soil microbial activity. In addition, sandy soils had relatively high porosity, which can facilitate water and nutrient loss, resulting in suboptimal plant height growth.

Table 1. Effect of various nutrient sources and soil types on plant height (cm) at 7 WAP

Soil types (M)	Source of Nutrients (P)			
	P0	**P1**	**P2**	**P3**
M1	39.28a A	40.17a A	42.12a B	39.02a A
M2	37.80a A	43.67b B	35.13a A	44.85b B

Note: The average value followed by the same letter in the same column or row means the effect was insignificant according to the 5% DMRT. P0: no fertilizer; P1: Chicken manure 20 $t.ha^{-1}$; P2: NPK (200 $kg.ha^{-1}$ urea, 150 $kg.ha^{-1}$ SP-36 and 200 $kg.ha^{-1}$ KCL; P3: Combination of chicken manure+NPK; M1: Peat soil, M2: Sandy soil

Table 2. Effect of various nutrient sources and soil types on plant height (cm) at 11 WAP

Soil types (M)	Source of Nutrients (P)			
	P0	**P1**	**P2**	**P3**
M1	8.33a A	53.17c B	31.83b A	48.83c B
M2	6.67a A	36.33b A	9.17a A	31.33b A

Note: The average value followed by the same letter in the same column or row means that the effect was insignificant according to the 5% DMRT. P0: no fertilizer; P1: Chicken manure 20 t.ha-1; P2: NPK (200 $kg.ha^{-1}$ urea, 150 $kg.ha^{-1}$ SP-36 and 200 $kg.ha^{-1}$ KCL; P3: Combination of chicken manure+NPK; M1: Peat soil, M2: Sandy soil

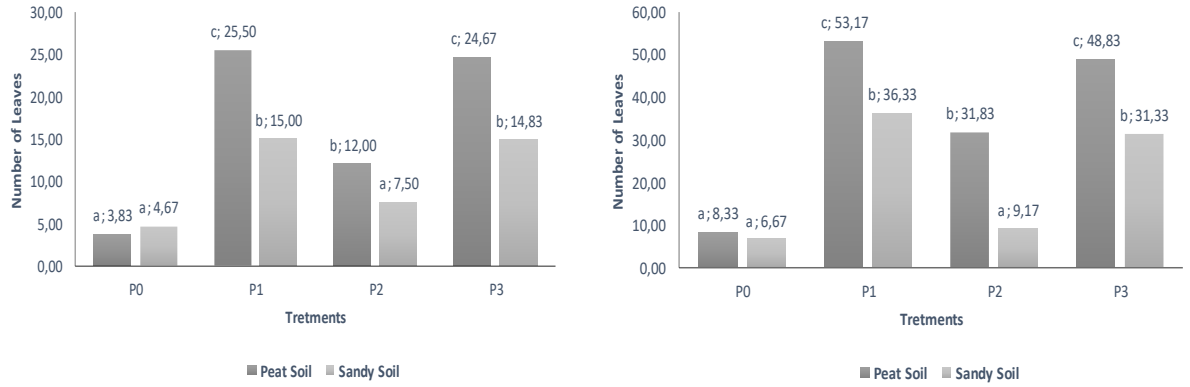


Figure 3. Number of leaves in *E. palmifolia* plant at 7 (left) and 11 WAP (right) age groups on different nutrient sources and two types of soil treatments. The letter in front of the bar value indicate the significant differences according to α =5% DMRT

Number of leaves

It was observed that the number of plant leaves increased due to the addition of nutrient sources. On peat soil (M1) number of leaves were (25.50 and 53.17), on sandy soil (M2) (15.00 and 36.33), chicken manure (P1) was able to increase the largest number of plant leaves at the age of 7 and 11 WAP. The effect was not significantly different for the two peat and sandy soil in treatment B0 (without nutrient sources); however, the P1, P2, and P3 treatments had significantly different effects on the two peat and sandy soil. Treatments P1, P2, and P3 had the greatest effect on the number of leaves on peat soil (Figure 3).

The effect of adding chicken manure to peat soil showed that it increased soil pH, which was associated with greater uptake of plant-available nutrients. The availability of nutrients for plants as evidenced by the increase in the number of leaves affects the sunlight captured by the leaves during photosynthesis; likewise, the addition of chicken manure to sandy soil had an effect on high soil porosity. Besides increasing soil pH, it also increases the soil's ability to absorb nutrients and water. Subramaniam et al. (2012) reported that *E. palmifolia* s cultivated on peatlands shows optimal growth and yield if supplied with chicken manure. It was also reported that cultivating *E. palmifolia* s on sandy soil had optimal growth and yield of tubers on chicken manure 20 tons/ha and NPK (200 kg/ha Urea + 150 kg/ha SP 36 + 200 kg/ha KCl), resulting in growth and ideal tuber yield (Atikah et al. 2017).

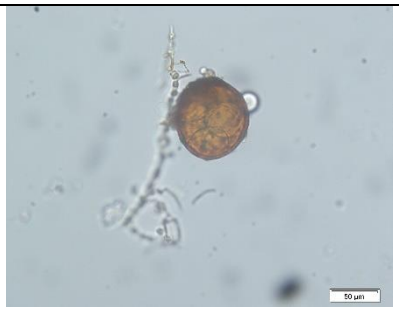
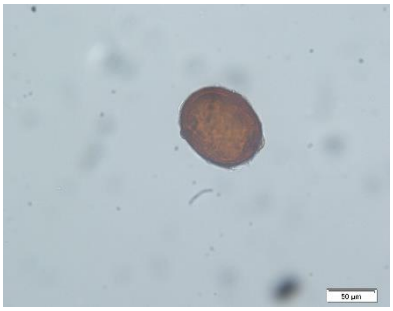
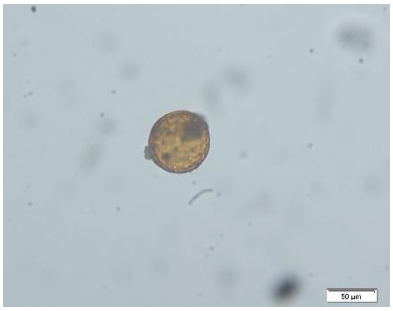
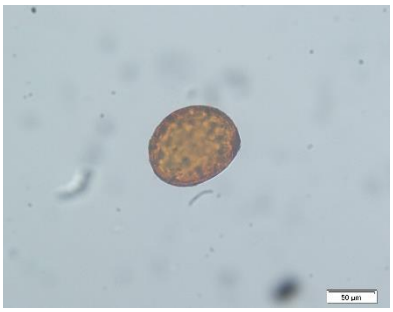
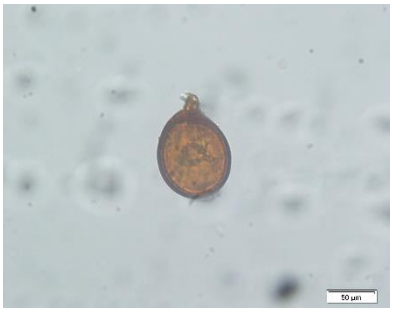
Morpho-species identification

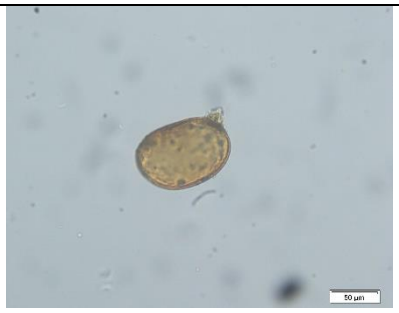
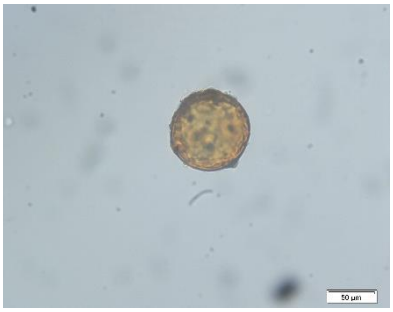
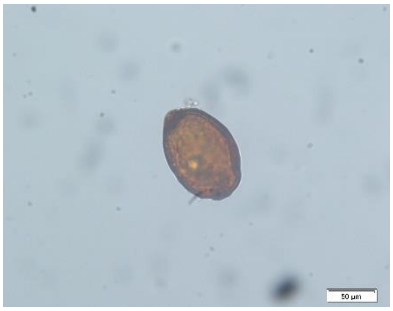
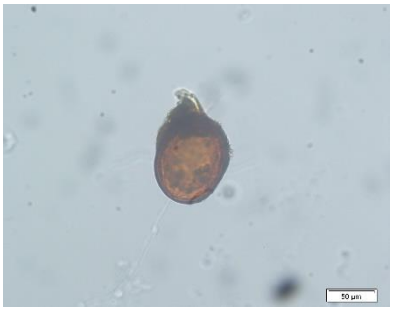
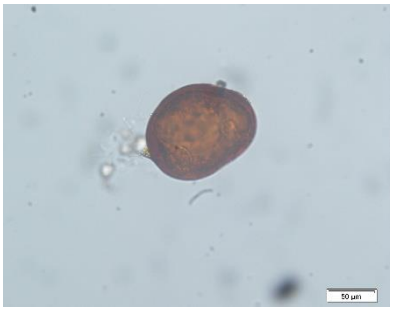
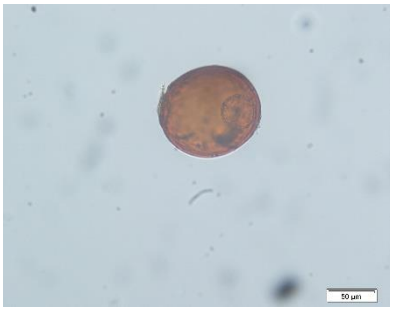
A total of 11 glomales morphospecies were isolated from the samples. Arbuscular mycorrhizae isolated from each experimental unit were dominated by the genus Glomales. The classification of glomales species was divided into morphological species according to their characteristics. Glomales spores can be identified based on shape, size, and color. Some species had a round shape, oblong (oval), or spherical shape. Glomales spore size ranged from very small (20-50 µm) to very large (200-1.000 µm). The color of spores varies and can be identified using the Brundrett color map (Rajtor and Piotrowska-Seget 2016). The morphological characteristics used to differentiate were the shape of spores (round, oval, oval), structure of the walls (2 or 3 layers), and the color of spores (brown, light brown, or dark brown). The classification results are presented in Table 3.

The size of isolated glomales spores varied from 68.78 to 127.59 m, which was classified as medium size. Glomales spore size found on peat soil tends to be smaller (range 68.78-103.53 m). Glomales spore size on sandy soil was larger, ranging from 82.77-127.59 m. In peat soil, 6 morphospecies were found with the dominant spherical shape of spores. In sandy soil, 10 morphospecies were found with round and oblong spores. There are only 5 morphospecies found in both media.

Glomales fungus spore wall has one or more layers that differ in thickness, structure, appearance, and color reaction. There are eight types of wall layers: laminated walls, evanescent walls, unit walls, germinal walls, membranous walls, coriaceous walls, beaded walls, and amorphous walls (http: //invam.caf.wvu.edu/fungi/taxonomy/concepts/convtrad.htm). The spore wall is divided into four types, namely: unit, laminated, evanescent, and membrane (Simanungkalit 1996; Piotrowska-Seget 2016). Acaulospora, Entrophospora, and Scutellospora typically have a complex wall structure consisting of one thick outer wall and one or more thin inner wall layers. These wall layers can only be observed in squeezed spores and under a microscope (Ait-El-Mokhtar et al. 2019). Melzer's color reaction can occur on all genera's inner or outer wall layers of spores, but the typical color reaction does not occur in old, damaged, or stored preservatives. Glomus or Gigaspora generally have a simpler structure than other genera, but glomus often has several layers of walls. Glomus spores isolated from dominant peat soil had two layers of spore walls. Glomales obtained from sandy soil generally have 3 layers of cell walls (Pakarinen et al. 2021).

Table 3. Description of Glomales morpho-species

Morphospecies	Description	Picture	Plot designs
Glomus sp. 1	color: brown form: round shape spore size: 89.45 µm wall structure: 3 layers wall thickness: 3.78 µm		Peat soil Peat soil + inorganic fertilizer Sand soil + inorganic fertilizer
Glomus sp. 2	color: dark brown form: round shape spore size: 96.20 µm wall structure: 3 layers wall thickness 6.26 µm		Peat soil Sand soil
Glomus sp. 3	color: light brown form: round shape spore size: 68.78 µm wall structure : 3 layers wall thickness 3.97 µm		Peat soil Peat soil + organic fertilizer Peat soil + mixed fertilizer
Glomus sp.4	color: brown form: oblong spore size: 101.55 µm wall structure: 3 layers wall thickness 4.00 µm		Peat soil + organic fertilizer Peat soil + inorganic fertilizer Sand soil + mixed fertilizer
Glomus sp. 5	color: brown form: oblong spore size: 97.12 µm wall structure: 3 layers wall thickness 6.66 µm		Peat soil + organic fertilizer Peat soil + inorganic fertilizer Sand soil + mixed fertilizer

Glomus sp. 6	color: light brown form: oblong spore size: 103.53 µm wall structure: 3 layers wall thickness 4.43 µm		Peat soil + pupuk campur Sand soil Sand soil+organic fertilizer
Glomus sp. 7	color: light brown form: round shape spore size: 87.94 µm wall structure: 2 layers wall thickness 5.12 µm		Sand soil
Glomus sp. 8	color: dark brown form: oblong spore size: 110.82 µm wall structure: 2 layers wall thickness 5.27 µm		Sand soil+organic fertilizer Sand soil+inorganic fertilizer
Glomus sp. 9	Warna: brown form: oblong spore size: 100.37 µm wall structure: 2 layers wall thickness 4.33 µm		Sand soil+organic fertilizer
Glomus sp. 10	color: dark brown form: oblong spore size: 123.92 µm wall structure: 3 layers wall thickness 6.33 µm		Sand soil+organic fertilizer
Glomus sp. 11	color: dark brown form: oblong spore size: 109.02 µm wall structure: 3 layers wall thickness 6.33 µm		Peat soil + inorganic fertilizer

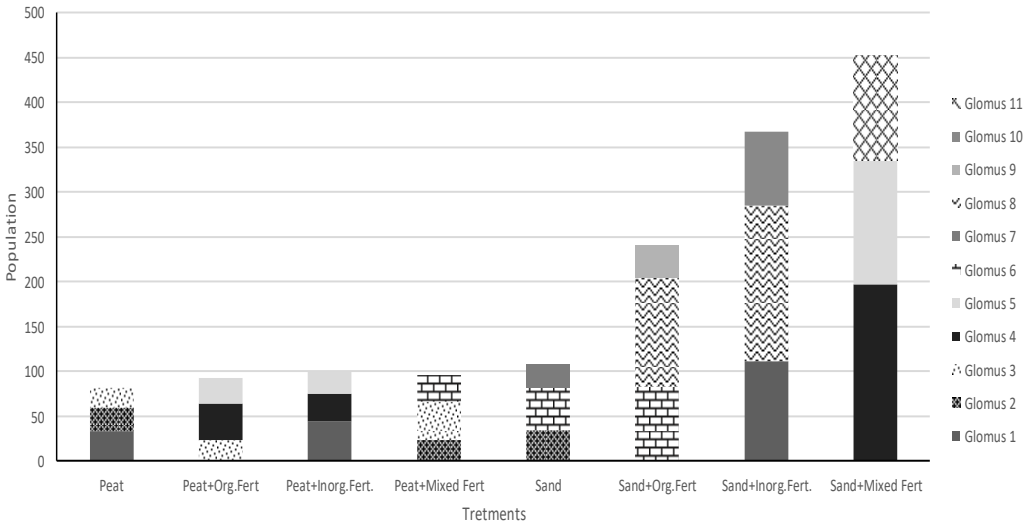


Figure 3. The population of 11 glomales morpho-species per plot

Population of glomales

The calculations showed that the population of glomales from morpho-species 1 to morpho-species 11 was higher in sand media than in peat media (Figure 3). The total glomales population per 50 g of soil in all experimental units on peat media was 462 spores, while in sand media, it was 1.441 spores. Glomales have a higher adaptability to adverse environmental conditions. Glomales are often found indigenous on peatlands (Matysek et al. 2019), but in the present study, the population of glomales in sand media was higher. Peat soil and sand are classified as marginal planting media. Peat soil contains low-quality organic matter and a high C/N ratio (Wahyunto et al. 2013). Peat is a sub-optimal soil in which agricultural crops are generally difficult to grow in natural conditions. As a planting medium, peat has an inhibiting factor in chemical fertility, which is caused by low pH, low base saturation, and poor drainage (Antoun 2012). Glomales require carbon as an energy source. The carbon widely available in peat soil is the preferred energy source for glomales. The consequence of high carbon is soil acidity. In the experimental unit induced with agricultural lime, it was observed that the glomales population was more numerous.

Sandy soil, also a marginal plant medium because of the ongoing weathering process, involves various soil microorganisms, including glomales. The development of the glomales population is not only influenced by the nature and physics of the soil; the growth factors of plant roots also influence it as symbionts. According to Padri et al. (2015), there is a symbiotic mutualism between glomales and plant roots. As plants age, roots lose their cruising range in search of nutrients (Ortas 2015). The hyphae infect the roots, develop and colonize, so that the number of spores is greater (Ali et al. 2018). Glomales spores help increase the capacity of the roots to absorb nutrients and water. On the other hand, colonization and formation of glomales spores are affected by the excretion of exudate from the host plant's roots. Another factor that also affects the formation of spores is the growth of the host plant. *E. palmifolia* plant growth on sand media was better than on peat media. This can explain the high glomales propagules in sand media without fertilizer or adding fertilizer (Nadeem et al. 2014).

Both peat and sandy soil, glomeles populations in *E. palmifolia* plantations were found to be able to reduce the intensity of *Fusarium* sp. wilt disease or mole disease. Atikah et al. (2017) stated that monoculture shallot cultivation system has a 50% greater potential for fungus disease than polyculture, especially in a 1: 1 cropping pattern, namely one row of shallots and one row of *E. palmifolia* s. The compounds contained or released by *E. palmifolia* s or mycorrhizal symbionts of their roots can suppress moler disease (Rizali et al. 2021).

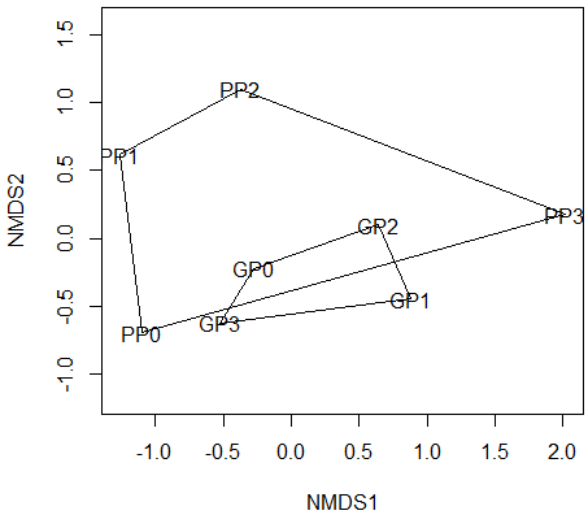


Figure 4. Plotting of community structure of glomales morpho-species (P: sand; G: Peat; 0: only peat/ only sand;1: +organic fertilizer; 2: +inorganic fertilizer;3: +mixed fertilizer)

Structural similarity analysis of species composition

The results of plotting the species structure are presented in Figure 4. Glomales occupy a narrow space on peat soil media. That shows the species composition and population were lower than in sandy soil media. The nMDS plotting resulted in a stress value of 9.8 × 10-5, or very small and close to 0. This illustrates that the plot had high accuracy with a low level of interpretation error. The distance between points that far apart shows a clear difference between the structure of glomales species in sandy soil and peat soil. The anomic value at the 95% confidence interval ($\alpha = 0.05$) was 0.287. The anosim value or R stat was obtained from the ratio of species structure comparisons per experimental unit. The closer the anomic value to the number 1 means that each experimental unit has a similar species structure. Anosim values close to 0 indicate that each experimental unit has a different species structure (Waongo et al. 2015).

Glomales in symbiosis with *E. palmifolia* plants in sandy soil media are more prospective to be used as sources of inoculants or active ingredients of biological fertilizers. In the experimental unit of mixed soil + mixed fertilizer media, glomels performed best as compared to other experimental units. This proves the organic matter content in organic fertilizers supports the diversity and colonization of glomales. The application of inorganic fertilizers meets the nutritional needs of plants, resulting in healthier roots. Healthy roots produce root exudates that can attract glomales populations as symbionts.

In conclusion, results of present study revealed that the highest growth in plant height and number of leaves was shown in plants aged 7 and 11 WAP when Dayak onion plants were planted on peat soil with a source of nutrients from the addition of organic fertilizer in the form of chicken manure at a dose of 20 tonnes/ha. *E. palmifolia* planting with peat soil and sandy soil media resulted in different glomales species structures. The number of morpho-species and populations of glomales on sandy soil was 10 and 1.441, respectively, more than those on peat soil 6 and 462. The potential utilization of former *E. palmifolia* growing media as a source of mycorrhizal inoculants from sandy soil was greater. The resulting mycorrhizal inoculants function as decomposers of organic matter into a form available to plant roots and induce plant resistance to drought stress and fusarium wilt disease.

ACKNOWLEDGEMENTS

Sincere thanks and appreciation are conveyed to the Institute for Research and Community Service, University of Palangka Raya, as a funding source, Tomo Agus Supriyantono, Amd., ST. Laboratory assistant of Mycology Department of Pests and Plant Diseases Universitas Brawijaya, for his contribution to writing this manuscript. Also, Plant protection Lab. of Politeknik Pembangunan Pertanian Malang for analysis facilities.

REFERENCES

Ait-El-Mokhtar M, Laouane RB, Anli M, Boutasknit A, Wahbi S, Meddich A. 2019. Use of mycorrhizal fungi in improving tolerance of the date palm (*Phoenix dactylifera* L.) seedlings to salt stress. Sci Hortic 253: 429-438. DOI: 10.1016/j.scienta.2019.04.066.

Antoun H. 2012. Beneficial microorganisms for the sustainable use of phosphates in agriculture. Proc Eng 46: 62-67. DOI: 10.1016/j.proeng.2012.09.446.

Atikah TA, Wardiyati T, Nihayati E. 2017. The growth patterns and eleutherine content of dayak onion (*Eleutherine palmifolia* Merr.) in sandy mineral soil and peat soil. Intl J Biosci 10 (04): 222-231. DOI: 10.12692/ijb/10.4.222-231.

Bharti N, Barnawal D, Shukla S, Tewari SK, Katiyar RS, Kalra A. 2016. Integrated application of *Exiguobacterium oxidotolerans*, *Glomus fasciculatum*, and vermicompost improves growth, yield and quality of Mentha arvensis in salt-stressed soils. Ind Crops Prod 83: 717-728. DOI: 10.1016/j.indcrop.2015.12.021.

Borges ES, da Rocha Galucio NC, Veiga AS, Busman DV, de Almeida Lins AL, de Oliveira Bahia M, Rissino JD, dos Santos Correa RM, Burbano RM, Marinho AM, Casique JV. 2020. Botanical studies, antimicrobial activity and cytotoxity of *Eleutherine bulbosa* (Mill.) Urb Res Soc Dev 9 (11): e3369119992. DOI: 10.33448/rsd-v9i11.9992.

Brundett M, Dell B, Malajezuk N. 1994. Mycorrhizas for plantation forestry in Asia. Proceedings of an international symposium and workshop. Kaiping, Guangdong Province, China, 7-11 November 1994.

Couto CL, Moraes DF, Maria do Socorro SC, do Amaral FM, Guerra RN. 2016. Eleutherine bulbous (Mill.) Urb.: A review study. J Med Plants Res 10 (21): 286-297. DOI: 10.5897/JMPR2016.6106.

Feng WE, Rong F, Passey T, HU XP, Xu X. 2016. Identification of candidate soil microbes responsible for small-scale heterogeneity in strawberry plant vigour. J Integr Agric 15 (9): 2049-2058. DOI: 10.1016/S2095-3119(16)61354-0.

Fransira I, Yanuhar U, Maftuch M. 2019. Potential of Dayak onion (*Eleutherine palmifolia* (L) Merr) extract as antibacterial against *Pseudomonas fluorescens*. J Exp Life Sci 9 (2): 76-80. doi: 10.21776/ub.jels.2019.009.02.03.

Fransira I, Yanuhar U, Noercholis A, Maftuch. 2020. The effect of Eleutherine palmifolia root extract on the hematology of *Oreochromis niloticus* infected with *Pseudomonas fluorescens*. AACL Bioflux 13 (1): 346-359.

Gomes AR, da Rocha Galucio NC, de Albuquerque KC, Brígido HP, Varela EL, Castro AL, Vale VV, Bahia MO, Burbano RM, de Molfeta FA, Carneiro LA. 2021. Toxicity evaluation of *Eleutherine plicata* Herb. extracts and possible cell death mechanism. Toxicol Rep 8: 1480-1487. DOI: 10.1016/j.toxrep.2021.07.015.

Harrison MJ. 1997. The arbuscular mycorrhizal symbiosis : an underground association. In: Trends in Plant Science. Plant Biology Division, USA. DOI: 10.1007/978-1-4615-6019-7_1.

Jiang H, Man WJ, Hou AJ, Yang L, Xing XD, Yan ML, Guo XY, Yang L. 2018. The chemical constituents from the active fractions of *Eleutherine bulbosa* with their antimicrobial activity. Nat Prod Res 34 (12): 1743-1749. DOI: 10.1080/14786419.2018.1530229.

Jiménez-Moreno MJ, del Carmen Moreno-Marquez M, Moreno-Alías I, Rapoport H, Fernández-Escobar R. 2018. Interaction between mycorrhization with *Glomus intraradices* and phosphorus in nursery olive plants. Sci Hortic 233: 249-255. DOI: 10.1016/j.scienta.2018.01.057.

Insanu M, Kusmardiyani S, Hartati R. 2014. Recent studies on phytochemicals and pharmacological effects of *Eleutherine Americana* Merr. Procedia Chem 13: 221-228. DOI: 10.1016/j.proche.2014.12.032.

Kamarudin AA, Esa NM, Saad N, Sayuti NH, Razak NA. 2020. Heat assisted extraction of phenolic compounds from *Eleutherine bulbosa* (Mill.) bulb and its bioactive profiles using response surface methodology. Ind Crops Prod 144: 112064. DOI: 10.1016/j.indcrop.2019.112064.

Koegel S, Brulé D, Wiemken A, Boller T, Courty PE. 2015. The effect of different nitrogen sources on the symbiotic interaction between *Sorghum bicolor* and *Glomus intraradices*: Expression of plant and fungal genes involved in nitrogen assimilation. Soil Biol Biochem 86 (3): 159-163. DOI: 10.1016/j.soilbio.2015.03.003.

Matysek M, Leake J, Banwart S, Johnson I, Page S, Kaduk J, Smalley A, Cumming A, Zona D. 2019. Impact of fertiliser, water table, and warming on celery yield and CO2 and CH4 emissions from fenland agricultural peat. Sci Total Environ 667: 179-190. DOI: 10.1016/j.scitotenv.2019.02.360.

Nadeem SM, Ahmad M, Zahir ZA, Javaid A, Ashraf M. 2014. The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. Biotechnol Adv 32 (2): 429-448. DOI: 10.1016/j.biotechadv.2013.12.005.

Ortas I. 2015. Comparative analyses of Turkey agricultural soils: Potential communities of indigenous and exotic mycorrhiza species' effect on maize (*Zea mays* L.) growth and nutrient uptakes. Eur J Soil Biol 69: 79-87. DOI: 10.1016/j.ejsobi.2015.05.006.

Pakarinen A, Fritze H, Timonen S, Kivijärvi P, Velmala S. 2021. Boreal soil microbial diversity and seed onion mycorrhizal colonization is unaffected by preceding one season crop cultivation. Eur J Soil Biol 105: 335-346. DOI: 10.1016/j.ejsobi.2021.103335.

Pankaj U, Singh G, Verma RK. 2019. Microbial approaches in management and restoration of marginal lands. New and Future Developments in Microbial Biotechnology and Bioengineering. Divion of Agronomy and Soil Science, CSIR-Central Institute of Medicinal and Aromatic Plants, India. DOI: 10.1016/B978-0-12-818258-1.00020-0.

Rajtor M, Piotrowska-Seget Z. 2016. Prospects for arbuscular mycorrhizal fungi (AMF) to assist in phytoremediation of soil hydrocarbon contaminants. Chemosphere 162: 105-116. DOI: 10.1016/j.chemosphere.2016.07.071.

Rezaei-Chiyaneh E, Amirnia R, Machiani MA, Javanmard A, Maggi F, Morshedloo MR. 2020. Intercropping fennel (*Foeniculum vulgare* L.) with common bean (*Phaseolus vulgaris* L.) as affected by PGPR inoculation: A strategy for improving yield, essential oil and fatty acid composition. Sci Hortic 261: 108951. DOI: 10.1016/j.scienta.2019.108951.

Seleiman MF, Santanen A, Kleemola J, Stoddard FL, Mäkelä PS. 2013. Improved sustainability of feedstock production with sludge and interacting mycorrhiza. Chemosphere 91 (9): 1236-1242. DOI: 10.1016/j.chemosphere.2013.02.004.

Subramaniam K, Suriyamoorthy S, Wahab F, Sharon FB, Rex GR. 2012. Antagonistic activity of *Eleutherine palmifolia* Linn. Asian Pac J Trop Dis 2 (1): S491-S493. DOI: 10.1016/S2222-1808(12)60208-4.

Sun X, Shi J, Ding G. 2017. Combined effects of arbuscular mycorrhiza and drought stress on plant growth and mortality of forage sorghum. Appl Soil Ecol 119: 384-391. DOI: 10.1016/j.apsoil.2017.07.030.

Wahyunto W, Supriatna W, Agus F. 2013. Land use change and recommendation for sustainable development of peatland for agriculture: Case study at Kubu Raya and Pontianak Districts, West Kalimantan. Indo J Agric Sci 11 (1): 32. DOI: 10.21082/ijas.v11n1.2010.p32-40.

Wang Z, Xu G, Xu H. 2017. Determining diversity of protozoa for bioassessment in coastal ecosystems using community-based dispersions. Ecol Indicators 72: 47-52. DOI: 10.1016/j.ecolind.2016.08.001.

Waongo A, Ba NM, Dabiré-Binso LC, Sanon A. 2015. Diversity and community structure of insect pests developing in stored sorghum in the Northern-Sudan ecological zone of Burkina Faso. J Stored Prod Res 63: 6-14. DOI: 10.1016/j.jspr.2015.05.002.