

Diversity of arbuscular mycorrhizal fungi in the habitat of *Nepenthes pitopangii* Lee along the Rore Kautimbu Hiking Trail, Indonesia

Rahmawati Rahmawati^{ID*}, Yusran Yusran^{ID}, Gilang Ramadhan Syahputra^{ID}, Irmasari Taha^{ID}, and Kartika Megawati^{ID}

Department of Forestry, Faculty of Forestry, Tadulako University, Jl. Soekarno-Hatta Km. 9, Palu, Central Sulawesi, 94118, Indonesia. *E-mail: rahmawati89@untad.ac.id

Received: 07 February 2026 / Accepted: 15 May 2026 / Available online: 21 May 2026



Open Access: This work is distributed under the Creative Commons Attribution 4.0 License.

Abstract

Nepenthes spp. inhabit nutrient-poor environments where nutrient acquisition may involve not only carnivory but also interactions with arbuscular mycorrhizal fungi (AMF). However, information on AMF morphotype diversity associated with endemic *Nepenthes* species in tropical forest ecosystems remains limited. This study aimed to assess the diversity of AMF in the rhizosphere of *Nepenthes pitopangii* along the Rore Kautimbu Hiking Trail, Central Sulawesi, Indonesia. Soil samples were collected from five sampling points, and AMF spores were isolated using wet sieving and decanting followed by centrifugation, and identified based on morphological characteristics. Six AMF morphotypes belonging to two genera, *Glomus* and *Acaulospora*, were identified, with *Glomus* as the dominant genus. Spore density varied among sampling points, while soil conditions were characterised by acidic pH and low phosphorus availability. These conditions may favour AMF occurrence, particularly *Glomus*, which appears to have higher ecological tolerance to nutrient-limited environments. This study provides initial ecological insights into AMF diversity associated with *N. pitopangii* and highlights the importance of plant-microbe interactions in nutrient-poor ecosystems. Further studies, incorporating root colonisation and molecular approaches, are recommended.

Key words: Central Sulawesi, mycorrhizal diversity, *Nepenthes* habitat, rhizosphere soil, spore density, spore morphology.

Introduction

Nepenthes spp. are commonly found in environments with limited nutrient availability, where plants rely on specialised strategies, such as carnivory to obtain essential nutrients (Lee et al. 2016). Un-

der such conditions, interactions with soil microorganisms may also contribute to nutrient acquisition. Arbuscular mycorrhizal fungi (AMF) are an important component of the soil microbial community and have been widely reported to enhance plant nutrient uptake, particularly under

nutrient-limited conditions (Brundrett et al. 1996). Therefore, examining the presence and diversity of AMF in the rhizosphere of *Nepenthes* is important for understanding plant–microbe interactions in nutrient-poor ecosystems.

One of the *Nepenthes* species found in Central Sulawesi is *Nepenthes pitopangii* Lee, an endemic species characterised by a maximum stem length of approximately 2 m and a preference for shaded habitats with moderate light intensity, where it is often found in locally aggregated patches within a heterogeneous (mosaic) vegetation structure (Khalid et al. 2015).

Lore Lindu National Park (LLNP) in Central Sulawesi is a designated conservation area with relatively intact forest ecosystems. Mount Rore Kautimbu, located within this national park, represents one of the habitats where *N. pitopangii* occurs naturally (Natalia et al. 2014).

Previous studies have indicated that carnivorous plants, such as *Nepenthes*, primarily obtain nutrients from captured prey; however, this strategy does not exclude the possibility of additional below-ground nutrient acquisition through symbiotic associations with soil microorganisms (Santiago and Darnowski 2012). Arbuscular mycorrhizal associations have also been reported in other carnivorous plant genera, such as *Drosera* spp. (Harikumar 2013), further supporting the potential role of AMF in nutrient acquisition under nutrient-limited conditions. Arbuscular mycorrhizal fungi have been reported in several carnivorous plant taxa, suggesting that plant–microbe interactions may complement carnivorous adaptations, particularly in acidic and nutrient-poor environments (Brundrett et al. 1996).

Previous research, conducted in the Lore Lindu area, has demonstrated that *Nepenthes* spp. can form associations

with AMF, with findings indicating the presence of genera like *Glomus* and *Gigaspora*, along with reported root colonisation in previous studies (Rahmawati et al. 2023). That study, however, focused primarily on colonisation status and species occurrence across multiple sites, without detailed examination of morphotype diversity or habitat-specific variation. In contrast, the present study focuses exclusively on AMF spore morphology and does not assess root colonisation.

Despite these findings, information on the diversity and distribution of AMF morphotypes associated with specific endemic *Nepenthes* species, particularly *N. pitopangii*, remains limited. In addition, the spatial variation of AMF communities within specific habitat gradients, such as along hiking trails in montane forest ecosystems, has not been well documented.

This study was conducted as an exploratory baseline assessment; therefore, no formal hypothesis was formulated. However, it is expected that AMF morphotype diversity in the rhizosphere of *Nepenthes pitopangii* reflects adaptation to acidic and nutrient-poor soil conditions. This study aims to provide initial ecological information on AMF morphotype diversity within a specific *Nepenthes* habitat, which may contribute to future research on plant nutrient-poor microbe interactions and conservation strategies in tropical forest ecosystems.

Material and Methods

Study area and sampling design

This study was conducted from July to September 2023. Soil samples were collected from the rhizosphere of *Nepenthes pitopangii* along a segment of the Rore

Kautimbu Hiking Trail within Lore Lindu National Park, Central Sulawesi, Indonesia. The study area can be generally classified as a montane tropical forest ecosystem. The sampling area extended from the trailhead (01°19'21.7"S, 120°18'29.3"E) to the helipad landing area (01°18'33.82" S, 120°18'33.04" E) (Fig. 1). Within this segment, five sampling points were established along the trail to represent local variability within the *N. pitopangii* habitat. The elevation of the sampling sites ranged from 1744 to 2080 m a.s.l. The selection of sampling points along the hiking trail was based on an exploratory approach aimed at capturing small-scale environmental variation within the habitat, rather than representing the entire spatial heterogeneity of the study area. The sampling points were defined based on

relative distances along the trail segment and are therefore not presented as exact geographic coordinates.

One sampling point was located in close proximity to *N. pitopangii* individuals (approximately 5–10 cm from the stem base) to represent rhizosphere soil, while the remaining four sampling points were distributed along the same trail segment to represent surrounding habitat conditions. At each sampling point, a single soil sample was collected to represent local conditions, and subsampling replication was not performed, as the study was designed as an exploratory baseline assessment focusing on descriptive patterns rather than statistical comparison. This sampling approach was intended to provide baseline descriptive information on AMF occurrence within the study area

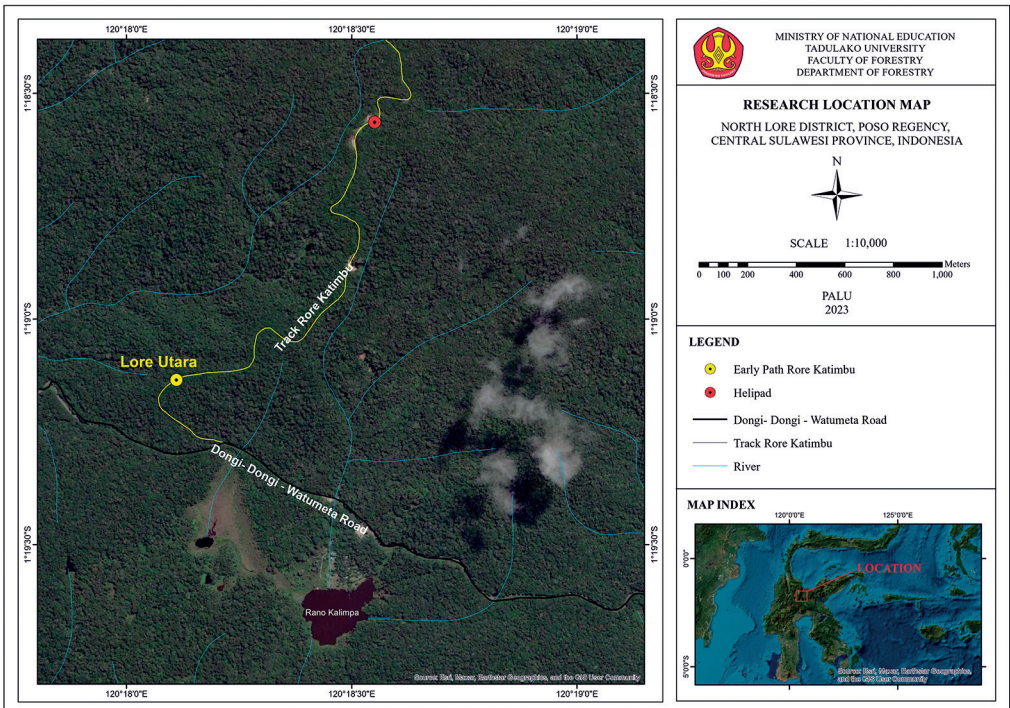


Fig. 1. Location of the study area and sampling sites.

rather than representing the full spatial heterogeneity of the habitat. In addition to *N. pitopangii*, the surrounding vegetation likely included other plant species that may serve as hosts for arbuscular mycorrhizal fungi, and therefore the observed AMF spores may not be exclusively associated with a single plant species.

Soil sampling and laboratory analysis

Soil samples from the five sampling points were treated as individual samples for AMF spore observation. For soil physico-chemical analysis, subsamples from each point were combined into a single composite sample to represent general habitat conditions and minimise local-scale variability. This approach was adopted to provide an integrated representation of the study area, consistent with the exploratory nature of the study.

At each sampling point, surface litter, such as leaves and small debris, was first removed prior to soil collection. Soil samples were then collected at a depth of approximately 10 cm. Approximately 1 kg of soil was collected from each sampling point, placed in labelled plastic bags, and transported to the laboratory for further analysis.

Spore isolation

The technique used for the isolation of arbuscular mycorrhizal fungi (AMF) spores was the wet sieving and decanting method (Pacioni 1992) without the addition of sucrose, followed by centrifugation (Brundrett et al. 1996). Intact spores that presumably contained lipid droplets were then counted. Spore density was calculated using Formula (1).

$$\text{Spore density} = \frac{\text{Number of spores}}{20 \text{ g soil}} \quad (1)$$

Spore density estimation was based on a single 20 g subsample taken from each sampling point, and replicate subsamples were not analysed in this study. Therefore, spore density values are presented as descriptive observations for each sampling point. The use of a 20 g soil subsample in this study follows the laboratory protocol applied during sample processing and differs from the approach reported in Rahmawati et al. (2023), where a different subsample weight was used. This difference reflects variation in sample handling procedures rather than inconsistency in the analytical method, and does not affect the descriptive interpretation of spore density within each study.

Spore morphology identification was performed at the genus level based on morphological characteristics, following the criteria provided by the INVAM database (International Culture Collection of (Vesicular) Arbuscular Mycorrhizal Fungi, West Virginia University). Identification was conducted based on spore colour, shape, size, hyphal attachment, and wall ornamentation. Spore observations were carried out using a stereomicroscope, while detailed morphological examination was performed using an Axio Imager microscope at 200× magnification. Due to the use of morphology-based identification, taxonomic resolution was limited to the genus and morphotype levels, and species-level identification was not confirmed by molecular analysis. Therefore, the results should be interpreted as an initial assessment of AMF diversity based on spore morphology, rather than a comprehensive taxonomic or functional characterisation. Species-level confirmation and verification of functional association with *Nepenthes pitopangii* require further molecular analysis and root colonisation assessment.

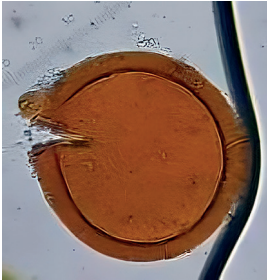
Results and Discussion

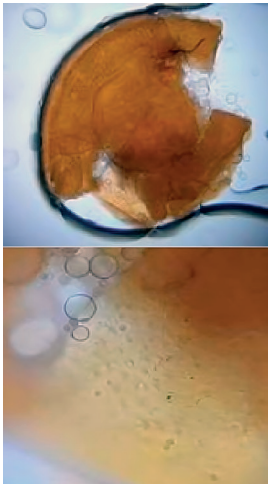
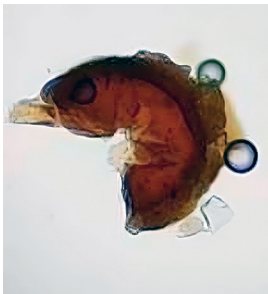
Diversity of AMF morphotypes

Based on the analysis of soil samples collected from five sampling points along the Rore Kautimbu Hiking Trail, six AMF morphotypes were identified, consisting of five *Glomus* spp. and one *Acaulospora* sp. Although five soil samples were collected, two *Glomus* morphotypes were identified within a single sampling point, resulting in a total of six morphotypes across the study area. The predominance of *Glomus*

morphotypes observed in this study suggests a potential ecological preference of this genus under the environmental conditions of the study site, particularly in acidic and nutrient-limited soils typical of *Nepenthes* habitats. This finding is consistent with previous observations in the Lore Lindu area, where *Glomus* was also reported as a dominant genus associated with *Nepenthes* spp. (Rahmawati et al. 2023), indicating a possible pattern of adaptation across similar habitats. A detailed description of the identified morphotypes is presented in Table 1.

Table 1. AMF morphotypes identified within the *Nepenthes* habitat zone along The Rore Kautimbu Hiking Trail, Central Sulawesi.

No	Morphotype	Description	Documentation
1	<i>Glomus</i> sp1.	Spores of the genus <i>Glomus</i> are light yellowish to brown in colour, with diameters ranging from 100 to 150 µm, and possess a single thick spore wall characteristic of <i>Glomus</i> , with spore-wall layers connected to the subtending hyphae	
2	<i>Glomus</i> sp2.	Spores of the genus <i>Glomus</i> are yellowish in colour, with a diameter of approximately 100 µm, and possess a single spore wall	
3	<i>Glomus</i> sp3.	Small spores of the genus <i>Glomus</i> are light yellowish to brown in colour, approximately 100 µm in diameter, with multiple clear spore-wall layers.	

No	Morphotype	Description	Documentation
4	<i>Glomus</i> sp4.	Spores of the genus <i>Glomus</i> are dark in colour, with a diameter of approximately 150 μm .	
5	<i>Acaulospora</i> sp1.	Spores of the genus <i>Acaulospora</i> are yellow in colour, with a diameter of approximately 300 μm , and possess both a spore wall and a germinal wall. Ornamentation is present on the spore wall, while a germination orb is observed on the germinal wall in a broken or separated condition.	
6	<i>Glomus</i> sp5.	Spores of the genus <i>Glomus</i> are brown in colour, with diameters ranging from 150 to 200 μm , and form only a spore wall.	

Note: The micrographs presented in Table 1 are intended as qualitative illustrations of spore morphology. As the original images were obtained without calibration or magnification metadata, scale bars cannot be added retrospectively without risking inaccuracies. Therefore, quantitative size information (spore diameter) is provided in the descriptions based on independent measurements. Some spores may appear partially fragmented, reflecting their condition during extraction and preparation and are presented to illustrate general morphological characteristics.

The dominance of *Glomus* spp. observed in this study may be closely related to the soil conditions within the study area, which are characterised by acidic pH and low nutrient availability. Variations in soil chemical and physical properties

are known to influence the distribution and composition of AMF communities (Suamba et al. 2014). Such environmental conditions are typical of *Nepenthes* habitats, where nutrient limitations may favour AMF genera with broader ecological tolerance and efficient nutrient acquisition strategies.

In this study, two arbuscular mycorrhizal fungal genera were identified, namely *Glomus* and *Acaulospora*. The predominance of *Glomus* may be associated with its higher adaptive capacity under a wide range of environmental conditions, particularly in acidic and nutrient-poor soils.

A similar pattern was reported by Rahmawati et al. (2023), where *Glomus* was identified as one of the dominant genera associated with *Nepenthes* spp. in the Lore Lindu area, along with *Gigaspora*. However, the absence of *Gigaspora* in the present study may reflect differences in microhabitat conditions, sampling focus, or spatial scale between the two studies, and may also be influenced by the limited number of soil samples examined.

This suggests that AMF community composition associated with *Nepenthes* may vary with local environmental conditions and habitat specificity, even within the same conservation area. The occurrence of AMF spores in soils surrounding plants can be influenced by the adaptive characteristics of different fungal genera (Saputra et al. 2015), as spores exhibit varying levels of environmental tolerance.

Glomus was the most frequently encountered genus in the present study, which may reflect its relatively high ecological adaptability compared to other genera. This genus has been reported to tolerate a wide range of environmental conditions (Yusriadi et al. 2018), whereas *Acaulospora* is generally considered to

have more specific environmental requirements.

Characteristics and ecological relevance of *Glomus* spp.

The genus *Glomus* (family Glomeraceae) is characterised by spores with variable colours, ranging from yellow to dark brown, and by the presence of multilayered spore walls typically lacking ornamentation, often associated with straight hyphal attachments (Nusantara et al. 2012). In this study, *Glomus* was the dominant genus across the sampling sites, which is consistent with its known wide ecological distribution and adaptability to diverse soil conditions.

The dominance of *Glomus* may indicate its ability to persist under acidic and nutrient-limited conditions typical of *Nepenthes* habitats, suggesting a potential ecological advantage over other AMF genera in such environments. *Glomus* is widely reported as one of the most frequently encountered genera of arbuscular mycorrhizal fungi in various ecosystems (INVAM 2013).

Characteristics and ecological occurrence of *Acaulospora* sp.

The genus *Acaulospora* is characterised by relatively thick spore walls with variable ornamentation and typically consists of two wall layers, with the inner wall containing a germination orb (Sanana et al. 2022). Spore colour ranges from yellow and orange to dark reddish brown (INVAM 2013). In contrast to *Glomus*, *Acaulospora* was identified in only one sampling point, indicating a more limited distribution within the study area. This limited occurrence may reflect narrower ecological tolerance or specific habitat requirements compared

to *Glomus*, particularly under the prevailing soil conditions of the study site.

Soil chemical properties in relation to spore density and AMF morphotype distribution

Based on the analysis of soil samples collected from five sampling points within the *Nepenthes pitopangii* habitat zone, two AMF genera were identified, namely *Glomus* and *Acaulospora*.

Glomus was the most frequently encountered genus across the five sampling locations, which may reflect its broader ecological distribution and adaptability compared to other AMF genera.

This distribution pattern suggests that soil environmental factors may play an important role in shaping AMF community composition within the study area. The identification results from the five sampling locations along the Rore Kautimbu Hiking Trail are presented in Table 2.

Table 2. Distribution of AMF morphotypes and spore density across five sampling sites along the Rore Kautimbu Hiking Trail.

Sample location	Morphotype	Number of spores per 20 g sample
1	<i>Glomus</i> sp1.	2
1	<i>Glomus</i> sp2.	2
2	<i>Glomus</i> sp3.	21
3	<i>Glomus</i> sp4.	8
4	<i>Acaulospora</i> sp1.	1
5	<i>Glomus</i> sp5.	5

Spore density values are presented descriptively, as samples were analysed without replication and no statistical comparison among sites was performed.

The temperature and relative humidity at the sampling sites were approximately 22 °C and 75.9 %, respectively. The results of soil chemical analysis are present-

ed in Table 3.

Table 3. Chemical and physical properties of soil in the study area.

No	Parameter	Value	Unit
1	pH H ₂ O (1:2.5)	4.82	-
2	pH KCl (1:2.5)	3.65	-
3	Organic C	3.62	%
4	P ₂ O ₅ HCl 25%	7.27	mg per 100 g
5	P (Bray)	0.69	ppm
6	Texture class	silty clay loam	-

The soil texture classification based on particle size distribution is illustrated in Figure 2.

The occurrence of AMF morphotypes observed in this study appears to be influenced by the soil conditions at the sampling sites. The soil was characterised by acidic pH and low phosphorus availability, which are typical of *Nepenthes* habitats.

Such conditions are known to favour mycorrhizal associations, as plants growing in nutrient-poor environments may rely more on symbiotic interactions to enhance nutrient uptake. Previous studies have shown that soil properties, including pH and nutrient availability, can influence the distribution and abundance of arbuscular mycorrhizal fungi (Yusriadi et al. 2018, Sanana et al. 2022).

In this study, the dominance of *Glomus* across the sampling points may be associated with its ability to tolerate acidic soil conditions and adapt to a wide range of environmental factors. This is consistent with the higher spore counts recorded at certain sampling points (e.g., location 2), suggesting that local microenvironmental conditions may enhance the proliferation of specific AMF morphotypes. The low phosphorus content observed in this study may further support the presence of AMF, as mycorrhizal associations play an important role in facilitating phosphorus

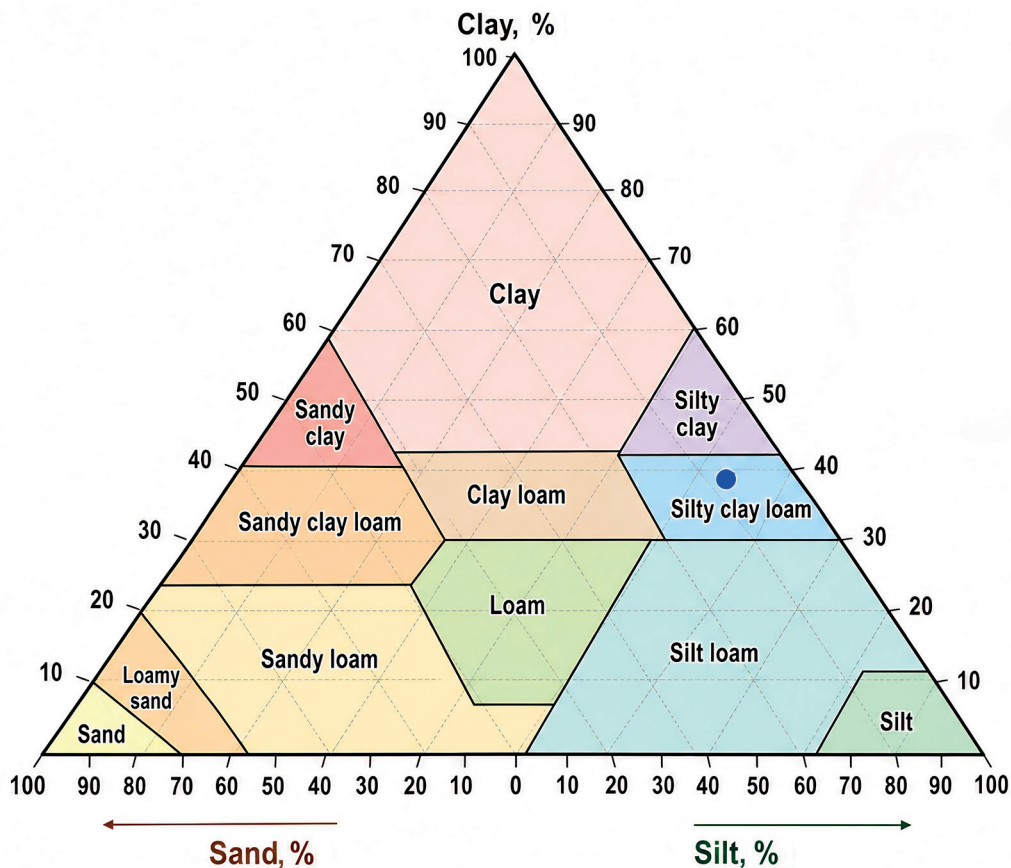


Fig. 2. Soil texture triangle showing the classification of the composite soil sample as silty clay loam based on particle size distribution (sand 12.4 %, silt 58.8 %, clay 28.8 %).

uptake under nutrient-limited conditions (Yusriadi et al. 2018, Sanana et al. 2022).

The soil texture was classified as silty clay loam based on particle size distribution according to the USDA soil texture classification, although the laboratory description referred to it as 'lempung liat berpasir'. Organic carbon content, which was relatively moderate, may contribute to microbial activity and provide favourable conditions for AMF development. The silty clay loam texture may also influence AMF distribution by regulating soil aeration, water retention, and root penetration, which are key factors for fungal growth

and spore formation.

Environmental factors, such as temperature, may also influence AMF development. The recorded temperature (approximately 22 °C) falls within the range considered suitable for fungal growth (Nurhalimah et al. 2014). However, it should be noted that soil chemical properties in this study were derived from composite analysis, and therefore the relationships between soil parameters and AMF distribution should be interpreted cautiously as general habitat level patterns rather than point-specific correlations.

Overall, the combination of acidic soil conditions, low phosphorus availability, and suitable environmental factors may contribute to the presence and distribution of AMF morphotypes in the *Nepenthes* habitat. These findings provide preliminary ecological insights into AMF distribution in a specific *Nepenthes* habitat; however, further studies integrating root colonisation assessment, replicated sampling, and molecular approaches are required to better understand the functional role of AMF in this ecosystem.

Conclusions

This study provides baseline information on the diversity of arbuscular mycorrhizal fungi (AMF) in the rhizosphere of *Nepenthes pitopangii* along the Rore Kautimbu Hiking Trail, Central Sulawesi. The results revealed the presence of two AMF genera, namely *Glomus* and *Acaulospora*, with *Glomus* being the dominant genus across the sampling sites. This dominance suggests that *Glomus* may have a greater ecological tolerance to acidic and nutrient-limited soil conditions typical of *Nepenthes* habitats, indicating a potential role in supporting plant adaptation in such environments. As an exploratory study, these findings highlight the variability of AMF community composition within a specific habitat and provide initial ecological insights into plant-microbe interactions associated with endemic *Nepenthes* species.

Further studies incorporating root colonisation assessment, replicated sampling, and molecular identification are required to better understand the functional role and ecological significance of AMF in *Nepenthes* ecosystems.

Acknowledgements

The authors gratefully acknowledge the Rector of Tadulako University for financial support, provided through the Excellent Research Fund of Tadulako University, Faculty DIPA, Postgraduate Programme, PSDKU Tojo Una-Una, under the Ministry of Education and Culture, Republic of Indonesia, Grant No. 6805/UN28/KU/2023 (dated 25 May 2023).

References

- BRUNDRETT M., BOUGHER N.L., DELL B., GROVE T.S., MALAJCZUK N. 1996. Working with Mycorrhizas in Forestry and Agriculture. Australian Centre for International Agricultural Research, Canberra, AU. 374 p.
- HARIKUMAR V.S. 2013. Are there arbuscular mycorrhizal associations in carnivorous plants *Drosera burmanii* and *D. indica*? Botanica Serbica 37(1): 13–19. <https://www.researchgate.net/publication/261100312>
- INVAM 2013. International Culture Collection of (Vesicular) Arbuscular Mycorrhizal Fungi, The Pennsylvania State University. Available online: <https://invam.wvu.edu/> (accessed 16 Feb 2026).
- KHALID I., MALLOMBASANG S.N., IRMASARI I. 2015. Distribution pattern of pitcher plants (*Nepenthes* spp.) on Mount RoreKautimbu in the Lore Lindu National Park area [Pola penyebaran (*Nepenthes* spp.) di Gunung RoreKautimbu kawasan Taman Nasional Lore Lindu]. Jurnal Warta Rimba 3(2): 9–14 (in Indonesian).
- LEE L., ZHANG Y., OZAR B., SENSEN C.W., SCHRIEMER D.C. 2016. Carnivorous Nutrition in Pitcher Plants (*Nepenthes* spp.) via an Unusual Complement of Endogenous Enzymes. Journal of Proteome Research 15(9): 3108–3117. <https://doi.org/10.1021/acs.jproteome.6b00224>
- NATALIA D., UMAR H., SUSTRI 2014. Distri-

- bution pattern of pitcher plant *Nepenthes tentaculata* Hook.f. in Mount Rorekautimbu, Lore Lindu National Park [Pola penyebaran kantong semar (*Nepenthes tentaculata* Hook.f.) di Gunung Rorekautimbu kawasan Taman Nasional Lore Lindu]. *Warta Rimba* 2(1): 35–44 (in Indonesian). <https://scispace.com/pdf/pola-penyebaran-kantong-semar-nepenthes-tentaculata-hook-f-18o3g7ls4h.pdf>
- NURHALIMAH S., NURHATIKA S., MUHIBUDDIN A. 2014. Exploration of indigenous vesicular–arbuscular mycorrhiza (VAM) in Regosol soils of Pamekasan, Madura [Eksplorasi Mikoriza Vesikular Arbuskular (MVA) Indigenous pada Tanah Regosol di Pamekasan, Madura]. *Jurnal Sains Dan Seni Pomits* 3(1): 2337–3520 (in Indonesian). <https://media.neliti.com/media/publications/15377-ID-eksplorasi-mikoriza-vesikular-arbuskular-mva-indigenous-pada-tanah-regosol-di-pa.pdf>
- NUSANTARA A.D., BERTHAM R.R.Y.H., MANSUR H.I. 2012. Working with arbuscular mycorrhizal fungi [Bekerja Dengan Fungi Mikoriza Arbuskula]. Bogor, Indonesia: SEAM-EO BIOTROP. 82 p. (in Indonesian).
- PACIONI G. 1992. Wet-sieving and Decanting Technique for the Extraction of Spores of Vesicular-arbuscular Fungi. In: Norris J.R., Read D.J., Varma A.K. (Eds), *Methods in Microbiology*. Chapter 16, Academic Press, San Diego, CA, USA: 317–322.
- RAHMAWATI R., MEGAWATI K., YUSRAN Y. 2023. Arbuscular mycorrhizal fungi status of *Nepenthes* spp. around Lore Lindu National Park, Central Sulawesi, Indonesia. *Forestry Ideas* 29(1): 94–108.
- SANANA S.T.S., ASMARAHMANN C., RINIARTI M., DURYAT D. 2022. Diversity of arbuscular mycorrhizal fungi in the rhizosphere of post-gold mining revegetation areas at PT Natarang Mining [Keanekaragaman Fungi Mikoriza Arbuskular Pada Rhizosfer Areal Revegetasi Lahan Pascatambang Emas PT Natarang Mining]. *Jurnal Belantara* 5(1): 81–95 (in Indonesian). <https://doi.org/10.29303/jbl.v5i1.844>
- SANTIAGO Y., DARNOWSKI D.W. 2012. Mycorrhizal formation by various carnivorous plants. *Carnivorous Plant Newsletter* 41: 4–7. https://cpn.carnivorousplants.org/articles/CPNv41n1p4_7.pdf
- SAPUTRA B., LINDA R., LOVADI I. 2015. Arbuscular vesicular mycorrhizal fungi (MVA) in the rhizosphere of three soil types of Nipah banana (*Musa paradisiaca* L. var. *nipah*) in Pontianak Regency [Jamur Mikoriza Vesikular Arbuskular (MVA) Pada Tiga Jenis Tanah Rhizosfer Tanaman Pisang Nipah (*Musa paradisiaca* L. var. *nipah*) di Kabupaten Pontianak]. *Protobiont* 4(1): 160–169 (in Indonesian).
- SUAMBA I.W., WIRAWAN I.G.P., ADIARTAYASA W. 2014. Isolation and identification of arbuscular mycorrhizal fungi (AMF) by microscopy in the rhizosphere of citrus (*Citrus* sp.) plants in Kerta Village, Payangan District, Gianyar Regency [Isolasi dan Identifikasi Fungi Mikoriza Arbuskular (FMA) secara Mikroskopis pada Rhizosfer Tanaman Jeruk (*Citrus* sp.) di Desa Kerta, Kecamatan Payangan, Kabupaten Gianyar]. *E-Jurnal Agroekoteknologi Tropika* 3(4): 201–206 (in Indonesian). <https://ojs.unud.ac.id/index.php/jat/article/view/10839/9094>
- YUSRIADI, PATA'DUNGAN Y.S., HASANAH U. 2018. Density and diversity of arbuscular mycorrhizal fungi (AMF) spore communities in the root zones of several food crops in agricultural land of Sidera Village [Kepadatan dan Keragaman Spora Fungi Mikoriza Arbuskula pada Daerah Perakaran Beberapa Tanaman Pangan Di Lahan desa Sidera]. *Jurnal Agroland* 25(1): 64–73 (in Indonesian).