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Exploring ectomycorrhiza in peat swamp forest of Nyaru Menteng Palangka Raya Central Borneo

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Abstract

The ecosystem of peat swamp forest was found unique and stable in regulating the balance in water system as well as maintaining diversity of flora, fauna and microbes. Peat swamp forest destruction due to fire, illegal logging, or forest conversion into industrial and agricultural areas would spoil balance in biological ecosystem in the forest. This research, therefore, aimed to obtain information on fungi as ectomycorrhiza in peat swamp forest. This research is categorised as explorative observation using surveying method delivered in peat swamp forest of Nyaru Menteng, Palangka Raya, Central Borneo. Samples were obtained randomly from under a forest stand planted on 35 sample points. The results of the observation revealed that there were 15 species of fungi which were potential to be ectomycorrhiza, such as *Russula* sp.1*, Russula* sp.2*, Russula* sp.3*, Russula* sp.4*, Russula* sp.5*, Russula aerugine, Russula minutula, Hygrocybe* sp. 1*,* dan *Hygrocybe* sp. 2*, Scleroderma* sp.*, Amanita* sp.*, Collybia* sp.*, Lycoperdon* sp.*, Lepiota* sp.*,* dan *Laccaria* sp. Of those kinds, 48.04% were dominated by Russulaceae family. Basidiocarp was found to be associated with a stand of Angiospermae, more like the kind of *belangiran* (*Shorea balangeran*, Dipterocarpaceae), nyatoh (*Palaquium* sp., Sapotaceae), guava (*Syzygium* sp., Myrtaceae), *geronggang* (*Cratoxylum arborescens,* Hypericaceae), wood charcoal (*Diospyros* spp., Ebenaceae), rubber (*Hevea brasiliensis,* Euphorbiaceae), or trees of Gymnospermae such as melinjo (*Gnetum gnemon,* Gnetaceae). The abundance of basidiocarp Russulaceae presumably related to the nutrient content of the soil in the form of C - organic and P very high element.

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Introduction

Peat swamp forests in Indonesia now decrease in number due to both legal and illegal logging, function swift from forest to agricultural areas and dwellings, which mainly contribute to the destruction of peat swamp forests impacting on environmental damage.

There are 3.010.600 ha of peat swamp forest in the Province of Central Borneo (Anshari *et al*., 2010), while another source reveals that there are 4.361.304 ha (Government of the Province of Central Borneo, 2008). Some parts of the forest have suffered from serious damage due to the channel development supporting peat swamp project, illegal logging, and forest fire occurring almost every year during drought. As a consequence, flora, fauna and indigenous microbes such as mycorrhiza within the peat ecosystem are prone to extinction. The abundant diversity of trees within the forest involves meranti, ramin, jelutong, gemor, pulai rawa and bintangor. Those trees are known to be symbiotically correlated with ectomycorrhiza in a natural way within the ecosystem of peat swamp forest at varied levels of colonisation (Tawaraya *et al*., 2003). Ectomycorrhiza, potential as a host plant, comprises the following fungi: *Amanita muscaria, Laccaria leccata, Boletus edulis, Lactarius deliciosus, Pisolithus tinctorius, Hebeloma crustuliniforme,* dan *Cenococcum geophilum* (Smith and Read, 2008). In indonesia, ectomycorrhiza stemming from a family of Sclerodermataceae is found to be associated with melinjo *(Gnetum gnemon)*, pine, and dipterocarp. Tata (2013) believed that forest and its biotic components consisting of flora, fauna and microbes such as ectomycorrhiza serve as a provider which supports ecosystem, offering human beings nature to cultivate.

Ectomycorrhiza is a form of mutualistic symbiosis occurring between fungi on the roots of higher plants which produce macroscopic basidiocarp, commonly known as bio-tropic stability differentiator in an ecosystem. Ectomycorrhiza gives benefits to plants such as assisting in nutrient uptake in plants by increasing root surface, altering phosphoric element (P) from unavailable state due to being bound by complex ions such as Al and Fe into available state, playing an important role in nutrition cycle and productivity of trees in forests (O'dell *et al*., 1999; Jayakumar and Tan, 2005; Rosling and Rosenstock, 2008; Pradeep and Vrinda, 2010; Riniarti, 2010).

As estimated, there are about 5000-7750 species of macrofungi as ectomycorrhizza, which are associated with woody plants, such as those from the family of Betulaceae, Fagaceae, Pinaceae, Caesalpinaceae, Dipterocarpaceae, Myrtaceae, Casuarinaceae, Acaciaceae, and Gnetaceae, in the ecosystem of boreal forests with temperate and tropical climates (Ishida *et al*., 2007; Agarwal and Sah, 2009; Jha and Kumar, 2011; Pala *et al*., 2012; Turjaman, 2013). These fungi are capable of forming basidiocarp supporting reproduction. Basidiocarp could be formed either above soil surface (epigeous) or below ground (hypogeous). Basidiomycetes forming ectomycorrhiza involves family of Russulaceae, Cortinariaceae, Entolomataceae Hygrophoraceae, Tricholomataceae, Amanitaceae, Boletaceae, Agaricaceae and Sclerodermataceae (Brundrett *et al*., 1996).

Degrading peat swamp forests lead to lower number of forest resources; without natural regeneration and vegetation, forest will be dominated by ferns and shrubs (Turjaman *et al*., 2011; Sidiyasa, 2012). In a forest ecosystem, ectomycorrhiza plays a significant role in tree regeneration and ecological function of several terrestrial ecosystems (Kennedy *et al*., 2007; Agarwal and Sah, 2009; Kranabetter *et al*., 2009). Turjaman *et al* (2011) reports that *Boletus* sp. and *Scleroderma* sp. are capable of increasing the growth of *Shorea balangeran* on peat soil either during nursery or at field. *Shorea balangeran* (Dipterocarpaceae) is one of some types of trees which gives significant wood produce grown on peat soil in Indonesia. In heath forests with podzolic soil type, organic decomposition runs slow due to being soaked in water, and because of its high acidic level, Boletus, Entroma, Cortinarius, Amanita, and

Tricholoma are mostly found in such areas (Turjaman, 2013). As many as 273 types of Basidiomycetes forming dipterocarp were found in primary peat swamp forests in Sebangau, Central Borneo. This type of mushroom is edible and cultivated for medicine besides its capability of forming mycorrhiza (Putir, 2007). Meanwhile, around the downstream of watershed in Kahayan, several dipterocarps were found around peat swamp forest in Nyaru Menteng, where 22 families and 40 types of Basidiomycetes mushrooms existed, some of which were ectomycorrhiza such as *Russula, Schizophyllum, Marasmius, Collybia, Filoboletus, Naematoloma, Mycena, Ramaria, Lepiota, Laccaria, Clavariadelphus, Calvaria, Amanita, Bolbitius,* and *Pisolithus* (Mulyani *et al.*, 2009). This research, therefore, aimed to obtain information on fungi as ectomycorrhiza in peat swamp forest.

Materials and methods

Observation Site

The observation was carried out in a peat swamp forest in Nyaru Menteng, Palangka Raya, Central Borneo from April to July, 2013. Geographically, the site of the observation lies on 113°47' east longitude and 2°03' south latitude. The area with 65.2 ha in width is topographically located at 40-60 m above sea level (Statistical Bureau of Palangka Raya, 2012). The soil was categorised into organosol, alluvial and regosol taken from alluvial source rocks with the physiographic land and drainage periodically soaked in water.

Thus, this land was categorised into peat swamp land, where the peat was 1-2 m in thickness (Natural Resource Conservation Service, Central Borneo, 2010) and the ripeness level was categorised into sapric (Analytical and Basic Laboratory of Palangka Raya University, 2013). The average rainfall was 228.78 mm per month, with the daily temperature of 27.55°C, and the average humidity level reached 85.75% (Meteorological Centre of Palangka Raya, 2013).

Obtaining Basidiocarps

Basidiocarps were obtained from under the stand of trees periodically. Samples were taken purposively from 35 sample points in the areas under the stands where basidiocarps were available. The basidiocarps were then put into transparent plastic bag, followed by describing and identifying the basidiocarps of fresh ectomycorrhiza based on morphological characteristics comprising size, shape, colour, texture of cap and the lower surface of the cap, and the base of basidiocarp of mushroom (Brundrett *et al.*, 1996). The condition of the area where the mushrooms grew, tree type, and distance to host tree were all recorded. To support the data collected, analysis on soil nutrient of some points representing the habitats of ectomycorrhiza basidiocarps were found.

Abundance of Ectomycorrhiza family

In order to obtain dominance proportion of ectomycorrhiza, percent abundance was measured by collecting and calculating the number of certain types of basidiocarps found before it was then compared to the total number of basidiocarps identified (Islam *et al.*, 2007).

Results and discussion

Types of Ectomycorrhiza

From the observation results, it was found that fifteen species of ectomycorrhiza were associated with the stand dominantly growing in the peat swamp forest with varied basidiocorps. Morphologically, the shape of basidiocarps found resembled the shape of umbrella (mushroom) and puffball, which was categorised into Basidiomycetes. Based on the result of morphological identification, the ectomycorrhiza found involved the family of Russulaceae: *Russula* sp.1, *Russula* sp.2, *Russula* sp.3, *Russula* sp.4, *Russula* sp.5, *Russula aeruginea, Russula minutula*; family of Sclerodermataceae : *Scleroderma* sp.; family of Hygrophoraceae : *Hygrocybe sp. 1, Hygrocybe sp. 2*; family of Agaricaceae : *Lycoperdon* sp., *Lepiota* sp.; family of Tricholomataceae: *Collybia* sp.; family of Hydnangiaceae : *Laccaria* sp. ; and family of Amanitaceae : *Amanita* sp.

Genus *Russula*

The colour of basidiocarp varies, from yellowish white, light brown, pink, to dark red (Fig. 1). The diameter of the mushroom cap ranged from 4-9 cm in average, with the smooth, soft, but delicate texture of the cap. The upper surface of the cap was flat, convex, and a little bit concave, with the wavy edge o the cap. Right under the cap was gill. The stalk was cylindrical with the length of the stalk ranging from 3.4 to 10 cm, and the base of the stalk was not bulgy (Fig. 2). The habitat of such mushroom is on soil with litter, shaded under the stand of *nyatoh* trees (*Palaquium* sp., *Sapotaceae*), guava (*Syzygium* sp., Myrtaceae), geronggang (*Cratoxylum arborescens*, Hypericaceae), and wood charcoal (*Diospyros* spp., Ebenaceae), blangeran (*Shorea balangeran*, Dipterocapraceae), rubber (*Hevea brasiliensis*, Euphorbiaceae), and melinjo (*Gnetum gnemon*, Gnetaceae). Those types of mushroom commonly grow well in peat swamp forests and other wet areas which are usually soaked with water (Sidiyasa, 2012). Pradeep and Vrinda (2010) agreed that genus Russula was generally found on soil surface (epigeous), and it grew solitarily, spreading to other areas such as under *Myristica malabarica* tree, *Vateria indica*, *Pongamia pinnata* and *Calophyllum apetalum*. Morina *et al.* (1992) observed that the trees generally associated with ectomycorrhiza involved the family of Pinaceae, Fagaceae, Caesalpinaceae, Betulaceae, Dipeterocarpaceae, Myrtaceae, Casuarinaceae, dan Acaciaceae.

Fig. 1. Genus *Russula*. A1-A2. *Russula* sp 1.; B1-B3. *Russula* sp 2.; C1-C2. *Russula minutula*.; D1-D3. *Russula* sp 3.; E. *Russula* sp 4.; F. *Russula* sp 5; G1_G2. *Russula aeruginea*.

Contrary to the results of this research, genus *Russula* was mostly found at medium dominance level of burnt forests, while such a genus was found at low dominance level of unburnt forests (Mardji, 2014). Pala *et al.* (2012) confirmed that 750 species of mycorrhiza found in the universe were categorised into the genus *Russula*. Moreover, it was reported that ectomycorrhiza from genus *Cantharellus, Laccaria, Russula,* and *Amanita* was associated with local endemic trees, such as *Hopea parviflora, Vateria indica, Myristica malabarica, Terminalia paniculata,* and *Dipeterocarpus indicus,* which mostly grow in Western Ghats forest (Pradeep and Vrinda, 2010). Symbiosis of potential ectomycorrhiza could occur on host trees of several habitats, and ectomycorrhiza colony represents the characteristics of forests.

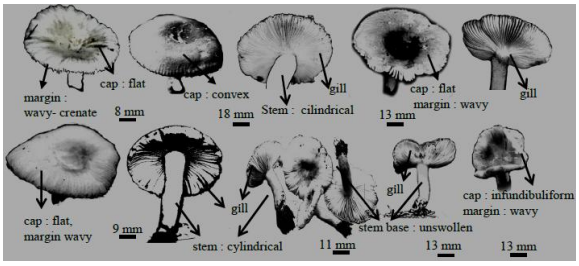

Fig. 2. Morphology of basidiocarp genus *Russula* (fam : Russulaceae).

Genus *Hygrocybe*

Two species of genus *Hygrocybe* such as *Hygrocybe* sp 1 and *Hygrocybe* sp 2, from the family of *Hygophoraceae*, were found. The basidiocarps of these genuses were usually red, yellow, and orange. They were in small size and medium (Fig. 3). The diameter of the cap ranged from 1.5-3.6 cm, with smooth texture and glossy surface. The cap surface was flat and conical resembling the shape of umbrella. The edge of the cap was usually smooth, soft and a bit wavy. The lower surface of the cap was in gill shape. The stalk was cylindrical, with its length reaching 2.5 cm in average. The base of the stalk was not bulgy (Fig. 4). The habitat of this mushroom was in dry spots, unshaded, and it grew near *melinjo* (*G. gnemon*) and rubber tree (*Hevea brasiliensis*), with some bushes and weeds *Ageratum conyzoides* all

around. To Dayak community in Central Borneo, genus *Hygrocybe* was called *kulat siaw* in their local language, meaning edible mushroom, and it is believed to maintain physical health. Local people usually collect the mushrooms taken from the forest and are sold in local traditional markets. The abundance of this type of mushroom depends on climate (Chotimah *et al.*, 2013). In Turkey, genus *Hygrocybe* is commonly found during summer to fall. *Hygrocybe* is scattered over unfertilised pasture, mossy surface with the soil condition ranging from acidic to neutral, sandy and argillaceous (Akata *et al.*, 2011).

Fig. 3. Genus *Hygrocybe*. A1-A2. *Hygrocybe* sp 1. B1-B2. *Hygrocybe* sp 2.

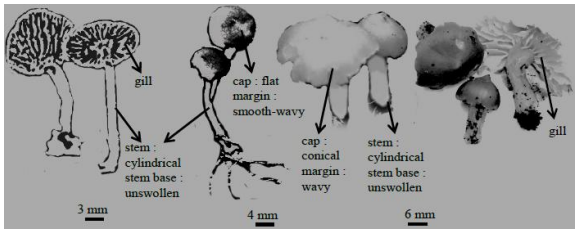

Fig. 4. Morphology of basidiocarp genus *Hygrocybe* (fam : Hygrophoraceae).

Genus Scleroderma

Genus *Scleroderma* is categorised into the family of Sclerodermataceae, in the genus of *Gasteromycetes*. Basidiocarp is in puffball shape called *gasterothecium*, a bright yellow to brownish periderm with coarse and hard surface texture. This mushroom has more spores than those of umbrella-shaped ectomycorrhiza with their light brown to black. The dense bundle of such spores is known as Gleba, formed in an enclosed basidiocarp. Spore wall is usually thicker and lasts longer in unpredictable environment (Darwo and Sugiarti, 2008). The average diameter of the puffball was about 4.6 cm, with no exact shape of stalk (Fig. 5). Ectomycorrhiza mushrooms grow in open and dry areas around their host trees, *melinjo* (*G.gnemon*). Basidiocarps grow either in colony or solitarily. Genus Scleroderma is known as edible mushroom found in India, which always comes to the liking of the local people (Tapwal *et al.*, 2013).

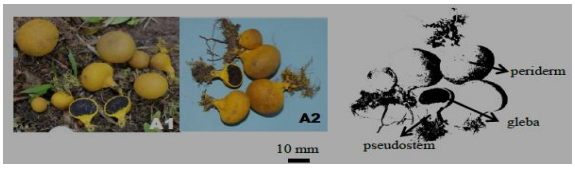

Fig. 5. Genus *Scleroderma*. A1-A2. *Scleroderma* sp. Morphology of genus *Scleroderma* (fam. Slerodermataceae).

Genus Collybia

Ectomycorrhiza of Collybia is categorised into the family of Tricholomataceae, where the basidiocarp is usually found in peat swamp soil with not too much litter, associated with the stand of belangiran trees (*Shorea balangeran*), known as meranti trees grown in swamp areas. This genus has small basidiocarps with convex cap. The diameter of the cap was around 1.5 – 3.5 cm in brown, with coarse texture and white gill on the lower part of the cap. The stalk had hard texture and was cylindrical with the average length of 5.5 cm. the base of the stalk was not bulgy (Fig. 6). In Kutai National Park forest, *Collybia* could be found in burnt forests (Mardji, 2014).

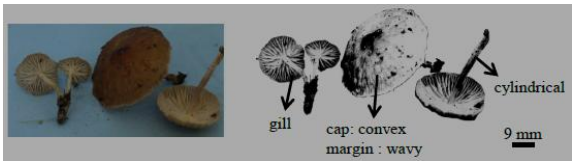

Fig. 6. Basidiocarp and Morphology of genus *Collybia* (fam. Tricholomataceae).

Genus Laccaria

Laccaria is categorised into the family of Hydnangiaceae, mostly found in the areas with temperate and tropical climate. In Peat swamp forests, basidiocarps were found to be associated with the stand of belangiran trees (*Shorea balangeran*) growing on the cracked soil with litter on it. The cap was convex, brown, and the centre of the cap was

white. The texture of the cap was coarse. The diameter of the cap was 4.5 cm in average, and the lower part of the cap was brown gill. The average length of the stalk was 5 cm, white, and was not bulgy on the base of the stalk (Fig. 7). *Laccaria* was found in the areas of the unburnt forests within the area of Kutai National Park, East Borneo (Mardji, 2014). *Laccaria* could be associated with several types of trees such as those of Pinaceae, Fagaceae, and Betulaceae.

Fig. 7. Basidiocarp and Morphology of genus *Laccaria* (fam. Hydnangiaceae).

Genus Lepiota

Lepiota is categorised into the family of Agaricaceae. The basidiocarp was white. The cap was flat, while it is parabolic when it's still young. The texture of the cap was smooth, and the edge of the cap was striate. The average diameter of the cap was 4 cm, and the lower part of the cap was gill. The stalk was cylindrical, and the average length of it was 3 cm. The base of the stalk was not bulgy (Fig. 8). The habitat was around the open area. This type of mushrooms grows under the stand of Nyatoh trees (*Palaquium* sp.), and on soil with litter.

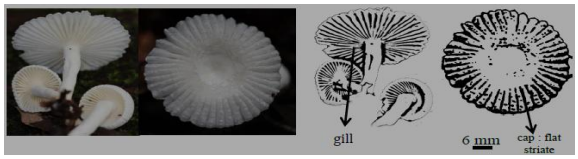

Fig. 8. Basidiocarp and morphology of genus *Lepiota* (fam. Agaricaceae).

Genus Lycoperdon

Lycoperdon is categorised into the family of Agaricaceae. The basidiocarp was puffball-shaped. This type of mushrooms grows under the stand of geronggong tree (*Cratoxylum arborescens*), on soil with litter shaded under the tree. The basidiocarp was brown, and the diameter of basidiocarp ranged from 2.3 to 3 cm. The exoperidium texture was coarse. When the mushroom was ripe, there was a hole on top of the surface of the cap through which the spores were released (Fig. 9). Apart from its function as ectomycorrhiza, the basidiocarp of *Lycoperdon* is edible when it is still young. Based on the analysis on nutrition, the basidiocarp contains protein, carbohydrate, fat and some micronutrients. Dominant fatty acids the bacidiocarp contains involve linoleate, oleate, palmitate, and stearate (Tapwal *et al.*, 2013). The inoculum of *Lycoperdon* was used to inoculate the seedlings of Sal tree (*Shorea robusta)* grown outside their natural habitat, and it managed to show higher growth (Pyasi, *et al.*, 2013).

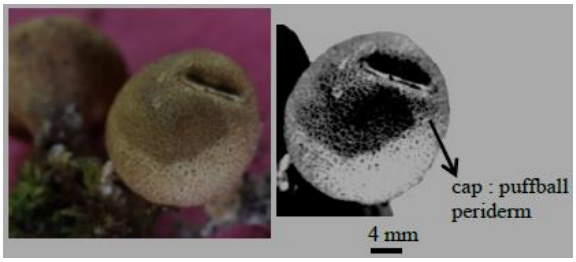

Fig. 9. Basidiocarp and morphology of Genus *Lycoperdon* (Agaricaceae).

Genus Amanita

Amanita is categorised into the family of Amanitaceae, into which 500 species are included. Most of this genus is poisonous. The cap was flat, and the surface of the cap was white to brownish grey. The average diameter of the cap was 5.1 cm and the edge of the mature basidiocarp was undulating-striate. The texture was smooth, and the lower part of the cap was white gill. The stalk was in cylindrical shape, white, central, and the average length of it was 11 cm. On the base of the stalk was a bit bulbous, and there was volva (Fig. 10). Its habitat was under Nyatoh tree (*Palaquium* sp), shaded, and on soil covered with litter. The genus of Amanita was mostly found in nature reserve of Hirpora, India. This genus is associated with conifer and deciduous trees (Pala, *et al.*, 2013). Such a genus is also found in burnt forest of Kutai National Park, but it is impossible to be found in unburnt forests (Mardji, 2014).

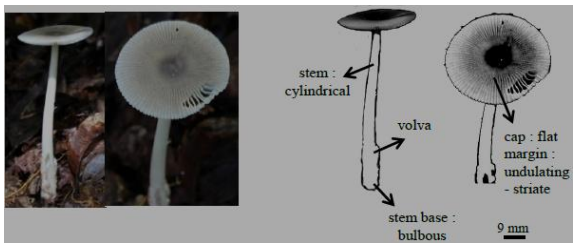

Fig. 10. Basidiocarp and Morphology of genus *Amanita* (fam. Amanitaceae).

The basidiocarp is usually found on soil surface (epigeous). Macroscopically, Ectomycorrhiza mushrooms are diverse in shape, size, colour, root and mantle surface geometry. In peat swamp forests, several types of ectomycorrhiza were associated with belangiran (*Shorea balangeran*) as their host tree, producing commercially valuable wood products. It was reported that several kinds of *Russula* could form ectomycorrhiza associated with different types of trees. *Russula bresives*, for instance, could have mutualistic symbiosis with *Pinus wallichiana* and *Abies lacicarpa* (Niazi *et al*., 2006).

Research results showed that several types of ectomycorrhiza could have symbiotic relation with one type of host plant. The basidiocarp was found to grow close to soil with litter, with the distance between basidiocarp and the stalk of host plant ranging from 9 cm to 2,5 m. Symbiosis between ectomycorrhiza and the tree or other plants results in carbohydrate needed such as sucrose and glucose. In reverse, mushroom mycelium could gain longer roots to reach further into soil. The carbohydrate is translocated from its source to root tissue and ectomycorrhiza (Pyasi *et al*., 2013). On the other hand, the ectomycorrhiza obviously provides nutrition for plants, supports the plant to grow, and serves as a biological control against pathogens, leading to fruitful forest reclaiming or peat swamp reclaiming. In addition, the availability of ectomycorrhiza mushrooms in the nature ecologically plays an important role in maintaining ecosystem balance, especially forest ecosystem, in addition to its value as natural herb (Pala *et al*., 2013).

Twieg *et al*, (2009) confirmed that the colony of ectomycorrhiza mushrooms in forest ecosystem could be affected by the composition of tree type, forest structure, the age of tree, and soil nutrients. Specification of ecology and host trees has an influence on the diversity of ectomycorrhiza (Ishida *et al*., 2007). The older the tree means the higher the chance for ectomycorrhiza to be associated with the tree. In the forest of *Shorea robusta*, Bangladesh, 45% association between ectomycorrhiza and its fifteen-year-old tree was found (Islam *et al*., 2007). Ectomycorrhiza mushrooms hold specific characteristics in term of types of host plants and condition of certain habitats. One kind of host tree has the possibility to have a symbiosis with several types of ectomycorrhiza, and vice versa. All families of Dipterocarpaceae were found to be associated with ectomychorrizha mushroom, where the ectomyco-rrhiza increases plant endurance against drought, high temperature, and organic and inorganic poison, and high soil acid (Islam *et al*, 2007). Such a condition comes as a hindrance mostly appearing in peat soil. High acid level of peat soil is caused by the release of organic humic and fulvic acids (Budianta, 2003).

The existence of ectomycorrhiza could positively influence the productivity of host trees and the growth of the seedlings either in Dipterocarpaceae forests or mixed forests of pines and broadleaf trees (Natarajan *et al*., 2005; Ishida *et al*., 2007). Russulaceae, Sclerodermataceae, and Boletaceae, as reported, were ectomycorrhiza associated with Dipterocarpaceae in Indonesia and Malaysia (Natarajan *et al*., 2005). Turjaman (2013) points out that the varied ectomycorrhiza mushrooms in tropical forests of Indonesia could be seen to grow on dipterocarp, pine, eucalyptus, castanopsis, and *melinjo*. Ectomycorrhiza mushrooms are mostly found in heath forest. In *Pinus merkusii* forest of Central Aceh, *Pisolithus, Scleroderma, Suillus, Boletus, Lactarius, Russula*, and *Amanita* are commonly found.

The number of basidiocarps of ectomycorrhiza found in the forest areas could serve as a bio-indicator of the forest ecosystem. Mardji (2014) agrees that unburnt forests have more diverse and number of ectomycorrhiza mushrooms than burnt forests. Peat forests are commonly delicate, meaning that clearing the forests may impact on the ecosystem, and putting it back may require a great deal of time. It is because the biotic components of the forests take years to interact with their environment. Peat is formed by litter of dead plants which is always soaked in water. This condition may lead to diverse plants and more number of basidiocarps in peat swamp forest. Different from the ecosystem condition in mixed forests of conifer and broadleaf trees, more number of ectomycorrhiza mushrooms (250 species) were found in such mixed forests (Ishida *et al*., 2007). In forests with endemic, indigenous, and exotic trees of Kerala, more than 160 types of ectomycorrhiza and the family of Russulaceae were found (Pradeep and Vrinda, 2010).

Climate has influence on basidiocarp formation. Ecologically, the formation of basidiocarps of macro musrhooms is different, depending on climatic condition. Precipitation, humidity, and temperature are the main factors contributing to the formation of basidiocarps in macrofungi, including ectomycorrhiza mushrooms (Hernandez and Linera, 2011; Tapwal *et al*., 2013). High rainfall during observation completely soaked forest ground, causing the roots of trees to be saturated. In such a condition, the oxygen supply either to the roots or for respiration was reduced, influencing symbiosis process between ectomycorrhiza and host plants. Furthermore, such a climate condition and life cycle of ectomycorrhiza mushrooms made the existence of basidiocarp difficult to investigate during observation. The life of basidiocarp was quite short during its growth, ranging from 2 to 3 days, but its production could last over three months during rainy seasons.

Basidiocarp of ectomycorrhiza does not exist at any time. In addition, some kinds of ectomycorrhiza types are rarely to form basidiocarp, especially under inclement weather such as drought and rainy seasons with too much rainfall. The development and growth of basidiocarp of ectomycorrhiza are triggered by external factors such as suitable microclimate and the availability of induction from host plants producing root exudates (Tata, 2013). In Turjaman *et al* (2011), ectomycorrhiza of *Boletus* sp. and *Scleroderma* sp. positively influences the increase in the growth of *Shorea balangeran* after 6 months of nursery and 40 months after seed transfer to field. Generally, *Sceroderma* spp. could be associated with *Shorea* spp. of *Shorea selanica, Shorea mesisopterik, Shorea seminis, Shorea balangeran, Shorea javanica, Shorea leprosula, Shorea, Shorea ovalis, Shorea johorensis* dan *Shorea crysophylla* (Riniarti, 2010).

Boletus sp. and *Scleroderma* sp. are known to be able to adapt well to the ecosystem of peat swamp forest, so that this type could support reforestation for degrading peat swamp forest. *Russula* spp. is categorised into dominant genus, where it is possible for such a genus to be applied on forest plants, horticultural plants, and crops. Pyasi *et al*. (2013) reported that the application of ectomycorrhiza inoculum such as *Lycoperdon compactum* and *Russula michiganensi* outside the real forest habitat of Sal tree (*Shorea robusta*) could help the growth of Sal seedlings in India.

Abundance of Family of Ectomycorrhiza.

Seven families were found to be associated with tree stand in peat swamp forest. The highest abundance of basidiocarp fell on the family of Russulaceae, followed by the family of Hygrophoraceae and Sclerodermataceae (Table 1). In dipterocarpaceae forests in India and Bangladesh, Russulacea, Amanitaceae, and Sclerodermataceae were dominant over other types of mushroom. In Malaysia and Indonesia, Russulaceae, Amanitaceae, and Boletaceae were mostly associated with Dipterocarpaceae (Natarajan *et al*., 2005; Islam *et al*., 2007), while in pine forests of North Sumatera, Russulaceae and Boletaceae were dominantly associated (Darwo and

Sugiarti, 2008). In a stand of eucalyptuses in East Nusa Tenggara, types of *Pisolithus, Scleroderma*, *Boletus, Suillus, Russula, Lactarius, Laccaria, Amanita,* and *Lepiota* were found (Turjaman, 2013).

Table 1. Family and number of ectomycorrhiza basidiocarps in peat swamp forest (per 35 sample points).

Family	Genus	Individual (basidiocarp)	Family Abundance (%)
Russulaceae	*Russula* sp.	49	48.04
Hygrophoraceae	*Hygrocybe* sp.	20	19.61
Sclerodermataceae	*Scleroderma* sp.	17	16.67
Agaricaceae	*Lepiota* sp.	8	7.84
	Lycoperdon sp.	2	1.96
Tricholomataceae	*Collybia* sp.	4	3.92
Hydnangiaceae	*Laccaria* sp.	1	0.98
Amanitaceae	*Amanita* sp.	1	0.98
Total number of individuals		102	100

In Islam *et al.* (2007), the association of ectomycorrhiza is higher when trees get older. In this research, the age of the trees was not recorded, but it was assumed that other factors may have contributed to the abundance of ectomycorrhiza basidiocarp on the forest ground. Ectomycorrhiza could increase macro and micro nutrient uptake which could help increase the growth of plants. Furthermore, it could also increase water uptake and endurance of plants against pathogens and drought. The colony and diversity of ectomycorrhiza in forest ecosystem were affected by the condition of host plants and soil nutrients. The formation of basidiocarp was triggered by environmental condition, especially rainfall, temperature, humidity, and soil chemistry. Bad environmental condition would affect the formation of basidiocarp. According to Hernandez and Linera (2011), the abundance of macrofungi, including ectomycorrhiza and its distribution are related to the composition and structure of the tree colony in habitats with temperate and tropical climate. Specifically, in tropical regions, the existence of macrofungi and their genus distribution are related to presipitation and type of vegetation. The growth of ectomycorrhiza mushrooms is also influenced by environmental factors such as light intensity, temperature, humidity, soil fertility, aeration, and root exudate (Mardji, 2014).

Peat swamp forests with acidic reaction has a potential to be poisoned by Al, to lack organic matters, to be prone to erosion, and to have small amount of nitrogen (N) and phosphorus (P). These nutrients may not be available for plants, especially P, due to the incapability of peat soil in retaining the P. Besides, the release of organic acids during the process of decomposition and high organic matters which compose the peat forests cause soil pH, P, K content and Alkali to be lower, which acts as hindrance for the chemical fertility of peat soil in both agricultural areas and forests (Table 2). Ectomycorrhizal mushrooms, those forming basidiocarp or not, perform symbiotic relation with trees in forests, and they play an important role in maintaining the stability of forest ecosystem. Ectomycorrhiza effectively absorbed P, which is generally and complexly bound with Al, Fe, Ca, and Mg in peat soil (Turjaman, 2013). There was a significant correlation between ectomycorrhizal mushrooms and the availability of organic P. The P availability was positively correlated with the abundance of two genuses of ectomycorrhiza such as *Rhizopogon vinicolor* and *Cenoccocum geophilum* (Twieg *et al*., 2008). P deficiency could limit the growth of ectomycorrhizal mushroom such as *Pisolithus tinctorius*.

Based on the criteria of soil fertility (Land Research Center , 1983) , soil acidity (pH) of peat forest classified as very sour, while the nutrients N , P , K , and C - organic where all basidiokarp ectomycorrhizal found was moderate to very high, except for the element K in zone 2 and 3 are low. The abundance of basidiocarp Russulaceae presumably related to the

nutrient content of the soil in the form of C - organic and P very high element. Jayakumar and Tan (2005) reported that in *Acacia mangium* seedlings inoculated with ectomycorrhizal *Pisolithus tinctorius* showed the rate of growth, the content of N and P were higher compared with non-inoculated seedlings. The abundance of ectomycorrhizal mushrooms were more influenced by the age of the trees instead of specific soil nutrients, because the nutrients were more affected by the quality of tree growth in the forest. Unlike in boreal forest, which has mineral soil, the soil nutrients serve as primary factors for ectomycorrhizal diversity (Rosling *et al.*, 2008). Tree density in peat swamp forests of Nyarung Menteng was 1.004 trees ha^{-1}, consisting of 64 species that became the main factors for the existence of ectomycorrhiza in keeping the stability of forest ecosystem (Sidiyasa, 2012).

Table 2. Soil nutrient conditions at sampling locations of basidiocarp.

Zone	Family of Ectomycorrhiza	C- Org (%)	N (%)	P (ppm)	K (me/100g)	pH H2O
Zone 1	Russulaceae Amanitaceae Entolomaceae	57.03	0.48	23.58	0.46	3.70
Zone 2	Hygrophoraceae Sclerodermatceae	54.81	0.44	56.52	0.36	3.74
Zone 3	Agaricaceae Tricholomataceae	57.16	0.43	53.00	0.28	3.66

*) Analisys of soil Lab. Basic and Analytic University of Palangka Raya.

Conclusion

Fifteen genuses of ectomycorrhizal mushroom found in peat swamp forest of Nyaru Menteng comprised *Russula* sp.1, *Russula* sp.2, *Russula* sp.3, *Russula* sp.4, *Russula* sp.5, *Russula aerugine, Russula minutula, Hygrocybe sp. 1, Hygrocybe sp. 2., Scleroderma* sp., *Amanita* sp., *Collybia* sp., *Lycoperdon* sp., *Lepiota* sp., dan *Laccaria* sp. The highest abundance of basidiocarp fell on the family of Russulaceae (48.04%), followed by Hygrophoraceae (19.61%), and Sclerodermataceae (16.67%). The abundance of basidiocarp Russulaceae presumably related to the nutrient content of the soil in the form of C - organic and P very high element.

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