



## Linking ectomycorrhizal mushroom species richness and composition with dominant trees in a tropical seasonal rainforest

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### Abstract

Vegetation, elevation gradient and soil temperature are considered as major drivers of ECM fungi species richness. ECM sporocarps were collected during rainy seasons for two years to study the link between the distribution of ECM mushrooms with *Castanopsis echinocarpa*, *Parashorea chinensis*, and *Pittosporopsis kerrii* with varying elevations and soil temperatures, in a tropical rain forest Xishuangbanna, Yunnan, China. For each tree species, 60 trees of approximately the same size were selected, where half of them were growing at higher elevation levels and the rest at lower levels. The highest total counts of ECM fungi, as well as the highest species richness were produced by *P. chinensis* followed by *C. echinocarpa* and *P. kerrii*. Highest species richness was shown in September by *P. chinensis*, while *P. kerrii* trees had the lowest count of mushrooms across rainy seasons. Species of Boletales were recorded with highest species richness followed by species of order Agaricales around both *C. echinocarpa* and *P. chinensis*. ECM fungi count declined with increased elevation. Furthermore, fungi species richness increased positively with increased soil temperature in a tropical seasonal rainforest.

**Key words** – Ectomycorrhizal fungi – elevation – soil temperature – diversity – Xishuangbanna

### Introduction

Ectomycorrhizal (ECM) fungi are considered important and diverse symbiotic organisms that significantly enhance host plant nutrition. ECM macrofungi play a significant role in maintaining biodiversity, decomposition, nutrient transportation and carbon cycling (Hobbie et al. 1999, Lin et al. 2015). ECM symbiosis has been recorded in both temperate and tropical forests. In tropical forests ECM symbiosis is considered as rare, but recorded from many tropical forests (Ediriweera et al. 2020, Corrales et al. 2018). ECM plant species in tropical rainforests occur in low densities

with patchy distributions in a plant community dominated by arbuscular mycorrhizal plants (Smith et al. 2013).

Trees establish associations with ectomycorrhizal (ECM) fungi, whose diversity can approach 100 mushroom species within a single forest (Dickie et al. 2002, Courty et al. 2008, Smith & Read 2008). ECM mutualism is necessary for the growth of some native plant species, as nearly 90% of roots of some tree species are colonized by ECM fungi (Visser 1995). Despite this, little is known about what manages the community structures and distribution of root-associated mushrooms in forest systems (Leake 2001, Lilleskov et al. 2004). The manifestation of root-associated fungi may depend on different soil characteristics (temperature, moisture, nutrient availability) and the existence of favorable host plants (Taylor & Bruns 1999, Erland & Taylor 2002, Hillebrand 2004, Lentendu et al. 2011, Bahram et al. 2012, Tedersoo et al. 2014a).

Plant distribution alongside soils, temperature and precipitation, play the strongest roles in determining the underground diversity of root-associated fungi and many ECM fungi can colonize a vast range of plant species (Trappe 1977, Burke et al. 2009, Tedersoo et al. 2014 a,b), especially those belonging to Russulaceae and Thelephoraceae families (Horton & Bruns 2002, Izzo et al. 2005, Tedersoo et al. 2008). Additionally, certain ECM fungi are uniquely associated with specific tree host species (e.g. species of *Suillus* and *Rhizopogon* are unique to tree species belonging to the family Pinaceae) (Kretzer et al. 1996, Kretzer & Bruns 1999). Topography is a major proximate factor for measuring spatial distribution patterns in plant and mushroom species compositions (Costa et al. 2005, Bohlman et al. 2008). Topography is strongly linked to microhabitat gradients across soil water and nutrient availability at local scales (Balvanera et al. 2012).

Many studies have been carried out investigating the effects of influential factors on the distribution of soil biota (Zhang et al. 2010, Kuszegi et al. 2015, Luo et al. 2016). Until now, however, the collective interaction of factors like temperature and elevation on the distribution of ECM fungi across different vegetation in tropical forests has been overlooked. Therefore, this study presents research findings carried out on macrofungi identified in a seasonal tropical rainforest in Xishuangbanna Prefecture, Yunnan Province, China. The objective of the study was to determine the affinity of ECM fungi with tree species. Furthermore, we aim to investigate the potential effects of tree species, soil temperature and elevation on the richness and composition of ECM fungi associated with these trees. Additionally, we hypothesized that ECM fungi species richness changes in accordance with elevation and soil temperature.

## Materials & methods

### Study site

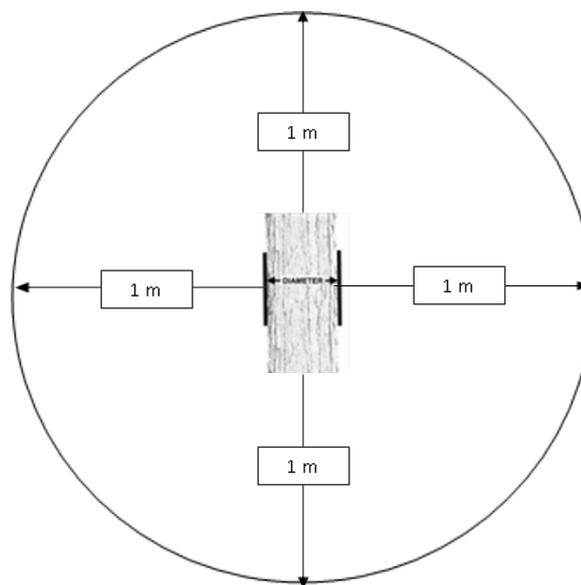
The seasonal tropical rainforest in Xishuangbanna is one of the most species-rich forest ecosystems in China (Cao & Zhang 1997, Lan et al. 2012) and is listed as a biodiversity hotspot. The site contains over 5000 species of vascular plants, comprising 16% of the total plant diversity in China and plays a critical role in global biodiversity conservation (Cao et al. 2008).

The site Xishuangbanna Tropical Seasonal Rainforest Dynamics Plot (XTRDP) was established in a *P. chinensis* forest at 101° 34' 26" ~ 101° 34' 47" E, 21° 36' 42" ~ 21° 36' 58" N, where the forest features a canopy 40~60 m high, with three distinct tree layers, a shrub and herbaceous layer. Plot elevation ranged from 709.27 to 869.14 m above sea level and the point of highest elevation was in the northwest area of the plot (Cao et al. 2008).

After establishing a 20-ha permanent plot, fieldwork included topographical mapping, corner post setting, tree tagging and an initial tree census, all of which began in April 2006 and were completed in June 2007, paving the path for a number of further studies and research on tropical rain forests. Major research has focused on the effects of climatic factors, tree species diversity in tropical forest vegetation, litterfall dynamics, soil dynamics, hydrological effects, forest structures, biogeographical studies and studies on biodiversity changes. With different studies (Ediriweera et al. 2020) initiated in 2014, we explored macrofungal diversity in XTRDP.

## Experimental design

For the experiment, two elevation levels were considered for the study as site 1 and site 2 where site 1 was < 760m of elevation and site 2 with elevation >760 m. Based on abundance and tree type trees of *Castanopsis echinocarpa*, *Parashorea chinensis* and *Pittosporopsis kerrii* trees with 10 cm DBH (Diameter at Breast Height) were selected using a random sampling method. For each tree species, 60 trees were selected in total, with 30 trees of each species for each site. The region of each tree with 10 cm DBH was painted red to facilitate identification and each tree was tagged with a unique code. Fungi were collected once every five days within a 1 m radius originating from the 10 cm DBH point of each tree during both rainy seasons where each season consisted of three months (August to October). Descriptions were made of collected fungi based on morphological characteristics and then fungi were dried in a portable dryer at 40°C for 24–48 hours before being sealed in Ziploc plastic bags containing silica gel as a desiccant. Dried specimens were separated and data about collected fungi were entered in a table created in MS-Excel. Soil temperature was measured weekly using CE IP65 Pen Type Digital Soil Thermometer.



**Fig. 1** – Considered area of a tree for mushroom collection

## Sporocarp Identification

Macrofungi collected from the study area were returned to the laboratory and examined. Apparent macromorphological characteristics such as colour, shape and size of the macrofungi cap, stipe, gills and other facets such as odor, taste, color changes and habitat were annotated. Spore prints were made to determine the colour of the basidiospores, which were then used for measurements. Guide books, monographs (Corner 1966, Guzman 1983, Phillips 1981, Moser 1983, Arora 1986) journal articles (Das et al. 2013, Itoo et al. 2013, Ovrebo & Baroni 2007, He et al. 2012) and online resources (<http://www.indexfungorum.org>, <https://www.mushroomexpert.com>) were used to identify the specimens up to species level and others to genus level. The taxonomic classification of species was based on Kirk et al. 2008, while Index Fungorum (2017) was used as the source of fungal nomenclature. After examination of specimens, they were dried in a portable food dryer for 24-32 hours at 35°C and sealed separately in plastic bags.

## Compilation of data

Collected data including tree number, number of macrofungi collected from each tree and names of species collected from each throughout the wet season were recorded separately. Three different codes were used for labeling the trees species: CE for *C. echinocarpa*, PC for *P. chinensis* and PK for *P. kerrii*. For the easy identification of trees, numbers from 1 to 60 were assigned (e.g.

PC1, CE1, PK 1). Statistical analysis was performed with statistical software SPSS (Statistical Package for Social Sciences).

### Data analysis

For data analysis, we used ANOVA Random Complete Block Design (RCBD), considering two different elevation levels as blocking factors, to analyze species richness across two different elevation levels. For multiple comparisons of three tree species and time of collecting season (Month) we applied Turkey's test and Dunnett's test. The Pearson correlation coefficient (R) was used to determine correlation between total number of mushroom species with soil temperature variation and along an elevation gradient.

### Results

Counts of ECM fungi species collected in August, September and October in two consecutive seasons were 21, 45 and 6 with relevance to *Castanopsis echinocarpa*, *Parashorea chinensis* and *Pittosporopsis kerrii* which shows a significant difference at least between two vegetation types where  $P < 0.05$ . The species richness of ECM fungi in upper elevation level and lower elevation level was significantly different with each level where  $P < 0.05$  and the species richness of ECM fungi in August, September and October was significantly different. The variation of count of ECM fungi species with relevance to both month and elevation was significantly different and obtained results are shown in table below (Table 1).

**Table 1** Effects on species richness of ECM fungi with relevance to different factors

Source	Type III sum of squares	df	Mean square	F	significance
ECM Species	6374.978	2	3187.489	579.732	.000
Elevation	2587.267	1	2587.267	470.465	.000
Month	1391.811	2	695.906	126.569	.000
Species * elevation	554.711	2	277.356	50.445	.000
Species * month	780.111	4	195.028	35.471	.000
Species * elevation * month	2870.067	4	31.878	5.798	.000

Among the values of species richness associated with *C. echinocarpa*, *P. chinensis* and *P. kerrii* the highest species richness was recorded from *P. chinensis* with a 45 mushroom species where it is significantly higher ( $P < 0.05$ ) compared to *C. echinocarpa* and *P. kerrii*. *C. echinocarpa* was recorded with 21 ECM fungi species where it was significantly different compared to *P. kerrii* ( $P < 0.05$ ) (Table 2).

**Table 2** Multiple comparisons for ECM species richness between host tree species

Host tree species	Host tree species	Mean difference	Standard error	Significance
<i>Castanopsis echinocarpa</i>	<i>Parashorea chinensis</i>	-3.22	.247	.000
<i>Parashorea chinensis</i>	<i>Pittosporopsis kerrii</i>	5.12	.247	.000
<i>Pittosporopsis kerrii</i>	<i>Castanopsis echinocarpa</i>	3.22	.247	.000
<i>Parashorea chinensis</i>	<i>Pittosporopsis kerrii</i>	8.34	.247	.000
<i>Castanopsis echinocarpa</i>	<i>Parashorea chinensis</i>	-5.12	.247	.000
<i>Parashorea chinensis</i>	<i>Castanopsis echinocarpa</i>	-8.34	.247	.000
<i>Castanopsis echinocarpa</i>	<i>Castanopsis echinocarpa</i>	3.22	.247	1.000
<i>Pittosporopsis kerrii</i>	<i>Castanopsis echinocarpa</i>	-5.12	.247	.000

With relevance to time of rainy season the species count of ECM fungi varies in August, September and October. The highest species count has been recorded in August with relevance to all three vegetation types where  $P < 0.05$ .

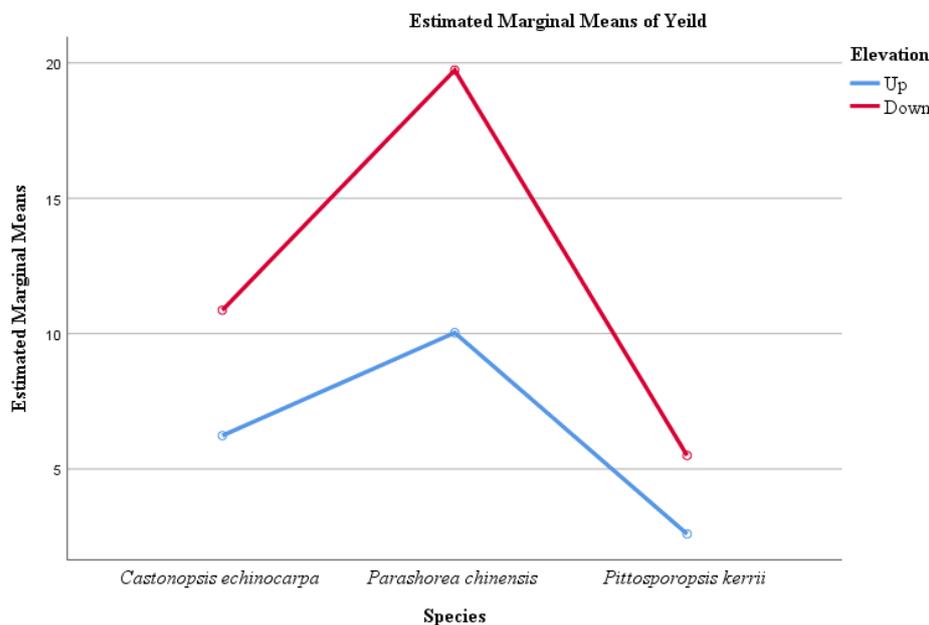
**Table 3** Multiple comparisons between time periods (Month) for the effect on ECM species richness

Month	Month	Mean difference	Standard error	Significance
August	September	3.84	.247	.000
	October	2.64	.247	.000
September	August	-3.84	.247	.000
	October	-1.21	.247	.000
October	August	-2.64	.247	.000
	September	1.21	.247	.000
August	October	2.64	.247	1.000
September	October	-1.21	.247	.000

The total species richness of ECM fungi in lower elevation level and upper elevation level in XTRDP during both collection seasons, the lower elevation level bears highest species richness in XTRDP where  $P < 0.05$ .

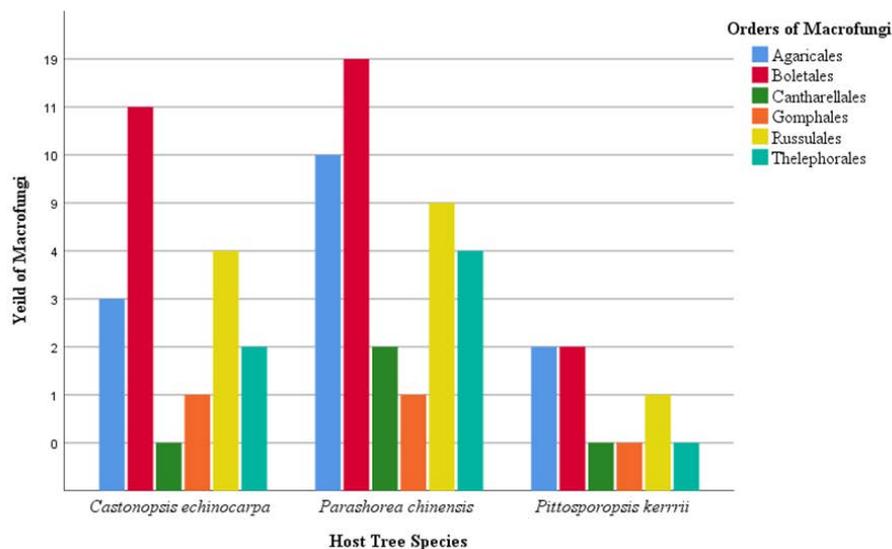
**Table 4** Pairwise comparison of ECM species richness at two elevation levels

Elevation	Elevation	Mean difference	Standard error	Significance
Upper	lower	-4.378	.202	.000



**Fig. 2** – Variation of ECM mushroom species richness in lower and upper elevation in XTRDP

The highest count of mushroom species were recorded from order Boletales, Agaricales and Russulales from *P. chinensis* followed by *C. echinocarpa*. Least counts were recorded by *P. kerrii*. An equal number of species were represented by order Gomphales from *P. chinensis* and *C. echinocarpa* whilst equal number of species were produced by order Cantharellales from *C. echinocarpa* and *P. kerrii*. Order Cantharellales, Gomphales and Thelephorales were equally presented in association with *P. kerrii* (Fig. 3).

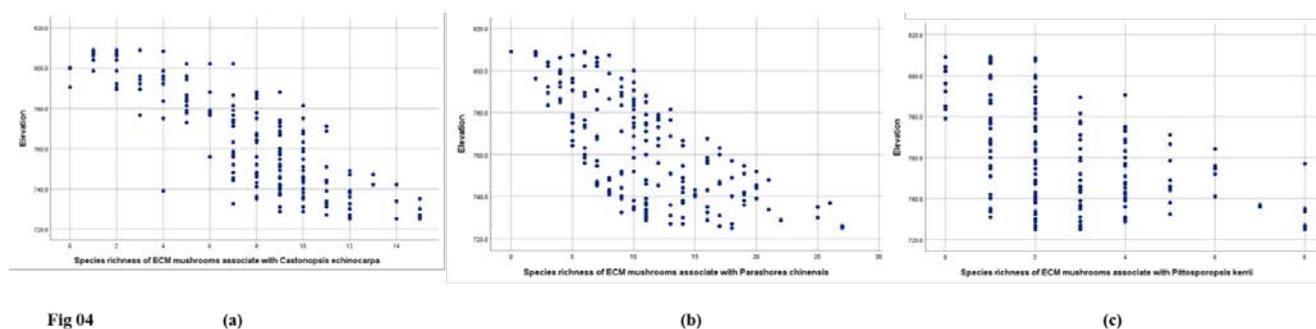


**Fig. 3** – Number of ECM mushroom species yielded from different Orders

Among the ECM species associated with *C. echinocarpa*, site 1 was dominated with fungi belong to order Agaricales and Russulales with 2 and 4 species respectively whilst site 2 was rich with species of Boletales and Thelephorales (Table 5). Seven ECM species have been found common to both sites in association with *C. echinocarpa*. In association with *P. chinensis*, site 1 was dominated with species of Agaricales (9 species), Russulales (7 species) and some species of Boletales while few ECM species of Cantharellales and Gomphales too were reported. In site 2, most recorded species were from Boletales with 7 species while 4 species were recorded from Thelephorales. ECM association with *P. kerrii* was recorded as very poor.

*Lactarius piperatus*, *Gyroporus castaneus*, *Thelephora terrestris*, *Thelephora palmate*, *Strobilomyces strobilaceus*, *Suillus luteus*, *Ramaria botrytis* and *Russula delica* were common to both *C. echinocarpa* and *P. chinensis*. *Laccaria laccata*, *Boletus badius* and *Amanita vaginata* were common to all host tree species while *Suillus grevillei* was common to *P. chinensis* and *P. kerrii*. *Russula albida* was the only recorded as common for *C. echinocarpa* and *P. kerrii*.

The total count of ECM fungi species produced in August, September and October in both seasons were significantly negatively correlated with elevation gradient ( $R = -0.499$ ;  $P < 0.05$ ) (Fig. 3). The correlation between ECM mushroom species richness with of *C. echinocarpa* and *P. chinensis* show strong significant negative correlation ( $R^2 = -0.832$ ;  $P < 0.05$ ,  $R^2 = -0.699$ ;  $P < 0.05$ ) and *P. kerrii* show moderate negative correlation between ECM species richness with elevation ( $R^2 = -0.533$ ;  $P < 0.05$ )



**Fig. 4** – Correlation of ECM fungi species richness associate with (a) *C. echinocarpa*, (b) *P. chinensis* and (c) *P. kerrii* with elevation gradient

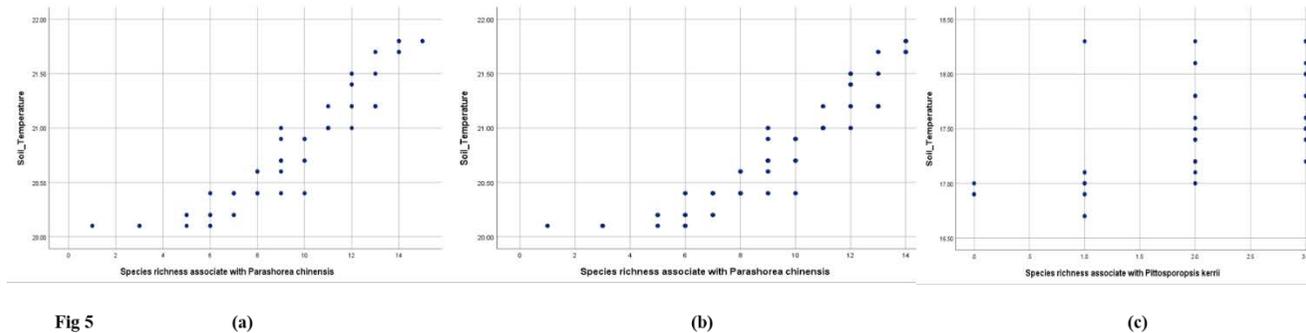
**Table 5** ECM fungi species recorded with relevance to each tree species in each site

Host tree species	Order	Site 1	Site 2	Common species to both sites
<i>Castanopsis echinocarpa</i>	Agaricales	<i>Cortinarius iodes</i> <i>Amanita vaginata</i>		<i>Laccaria laccata</i>
	Boletales	<i>Strobilomyces strobilaceus</i>	<i>Imleria badia</i> <i>Boletus sinoaurantiacus</i> <i>Boletus aereus</i> <i>Xerocomellus zelleri</i>	<i>Gyroporus castaneus</i> <i>Hortiboletus rubellus</i> <i>Suillus luteus</i> <i>Butyriboletus floridanus</i> <i>Suillus cavipes</i> <i>Sutorius eximius</i>
	Gomphales	<i>Ramaria botrytis</i>		
	Russulales	<i>Russula delica</i> <i>Russula cyanoxantha</i> <i>Lactifluus neuhoffii</i> <i>Russula albida</i>		
<i>Parashorea chinensis</i>	Thelephorales		<i>Thelephora palmata</i> <i>Thelephora terrestris</i>	
	Agaricales	<i>Cortinarius orellanosus</i> <i>Cortinarius fulviconicus</i> <i>Pseudosperma rimosum</i> <i>Laccaria amethystina</i> <i>Amanita flavorubescens</i> <i>Inocybe geophylla</i> <i>Amanita rubrovolvata</i> <i>Hygrophorus discoxanthus</i> <i>Amanita vaginata</i>		<i>Laccaria laccata</i>
	Boletales	<i>Paxillus involutus</i> <i>Suillus granulatus</i> <i>Strobilomyces strobilaceus</i> <i>Suillus grevillei</i> <i>Astraeus hygrometricus</i>	<i>Butyriboletus brunneus</i> <i>Boletopsis grisea</i> <i>Boletellus emodensis</i> <i>Imleria badia</i> <i>Boletus shiyong</i> <i>Phlebopus portentosus</i> <i>Pulveroboletus ravenelii</i>	<i>Caloboletus radicans</i> <i>Gyroporus castaneus</i> <i>Suillus luteus</i> <i>Xerocomellus chrysenteron</i> <i>Suillus placidus</i> <i>Caloboletus calopus</i> <i>Caloboletus firmus</i>
	Cantharellales	<i>Cantharellus vaginatus</i> <i>Cantharellus appalachiensis</i>		

**Table 5** Continued.

Host tree species	Order	Site 1	Site 2	Common species to both sites
	Gomphales	<i>Ramaria botrytis</i>		
	Russulales	<i>Russula virescens</i>		<i>Lactifluus neuhoffii</i>
		<i>Russula maculata</i>		<i>Russula crustosa</i>
		<i>Russula griseocarnosa</i>		
		<i>Lactarius pyrogalus</i>		
		<i>Russula claroflava</i>		
		<i>Russula delica</i>		
		<i>Russula violeipes</i>		
	Thelephorales		<i>Thelephora palmata</i>	
			<i>Thelephora terrestris</i>	
			<i>Thelephora ganbajun</i>	
			<i>Thelephora caryophyllea</i>	
<i>Pittosporopsis kerrii</i>	Agaricales	<i>Amanita vaginata</i>		<i>Laccaria laccata</i>
	Boletales			<i>Suillus grevillei</i>
	Russulales			<i>Imleria badia</i>
				<i>Russula albida</i>

Note – ECM fungi species recorded from both sites but recorded < 10 times from each site during the study were considered as common species to both sites



**Fig. 5** – Correlation of ECM fungi species richness associate with (a) *C. echinocarpa*, (b) *P. chinensis* and (c) *P. kerrii* with soil temperature

The mean soil temperature associated with each tree species was found to be significantly different (Fig. 5). Along the elevation gradient, ECM fungi species richness was significantly positively correlated with soil temperature, however this effect was most pronounced in the plots surrounding *C. echinocarpa* and *P. chinensis* ( $R^2 = 0.908$ ;  $P < 0.05$ ,  $R^2 = 0.937$ ;  $P < 0.05$ ), compared to *P. kerrii* ( $R^2 = 0.664$ ;  $P < 0.05$ ).

## Discussion

The results of our study show that the forest soils associated with *Parashorea chinensis* in the study area have a significantly greater species richness of ECM mushrooms than that of the areas surrounding *Castonopsis echinocarpa* and *Pittosporopsis kerrii*. These findings are in agreement with the work of Corrales et al. (2018) who reported that *P. chinensis* of family Dipterocarpaceae is the best host that forms ECM symbiosis in region of Southeast Asia. Smith et al. 2013 also reported that tree species within *Dipterocarpaceae* host large numbers of ECM fungi when compared against other tree families, such as *Fagaceae*. Singh (1966) reported evidence for the first time on species richness of ECM fungi associate with Dipterocarpaceae from Southeast Asia confirming 13 ECM associations from Malaysia and Hong too published species list of ECM fungi associated with Dipterocarpaceae in 1979 (De Alwis & Abeynayake 1980, Alexander & Hogberg 1986, Corrales et al. 2018).

ECM fungi species belong to Agaricales, Boletales, Russulales and Thelephorales has been reported from tropical rainforests in previous studies. Also it is reported that number of vital ECM associations are dominated across tropical environments despite the contrasting information reported on rareness of ECM lineages in tropics (Tedersoo et al. 2009, 2012). ECM fungi belong to *Amanita*, *Russula*, *Lactarius* and *Boletus* report wide outbreak across tropical forests (Tedersoo et al. 2009, Tedersoo & Smith 2013, Corrales et al. 2018). The Pantropical distribution shown by these species reveal that these ECM species are well adopted to tropical environment.

With relevance to all three tree species considered for the present study, count of ECM fungi species shows a noted decline with rising elevation. Species belong to order Agaricales and Russulales were dominated with higher species counts in site 1 (at lower elevations) while *Boletus* species were dominated in site 2 (at higher elevation) with affinity of *C. echinocarpa* and *P. chinensis*. This phenomenon of species decline at higher elevations was explained by Kernaghan & Harper 2001, Jang & Hur 2014 elaborating declining numbers of fungi species with increasing elevation in tropical rainforests (Kernaghan & Harper 2001, Jang & Hur 2014). The cause for growth variability of mushrooms at different elevation levels can be attributed to two likely factors. First would be a loss of nutrients from upslope to downslope areas, thus a higher nutrient collection in the lower elevation areas within the study site, and secondly, a change in soil moisture, with dryer soils being more prominent upslope. Within our study site, the soil moisture content was greatest in the lower elevations compared to higher elevations. Past studies have shown that soil moisture is key for the production of ECM fungi, as given by the studies of Ohenoja & Metsanheimo 1982, Park et al. 1998, Hall et al. 1998.

The highest counts and levels of species richness of ECM fungi have been reported mid-rainy season over two years. This is well explained by Mani & Cao 2016 presenting information on nutrient release in the tropical rainforests of Xishuangbanna. Mani & Cao 2016 corroborate that soil nutrients do not increase immediately though litterfall is high in the late dry season. Drought precludes the function of decomposers to release large amounts of nutrients from the litter into the soil. From the beginning of the rainy season at the end of May, decomposition of litterfall surges, leading to increased soil nutrients in the middle of the rainy season, demonstrating a two month delay in nutrient release from litter to soil.

Among the species collected from the study, species belong to Boletales were counted as the highest around both *C. echinocarpa* and *P. chinensis*. This result has been proven with findings of Binder & Hibbett 2007 where they revealed that *Boletus* species are well known to form associations with Dipterocarpaceae and Fagaceae. It is reported that *Boletus* species represent 18 – 25% of all ECM fungi (Hawksworth et al. 1995) and in last twenty years number of *Boletus* species were recorded from tropical forests including novel species.

Among ECM fungi collected, *Laccaria laccata* showed higher abundance throughout the seasons without distinguishable differences at lower and higher elevations. Duponnois & Garbaye 1991 reported similar finding on *L. laccata* showing that *L. laccata*, as a common ectomycorrhizal fungi in hard woods. It is further elaborated by Duponnois & Garbaye 1991, Wilson et al. 2017,

Ediriweera et al. 2020) explaining that *L. laccata* has potential of growing under vast types of ecosystems and varying edaphic factors.

In our study *Thelephora* species were identified as ECM species restricted only to site 2 in association with *C. echinocarpa* and *P. chinensis* where moisture content of low compared to lower elevation levels of forest. This finding agrees with results revealed by Koide et al. 2007 where he explained these species are known as drought tolerant species where it fruits in low moisture levels and identified as “contact type” mycorrhizae (Agerer 2001). Studies have revealed that *Thelephora* species show higher diversity though their counts are underestimated due to inconspicuous fruitbodies (Koljalg et al. 2000, Tedersoo et al. 2014b).

Our study reveals that ECM fungi species richness positively correlates with soil temperature, similar to reports made by Park et al. 1998, Swaty et al. 1998, Clemmensen et al. 2006, Gange et al. 2007. Both Clemmensen et al. 2006, Gange et al. 2007 demonstrated further the fruiting of ECM fungi being correlated to temperature where the colonization of ECM mushrooms is enhanced by increasing temperatures. Furthermore, Rygielwicz et al. 2000 have reported that increasing temperature can change species abundance of ECM fungi.

Species richness associated with *P. kerrii* were very lower than ECM fungi counts associated of fungi and number of fungal with *C. echinocarpa* and *P. chinensis*. In this study *P. kerrii* was considered for the experiment as a participant forms Arbuscular mycorrhizal (AM) symbiosis to compare fungi yields obtained from *C. echinocarpa* and *P. chinensis*. Since *P. kerrii* is an arbuscular mycorrhizal tree, even the lesser number of ECM fungi species recorded due to roots of nearby tree species form ECM symbiosis. Among the few ectomycorrhizal fungi species found to associate with *P. kerrii*, *L. laccata* is found to have the highest count with *P. kerrii*. However, previous studies have found no evidence of association between *L. laccata* and *P. kerrii*.

The idea of rareness and nonexistence of ECM fungi in tropics established based on results of previous studies on AM symbiosis despite reported evidence on ECM associations in tropics (Malloch et al. 1980, Corrales et al. 2018). Scattered records on tropical ECM fungi has been caused miscommunication and poor synthesis. However, the idea of nonexistence and rareness of ECM associations persisted throughout 20<sup>th</sup> century. But with the easy access to tropical forests worldwide and improvement of different software tools have broadened the research opportunities from 1990s. Hence during last 20 years’ time field of mycology was widened with novel information gathered on ECM associations in tropics challenging the persisting idea of rareness and nonexistence of ECM fungi in tropics (Heinemann 1954, Singer 1963, Corrales et al. 2018, Ediriweera et al. 2020).

Globally, attempts of conserving fungi lack far behind of animals and plants. Maintenance of long-term data and field information is the most crucial factor for conservation of ECM symbiosis. Present study, as many, just produce a snapshot on ECM diversity and levels of affinity of different ECM species to host plants. Hence, for the identification of ECM relationships with different hosts and their variation with environmental factors, the foremost step should be to assemble extensive ECM studies with identification, compiling both species, environmental factors and improved attentiveness on ECM fungi conservation.

## Conclusions

Study site of the tropical rainforest is rich with more than 45 ECM species. The highest number of ECM fungi species are associated with *P. chinensis*, while the lowest affinity is shown with *P. kerrii*. Over the two-year period, ECM fungi species count peaked in September with respect to *P. chinensis*. Boletales species were shown to be dominated with both *C. echinocarpa* and *P. chinensis* followed by Order Agaricales while majority of Agaricales and Russulales were dominant in lower elevation levels. *Boletus* and *Thelephora* species found being restricted to upper elevations. Furthermore, species richness of ECM fungi species declined with increasing elevation and species richness levels increased positively with increasing soil temperature. Extensive studies analyzing ECM symbiosis could reveal the reasons behind the different distribution patterns, host specificity of ECM fungi and significance of the symbiosis in tropical forests.

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