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Observations of Arbuscular Mycorrhizas on Dipterocarpaceae Grown in Tropical Rainforest in China

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Abstract: The mycorrhizal colonization patterns, fungal spore density, species richness, occurrence frequency and relative abundance of arbuscular mycorrhizal (AM) fungi in the rhizosphere of Dipterocarpaceae plants grown in tropic rainforest in south China were investigated. Twenty-one Dipterocarpaceae species in 54 sites of 11 regions were involved in Yunnan Province and Hainan Island, China. Arbuscular mycorrhizal typical structures were observed for the first time in roots of *Parashorea chinesis* Wang Hsie, *Vatica astrotricha* Hance, *Dipterocarpus turbinatus* Gaertn.f., *Hopea exalata* Lin, Yang et Hsue, *Shorea assamica* Dyer, *S. robusta* Gaertn. and *H. hainanensis* Merr. et Chun. Sixty-four AM fungal species belonging to 7 genera were identified. Species richness and spore density of AM fungi varied from 1.43 to 5.04 and from 3.05 to 8.26 per 20 ml rhizospheric soil, respectively. *Glomus* and *Acaulospora*, *Glomus etunicatum* Becker and Gerd., *G. claroideum* Schenck and Smith, *G. dolichosporum* Zhang and Wang, *G. macrocarpum* Gerd. and Trappe, *Acaulospora spinosa* Walker and Trappe and *A. denticulata* Sieverding and Toro were dominant genera and species, respectively in the rhizosphere of Dipterocarpaceae in tropic rainforest of China.

Key words: Arbuscular mycorrhizal fungi · Dipterocarpaceae · spore density · species richness · relative abundance

INTRODUCTION

As the symbol of tropical rain forest, trees of the Dipterocarpaceae family are the most ecologically and economically important resource in tropical forest. Besides being the main source of very valuable tropical hardwood timber much in demand throughout the world, members of the Dipterocarpaceae also yield various other minor products such as resin and gums. At present, there are about 16 genera (520 species) in this family which distribute mainly in tropical Asia [1]. South China is the north edge of the distribution of Dipterocarpaceae. There are 13 species in 5 genera native to China and they are geographically distributed in southeastern Tibet, southern Yunnan, southern Guangxi and Hainan Island [2]. Presently, 29 species of this family have been planted and maintained in tropical China thanks to the national reservation and introduction programs. However, most of these species, including exotic trees, are endangered in China and attention has been raised for their sustainable development by the governments.

Arbuscular mycorrhizas evolved concurrently with the first colonization of land by plants some 450–500 million years ago and persist in most extant plant taxa [3]. Arbuscular mycorrhizas associations are the most widespread amongst the extant flora, occurring in the roots of most angiosperms and pteridophytes, along with some gymnosperms and the gametophytes of some lower plants like mosses and lycopods [4]. In recent years, there has been increasing interest in the arbuscular mycorrhizae of tropical rain forest plants [5-10]. For a long time, Dipterocarpaceae is believed to be ectomycorrhizal species [11-14]. Only a few reports have been published on the arbuscular mycorrhizal (AM) status of *Hopea odorata* [15], *Dipterocarpus macrocarpus* [16] and other 3 *Shorea* species [6]. Unfortunately, little has been known on the mycorrhizal status of Dipterocarpaceae in China [17]. Based on a broad field survey conducted in tropical Yunnan Province (Southwest of China) and Hainan Island (South of China), this paper presents the results on the AM status of 21 Diptericarpaceae tree species in these regions.

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MATERIALS AND METHODS

Site location: This study was conducted at 11 locations within the tropical Yunnan Province and the whole Hainan Island of China. Hainan Island lies in the climate zones of the tropical monsoon and the tropical ocean, with annual mean temperature of 22-26°C, annual rainfall at 1,600mm and annual mean sea water temperature at 27°C. Yunnan Province is located in the southwest boundary of China, between 20°8'32"-29°15'8"N and 97°31'39"-106°11'47"E. The south part of Yunnan Province is on the belt of the Tropic of Cancer, which is dominated by a tropical rainforest climate with the average temperature of 21°C.

Collection of soil and root samples: Soil and root samples were colleted according to the procedures described by Liu and Li [18]. Twenty-one Dipterocarpaceae species were involved from 54 sites in 11 locations (Table 1). Six soil samples with fine roots were randomly collected from the plant rhizosphere per tree species. Care was taken during collection of individual plants that roots could be positively identified as belonging to a particular plant. To make sure that the roots were connected to the sampled plants, root samples of host plants were usually traced back to the stem. Samples were collected from 20-50 cm soil. Samples of plant roots were returned to the laboratory for determination of root colonization. The soil samples were then air-dried in the shade at laboratory temperature for spore extracting, counting and identification.

Measurement of AM colonization: Fresh roots were processed by washing free of soil and cleared in 10% (w/v) KOH by heating to approximate 90°C in a water bath for 30-60 min depending on the lignin degree of the root and their pigmentation. The cooled root samples were washed and cut into 0.5 to 1.0 cm segments and stained with 0.5% acid fuchsin [19]. For each samples, eight slides with 20 root fragments each were mounted to examine vesicles, arbuscules and hyphae and colonized root tissue was evaluated as the proportion of total length of observed roots (percent root length colonized) under a microscope (BX50 Olympus microscope with Automatic Photomicrographic System). The type of arbuscular mycorrhizas and fungal structure were described.

Isolation and identification of AM fungi: Spores of AM fungi in aliquots (20 ml) of soil were extracted by wet sieving and sucrose density gradient centrifugation [20]. Morphological features of spore were described with a various treatments including water, lacto phenol, PVA and Melzer's reagent, respectively [21]. Fungal identification was based on the spore size, color, surface ornamentation and wall structure according to the procedure described by Schenck and Perez [22] and INVAM (http:// invam.caf.wvu.edu).

Measurement of species richness, spore density, frequency and relative abundance of AM fungi: Spore density, species richness, frequency and relative abundance of AM fungi were counted according to the methods described by Zhang *et al.* [23], the formulas were

Table 1: The description of species investigated in Dipterocarpaece, arbuscular mycorrhizal patterns of colonization, species richness and spores density of AM fungi in the rhizosphere of Dipterocarpaceae in tropic rainforest in China

Sample codes	Host plants	Sites	Soil types***	Tree ages (years)	Patterns of colonization**	Species richness	Spores density (Degree/ No. of samples)
D1	*Hopea hainanensis* Merr. et Chun	Puwen	LRE	28	h,v	3.17 c	3.83 f
D2	*Vatica xishuangbannaensis* G.D. Tao et J.H. Zhang	Puwen	LRE	22	h	2.66 d	4.54 ef
D3	*H. hainanensis* Merr. Et Chun	Puwen	PLRE	30	h,c	2.43 d	3.32 g
D4	*H. horgayensis* Trad-blot	Puwen	LRE	9	h,c,v	3.78 bc	3.21 g
D5	*Dipterocarpus tuberculatus* Roxb.	Puwen	LRE	20	h	2.13 de	4.87 e
D6	*H. odorata* Roxb.	Puwen	LRE	21	h,v	2.40 d	3.75 f
D7	*Shorea robusta* Gaertn.	Puwen	LRE	13	h,c,v	3.79 bc	3.80 f
D8	*H. mollissima* C.Y. Wu.	Puwen	LRE	15	h	1.97 e	7.76 ab
D9	*Parashorea chinesis* Wang Hsie	Puwen	LRE	23	ar,h,v	4.31 b	3.56 fg
D10	*D. turbinatus* Gaertn.f.	Puwen	LRE	20	ap, h	2.33 d	3.45 g
D11	*D. turbinatus* Gaertn.f.	Puwen forest farm	LRE	37	h	1.78 e	3.18 g
D12	*V. xishuangbannaensis* G.D. Tao et J.H. Zhang	Xishuangbanna	L	19	h	1.84 e	3.32 g

Table 1: Continued

Sample codes	Host plants	Sites	Soil types***	Tree ages (years)	Patterns of colonization**	Species richness	Spores density (Degree/ No. of samples)
D13	*H. hainanensis* Merr. Et Chun	Xishuangbanna	L	39	h	2.07 de	4.65 e
D14	*S. assamica* Dyer	Xishuangbanna	L	21	h	1.63 e	3.15 g
D15	*D. tuberculatus* Roxb.	Xishuangbanna	L	21	h	1.72 e	3.21 g
D16	*D. alatus* Roxb.	Xishuangbanna	L	22	h	3.03 cd	3.48 g
D17	*V. astrotricha* Hance	Xishuangbanna	L	39	h	2.52 d	3.09 g
D18	*H. hainanensis* Merr. et Chun	Xishuangbanna	L	26	h	1.81 e	3.51 g
D19	*S. robusta* Gaertn.	Xishuangbanna	L	12	h	1.77 e	3.13 g
D20	*D. intricatus* Dyer	Xishuangbanna	L	22	h	2.14 de	5.06 e
D21	*D. retusus* Bl.	Xishuangbanna	L	14	h	1.88 e	7.21 b
D22	*D. turbinatus* Gaertn.f.	Xishuangbanna	L	14	h	2.21 d	5.43 d
D23	*V. guangxiensis* S.L.Mo.	Xishuangbanna	L	11	ap,h	1.69 e	3.45 g
D24	*H. chinensis* Hand.-Mazz.	Xishuangbanna	L	11	h	1.67 e	3.44 g
D25	*D. zeylanicus* Thw.	Xishuangbanna	L	24	h	1.70 e	3.27 g
D26	*H. mollissima* C.Y.Wu.	Xishuangbanna	L	25	h	2.35 d	3.57 fg
D27	*H. horgayensis* Trad-blot	Xishuangbanna	L	36	h	3.36 c	4.06 f
D28	*Anisoptera laeris* Ridl.	Xishuangbanna	L	21	h	1.56 e	3.09 g
D29	*Shorea obtusa* Wall Teng	Xishuangbanna	L	17	h,v	1.62 e	3.43g
D30*	*P. chinesis* Wang Hsie*	Mengla	MRE	175	ap,ar,h,v,c	3.82 bc	7.83 a
D31	*D. turbinatus* Gaertn.f.	Mengla county	MRE	90	ar,h,v	3.45 c	6.46 c
D32	*V. astrotricha* Hance	Xinglong	L	8	h,v	1.58 e	3.05 g
D33*	*V. astrotricha* Hance	Wuzhi mountain	MRE	70	ap,ar,h,v,c	4.45 ab	7.87 a
D34*	*V. astrotricha* Hance	Diaoluo mountain	MRE	65	ap,ar,h,v,c	4.47 ab	7.76 ab
D35*	*V. astrotricha* Hance	Shimei bay	SS	85	ap,ar,h,v,c	4.86 a	8.26 a
D36*	*H. exalata* Lin, Yang et Hsue	Baoting	A	58	ap,ar,h,v	3.39 c	6.37 c
D37	*V. hainanensis* Chang var. parvifolia Chang var. nov.	Jianfengling forestry bureau	YS	35	h	1.49 ef	3.11 g
D38	*V. astrotricha* Hance	Jianfengling forestry bureau	YS	35	h	2.03 de	3.46 g
D39	*S. robusta* Gaertn.	Jianfengling forestry bureau	YS	35	ar,h	3.28 c	5.44 d
D40	*H. hainanensis* Merr. Et Chun	Jianfengling forestry bureau	YS	35	h	1.55 e	3.86 f
D41	*H. chinensis* Hand.-Mazz.	Jianfengling forestry bureau	YS	35	h	3.43 c	5.09 e
D42	*H. exalata* Lin, Yang et Hsue	Jianfengling forestry bureau	YS	35	ar,h	1.43 f	3.78 f
D43	*D. alatus* Roxb.	Jianfengling forestry bureau	YS	35	h	1.56 e	3.09 g
D44	*S. assamica* Dyer	Jianfengling forestry bureau	YS	35	ap,ar,h,v	3.81 bc	6.78 b
D45	*D. turbinatus* Gaertn.f.	Jianfengling forestry bureau	YS	35	ar,h,v	3.06 cd	5.67 d
D46	*H. mollissima* C.Y.Wu.	Jianfengling forestry bureau	YS	35	a,v	2.54 d	4.08 f
D47	*P. chinesis* Wang Hsie	Jianfengling forestry bureau	YS	35	ap,h	2.37 d	3.90 f
D48	*V. xishuangbannaensis* G.D. Tao et J.H. Zhang	Jianfengling forestry bureau	YS	32	h	1.98 e	3.07 g
D49	*H. horgayensis* Trad-blot	Jianfengling forestry bureau	YS	35	ap,h,v	3.36 c	5.66 d
D50	*V. astrotricha* Hance	Jianfengling mountain	CS	45	ap,h,v	4.27 b	6.39 c
D51*	*V. astrotricha* Hance	Bawangling mountain	L	70	ap,ar,h,v,c	5.04 a	8.07 a
D52*	*H. hainanensis* Merr. et Chun	Bawangling mountain	L	75	ap,ar,h,v	4.33 b	7.06 b
D53	*V. astrotricha* Hance	Danzhou	L	46	h,v	2.46 d	6.32 c
D54	*H. hainanensis* Merr. et Chun	Danzhou	L	45	h	2.09 de	4.05 f

Note: * means natural forest. **ap appressoria, ar arbuscules, h hyphea, v vesaicles, c coils. ***RE, latosolic red earths; PLRE, purple latosolic red earths; MRE, mountain red earth; YS, yellow soil; CS, coarse soil; L, latosols; SS, sandy soil; A, aquod. Different letters after each number mean significant difference between each treatment at p=0.05 level given below. Different grades were separated in order to decrease statistical error. Five spores were stipulated as a grade, namely, the first grade includes 1 to 5 spores, the second grade includes 6 to 10 spores and the rest may be deduced by analogy.

Species richness = times number of all AM fungal species appearance/number of all soil samples (1)

Spore density = sum of all AM fungal species grades/ number of all soil samples (2)

Frequency = number of present times of a AM fungal genera or species/number of all soil samples (3)

Relative abundance = number of grade of a AM fungal genera or species/total grade number of AM fungal spores in rhizosphere of a plant species ×100% (4)

RESULTS

The arbuscular mycorrhizal pattern of 21 Dipterocarpaceae species and arbuscular mycorrhizal fungal species richness and spore density in rhizosphere soils in 54 sites of were demonstrated in Table 1. Arbuscular mycorrhizal colonization was observed in all plant roots collected. Among them, frequent AM structures including appressoria, arbuscules, hyphea, vesicles and hyphal coils were presented in roots of *Parashorea chinesis* Wang Hsie (D30) and *Vatica astrotricha* Hance (D33, D34, D35 and D51). If at least vesicles and arbuscules were presented in roots, then the plant was regarded as arbuscular mycorrhizal plant. Six Dipterocarpaceae species, i.e. *P. chinesis* Wang Hsie (D9, D30), *D. turbinatus* Gaertn. f. (D31, D45), *V. astrotricha* Hance (D33, D34, D35, D51), *H. exalata* Lin, Yang et Hsue (D36), *S. assamica* Dyer (D44) and *H. hainanensis* Merr. et Chun(D52), were able to form arbuscular mycorrhizas. As we know that AM fungi of the genera *Scutellospora* and *Gigaspora* are not able to form vesicles during colonization, root samples of *S. robusta* Gaertn. (D39) and *H. exalata* Lin, Yang et Hsue (D42) may be considered to be AM plants as fungi from these two genera were presented in other ways. Generally speaking, 7 out of 21 Dipterocarpaceae species collected from 54 sites formed arbuscular mycorrhizas. There were significant differences of species richness and spore density among different Dipterocarpaceae species and sites. The species richness varied from 1.43 (D42) to 5.04 (D51) and the spore density from 3.05 (D32) to 8.26 (D35). The difference of species richness was significant between natural forest (7.60) and planted forest (4.21).

Sixty-four species of AM fungi belonging to *Acaulospora*, *Archaeospora*, *Gigaspora*, *Glomus*, *Paraglomus*, *Scutellospora* and *Entrophospora* were

Table 2: The frequency (F) and relative abundance (RA) of AM fungi on different species of Dipterocarpaece

Arbuscular mycorrhizal fungi	F(%)	RA(%)	Codes of host plants
Acaulospora (15 species)			
A. appendicola Rothwell and Trappe	12	1.5	D1, D4-6, D7, D9-11, D13, D21-22, D30, D32-35, D41, D44, D51-53
A. denticulate Sieverding and Toro	30	3.7	D1-2,D4,D6-7,D9-10,D12,D14,D16,D18-25,D27-31,D33-36,D42-45, D48-52, D54
A. dilatata Morton	13	1.5	D2-3,D5-8,D13,D15,D23,D29-36,D44, D51
A. elegans Trappe and Gerdemann	16	1.9	D4-7,D11,D13-17,D30-31,D33-36,D39,D41,D44-45, D49,D51-52
A. excavate Ingleby and Walker	12	1.5	D3-4,D7,D9,D16-17, D20, D22, D26, D27-31, D33-36,D39,D41,D44,D51-52
A. foveata Trappe and Janos	21	2.6	D1-4,D6-7,D9-11, D15-17, D2, D23, D26, D30, D31,D33-39,D41-45,D49-52
A. lacunose Morton	16	1.9	D2, D4, D7, D9, D14, D17, D19, D21, D24, D26-30, D33-39,D46-48,D50-54
A. laevis Gerdemann and Trappe	10	1.2	D1,D4,D6-7,D9-10,D23,D29-31,D33-36,D39, D50
A. mellea Spain and Schenck	9	1.2	D4,D-8,D11-13,D16,D20-22,D37-38,D47-48,D53-54
A. morrowae Spain and Schenck	11	1.3	D1-3,D6-7,D10,D14-15,D17-19,D30-36,D41,D45,D51-52
A. rehmii Sieverding and Toro	4	1.3	D9,D30-31,D33-36,D51-52
A. rugosa Morton	9	1.2	D7,D9,D23,D27-31,D32,D36,D42-44,D45,D49,D51-54
A. scrobiculata Trappe	13	1.6	D1-4,D9,16-19,D21-25,D37-39,D44-45,D47,D51,D53
A. spinosa Walker and Trappe	32	4.0	D1-13, D16-18, D21-22, D26-28,D31,D33-36, D39,D41,D44-46,D48,D50-51
A. tuberculata Janos and Trappe	9	1.1	D1,D4,D6-7,D10,D23,D29-31,D33-36,D41,D44-45,D49,D54
Archaeospora (2 species)			
Ar. gerdemannii (Rose, Daniels and Trappe) Morton and Redecker	7	1.0	D7,D9-10,D30-31,D33-36,D39,D41,D44, D50- 52
Ar. Leptoticha (Schenck and Sm) Morton and Redecker.	9	1.3	D2, D4, D7, D9, D13-14,D16-19, D28,D37, D40-41, D47-48

Table 2: Continued

Arbuscular mycorrhizal fungi	F(%)	RA(%)	Codes of host plants
Entrophospora (1 species)			
E. infrequens (Hall) Ames and Schneider	8	1.1	D4,D7,D9-10,D30-31,D33-36,D39,D41,D44, D50-52
Gigaspora (3 species)			
Gi. albida Schenck and Smith	10	1.2	D1,D4,D6-7,D9-10,D24-25,D29-31,D33-36, D39, D52
Gi. decipiens Hall and Abbott	9	1.1	D1,D4,D6-7,D10,D21-22,D30-31,D33-36,D41,D44-45,D49,D54
Gi. margarita Becker and Hall	13	1.6	D2-4,D7, D9,D16-17,D20, D22,D26, D27-31,D33-36,D38, D42,D44, D51-52
Glomus (38 species)			
G. aggregatum Schenck			
and Smith emend. Koske	18	2.2	D1-4, D6-7, D9-11, D15, D21, D23, D25, D30-31, D33-39,D43-45,D49-52
G. albidum Walker and Rhodes	8	1.0	D5-6,D8-9,D11,D30-31,D33-36,D39,D41,D44, D50-53
G. ambisporum Smith and Schenk	6	0.8	D1,D4, D9-10,D13-14,D23,D27,D33-36, D39, D51
G. caledonium (Nicol. and Gerd.)			
Trappe and Gerd.	10	1.1	D3-4,D6-8,D11-13,D16,D20-22,D37-38,D47-48,D51-54
G. canadense (Thaxter)			
Trappe and Gerdemann	6	0.8	D33-35,D51,D53
G. chimonobambusa Wu and Liu	8	0.9	D9-10,D30-31,D33-36,D43,D46
G. citricolum Tang and zang	11	1.4	D3-4, D8, D9, D16-17, D21-22,D25, D27-31, D33-36,D39,D41,D44,D51-52
G. claroideum Schenck and Smith	35	4.3	D1-11,D13,D16-19,D21-22,D24,D26-28,D32,D33-36,D39,D41-42,D44-46,D48,D50-51
G. clarum Nicolson and Gerdemann	21	2.6	D1-4,D6-7,D9-11,D15,D20,D22-23,D30-31,D33-39,D41,D43-45,D49-52, D54
G. constrictum Trappe	16	2.3	D2-7, D12,D13-17,D30-31, D33-36,D39,D41, D44-45,D49-52
G. convolutum Gerdemann and Trappe	3	0.4	D30,D37,D47
G. deserticola Trappe, Bloss and Menge	9	0.9	D1,D4,D6-7,D9,D23,D29-31,D33-36,D41,D44-45,D49,D54
G. diaphanum Morton and Walker	6	0.7	D3-4, D9-10,D13-14,D23,D27,D33-36, D39, D52
G. dimorphicum Boyetchko and Tewari	5	0.8	D4, D15-16, D30-31,D33-36,D50-52
G. dolichosporum Zhang and Wang	31	3.7	D1-9, D11-22, D26, D30-31,D33-37, D40-45, D49-52
G. etunicatum Becker and Gerd.	36	4.5	D1-12, D14, D16-27,D29-36,D39,D41,D44-45, D49-53
G. fasciculatum (Thaxt.)Gerd. and Trappe	7	2	D2, D6, D7, D9, D14-15,D28-31,D33-34,D37, D51-52
G. formosanum Wu and Chen	11	1.3	D1-4, D7, D9, D17,D19,D23,D29-34,D38-39, D47-48,D53-54
G. geosporum (Nicol. and Gerd.) Walker	8	0.7	D3, D6, D16-17, D20,D26, D30-31,D33-36,D38 D50-52
G. glomerulatum Sieverding	10	1.1	D4,D6-8,D11-13,D16,D19-22,D36,D47-48,D51-54
G. hoi Berch and Trappe	6	0.5	D10,D16, D20,D30-31,D33-36,D50-52
G. intraradices Schenck and Smith	8	0.9	D7,D8-10,D23,D30-31,D33-36,D39,D41,D44, D50-52
G. liquidambaris Wu and Chen	7	0.9	D4,D7,D30-31,D33-36,D49,D53-54
G. macrocarpum Gerd. and Ttappe	33	3.9	D1-13,D16-18,D20,D22-26,D29-36,D39,D41,D44-45, D49-52
G. magnicaule Hall	6	0.6	D24,D30,33-35,D41,D46,D49-52
G. manihotis Howeler,			
Sieverding and Schenck	9	1.0	D3,D6-7,D9,D23,D30-31,D33-36,D41,D44-45,D49,D51-52
G. microaggregatum Koske,			
Gemma and Olexia	21	2.6	D2-4,D6-9,D16-18,D20,D22,D25-26,D29-36,D38-39, D41,D49,D51-52
G. microcarpum Tul. and Tul.	19	2.5	D1, D4-6, D12, D16, D19, D21, D24, D29-31, D33-36, D38-39,D41, D51-52
G. mosseae (Nicol. and Gerd.)			
Gerd. and Trappe	23	2.7	D1-4,D6-7,D9-11,D13-15,D20,D22-23,D30-31,D33-39,D41,D43-45, D49-52, D54
G. pansihalos Berch and Koske	18	2.4	D1-3,D5-7,D8,D10-11,D15,D21, D23, D25, D30-31, D33-39,D43-45,D49-52
G. pustulatum Koske, Friese,			
Walker and Dalpe	12	1.5	D1-4,D7,D9,D17,D19,D23,D29-34,D38-39,D47-48, D53-54
G. reticulatum Bhattacharjee and Mukerji	9	1.0	D4,D6-7, D9-10, D14, D23, D29,D35-36,D38- 39, D41,D51-52
G. taiwanensis Wu and Chen	9	1.1	D3, D6, D16-17, D20,D26, D30-31,D33-36,D38 D50-52

Table 2: Continued

Arbuscular mycorrhizal fungi	F(%)	RA(%)	Codes of host plants
G. tenebrosum Berch	8	0.9	D4,D7,D9-10,D30-31,D33-36,D39,D41,D44, D50-52
G. tortuosum Schenck and Smith	10	1.2	D1-3,D6-7,D11,D15-16,D18-19,D33-36,D41,D45, D48-49,D51-52
G. versiforme (Karsten) Berch	20	2.3	D4,D7,D9,D11,D14-17,D21,D23-25,D27-28,D30-31,D33-36,D38-39,D41, D44, D51-52
G. sp.1	2	0.6	D30-31,D35
G. sp.2	2	0.6	D35,D51,D53
Paraglomus (1 species)			
P. occltum (Walker) Morton et. Redecker	7	0.9	D3, D7, D9, D27, D29-31,D33-36,D44,D50-52
Scutellospora (4 species)			
Scu. aurigloba Walker and Sanders	9	1.1	D4,D6-7,D9,D23,D29-31,D33-36,D41,D44-45,D49, D50-52
Scu. calospora Walker and Sanders	6	0.6	D1,D3-4, D9-10,D13-14,D23,D27,D33-36, D39, D51
Scu. nigra (Redhead) Walker and Sanders	3	0.7	D36,D41-42
Scu. reticulata (Koske, Miller and Walker) Walker and Sanders	10	1.2	D4,D9,D11-13,D16-17,D19-22,D36,D47-48, D51-54

isolated from rhizosphere of 21 Dipterocarpacea species in 54 sites. The occurrence frequency and relative abundance of AM fungi ranged from 2 to 36 and, 0.4 to 4.5, respectively. The occurrence frequency and relative abundance of each species were listed in Table 2. *Glomus etunicatum* Becker and Gerd., *G. claroideum* Schenck and Smith, *G. macrocarpum* Gerd. and Ttappe, *Acaulospora spinosa* Walker and Trappe, *G. dolichosporum* Zhang and Wang and *A. denticulata* Sieverding and Toro were dominant species and consequently the two genera were considered to be dominant in the surveyed regions.

DISCUSSION

Most trees in tropical forest might be associated with arbuscular mycorrhizas [8-10, 24-27]. The colonization of AM fungi might be very important in increasing seedling life rate of trees. Regarding to the mycorrhizal status of Dipterocarpaceae in the literature, two early reports by Shamsudin [15] and Chalermpongse [16] and a recent publication by Tawaraya *et al*. [6] were searched while others were only targeted on ectomycorrhizas (ECM). Lee and Alexander surveyed 7-month old seedlings of *Shorea leprosula* Miq. at three sites in the West Malaysia and they found that roots had well-developed ectomycorrhizas, but no observation on the arbuscular mycorrhizas [11]. Moyersoen investigated fungal richness of ectomycorrhizas and arbuscular mycorrhizas in tropical heath forest, but he did not find any Dipterocarpaceae trees infected by AM fungi [28].

Our results indicated that Dipterocarpaceae plants were able to form arbuscular mycorrhizas. In particular, arbuscules were observed in root samples of *P. chinesis*, *D. turbinatus*, *V. astrotricha*, *H. exalata*, *S. assamica*, *H. hainanensis* and *S. robusta*. This result agreed with the previous reports [6, 15, 16]. A potential reason to explain why the previous studies on ectomycorrhizas outweigh those on arbuscular mycorrhizas of Dipterocarpaceae is that young seedlings of the family are lack of root hairs and they may have less chance to be colonized by AM fungi in a short term.

In addition, the occurrence of arbuscules was lower than vesicles (Table 1) as we believe the survey season may affect the result of the present of arbuscules. Many researches pointed out that mycorrhizal colonization including hyphal colonization, vesicular colonization and arbuscular colonization, spore density and species diversity were influenced by seasonal variation [29-31]. Brundrett and Kendrick observed a gradual collapse of the arbuscules in *Erythronium americanum* from late autumn throughout the spring [32]. Important reductions in arbuscular content were also shown in winter cereals during the summer [33]. However, we cannot rule out the possibility that decrease of arbusculars was an adaptive mechanism formed chronically between AM fungi and Dipterocarpaceae plants. Toth and Miller have suggested that arbuscules could be digested by host cells when they are no longer needed for phosphorus transfer [34].

Species richness and spore density of AM fungi in the rhizosphere of Dipterocarpaceae plants varied with the difference of sites. Species richness and spore density of AM fungi in the rhizosphere of same plants were also significantly different. Species richness and spore density of AM fungi in natural forests were higher than those in plantations. One of the possible reasons might be the disturbance in plantation areas [5].

Some AM fungi of *Acaulospora* and *Glomus* were dominant in the rhizosphere of Dipterocarpaceae plants, since 82.8% of the encountered AM fungi were within the two genera, while *Archaeospora*, *Entrophospora*, *Gigaspora*, *Paraglomus* and *Scutellospora* were 2.3, 1.1, 3.9, 0.9 and 3.6%, respectively.

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