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Host Specificity and Distribution of Putative Ectomycorrhizal Fungi in Pure Stands of Twelve Tree Species in Korea

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韓國 12個 樹種 林分內의 外生菌根 버섯의 寄主選擇性과 分布에 關한 硏究

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ABSTRACT: To understand host ranges and host specificity of ectomycorrhizal fungi and fungus specificity of host tree species, higher fungi from pure forest stands of following twelve tree species were collected for six years from 1981 to 1986 : *Pinus densiflora, P. rigida, P. koraiensis, Picea koraiensis, Larix leptolepis, Abies holophylla, Populus alba×glandulosa, Castanea crenata, Quercus aliena, Q. acutissima, Q. mongolica,* and *Betula platyphylla.*

A total of 196 ectomycorrhizal species with 8 varieties in 48 genera were identified. Thirty-one species with one variety belonged to *Russula,* 22 species with 5 varieties to *Amanita,* 18 species with one variety to *Lactarius.* Fungi belonging to above three genera, *Laccaria,* and *Cantharellus* had a relatively wide host range. *Laccaria laccata* was collected under all the 12 tree species, *Amanita vaginata* group under 11 tree species, *Laccaria amethystina* and *Russula foetens* under 10 tree species, *Lactarius gerardii* and *Russula sororia* under 9 tree species, and *Amanita agglutinata, Cantharellus cibarius, Russula bella,* and *R. virescens* under 8 tree species. Above 10 fungal species may be classified to have a wide host range. Following fungi were collected under 4 to 5 tree species of both conifers and broad-leaved trees: *Amanita citrina, Boletus bicolor, B. erythropus, Lactarius piperatus, L. subzonarius,* and Russula pseudodelica. Above fungi may be classified to have an intermediate host range. *Chroogomphus, Gomphidius, Rhizopogon,* and *Suillus* were collected only under Pinaceae and may be classified to have a narrow host range. Particularly *Suillus grevillei* was collected only under *Larix leptolepis,* and appeared to have high host specificity.

A total of 83 ectomycorrhizal species were collected under *Abies holophylla,* 66 species under *Pinus densiflora,* 50 species under *Pinus rigida,* 49 species under *Pinus koraiensis,* 46 species under *Quercus aliena,* and 23 fungal species under *Larix leptolepis.* Particularly, *Larix leptolepis* was associated with different fungal flora, with fewer species of *Amanita, Lactarius* and *Russula,* and more species of *Laccaria.* Most host tree species surveyed in the present study appeared to have low fungus specificity for ectomycorrhizal formation.

KEYWORDS: Ectomycorrhizal fungi, Fungus specificity.

Introduction

Mycorrhiza is one of the several types of symbiosis between higher plants and microorganisms existing in complex foret ecosystem. Most of the forest tree species have been known to form either ectomycorrhiza or endomycorrhiza or both(Lee and Koo, 1983). Ectomycorrhizae are formed mostly by higher fungi and it has been long recognized that many higher fungi in forests are associated with certain types of trees. For example, *Amanita muscaria, Russula emetica,* and *Boletus edulis* exhibit low host specificity and are associated with a wide range of host trees(Trappe, 1962), while *Suillus, Gomphidius* and *Rhizopogon* have high host specificity and are associated only with Pinaceae(Miller, 1972). This assumption has been based on the repeated field observations of many higher fungi collected under various types of trees. Most commonly found higher fungi in forests, such as *Amanita, Russula, Lactarius,* and *Laccaria,* are all mycorrhiza -former and were reported to be associated with various tree species(Lee and Kim, 1985, 1986).

Recently, pure culture synthesis of ectomycorrhiza *in vitro* between known host trees and fungi indicates not only that specific host-sporocarp association in field observations may be confirmed, but that in some cases higher fungi found only under specific host trees may form mycorrhiza *in vitro* with non-associated trees (Molina and Trappe, 1982a). This suggests that host-sporocarp associations in field observations may not give us conclusive answer to the host specificity of ectomycorrhizal fungi.

Host tree species also show differences in their ability to form ectomycorrhizae with diverse fungi. In pure culture synthesis *Arbutus menziesii* showed low fungus specificity (broadly receptive to numerous ectomycorrhizal fungi)(Molina and Trappe, 1982b), while *Alnus* species showed extremely high fungus specificity (Molina, 1979, 1981).

The objectives of this study were to identify host range and host specificity of ectomycorrhizal fungi and fungus specificity of host tree species through compilation of field observations for a period of six years from pure stands of 12 host tree species.

Materials and Methods

In Korea fruiting seasons of higher fungi may start in April and last until November. In the present study, fruiting bodies of higher fungi were collected from June through October starting in 1981 until 1986. A total of 12 locations throughout the country were visited as many times as possible (Table 1). Of the 12 locations, Suwon and Kwangnung areas were visited most frequently and yearly due to easy access to these two areas. Only pure forests were considered in this study to positively identify host trees associated with the higher fungi. The pure forests in Suwon area were established 20 to 30 years ago as experimental forests for Institute of Forest Genetics. The pure forests in Kwangnung area is recognized as one of the oldest plantations in Korea established about 60 years ago. Mushrooms produced on the forest floor, preferably on bare soil or litter layer, were collected and classified for ectomycorrhizal fungi. Criteria for putative ectomycorrhizal status were based on Miller (1982). Some mushrooms, such as *Agaricus, Clitocybe, Collybia, Lepiota, Marasmius, Mycena, Phallus, and Psathyrella,* may be produced on forest floor, but these were not considered mycorrhizal in this study. However, present report considered some fungi mycorrhizal such as *Calocybe, Cystoderma, Clavaria, Clavulina, Geastrum, Lycoperdon, Melanoleuca,* and *Ramaria,* whose mycorrhizal status is in dispute.

In Korea major ectomycorrhizal tree families include Pinaceae, Salicaceae, Fagaceae, Betulaceae, and Tiliaceae (Lee and Koo, 1983). In the present study major ectomycorrhizal tree genera were included for comparison. For example, two-needle pine (*Pinus densiflora*), three -needle pine (*Pinus rigida*), and five-needle pine (*Pinus rigida*), and five-needle pine (*Pinus koraiensis*) were included in the genus, *Pinus.* Other genera in Pinaceae, such as *Picea koraiensis, Larix leptolepis,* and *Abies holophylla,* were surveyed in this study. Among many ectomycorrhizal broad-leaved tree species in Korea, *Populus alba* × *glandulosa* in Salicaceae, *Betula platyphylla* in Betulaceae, *Castanea crenata* and three species of *Quercus* in Fagaceae were selected to represent respective families. For comparison *Quercus aliena* (man-made), *Q. accutissima* (man-made), and *Q. mangolica* (natural pure stands) were surveyed within genus *Quercus.* A total of 12 tree species in pure stands were surveyed, while two mixed forest stands (mixture of conifers with oaks) were also included for comparison.

Table I. Locations, names, approximate ages of pure forests where mushrooms were collected, and periods of mush collection

Locations (Symbols used in Table 2)	Names of Pure Forests (Ages in Parenthesis)	Years of Mushroom Collections
1. Suwon, Kyonggido (○)	Pn. dn. (20, Pn. rg. (30), Pn. kr. (20), Lx. lp. (25), Pp. ag. (20), Cs. cr. (20), Bt. Pl. (15).	1981, 1982, 1983, 1984, 1985, 1986.
2. Kwangnung, Kyonggido (×)	Pn. kr. (60), Pc. kr. (60), Lx. lp. (30), Ab. hl. (60), Qc. al. (50), Qc. ac. (20), Bt. pl. (20).	1982, 1983, 1984, 1985, 1986.
3. Chungok, Kyonggido (◎)	Qc. al. (30).	1984.
4. Anmyondo, Chungnam (△)	Pn. dn. (60).	1983.
5. Yangyang, Kangwondo (●)	Pn. dn. (60), Lx. lp. (30).	1984.
6. Woljong Temple, Kangwondo (□)	Lx. lp. (20), Ab. hl. (70).	1984, 1985.
7. Hongchon, Kangwondo (▲)	Pn. kr. (50), Lx. lp. (20), Qc. mn. (30), Mixed stand (30－50).	1984, 1986.
8. Tokyu Mt., Chonbuk (*)	Pn. dn. (50), Mixed stand (30－50).	1986.
9. Kwangyang, Chonnam (⊗)	Pn. dn. (30), Cs. cr. (30).	1986.
10. Haenam, Chonnam (■)	Pn. dn. (60), Qc. al. (40).	1986.
11. Hapchon, Kyongbuk (V)	Cs. cr. (20), Qc. mn. (30).	1986.
12. Kyongsan, Kyongbuk (▣)	Pn. dn. (20).	1986.

Abbreviation: Pn. dn. (*Pinus densiflora*), Pn. rg. (*Pinus rigida*), Pn. Kr. (*Pinus koraiensis*), Pc. Kr. (*Picea koraiensis*), Lx. lp. (*Larix leptolepis*), Ab. hl. (*Abies holophylla*) Pp. ag. (*Populus alba×glandulosa*), Cs. cr. (*Castanea crenata*), Qc. al. (*Quercus aliena*), Qc. ac. (*Quercus acutissima*), Qc. mn. (*Quercus mongolica*), Bt. pl. (*Betula platyphylla*).

Results and Discussion

Table 2 shows an alphabetic list of putative ectomycorrhizal fungi collected from 1981 to 1986 at pure forest stands of 12 tree species. A total of 196 fungal species with 8 varieties in 48 genera were identified in this study. Some mushrooms were collected from mixed stands only in 1986, and it may be difficult to identify host trees for these fungi. The years of collections are also listed and yearly appearance of these fungi during six years of study can be easily seen from this table. The Table 2 indicates that among the 48 ectomycorrhizal genera, *Amanita, Laccaria, Lactorius,* and *Russula* were collected more frequently than other genera listed in this table. Rarely collected genera included *Chroogomphus, Hygrophorus, Leucopaxillus, Lyophyllum, Tricholoma,* and *Rhodophyllus.*

Table 3 shows distribution of fungal species in relation to the cumulative number of associated host tree species observed during a six-year period. Thirty one species of *Russula* with one variety were collected and it was the most diversified fungal genus in this study. *Amanita* was the second most diversified genus with 22 species (5 varieties), and *Lactarius* the third with 18 species (one variety). Table 3 indicates that *Laccaria, Amanita, Russula, Lactarius,* and *Cantharellus* have relatively wide host ranges compared with other mycorrhizal genera. For example, *Laccaria laccata* known to be polymorphic was the only fungus collected from all the 12 host tree species, and appears to have a widest host range among 196 mycorrhizal species observed in this study. A fungus with the second under broad-leaved tree species in this study. Miller (1972) stated that *Hebeloma crustuliniforme* was found under hardwood trees and mixed woods, while Acsai and Largent (1983) collected this fungus under *Pseudotsuga menziesii*, and Malajczuk *et al.* (1984) considered this fungus to have a broad host range. Further study may be necessary to confirm the host range of *Hebeloma*. *Boletus bicolor* was found under *Larix, Abies* and *Betula*, but not under oak, while Miller (1972) stated that this fungus was usually found under hardwood, especially under oaks. Two species of *Geastrum* and one species of *Astraeus* was found only under conifers in this study, while Miller(1972) and Phillips(1981) indicated them to be found under both conifers and hardwood.

Suillus has been known to be associated strictly with Pinaceae(Harley and Smith, 1983). In the present study seven species of *Suillus* were collected and all of them were found under conifers. However, *Suillus* was not found under *Pinus rigida* or *Picea koraiensis* in this study. *Suillus grevillei* has been known to be associated strictly with *Larix* species(Miller, 1972), and we also confirmed that this fungus was found only under *Larix leptolepis* and *Larix gmelini*.

Table 4 shows fungal diversity and fungus specificity in the pure stands of 12 tree species. The lowest fungus specificity was observed under *Abies holophylla* stands in which 83 fungal species were collected. *Pinus densiflora* stands ranked second(66 fungal species) and *P. rigida* third(50 fungal species) in low fungus specificity. Relatively high fungus specificity was observed in *Larix leptolepis, Quercus acutissima* and *Betula platyphylla*. Considering the fact that *Q. acutissima* stands were visited only in 1986 and that *B. platyphylla* stands were very young and small in area, which resulted in fewer number of fungal collections, *Larix leptolepis* stands appeared to have relatively high specificity for fungal partners. During the six years of study, fewer number of mushrooms and fewer number of fungal species were encountered under *Larix leptolepis*, particularly fewer species of *Amanita, Lactarius*, and *Russula* and more species of *Laccaria*.

It should be mentioned that high fungal diversity(low fungus specificity) in *Abies holophylla* stands appeared to be related to the old age of the stands, while low fungal diversity in *Betula platyphylla* be related to young age of the stands as shown in Table 1. Accumulated litter and organic matters on the forest floor of old stands seemed to be an important factor to promote diversified mycorrhizal symbiosis and fungal flora in *Abies holophylla* and *Pinus densiflora* stands. Another possibility for the higher fungal diversity in older stands may be a consequence of continued fungal succession which may require diverse environmental conditions for successful progress as in the case of aged forest stands.

Present study showed that host ranges of ectomycorrhizal fungi varied from a wide host range in case of some *Amanita, Laccaria, Lactarius*, and *Russula* to a narrow host range in case of *Gomphidius* and *Suillas*(especially *S. grevillei*). These results agreed with known host specificity of some ectomycorrhizal fungi(Trappe, 1962 ; Harley and Smith, 1983). However, present study failed to give further information on detailed host specificity for many fungi listed in Table 2, mainly due to the limited collection of these fungi in a relatively short period of six years. This kind of host specificity study requires as many observations as possible from different host tree species for a longer period.

Even though present study did not show us a full picture of host specificity of many ectomycorrhizal fungi, it may be concluded that majority or most of fungi listed in Table 2 may have a broad host range, and that majority of tree species listed in Table 4 may form ectomycorrhize with a broad range of fungal species. Recent experiments on mycorrhizal synthesis *in vitro* between known host trees and fungi further support the general idea of lack of host specificity in many ectomycorrhizal fungi(Molina and Trappe, 1982a, 1982b; Malajczuk *et al.*, 1982). Kropp and Trappe (1982) through pure culture synthesis and field observation listed more than 150 ectomycorrhizal fungal species for *Tsuga heterophylla* and suggested little presence of fungal specificity. Lack or little presence of host specificity from the stand point of fungal partners and lack or little presence of fungal specificity from the stand point of host trees may be advantageous strategies to maintain abundant symbiotic relations between soil fungi and higher plants. In the process of evolution heavy

Table II. Host ranges of putative cetomycorrhizal bung collected from pure forest sta see Table I for the abbreviations of tree names and explinations for symbols

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
Albactrellus flettii (Morse) Pouz.		84 ●		
Amanita *aspera* (Fr.) Hooker				
A. *agglutinata* (Berk, et Curt.) Sing	큰주머니 광대버섯	84, 86 84 ○ ●	81, 82, 83, 84, 86 ○	86 ▲
A. *citrina* (Schff.) S. F. Gray	애광대버섯			84 ×
A. *citrina* var. *alba* (Gillet) Gilbert				
A. *echinocephala* (Vitt.) Quêl.				
A. *farinosa* Schw.	애우산광대버섯	86 ⊗	81, 82, 84, 86 ○	
A. *griseofarinosa* Hongo	잿빛가루광대버섯			84, 85 ×
A. *hemibapha* (Berk, & Br.) Sacc.	달걀버섯			
A. *inaurata* Secr.	점박이 광대버섯	86 □		85 ×
A. *longistriata* Imai	긴골광대버섯아재비	86 ○	81, 82 ○	
A. *melleiceps* Hongo	파리버섯		81, 82, 84 ○	
A. *pantherina* (DC ex Fr.) Secr.	마귀광대버섯	83 △		
A. *pantherina* var. *cothurnata* Atk.				
A. *phalloides* (Vaill. ex Fr.) Secr.	알광대버섯			
A. *pseudoporphyria* Hongo	암회색광대버섯아재비			
A. *regalis* (Fr.)				
A. *rubescens* (Pers, ex Fr.) Gray	붉은점박이광대버섯	86 ⊗	83 ○	86 ▲
A. *rubrovolvata* Imai	붉은주머니광대버섯			
A. *solitaria* (Fr.) Quêl.				
A. *spissacea* Imai	뱀껍질광대버섯	83 ○	81, 82 ○	
A. *spreta* Peck	턱받이광대버섯			
A. *vaginata* (Fr.) Vitt.	우산버섯	86 ⊗	81, 82, 84, 86 ○	84 ×
A. *vaginata* var. *crocea* (Quêl.) Sing.				

Host Tree Species									
Pc. kr.	Lx, lp.	Ab. kl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
		85 □							86 ✳
84 ×		85, 86 85 × □	81, 82, 84 ◠		84 ×	86 ×			86 ▲
		84, 85, 86 85 × □			84 ×	86 ×	86 ▲		86 ×
		85 ×							
					84 ×				
					84 ×	86 ×			
86 ×		83, 84, 85, 86 ×			85 ×				
		85, 86 85 × □							84 ×
85 ×		84, 86 ×	82, 84 ◠	83 ◠					
84 ×		83 ×	82, 84 ◠	83, 84 ◠				83, 84 ◠	
			82 ◠						
					83, 84 ×				
					85 ×				
									86 ▲
					83 ×				
84 ×					85 ×				
83, 84 ×		83, 84, 85 85 × □					86 ▲		86 ▲
									86 ✳
									86 ▲
		84 ×	84, 86 ◠	84, 86 ◠				83, 85 ×	
83, 84, 86 ×	85 ×	83, 84, 86 ×	82 ◠	83 86 86 ◠ ⊗ V	84 84 ◠ ×	86 ×	86 V		86 ✳
84 ×									

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
A. vaginata var. *fulva* (Schff. ex) Pers.	고동색 우산버섯	86 ⊗	82 ○	
A. vagina var. *punctata* (Cleland & Cheel) Gilb.	큰 우산버섯		82 ○	
A. verna (Bull. ex Fr.) Pers, ex Vitt.	흰알 광대버섯			
A. virosa Lam, ex Secr.	독우산 광대버섯		86 ×	
Astraeus hygrometricus (Pers.) Morgan	먼지버섯	84 ●	83 ○	
Boletopsis leucomelas (Fr.) Fayod	흰굴뚝버섯	84 ●		
Boletus badius Fr.	밤꽃그물버섯			
B. bicolor Pk.				
B. edulis Bull, ex Fr.	그물버섯			
B. erythropus (Fr. ex Fr.) Krombh.	붉은대 그물버섯			
B. fraternus Pk.				85 ×
B. laetissimus Hongo	꾀꼬리 그물버섯			
B. pinicola Vitt.				
B. piperatus Fr	매운맛 그물버섯			
B. pulverulentus Opat.	밤꽃 그물버섯			85 ×
B. queletii Schulz.				
B. retipes Berk, & Curt.				
B. rubellus Krombh.	붉은 그물버섯	84 ○	81 ○	84 ○
B. splendidus Martin				
Calocybe alpestris (Britz.) Sing, ss, Huijsman.				
Cantharellus cibarius Fr.	꾀꼬리 버섯	83 ○ 86 ◘	81, 86 ○	86 ×
C. cinnabarinus Schw.				
C. friesii Quêlet				84 ×
C. lutescens Fr.		84 ●	82, 84 ○	
C. minor Pk.	애기꾀꼬리버섯		84 ○	86 ×
Chroogomphus helveticus (Sing.) Mos.				
C. rutilus (Schff. ex Fr.) O. K. Miller	못버섯	84 ●		
C. sibiricus Pk.		84 ■		84 ×

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
86 ×		84, 86 ×	82 ◠	86 86 ⊗ V	84 ×	86 ×	86 V		86 86 ▲ ⋇
83, 86 ×	86 ▲	86 ×				86 ×			
		86 ×							
84, 86 ×		84, 85, 86 85 × □			83, 84 ×		86 ▲	83 ×	86 ▲
	84 ×								
	85 ×	84 85 × □						85 ×	
		83 85 × □					86 V		
	85 ×	85 □			84 ×		86 V		
		85 ×						85 ×	
		86 ×							86 ⋇
		85 □							
		83 85 × □							
83 ×		85 □							
					83 ×				
		85 □							
	84 ◠	83 84 ◠ ×	81, 82, 84 ◠						
		85 □							
84 ×									
		84, 86 ×		86 V	84 ◠	86 ×	86 V		86 ⋇
									86 ▲
		84, 86 ×		84 ◠	84, 85 ×		86 ▲		
									85 □

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
Clavaria purpurea Fr.	자주국수버섯	86 ⧈		
C. vermicularis Fr.	국수버섯			
Clavulina cristata (Fr.) Schroet.	볏싸리버섯		84 ○	
Cortinarius pseudosalor Lange	가지색끈적버섯아재비			
C. pseudopurpurascens Hongo				
C. purpurascens Fr.	풍선끈적버섯			
C. salor Fr.	푸른끈적버섯			
C. torvus (Bull, ex Fr.) Fr.				
C. variicolar (Fr.) Fr.	자주끈적버섯			84 ×
C. vibratilis (Fr.) Fr.				
Craterellus aureus Berk, et Curt.			84 ●	
C. cornucopioides (Fr.) Pers.	뿔나팔버섯			
Cystoderma carcharias (Pers, ex Secr.) Fay.				
Dermocybe sanguinea (Wulf ex Fr.)	전나무 끈적버섯			
Descolea flavoannulata (Vass.) Horak	노란털 돌버섯			
Geastrum minimum Schw.				84 ▲
G. triplex Jung.	목도리방귀버섯			
Gomphidius glutinosus (Schff.) Fr.		84 ●		
G. maculatus (Scop.) Fr.				
G. roseus (L.) Fr.	큰마개버섯	84 ● 84 ■ 86 ⧈		
G. subroseus Kauff.		84 ●		
Gomphus floccosus (Schw.) Sing.	나팔버섯	83 △		
Gyroporus castaneus (Bull, ex Fr.) Quêl.	흰둘레그물버섯	86 ⧈	81, 84 ○	
Hebeloma crustliniforme (Bull, ex Fr.) Quêl.				
H. mesophaeum (Pers, ex Fr.) Quêl.				
H. radicosum (Bull, ex Fr.) Ricken	뿌리자갈버섯			
Hydnellum aurantiacum (Fr.) Karst.				

Scientific Name									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
								85 ×	
			84 ○	84 ○					
		84 ×							
							86 V		
		83 ×					86 ▲		
	86 ▲								86 ▲
					83 ×				
								83	
					84 ×				
					85 ×				
		84 ×							
		85 □					86 ▲		86 ✳
		84, 85, 86 85 × □			83, 84 ×				
	84 ◎								
		86 ×							
	84, 85 □								
	84 ●								
		83, 84, 85, 86 ×							
			81, 82, 84 ○	83, 84 ○	84 83 ○ ×				86 ✳
				86 ○				86 ○	84 ○ *Salix*
			83 ○	83 ○					
			84 ○						
	85 □								

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
Hydnum albidum Peck	흰 턱수염버섯	84 ■		
H. imbricatum L. ex Fr.		84 ●		
H. repandum Fr.	턱수염버섯	84 84 ● ■		
Hygrophorus borealis Pk.		84 ■		
H. camarophyllus (A. & S. ex Fr.) Fr.	노란구름벚꽃버섯			
H. conicus (Fr.) Fr.	붉은산 벚꽃버섯			
H. marchii (Bres.) Sing.				
H. nemoreus (Lasch) Fr.		84 ■		
H. russula (Schff, ex Fr.) Quêl.	벚꽃버섯			
H. strangulatus Orton				
Inocybe calamistrata (Fr.) Gill.	털실땀버섯			
I. cincinnata (Fr.) Quêl. ss. lat.	곱슬머리 땀버섯			
I. fastigiata (Schff, ex Fr.) Quêl.	솔 땀버섯		81, 82, 86 ○	86 ×
I. lacera (Fr.) Kummer				
I. umbratica Quêl.	하얀땀버섯			
Kobayasia nipponica (Kobay.) Imai et A. Kawan	흰 찐빵버섯	84 84 ○ ●	84 ○	
Laccaria amethystina (Bolt, ex Hooker) Murr.	자주졸각버섯	86 ⊡	82, 83, 84 ○	
L. bicolor (R. Mre.) Ortor		84 ●		
L. laccata (Scop, ex Fr.) Bk, & Br,	졸각버섯	84 86 ● ○	81, 84, 86 ○	84 84, 86 86 ○ × ▲
L. nigra Hongo	검정졸각버섯			
L. proxima (Boud.) Pat.	큰 졸각버섯			
L. tetraspora Sing.				
L. vinaceoavellanea Hongo	색시졸각버섯		82 ○	
Lactarius akahatsu Tanaka	피젖버섯	84 ■		84 ×
L. camphoratus (Bull. ex) Fr.	민맛젖버섯			
L. chrysorrheus Fr.	노란젖버섯	86 ⊡		
L. deliciosus var. *japonicus* Kawam.	맛젖버섯			
L. gerardii Pk.	애기젖버섯	86 ⊗	81, 82, 83, 84, 86 ○	86 ×

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
84, 86 ×							86 V		
86 ×							86 V		
					84 ◎				
									86 86 ▲ ⋇
									86 ⋇
					84 ◎				
							86 86 ▲ V		86 ▲
						86 ×			
									86 ⋇
84 ×									84 *Quercus* × *rubra*
			82 ○	83, 84 ○	84 84 ○ ×				86 ⋇
	86 ▲							83, 86 ○	
		86 ×							
	86 85 ▲ □	84 ×	82, 83 ○	86 ○	83, 84, 85 84 × ■	86 ×	86 86 ▲ V	86 ×	86 ⋇
85 ×	85 86 × ▲	84 ×	84, 86 ○	86 ○	84, 84 ○ ×	86 ×	86 V	83, 85, 86 ○	86 ⋇
	86 ▲								
				86 ⊗					
	84 ●								
		83, 86 ×	82, 84 ○	83, 84 86 86 ○ ⊗ V	84 83, 84 ○ ×	86 ×		83, 84, 85, 86 ○	
									86 ⋇
		86 ×							
84, 86 ×		86 ×	86 ○	86 V	83, 84 ×	86 ×			

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
L. hatsudake Tanaka	젖버섯아재비	84 86 ● ▣		84, 86 86 ○ ×
L. hisginus (Fr.) Fr.				
L. hygrophoroides Berk, & Curt.	넓은갓 젖버섯			86 ×
L. pergamenus (Swartz ex Fr.) Fr.				
L. piperatus (L. ex Fr.) S. F. Gray	굴털이	83 84 △ ●	86 ○	
L. piperatus var. *glaucescens* (Crossl.) Hes. & Sm.	푸른유액젖버섯		81, 82 ○	
L. salmonicolor Heim & Lecl.				
L. subdulcis Bull, ex Fr.				
L. subvellereus Peck	털젖버섯아재비	86 ▣	81 ○	
L. subzonarius Hongo	당귀젖버섯	86 ▣	81 ○	
L. lepidotus Smith & Hesler				
L. uvidus. Fr.	잿빛 젖버섯			
L. vellereus (Fr.) Fr	새털 젖버섯			
L. volemus Fr.	배젖버섯	86 ⊗	81, 82 ○	85 ×
Leucopaxillus giganteus (Fr.) Sing.	대형 흰우단버섯			
Leccinum aurantiacum (Bull, ex St. Am.) S. F. Gray	등색껄껄이그물버섯		83 ○	
L. extremiorientales (Vass.) Sing.	접시껄껄이그물버섯	83 △		
Lycoperdon candidum Persoon				
L. perlatum Pers.	말불버섯	84 ○		84 ○
L. fetidum Bon.				
L. pusillum (Batch, ex Pers.) Schu	애기말불버섯			85 ×
Lyophyllum connatum (Schum, ex Fr.) Sing.				
L. semitale (Fr.) Kuehn	모래꽃만가닥버섯			
L. transforme (Britz.) Sing.				
Melanoleuca melaleuca (Pers, ex Fr.) Mre.	잔디배꼽버섯			
Paxillus curtisii Berk.				85 ×
Phylloporus bellus (Mass.) Corner	노란길민그물버섯		81, 82, 83, 84 ○	
Pisolithus tinctorius (Pers.) Coker et Couch	모래밭버섯	81, 84 86 ○ ▣	81, 82, 83, 84 ○	84 ○

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
									86 ▲
		84, 85, 86 ×							85 ×
		86 ×					86 V		86 ▲
		85, 86 ×		86 V			86 ▲		
	85 ×	83 ×							86 ▲
		84, 86 × 86 □							
		84 ×							
84 ×		84, 85, 86 ×				86 ×			
				83 ○ 86 V		86 ×	86 V		86 ▲
					84 ×				
							86 ▲		86 ▲
		86 ×					86 ▲		86 ▲
84 ×		85 ×		86 V			86 ▲ 86 V		86 ▲
							86 V		86 ▲
			82, 83, 84 ○					83 ×	
84 ×		84, 85, 86 ×							86 ▲
			84 ○						
84 ×		84 ×			84 ○				
		85 □							×
84 ×									
									86 ▲
									86 ▲ 86 ⋇
		84 ×							
		83, 86 ×		84 ○ 86 V	85, 86 ×				
			82 ○	86 ⊗					

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
Polyozellus multiplex (Vnderw.) Murr.	까치버섯	84 ●		
Pulveroboletus ravenelii (Berk, & Curt.) Murr.	갓그물버섯		82(?) ○	
Ramaria botrytis (Fr.) Ricken	싸리버섯	84 ●		
R. *flava* (Fr.) Quél.	노랑싸리버섯			
R. *sanguinea* (Pers, ex Secr.) Quél.				
Rhizopogon sp.	알버섯속		84 ○	84 ○
Rhodophyllus clypeatum (L. ex Fr.) Kummer				
R. *coelestinus* var. *violaceus* (Kaufm.) A. H. Smith	보라꽃외대버섯			
R. *salmoneus* Peck (Sing.)	붉은꼭지버섯			
R. *staurosporus* (Bres.) Lange				
Russula adusta Fr.	흙갈색무당버섯		82, 86 ○	
R. *aeruginea* Lindbl.	구리빛무당버섯			
R. *albonigra* Krbh.	박하무당버섯			84 84 × ▲
R. *aurata* (Witt.) ex Fr.	금무당버섯	84 ●		
R. *azurea* Bres.				
R. *bella* Hongo	수원무당버섯	84 ○	81, 82, 84 ○	84 84 × ▲
R. *cutefracta* Cke.	청버섯		82 ○	
R. *cyanoxantha* Schff. ex Fr.	청머루무당버섯		84 ○	
R. *delica* Fr.	푸른주름무당버섯			86 ×
R. *densifolia* Secr. (ss. Romagn.)	애기무당버섯	83 86 ○ 回		84 ×
R. *emetica* Fr.	냄새무당버섯			84 86 ○ ▲
R. *emetica* var. *silvestris* Sing.		84 ■		
R. *foetens* Fr.	깔때기무당버섯	83 86 86 ○ 回 ⊗	81, 82, 84 ○	85 ×
R. *flavida* Frost ex Peck.	노랑무당버섯		82 ○	
R. *integra* L. ex Fr. ss. R. Mre.				84 ×
R. *laurocerasi* Melzer	밀짚색무당버섯			84 ×
R. *lepida* Fr.	졸각무당버섯	84, 86 84 ○ ■	81, 82, 84, 86 ○	84 86 ▲ ×
R. *lilacea* Quél.	연보라무당버섯			84 ×

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
							86 ▲		
									86 ▲
		83 ×					86 ▲		
		86 ×							
84 ×									
					84 ×				
						86 ×			
	86 ▲								
		84 ×	83, 84 ○						86 ▲
83 ×									
		84 85 × □							
							86 ▲		86 ⋇
		84 □							
83 ×	84 85 □ ×		81, 82 ○	84 ○	84, 85 ○				
		85 86 × ○	84 ○		84 ×				86 ▲
84, 86 ×	84 □	86 ×			84 ×		86 V		
84, 86 ×	85 ×			86 V					
							86 86 ▲ V		86 ▲
		84 □							
84, 86 ×		83, 84, 85, 86 85 × □	84 ○	86 V	83, 85 ×	86 ×	86 V		86 ⋇
						86 ×			
85 ×									
		84, 86 ×	86 ○	84, 86 86 ○ V				84 ○	

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
R. *metachroa* Hongo group	색갈이무당버섯			
R. *minutula* Vel.				
R. *nigricans* (Bull.) Fr.	절구버섯	86 ⊡	81, 82, 84 ◌	
R. *pseudodelica* Lange	흰무당버섯아재비		81, 82, 84 ◌	
R. *pulchella* Borszcow				
R. *rosea* Quél.		84 ■	84 ◠	
R. *sanguinea* (Bull. ex St. Am.) Fr.	혈색무당버섯			84 ×
R. *senecis* Imai	흙무당버섯		86 ◠	
R. *sororia* (Fr.) Romell, ss. Boud.	회갈색무당버섯	84, 86 ◌	82, 86 ◌	84 ◠ 84 ×
R. *subnigricans* Hongo		83 △		
R. *vesca* Fr.	조각무당버섯		82 ◠	
R. *violeipes* Quél.	자주빛무당버섯			84 ×
R. *virescens* (Schff, ex Zant.) Fr.	기와버섯	84 86 ● ⊡	81, 84 ◌	83 ×
Scleroderma citrinum Pers.				
S. *flavidum* Ellis & Everhart				
S. *lycoperdoides* Schwein.	점박이어리알버섯		81, 84 ◌	
Strobilomyces confusus Sing				84, 85 ×
S. *floccopus* (Vahl in Fl. Dan. ex Fr.) P. Karst.	솜귀신그물버섯			
Suillus aeruginascens (secr.) Snell	녹슬은그물버섯			
S. *bovinus* (L. ex Fr.) O. Kuntze	황소비단그물버섯	84 86 ● ⊡		86 ×
S. *granulatus* (L. ex Fr.) O. Kuntze	젖비단그물버섯	84 86 ● ⊠		84 ×
S. *grevillei* (Klotzsch) Sing.	큰비단그물버섯			
S. *luteus* (L. ex Fr.) S. F. Gray	비단그물버섯	84 84 86 86 ● ■ ⊡ ✳		84 ◌
S. *pictus* (Peck) Smith & Thiers	붉은비단그물버섯	86 ⊡		83 84, 85 84, 86 ○ × ▲
S. *sibiricus* Sing.				84 × 84 ▲
Thelephora palmata Scop, ex Fr.	단풍사마귀버섯			84 ▲
T. *spiculosa* (Fr.) Burt.				
T. *terrestris* Fr.	사마귀버섯	81 ○	81 ○	81 ○

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
							86 V		
		84 ×							
		86 ×	84 ○			86 ×			
84 ×		83, 86 ×	81, 82, 83, 84 ○		85 ×				
					84 ×				
85, 86 ×		85, 86 ×		86 V	84 ×				
83, 84 ×		83, 84 ×	84, 86 ○	83, 84, 86 ○ 86 V	84 ○		86 V		
		85 ×							
						86 ×			
		84 ×							
		83, 86 ×	84 ○		83 ×	86 ×	86 V		84 ×
				86 ○ 86 V					
			84 ○						
			84 ○	83, 84 ○	84 ○			84 ○	
							86 ▲		86 ▲
				86 ⊗ 86 V	86 ×		86 ▲		86 ▲
	84 □ 84, 86 ▲								
									86 ▲
	84, 86 × 84 ● 84 □ 84, 86 ▲								
									86 ▲ 86 ✳
		85 ×							86 ▲
		86 ×			85 ×				
									86 ▲
							86 ▲		86 ▲

Table 2. Continued

Scientific Name	Korean Name	Host Tree Species		
		Pn. dn.	Pn. rg.	Pn. kr.
Tricholoma atrosquamosum (Chev.) Sacc.				
T. batschii Gulden				
T. inamoenum (Fr.) Quél.				84 ×
T matsutake (S. Ito & Imai) Sing.	송이	84 ●		
T. pardinum Quél.				
T. sejunctum (Sow. ex Fr.) Quél.	쓴송이	84 ●		
T. terreum (Schff, ex Fr.) Kummer		84 ■		
Tylopilus neofelleus Hongo	제주쓴맛그물버섯			
T. plumbeoviolaceus (Snell et Dick) Sing.				
T. rubrobrunneus Mazzer et A. H. Smith Quel				
Xerocomus chrysenteron (Bull. ex St. Amans) Quél.	마른산그물버섯	86 ○		
X. subtomentosus (L. ex Fr.) Quél.	산그물버섯			

widest host range appeared to be *Amanita vaginata* group. During the six years of field work, four varieties of this fungus was collected, and *Amanita vaginata* var. *vaginata* was collected under all the tree species except *Betula platyphylla*. Fungi with third widest host range seemed to be *Laccaria amethystina* and *Russula foetens*. These two fungi were collected from 10 different host tree species. Fungi with fourth widest host range seemed to be *Lactarius gerardii*, and *Russula sororia*. These two fungi were observed under 9 different host tree species. There were four fungal species which were collected under 8 different host tree species, and these included *Amanita agglutinata, Cantharellus cibarius, Russula bella*, and *Russula virescens*. Above mentioned 10 fungal species may be classified to have "wide host ranges".

Fungal species with "intermediate host ranges" may be difficult to identify from Table 3. However, many species in *Amanita, Boletus, Lactarius*, and *Russula* can be grouped into this category. For example, *Amanita citrina, A. farinosa, Boletus bicolor, B. erythropus, Lactarius piperatus, L. subzonarius, Russula cyanoxantha*, and *R. pseudodelica* were observed from 4 to 5 different host tree species of both conifers and broad-leaved trees.

Ectomycorrhizal fungi with "narrow host ranges" may be difficult to identify from Table 3 in which a total of 92 fungal species were listed to have single host trees. As shown in Table 1, not all the plantations in 12 locations throughout the country were yearly visited. For example, fungi in *Quercus acutissima* and *Q. mongolica* stands were collected in 1986 only. It is possible that these 92 fungal species collected under single host trees could be further found under other host tree species if this study is continued in the future. For example, *Amanita echinocephala* was found only under *Quercus aliena* in the present study, and it has been known to be rarely found (Phillips, 1981).

Two species of *Chroogomphus*, three species of *Gomphidius*, and one species of *Rhizopogon* were found only under Pinaceae in this study and it agreed with the observations by Miller (1972) and Phillips (1981). Trappe (1962) in his review of literature on fungus associates of ectomycorrhizal trees indicated that *Gomphidius* was found only under Pinaceae.

Three species of *Hebeloma* were observed only

Host Tree Species									
Pc. kr.	Lx. lp.	Ab. hl.	Pp. ag.	Cs. cr.	Qc. al.	Qc. ac.	Qc. mn.	Bt. pl.	Mixed Stand
		84 ×							
									85 □
		84 ×							
					85 ×		86 ▲		86 ▲
		84 ×							
		85 ×							
		85 ×							
									85 × *Picea abies*
	86 ○	86 ×	86 ○	86 ○ 86 V					
		85 ×					86 V		

Table III. Distribution of ectomycorrhizal fungal species in relation to the cumulative number of associated host tree species observed from pure stands of 12 tree species during a six-year period

(Unit: Number of fungal species)

Genus	Number of Associated Host Tree Species												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Amanita	8	4		3	1	3	1	1			1		22 (4 var.)
Boletus	7		3	2		1							13
Cantharellus	2	1				1		1					5
Cortinarius	5	2											7
Hygrophorus	4	1											5
Inocybe	2	1				1							4
Laccaria	4						1			1		1	7
Lactarius	8	5			3	1	1		1				18 (1 var.)
Russula	11	8	2	1	4	1	1	2	1	1			31 (1 var.)
Suillus	3	3	1										7
Tricholoma	4	1	1										6
Other genera	34	14	8	2	5								63
Total	92	40	15	8	13	8	4	4	2	2	1	1	190

Table IV. Number of ectomycorrhizal fungal species associated with the listed individual 12 host tree species

Host Tree species	Fungal Genera								Total
	Amanita	*Boletus*	*Cantharellus*	*Lactarius*	*Laccaria*	*Russula*	*Suillus*	Other Genera	
Pinus densiflora	9	1	3	3	8	11	4	27	66
Pinus rigida	10	1	3	3	6	14	0	13	50
Pinus koraiensis	6	3	3	1	5	14	5	12	49
Picea koraiensis	11	1	0	1	3	9	0	8	33
Larix leptolepis	2	4	0	4	1	3	2	7	23
Abies holophylla	15	11	2	3	11	16	1	24	83
Populus alba × *glandulosa*	7	1	0	3	1	9	0	11	32
Castanea crenata	5	0	2	4	4	6	0	11	32
Quercus aliena	12	2	2	3	3	9	0	15	46
*Quercus acutissima**	6	0	1	3	3	5	0	2	20
Quercus mongolica	5	2	2	2	6	7	0	14	38
*Betula platyphylla**	3	1	0	3	0	1	0	6	14
Mixed stand	11	1	2	2	9	6	3	21	55

* *Quercus acutissima* and *Betula platyphylla* stands were relatively young in age and small in occupied area.

competition for nutrients among understory vegetations might have been a driving force to induce abundanant symbiotic relations which are essential for early successful growth of host trees.

摘　要

外生菌根버섯의 寄主範圍와 寄主選擇性을 究明하고 主要 造林樹種의 菌根菌 選擇性을 相互比較하기 위하여 1981年부터 1986年까지 全國의 여러 곳에서 12個樹種의 純林(소나무, 리기다소나무, 잣나무, 종비나무, 일본잎갈나무, 젓나무, 현사시, 밤나무, 갈참나무, 상수리나무, 신갈나무, 자작나무)를 對象으로 菌根버섯을 採集하여 分析을 比較하였다.

6 年동안 總 48屬 196種 8 品種의 菌根 버섯을 同定하였으며 그 중 *Russula* 가 31種 1 品種, *Amanita* 가 22種 5 品種, *Lactarius* 가 18種 1 品種이었다. 寄主範圍가 넓은 種은 *Russula, Amanita, Lactarius, Laccaria, Cantharellus* 屬에 屬해 있었다. *Laccaria laccata* 는 12個調査樹種中에서 12個樹種全体의 林分에서, *Amanita vaginata* group 은 11 固 樹種에서, *Laccaria amethystina* 와 *Russula foetens* 는 10個樹種에서, *Lactarius gerardii* 와 *Russula sororia* 는 9 個樹種에서, *Amanita agglutinata, Cantharellus cibarius, Russula bella, Russula virescens* 는 8 個樹種의 針闊葉樹林分에서 採集되어 寄主의 範圍가 넓은 버섯으로 分類되었다. *Amanita citrina, Boletus bicolor, Boletus erythropus, Lactarius piperatus, L. subzonarius, Russula pseudodelica* 는 針闊葉樹의 4～5個樹種에서 採集되어 寄主의 範圍가 中間程度인 버섯으로 分類되었 다. *Chroogomphus, Gomphidius, Rhizopogon, Suillus* 는 소나무科의 純林에서만 採集되어 寄主의 範圍가 좁은 버섯으로 分類되었으며 특히 *Suillus grevillei* 는 잎갈나무에서만 採集되어 寄主의 範圍가 가장 좁은 버섯으로 判明되었다.

12個樹種의 林分中에서 菌根버섯의 種類가 가장 많은 젓나무林으로써 83種의 菌根버섯을 採集했으며, 소나무(赤松)林에서 66種을, 리기다소나무林에서 50種을, 잣나무林에서 49種을, 갈참나무林에서 46種을 採集했다. 일본잎갈나무林에서는 23種의 菌根버섯을 採集 했는데 다른 林分과 달리 *Amanita, Lactarius, Russula* 는 적고 대신 *Laccaria* 가 많이 觀察되었다. 本 實驗에서 調查된 12個樹種의 大部分은 多樣한 菌根버섯과 共生하는 듯하며 菌選擇性이 적은 것으로 思料된다.

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