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Biodiversity and Distribution of Arbuscular Mycorrhizal Fungi in Korea

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ABSTRACT : In this study, we summarized previous studies on diversity and distribution of arbuscular mycorrhizal fungi (AMF) for last 30 years in Korea. According to a review of the literature concerning AMF in Korea, 14 genera and 89 species have been recorded. Host plants for AMF are very diverse and include crop species and woody plants in natural forests. Based on the achievements of the last 30 years of study on AMF, we anticipate that relatively more intensive studies of the functional and genetic diversity of AMF will be conducted.

KEYWORDS : Arbuscular mycorrhiza, Distribution, Diversity, Glomeromycota, Korea

Introduction

Arbuscular mycorrhizal fungi (AMF), which maintain symbiotic relationships with most terrestrial plants, appeared on land more than 460 million years ago, and they helped plants adapt to the terrestrial environment [1]. AMF evolved specialized organs such as arbuscules, vesicles, etc., to interact with roots of plants and they provide resistance to environmental stresses (e.g., draught and salinity), help defend against disease, and absorb minerals, all of which benefit the host plants. The number of species of vascular plants worldwide is estimated at approximately 270,000 [2], while that of AMF is around 240 [3]; this asymmetric symbiotic relationship has generated tremendous academic interest. It is generally accepted that AMF exhibit relatively high genetic and functional diversity to overcome their limited species diversity [4].

In Korea, the history of AMF-related study is relatively short (ca. 30 years). Vascular plants distributed in the Korean peninsula have been reported to contain 3,000 to 5,000 taxa [5,6]; however, precise estimates of AMF species in Korea are currently lacking. Here, we review the state of AMF research in Korea in an attempt to determine the diversity of AMF species and their host plants in order to provide a basis for future AMF studies. Published papers were examined to ascertain the results of AMF-related research carried out in Korea, and a taxonomical treatment was conducted according to Schüßler and Walker [3].

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AMF species diversity

A total of 89 species of AMF have been reported in Korea; however, new species have not been discovered (Table 1). Among them, species in the genera *Acaulospora* and *Glomus* have the most abundant (19 species), followed by *Scutellospora* (15 species), *Pascispora* and *Paraglomus* (two species each), and *Diversispora* and *Redeckera* (one species each). *Gigaspora margarita* was the most frequently appeared species in the literatures. Also, *Acaulospora scrobiculata*, *Funneliformis mosseae* and *Sclerocystis rubiformis* were also frequently appeared in the literatures.

In most of studies, AMF were identified using morphological characteristics of spores extracted from field-collected soils. Of the 89 AMF species, approximately 25% was identified by using both morphological and molecular data, but the remainder by using only morphological characteristics (Table 1). AMF, compared with

Table 1. List of Glomeromycota studied on different sites in Korea

Species names	Study type	Reference
Acaulospora bireticulata Rothwell & Trappe	Mor	[7-12]
A. colombiana (Spain & Schenck) Kaonongbua, Morton & Bever	Mor	[12]
A. denticulata Sieverd. & Toro	Mor	[10, 13, 14]
A. dilatata Morton	Mor	[15]
A. elegans Trappe & Gerd.	Mor	[10, 12, 16]
A. foveata Trappe & Janos	Mor	[10, 17]
A. kentinensis (Wu & Liu) Kaonongbua, Morton & Bever	Mor	[12]
A. laevis Gerd. & Trappe	Mor	[12, 16-20]
A. lacunosa Morton	Mor	[12]
A. longula Spain & Schenck	Mor, DNA	[12, 19-22]
A. mellea Spain & Schenck	Mor, DNA	[12, 22]
A. morrowiae Spain & Schenck	Mor	[12, 14, 19]
A. myriocarpa Spain, Sieverd. & Schenck,	Mor	[23]
A. rehmii Sieverd. & Toro	Mor	[10, 12, 24]
A. rugosa Morton	Mor	[12, 19]
A. scrobiculata Trappe	Mor, DNA	[8, 12-14, 16-20, 25-28]
A. spinosa Walker & Trappe	Mor, DNA	[9, 12, 16, 21, 23, 29]
A. sporocarpia Berch	Mor	[12]
A. undulata Sieverd.	Mor	[16, 20]
Ambispora appendicula (Spain, Sieverd. & Schenck) Walker	Mor	[10, 12, 24]
A. fecundispora (Schenck & Sm.) Walker	Mor	[14, 19]
A. leptoticha (Schenck & Sm.) Walker, Vestberg & Schüßler	Mor, DNA	[22, 30]
Claroideoglomus claroideum (Schenck & Sm.) Walker & Schüßler	Mor, DNA	[24, 30]
C. lamellosum (Dalpé, Koske & Tews) Walker & Schüßler	Mor, DNA	[30]
C. etunicatum (W.N. Becker & Gerd.) Walker & Schüßler	Mor, DNA	[14, 21, 23, 30]
Diversispora spurca (Pfeiff., Walker & Bloss) Walker & Schüßler	Mor, DNA	[12, 31]
Funneliformis vesiculifreum Walker & Schüâler	Mor	[11, 28]
F. mosseae (Nicolson & Gerd.) Walker & Schüâler	Mor, DNA	[12, 14, 15, 17, 20, 21, 24, 25, 30, 32]
F. caldedonium (Nicolson & Gerd.) Walker & Schüâler	Mor, DNA	[10, 16, 18, 23, 24, 32]
F. constrictum (Trappe) Walker & Schüâler	Mor	[12, 13, 17, 18, 24]
F. geosporum (Nicolson & Gerd.) Walker & Schüâler	Mor	[11, 12, 14, 25, 28]
Gigaspora albida Schenck & Sm.	Mor	[33]
G. decipiens Hall & Abbott	Mor	[8-10, 12, 17, 23, 24]
G. gigantea (Nicolson & Gerd.) Gerd. & Trappe	Mor, DNA	[8, 10, 12, 17, 30]
G. margarita Becker & Hall	Mor, DNA	[8, 12-14, 16, 17, 19-22, 25, 27-29, 34, 35]
G. rosea Nicolson & Schenck	Mor	[35]
Glomus aggregatum Schenck & Smith	Mor	[14, 20, 25, 28]
G. albidum Walker & Rhodes	Mor	[8, 12, 16, 18-20]
G. ambisporum Smith & Schenck	Mor	[10, 25]
G. australe Berch	Mor	[13]
G. boreale Trappe & Gerd.	Mor	[12]
G. cerebriforme McGee	Mor	[12]
G. convolutum Gerd. & Trappe	Mor	[13, 28]

Table 1. List of Glomeromycota studied on different sites in Korea (continued)

Species names	Study type	Reference
G. deserticola Trappe, Bloss & Menge	Mor	[9, 11, 19]
G. dimorphicum Boyetchko & Tewari	Mor	[19, 36]
G. flavisporum (Lange & Lund) Trappe & Gerd.	Mor	[13, 28]
G. glomerulatum Sieverd.	Mor	[13, 16, 23]
G. heterosporum Sm. & Schenck	Mor	[17, 20]
G. hoi Berch & Trappe	Mor	[10]
G. invermaium Hall	Mor	[20, 24]
G. macrocarpum Tul. & Tul.	Mor	[15, 16, 20]
G. microcarpum Tul. & Tul.	Mor	[20, 23]
G. monosporum Gerd. & Trappe	Mor	[15, 24]
G. reticulatum Bhattacharjee & Mukerji	Mor	[15]
G. tortuosum Schenck & Sm	Mor	[13, 16, 23, 28]
Pacispora chimonobambusae (Wu & Liu) Sieverd. & Oehl	Mor	[24]
P. scintillans (Rose & Trappe) Sieverd. & Oehl	Mor	[16, 19]
Paraglomus brasilianum (Spain & Miranda) Morton	DNA	[31]
P. occultum (Walker) Morton & Redecker	Mor, DNA	[7, 12, 19, 21, 22, 30, 37]
Racocetra castanea (Walker) Oehl, Souza & Sieverd.	Mor, DNA	[30]
R. coralloidea (Trappe, Gerd. & Ho) Oehl, Souza & Sieverd	Mor	[10, 20, 25, 27]
R. fulgida (Koske & Walker) Oehl	Mor	[12]
R. gregaria (Schenck & Nicolson) Oehl	Mor	[8, 12, 14, 24, 28]
R. minuta(Ferrer & R.A. Herrera) Oehl	Mor	[12]
R. persica (Koske & C. Walker) Oehl	Mor	[9, 12, 28]
R. verrucosa (Koske & Walker) Oehl, Souza & Sieverd	Mor	[16, 36]
R. weresubiae (Koske & Walker) Oehl, Souza & Sieverd	Mor, DNA	[30]
Redeckera pulvinatum (Henn.) Walker & Schüßler	Mor	[8, 16, 18]
Rhizophagus clarus (Nicolson & Gerd.) Walker & Schüâler	Mor, DNA	[7, 17, 19, 21, 30, 35]
R. diaphanous (Cano & Dalpé) Walker & Schüâler	Mor	[13, 28]
R. fasciculatus . (Thaxt.) Walker & Schüâler	Mor, DNA	[12, 14, 15, 32]
R. intraradices(N.C. Schenck & Sm.) Walker & Schüâler	Mor, DNA	[7, 14, 35]
R. manihotis(Howeler, Sieverd. & Schenck) Walker & Schüâler	Mor	[8, 13]
R. proliferus(Blaszk., Kovács & Balázs) Walker & Schüâler	Mor, DNA	[32, 38]
Sclerocystis clavispora Trappe	Mor	[17, 39, 40]
S. liquidambaris Wu & Chen	Mor	[39, 40]
S. sinuosa Gerd. & Bakshi	Mor, DNA	[12, 15, 17, 37-40]
S. microcarpus S.H. Iqbal & Perveen	Mor	[13]
S. rubiformis Gerd. & Trappe	Mor	[10-12, 14-17, 19, 28, 39, 40]
S. taiwanensis Wu & Chen	Mor	[17, 39, 40]
Scutellospora arenicola Koske & Halvorson	Mor	[24]
S. aurigloba(Hall) Walker & Sanders	Mor, DNA	[7, 10, 12, 20, 30]
S. calospora(Nicolson & Gerd.) Walker & Sanders	Mor	[10, 12, 16, 17, 23, 40]
S. cerradensis Spain & Miranda	DNA	[30]
S. dipapillosa (Walker & Koske) Walker & Sanders	Mor	[12]
S. erythopa(Koske & Walker) Walker & Sanders	Mor, DNA	[8, 12, 14, 17]

Table 1. List of Glomeromycota studied on different sites in Korea (continued)

Species names	Study type	Reference
S. gilmorei(Trappe & Gerd.) Walker & Sanders	Mor	[7, 12, 17, 20]
S. heterogama(Nicolson & Gerd.) Walker & Sanders	Mor	[16, 25, 27, 34]
S. nigra (Redhead) Walker & Sanders	Mor	[12]
S. pellucida (Nicolson & Schenck) Walker & Sanders	Mor	[17, 19, 24, 36]
S. savannicola(Herrera & Ferrer) Walker & Sanders	Mor	[17]

vascular plants and animals, have few key morphological characteristics and the morphology of spores extracted from field soil has been affected by various environmental factors, leading to misidentification; thus, sound molecular data are needed for accurate AMF identification.

Host plant diversity

Host plants for AMF are divided into three categories, herbaceous, woody, and crop species, and, in total, AMF were found from about 100 host plants (Table 2). Among them, about 25% are crop species, 24% woody plants, and 51% herbaceous plants. Most crop species are also herbaceous plants; thus, it would be reasonable to focus on woody plants for investigating AMF biodiversity. The literature shows that most host plants are common species; thus, rare species such as alpine or endangered species that are sensitive to climatic change or human development also need to be investigated.

Regional diversity

The distribution of sampling sites for AMF in Korea to date is illustrated in Fig. 1. The region of greatest focus

Table 2. Host plant species reported to be studied AMF in Korea

Herbaceous plants	*Agropyron yesoense*	*Lespedeza cunneata*
	Amphicarpaea edgeworthii	*Lotus corniculatus* var. *japonicus*
	Artemisia annua	*Miscanthus sinensis*
	Artemisia iwayomogi	*Orostachys japonica*
	Artemisia princeps var. *orientalis*	*Persicaria blumei*
	Artemisia scoparia	*Persicaria thunbergii*
	Aster tripolum	*Phragmites communis*
	Botrychium ternatum	*Polygonatum odoratum* var. *pluriflorum*
	Calamagrostis epigeios	*Sedum oryzifolium*
	Cassia mimosoidea var. *nomame*	*Setaria viridis*
	Chenopodium ficifolium	*Sedum sarmentosum*
	Commelina communis	*Sonchus brachyotus*
	Chrysanthemum morifolium	*Sonchus oieraceus*
	Desmodium oxyphyllum	*Sophora flavescens*
	Digitaria sanguinalis	*Stellaria aquatic*
	Disporum smilacinum	*Tephroseris kirilowii*
	Erigeron bonariensis	*Themeda triandra* var. *japonica*
	Glycine soga	*Trifolium respens*
	Impatiens balsamina	*Veronica undulate*
	Imperata cylindrica	*Vicia amoena*
	Isachne globosa	*Vicia unijuga*
	Ixeris dentata	*Viola mandshurica*
	Kummerowia striata	*Zoysia japonica*

Table 2. Host plant species reported to be studied AMF in Korea (continued)

Crop & Vegetables	*Allium cepa*	*Lycopersicon esculentum*
	Allium fistulosum	*Panax ginseng*
	Allium scorodorpasum var. *viviparum*	*Petasites japonicas*
	Arachis hypogaea	*Phaseolus angularis*
	Brassica napus	*Phaseolus radiates*
	Capsicum annum	*Platycodon grandiflorus*
	Cucumis meto var. *makuwa*	*Sesamum indicum*
	Cucumis sativus	*Solanum melongena*
	Fagopyrum esculentum	*Sorghum bicolor*
	Glycine max	*Vigna unguiculata*
	Ipomoea batatas	*Vigna vexillata*
	Lactuca sativa	*Zea mays*
Woody plants	*Albizzia julibrissin*	*Liriodendron tulipifera*
	Amorpha fruticosa	*Morus alba*
	Citrus unshiu	*Pueraria thunbergiana*
	Chamaecyparis obtusa	*Rhododendron mucronulatum*
	Chamaecyparis pisifera	*Robinia pseudoaccasia*
	Cryptomeria japonensis	*Rosa multiflora* var. *multiflora*
	Dendropanax morbifera	*Rhus javanica*
	Indigofera kirilowii	*Stephanandra incisa*
	Lespedeza bicolor	*Styrax obassis*
	Lespedeza chiisanensis	*Symplocos sawafutagi*
	Lindera obtusiloba	*Torreya nucifera*
		Veronica undulata

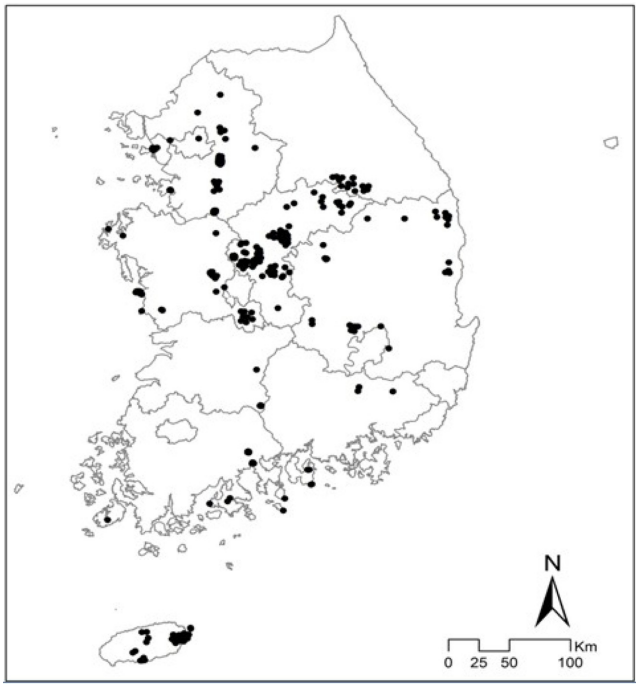

Fig. 1. AMF sampling sites in Korea.

is the center of South Korea (e.g., Chungbuk province and the regions in its vicinity). Therefore, these would be appropriate reference sites for selecting new sampling sites for future studies of AMF. The northern and the southern part of South Korea have not been evaluated extensively in AMF studies. The vegetation in the southern Korea is different from that in the rest of Korea, and similar to that in other countries such as southern China and Kyushu in Japan. Moreover, these countries share some plant species; thus, comparative analysis of AMF between plants or between regions of these countries would be possible. In the case of the north western Korea, there are many alpine regions; hence, its diversity with respect to alpine plants and geological features would likely affect AMF species diversity and distribution.

Conclusion

From the perspective of this review, AMF-related research in Korea is relatively narrow in scope compared with that in other countries with respect to AMF diversity. In particular, the number of investigated host plants is merely 1/300 to 1/500 of the entire Korean plant taxa, and regionally and geologically, only Chungbuk province has been investigated relatively intensively. Thus, investigations that are more comprehensive are needed to establish a more complete understanding of AMF diversity in Korea. With respect to biodiversity, basing future AMF study of undiscovered areas and host plants on the results of this review will be a good strategy for improving Korean biodiversity, including that of AMF.

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