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Biodiversity, Spore Density and Root Colonization of Arbuscular Mycorrhizal Fungi at Expressway Cut-slopes in Korea

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Abstract : This study was conducted to investigate the arbuscular mycorrhizal fungal biodiversity, spore density and root colonization in relation to site ages at expressway cut-slopes in Korea. Stabilization of exposed surface involved soil amendments and spraying seed mixture of turf grasses and/or nitrogen-fixing shrub species. Eighteen sites were selected with varying ages (2 to 16 years). Soil samples collected in October from each site were analyzed for fungal diversity and spore counts. Fine root samples from the plants were assayed for fungal colonization. Of the total 37 plants inspected in the sites, 26 species had endomycorrhizal colonization with an average root colonization rate of 18%, and with a range from 1 to 67%. The average endomycorrhizal colonization rate of initially introduced *Festuca arundinacea* which became the most dominant grass in later stage showed 22.8%, while that of *Lespedeza bicolor* which became the most dominant woody species were 21.6%. Naturally-invading *Robinia pseudoacacia* showed higher colonization rate in the old sites. Although site age did not show significant effects on fungal diversity, the root colonization rates of initially introduced plants decreased with the site aging, while those of invading plants increased with aging of the sites. The soil chemical properties, pH, N, and P contents, were negatively correlated with spore density, root colonization and endomycorrhizal species diversity. A total of forty arbuscular mycorrhizal fungal species in seven genera were identified. Of the 40 species, *Acaulospora lacunosa*, *Glomus aggregatum*, *Glomus constrictum*, *Scutellospora erythropa*, and *Acaulospora spinosa* were the five most dominant species in the decreasing order.

Key words **:** *AM fungi, root colonization, cut-slope, biodiversity, rehabilitation, soil chemical property*

Introduction

Korea is a mountainous country and extensive areas of mountains covered by forest have been damaged with the progress of economic development from late 1960s. A total of 188,090 ha of forest lands were cleared between 1979 and 2007 for other uses, like agriculture, residence, factories, roads, golf courses, etc. Of the converted areas, the areas for road construction were the largest, which accounted for 12.9% of the total conversion (Korea Forest Service, 1983-2008). Road construction in mountainous areas inevitably has produced a great number of cut or embanked slopes across the nation. Bare slopes resulted from road constructions are exposed to accelerated erosion, and should be stabilized as early as possible with diverse measures in accordance with the unique environment of slopes utilizing various kinds of soils and plants.

Exotic herbaceous turf grass seeds, such as *Festuca arundinacea,* were popular in the stabilization works because of their advantages of initial fast growth, availability of high quality seeds in bulk, etc. After stabilization works, succession starts in the slopes as in the damaged forest areas. Additional plants growing in the forest surrounding the slopes invade the area as time goes by (Jeon, 2004). Nowadays, indigenous plants which are growing naturally in Korea are recommended at the stabilization works because exotic plants on the slope caused retardation of the ecological succession due to their high density (Song *et al*., 2005).

Arbuscular mycorrhizas (AM) are the most common mycorrhizal types and are formed in a wide variety of host plants including angiosperms, gymnosperms and pteridophytes. In disturbed sites AM association has been reported to be beneficial for the survival of the

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plants because it reinforces the drought tolerance during the stress and also recovery through its improving water and nutrient uptake. Li and Zhao (2005) reported that high AM fungal spore density and root colonization were presumably a selective adaptation toward the hot and arid ecosystem. All colonizing species at disturbed areas by road construction in La Gran Sabana (Venezuela) were mycorrhizal, and for this reason Rosales *et al.* (1997) recommended that the restoration program in these degraded areas should take mycorrhizae into account.

The cut-slopes in expressway roadbanks are characterized by deficiency of top soil, nutrients and water for the growth of plants. While arbuscular mycorrhizal fungi (AMF) have been considered to be important functional components in severe environments, a study on AM fungal diversity in these sites has not been conducted in Korea. Furthermore, the role of AMF in early survival of introduced turf grasses and invading plants at the droughty cut-slopes with AM propagules has been little known.

The objectives of this study were as a preliminary study for understanding the roles of AMF in early survival of introduced plants in cut-slopes 1) to investigate AM fungal biodiversity in the cut-slopes, 2) to compare mycorrhizal colonization between initially introduced and subsequently invading plant species along the plant succession, and 3) to understand relationships between site factors (age, fertility) and root colonization rates.

Materials and Methods

1. Site description

Preliminary survey sites for this study consisted of 29 cut-slopes created along the expressways in Gyeonggi Province, Korea. New vegetation was established by various measures like hydro-seeding, spraying seed with soil stabilizer, using exotic turf grasses, including tall fescue (*Festuca arundinacea*), weeping lovegrass (*Eragrostis curvula*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), and/or indigenous plants like N-fixing plants (*Lespedeza* sp.) and *Themeda triandra* var. *japonica*. Most surveyed slopes have been dominated by initially introduced *F. arundinacea* and *Lespedeza bicolor*, *Robinia pseudoacacia* among invading plants were the most frequently found species at the aged sites.

A total of eighteen sites with past records of construction and maintenance were selected out of the 29 preliminary survey sites on expressways. As shown in Table 1, the eighteen sites were classified into three groups with six sites each based on site age. Young age sites (two to five years old after the construction of the expressways) were on Seoul Ring Expressway between Cheonggye Tollgate and Pangyo Junction, intermediate age sites (9 years old) were on Yeongdong Expressway between Ansan and Bugok Interchanges, and advanced age sites (16 years old) were on Jungbu Expressway between Hanam Junction and Gonjiam Interchange.

2. Fine root and soil sampling and soil analysis

Fine roots of 37 plant species growing on the surveyed sites were sampled in October to examine the mycorrhizal colonization. The samples were collected from each site, and the replication of each species was determined by the frequency of the plants at the sites with the range between minimum two for rare species and up to five for dominant ones (Table 1).

After removing the organic layer, duplicate soil samples from 18 sites were also collected from the soil up to 15 cm deep near the roots of dominant species, *F. arundinacea*, except one intermediate age site (collected triplicate soil samples) of which initially introduced plant was *E. curvula* (Table 2). Soil samples were analyzed for their available phosphorus (P), total nitrogen (N), pH and the spore density of AMF.

Available phosphorus in the soil was determined using Bray No. 1 solution (0.03N NH_4F+0.025N HCl) as an extractant. Twenty mL of the solution was dispensed into the oven-dry equivalent of 2.85 g of air-dry soil (7:1) and the extract was analyzed by optical emission spectrometer equipped with ICP (Bray and Kurtz, 1945).

Total nitrogen (N) in the soil was determined by micro-Kjeldahl method. One gram of air-dry soil was placed in a micro-Kjeldahl digestion flask, and 1.1 g of K_2SO_4-catalyst mixture and 3 mL of concentrated H_2SO_4 were added, then the flask was heated cautiously on the digestion stand. After completion of digestion, flask was allowed to cool, and about 20 mL of water was added. Then flask was distillated and concentration of total nitrogen in the distillate was determined by titration with

Table 1. Site age of 18 cut-slopes of expressway roadbanks in Gyeongi Province, Korea where arbuscular mycorrhizal formation was studied, and numbers of soil and fine root samples for the study.

Age class	Young age (2-5 Years)	Intermediate age (9 Years)	Advanced age (16 Years)	Total
Number of sites investigated	6	6	6	18
Number of fine root samples collected	60	54	71	185
Number of soil samples collected	12	13	12	37

Table 2. Distribution frequency by age class and AM root colonization rates of initially introduced and invading plants at 18 cut-slopes of expressway roadbanks in Gyeongi Province, Korea. The most dominant herbaceous and woody plants at the surveyed cut-slopes were initially introduced *Festuca arundinacea* Schreb., and invading *Robinia pseudoacacia* L., respectively. Mean root colonization rate of all species was 18%. (SE: standard error)

Names of species	AM root colonization (mean±SE, %)	Distribution frequency (No. of sites with the plant out of total 18 sites)			
		Young age (2~5 years)	Intermediate age (9 years)	Advanced age (16 years)	Total
Initially introduced plants					
Lespedeza cuneata (Dum-Cours.) G. Don	9.6±5.6	3	2		5
Eragrostis curvula (Schrad.) Nees	15.1±7.3	3	2	2	7
Lespedeza bicolor Turcz.	21.6±5.3	4	3	1	8
Festuca arundinacea Schreb.	22.8±2.2	6	5	6	17
Dactylis glomerata L.	24.8±13.7	1			1
Poa pratensis L.	39.6±14.1	1			1
Invading plants					
Ailanthus altissima (Mill.) Swingle	2.7±1.5			1	1
Wisteria floribunda (Willd.) DC.	3.1±0.9	1			1
Spiraea prunifolia for. *simpliciflora* Nakai	3.9±1.8			2	2
Echinochloa crus-galli (L.) P. Beauv. var. *frumentacea* (Roxb.) W. Wight	7.3±1.3		1		1
Robinia pseudoacacia L.	7.5±4.5	3	3	3	9
Salix caprea L.	7.6±2.0	1			1
Artemisia princeps var. *orientalis* (Pampan.) Hara	10.0±2.5	1	3		4
Pueraria thunbergiana (Siebol & Zucc.) Benth.	13.6±5.0	1	1		2
Chrysanthemum boreale Makino	15.7±7.7		2		2
Allium thunbergii G. Don	15.8±12.4			1	1
Zelkova serrata (Thunb.) Makino	17.6±3.0			1	1
Paulownia tomentosa (Thunb.) Stuedal	18.1±2.0			1	1
Acer tataricum Subsp. *ginnala* (Maxim) Wesmall	20.4±2.3			2	2
Ligustrum obtufifolium Siebold et Zucc.	20.6±2.3			1	1
Rubus oldhamii Miq.	20.8±3.8		1		1
Miscanthus sinensis Anderss.	22.0±3.2		1	3	4
Rubus crataegifolius Bunge	22.5±6.7			3	3
Artemisia capillaries Thunb.	24.0±2.3			5	5
Rhus trichocarpa Miq.	25.1±3.0			1	1
Humulus japonicus Siebold & Zucc.	28.9±13.8		1	1	2

0.005 *M* H_2SO_4 using a 10 mL burette graduated at 0.01 mL intervals (Bremner, 1996).

Hundred mL of deionized water was added to 20 g of air-dry soil (5:1), and the suspension was mixed well. Soil pH was determined with pH meter after standing the suspension for 1 hour (Thomas, 1996).

3. Spore collection, identification of fungal species and determination of root colonization rate

Spores of mycorrhizal fungi in the soil samples were separated through wet-sieving and decanting procedures (An *et al.*, 1990). Each soil sample (100 g) was independently suspended in 1 liter of water with a magnetic stirrer for 2 minutes and allowed to settle for 30 seconds. The suspension was decanted, and particles between 425 and 38 μm in diameter were collected using a series of wire sieves. The sediment was re-suspended in 1 liter of water, and the procedure was repeated twice. The sieved samples were combined and centrifuged first in tap water for 5 minutes at 1270×g, then in 2 *M* sucrose solution for 1 minute. After final centrifugation, spores were rinsed in tap water and observed in Petri dishes under a light microscope.

Spores were identified based on spore color, size, surface ornamentation and wall structure with reference to the morphological description provided by the International Culture Collection of (Vesicular) Arbuscular Mycorrhizal Fungi (INVAM, 2009).

A technique modified from Kormanik *et al.* (1980) was applied to examine endomycorrhizal colonization of the roots by staining fine roots with aniline blue. Proportion of root length colonized by arbuscular mycorrhizal fungi was measured by the grid-line intersection method (Giovannetti and Mosse, 1980).

4. Data analysis

Differences among means of the age classes were separated by Fisher's least significant difference (LSD) at the 95% confidence level ($P \leq 0.05$) following the analysis of variance (ANOVA). Correlation analyses were made to examine the relationships between soil properties and site age, and fungal parameters of spore density, root colonization and diversity of fungal species.

Results

1. Plant biodiversity and rate of AM fungal colonization by host plants

A total of 37 plant species were identified at the 18 sites, and 26 species, 70% of total plant species observed, had endomycorrhizal colonization (Table 2). The average root colonization rate in all was 18% and the rate of individual plant was widely ranged from 1 to 67%. By the way, some plants such as *Indigofera kirilowii*, *Morus alba*, *Amorpha fruticosa* showed little colonization. Of the 26, six species were initially introduced plants and the other twenty were invading ones. The diversity of initially introduced plants was higher at young age sites, while advanced age sites had higher diversity in invading plants. Of the total 37 plant species in the 18 surveyed sites, *F. arundinacea* among the initially introduced plants and *R. pseudoacacia* among the invading ones were the most dominant species.

The cut-slopes were rehabilitated by introduction of plants such as *F. arundinacea*, *Lespedeza cuneata*, *E. curvula* and *L. bicolor* mainly. Of the plants *F. arundinacea* was initially introduced to the all sites except for one site. As time goes by, plants growing near the sites such as *R. pseudoacacia*, *Artemisia* sp., *Rubus* sp. and *Miscanthus sinensis* gradually invaded the sites.

In AM root colonization, the rates of *P. pratensis*, *D. glomerata* and *F. arundinacea* were high among initially introduced plants, and among the invading plants the rates of *Humulus japonicas*, *Rhus trichocarpa*, *A. capillaries*, *Rubus crataegifolius* and *M. sinensis*, which were mainly distributed at advanced age sites, were relatively higher than the other species. *L. cuneata* among initially introduced plants and *R. pseudoacacia* among invading ones showed the lower colonization rates which were below ten per cent.

2. Changes in root colonization rates, number of spores and fungal diversity with increasing site ages

Table 3 shows a little different trend in the colonization rates with aging of the sites between initially introduced plants and invading ones. Among the three initially introduced plant species, the rate of *F. arundinacea* at the young age sites was significantly higher than that at advanced age sites (P=0.029), and in case of *E. curvula*, the rate at intermediate age sites was significantly lower than that at young age ones (P=0.019). The rates of two major invading plants showed higher colonization rates at the sites of advanced age.

Number of spores per unit soil volume varied with ages of the sites (Table 4). Average number of spores was 1,213±465 per 100 g soil in the young age sites and abruptly increased to 2,289±583 in more aged sites. The number of the intermediate age sites was significantly lower than the advanced age (P=0.047). Root colonization rates ranged from 10.1±2.0% in the intermediate

Table 3. Changes in the root colonization rates of major plants with aging of 18 cut-slopes of expressway roadbanks. (SE: standard error; Means with the same letter are not significantly different at $P \leq 0.05$.)

Site class	Initially introduced plants (mean±SE, %)			Invading plants (mean±SE, %)	
	Festuca arundinacea	*Lespedeza bicolor*	*Eragrostis curvula*	*Robinia pseudoacacia*	*Miscanthus sinensis*
Young age (2~5 years)	27.5±3.6 a	30.5±6.7 a	25.9±8.0 a	4.7±2.7 a	plant absent
Intermediate age (9 years)	19.2±2.1 ab	16.1±5.0 a	2.9±1.3 b	1.5±1.5 a	15.8±0.7 a
Advanced age (16 years)	15.8±3.1 b	16.6±14.1 a	12.7±3.9 ab	22.9±5.9 b	24.2±4.8 a

Table 4. Average spore density, diversity of AM fungal species, and root colonization rates of 18 cut-slopes of expressway roadbanks at different site ages. (SE: standard error; Means with the same letter are not significantly different at $P \leq 0.05$.)

Age class	No. of spores per 100 g soil (mean±SE)	No. of AM fungal species	Root colonization rate (mean±SE, %)
Young age (2~5 years)	1,213±465 ab	25	21.2±4.9 a
Intermediate age (9 years)	549±135 b	24	10.1±2.0 b
Advanced age (16 years)	2,289±583 a	24	17.5±3.0 a

age to 21.2±4.9% in the young age. The rate in the site of intermediate age was significantly lower than the other two sites (*P*=0.022 with young age sites and *P*=0.029 with advanced sites, respectively). The fungal density and the root colonization rate showed similar direction. Fungal diversity showed little difference among three site ages, which suggested that the fungal diversity was not affected by the aging of sites.

Table 5. Correlation coefficients (*r*) and coefficient of determination (r^2: numbers in parentheses) between soil properties and site age, and fungal parameters of spore density, root colonization and diversity of fungal species.

	Spore density	Root colonization	Fungal diversity
Soil pH	−0.75(0.56)	−0.58(0.34)	−0.64(0.41)
Soil P (ppm)	−0.60(0.36)	−0.69(0.48)	−0.84(0.71)
Soil N (%)	−0.76(0.58)	−0.49(0.24)	−0.66(0.44)
Site Age	0.48(0.23)	0.31(0.10)	0.11(0.01)

3. Correlation coefficients between soil characters and fungal parameters

The correlations between soil properties and fungal parameters of spore density, root colonization and fungal species diversity showed negative correlations, while correlations between site age and fungal parameters were insignificant (Table 5). Correlations between available P and the fungal diversity, between soil N and spore den-

Table 6. Soil chemical properties of the cut-slopes at the expressway roadbanks at different site ages. (SE: standard error; Means with the same letter are not significantly different at $P \leq 0.05$.)

Site Age	Soil pH (mean±SE)	Available P (mean±SE, ppm)	Soil N (mean±SE, %)
Young Age (2~5 years)	6.9±0.5 a	29±6.2 a	0.09±0.03 a
Intermediate Age (9 years)	7.6±0.4 a	25±12.6 a	0.07±0.01 a
Advanced Age (16 years)	5.9±0.1 b	14±3.5 b	0.13±0.00 b

Table 7. A list of arbuscular mycorrhizal fungi (AMF) identified from the soils of 18 cut-slopes of expressway roadbanks in Gyeongi Province, Korea. A total of 40 AMF species in 7 genera were identified.

Names of genus (No. of species)	Names of species	
Acaulospora (12)	*appendicula* Spain, Sieverding & Schenck	*bireticulata* F.M. Rothwell & Trappe
	elegans Trappe & Gerd.	*lacunosa* J.B. Morton
	laevis Gerd. & Trappe	*mellea* Spain & N.C. Schenck
	morrowiae Spain & N.C. Schenck	*rehmii* Sieverd. & S. Toro
	rugosa J.B. Morton	*scrobiculata* Trappe
	spinosa C. Walker & Trappe	*sporocarpia* S.M. Berch
Diversispora (1)	*spurca* (C.M. Pfeiff., C. Walker & Bloss) C. Walker & Schüßler	
Entrophospora (2)	*columbiana* Spain & N.C. Schenck	*kentinensis* Wu & Liu
Gigaspora (4)	*albida* N.C. Schenck & G.S. Sm.	*decipiens* I.R. Hall & L.K. Abbott
	gigantea (T.H. Nicolson & Gerd.) Gerd. & Trappe	*margarita* W.N. Becker & I.R. Hall
Glomus (10)	*aggregatum* N.C. Schenck & G.S. Sm.	*albidum* C. Walker & L.H. Rhodes
	boreale (Thaxt.) Trappe & Gerd.	*cerebriforme* McGee
	constrictum Trappe	*fasciculatum* (Thaxt.) Gerd. & Trappe emend. C. Walker & Koske
	geosporum (T.H. Nicolson & Gerd.) C. Walker	*mosseae* (T.H. Nicolson & Gerd.) Gerd. & Trappe
	rubiforme (Gerd. & Trappe) R.T. Almeida & N.C. Schenck	*sinousum* R.T. Almeida & N.C. Schenck
Paraglomus (1)	*occultum* (C. Walker) J.B. Morton & D. Redecker	
Scutellospora (10)	*aurigloba* (I.R. Hall) C. Walker & F.E. Sanders	*calospora* (T.H. Nicolson & Gerd.) C. Walker & F.E. Sanders
	dipapillosa (C. Walker & Koske) C. Walker & F.E. Sanders	*erythropa* (Koske & C. Walker) C. Walker & F.E. Sanders
	fulgida Koske & C. Walker	*gilmorei* (Trappe & Gerd.) C. Walker & F.E. Sanders
	gregaria (N.C. Schenck & T.H. Nicolson) C. Walker & F.E. Sanders	*minuta* (Ferrer & R.A. Herrera) C. Walker & F.E. Sanders
	nigra (J.P. Redhead) C. Walker & F.E. Sanders	*persica* (Koske & C. Walker) C. Walker & F.E. Sanders

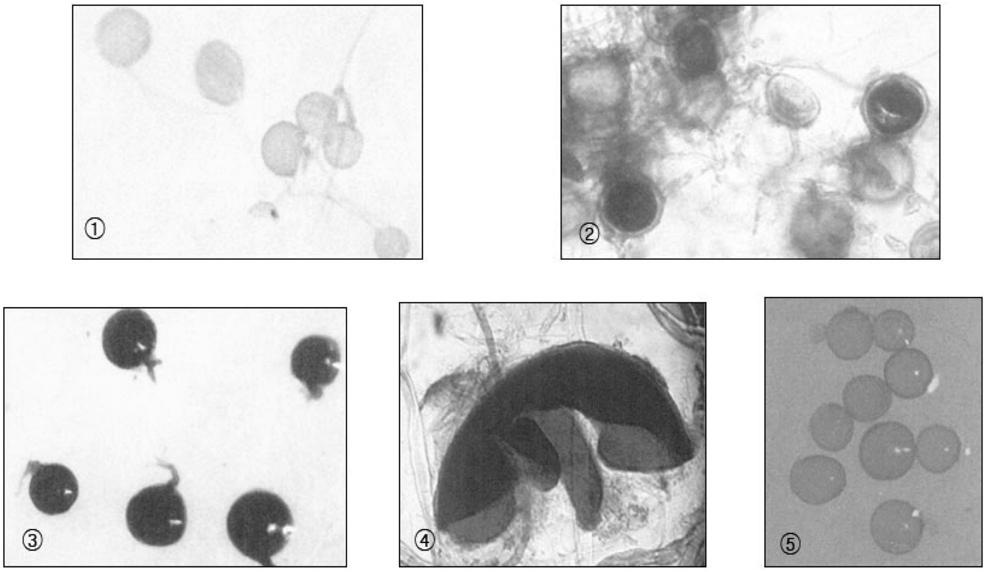

Figure 1. Five most dominant species out of total forty AM fungal species identified from the soil of the cut-slopes at the expressways in Gyeonggi Province, Korea. *Acaulospora lacunosa*, *Glomus aggregatum*, *Glomus constrictum*, *Scutellospora erythropa*, and *Acaulospora spinosa*.

sity, and between soil pH and spore number were relatively high (r^2=0.71, 0.58 and 0.56, respectively).

4. Variation of soil chemical properties

The acidity at the site of advanced age (5.9±0.1) was significantly higher than the other age classes (P=0.002 each) (Table 6). Available phosphorous in the soils at the site of advanced age was 14±3.5 ppm, which was significantly lower than that at the young age one of 29±6.2 ppm (P=0.003), while soil nitrogen content at the site of advanced age (0.13±0.00%) was significantly higher than that at the young age sites (P=0.002).

5. AM fungal diversity at the cut-slopes of expressway roadbanks

A total of 40 AMF species in 7 genera were identified, and species belonging to Glomineae, genera *Acaulospora*, *Entrophospora*, *Glomus* and *Paraglomus*, covered two thirds of the species (Table 7). Three quarters of total AM fungi belonged to the three most common genera, *Acaulospora*, *Glomus* and *Scutellospora,* with 12, 10 and 10 species, respectively. Of 40 species *Acaulospora lacunosa* was the most dominant species and found at almost all the sites. The next dominant species were *Glomus aggregatum*, *Glomus constrictum*, *Scutellospora erythropa* and *Acaulospora spinosa* in the decreasing order (Figure 1).

Discussion

In rehabilitation of the cut-slopes along the expressway roadbanks in Korea, exotic and indigenous species of plants listed in Table 2 have been recommended. At first, exotic species were preferred because of their advantages of initial fast growth and availability of cheap high quality seeds. But indigenous species are more recommended nowadays because of retarded succession caused by exotic plants (Jeon, 2004). After stabilization works for those slopes, similar species were also reported as invading plants in advanced cut-slope areas of expressway in Korea. The older the sites were, the more invading species were found according to the successional sequence of plant communities covering the sites. Particularly *Artemisia* species and *M. sinensis* which are highly resistant to drought have been known to invade during the early succession open and dry sites disturbed by human activities (Woo *et al*., 1996; Song *et al.*, 2005).

The mycorrhizal colonization was highly variable according to the species and environments of the sites. Cui and Nobel (1992) reported that the colonization for glasshouse-grown three desert succulents varied from 8 to 64%. The colonization rates of four leguminous tree species in 10-year-old plots at Bandia, Senegal varied with the range from 31 to 64% (Ingleby *et al*., 1997). Much variation of the rates was also found in semi-natural grassland in UK without exception (Sanders and Fitter, 1992). This kind of variety would be caused by preferential establishment of symbiosis between certain plant and AMF species (Mathimaran *et al*., 2005) and highly plastic and responds to environmental factors in AMF root colonization that we do not yet understand (Busso *et al*., 2008). Higher mycorrhizal colonization of the invading plants in the advanced age sites were similar to the results of the study that the colonization in the late-seral was higher than in the earlier-seral species, which may partly explain its higher competitive ability in comparison with the earlier-seral species (Busso *et al*., 2008).

In spite of positive correlations between spore density and root colonization rate, and negative correlations between soil properties and fungal parameters in this study, the results of the former studies are in confusion. Some inoculation experiments revealed positive relationship between mycorrhizal root colonization and spore density as this study (Guevara and López, 2007; Nagesh *et al*., 1999), but no significant correlations were observed from another studies at cultivated lands (Akond *et al*., 2008; Li *et al*., 2007). On the other hand, the relationships were negative in rain forests and moderately fertile alkaline soils (Louis and Lim, 1987; Moreira *et al*., 2006; Udaiyan *et al*., 1996). Correlation between soil pH and AM colonization is also equivocal. Overall AM colonization was significantly reduced by acid deposition (Brewer and Heagle, 1983; Kim *et al*., 2006), while the effects of acid were less obvious in other cases (Heijine *et al*., 1996; Nowotny *et al*., 1998; Mohammad *et al*., 2003).

Many studies suggest that a various interaction between host plants and AM fungi may cause an irregularity in the spore density in soil. According to the test of the abilities of three types of propagules (spores, fresh root fragments with adhering hypae and hyphal fragments) from eight AM fungi to colonize roots of *Allium porrum*, *Glomus* and *Acaulospora* species colonized roots from all three inoculums sources, but *Scutellospora* sp. and *Gigaspora* sp. appear to depend entirely on spores (Klironomos and Hart, 2002). Mathimaran (2005) observed strong effect of crop plant species on spore densities in the soil at the survey in a long-term field fertilization experiment in Switzerland. In addition, effects of fertilization on the abundance and diversity of AM fungi depended upon the sensitivity of the fungal species to the fertilization (Bhadalung *et al*., 2005). Further studies, considering interaction among AM fungi, host plants and environmental factors, are needed to determine the correlation among the root colonization, spore density and soil properties.

Limited researches on soil chemical properties of cut-slopes created by road construction are available in Korea. Korea Highway Corporation (1995) reported that national average of acidities of cut-slopes on the expressways were pH 6.7~7.0, and Woo *et al*. (1996) reported that those of 8 year aged highway cut-slope were pH 6.4~6.9, which were similar to those at the sites of young and intermediate age in this study. The 3 years old slopes on the local road constructed in the Jiri mountain showed lower pH of 5.8~6.6, similar to that of the advanced age ones. The average of available P of the slopes were 5.8 ppm, lower than those of the present study, while the average of the soil N was 0.12%, similar to that of the advanced age ones (Seo *et al*., 1991). These kinds of variations in soil chemical properties might be caused by the diversity of rehabilitation methods of the cut-slopes. Comparing the soil chemical properties of advanced age sites with those of forest soils adjacent to the slopes in Jiri mountain, pH of the forest soil (5.3) was lower, but available P (22.1 ppm) and soil N (0.49%) were higher than those of the advanced age sites of the present study (Seo *et al*., 1991).

The biodiversity of 40 AM fungi in the cut-slopes of expressway in the present study was similar to 43 species in the hot-dry valley of the Jinsha River, southwest China (Zhao and Zhao, 2007), and was greater than 27 AM fungal species in the tropical rain forest of Xishangbanna, southwest China (Zhao *et al*., 2001; Zhao *et al*., 2003), 21 species in arid regions of southwestern North America and Namibia (Stutz *et al*., 2000), and 7 species in semi-arid areas of Senegal (Diallo *et al*., 1999). This relatively higher diversity of AM fungi could result from a wide variation in establishing ages of the sites causing plant diversity (van der Heijden *et al*., 1998; Zhao and Zhao, 2007).

Major AM fungal species were also various. The fungi most frequently found in Yuan River, southwest China, Senegal and moist tropical forest in Cameroon were members of the genera *Acaulospora* and *Glomus* (Musoko *et al*., 1994; Diallo *et al*., 1999; Li and Zhao, 2005). Likewise in the hot-dry valley of Jinsha River, southwest China, 28 out of 43 fungal species belonged to genus *Glomus* (Zhao and Zhao, 2007). Relatively high frequency of large-spored AMF species, *Scutellospora* sp. and *Gigaspora* sp., implied increasing plant diversity (Burrows and Pfleger, 2002).

The two suborders, Glomineae and Gigasporineae, under the order of Glomales have been reported to establish symbiotic mycorrhizal association with approximately 80% of terrestrial plants species in their roots (Trappe, 1987). In Korea AM fungal taxonomy and diversity have been studied by some scientists for agricultural and horticultural purposes (Lee *et al*., 1993; Lee *et al*., 1994). There are very few reports on the AM fungal diversity in woody plants or forest ecosystems. In this study a total of 40 AMF species were identified from cut-slopes of expressway roadbanks where several grasses and woody plants showed some successional changes over time. *A. lacunosa*, *G. aggregatum*. *G. constrictum*, *S. erythropa* and *A. spinosa* were the five most dominant species. AMF species mentioned above may be considered as a fungal population that have been adapted to the harsh environments of the cut-slopes with high water stress during dry seasons in Korea. These fungi may be introduced in the future to the new cut-slopes as an initial soil inoculum to promote early establishment of endomycorrhizal association.

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