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Recent Progress in Lichen Research in Korea – from Taxonomic Study to Environmental Application

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Lichen is one of the most widely distributed eucaryotic organisms in the world. Lichen is the result of a symbiotic association between two unrelated organisms - a fungus and an alga (or cyanobacterium). In USA, Japan and European countries, there has been a resurgence of interest in lichens as source of novel, pharmacologically active molecules during the last 20 years. However, lichen researches in Korean lichens were mainly focused on investigation of Korean lichen flora and most of them were primitive and short-term based projects until 1990s. In this communication, general introduction of lichens was attempted to draw the attention of Korean researchers to Korean lichen bioresource. Research activities on Korean lichens during the past were also summarized. Recent progress in Korean lichen research is briefly discussed with emphasis of KoLRI (Korean Lichen Research Institute) activities and roles in national researches projects on bioresource development in Korea.

What Lichens are?

Lichens are unique in the world of vegetation in that they cannot be neatly classified into any of the ordinary categories we think of as "plants". The reason is simple: a lichen is not a single entity, but a composite of a fungus and an organism capable of producing food by photosynthesis. Lichen fungi can associate with green algae or cyanobacteria (the latter also known as blue-green algae), or sometimes both, and none of these three groups are plants in the strict, modern sense (which now include mainly mosses and vascular plants). The special biological relationship found in lichens is called symbiosis. The resulting composition of a fungus and its photosynthetic symbiont (photobiont) has been such an evolutionary success that there are close to 14,000 species of lichens in the world, tremendously diverse in size, form, and color. They are found from the poles to the tropics, from the intertidal zones to the peaks of mountains, and on every kind of surface from soil, rock, and tree bark to the backs of living insects.

Lichenization is one of the most successful methods by which fungi fulfill their requirement of carbohydrates from a photosynthetic partner. The fungus produces a thallus or body, within which the photobionts are housed and protected from adverse stresses such as UV and dryness. The fungi that form lichens belong, for the most part, to the Ascomycetes, or "sac fungi", distinguished by producing their microscopic reproductive spores in tiny sacs called asci (Table 1). There are almost 30,000 species of

Table 1. Numbers of lichen-forming species in the various subdivisions of the fungi (Hawksworth, 1988)

Subdivision	Number of species	Number of Lichenized species	Lichenized species (%)
Ascomycotina	28,650	13,250	46.25
Basidiomycotina	16,000	50	0.31
Deutromycotina	17,000	200	1.18
Mastigomycotina	1,170	1	0.09
Myxomycotina	625	2 (?)	0.32 (?)
Zygomycotina	765	0	0
Total (rounded)	64,200	13,500	21

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Table 2. Alphabetic list of algal genera reported as phycobionts (Tschermak-woess, 1988)

Anabaena*	Dichothrix*	Mostoc*
Anacystis*	Dictychloropsis	Petroderma*
Aphanocapsa*	Dilabfilum	Phycopeltis
Asterochloris	Elliptochloris	Prasiola
Blidingia	Gloeocapsa*	Protococcus
Calothrix*	Gloeocystis	Pseudochlorella
Cephaleuos	Gongrosira	Pseudotrebouxia
Chlamydomonas	Heterococcus*	Scytonema*
Chlorella	Hormathonema*	Stichococcus
Chlorosarcinopsis	Hyella	Stigonema*
Chroococcidiopsis*	Hyphomorpha*	Tolypothrix*
Chroococcus	Leptosira	Trebouxia
Cladophora	Myrmecia	Trentepophlia
Coccobotrys	Myxosarcina*	Trochiscia
Coccomyxa	Nannochloris	

*Cyanophyceae

ascomycetes, almost half of which form lichens. A large and diverse variety of ascomycetes, including 13 major groups (orders) out of 43, are represented among the lichens. Because such a large number of unrelated fungi are involved in lichen formation, biologists know that lichens have not evolved from a common ancestor.

There are about 25 genera of green algae, a few golden algae, one brown alga, and 12 genera of cyanobacteria (or blue-green algae) that become associated in lichens as photobionts (Table 2). Another few are algae of other kinds. Only a dozen genera, however, represent the photobionts in the vast majority of lichens (Tschermark-Woess, 1988). Many photobionts are not easy to identify within the lichen thallus, because they can be substantially changed by the symbiotic state. To be identified with absolute certainty and precision, even to genus, most have to be isolated from the lichen and growth by themselves in culture.

The appearance of each lichen is determined almost entirely by the genetic information contained in the fungus, which, in most cases, determines the lichens structure. Evidence of various kinds supports the assumption that, with few exceptions, every recognizable lichen is derived from a different species of lichenized fungus. For this reason, and in agreement with internationally accepted rules of nomenclature, the name we give to a lichen is actually the name of its fungal component. When we say, "This lichen is *Cladonia cristatella*", we mean that the fungus of the lichen *is Cladonia cristatella*; the photobiont has its own name, in this case, the green algae *Trebouxia erici*.

We cannot place intact lichens within the hierarchical systems of biological classification according to categories including kingdom, phylum, class, order, family, genus, and species, because lichens are dual organisms, and each component has its own classification. Relationships among lichens are expressed in the classification of the lichen-forming fungus alone. Such systematic classifications have been and may still are highly heterogeneous. Many older proposals for systematic arrangement of families and genera had to be changed due to an increasing attention to ultrastructure, primarily of asci and ascospores, to ontogenetic features of fruiting bodies, and to recent work with DNA. This process of changes in systematic arrangements, due to more detailed studies by modern means, is still incomplete.

In talking about growth forms, we refer to the vegetative body of the lichen, the thallus. In most cases, the bulk of lichen consists of its thallus (as opposed to the reproductive or fruiting structures). A thallus consists of a cortex and medulla, both made up of fungal tissue, and a photobiont layer in which the algal or cyanobacterial cells are enveloped by fungal hyphae. The cortex protects the photobiont cells from drying and excessive light while the loosely woven medulla facilitates gas exchange. Cells in the photobiont layer, which makes up about 7% of the total thallus volume, are arranged in a manner to obtain optimal sunlight for photosynthesis. The different layers and their position in the thallus are the result of adaptive responses of the bionts to each other and to their external environment. There are three major kinds of thalli, namely, crustose, foliose and fruticose.

Lichens play a significant role in nature, influencing soil fertility, the growth of surrounding plants, and the formation of soil over bare rock or sand, as well as providing food, nesting materials and shelter for mammals, birds, and invertebrates. Lichens also have any commercial or practical values. People have used lichens over the centuries as food and decoration, and as a source of dyes, medicines, poisons, and fiber. More recently, they have been employed mainly in the manufacture of perfumes and antibiotics, and as pollution monitors and indicators of old growth forests. In Asian countries such as Japan, Korean and China, one kind of rock tripe, called rock mushroom (*Umbilicaria esculenta*; Iwatake, 石耳), has been used as medicine and food for a long time.

During the past 20 yr there has been a resurgence of interest in fungi and other microorganisms as source of novel, pharmacologically active molecules. Lichen-forming fungi produce a wide range of natural products among which approximately 350 secondary metabolites have been identified (Elix et al., 1984; Galun and Shomerllan, 1988); many are unique to lichens and appreciable number have been shown to have several biological activities of potential economic values (Olafsdottir

and ingolfsdottir, 2001).

Lichen-forming fungi have been shown to retain in axenic culture the capacity to biosynthesize secondary products found in the lichenized state (Leuckert et al., 1990; Culberson et al., 1992) although the metabolites produced in the great abundance might differ from those found in lichen (Miyagawa et al., 1993; Hamada, 1993). Intact lichens cannot be cultivated readily and the majority of species are thin crust which are often immersed in rock or bark substrata, making the harvesting of natural populations impractical. Furthermore, large scale collection programs are likely to conflict with conservation interest. Therefore, laboratory cultures of lichen-forming and lichenicolous fungi provide a means by which lichen secondary metabolites can be produced for the purpose of evaluation in programs to discover microbial products (Crittenden et al., 1995).

Researches on Korean Lichens During the Last Few Decays

Since Korean lichens were first reported by Hue on 1915, Japanese researchers mainly investigated flora of Korean lichens until 1945 (佐藤月二 , 1939; Ashina & Sato, 1939; 佐藤正己 , 1943). Few Korean researchers have investigated the flora of Korean lichens from early 1970s to 1990s (Kim, 1981; Park, 1982; Park, 1990). According to Kims report (1981), there were 28 families, 52 genera and 217 species of Korean lichens. Many specimens of Korean lichens were supposed to be prepared and conserved at that time, but most of them are not available at this moment. Park (1990) also reported 17 families, 46 genera and 189 species of macrolichens in Korea. Her specimens were deposited at the lichen herbarium of Duke University. There were 248 species of lichens reported in North Korea (Hawksworth & Ahti, 1990).

Researches on Korean lichens until early 1990 were mainly focused on investigation of Korean lichen flora. However, most of the works were not submitted to international community and thus, were not internationally approved. Because there has been no research core for lichen studies in Korea during the last 50 year, official specimen, data and information on Korean lichens have not been accumulated. Application of lichens to air pollution monitoring study was launched in Korea at early 1990 (Ka et al., 1995; Yu et al., 1995). Recently, isolation of lichen-forming fungi and investigation on polysaccharides of Korean lichens were attempted (Hur et al., 1999; 2003d; Lee & Kim, 2000). Most researches on Korean lichens during the past were primitive and short-term based projects.

Recent Progress on Lichen Research in Korea

Taxonomic studies of Korean lichen. Most recent publication on taxonomical study of Korean lichens was reported by Kashiwadani and Moon (2002). Dr. Moon is one of well-known Korean taxonomists on lichen, especially *Parmeliacea* lichens. She has reported many taxonomical researches on Korean lichens since mid 1990s. Recently, KoLRI (Korean Lichen Research Institute, Sunchon Nation University, Korea) was established and launched national wide campaign on Korean lichen collection. More than 700 specimens of Korean lichens were collected in 2003. Ninety-three species in 40 genera were officially identified and reported (Hur et al., 2003a). In this revised lichen flora of South Korea, 35 species are apparently new to the territory (Table 3, Fig. 1). Voucher specimens are deposited in KoLRI and are duplicated to National History Museum and Institute, Chiba (CBM) in Japan. More than 50 species of highland (elevation is more than 2500 m) macrolichens in Yunnan, China were also deposited in KoLRI. Most of them are rarely found in South Korea.

For lichen identification and taxonomic works, lichen taxonomists generally used morphological and chemical characteristics (Culberson et al., 1988; Fahslt, 1996). There are many illustration books on the lichens of North America, Europe, Australia, Japan, Taiwan and other countries with their own identification keys and full description on morphology and chemical compounds. However, no such books on Korean lichens are available, yet. Parks floristic study (1990) on 192 marcolichen species in South Korea is internationally accepted and most frequently cited publication until now. Most of Korean lichen species are deposited in oversea herbariums in U.S.A., Europe and Japan. Due to lack of accumulated information on Korean lichens and of reference lichen specimens, it is very hard for Korean lichenologists to identify Korean lichen at the species level for taxonomic study without cooperative works with foreign experts. Therefore, the followings should be the prerequisitions for basic taxonomic works for Korean lichenologists; 1) intensification of cooperative works with foreign lichenologists and institutes, 2) construction of data base of Korean lichens, 3) collection and preservation of Korean lichens as many as possible, and 4) establishment and management of national herbarium of lichens. KoLRI will make best effort to be the core of all these activities in Korea in the near future. Newly released publications on basic knowledge and techniques for lichen collection, specimen preparation and identification will be good references to whom lichen study is a relatively new experience (Brodo et al., 2001; Kranner

Table 3. Macrolichens of South Korea (Bold means newly reported species in 2003)

Ascomycetes	Lecanorales	Physciaceae	*Anapthchia*	*isidiza*
				palmulata
			Dirinaria	*applanata*
			Heterodermia	*dissecta*
				hypoleuca
				japonica
				microphylla
			Phaeophyscia	*ciliata*
				limbata
			Physcia	*orientalis*
				phaea
			Physciella	*denigrata*
				melanchra
			Pyxine	*endochrysna*
		Telischistaceae	*Xanthoria*	*mandscurica*
		Usneaceae	*Ramalina*	*commixata*
				conduplicans
				excilis
				purtusa
				siliquosa
				sinensis
				yasudae
		Anziaceae	*Anzia*	*colpota*
				opuntiella
		Parmeliaceae	*Canoparmelia*	*texana*
			Cetrelia	*japonica*
			Flavoparmelia	*caperata*
			Hypotrachyna	*osseoalba*
			Menegazia	*terebrata*
			Myelochroa	*aurulenta*
				entotheiochroa
				irrugans
			Pamelia	*adaugescens*
				lavior
				marmariza
				marmophylla
				omphalodes
				pseudolaevior
			Parmotrema	*Austrosinense*
				Tinctorum
				ultralucens
			Parmelinella	*wallichiana*
			parmeliopsis	*horrescens*
				minarum
			Puncteria	*Rutecta*
			Rimelia	*clavulifera*
				reticula
		Umbilicariaceae	*Umbiilicaria*	*esculanta*

Table 3. Macrolichens of South Korea (Bold means newly reported species in 2003)

Ascomycetes	Lecanorale	Parmeliaceae	*Pamelia*	*fertilis*
				ksovana
			Lasallia	*sinorientalis*
				phensylvanica
		Cladoniaceae	*Cladonia*	*amaurocraea*
				angustata
				ceratophyllina
				chlorophaea
				furcata
				gracilis
				granulans
				humilis
				ramulosa
				rangiferina
				scarbriuscula
			Cladia	*aggregata*
		Sterocaulaceae	*Pilophorus*	*clavatus*
			Sterocaulon	*extum*
				japonicum
Ascomycetes	Lecanorales	Sterocaulacea	*Sterocaulon*	*sorediferum*
		Collemataceae	*Collema*	*flaccidum*
				japonica
			Leptogium	*azureum*
				buenetiae
				pedicellatum
		Linchinaceae	*Phylliscum*	*japonicum*
		Stictaceae	*Lobaria*	*japonica*
				retigera
			Sticta	*wrightii*
		Peltigeraceae	*Peltigera*	*degenii*
				elizabethae
				horizintalis
				nigripunctata
				polydactylon
				praetextata
				rufescens
			Nephroma	*bellum*
				helveticum
				parile
		Coccocarpiaceae	*Coccocarpia*	*palmicola*
	Sphaeriales	Verrucariaceae	*Dermatocarpon*	*miniatum*
Fungi imperfecti			*Laprocaulon*	*arbuscula*

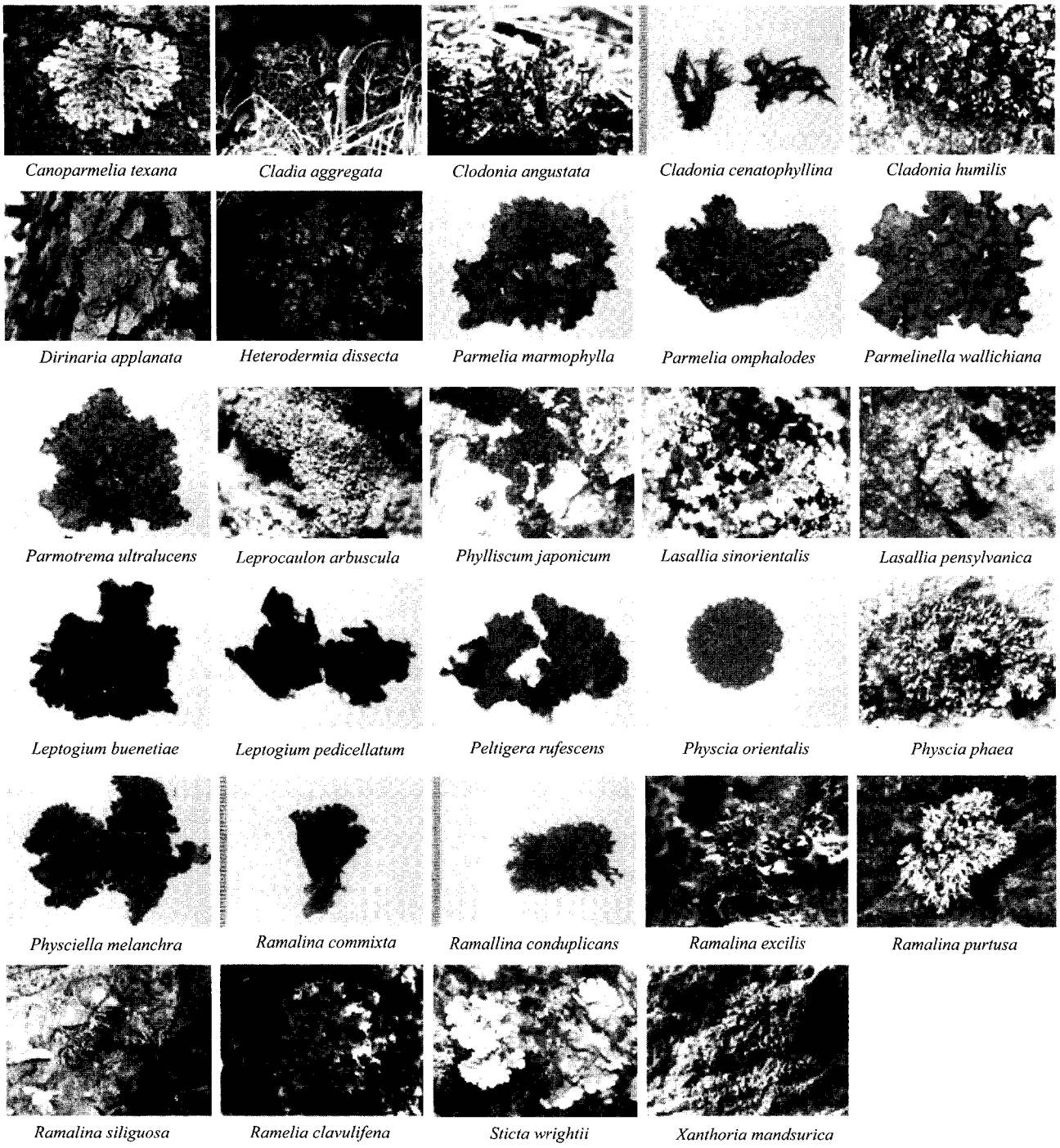

Fig. 1. The foliose and fructicose lichen species recognized presented in Table 3.

et al., 2002).

Molecular studies of Korean lichens. A number of studies have been made to assess the extent of genetic variation in lichens and lichen-forming fungal species, relying on morphological and physiological markers (Fahselt, 1996). However, such markers are subject to environmental and cultural influences (Fahselt et al., 1995) so may not prove totally reliable. The situation has changed now due to the possibility of assessing the DNA sequence data of mycobionts and using these data in phylogenic analyses. DNA sequence data for lichen-forming fungi were collected from the internal transcribed spacer (ITS) regions of ribosomal DNA (rDNA), which have been shown to possess variability that is useful at the species

level in many groups of organisms (Hills and Dixon, 1991). A number of large-scale, molecular phylogenic studies of lichenized ascomycetes have been initiated at the ordinal and higher levels (Gargas et al., 1995; Tehler, 1995).

More recently, primary genetic markers have been developed based on knowledge of the ribosomal DNA repeat unit structure. Sequence divergence within this gene cluster is widely used as a phylogenic tool to delineate fungal species including lichenized genera (Gargae et al., 1995), and some studies have now rDNA analysis to investigate variation within lichen populations. Randomly amplified polymorphic DNAs (RAPDs) technique is based on the amplification of genomic DNA with single primers of arbitrary sequence and results in the production of several DNA fragments that may be resolved by gel electrophoresis to generate a genetic fingerprint. It is a particularly useful tool for a number of reasons. RADP markers have been used to discriminate between species, populations, sub-populations and individuals, providing greater sensitivity than rDNA analysis (Rohel et al., 1997). Little starting material and no prior knowledge of the nucleotide sequence of the target genome are required. Also the technique is relatively quick and simple, allowing high throughput of samples. RADP analyses have rarely been used in lichenized fungi, yet (Lohtander et al., 1998; Murtagh et al., 1999; Printzen et al., 1999)

A brief and practical summary of some of the most important factors affecting the outcome of a PCR, with particular reference to direct sequencing projects in lichenized fungi, was also reported (Ekman, 1999).

Molecular studies on Korean lichens have first been made in 2003 to analyze the internal transcribed spacer (ITS) regions of ribosomal DNA (rDNA) of more than 30 lichen species in U-do islet in Jeju (Kahng et al., 2003). DNA sequence analysis of ITS1, 5.8S rDNA, and ITS2 regions of 93 lichen species presented in Table 3 is now under progress in KoRLI.

Isolation of lichen-forming fungi from Korean lichens. The separation, isolation and culture of the symbionts offer the scientists a fascinating opportunity to study the components and contribute to the understanding of the nature of the symbiosis in lichens. The culture of mycobionts, photobionts and lichen thalli is central for the establishment of experimental system for lichens, needed to solve questions associated with symbiosis biology. In addition, they are essential to solving the many fundamental problems of lichen physiology, morphogenesis and molecular biology. Cultures of lichen symbionts were considered to be too difficult to study mainly because of the time consuming, long-term techniques necessary for successful culture of the symbionts. In the past two or three decades, research on mycobionts, photobionts, and on resynthesis of lichens from isolated symbionts has made considerable progress. Cultures of lichen mycobionts and photobionts can be obtained by different methods (Yamamoto et al., 2002).

Lichen-forming fungi (LFF) produce a wide range of natural products among which approximately 350 secondary metabolites have been identified (Elix et al., 1984; Galun and Shomer-Ilan, 1988). Many of them are unique to lichens and appreciable numbers have been shown to have antimicrobial activity (Lawrey, 1986) or other biological activities of potential economic value (Nishitoba et al., 1987; Higuchi et al., 1993).

In Korea, few attempts have been made to isolate mycobionts from Korean lichens and screen their antifungal activities to plant pathogenic fungi (Hur et al., 1999; 2003d). Once mycobionts were isolated with techniques of discharges spore method with use of ascospore and tissue culture method with use of fragments of intact thalli (Crittenden et al, 1995; Yamamoto et al., 2002), researchers usually considered the isolated fungi to be the mycobionts of the examined lichen due to their cultural characteristics. Strictly speaking, no confirmation may be made until any evidences are proved. In fact, my research group isolated likely lichen-forming fungi from Korean lichen of *Umbilicaria esculanta* which showed typical cultural characteristics slow growing, red-color pigment, short and hairy mycelia on the surface of colony. However, DNA sequence data of ITS1, 5.8S rDNA, and ITS2 regions was totally different from the DNA sequence of the intact lichen and registered in NCBI. Now, all mycobionts isolated from Korean lichens are confirmed by comparison of their DNA sequence with that of their origins. Until now, 11 mycobionts in 4 species were isolated from Korean lichens and are deposited in KoLRI. Elucidation of their optimal cultural conditions and screening of their biological activies are now under progress in KoLRI.

Ecological application of Korean lichens as a bioindicator. Undoubtedly, the most important morden use of lichens is for monitoring air quality. For over 140 years, lichens have been known to be extremely sensitive to air pollution. This sensitivity derives from their ability to absorb chemicals rapidly from the air and rainwater, and from the delicate balance within the lichen symbiosis between the needs of the fungus and those of the photobiont. If a pollutant even slightly affects the well-being of one component, the partnership quickly breaks down and lichen dies.

Lichens can be harmed by a variety of pollutants, especially sulphur dioxide. Sulphric acid and nitric acid (components of acid rain), fluorides, ozone, hydrocarbons and metals such as copper, lead, and zinc are other important pollutants affecting lichens. Some lichens are

more sensitive than others to these pollutants, so a survey of the lichens in and around an urban or industrial area can give a good indication of air quality when the survey is combined with a study of the lichens found in more pristine habitats in the same region or historical records of lichens from the area. The most pollution-sensitive lichens include the filamentous, fruticose species such as *Usnea, Ramaliana* and *Teloschistes* as well as epiphytic lichens containing cyanobacteria as the principal or secondary photobiont for example, species of *Lobaria*, *Panaria*, and *Nephroma*.

Because lichens absorb pollutants far more efficiently than most other organisms, they can be analyzed in the laboratory for the polluting compounds. Such laboratory analysis of lichen samples has been used to assess environmental contamination by aromatic hydrocarbons and highly toxic polychlorinated biphenyls (PCBs) as well as sulphur dioxide and metal pollution emanating from smelters and other industrial sites. Lichen analysis was used to monitor the deposition of radioactive materials following the Chernobyl incident. Often, floristic surveys and lichen tissue sampling are done together to provide a more complete picture of pollution level. Transplanting healthy lichens into polluted areas or into areas that are undergoing pollution abatement programs can give investigators a good idea of the extent of pollution or the effectiveness of the abatement.

Floristic survey of lichen richness around industrial area and urban area has been attempted in the past in Korea (Yu et al., 1995). Screening of sensitive lichen species to atmospheric ozone was also made to select suitable bioindicator for air quality monitoring (Hur and Kim, 2000). Transplanting healthy lichen to urban area (Seoul) and industrial area (Pohang) was investigated and analyzed for evaluation of air pollution risk (Ka et al., 1995; Hur et al., 2003c).

Recently, some soil lichens such as *Cladonia* was reported to play an important roles in stabilization of abandoned coal waste dump soil in Taeback, Korea. The lichen species are acidophilous and tolerant to heavy metals accumulation. Soil microbial activity can be triggered by lichen leakages into coalmine waste soil. The ecological role of these soil lichens in man-induced disturbed habitats such as an abandoned coalmine waste dump was first discussed with the emphasis of restoration of soil ecosystem in a pioneer stage of succession (Hur et al., 2003b).

Bioinformation of lichens on internet. The Internet has completely changed the ways biologists search for information. At present, biologists can easily access to biological resources such as biological data, scientific articles, and software tools to use in analyzing biological data, through the Internet.

Biodiversity is distributed all over the Earth and there is an enormous amount of information already collected about the worlds biodiversity. However, most of biodiversity information has not been digitized. This information is, moreover, largely concentrated in developed countries. For example, a vast number of specimens and associated information of the specimen are held in the natural history museums and herbaria in developed countries rather than in its source country (James et al., 2000).

A number of biodiversity databases have recently been developed in many countries. Research scientists have difficulty in accessing biodiversity data, since they are scattered in the museums and herbaria of the world. The global biodiversity information facility (GBIF) was established for facilitating the digitization of biodiversity data and for making interoperable biodiversity databases that are distributed worldwide (James et al., 2000). The participants, working through GBIF, will establish and support a distributed information system that will enables users to access and utilize considerable quantities of existing and new biodiversity data (http://www.gbif.org). Korea was a member of the interim steering committee for GBIF and joined the GBIF as a participant in 2001.

Lichen like other biological resources is distributed all over the Earth.

www.botany.hawaii.edu/lichen
http://ces.asu.edu/ASULichens
http://ucjeps.berkeley.edu/rlmoe
http://www.ut.ee/lichens
http://www.kulawanka.ne.jp/~yozyamam/lichen.htm
http://www.lias.net/index.html
ttp://mgd.nacse.org/hyperSQL/lichenland
http://users.argonet.co.uk/users/jmgray/
http://home.hiroshima-u.ac.jp/lichen/lsjle.htm
http://www.unomaha.edu/~abls/
http://www.blwg.nl/
http://www.lichen.com/
http://dbiodbs.univ.trieste.it/sli/home.html

KoLRI started to construct DB of Korean lichens and to provide some information on line. The homepage of KoLRI is http://ichen.suncon.ac.kr. However, most parts of the homepage are now under construction and official opening will be in early summer of 2004.

Future works on Korean lichens. The Fundamental investigation on classification and identification of Korean lichens should be precisely completed. Although Korean lichen flora has been investigated for the last few decays and some reports were worth of scientific citation, systematic classification of Korean lichen and proper organization of Korean lichen flora are still far from the standard of international lichenology societies. This underestimated status of Korean lichen may be due to the lack of experts and/or specialized research groups of

Korean lichens. Personal curiosity and interest in Korean lichens cannot drive national-based research programs no long under the circumstance of globalization. Long-term programs for raising researchers and expert groups (associations) should be established and continuously supported by national-base organizations.

For identification of Korean lichens, systematic classifications of North American lichens, Japan lichens and European lichens are practically used because of no established systematic classification of Korean lichens. With use of these classifications, most of Korean lichens can precisely be identified at the level of order, family and genus, but hardly be identified at the level of species. Establishment of systematic classification of Korean lichens is the most fundamental and prerequisite work for Korean lichen research. Therefore, the information of individual lichens should be prepared, accumulated, and integrated into the whole frame requiring establishment of Korean lichen systematic classification. For example, characteristics of morphology and their description should be completed with visible evidences such as photos and drawings. Recently, KoLRI (Korean lichen Research Institute) at Sunchon National University started to collect the information and to construct D/B system accessible online by internet. In addition to morphological characteristics, information on spot tests, chemical compounds, and nucleotide sequence of 5.8S rDNA have also been prepared and accumulated. Molecular works on 5.8S rDNA of Korean lichens will provide with new features of Korean lichen classification and allow comparative study of Korean lichens with the lichens in other countries.

Lichens specimens are usually deposited and conserved at specialized herbarium of university and national institute. There are many famous lichen herbariums in USA, Japan, UK, and several countries. Unfortunately, there is no official lichen herbarium and special curators in Korea, so far. Establishment of Korean lichen herbarium is also needed in the near future. The herbarium will take charge of all specimens of Korean lichens and join the international exchange program of lichen specimens. Recently, far-east Asian network of lichenology was launched by the Japanese Society of Lichenology. Lichenologists in Korea and China were invited to participate the network for collaborate works. KoLRI is now ready to join the network to share information and natural bioresource.

Laboratory cultures of lichen-forming and lichenicolous fungi provide a means by which lichen secondary metabolites can be produced for the purpose of evaluation in programs to discover microbial products (Crittenden et al., 1995). There have been several methods to isolate lichen-forming fungi from intact lichens (Ahmadjian, 1993). Although ascospore or intact thallus is mainly used

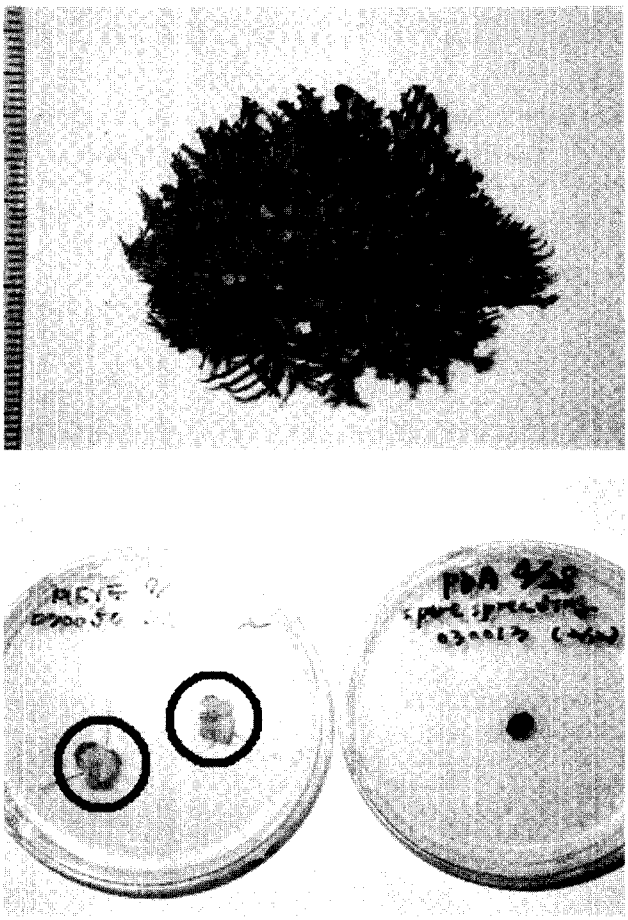

Fig. 2. Fungal isolates obtained from *Ramalina conduplicans.*

to isolate the fungi, it is very difficult to obtain pure isolate of the lichen-forming fungus because of high rates of contamination, and low rates of germination and/or cultivation on artificial media. It is also difficult to distinguish lichen-forming fungal isolate form lichenicolous fungal isolates originated from the same lichen. Currently, isolation of lichen-from fungi from Korean lichens has intensively been attempted with several novel techniques such as micro-manipulation and differential centrifugation. Molecular work on 5.8 S rDNA was also employed to identify the real lichen-forming fungal isolate from contaminated fungi. Few lichen-forming fungi of Korean lichens were successfully isolated (Fig. 2). These isolates will be registered and deposited at KoLRI as a type culture. Screening, isolation and chemical identification of their compounds having biological activity against pathogens is now under progress.

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