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Primary Succession on Talus Area at Mt. Kariwangsan, Korea

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가리왕산 일대 돌서렁에서의 일차천이

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ABSTRACT

Stages of vegetation development on talus area were studied to examine temporal changes in species composition and vegetation structure, and to elucidate the mechanism of early patch formation. While ground coverage of lichens, which may form substrate for moss colonization and mitigate the heat-stress on rocks, decreased gradually, coverage of mosses increased slightly during primary succession. Ecological role of mosses related with water retention in community may be very important not only at pioneer stage but also at later stages because of little soil development on this talus area. Species diversity and species richness increased during the early stages of succession. *Parthenocissus tricuspidata* and *Sorbaria sorbifolia* var. *stellipa* dominated in liana stage, *Ulmus davidiana* for. *suberosa* and *Lindera obtusiloba* in shrub stage , and *Fraxinus rhynchophylla* and *Actinidia arguta* in subtree stage. Tree stage, however, was composed of mixed forest of several tree species.

U. davidiana for. *suberosa*, *L. obtusiloba*, *Securinega suffruticosa* and *Rhus chinensis* were relatively important woody species in early patch forming process. The results, however, suggested that early establishment on talus area might be strongly associated with chance for safe-site because both pioneer species and later species could take part in early patch forming process.

Key words: Primary succession, Talus area, Patch formation, Safe-site, Chance

INTRODUCTION

After formation of deglaciated terrain, sand dune, landslide, volcano, rock outcrops or talus area, such bare area is colonized by a series of species along primary succession (Tilman 1986). The life-history of the initial colonists in primary succession is determined largely by the nature of the substrate (Grubb 1986). Most primary successions are strongly associated with soil nitrogen level, height of the mature plant and specific microsite or safe site (Crawly 1986, Moral and Wood 1993, Walker *et al.* 1986).

Talus area, accumulated heap or mass of coarse and angular rock fragments at the foot of a steep mountainside or cliff, are made by a suite of weathering and mass movement processes (Whitney and Harrington 1993), and there are severe drought and heat stress for plant growth. Cox and Larson (1993) suggest that the talus vegetation develops in response to a positive feedback mechanism involving input of organic detritus from the neighboring cliffs, followed by accelerated vegetation development on patches of fertile organic matter. Though many primary successions have been studied on vegetation development concerning with soil development processes (Matson 1990, Uno and Collins 1987), early primary succession on talus area at Mt. Kariwangsan is little associated with soil development processes because of poor soil formation and little input of organic detritus from the neighboring stands. The purpose of this study is to elucidate temporal changes in species composition and structure of vegetation, and the mechanism of early patch formation on talus area at Mt. Kariwangsan, Korea.

STUDY SITE

This study was conducted on the Mt. Kariwangsan on the borderline between Pyongchang-gun and Chongson-gun (37°28′ N and 128°35′ E), Kangwon Province. The study sites are located at 500~650m in elevation and 25~30° in slope. Site 1 (S1) is located at Mapyongri, Chinbu-myon, Pyongchang-gun, north facing and 1.6 ha in area, and site 2 (S2) at Sukamri, Bukpyong-myon, Chongson-gun, east facing and 2.5 ha in area (Fig. 1). Mean annual temperature records 6.3°C and annual precipitation 1,894 mm at the Taegwallyong Meteorological Station located 30 km NE from the study site. Talus areas studied are formed by way of weathering of Triassic sedimentary rocks (Geological and Mineral Institute of Korea 1975).

METHODS

Division of successional stages

Vegetation developments were divided into 6 stages based on the height of vegetation and the patch size established. The lichen and moss stage (stage I) was characterized by colonization of lichens and mosses on rock surface without any vascular plants. The liana stage (stage II) was composed of one small and low patch, smaller than 1 m^2 in patch size and lower than 1 m in height. Earlier shrub stage (stage III) was composed of patches of 1 to 4 m^2 and 1 to 2 m. The later shrub stage (stage IV) was composed of patches of 4 to 20 m^2 and 2 to 4 m by expansion and combination of several small patches established earlier. The subtree stage (stage V) was completely covered by vascular plants of 4 to 7 m. The tree stage(stage VI) was made up of taller and stratified vascular plants of 8 to 15 m.

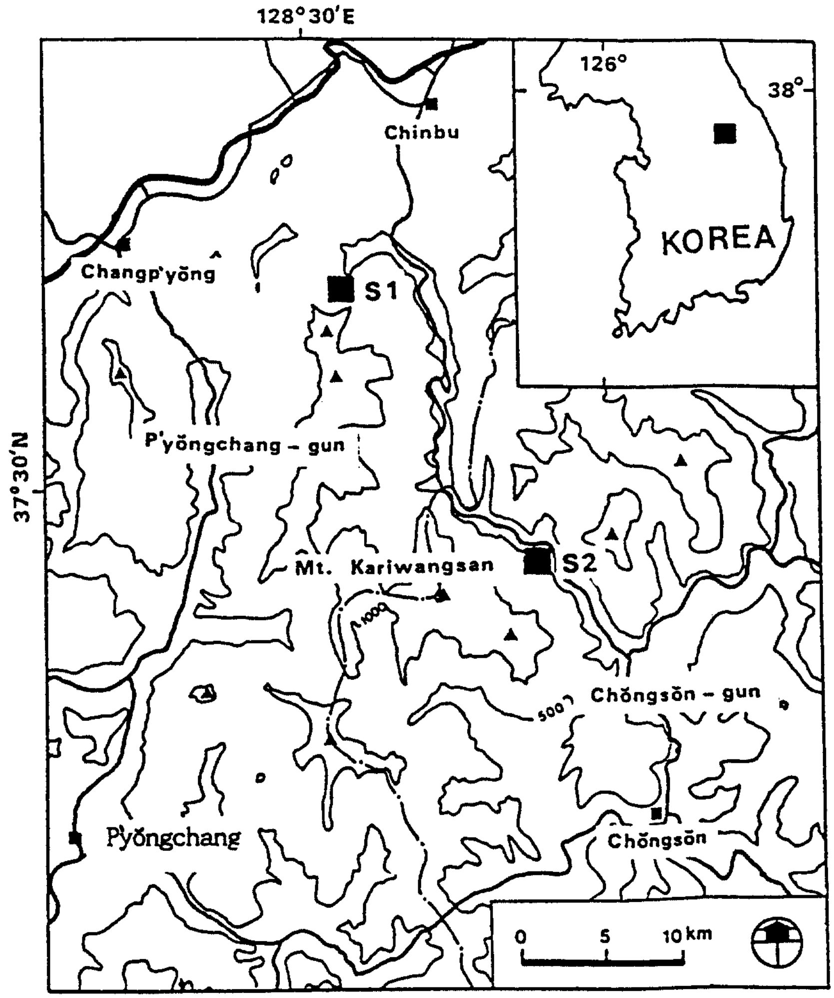

Fig. 1. Map showing the studied talus area (S1 and S2). S1 is located at Mapyongri, Chinbu-myon, Pyongchang-gun and S2 at Sukamri, Bukpyong-myon, Chongson-gun.

Community structure

During the growing season in 1993, 127 quadrats were placed in 6 seral stages. Quadrat dimension varied from 1 m^2 to 400 m^2 according to the state of vegetation development, considering the patch size and the vegetation height. Ground coverages of lichens, mosses and vascular plants and vegetation height were tallied. Relative coverage and frequency of each vascular species were calculated in 6 seral stages. Species richness (S), total number of species in each stage, was determined as well as that of life-form, such as tree, shrub, liana and herb. From the vegetation data, community attributes such as Shannon

Table 1. Summary of structural changes at various successional stages

Variables	Successional stage					
	I	II	III	IV	V	VI
Number of quadrats	10	9	28	49	17	14
Height of vegetation(m)	–	0.5^{a}	1.9^{b}	3.0^{c}	5.0^{d}	12.4^{e}
Ground coverage(%)						
Vascular plants	–	21.7^{a}	73.8^{b}	89.0^{c}	98.2^{d}	98.6^{d}
Lichens	26.0^{c}	27.2^{c}	12.4^{b}	14.0^{b}	5.2^{ab}	2.5^{a}
Mosses	32.5^{a}	45.6^{a}	53.8^{ab}	46.0^{a}	43.3^{a}	69.3^{b}
Species diversity(H')	–	0.76^{a}	0.95^{a}	1.10^{a}	2.04^{b}	2.47^{c}
Dominance index(C)	–	0.55^{b}	0.51^{b}	0.45^{b}	0.21^{a}	0.13^{a}
Evenness(e)	–	0.71^{ab}	0.63^{a}	0.63^{ab}	0.74^{ab}	0.78^{b}
Spatial heterogeneity (SD/H')		0.39	0.44	0.34	0.19	0.06
Aperial species richness (No. /quadrat)	–	2.44^{a}	5.07^{b}	6.06^{b}	16.35^{c}	24.14^{d}
Species richness						
Tree	–	–	2	12	14	15
Shrub	–	4	17	17	27	23
Liana	–	2	3	7	5	5
Herb	–	7	14	24	31	22
Total	–	13	36	60	77	65

Developmental stages were tesed by ANOVA. When variation among stages was significant, menas were tested using the Duncan's multple range test ; Values with the same letter were not significantly different.
Successional stage : I ; lichens+moss stage, II ; liana stage, III ; earlier shrub stahe, IV ; later shrub stge, V ; subtree stage, VI ; tree stage

and Weaver's species diversity index (H'), Pielou's evenness index (e), Simpson's dominance index (C) and spatial heterogeneity (SD/H'; Tramer 1975) were calculated. Analysis of variance (ANOVA) was used to test for any significant differences in community structure or diversity among developmental stages (Sokal and Rohlf 1981).

Relative frequency of early patch forming woody species

The most vigorous woody species in an isolated patch were regarded as the early patch forming species. In the liana and shrub stages, 85 isolated patches were taken a census for early patch forming species and their relative frequency was calculated.

RESULTS

As the vegetation develops from the liana stage to the tree stage, the vegetation height and the vascular plant coverage increased from 0.5 m and 22% in liana stage to 12.4 m and 99% in tree stage, respectively. While ground coverage of lichens decreased gradually, coverage of mosses increased slightly during vegetation development (Table 1).

Table 2. Relative coverage(RC) and frequency(F) of selected[a] vascular species found at various successional stages

Successional stages	I		II		III		IV		V		VI	
Number of Quadrats	10		9		28		49		17		14	
Species	RC	F	RC	F	RC	F	RC	F	RC	F	RC	F
Parthenocissus tricuspidata(V)			41.5	3	4.6	9	3.4	17	1.2	6		
Sorbaria sorbifolia var. *stellipila*(S)			21.2	3	1.7	5	2.3	8	2.3	7	1.0	5
Rhododendron mucronulatum(S)			7.8	3	2.8	3	1.8	2	0.7	2	0.2	1
Sedum polystichoides(H)			7.8	3	0.1	2	0.1	2	0.1	1		
Vitis coignetiae(V)			4.6	1	2.1	4	2.0	5	0.2	4	0.6	9
Deutzia prunifolia(S)			2.3	1	1.8	3			0.1	1		
Agastache rugosa(H)			2.3	1	1.0	9	0.1	5	0.1	1		
Syringa reticulata var. *mandshurica*(S)			9.2	1	7.7	7	3.8	10	7.3	7	9.8	12
Ulmus davidiana for. *suberosa*(T)					23.5	13	30.8	34	4.5	10	9.3	14
Lindera obtusiloba(S)					15.1	10	8.5	27	6.0	15	2.5	13
Securinega suffruticosa(S)					9.5	6	4.9	13	1.0	5	0.7	2
Lespedeza maximowiczii(S)					5.9	5	2.1	8	3.7	9		
Rhus chinensis(S)					4.7	6	7.9	14	1.3	9	0.2	2
Celastrus orbiculatus(V)					2.0	2	0.1	1				
Artemisia iwayomogi(H)					1.6	10	1.8	18	0.1	1		
Lonicera praeflorens(S)					1.7	3	0.6	2				
Aralia elata(S)					1.1	5	0.3	1	1.1	8	1.0	8
Deutzia glabrata(S)					3.4	3	3.2	7	3.1	6	9.6	14
Juglans mandshurica(T)					0.1	1	0.1	1			4.3	7
Philadelphus schrenckii(S)					2.0	1	1.4	2	1.3	4	3.4	14
Fraxinus rhynchophylla(T)							6.4	10	19.5	12	8.2	11
Quercus mongolica(T)							2.1	3	6.6	8	10.0	7
Actinidia arguta(V)							1.6	5	6.4	11	4.4	14
Magnolia sieboldii(T)							2.3	3	2.2	4	5.4	13
Styrax obassia(T)							0.8	3	4.3	4	0.5	1
Corylus sieboldiana(S)							1.1	3	3.7	6	0.9	6
Acer mono(T)							2.0	2	1.9	5	3.6	14
Picrasma quassioides(T)							1.1	2	2.8	4	0.4	5
Maackia amurensis(T)							0.4	1	1.4	4	2.4	4
Tilia mandshurica(T)							2.1	2			1.7	5
Betula davurica(T)							1.9	2			0.3	1
Smilax sieboldii(V)							0.1	4	1.0	7		
Prunus sargentii(T)									0.6	2	4.7	5
Weigela subseesilis(S)									2.8	6	1.3	10
Celtis sinensis(T)									2.6	1		
Acer pseudo-sieboldianum(T)									1.1	4	2.0	7
Spiraea fritschiana(T)									0.9	5	1.6	10
Euonymus oxyphyllus(S)									0.3	2	1.6	11

Table 2. Continued···

Dryopteris crassirhizoma(F)			0.2	5	1.5	14
Morus bombyscis(S)					1.0	5

[a] Selected species had a relative coverage (RC)>1 for at least one succesional stage.
Successional stage : I ; lichens and moss stage, II ; liana stage, III ; earlier shrub stage, IV ; later shrub stage, V ; subtree stage, VI ; tree stage.
Parenthesis followed by species means life-form. T ; tree species, S ; shrub species, V ; woody vine species, H ; herb species, F ; fern species.

As the vegetation develops, species richness (S) of whole vascular plants tended to increase gradually from liana stage to subtree stage but decreased slightly in tree stage. The same trends were shown in those of shrub and herb species. As the vegetation develops, species diversity (H') and aerial species richness (No. /quadrat) increased but domminance (C) decreased gradually. Species evenness (e) increased from earlier shrub stage

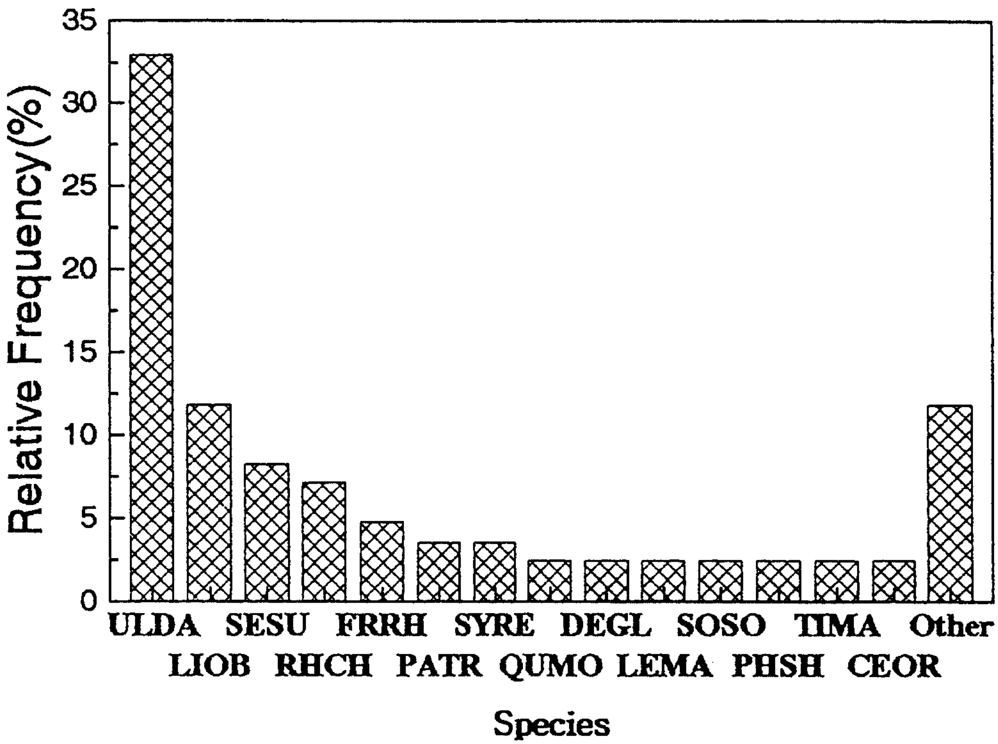

Fig. 2. Relative frequency (%) of early patch forming woody species in isolated patches on talus area.
ULDA : *Ulmus davidiana* for. *suberosa*, LIOB : *Lindera obtusiloba*, SESU : *Securinega suffruticosa*, RHCH : *Rhus chinensis*, FRRH : *Fraxinus rhynchophylla*, PATR : *Parthenocissus tricuspidata*, SYRE : *Syringa reticulata* var. *mandshurica*, QUMO : *Quercus mongolica*, DEGL : *Deutzia glabrata*, LEMA : *Lespedeza maximowiczii*, SOSO : *Sorbaria sorbifolia* var. *stellipila*, PHSH : *Philadelphus schrenckii*, TIMA : *Tilia mandshurica*, CEOR : *Celastrus orbiculatus*.

to tree stage except for the liana stage. Spatial heterogeneity (SD / mean H') tended to decrease gradually from early shrub stage to tree stage (Table 1).

The liana stage was dominated by *Parthenocissus tricuspidata*, *Vitis coignetiae*, *Sorbaria sorbifolia* var. *stellipila*, *Rhododendron mucronulatum* and *Sedum polystichoides*; the shrub stage was dominated by *Ulmus davidiana* for. *suberosa*, *Lindera obtusiloba*, *Securinega suffruticosa* and *Rhus chinensis*; the subtree stage by *Fraxinus rhynchophylla*, *Actinidia arguta* and *Corylus sieboldiana*; the tree stage was composed of of several tree species such as *Quercus mongolica*, *U. davidiana* for. *suberosa*, *F. rhynchophylla*, *Magnolia sieboldii*, *Prunus sargentii* and *Deutzia glabrata* (Table 2).

To elucidate early patch forming processes, a census was taken for early patch forming species in isolated patches on talus area. Although very small patches were formed by herb species such as *Sedum polystichoides* and several ferns, most isolated patches of 1 m^2 to 6 m^2 in patch size were formed by woody species such as *U. davidiana* for. *suberosa*, *L. obtusiloba*, *S. suffruticosa*, *R. chinensis*, *F. rhynchophylla*, *Syringa reticulata* var. *mandshurica*, *P. tricuspidata* and the other species with 32.9, 11.8, 8.2, 7.1, 4.7, 3.5, 3.5 and 24.3% in relative frequency, respectively (Fig. 2).

DISCUSSION

Early primary succession on this talus area was characterized by poor soil development and little input of organic detritus from neighbouring communities. On the smooth rock surface, the first colonists were lichens (Grubb 1986). They, however, colonized more easily at the edge of the rock or on rock crevice and convert smooth rock surface into crude and rough one (Cooper and Rudolph 1953). Mosses colonized on the ribbed rock or crude and rough rock, microsite of which was created by lichens (Grubb 1986). Mosses tended to grow vigorously under shade formed by establishment of vascular woody plants at rock crevice (Table 1). They could spread out their distribution area onto naked smooth or slightly rough rock following the establishment of lichens. The ecological role of mosses, i. e. to retain water in the community, may be very important not only at the pioneer stage but also later stages because of poor soil development on this talus area.

The highest species richness (S) in the subtree stage was explained by coexistence of pioneer species, shade intolerant and heat tolerant, and later successional species, shade tolerant and heat intolerant. A slight decline of species richness in tree stage was due to the decrease of shrub and herb species, shade intolerant, following thick canopy closure (Table 1, Table 2). Species diversity patterns coincided with the conventional theory that diversity increases during the early successional stages (Margalef 1968, Odum 1969). Spatial heterogeneity (SD / H') of early stages formed by isolated patches was higher than that of later stages (Tramer 1975). The result suggested that early patch forming process might be strongly associated with chance for safe site.

A conceptual model of primary succession on talus area was depicted in Fig. 3. Estab-

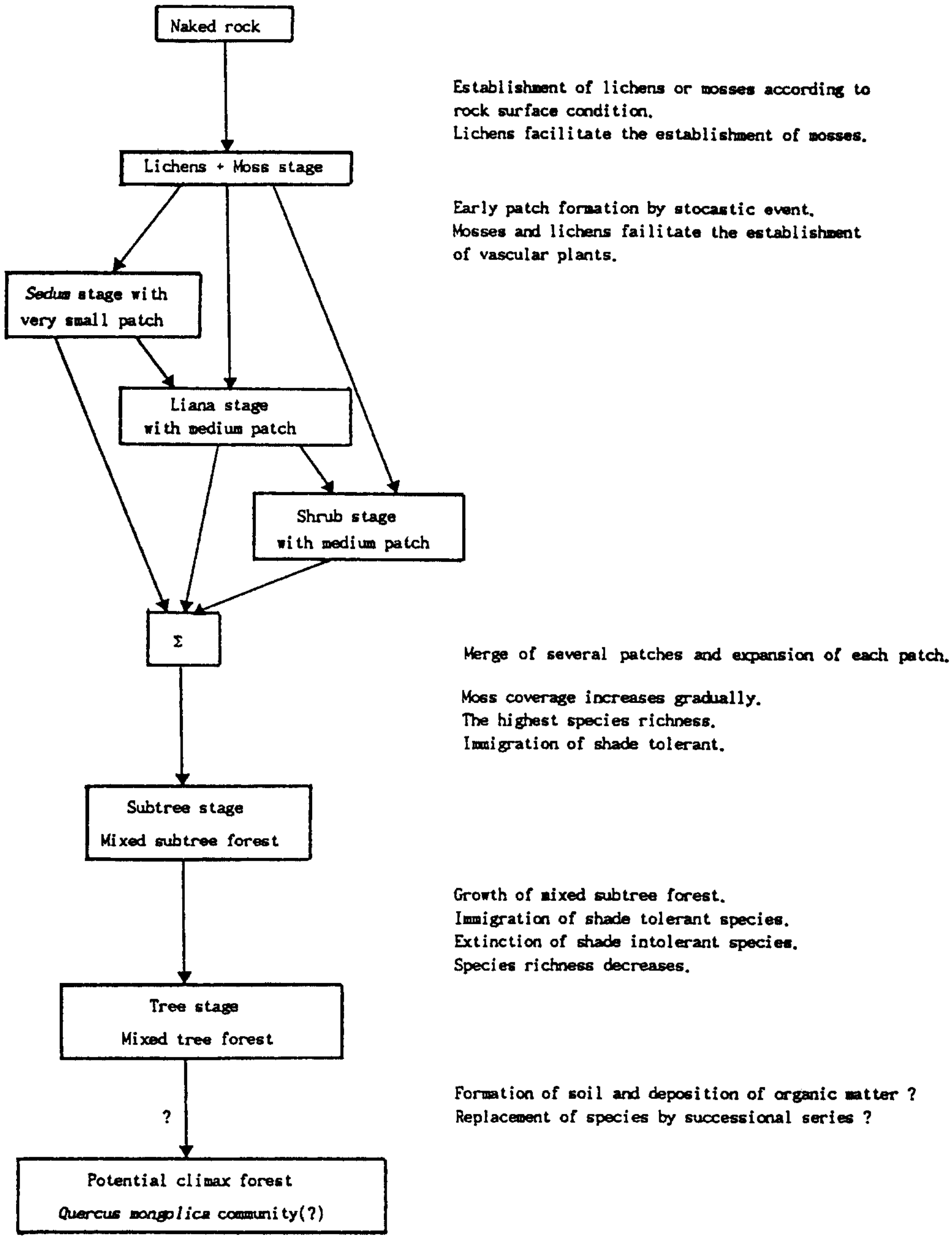

Fig. 3. A conceptual model of primary succession on talus slopes at Mt. Kariwangsan.

lishment of lichens and mosses on naked rock creates the microsites or safe-sites for patch formation of earlier vascular plants. They will mitigate heat stress and accelerate water retention capacity, and then they will facilitate the establishment of vascular plants. Early establishment of vascular plants may be strongly associated with a chance for safe site, for which species among the tolerant to heat and drought stress, not only pioneer species but also later successional species, can colonize at microsite formed by microtopography or lichens and mosses (Moral and Wood 1993). The most frequent vascular woody plants invading at such microsite were *U. davidiana for. suberosa, L. obtusiloba, R. chinensis, S. suffruticosa* and *P. tricuspidata*, and these species may have the strategy of tolerance to drought and heat stress (Table 2, Fig. 2). Vascular herb plant invading at very small microsite formed by lichens and mosses on rock surface was *Sedum polystichoides*, a facultative CAM plant which is able to shift from C_3 to CAM according to habitat moisture condition (Lee and Kim 1994). Liana stage or shrub stage develops into mixed subtree forest through merging several patches formed earlier and through expanding each patch. Mixed subtree forest develops into mixed tree forest, which is composed of several major trees such as *Q. mongolica, F. rhynchophylla* and *U. davidiana* for. *suberosa* (Table 2). Mixed tree forest may develop into *Q. mongolica* community, the potential climax in this area, by way of deposition of organic detritus and soil forming processes (Fig. 3).

적 요

돌서렁 경사지에서 일차천이의 식생발달단계를 밝히려고 군반의 넓이와 식물의 키를 기초로 지의류 + 이끼류 단계, 덩굴식물단계, 초기관목단계, 후기관목단계, 아교목단계 및 교목단계의 6 단계로 구분하고 군집구조, 종조성의 변화 및 초기군반형성의 특징을 연구하였다. 돌서렁에서는 지의류 + 이끼류단계로부터 교목층단계까지 토양이 거의 형성되지 않았다. 지의류의 식피율은 식생이 발달함에 따라 지속적으로 감소하였고, 이끼류는 수분보유능을 증가시켰으며 식생이 발달함에 따른 짙은 그늘 밑에서 보다 왕성하게 자랐다. 종풍요도와 종다양성은 식생이 발달함에 따라 점차 증가하였다. 덩굴식물단계에서 담쟁이덩굴, 머루, 쉬땅나무, 진달래 및 바위채송화가, 관목단계에서 혹느릅나무, 생강나무, 광대싸리 및 붉나무가 그리고 아교목혼합림에서 물푸레나무와 다래가 우점하였고 교목단계에서 신갈나무, 물푸레나무, 혹느릅나무 등이 혼재하였다. 혹느릅나무, 생강나무, 광대싸리 및 붉나무가 상대적으로 높은 빈도로 초기군반형성과정에 참여하였다. 그런데, 이 과정에는 천이초기종과 천이후기종이 함께 참여하는 것으로 보아 돌서렁에서의 초기군반형성에는 안전정착지 (safe-site)에 대한 정착기회 (chance)의 역할이 중요할 것으로 해석되었다.

LITERATURES CITED

Cooper, R. and E. D. Rudolph. 1953. The role of lichens in soil formation and plant succession. Ecology 34:805-807.

Cox, J. E. and D. W. Larson. 1993. Spatial heterogeneity of vegetation and environmental factors on talus slopes of the Niagara Escarpment. Can. J. Bot. 71:323-332.

Crawly, M. J. 1986. Plant ecology. Blackwell Scientific Publications, Oxford. 496p.

Geological and Mineral Institute of Korea. 1975. Geology of the Jeongseon coalfield. Seoul, Korea. pp. 5-15.

Grubb, P. J. 1986. The ecology of establishment. In, Ecology and landscape, A. D. Bradshaw, D. A. Goode and E. Thorpe (eds.). Blackwell Scientific Publications, Oxford. pp. 81-102.

Lee, K. S. and J. H. Kim. 1994. Changes in crassulacean acid metabolism(CAM) of Sedum plants with special reference to soil moisture conditions. J. Plant Biol. 34:9-15.

Margalef, R. 1968. Perspectives in ecological theory. University of Chicago Press, Chicago. 112p.

Matson, P. 1990. Plant soil interactions in primary succession at Hawaii Volcanoes National Park. Oecologia 85:241-246.

Moral, R. D. and D. M. Wood. 1993. Early primary succession on a barren volcanic plain at Mount St. Hellens. Amer. J. Bot. 80:981-991.

Odum, E. P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co., SanFrancisco. 776p.

Timan, D. 1986. Resources, competition and the dynamics of plant communities. In, Plant ecology, M. J. Crawly (ed.). Blackwell Scientific Publications, Oxford. pp. 51-57.

Tramer, E. J. 1975. The regulation of plant species diversity on an early successional old-field. Ecology 56:905-914.

Uno, G. E. and S. L. Collins. 1987. Primary succession on granite outcrops in southwestern Oklahoma. Bull. Torrey. Bot. Club 114:387-392.

Walker, L. R., J. C. Zasada and F. S. Chapin, III. 1986. The role of life history processes in primary succession on an Alaskan floodplain. Ecology 67:1243-1253.

Whitney, J. W. and C. D. Harrington. 1993. Relict colluvial boulder deposits as paleoclimatic indicators in the Yucca Mountain region, southern Nevada. Bulletin of Geological Society of American 105:1008-1018.

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