<Articles>

Some Effects of Fire on Vegetation, Soil and Soil Microflora adjacent to DMZ in Korea

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植生, 土壤 및 土壤微生物에 미치는 불의 效果에 對하여

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ABSTRACT

In general there are few cases which were caused by lightening and no fire was observed to have been caused but by artificial or accidental fires during preliminary survey. And then the most scales of burning in Korea are like the fig. 2. Temperature 5 cm apart from flame at the burning site were known to range from 165° to 200°C in surface fire on Myozangdong, pine-quercus dominant community and from 120° to 145°C in surface fire of Wolwoonni, *Mischanthus* dominant area and from 120° to 140°C in ground fire of Wangzinkun, *Mischanthus* dominant, respectively.

Through the preliminary survey, fire indicater plants in Korea were confirmed as *Mischanthus coreensis* Hack and *Carex alterifolia* Franch. The plants of highest frequency appeared in the burnt sites were known to as *Potentilla cryptotaeniae* Max, *Mischanthus coreensis* Hack, *Carex alterifolia* Franch and *Artemisia brachyphylla* Kitamura.

Lespedezas were proved as one of the fire tolerant and *Pinus densiflora* was found out as the lowest intolerant plant to fire. The acidity of burnt soil was decreased according to the considerable amount of ash left on the ground. The acidity of surface soil was more decreased than the below 10cm of soil. The chemical composition (NO_3, P, K, Mg, Total-N and Organic-C) of burnt soil was more increased than those of the unburnt sites.

And the population changes of soil microflora seemed to have a certain tendency. The population of soil microflora was increased a little according to climatic conditions. Also there was an initial decrease in the population of microflora followed immediately by a significant increase.

INTRODUCTION

For the last 18 years the area in and near the demilitarized zone (DMZ) has been abandoned by its civilian population. Most of the area have been reoccupied by military forces who often burn the fields and forests in order to improve visibility. Civilians burn adjacent areas, to remove bush and litter for agricultural purposes, as have been the common practice for many hundreds of years. Forest fires may be seen in the area near the DMZ at any time of year but especially in the Spring, from March to June, and rarely during July and August, the rainy season.

Because of the frequency of fires in this areas, and the destruction caused by some of them, it is believed desirable to have a better understanding of its effect on vegetation growth and development, and reproduction and production. This paper attempts to elucidate some of the changes due to fire, and points out some mechanism whereby plants are able to withstand these frequent fires. These works were supported in part by the Smithsonean Institute-Korean Commision for the Conservation of Nature and Natural Resources from October, 1966 to August, 1968.

METHOD OF WORK

For convenience' sake, the methods of works are divided into two parts, field and laboratory works. Field works are plotting for experimental sites, herborization, soil sampling and measurement of temperature at the burning sites. Laboratory works were consisted of soil analysis, phenological study of indicator plants, flora of rehabitant after burning, and detection of population changes of soil microflora according to the ages of burnt soil.

A. **Field Work**

1) Experimental Sites in General

1. Mt. Bukhan, tall timber forest
2. Korangpo, grass field
3. Bangchuckgol (Myozangdong), grass and pine forest
4. Chulwon, grass land
5. 〃 lespedezas dominant shrub
6. Susangni, bush, salix and pine community
7. 〃
8. Mt. Dai-am, bush combined with pine
9. 〃 (Punch-bowl), grassland combined with pine
10. 〃
11. Chinboo Hill, quercus dominant shrub
12. Kunbongsa, quercus and carex dominant community
3. Whazinpo, pine forest
14. Mt. Samhack, shrub

The above sites are shown in fig.1.

MAP OF KOREA

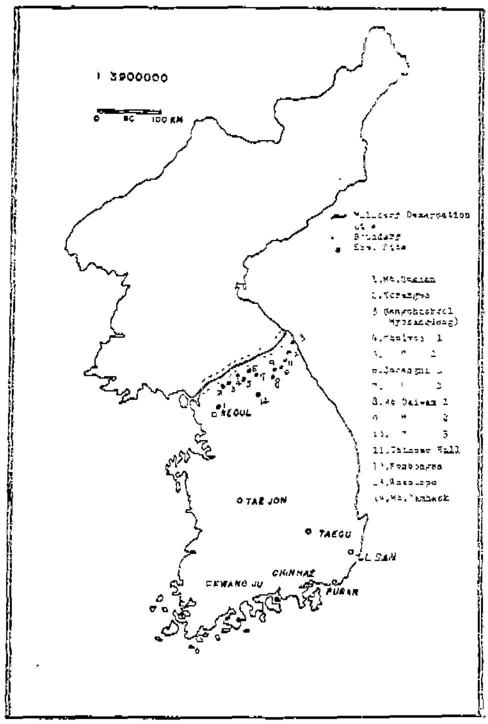

Fig 1

2) Soil Sampling

Soil samples used for analysis were taken from all the sites (burnt and unburnt control area) about 2 kg respectively in accordance with the soil profile. Soil samples were collected from the upper 5cm and to a depth of 10cm.

3) Herborization

The plants appeared in burnt area were herborized to determine the vegetation changes after burning, the phenological study of the indicater plants, and the classification for the both of tolerant and intolerant plants to fire.

4) Measurement of temperature at the burning site.

Temperatures by burning of plant were measured by high-scaled thermometer at the burning sites. The measurements were carried out at three sites, two of which were grasslands and the other was a young pine forest.

B. **Laboratory Works**

1) Phenological Study of Indicator Plants

Herborized plants were classified by their root types.

2) Chemical Soil Analysis

Soil analysis was carried out as the following methods;

Soil pH : The pH of soil was measured twice, once by soil pH meter in the sites and the other by the method of O.O1M $CaCl_2$ in laboratory.

Nitrogen: Semi-Micro Kjeldhal method.

Nitrate : Noll's method by using of Du-Spectrophotometer (470 mu)

Potassium: Sodium cobalt nitrite method by 〃 (505 mu)

Phosphorous: Ammonium molybdate blue method. 〃 (660 mu)

Organic matter: Walkley method by titration.

Magnesium: Mehlich's method by using of Spectrophotometer (525 mu)

3) Population Changes of Soil Microflora.

This study was carried out by the dilution plate method. Population changes were detected on three kinds of microflora cultured in incubator at $31\pm 1°C$. Bacteria were counted on the third day after inoculation, and both actinomycetes treated with 1 : 140 phenal water and other fungi were counted on the 7th day after inoculation. The media for the above were as follows;

a. Bacteria: Nutrient Agar Medium

b. Fungi: Czapek's Agar Medium

c. Actinomycetes: Jensen's Agar Medium

A and c were followed by pouring method, and c by surface method.

RESULTS AND DISCUSSION

1) Kind of Fire (Table 1.) and Temperature at the Burning Site.

a. Kind of Fire

Table 1.

(Exp. Site)	(day of burning)	(Kind of fire)
Mt. Bukhan	Apr. 21, 1968	Crown fire
Mt. Ice-Cream	March, 1967	Surface fire
Kaa-ri	May 19, 19667	〃
Chinboo down hill	June 19, 1967	〃
Bangchuckgol	June 1, 1967	〃
Korangpo	Aug. 10-12, 1967	〃
Myozangdong 1	Apr. 5-7, 1968	〃
〃 2	Apr. 1, 1968	〃
☆ 〃 3	〃 5, 1968	〃
Susangni 1	Mar. 1-2, 1968	〃
〃 2	Apr. 2-3, 1968	〃
〃 3	Apr. 5, 2968	〃
〃 4	Mar. 15-16, 1968	〃
Mt. Sam-Hack	Dec., 1967	〃
☆Wangjinkun	Apr. 16, 1968	Ground fire
Sam-ee-chun	Apr. 10-15, 1968	Surface fire
Nylon-Bridge	Apr. 5-10, 1968	Grnund fire
☆Wol-wooni	Apr. 27, 1968	Surface fire
Pallangni	〃 25-26, 1968	〃
Limdangni	Apr. 22-23, 1968	Ground fire
Chang-ga hill	Apr. 24-25, 1968	Surface fire
Kunbongsa 1	Apr., 1967	〃
〃 2	Apr. 15, 1968	〃
Whajinpo 1	Apr. 21, 1968	Crown fire
〃 2	Dec. 25-30, 1967	〃

The asterisked are the sites on which we applied the measurement of temperature.

Referring to the table 1, the fires occurred at the above sites(among 25 sites) were identified as 19 cases of surface fire, 3 cases of ground fire and 3 cases of crown fire. Therefore, it can be confirmed that the fires in Korea were mainly consisted of surface fires. Particulary in Korea there are few cases which were caused by lightening, and none of the fires were observed except artificial or accidental fires during preliminary survey. And then the scales of burning in Korea are nealy like the fig. 2.

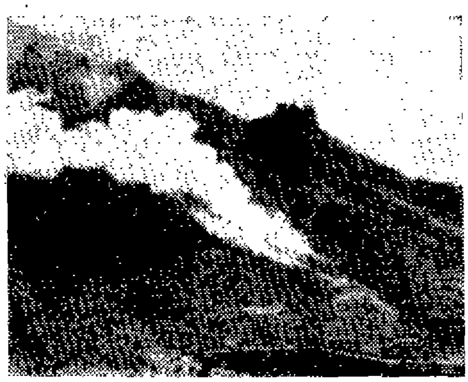

Fig. 2 Burningcale in general.

b. Temperature at the Burning Site.

i. Surface fire in the Area of Myozangdong

① Characteristics of the Plant Community; 10-15 years old of pine tree-dominant, 5-10 years old of rhodendron, 10 years old of alnus, *Lespedeza var. Pedunculata* Nakai,and *Quercus acutissima* CARP

② Temperatures measured; Temperatures at the burning site showed 165-200°C during burning 5 cm far from flame.

ii. Ground Fire in the Area of Wangzinkun

① Characteristics of Plant Community; *Mischan thus coreensis* dominant, *Quercus acutissima* CARP

Mischanthus coreensis was almost dried out and the *Ouercus* was already felled to improve visibility.

② Temperature measured; The temperature 5cm apart from flame showed 120–140° C.

fig. 3 Burning at Myozang dong

iii. Surface Fire in the Area of Wol-woonni

① Characteristics of Plant Community; *Mischanthus coreensis* dominant Pine trees (2-3 years old)

Mischanthus coreensis was almost dried out at that time and pine's litter layer covered soil surface.

② Temperature measured; The temperature showed 120–145°C 5 cm apart from flame during burning.

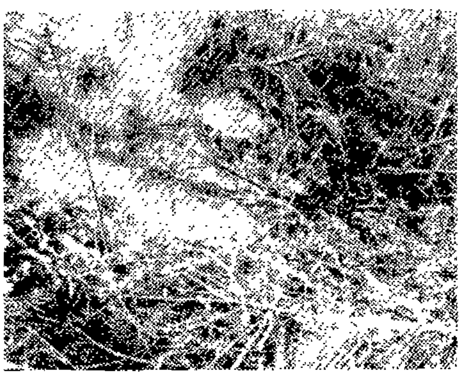

fig. 4 Burning at Wangzinkun

fig. 5 Burning at Wolwoonni

2) Classification of Rehabitant Plants. (Table 2)

Table 2. Rehabitant plants at the burnt sites

☆*Mischanthus coreensis* Hack	*Scilla sinensis* Meer
☆*Carex alterifolia* Franch	*Hosta clausa* Nakai

Carex var.nans Leveil et Van	*Pteridium* spp.
☆*Artemisia brachyphylla* Kitamura	*Zizania latifolia* Turcz
☆*Potentilla cryptotaeniae* Max	*Lespedeza* spp.
Rubus var. *concolor* Nakai	*Lysimachia chlethroides* Duby
Aster ageratoides Turcz	*Saussurea diamantica* Nakai
Lilium anabile Palib	*Adenophora coronopifolia* Fisch
Polygonatum japonicum Morr.et Van	*Syneilesis palmata* Max
Veratrum grandifolium Losen	*Sanguisorba Argutipens* Nakai
Senecio Pierotii Miq	*Pulsatilla koreana* Nakai
Thalictrum var. *japonica* Nakai	*Codenopsis lanceolata*
Lilium distichum Nakai	*Adenophora triphylla* A.DC.var. *Tetraphylla* Makino
Atractylodes var. *chinesis* Kitamur	*Pennisetum japonicum* Trinius

The above plants were identified as the fire tolerant plant which can survive the burning. Of the 28 kinds shown in table 2, 21 species have old root type, 4 bulb type and 3 storage type.

Through the preliminary survey from the start to the present, *Mischanthus coreensis* Hack and *Carex alterifolia* Franch were confirmed as fire indicator plant in the area near DMZ. And the plants of highest frequency appeared in the burnt sites were known as *Potentilla cryptotaeniae* Max, *Mischanthus coreensis* Hack, *Carex alterifolia* Franch, and *Artemisia brachyphylla* Kitamura which were astrisked in table 2. In the papers of Ahlgren (1960) it could be easily found out that *Marchantia, Carex* and *Aster* appeared only on burnt site as in case of table 2. Especially, *Lespedezas* which is reported as the intolerant plant to fire was proved as one of the fire tolerant plant in Korea. It can be easily found out the buds in fig. 6 which is sprout out from the scorched stem of *Lespedeza.*

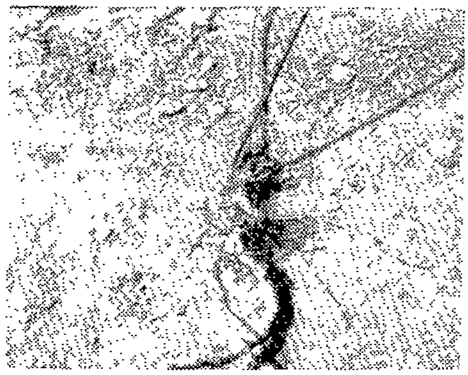

Fig. 6 Budding from scorched stem of *Lespedeza*

And then, *Pinus densiflora* which is represented as one of the dominant species in Korea was found out to be the lowest intolerant plant to fire. They are apt to die by light surface fire as well as crown fire. But they didn't die by ground fire. Refer to fig.7

Fig. 7 Dead pine forest

3) Soil Analysis

a. Mean Values of two Readings of Soil pH by 0.01M $CaCl_2$ Method (Table 3)

As it can be seen in table 3, it is reasonable to assume that the considerable amount of ash left on the ground after burning will decrease the acidity, since ash is rich in alkaline materials, and according to numerous papers,

Table 3 Soil pH

Site		Depth: 0-5cm	10cm
Mt.Samhack		5.1	4.5
Myozangdong	1	5.37	4.8
〃	2	5.5	4.9
〃	3	5.1	4.95
Kwanwoori		5.1	4.9
Susangni	1	5.7 (7.53)	5.4 (6.43)
〃	2	6.05 (7.37)	5.8 (5.38)
〃	3	6.05	5.43
〃	4	5.75	5.15
Mt.Ice-Cream		5.45	5.30
Kunbongsa (*Cont'd*)		5.9	5.5
Kunbongsa		6.15	4.7
Wolwoonni (*Cont'd*)		5.55	5.85
Wolwoonni		5.9	5.3
Cangga Hill (*Cont'd*)		5.7	5.3
Changga Hill		6.4	4.8
Paliangni		6.6	5.7
Whajinpo		6.3	4.55
Wangjinkun		6.86	4.63
Nylon Bridge	1	6.65	6.13
〃	2	6.76	5.32

☆The figures in table mean the values of soil pH on May and in parenthesis on June.

potassium carbonate (7%) and other similar salt dissolves well in water (Ahlgren, 1960). This change in acidity may vary with the depth and type of soil. Ahlgren found out that an increased pH of surface following burning lasted 10 years.On the other hand, the others found that the lowered acidity of surface soil returned to normal in a few months after burning. The above table is similar to these reports.

b. Chemical Soil Properties of Burnt Soil

According to Burn's (1952) paper, it is reported that there was an increase in both water-soluble compounds of alkaline earth metals, sulfates and carbonate after burning. Among the above chemical composition, it seemed that fire didn't affect organic material incorporated in the soil, probably because fire temperature below the surface soil were not raised high enough during the most fires.

The most significant factor affecting

Table 4. (May, 1968)

Site		Depth	g/kg of Dried Soil.				mg/g. of Soil
			NO_3	P	K	Mg	Total-N
Susangni	1.	0-5cm	8.8	9.7	8.5	26.9	3.80
〃	2.	10	5.5	0.9	—	3.2	0.224
(Cont'd)		〃	3.0	1.04	31.0	2.8	1.512
〃		〃	1.8	9.7	3.4	1.5	0.672
〃	3.	〃	8.2	5.4	1.7	24.0	1.517
〃		〃	5.0	0.19	—	4.4	0.42
Mt.Samhack	1.	〃	5.0	18.0	4.6	4.7	2.352
〃		〃	5.0	20.0	3.8	2.1	0.904
〃	2.	〃	5.7	0.4	0.1	5.4	1.167
〃		〃	4.9	0.25	0.2	1.9	0.42
(Cont'd)		〃	5.0	0.29	0.19	5.9	2.016
〃		〃	5.0	0.8	1.2	2.3	0.532
Myozangdong	1.	〃	17.0	0.74	0.59	24.4	1.974
〃		〃	8.3	0.79	0.05	7.2	0.532
(Cont'd)		〃	5.9	0.72	0.9	14.0	2.184
〃		〃	5.5	0.59	0.27	10.4	1.008

Mt.Ice-Cream	〃	5.2	2.0	5.8	10.0	3.92
〃	〃	2.6	1.9	4.2	7.5	0.42
Kunbongsa	〃	5.3	22.0	5.4	3.7	1.848
〃	〃	4.4	21.0	3.0	1.1	0.336

Table 5. (June, 1968)

Site	Depth	g/kg of Dried Soil.				mg/g.	Organic-C
		NO_3	P	K	Mg	Total-N	(%g)
Susangni 1.	0–5cm	2.7	0.59	0.04	13.0	5.04	3.16
	10	2.1	0.01	0.01	2.8	2.8	2.95
〃 2.	〃	5.2	0.29	0.35	21.0	5.9	2.9
	〃	3.8	0.01	0.01	7.3	2.04	1.47
Wangjinkun	〃	11.0	0.54	0.29	15.0	7.84	3.02
	〃	6.20	0.25	0.25	4.0	3.36	2.88
Nylon-Bridge 1.	〃	33.5	0.74	0.01	9.7	2.24	1.241
	〃	8.1	0.14	—	5.2	1.96	1.13
〃 2.	〃	13.0	0.34	0.02	19.0	2.24	2.32
	〃	3.4	0.09	0.005	6.7	1.12	0.94

soil fertilities is available nitrogen such as nitrate in burnt soil. Refering to the table 4 and 5, the relationships between nitrate and total nitrogen may not be closed to each other. Hayward (1937) and Barnette (1930) reported higher total nitrogen after burning in soils of the longleaf region. Garren (1943) also reported nitrogen increase in the southeastern states after burning, but Tryon (1948) detected no changes in the amount of available nitrogen with the addition of ashes. It may be assumed that nitrification process is greatly depend upon the effect of the changed pH on bacterial growth. Therefore, the amount of nitrate described in table 4 and 5 could be explained on the nitrification of soil microflora. In discussing the effect of burning on the biological process, Vlamis (1955) et al reported there was an increase in available phosphorous after fire. The amount of phosphorous in table 4 was increased a little more than in unburnt site. However, the different amount of phosphorous might be due to the eduction that the various kind of soil tends to bind phosphorous and make it unavailable.

Potassium is reported in many papers that it is increased with burning up to 166%, but it decrease with leaching the most ashes after burning. The similar results were obtained from the table 4 and 5, which show the decreasing tendency of amount of potassium following the ages of soil after fires. It can be explained on the basis of the fact that leaching decreases soil potassium.

Austin (1955) and Baisinger (1955) reported 337% increase in available magnesium following, which is detrimental to the maintenance of forest. The amount of magnesium in table 4 and 5 showed similar results like the above mentioned. Until the present time, no work has been done on the changes of chemical composition between burnt site and unburnt site in Korea. Chemical composition released to soil via ash subseguent rainfall of soluble mineral salts are believed the most significant effects of fire to the changes in plant growth and the population of soil microflora.

c. Population Changes of Soil Microflora

POPULATION OF SOIL MICROFLORA

Table 6 (April, 6 1968)

Site	Depth	Bact.	Fungi (No.×10^2/g. Dried soil)	Actino-mytes
Wangjinkun (250m)	0–10cm	320	80	2370
Nylon Bridge (50) 1.	〃	1210	160	1510
〃 2.	〃	800	140	2880
(cont'd)	〃	350	60	1850

Table 7. (May, 1968)

Wolwoonni (100m)	〃	960	130	2140
〃 (Cont'd)	〃	360	70	2080
Limdengni (350)	〃	620	140	1080
〃 (Cont'd)	〃	600	70	920
Changga Hill (200)	〃	1350	40	2550
〃 (Cont'd)	〃	370	50	1150
Kunbolgsa (500)	〃	280	110	1420
〃 (Cont'd)	〃	140	80	1010
Pallangni (300)	〃	900	90	1690
Whajinpo (100)	〃	790	80	1030

Table 8 (June, 1968)

Mt.Samhack (600)	〃	230	43	390
〃 (Cont'd)	〃	410	31	360
Limpangni	〃	40	62	53
〃 (Cont'd)	〃	113	27	139
Wolwoonni	〃	212	51	148
〃 (Cont'd)	〃	270	30	174
Kunbongsa	〃	228	32	57
〃 (Cont'd)	〃	350	13	53
Pallangni	〃	112	31	238
Changga Hill	〃	94	46	35
Whajinpo	〃	58	39	92

Table 9 (July, 1968)

Susangni (500)	〃	108	20	103
〃 (Cont'd)	〃	164	12	98

There are few peports related to the population changes in soil microflora after burning except those of soil bacteria. The soil bacteria population after burning is expected to grow small, since burning frequently raises the soil pH, a factor critical to bacteria growth. But the results described in the tables might not be exblained easily. However, Corbet (1934) found out the effects of burning that the number of microorganisms rose immediately after fire and remained there for nine months or longer. On the other hand, Hall (1921) discovered that if soil was heated for one hour to 100°C, there was an initial decrease in bacterial count followed shortly by a significant increase.

Referring to other papers, it is belived that charcoal in soil favored growth of bacteria and that burning causes a complete changes in microbial flora. Besides them, climatic conditions and the temperatures of burning might be a significant factor in the changes of microbial population. In fact, the temperature of burning varied from 120°C to 200°C during burning and the climatic records showed an increase of relative humidity in order of 57% on April, 70% on May and 76% on June at the experimental sites. And the average temperatures of soil in all the sites showed the continuative increase in order of 11.2°C on April, 17.2°C on May and 20.8°C on June as well as the tempera-

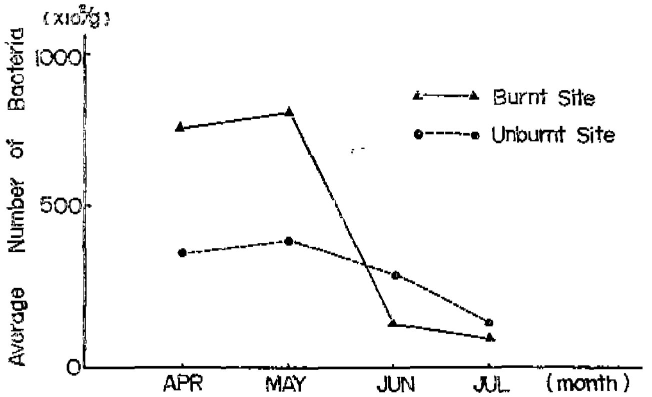

Fig. 8 Seasonal variation of bacteria population in burnt and unburnt soil. The number of microflora is equivalent to the unit X10²/g of dried soil.

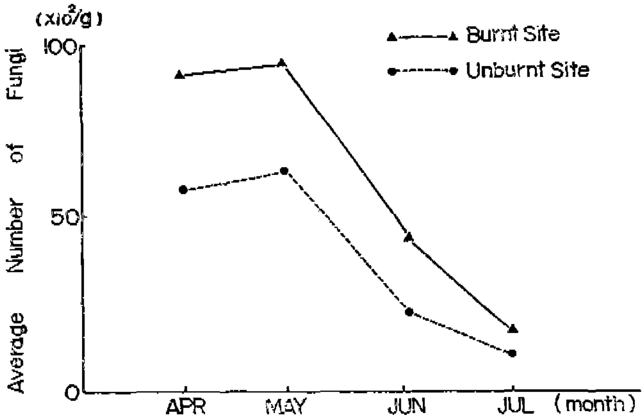

Fig. 9 Seasonal variation of fugi population in buunt and unburnt soil.

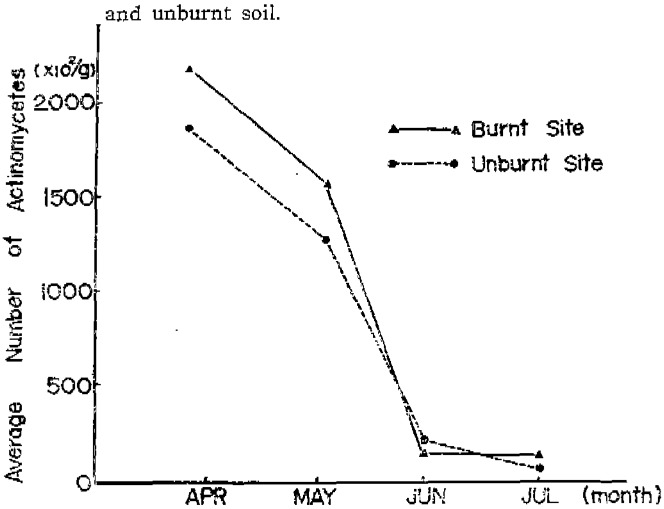

Fig. 10. Seasonal variation of actinomycetes population in burnt and unburnt Soil

ture of air. Considering the above conditions, it seemed that the relative humidity, an increase in soil pH and chemical composition of soil might be a critical factor in the growth of microbial flora, but temperature of soil and of air might not affect the growth of soil microflora. Comparing the the above results with the fig. 8 9 and 10 which were derived from table 6 7 8 and 9, bacteria and fungi showed an increase in population at maximum on May, and actinomycetes showed on April. In general, all the microflora were decreased in population after May. These facts is appreciated in view of relative humidity, increase unavailable chemical composition and an increase of soil pH. These facts are similar to the Hall's report.

摘 要

1966年 10月 부터 1968年 8月 까지 실시된 韓美合同의 生態調査計劃의 一部로서 休戰線南方地域에 흔히 發生하는 山火가 生態系에 미치는 基礎的인 영향 가운데서 特히 植生, 土壤 및 土壤微生物에 미치는 현상을 調査했다. 이 地域에서 일어나는 山火의 大部分은 Surface Fire 였으며 때로는 Crown Fire 및 Ground Fire에 屬하는 몇가지 例가 있었다. 本 調査에서 얻어진 結果는 다음과 같이 整理할 수 있다.

① 山火時에 植生에 미치는 불의 溫度는 묘장 동의 경우 165°～200°였으며 월운리의 경우는 120°～145°C이고 왕진군에서는 120°～140°C였다. 이 溫度는 불꽃으로 부터 約 5cm 떨어져서 잰 것이다.

② 韓國에 있어서 山火地의 指標植物格으로 생각되는 것은 참진억새 (*Mis-*

chanthus coreensis Hack), 선사초 (*Carex alterifolia* Franch) 및 비로봉쑥 (*Artemisia brachyphylla* Kitamura) 等임이 判別되었으며 이른 봄철의 山火地에서 比較的 출현빈도가 높은 식물은 세잎물양지꽃 (*Potentilla Cryptotaeniae* Max), 참진억새, 선사초, 비로봉쑥 等이다. 이들은 大部分이 宿根植物인 것으로서 비교적 높은 耐熱性을 가지고 있다. 特히 木本類에 있어서는 싸리종류도 耐熱性 植物群에 屬하는 것으로 간주되고, 이와 反對로 소나무 (*Pineus densiflora*)는 불에 對하여 弱한 樹木으로 관찰 되었다.

③ 山火가 土壤에 미치는 영향으로는 比較地域보다도 上下層모두 酸度가 감소되었으며 NO_3, Total-N, P, K, 및 有機炭素等은 山火가 일어난지 2個月 後(5月)에 最大의 含量을 보이고 곧 以後 leaching 현상에 依하여 점차로 감소하는 경향을 보였다.

④ 山火地土壤의 化學的 成分의 含量差異에 따라 Bacteria 와 Fungi 等의 分布에도 많은 變化를 보였는데 5月에는 最大의 增殖率을 나타내고 있으며 Actinomycetes 는 4月에 最大値를 보여 주었다.

⑤ 上記의 土壤微生物의 消長關係는 土壤의 水分含量 變化와 土壤의 酸度가 계속 떨어지는 傾向 및 재(灰)로 부터 Unavailable 한 化學成分이 계속 游離되어 온 때문으로 判別 할 수 있었다.

REFERENCES

1. Ahlgren C.E (1960) ; Some effects of fire on reproduction and growth of vegetation in northeastern Minnesota. Ecology 41 (3) ;431-445.
2. Ahlgren C.E. and I.F. Ahlhren (1960) ; Ecological effects of forest fire. Bot. Rev. Vol. 26. No. 4; 483-533.
3. Ahlgren C.E (1959) ;Some effects of fire on forest reproduction in Northeastern Minesota. Jounal of Forestry. Vol. 57 No. 3Mar.
4. Ahlgren I.F and C.E. Ahlgren (1965) ; Effects of prescribed burning on soil microorganism in a Minesota Jack Pine Forest. Ecology Vol. 46.No.3 Spring
5. Burns, P. Y. (1952) ; Effects of fire on forest soil in the pine barren region of New Jersey. Yale Univ. School of Forestry. Bull. 57; 1-50
6. Etsuyuki Iwata (1964) ;Development of a dense Thicket of shrubby Lespedeza following a forest fire-Studies in vegetation on Kitakamin Mountain Ranges, North-eastern Japan (2) Ann. Reprots. Col. of Lib. Arts. Univ. of Iwata Vol. 23
7. Barnette, R.M. (1930) ; Effects of burning upon the accumulation of organic matter in forest soil. Soil Sci. 29; 281-284
8. Heyward F (1937) ;. The effects of frequent fires on profile development of longleaf pine forest soil. Jour. Forestry. 35; 23-27
9. Garren, K.H. (1943) ; Effects of fire on vegetation of the Southeastern United States. Bot. Rev. 9 (9) ; 617-654.
10. Tryon, E.H. (1948) ; Effects of charcoal on certain physical, chemical, and biological properties of forest soils. Eco. Monogr. 18; 81-115
11. Krammes, J.S. and Dedano, L.F. (1966) ; Water repellent soils and their relation to wildfire temperature. Bull. I. A.S.H. No.2; 14-19
12. Etsuyuki Iwata (1966) ; Germination behaviour of shrubby lespedeza seeds with special reference to burning. Ecological Rev. Vol. 16. No.4

13. Vlamis, J.,H.H. Biswell and A. M. Shchultz (1955) ;Effects of prescribed burning on soil fertility in second growth ponderosa pine.Jour.Forestry 53 (12) ;905-909.
14. Austin, R. C. and D. H. Baisinger (1955) ; Some effects of burning on forest soil of western Oregen and Washington. Jour. Forestry 53 (4) 275-280
15. Corbet, A.S. (1934) ; Studies in tropical soil microbiology. II The bacterial numbers in the soil of the Malay Penninsula. Soil Sci. 38; 406-407
16. Hall, A.D. (1921) ; The soil.XV. 352 pp. J. Murray, London
17. ________ (1962-1967) ; Tall timbers fire ecology conference. Vol. 1-6