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Macrofungal Flora on the Volcano Usu, Deforested by 2000 Eruptions

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Abstract

An area on the volcano Usu was deforested by an eruption in 2000. Sporocarp occurrence of macrofungi in this devastated area and the surrounding area on its circumference was investigated. A total of 48 taxa of macrofungi were recorded. Sporocarps of *Lyophyllum decastes, Lyophyllum* sp., *Omphalina* sp., *Psathyrella velutina, Pholiota* sp. and two Pezizaceae were found only in the devastated area. *Coprinus comatus* and *Coprinus atramentarius* were present in both areas. In the area around the circumference, mainly the sporocarps of *Clitocybe*, *Armillaria, Collybia*, *Lepiota*, *Hypholoma*, *Inocybe*, *Hebeloma* and *Scleroderma* were observed. The species composition in the devastated area was largely different from that of the area around the circumference. Difference of several factors such as presence of litter layer, composition and maturity of woody plant species and moisture content of ground between both areas may affect the occurrence of sporocarps.

Key words: Volcanic eruption, Sporocarp, Macrofungi, Ectomycorrhizal fungi, Early primary succession

Introduction

Primary successional ecosystems such as burned sites, volcanic deserts, and deglaciated areas provide physically, chemically and biologically unique environments for fungal establishment. For example, Horikoshi *et al.* (1986) investigated the changes in fungal flora after fires in *Pinus densiflora* forests in southern Hiroshima prefecture. They found a discrepancy in fungal flora between burned and unburned sites. Generally, fungi play important roles in forest ecosystems in decomposition, in nutrient cycling, in the nutrient uptake of woody plant species, and as pathogens (Dix and Webster 1995). Thus, fungi, which are peculiar to primary successional ecosystems, may also affect nutrient dynamics and possibly the revegetation process in ecosystem rehabilitation. Recently, several investigations of fungal flora in primary successional ecosystems have been carried out. Nara *et al.* (2003a) investigated ectomycorrhizal sporocarp production in a volcanic desert on Mt. Fuji, and Jumpponen (2003) investigated the soil fungal communities in non-vegetated areas on the forefront of a receding glacier. However, there have been few published studies on fungal flora in devastated areas several years after the end of the main disturbance event.

In the present study, we undertook the investigation of fungal flora, collecting above ground sporocarps as an index, in an area devastated from the volcanic eruption of Mt. Usu, Hokkaido, Japan in 2000. The fungal flora in the circumference area, the area immediately surrounding the devastated area where some plant species survived after the volcanic eruption, was also investigated.

Materials and Methods

Study site

Mt. Usu is an active volcano located in southwest Hokkaido, Japan (42°32' N, 140°50' E, 773.1 m elevation). Mt. Usu has erupted repeatedly since 1663, and erupted again on March 31, 2000, 22 years after the last eruption. At this time, a number of small craters were formed at the foot of the Nishiyama and Konpira areas (Fig 1), and a large eruption clouded full of volcanic debris. This study was conducted in the devastated area around the craters at the foot of the Nishiyama area. Natural vegetation before the 2000 eruption consisted mainly of secondary forest of broadleaf trees such as *Betula* spp., *Acer* spp., *Quercus crispula* and *Magnolia* spp., and partially artificial *Larix kaempferi* and *Abies sachalinensis* forests. These forests were almost completely destroyed mainly by the deposition of volcanic debris such as fine volcanic ash and pumice about 1-3 m in depth. About 71 ha of forests around the craters were destroyed. Vegetation in the devastated area was described by Obase (2004); with *Salix sachalinensis*, *Salix hultenii* var. *angustifolia* and *Populus maximowiczii* being dominant as new recruits although dispersed at the low density of about 1000/ha in total in 2003. In the circumference area (Fig 2, 3), possibly because of the thin deposition of volcanic sediments, some woody plant species and herbaceous plant species survived and the plant cover recovered quickly, consisting mainly of *Salix*, *Larix*, and *Quercus* in woody plant species and *Reynoutria sachalinense* and *Petasites japonicus* var. *giganteus* in herbaceous plant species. Climatic data in 2004 for Date City (42°30' N, 1405°4' E, 84.7 m elevation), which is near Mt. Usu, indicates a mean annual

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precipitation of 835 mm and an average annual temperature of 8.9°C, with a range between –12.0°C in December and 30.8°C in August (Sapporo meteorological station).

Sampling and identification

We established four 20×40 m plots in both the devastated area (D plot) and the circumference area (C plot) (Fig. 2, 3). The investigations were done in each plot almost weekly from June to October in 2004 because most of sporocarps are produced in these seasons. In each plot, we recorded the habitat of sporocarps, such as soil conditions, presence of litter or plant cover and the woody plant species possibly associated with the sporocarps. For macro- and microscopic identification, several sporocarps for each fungal species were separately collected.

The characteristics of each fresh sporocarp were recorded immediately at the laboratory. Subsequently, specimens were dried at 60°C for 24-36 h for microscopic identification. To aid in identification, a number of sources were consulted including Akers and Sundberg (2001), Banerjee and Sundberg (1995), Breitenbach and Kranzlin (1984-2000), Cha (1992a, 1992b, 1999), Cripps (1997), Imai (1938), Imazaki and Hongo (1995, 1998), McNabb. (1968), Pegler (1995), Reid and Eicker (1999), Smith (1951, 1972), Ulje and Bas (1991), van de Bogart (1976, 1979) Vesterholt (1995), Vilgalys and Miller (1987), Yoshimi (2002). We put *Armillaria* species together as the *Armillaria mellea* complex.

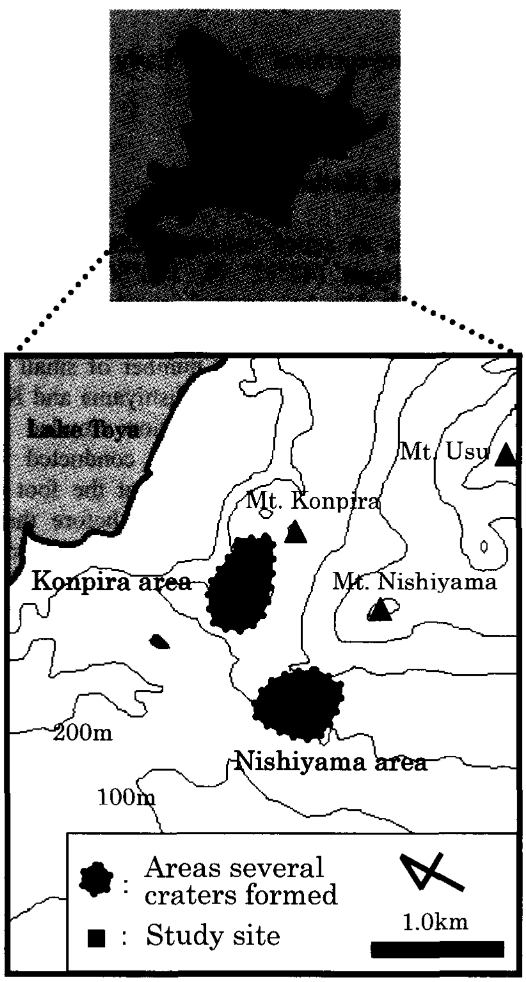

Fig. 1. Location of study site on Mt. Usu, Hokkaido, Japan.

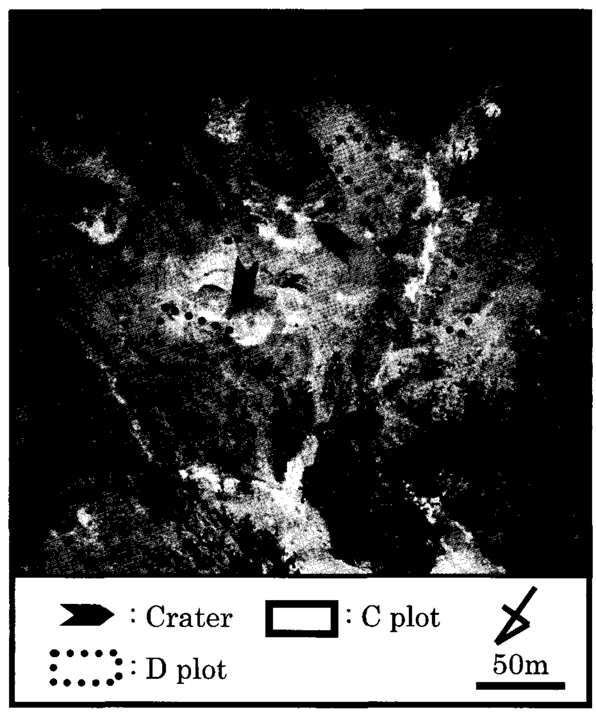

Fig. 2. Location of study plots in devastated area (D plot) and circumference area (C plot) around craters on Mt. Usu, Hokkaido, Japan.

Results

The total number of taxa recorded was 48 (Table 1). Most of the taxa appeared in September. We found 7 species only in the devastated area, 39 species only in the circumference area and 2 species in both areas. At the devastated area, we recorded the presence of *Lyophyllum decastes*, *Lyophyllum* sp., *Omphalina* sp., *Coprinus comatus*, *Coprinus atramentarius*, *Psathyrella velutina, Pholiota* sp. and two Pezizaceae. *Psathyrella velutina, Pholiota* sp. and two Pezizaceae, were observed mainly on north facing slopes or in gullies. *Lyophyllum decastes* and *Lyophyllum* sp. were observed near dead trees where there was no vegetation cover. *Omphalina* sp was observed on the moss in the gully. *Coprinus comatus* and *Coprinus atramentarius* were observed on slopes, in gullies on the slope, and also near and in the circumference area. In the circumference area, *Clitocybe*, *Armillaria, Collybia*, *Lepiota*, *Hypholoma*, *Inocybe*, *Hebeloma* and *Scleroderma* were the main species present. They were observed on the litter deposits of surviving mature trees such as *Quercus*, *Salix* and *Larix*, and herbaceous species such as *Reynoutria sachalinense* and *Petasites japonicus* var. *giganteus*, or on the moss under the canopy of surviving mature trees. Connections of the sporocarps to the woody debris buried in the volcanic sediments were recognized in some fungal species such as *Hypholoma fasciculare* and *Pluteus atricapillus*. Sporocarps of ectomycorrhizal fungi, *Laccaria* sp., two *Inocybe*, three *Hebeloma*, *Suillus laricinus*, *Suillus grevillei* and *Scleroderma bovista* were observed only in the circumference area. They were possibly associated with mature trees of *Larix kaempferi*, *Salix sachalinensis*, *Salix integra*, *Ulmus davidiana* var. *japonica* and *Castanea crenata*. In the research site in the devastated area, although seedlings 1-3 years old consisting mainly of *Salix sachalinensis*, *Salix hultenii* var. *angustifolia* and *Populus maximowiczii* were dispersed at a low density, no sporocarps of ectomycorrhizal fungi were observed.

Discussion

We found a discrepancy in macrofungal flora between devastated area and circumference area. The reasons for this result are not clearly understood at the present time. However, some causative factors can probably be inferred from field observations. First, a thin litter layer, about 0.5 cm in thickness was formed in the circumference area, unlike the research site in the devastated area which had exposed volcanic deposition with no litter layer. *Collybia* and *Lepiota* are generally observed on the litter or humus layer in a forest. In the present study, a hyphal net was formed in the litter layer under the sporocarps of *Collybia dryophila.* The presence of the litter layer may have affected the macrofungal flora. Second, in the circumference area, sporocarps of ectomycorrhizal fungi were found near surviving mature trees, while in the devastated area, which had 1-3 year old seedlings of ectomycorrhizal woody plant species dispersed at a low density, no sporocarps of ectomycorrhizal fungi were observed. In primary successional ecosystems, sporocarps of ectomycorrhizal fungi were observed 10 years after the first ectomycorrhizal woody plant species were recruited and established in the deglaciated area of Lyman Glacier (Jumpponen *et al.* 2002) and 5 years after in the volcanic area on Mt. St. Helens (Allen *et al.* 1992). In the present study, although 1-3 year seedlings were observed in the devastated area, they had probably not reached sufficient size to support the fruiting of ectomycorrhizal fungi. Moreover, the composition of woody plant species was different in the two areas in our study, mainly *Salix*, *Quercus*, *Larix* and other broad-leafed woody plant species in the circumference area, while in the devastated area, *Salix* were dominant. Association between ectomycorrhizal fungi and woody plant species is generally highly specific (Smith and Read 1997), for example *Suillus* usually are associated with Pinaceae. The composition of host woody plant species and host size may have been factors in the difference in the occurrence of sporocarps of ectomycorrhizal fungi. Finally, the moisture content of ground may differ between the two areas. In the circumference area, surviving mature trees, herbaceous plant species and litter shaded the ground from direct sunlight and this possibly contributed to preventing extreme dryness. In the research site in the devastated area, sporocarps occurred mainly on north-facing slopes and in gullies, where soil moisture was possibly maintained to some extent due to less direct sunlight. Drought stress may limit the occurrence of sporocarps, which possibly differ in their drought tolerance (O'Dell *et al.* 1999, Trudell and Edmonds 2004).

In the research site in the devastated area, *Coprinus comatus, Coprinus atramentarius* and *Psathyrella velutina* were observed over a long period. Generally, they are often observed outside of forests, in gardens, parks and roadsides, in areas rich with organic debris. In the circumference area, some sporocarps such as *Hypholoma fasciculare* and *Pluteus atricapillus* were found to be connected to the woody debris buried in the volcanic sediments. Regarding the three Coprinaceae mentioned above, although they might also be using plant remnants buried in the volcanic sediments as nutrient resources, we were not able to check precisely for the connection of the sporocaps to underground sources.

In the present study, we observed 9 taxa of ectomycorrhizal fungi in the circumference area. *Laccaria, Inocybe*, *Hebeloma and Scleroderma* are known to be associated with pioneer woody plant species in the volcanic desert on Mt. Fuji (Nara *et al.* 2003b). It was demonstrated that some species of these genera promote host growth under experimental or field conditions (Pera *et al.* 1999, Reddy and Natarajan 1997). Although we have not observed these pioneer fungi as sporocarps in the devastated area, ectomycorrhizal fungi in the circumference area might play an important role as an inoculum for ectomycorrhizal colonization, and influence the growth of seedlings established in the devastated area.

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Table 1. Sporocarps observed in devastated area (D) and/or circumference area (C) in 2004 on Mt. Usu, Hokkido, Japan.

Fungal species	Area	Habitat	May	Jun.			Jul.		Aug.					Sep.					Oct.		
			12	01	17	24	13	29	04	11	16	23	27	02	09	16	22	29	07	15	2
Laccaria sp.	C	Bare, near survived *C. crenata*															○				
Clitocybe sp. 1	C	Litter (*L. kaempferi*)												○	○	○	○				
Clitocybe sp. 2	C	Litter (*L. kaempferi*)															○	○			
Hygrocybe conica	C	Near survived *R. sachalinense*															○				
Lyophyllum decastes	D	Bare, near dead trees																○	○	○	○
Lyophyllum sp.	D	Bare, near dead trees				○															
Omphalina sp.	D	On the moss in a gully																○			
Macrocystidia cucumis	C	On the moss														○					
Armillaria mellea	C	Litter, near survived trees												○			○	○			
Collybia dryophila	C	Litter (*L. kaempferi, Salix*)					○														
Collybia sp. 1	C	Litter (*L. kaempferi, Salix*)															○				
Collybia sp. 2	C	Litter (*L. kaempferi, Salix*)						○	○			○									
Collybia sp. 3	C	Litter (*Salix*)							○												
Mycena sp	C	Litter (*Salix*)														○					
Tricholomataceae 1	C	Litter												○			○				
Tricholomataceae 2	C	Litter												○							
Tricholomataceae 3	C	Litter															○				
Tricholomataceae 4	C	Litter												○							
Pluteus atricapillus	C	Bare, woody debris				○															
Pluteus sp.	C	Litter														○	○				
Lepiota cristata	C	Litter (*L. kaempferi*)							○					○	○	○		○			
Phaeolepiota aurea	C	On the grass																	○	○	○
Coprinus comatus	C, D	Bare slope, in gullies, near survived trees											○	○	○	○	○	○	○	○	○
Coprinus atramentarius	C, D	Bare slope, in gullies, near survived trees	○	○	○										○	○	○	○	○	○	○
Coprinus micaceus	C	Litter (*Salix*)							○							○	○				
Coprinus disseminatus	C	Beside survived or dead trees	○	○													○	○	○	○	
Coprinus sp. 1	C	Litter (*Salix*)															○				
Coprinus sp. 2	C	Litter (*Salix*)														○					
Psathyrella velutina	D	North facing bare slope, in gullies				○						○	○	○	○	○	○	○	○	○	○
Psathyrella sp.	C	Litter															○				
Hypholoma fasciculare	C	Bare, woody debris			○							○				○	○	○	○	○	○
Pholiota squarrosa	C	Near survived *Q. crispula*															○				
Pholiota sp.	D	North facing slope, in gullies																	○	○	○
Inocybe nitidiscula	C	Around survived *L. kaempferi*, Litter													○	○	○				
Inocybe perbrevis	C	On the moss, near the survived *Salix*													○	○	○	○			
Hebeloma	C	On the moss, near the survived *Salix*														○		○			
Hebeloma mesophaeum	C	Litter (*Salix*), near the survived *Salix*		○	○										○	○	○	○		○	
Hebeloma sp.	C	On the moss, near the survived *Salix*															○				
Galerina sp.	C	Litter												○							
Suillus laricinus	C	Around survived *L. kaempferi*, Litter														○					
Suillus grevillei	C	Around survived *L. kaempferi*, Litter															○				
Scleroderma bovista	C	Bare, near survived trees						○	○	○	○	○	○	○	○	○	○	○	○	○	○
Helvella sp.	C	Bare, near survived trees							○												
Pezizaceae 1	D	North facing slope, in gullies																○		○	
Pezizaceae 2	D	North facing slope, in gullies																	○	○	
Xylaria polymorpha	C	Near survived trees							○	○	○	○	○	○	○						
Corticiaceae sensu lato	C	Litter (*L. kaempferi*)							○												
Unidentified	C	Litter (*L. kaempferi*)						○													

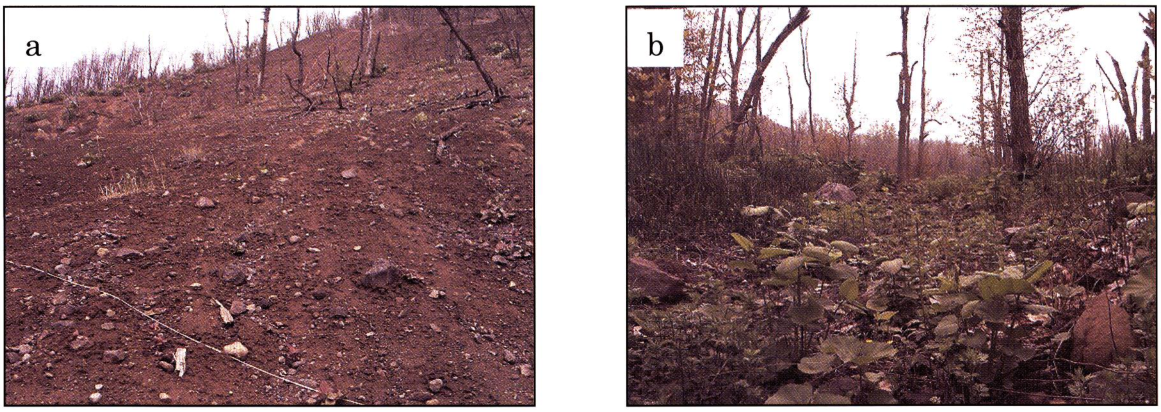

Fig. 3. Devastated area (a) and its circumference area (b), derived from volcanic eruption in 2000 on the foot of Mt. Usu, Hokkaido, Japan.