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Ectomycorrhizal Mushroom Occurrence around the Fairy Ring of *Tricholoma matsutake* at a Pine-Mushroom Forest

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송이 발생림의 송이 균환 주변에 출현하는 외생균근성 균류

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ABSTRACT: The occurrences of ectomycorrhizal fungi were investigated in a pine-mushroom forest at Hongcheon, Korea. The fairy rings of *Tricholoma matsutake* were figured by the sporocarp places of *T. matsutake* for three years (1995~1997), and the occurrences of other ectomycorrhizal fungi were surveyed with x and y dimensions for two years (1996~1997). The diameters of fairy rings of *T. matsutake* ranged from 2m to 10m, which indicated that the age of the fairy rings as 10~50 years when we consider that the growth of the fairy ring used to show about 10 cm per year. *Russula bella, R. sororia, R. delica* and *Cantharellus minor* were the major species occurred on the site during the survey period, and each species occupied 16.0%, 12.8%, 12.4% and 7.0% of total mushroom occurrence, respectively. From the results, we could conclude that the surveyed stand was a productivity-declining forest from the view point of pine-mushroom production. In addition, *Amanita pantherina, Suillus bovinus, Ramaria flaccida* and *Laccaria amethystea* were considered to be the indicator species for declining of pine-mushroom productivity since some fruiting bodies of the species appeared around the fairy ring of *T. matsutake*.

KEYWORDS: Indicator species, Mycological succession, Pine-mushroom productivity, *Pinus densiflora*

Pine-mushroom (*Tricholoma matsutake*) is a sort of ectomycorrhizal mushroom, and the mushroom is being collected only from forests since it is impossible to cultivate artificially so far. Lots of efforts have been given to improve or sustain the productivity with controling the environmental conditions, and the study on *T. matsutake* has been focused on the research from the view point of ecology. The pine-mushroom occurs in the stands of *Pinus densiflora* in Korea, but not all of the forests can produce the mushroom. The mushroom occurs at the specific sites which have the fairy ring of *T. matsutake* (Ryoo *et al.*, 1980). Thus, the ecological study of *T. matsutake* need to be started from examining the whole components of the pine-mushroom forest and to be developed onto the study for the response of *T. matsutake* against the changes in micro-environment.

The study for the microflora related to *T. matsutake* need to be conducted in detail as reported by Song and Min (1991), which gave an illustration of various microorganisms in vertical dimension with comparing the pine-mushroom productive and non-productive forests. But, the ecological study of the mushroom has primarily been focused on the feature of other mushrooms competitive to *T. matsutake*. Na and Ryu (1992) surveyed

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roughly for the occurrences of mushrooms in pine-mushroom forests, and Lee *et al.* (1986) compared the higher fungi occurred from pine-mushroom productive and those from non-productive forests. However, the flora of the higher fungi used to show a successional feature with the stand age as Fujita (1989) indicated, and the occurrence also show a large variation with environmental conditions such as soils. Thus, more specific research is needed to figure out the relations between *T. matsutake* and other mushrooms.

The flora of mushrooms in pine-mushroom forests also show a change in succession with the age of fairy ring of *T. matsutake* (Ogawa, 1991). Thus, the flora in a certain point may provide an index for the vitality of the fairy ring of *T. matsutake*, which in turn allows us to predict the future of the fairy ring. In this study, we surveyed the ectomycorrhizal flora around the fairy ring of *T. matsutake*. We tried to classify the mushrooms into several groups by the nearness of occurrence from the fairy ring of *T. matsutake*. The objectives of this study were ① to figure out the ectomycorrhizal mushroom competitive to *T. matsutake*, and ② to provide an outline of successional flora of ectomycorrhizal fungus around the fairy ring of *T. matsutake* in Korea.

Materials and Methods

Study site

The study site was a pine forest located at Nocheon-ri, Tong-myeon, Hongcheon-gun county, Kangwon-do province, Korea. The forest was a national forest and was thought to be a pine-mushroom productive stand. The surveyed site was located along the ridgeline of mountain with southwestern aspect, about 450m in altitude, and was so steep with 30° of gradient. The crown layer was occupied by 70 years old *Pinus densiflora* with about 70% of coverage, and the rest 30% was comprised by *Quercus variabilis*. *Rhododendron yedoense* var. *poukhanense* was the major species of the understory vegetation with some other shrubs such as *Styrax shiraiana, Lindera obtusiloba* and so on. The soil was a kind of Brown Forest Soil derived from coarse igneous rocks. The soil texture was loamy sand, and weak erosion was in process at the soil surface.

Survey method

The quadrats with 20m width were established around the fairy rings of *T. matsutake* within about 0.4ha of the study site. The quadrats were installed along the ridgeline, and the occurring points of various ectomycorrhizal mushroom including *T. matsutake* were recorded. Although the surveyed area reached about 150m in length, we used only 4 quadrats of 20m × 20m since the appearance of fruiting bodies of *T. matsutake* was not clear enough to figure out the exact form of fairy ring in other quadrats.

The left side of the upper line was used for the cardinal points of each plots, and an x-axis was installed from left to right, and a y-axis from top to bottom. The location of each ectomycorrhizal mushroom was recorded by the dimensions of x and y axes. The lines indicating 5m interval were installed within each plot to make a convenience for measuring exact location of each mushroom. The locations of the fruiting bodies of *T. matsutake* were recorded for three years from 1995 to 1997, and those of others were recorded for the summer and fall of two years from 1996 to 1997; four times (July 26, August 24, August 29 and September 4) in 1996 and six times (June 27, July 23, August 12, September 3, September 20 and October 2) in 1997. The pictorial books of Lee (1988), Park and Lee (1991), and Kim and Kim (1995) were used for the identification of each mushroom.

Analysis of the surveyed data

The occurring points of *T. matsutake* fruiting bodies recorded for three years (1995~1997) provided an outline of the fairy rings of *T. matsutake* when we plotted the data on a graph with x and y axes. But, the graph couldn't illustrate exact feature of fairy rings of *T. matsutake*. So, we raked the soil surface with a small horticultural rake to find the exact front line of physiologically active mycorrhizal zone during March of 1998 with the basic feature figured by the graph. The raking finally provided the exact location and form of the fairy ring of *T. matsutake*.

The data for the occurring points of each mushroom were classified into 4 groups on the basis of the nearness from the fairy ring of *T. matsutake*; inside of fairy ring, on the fairy ring, in front of fairy ring, and far from fairy ring. The inside includes the area that the fairy ring has already passed and the mycelia are under decomposition. The zone on the fairy ring includes the area from the point of pine-mushroom sporocarps occurred to the layer 30 cm apart from the point. The area indicates a physiologically active mycorrhizal zone since we found the front line of fairy ring used to apart 30 cm from the point of sporocarps of *T. matsutake*. The area in front of fairy ring includes 1m width layer apart from the front line of fairy rings, which would receive the mycorrhizal hyphae within 5~10 years since the fungus usually grows 10~20 cm per year. Finally, the zone far from the fairy ring indicates outside of the front layer, which was thought to have no specific relations to *T. matsutake*. However, the classification was not easily proceeded since several mushrooms appeared on various places. Therefore, we examined the significance of the occurrence of each mushroom species on each zone using χ^2-test (Ott, 1988).

Results

The fairy ring of *Tricholoma matsutake*

The diameter of fairy rings ranged from 2m to 10m. It indicated that the age of fairy rings ranged from 10 years to 50 years if we assume the growth rate of fairy ring as 10 cm/year (Figure 1). Thus, we could guess that the fairy rings were thought to be formed when the major species of the stand, *Pinus densiflora*, was more than 20 years old. Although the small fairy ring showed a circle-type, the fairy rings were mainly typed oval. It indicated that the stand is an old pine-mushroom forest since the old fairy rings used to show an oval-type or a line-type (Ogawa, 1991).

As mentioned in the previous section (Analysis of the surveyed data), the physiologically active mycorrhizal zone reached 30 cm of the front from the points of pine-mushroom sporocarps. It indicated that the fruiting bodies of *T. matsutake* were appeared on the mycelial layer established 3 years ago if we consider the growth rate of the mycelium as 10 cm/year. Thus, the physiologically active mycorrhizal zone could be considered to have about 30 cm's width. By the way, some mycelial layers did not produce any fruiting bodies during three years, which gave us vague information about the fairy rings when we tried to figure out the feature of fairy rings only with the locations of fruiting bodies.

Ectomycorrhizal mushroom appeared in a pine-mushroom forest

The study site showed the feature of an old stage of pine-mushroom production, with a transitional stage from an old *Pinus densiflora* stand to the deciduous stand mainly composed of *Quercus variabilis*. This feature made us find various mushrooms with lots of saprophytic fungi although we

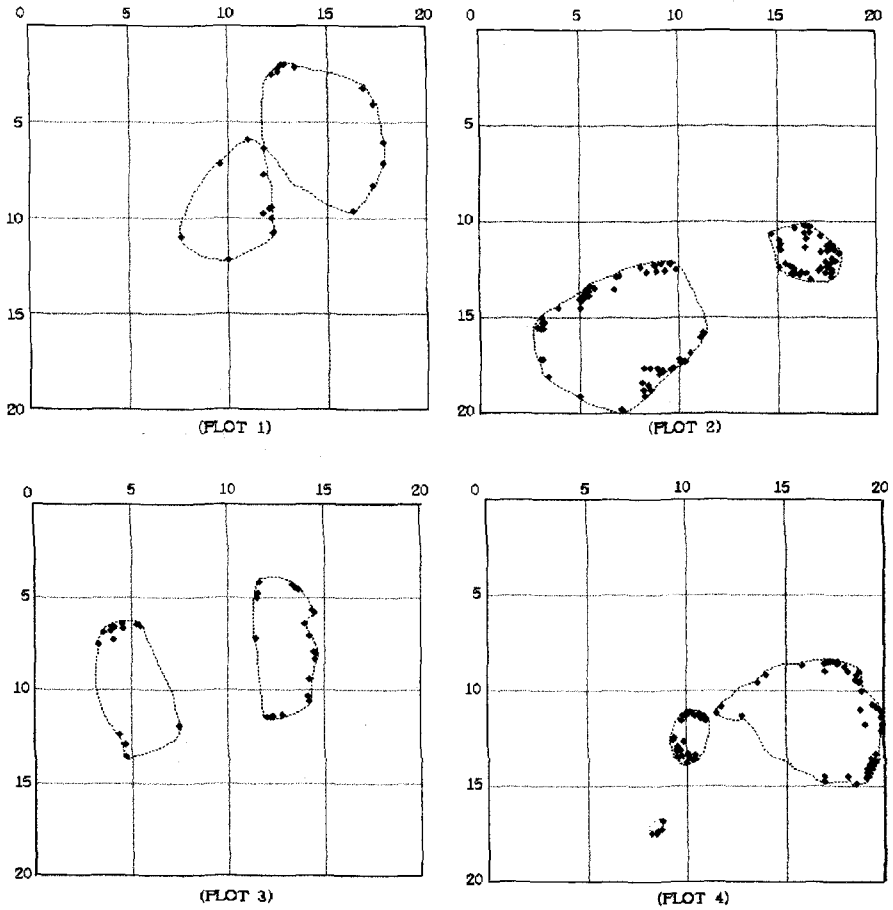

Fig. 1. The occurrence of the sporocarps of *Tricholoma matsutake* which gives the outlines of several fairy rings at the experimental site (unit: meter). Each points indicate the occurring points of pine-mushroom fruit-bodies, and the dotted line shows the front line of physiologically active mycorrhizal zone.

surveyed only for the ectomycorrhizal fungi. We found 960 fruiting bodies of ectomycorrhizal fungi within the site in addition to those of *T. matsutake* during summer and fall of two years. *Russula bella, R. sororia, R. delica*, and *Cantharellus minor* were the major species occurred on the site during the survey period, and each species occupied 16.0%, 12.8%, 12.4% and 7.0% of total mushroom occurrence, respectively. The species of ectomycorrhizal fungi appeared within the surveyed plots are listed on Table 1. But, the list of 34 species only illustrates the species with significantly large numbers within the surveyed plots by χ^2-test, and the other species appeared but insignificant are as follows: *Amanita vaginata* var. *fulva, A. hemibapha* subsp. *javanica, A. inaurata, A. spreta, A. virgineoides, Boletellus obscurecoccineus, Boletopsis leucomelas, Calostoma japonicum, Cantharellus infundibuliformis, Clavaria vermicularis, Clavicorona pyxidata, Gomphidius roseus, Gyroporus castaneus, Hydnellum concrescens, Hygrophorus russula, Lactarius hatsutake, Lepiota subcirtrophylla, Lepista nuda, Psathyrella velutina, Rhodophyllus crassipes, Russula emetica, R. flavida, R. nigricans, Stereopsis burtianum, Thelephora*

Table 1. Number of ectomycorrhizal fruit-bodies (except for *Tricholoma matsutake*) occurred at the surveyed sites from July of 1996 to October of 1997. Only the mushrooms with significance of χ^2-test at the 5% level were listed here

Species name	Location from the fairy ring of *T. matsutake*				Total
	Inside	On	Front	Far	
Russula bella	7	6	3	138	154
Russula sororia	2	0	6	115	123
Russula delica	8	0	1	110	119
Cantharellus minor	0	1	3	63	67
Amanita pantherina	5	4	0	40	49
Suillus bovinus	13	5	0	27	45
Boletus sp.*	23	5	1	10	41
Cantharellus cibarius	2	0	4	29	35
Ramaria flaccida	12	2	7	13	34
Pulveroboltus ravenelii	0	0	2	27	29
Russula aurata	1	0	0	23	24
Russula sp.*	0	0	0	23	23
Russula densifolia	2	1	5	12	20
Rhodophyllus clypeatus	0	0	0	13	13
Inocybe lacera	0	0	0	12	12
Rhodophyllus rhodopolius	0	0	0	10	10
Russula rosacea	0	0	1	6	7
Tylopilus neofelleus	0	0	0	7	7
Suillus granulatus	1	0	1	5	7
Suillus luteus	0	0	0	7	7
Russula alboareolata	2	0	0	4	6
Cortinarius purpurascens	0	0	0	6	6
Russula pseudodelica	0	0	1	4	5
Russula virescens	0	0	1	4	5
Laccaria amethystea	0	3	0	2	5
Ramaria sanguinea	0	1	0	4	5
Lactarius laeticolorus	0	0	0	4	4
Craterellus cornucopioides	0	0	0	4	4
Cantharellus cinnabarinus	0	0	0	4	4
Lactarius chrysorrheus	0	0	0	4	4
Strobilomyces confusus	0	0	0	3	3
Gomphidius subroseus	0	0	0	3	3
Amanita hemibapha	0	0	0	3	3
Lactarius piperatus	0	0	0	3	3

**Boletus* sp. and *Russula* sp. include the mushrooms of each genus couldn't be identified.

palmata, Xerocomus subtomentosus and so on.

The list shows quite different results from other reports of mushroom occurrence in pine-mushroom forests of Korea. Na and Ryu (1992) found no *Russula* spp. or *Amanita* spp., and Lee *et al.* (1986) found *Russula* spp. and *Amanita* spp. at the pine-mushroom non-productive sites instead of pine-mushroom productive stands. But, from the survey of ours, the mushrooms in *Russula* spp. and *Amanita* spp. were the major species of appearance with *Cantharellus* spp., *Boletus* spp. and *Suillus* spp. So, we could conclude that the occurrence of ectomycorrhizal mushrooms in the pine-mushroom productive forest are different with region, climatic condition or stand age.

According to the report of Ogawa (1991), the flora of mushroom in a pine-mushroom forest is largely dependent upon the age of stand. At the early stage of pine-mushroom production, *Tricholoma flavovirens, Sarcodon scabrosus*, and *Boletopsis leucomelas* are the major species of ectomycorrhizal mushrooms in the pine-mushroom forest. But, *Amanita pantherina, Lactarius* spp. and *Russula* spp. appear more frequently at the stage of productivity declining. Ogawa (1991) also noted that the saprophytic mushrooms take major portion of the microflora at non-productive stage of pine-mushroom. We found only one sporocarp of *Boletopsis leucomelas* with plenty of *Russula* spp. and saprophytic fungi. This feature indicated that the stand was on the stage of productivity declining.

Mushrooms appeared inside the fairy ring of *T. matsutake*

There was no significant mushroom species that occurs only inside the fairy ring of *T. matsutake*. Although we found a sporocarp of *Boletopsis leucomelas* within the area, it was difficult to say that the mushroom occurs only inside the fairy ring since we found only

one for three years.

Russula bella, Russula delica, Amanita pantherina, Suillus bovinus, Boletus sp., and *Ramaria flaccida* were found both from inside and outside of fairy ring. Especially, many sporocarps of *Suillus bovinus, Boletus* sp. and *Ramaria flaccida* were found inside fairy rings. The numbers of them occurred inside fairy rings were 13 (29% of total number) for *Suillus bovinus*, 23 (66% of total number) for *Boletus* sp. and 12 (35% of total number) for *Ramaria flaccida*, respectively. It might indicate that the species are easy to be seen inside the fairy ring compared to the other ectomycorrhizal species.

Mushrooms appeared on the fairy ring of *T. matsutake*

The mushrooms found only in the physiologically active mycorrhizal zone were an *Amanita* sp. and *Gomphidius roseus*. But, it was not possible to say the two species are competitive to *T. matsutake* since the two species were found only once during the survey period. *Russula bella, Amanita pantherina, Suillus bovinus, Boletus* sp. and *Laccaria amethystea* were found within the area more than three times, which allowed us to consider that the species have competitive or compensatory relationships with *T. matsutake*. Although it was impossible to give a clear illustration for the relationships with *T. matsutake*, the species might be thought as index species of pine-mushroom productivity declining since the surveyed stand was in the stage of productivity declining.

Mushrooms appeared in front of fairy rings of *T. matsutake*

Boletellus obscurecoccineus was observed only in front of fairy rings of *T. matsutake*, but it was observed only once. *Russula rosacea, Russula pseudodelica* and *Russula virescens* were also observed one time in front of the fairy rings, while plenty of them were observed outside of the fairy rings. Most of the mushrooms recorded more than 20 times were observed in front of the fairy rings, but they appeared inside or outside of the fairy rings more frequently.

Mushrooms appeared on the places far from the fairy ring of *T. matsutake*

799 sporocarps were observed on the places far from the fairy ring of *T. matsutake* among the 960 recorded sporocarps. Some of the species were found only at the area, and the species considered significantly to appear only at the area were as follows: *Amanita hemibapha, Cantharellus cinnabarinus, Cortinarius purpurascens, Craterellus cornucopioides, Gomphidius subroseus, Inocybe lacera, Lactarius piperatus, L. chrysorrheus, L. laeticolorus, Rhodophyllus rhodopolius, R. clypeatus, Strobilomyces confusus, Suillus luteus, Tylopilus neofelleus*, etc. That is, the species can be found in a pine-mushroom forest, but can not be used as the index species related to the vitality of *T. matsutake*.

Discussion

As Frankland (1998) indicated, the fungal succession has been ignored so far while the succession of plants is widely understood to be studied. From the view point of mycology, the fungal succession can be defined as 'a directional change in the composition, relative abundance and spatial pattern of species comprising communities'.

The fungal succession can be observed in a pine-mushroom forest. When the mycelial cluster of *Tricholoma matsutake* is established, the mycelial cluster derives antibiotics to remove or suppress the growth of other fungi or bacteria, which makes the own fairy ring of *T. matsutake* can be expanded widely with

little competition (Ogawa, 1991). Certainly, the fairy ring is getting older and weaker as time passes, and other fungal species occurs to compete with *T. matsutake*. However, the physiologically active mycorrhizal zone is considered to have relatively little competition with other fungi or bacteria when the fairy ring is young.

This study was conducted at the productivity declining pine-mushroom forest. Thus, the surveyed ectomycorrhizal flora was thought to show the competitive species against *T. matsutake*. We tried to find the species intensively appear on or in front of the fairy ring of *T. matsutake* since we assumed that the competitive species might occur on the area. However, it was so difficult to find the species more frequently appear on or in front of the fairy ring of *T. matsutake* compared to the other area.

By the way, we considered that the ectomycorrhizal mushrooms frequently occur on or inside fairy rings as the indicator of productivity declining of pine-mushroom which resulted from the vitality changes of *T. matsutake*. The consideration is based on the report of Ogawa (1991) who declared that the vitality change of *T. matsutake* resulted in the failure of antibiotics production for repelling other microorganisms. *Amanita pantherina, Suillus bovinus, Boletus* sp., *Ramaria flaccida* were considered to have a deep relations to the perishment of *T. matsutake*. In addition, *Laccaria amethystea* was observed more frequently on the fairy ring of *T. matsutake*, which makes us to think the species have a specific relationships with *T. matsutake*.

적 요

대한민국 홍천의 송이 발생림에서 외생균근성 버섯의 발생상에 대하여 조사하였다. 송이 균환은 3년간(1995~1997)의 송이 자실체 발생위치를 토대로 파악하였고, 다른 외생균근성 버섯의 출현 위치는 x축과 y축의 좌표를 표시하며 2년간(1996~1997) 조사하였다. 송이 균환의 직경은 2~10m의 범위를 나타내어, 송이 균은 대체로 연간 10 cm 정도 생장하는 것을 감안할 때 균환의 연령은 5~50년에 달하는 것으로 여겨졌다. 무당버섯(*Russula bella*), 회갈색무당버섯(*R. sororia*), 푸른주름무당버섯(*R. delica*), 애기꾀꼬리버섯(*Cantharellus minor*)이 조사기간에 주로 출현한 버섯이었는데 그 출현빈도는 전체 조사된 종류의 각각 16.0%, 12.8%, 12.4% 및 7.0%를 차지하고 있었다. 조사자료를 분석한 결과, 연구대상지는 송이의 생산량이 감소하는 숲으로 여겨졌다. 또한, 마귀광대버섯(*Amanita pantherina*), 황소비단그물버섯(*Suillus bovinus*), 다박싸리버섯(*Ramaria flaccida*) 및 졸각버섯(*Laccaria amethystea*)은 송이의 균환주변에 많이 출현하여 송이 생산성이 감소하는 상태에 있음을 나타내는 지표종으로 여겨졌다.

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