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Effects on the Pine Mushroom Yield of Controlling Environmental Conditions at the Pine Stands in Namwon, Korea[1*]

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南原 所在 소나무林의 環境調節 處理가 송이 發生量에 미치는 影響[1*]

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ABSTRACT

This paper is presenting a practical result of environmental manipulation effect on pine mushroom *Tricholoma matsutake* yield and a discussion of key factor seeking for improving pine mushroom production by analyzing the effects on mushroom yield for 10 years with applying five kinds of environmental control at the pine stands located in Namwon, Chollabuk-do, Korea. The environmental controls included density control and forest floor manipulations, and the treatments were applied during early summer of 1983. The mushroom yield itself did not show statistically significant differences among the treatments. But, we could manifest the treatment effects by calculating the relative yield in percent on the basis of pretreatment yield collected in 1982. The forest floor manipulation with density control may affect pine mushroom yield in short term, and continuous management should be applied to keep and improve the mushroom production. The fine root activity was the most important factor of pine mushroom production at the Namwon research site since the floor raking resulted in the largest effect on the mushroom yield although the environmental condition for the growth of fungi is important for pine mushroom production. In addition, the pine mushroom forest with sandy soils demands adequate litter layer since the litter removal showed relatively detrimental effects on pine mushroom yield compared to that in litter covered plot at the research site. That is, soil texture should be considered for forest floor manipulation, and it is reconfirmed that the environmental control to improve pine mushroom production should be applied differently by each region.

Key words : fine-root activity, floor raking, forest floor manipulation, regional treatment application, Pinus densiflora *S. et Z.*, Tricholoma matsutake

要 約

本 硏究는 全羅北道 南原 所在의 송이 發生林에서 各種 環境調節 處理後 10年間 調査한 송이 子實體 發生量의 變化를 檢討, 分析하여 各 處理가 송이 發生에 實質的인 도움을 주는가 알아보고 송이 增産을 爲하여 勸案하여야 할 因子에 대하여 考察한 內容이다. 環境調節 處理는 植生整理와 林床條件 調節이며 1983年 초여름에 實施하였다. 各 處理別 송이 子實體 生産量은 統計的 有意差를 나타내지 않았다. 하지만, 施業前인 1982年의 各 調査區別 송이 生産量을 1로 基準하여 每年 子實體 生産量을 %로 換算하여 比較한 結果, 施業效果를 區分해 낼 수 있었다. 植生整理와 더불어 地被物을 管理하는

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것은 短期的으로만 송이 生産量에 影響을 미치므로 持續的인 管理를 통해서만 송이山의 生産性을 維持, 增進할 수 있음을 確認하였다. 또한, 송이 菌의 生育條件도 重要하지만, 南原의 調査區에서는 地表긁기가 송이 生産性 向上에 가장 큰 影響을 나타내어 소나무 細根發達이 송이 生産性에 더욱 큰 影響을 미침을 確認할 수 있었다. 아울러, 本 試驗區에서는 落葉除去가 落葉被覆에 比하여 오히려 송이 發生에 惡影響을 미치는 것으로 나타나 砂質土壤을 지닌 송이山은 適當한 落葉이 必要함을 알 수 있었다. 卽, 土性을 考慮한 地被物 管理가 必要하며, 地域別 生産性 增進技法은 各 地域別로 差別化 하여야 함을 再確認 할 수 있었다.

INTRODUCTION

Pine mushroom is a fruiting body of *Tricholoma matsutake*, which is an ectomycorrhizal fungus. The fungus has a symbiotic relationship with various trees, but *Pinus densiflora* S. *et* Z. is the major species in Korea and Japan (Ogawa, 1975). The fungus demands specific site condition for living, which means not all of pine stand produces pine mushroom. This feature triggered several surveys for understanding site conditions (such as slope, soil texture, and stand structure, *etc.*) of pine mushroom mountain in Korea (Kim *et al.*, 1975; Ryoo *et al.*, 1980; Lee, 1983). Some researchers also surveyed microbial flora to understand microbial characteristics of the site since the major concern is a fungus which ultimately produces fruiting body (Lee *et al.*, 1986; Song and Min, 1991). Before the research conducted in Korea, many Japanese researchers had conducted the survey of pine mushroom mountains in Japan (Kinugawa, 1964; Ogawa, 1975a; 1975b; 1977a; 1977b), and plenty of trials were made to provide suitable condition for improving pine mushroom production (Tominaga, 1975; 1976; 1977; 1978; 1979; Kareki, 1980; Shimokawa, 1980).

Since the major market of pine mushroom is Japan, Japanese scientists have studied a lot for *Tricholoma matsutake* from early 20th century. Meanwhile, the study for pine mushroom in Korea has been started in early 1970s when the profitability of the mushroom had been recognized as Korea started to export pine mushrooms at the time. But, the study stayed in a small scale until 1980. The study has been enlarged from 1980 since a cooperative research for pine mushroom was signed at the Minister's convention of Korea-Japan in 1979 (Kim, 1984). The multilateral research provided an outline of site conditions for pine mushroom production in Korea (Lee *et al.*, 1983), and various trials had been conducted for artificial cultivation of the mushroom and for environmental manipulation to improve productivity of the mushroom (Lee *et al.*, 1984a; 1984b). However, fair result of the environmental manipulation could not be provided yet since the study took more than a decade for getting clear response as other forestry research used to take long time. So, Korean government and researchers usually quoted the Japanese result for the environmental control of pine mushroom mountains to explain the necessity of environmental manipulation for yield improvement.

But, the Korean peninsula is quite different from the Japanese island in climatic and site conditions. For example, the major reason for deterioration of pine stand in Korea is a pine needle gall midge, while that in Japan is a pine wood nematode. Therefore, the effect of environmental manipulation on pine mushroom yield should be examined in each country, respectively. In this study, we tried to figure out the manipulation effects of stand condition on pine mushroom yield in Korean peninsula. We also wanted to differentiate the result from Japanese's results and to provide discussion for seeking a key factor of pine mushroom production in the study site.

MATERIALS AND METHODS

Study Area

The study site is located at San 1, Mokdong-ri, Sandong-myon, Namwon-shi, Chollabuk-do, Korea. The stand could be considered as a pure pine stand which was mainly composed of *Pinus densiflora* S. *et* Z. with few ericaceous plants and *Juglans rigida*. The height of dominant tree

Table 1. Site and soil condition of the studied pine stand, which is located at San 1, Mokdong-ri, Sandong-myon, Namwon-shi, Chollabuk-do, Korea.

(a) Vegetation

Stand age	Height	Crown density	Stand condition	Understory
$\frac{40}{30-60}$	8.2m	Medium	Pure pine stand	Few

(b) Site condition

Altitude	Aspect	Parent material	Slope	Soil type
270−360m	S	Granite	27°	B_1~Im

(c) Soil condition

Texture	ERD*	O horizon	A horizon	B horizon
LS	18cm	2.5cm	5−10cm	10−30cm
Soil pH	OM*	Total N	P_2O_5	CEC
5.0	0.65%	0.07%	15ppm	9meq/100g

* ERD : effective rooting depth, OM : organic matter

reached around 8.2m before treatment applications (1982) which is about 11.5m now(1997). The stand age was about 40 years at the time with ranges of each tree from 30 to 60 years.

The soil condition of the studied site was a typical pine mushroom mountain at Namwon, Korea. The parent material of the soil was granite and soil texture was loamy sand, which had a good drainage. The mountain showed southern aspect with 27° slope around 300m in altitude.

Treatment Applications

Five kinds of environment manipulations were applied including ① crown density control (DC), ② DC followed by litter removal (LR), ③ DC followed by litter cover (LC), ④ DC and floor raking with fertilization (FR) and ⑤ control. The density control was conducted to fit the criterion for pine mushroom mountain (Kim, 1984), around 65~70% of crown density. The litter removal was tried to provide more opportunity for fine roots of pine to meet spores of *Tricholoma matsutake*. In the meantime, the litter coverage was applied with considering that the treatment may keep the soil in adequate moisture condition and the litter possibly supply nutrients to the soil ecosystem. The raking was applied in the same direction of contour line, which might stimulate the development of new fine roots of pines and the treatments were followed by fertilization of a solid fertilizer for forestry.

The treatments were applied during June of 1983 after surveying the previous conditions during 1982. Even though we tried to keep the study sites in the same condition as the original treatments by additive control, the original condition for each treatment could not be persisted after 1987 since the cooperative study was ceased in 1986 since the program was a five year plan. But, an additive control for density control by shrub removal and pruning had been continued for every other years since 1987, while the forest floor manipulation could not be kept like before.

Yield Assay and Statistical Analysis

The yield of pine mushroom from 1982 to 1991 of every plot were recorded to figure out the effect of each treatment. In addition, we calculated the relative production of pine mushroom after treatment application compared to the pretreatment yield of each plot by data manipulation into percent because the number of fairy rings and the mushroom yield per each fairy ring was not the same at first.

For the statistical analysis, we used ANOVA at the 5% of significance level, and the Duncan's multiple range test was adapted to compare mean of each treatment when the ANOVA indicated significant differences among treatments (SAS, 1985).

RESULTS AND DISCUSSION

The mushroom yield itself did not show statistically significant differences among the treatments. But, it did not mean that there was no effect of treatment applications since the number of fairy rings and the mushroom yield per each fairy ring was not the same at first in addition to the large variation of annual yield due to the changes in climatic condition. By the way, we could manifest the treatment effects by calculating the relative yield in percent on the basis of pretreatment yield recorded in 1982.

We found that the forest floor manipulation with density control may affect pine mushroom yield in short term. There was no significant differences in pine mushroom yield of each treatment compared to that of control after 1987 which was the fifth year after treatment application (Fig. 1), which indicated that the additive forest floor manipulation should be kept to see the treatment effects continuously.

Among the treatments, floor raking with fertilization and litter coverage after density control showed increased pine mushroom production during the four years, from 1983 to 1986. The effect of floor raking with fertilization indicated the importance of fine root development for mycorrhizal symbiosis as reported by Shimokawa (1980). In addition, the stimulated fine root turnover might supply more nutrient to the pines (McClaugherty *et al.*, 1982). It means that the key factor for pine mushroom productivity is dependent not only upon the climatic factors such as temperature and moisture (Tominaga, 1975), but also upon the fine root development of symbiotic plant.

By the way, litter removal resulted in negative effect compared to litter coverage for 1983, 1985, 1986 and 1990, which indicated that the sandy soil of the study site demanded the litter layer for some purposes. The litter layer was thought to be helpful for moisture condition since the sandy soil usually shows fast drainage which may result in poor condition for soil moisture. That is, it indicated that the study site should be kept in thicker than 2.5cm in litter layer as

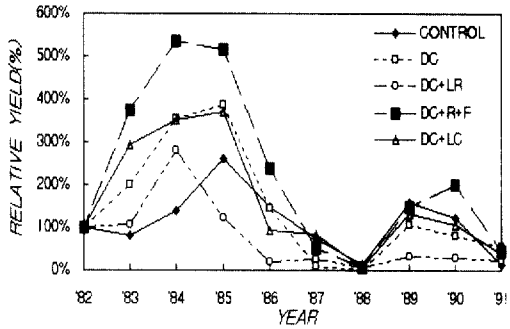

Fig. 1. Environmental manipulation effects on pine-mushroom yield. The values indicate percentage of each year's yield compared to that of pretreatment(1982) which is illustrated as 100% (unit : %) * DC : Density control, LR : Litter removal, R : Raking, F : Fertilization, LC : Litter coverage

the Japanese reports used to recommend keeping litter litter layer when the thickness is less than 4cm (Ogawa, 1991). Thus, the result manifested that we should apply different management scheme for each stand with different site condition as indicated by Park *et al.*(1996).

In summary, we could concluded that the floor manipulation affect pine mushroom yield in short-term, which indicated that continuous operation should be applied to accomplish investment goal, keeping and/or improving the mushroom production. Especially, the pine mushroom mountain with sandy soils demands adequate litter layer as we found that the litter removal resulted in a detrimental effect on pine mushroom yield compared to that in litter coverage. That is, soil texture need to be considered for forest floor manipulation. Although the environmental condition for the growth of fungus such as temperature and moisture is very important for pine mushroom production, the fine root activity was considered as the most important factor of pine mushroom production at the studied area since the floor raking resulted in the best production. That is, we recognized again the importance of symbiotic relationships between *Tricholoma matsutake* and *Pinus densiflora*, which make us to pay more attention to tree physiology of *P. densiflora* in addition to the fungus(*T. matsutake*) for improving pine mushroom productivity.

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