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The Significance of Mycorrhizae in Forest Ecosystems

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4.1 Introduction

In forests, various organisms live by interaction with other species. Fungi, in particular, have various modes of life such as those of saprophytes, parasites, and symbionts. For example, the honey mushroom (Armillaria spp.) is known as “a fungus shrouded in a mystery,” because it goes through various modes of life. It was recognized as the largest organism in the world by Nature in 1992 (Smith et al. 1992; Suzuki 1996). In recent years, it has been revealed that ectomycorrhizal fungi play a significant role in production of substances in forests. For example, the current amount of ectomycorrhizal fungi in the forest biomass of a 180-year-old fir stand in the United States is only 0.3%, but when rootlets are included, the ratio of ectomycorrhizal fungi to net primary production (NPP) goes up to 75%. In the case of a 50-year-old Douglas fir stand, the ratio is estimated to be 50% (Fogel and Hunt 1979; Vogt et al. 1982). Research on fir stands in Japan has shown that the ratio of mycorrhizal biomass to nonmycorrhizal biomass (rootlets) is 4:6 (Nara et al. 1992). Based on the results of these studies, it can be observed how significant a role ectomycorrhizal fungi play in forest ecosystems. It is expected that active methods based on symbiosis with mycorrhizae will be established for enhancement of forest functions in the future.

Species of the pine family such as pines, firs, spruces, and Douglas fir are dominant components of the forests of the northern hemisphere. The origin of the pine trees can be traced to the Bering Strait in the Mesozoic era. They expanded their area of distribution widely into the northern hemisphere to become the circumpolar plant species of the Tertiary period of the Cenozoic era, adapting to various environments around the world, and formed forests (Suzuki 1991). Recently, forest decline has become increasingly apparent in the United States and in European countries, and it

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has emerged as a serious issue (Fukuda et al. 1997). This forest decline can be attributed to complex interplays of biotic and abiotic factors. Therefore, the development and preservation of healthy forests, which, to a high degree, can fulfill their functions of producing substances and establishing an environment, are of critical importance in taking measures against global-scale environmental changes, such as global warming, which are expected to occur in the future. Of particular importance are most of the species of Pinaceae dominant in the northern hemisphere that form ectomycorrhiza. Their ability to produce substances is enhanced by symbiosis with ectomycorrhiza.

As described above, measures for allowing forests to fulfill their functions of producing substances and preserving environments will be of critical importance in coping with problematic environmental issues such as declining forests, changes in forest environments, and the worldwide spread of epidemic diseases such as a pine wilt disease. In particular, measures for enhancing the functions of pine forests and making effective use of them are critical to forests not only in Asia, but also in the northern hemisphere. This is because pine trees are the most important tree species for forest formation and the timber industry, and they are also vital environmental resources in Japan as well as in the northern hemisphere.

It can be considered that the symbiotic relationships between trees and fungi play an important role in the mechanism of maintaining forest ecosystems. Achievement of the following objectives is important to understand forest ecosystems: (1) elucidation of physiological and ecological characteristics of the symbiotic system between trees and ectomycorrhizal fungi, (2) evaluation of the function of trees in resisting environmental stress, which is based on the use of the symbiotic relationships, (3) elucidation of the symbiotic function of ectomycorrhizal fungi such as *Tricholoma matsutake*, and (4) contribution to the preservation of pine forests through effective use of the symbiotic function.

This chapter clarifies the phenomenon of symbiosis of ectomycorrhizal fungi such as *T. matsutake* by focusing on their structure and functions. First, a method for identifying strains of *T. matsutake* and its closely related species around the world is established by determining their genetic characteristics via polymorphic DNA analysis. Next, the morphogenesis of *Pinus densiflora* trees and matsutake mycorrhizal roots is examined. The following methods and technologies are developed: (1) methods for synthesizing artificial mycorrhizae, which can be used as ectomycorrhizal fungi such as *T. matsutake*, (2) methods for encouraging development of artificial shiros of *T. matsutake*, and (3) techniques for enabling *T. matsutake* to colonize and become established. Attempts were then made to make effective use of pine forests via the use of ectomycorrhizal fungi.

One of the features of this research is its focus on interactions between trees and fungi in forest ecosystems, a topic not fully addressed until now, and the study associated experimental systems in vitro with the ones in the field. The results of this research were presented at international symposiums such as *Ectomycorrhizal Ecosphysiology and Its Applications in Pine Forests* (Tange et al. 1999; University of Tokyo 2001; Aga et al. 2004).