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ECTOMYCORRHIZAL FUNGI ASSOCIATED WITH ALPINE CONIFERS FROM SOUTH WESTERN CHINA

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ABSTRACT 130 noteworthy ectomycorrhizal fungi in 34 genera associated with several species of conifers: *Abies georgei* Orr., *Picea likangensis* Pritz., *Pinus densata* Mast., *Pinus yunnanensis* Fr. from Tibet and Yunnan are discussed. The several types of ectomycorrhizal ramification and morphological anatomy of ectomycorrhizal are given.

KEY WORDS Coniferous ectomycorrhizal fungi; Tibet; Yunnan

Several survies was carried out during 1975 to 1985. The region under consideration is situated at the southeastern corner of Tibet, near the eastern border of the Himalayas and her adjacent regions Hengduan mountains (between 26°—29°N and 94°—103°20′E.). The whole of the area, including southeastern Tibet, Northwestern Yunnan and Western Sichuan. From the southern flank of the eastern Himalayas and to the Hengduan mountains, the snowcapped massives which, many over at 4000 m. tower above this area. The highest Himalayas of the world on the west, in the southeastern part of plateau the mountains trend north to south, being the so-called Hengduan mountains, where transversed by several northern-southern-ward large or medium sized rivers with their numerous tributaris essentially along the same direction, Yarlung Zangbo (River) is stretching as far north as 29°W along the Tibetan great gorge. Out of Tibet roar the great eastern. rivers, the Dulung River (a branch of Irrawaddy), Nu Jiang (Salween), Lancang Jian (Mekong) and Yangtze, each eroding its own chasm up to 1000 2000 m. deep, the altitudinal estremes, deep cayons, the mountain chains exactly more dissected, the gorges quite deep and narrow, although some place the riverbed is narrow, yet it is non-navigable river, rather difficult to be across, a great diversity in climate, a copious rainfall is naturally expected to support a rich and varied Conifers and ectomycorrhizal fungi. In symbiotic relationships, where the mycorrhizae represents are a quite remarkable relationship between the feeder roots of trees, especially the Conifers and beneficial fungi, some of these fungi develop a mantle or cover along with hyphae in threadlike extrensions on the trees feeder roots, within the root, the hyphae are mostly confined to the space between the cortical cells, water and hormones secreated by the fungus cause the root to branch, apparently, the roots secreat amino acids and possibly some other organic substances for fungi. Meanwhile, in nature, the growth of seedling usually seems to be limited by the amount of phosphorus available in the seed, until a mycorrhizal association can be set up. In soil that lack the mycorrhizal fungi, while the seedling are known to grow poorly, and the fungi also do not grow without their tree partners, since it is known that the pine cannot survive without mycorrhizae on the roots. (Melin, 1923; Trappe, 1962).

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The authors have performed phytosociological investigations on the alpine region of this area. In contrast to the other parts of China, the horizontal distribution pattern of Conifers and their ectomycorrhizal fungi in this area are relatively insignificant, the distribution patterns of dark leaves Conifers: *Abies spectabilis* (D. Don) Mirb. (2800—3800 m. alt., Tibet), *Abies squamata* Mast. (3800—4000 m. Tibet, W. Sichuan), *Abies georgei* Orr. (3800—3950 m. Chayu, Tibet; N. W. Yunnan and W. Sichuan) frequently correspond to those of the alpine Coniferous region as they are usually found in association with *Leccinum chromapes* (Frost.) Singer, *Leccinum scabrum* (Fr.) Gray. On the basis of these studies, the different Conifers and ectomycorrhizal fungi, their characteristic patches and vertical distributions of the following associations were found:

In the cooler part of alpine region (3000—4200 m.) the *Abies* spp. are dominated, under the forest, the common fungi: *Cortinarius caerulescens* (Schaeff.) Fr., *Cortinarius firmus* Fr., and *Strobilomyces alpinus* Zang are distributed. Moreover, a number of other dark leaves coniferous trees, spruces are dominated, such as *Picea likiangensis* (3500—4200 m. S. E. Tibet; W. Sichuan; N. Yunnan) particularly in moist and cooler places, the following fungi: *Spathularia flavida* Pers., *Amanita pantherina* (DC.: Fr.) Secr., and *Cortinarius colymbadius* Fr. are closely related, on the humus soil, *Leccinum scabrum, Laccaria amethystea* (Bull. ex Gray) Murr., *Rozites caparata* (Pers.: Fr.) Karst., are typical mycorrhizal fungi associated with *Picea*. Spruces growing in forest stands consisting of many tree species form mycorrhizae occurring also on other tree species, both Conifers and alpine *Quercus*. If the soil lacks mycorrhizal fungi, the trees cannot developed (Dominik, 1961).

Below 3000 m alt. the subalpine coniferous region, it boasts of the greatest wealth of the *Pinus* vegetation, under a certain condition of specific exposure to sunlight and steep slopes, where water readily flows down tthe persentage of mycorrhizal fungi are very low, for instance, under the *Pinus densata* (2900—3900 m. E. Tibet; N. E. Yunnan) and *Pinus yunnanensis* (1500—2500 m. Chayu, Tibet; Yunnan), the Boletales and Agaricales are not too more, only the *Pisolithus tinctorius* (Pers.) Coker et Couch, *Rhizopogon luteolus* Fr., *Melanogaster variegatus* (Vitt.) Tulasne are thriving in the dryer area. However, knowing the habits of *Pinus* mycorrhizae from that of other wetter terrain, the Boletales and Agaricales are extraordinary rich, all of them are producing ectomycorrhizae (Lakhanpal, 1988). Some species of fungi are commonly appeared, that are *Suillus bovinus* (L.: Fr.) Karst., *Suillus granulatus* (L.: Fr.) Ktze., *S. luteus* (Fr.) Gray, was usually found under the 3 needles pine association, where they developed well in decomposed humus and on dead remnants of *Pinus desata* (S. E. Tibet; N. W. Yunnan 2700—3700 m.) and *Pinus yunnanensis* rhizosphere. On the contrary, the *Suillus spraguei* (Berk. et Curt.) Kuntz. always associated with 5 needles pine: *Pinus griffithii* McClelland (S. E. Tibet, 2000—3000 m. W. Yunnan), *Pinus armandi* Franch (Yunnan, Sichuan, 1200—2600 m.) On the other hand, the *Suillus plorans* (Rolland) Kuntz and *S. larcinus* (Berk.) Kuntz. are exhibit interesting behavior in primeval association of *Larix potanii* (N. Yunnan; W. Sichuan 2700—3700 m.) form an ectomycorrhizal relations.

These investigations, the another interesting ectomycorrhizal fungi Matsutake (Pine mushroom) group, it is a most favorit edible mushrooms in Eastern Asia, *Tricholoma matsutake* (Ito et Imai) Singer, that is associated with pine forest and native to North eastern and South western China, it as well as in Japan and Korea, the mycorrhizal sets of different pines are observed, the short roots of *Pinus yunnanensis* are involved in this symbiosis with *Tricholoma ma-*

Table 1 The mainly ectomycorrhizal fungi associated with several Conifers

Coniferous trees / Abundance / Ectomycorrhizal Fungi	*Abies squamata* 3800—4000m.	*Abies georgei* 3800—3950m.	*Abies spectabilis* 2800—3800m	*Pices likiangensis* 2900—3900m	*Laris potaninii* 2800—3800m	*Pinus densata* 2800—3500m	*Pinus yunnanensis* 1800—2800m	*Pinus armandi* 1500—2500m
Amanita caesarea	+	++	++	+		++	++	
A. ceciliae		+		+				
A. fulva			++	+		+	+	
A. inaurata	+	+	++					
A. vaginata	++	++	++	++	+	+	+	
Boletus auripes				+	+	+	+	
B. citrifragrans				+			+	+
B. edulis						+	+++	+
B. erythropus				+	+	+	++	
B. firmus				+	+		+	
B. speciosus		+	+	+		+	++	
Fuscoboletinus glandulosus		+	+	++	+	+	+++	+
Leccinum albellum	+	+	+	++		+		
L. chromapes	+	+	++	++		+	+	
L. scabrum	+	+	++	++		+		
Suillus bovinus				+	+	++	+++	
S. flavo-luteus				+		+	++	
S. luteus						+	+++	
S. placidus				+	+	++	+++	

Suillus spraguei								+
S. subluteus				+	+	+	+++	
Tylopilus felleus			+	+		+	+	
Xerocomus badius			+	+	+	+	+	
X. chrysenteron				+	+	+	+++	+
Cortinarius armillatus			+	+				
Cortinarius caerulescens	+	++	+++	+				
C. glutinosus	+	++	++	+				
Inocybe fastigiata	++	++	++	+		+	++	
Rozites caperata	++	++	++	+		+		
Laccaria amethystea		+	++	++	+	+	+	
L. bicolor	+	++	++	++	++	+	+	+
Tricholoma fulvobrunneum		+	+	+				
T. matsutake						+	+++	
T. vaccinum			+	+				
Lactarius volemus				+	+	++	+++	++
L. torminosus				+	+	+	+	
Russula alutacea				+	+	+	++	
R. xerampelina			+	+		+	++	
Rhizopogon luteolus						+	++	

* Legent: + = rare occurrence; ++ = more frequent occurrence; +++ = mass occurrence.

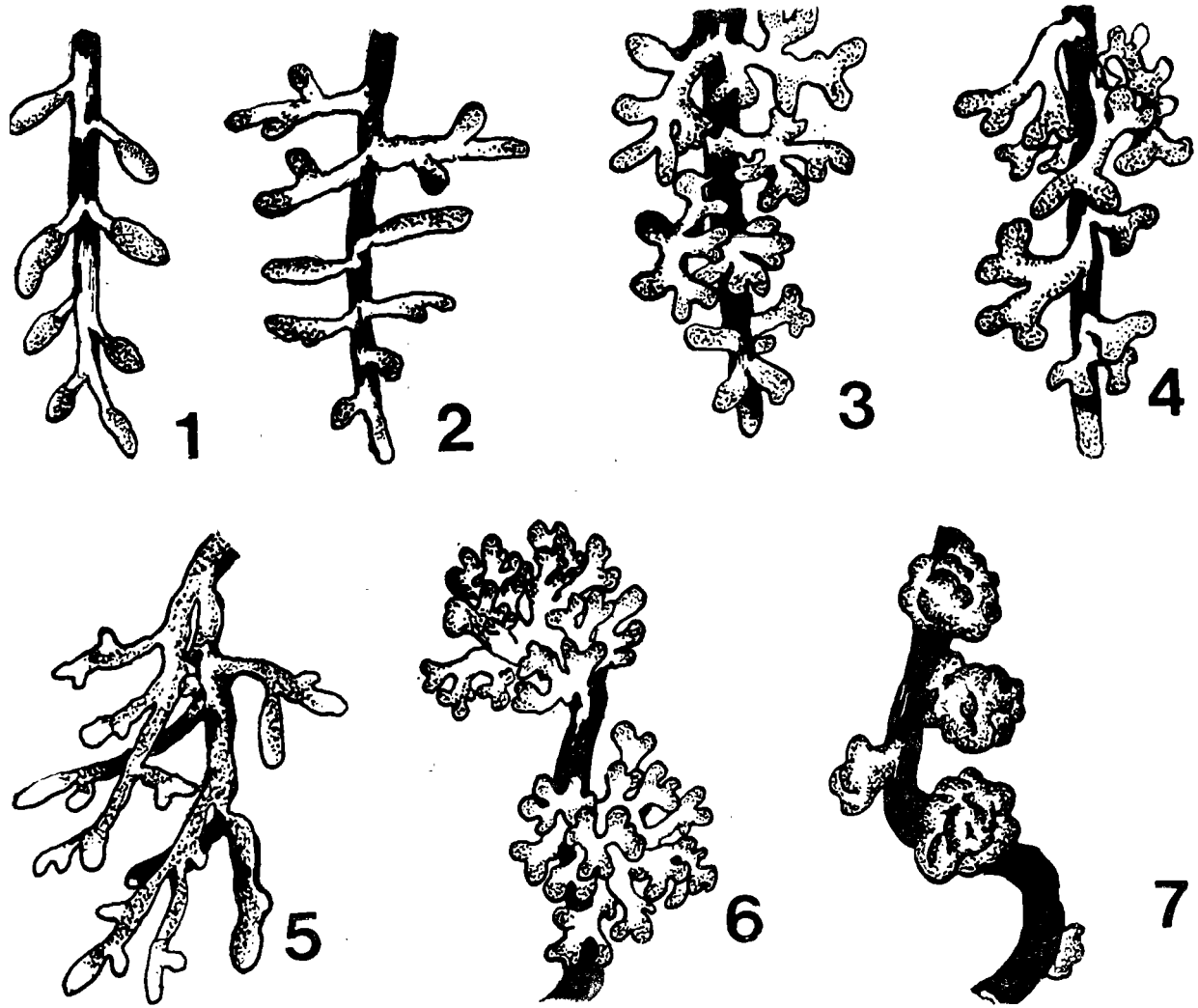

Fig. 1 Type of ectomycorrhizal ramification

1. Unramified ramification type 2. Monopodial-pinnate ramification type 3. Monopodial-pyramidal ramification type 4. Dichotomous ramification type 5. Irregular-pinnate with dichotomous ramification type 6 Coralloid. ramification type 7. Tubercle-like ramification type

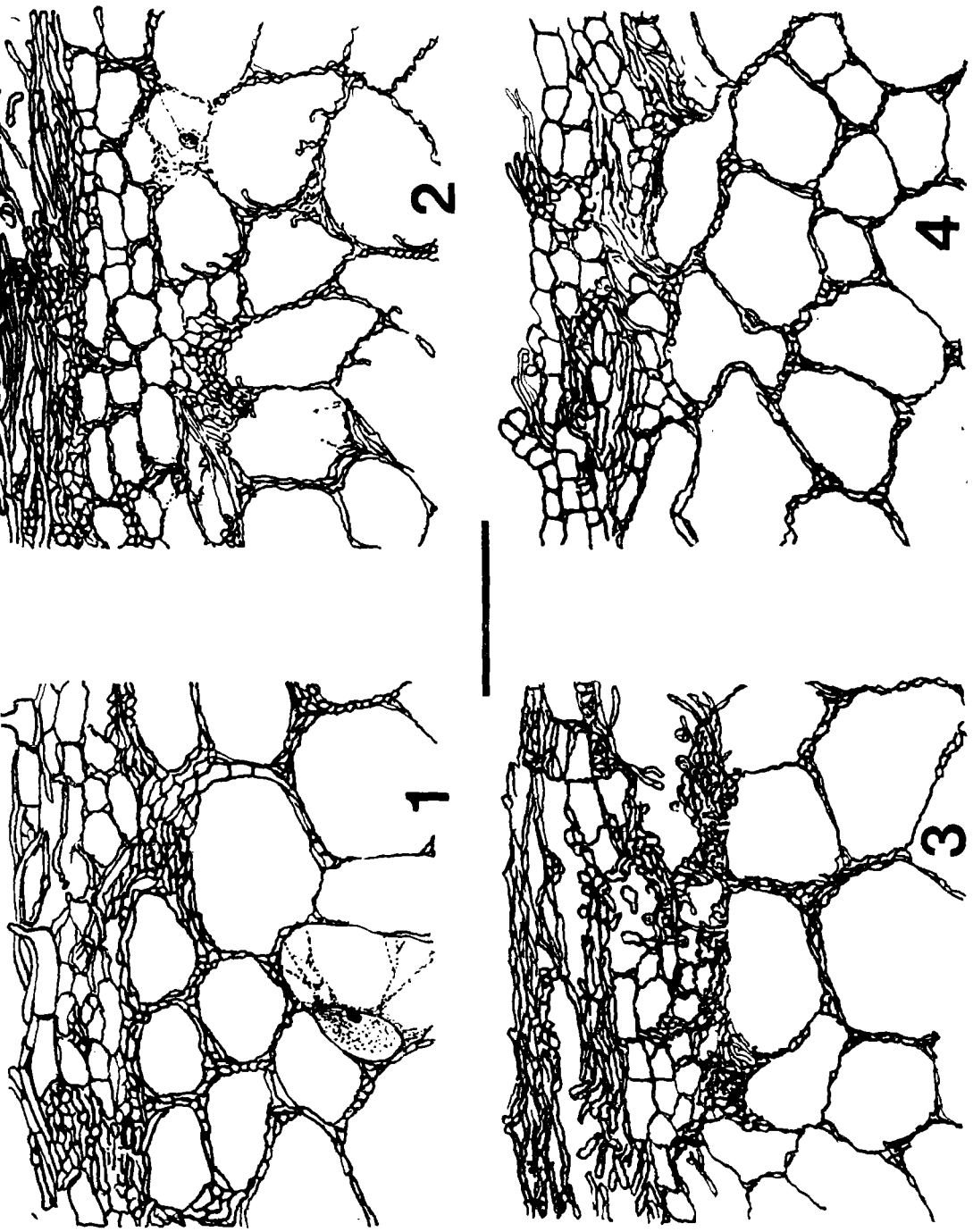

Fig. 2　Cross sections of mycorrhizal mantle

1. Mycorrhiza of *Xerocomus roxanae* + *Abies georgei* 2. Mycorrhiza of *Tricholoma vaccinum* + *Picea likiangensis* 3. Mycorrhiza of *Lactarius vellereus* + *Pinus yunnanensis* 4. Mycorrhiza of *Russula xerampelina* + *Picea likiangensis* Standard line=40μm

tsutake, there are numerous Conifers associated with this fungus, such as *Pinus thunbergii* Parl., *Tsuga sieboldii* Carr., etc. (Kawai & Ogawa, 1981) Matsutake group not only forming ectomycorrhiza with Conifers, even several species forming ectomycorrhizae with Family Fagaceae, belong to genera *Quercus*, *Castanopsis* and *Lithocarpus*, a common species *Tricholoma bakamatsutake* Hongo, that associated with different species of genus *Quercus* from Japan and South western China (Central Yunnan and W. Sichuan, 1500—2500 m.). They either species *Tricholoma quercicola* Zang, it occurs in North Yunnan and western Sichuan and S. E. Tibet, where is the eastern terminus of the Himalayas proper, in this area have the richest alpine *Quercus* and *Pinus* forest, however the Matsutake group has survived and thrived in better conditions than similar ones in Europea and North America.

The results of investigations on the mainly ectomycorrhizal fungi associated with several Conifers from this area are summarized in Table. 1. (Bi et al., 1989; Zang, 1980) Several types of ectomycorrhizal ramification

In natural soils it is mainly the shorter and shortest roots which become modified, after fungal infection, into mycorrhizal organs. When this has happened, the whole of the rootlet is enclosed by a fungal sheath and the apex is surrounded and covered with fungus or fungi. The mycorrhizal short roots usually develop thickness or many branches, each of which is also restricted growth in length, so that short lateral branches are formed which are completely enclosed the fungus or fungi. The appearance of these ectomycorrhizal ramification is variable (Harley, 1959), which often cannot be strictly subdivided. However, the ectomycorrhizal ramifications type used here for described are given in Agerer (1986; 1987; 1988). A criterion for studing the morphology and anatomy of ectomycorrhizae as evaluation of the characteristics used to identify them, the following types might be accepted as being more reasonable.

1. Unramified ramification type (Fig. 1-1)

The mycorrhizal system consists of simple, clavate, unramified mycorrhizae, pale brown to dark brown, the mantle merely ensheathes single roots, outer mantle layer loosely plectenchymatous, no distinct patterns recognizable; Hyphae usually 3—5 μm in diameter, emanating hyphae without clamps. This type is as follows: the ectomycorrhiza *Cenococcum* synthesized with *Picea likiangensis*. Melin (1923) has described the synthesized ectomycorrhizae with *Betula pendula* and *Tricholoma flavobrunneum* from Europe. A relative biotic components fungal species: *Tricholoma fulvocastaneus* Hongo and *Xerocomus roxanae* (Frost.) Snell, they are popular occur in western Sichuan and North-western Yunnan, it is probably with the unramified ramification synthesized ectomycorrhizae with *Abies georgei*. (Fig. 2-1)

The morphology of unramified ends and the axes in nature are fairly complicated, usually appeared in different forms, e.g. club-shaped, straight, slightly or distinctly bent, rather tortuous or twisted and beaded etc. It appears, the differential mycorrhizal fungi with their tree partners have been became certain faetures of the root system.

2. Monopodial-pinnate ramification type (Fig. 1-2)

The ectomycorrhizal system possesses an axis from which develop sidebranches, shorter than the axis, the sidebranches seems put on a par with one plane. The ramified ends 3—3.9 mm long, 0.3—0.5 mm broad, colour of tips whitish, the older parts more or less pale brown to umber brown, hyphae 2.5—4.5(6) μm diameter, hyphal walls slightly gelatinous, plectenchymatous developed, but lacking distinct layers. The thickness of Hartig' net: around tannin cells and nearby 3—5 μm, sometimes arranged in beaded manner, emanating hyphae with clamps.

Rhizomorphae are different, white and brownish (Agerer, 1987). The ectomycorrhiza formed by *Tricholoma vaccinum* and its tree partner *Picea likiangensis* (Zhong Dian, Yunnan 3600 m) (Fig. 2-2) The another example of this type is formed by *Laccaria amethystea* (Bull. ex Gray) Murr. and is common on Pine, Spruce and a great variety of other trees.

3. Monopodial-pyramidal ramification type (Fig. 1-3)

It is similar to the monopodial pinnate, but the sidebranches originate from the axis which spread out in several rows. The shape of unramified ends: straight, seldom slight bent, surface more or less roughly, fleshy brown with whitish brown, but the tips always whitish, farinose cover, the plectenchymatous with short cylindrical or ovoid projecting hyphal ends, the size of hyphal cells 3—4 μm in diameter, laticiferous hyphae are present. 5—7 μm in diam. Mantle thickness and differentiation, 40—60 μm, differentiated into two or three layers. Hartig' net thickness, between tannin cells 2—6 μm, between cortex cells 2—4 μm. Rhizomorphae colourless. Clamless. The ectomycorrhizal fungus *Lactarius vellereus* Fries associated with its tree partner *Pinus yunnanensis* (Yunnan, 1800—2800 m) (Fig. 2-3)

4. Dichotomous ramification type (Fig. 1-4)

The root meristem always divides dichotomously, the both sidebranches then grow to the same length, the ramifications may occur repeatedly, ramified end with smooth surface, dark fleshbrown to dark reddish brown 0.5—2 mm long, 0.3—0.8 mm broad, mantle surface with anastomosing hyphae, hyphal cells 2—4 μm diameter. Shape of H'net cells in section: often elongated, but cells of the outer cortex layer mostly more or less round. The mycorrhizal fungus *Rhizopogon rubescens* Tul. usually under *Pinus yunnanensis*, on dry sandy soils near the soil surface, more often semi-hypogeous. They are occur in Yunnan and South-eastern Tibet.

5. Irregular-pinnate with dicholomous ramification type (Fig. 1-5)

The dichotomous ramification is somewhat obscured, of which the one of two ramified ends seem grow faster than the other, the similar shapes develop completely if sidebranches of the proximal monopodial systems grow almost as fast as the axis, the ramified end with smooth surface. Rhizomorpha presence, umber brown to dark reddish brown. The mantle surface with plectenchymatous individual hyphae, 2—3.5 μm in diameter. Shape of H' net cells in section often elongated, but cells of the outer cortex layer mostly more or less round. Agerer (1986) described the *Russula xerampelina* (Schaeff.) Fr. is a synthesized mycorrhiza with *Picea sitchensis*, his photographs and descriptions of the synthesized mycorrhiza is noteworthy. In Western China, the *Russula xerampelina* is common associated with *Picea likiangensis*, *Pinus yunnanensis* and *Pinus densata* etc. (Fig. 2-4).

6. Coralloid ramification type (Fig. 1-6)

Dichotomously ramified mycorrhizal system possessing short axes are quite densely ramified thus resembling coral in appearance. The internal structure shows a great development of intra-cellular hyphae penetrating the cortical cells. It was easily found, the *Rhizopogon luteolus* Fr. et Nord. often associated the coralloid mycorrhizal system with *Pinus*.

7. Tubercle-like ramification (Fig. 1-7)

It is another kind in which the fungal partner appears to be extremely active. The racemose branched mycorrhizal axes are densely bound together in nodule by mycelium. Nodules up to 0.5—0.8 cm in diameter have been found in waterlogged soils under *Pinus* forest.

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我国西南高山针叶林的外生菌根组合

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摘要 本文报道了大致位于东喜马拉雅山脉和横断山脉的部分高山针叶林带的外生菌根菌和针叶林有关树种的菌根组合。并例举了有关菌的分布与树种的依赖关系以及菌根的外部和内部形态。

关键词 针叶林外生菌根菌；滇、藏。