MYCORRHIZAL FUNGI OF PINUS RADIATA PLANTED ON FARMLAND IN NEW ZEALAND

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(Received for publication 10 March 1987)

ABSTRACT

Mycorrhizal fungi of **Pinus radiata** D. Don were studied on agroforestry sites in the central North Island of New Zealand. **Rhizopogon rubescens** Tul., the most common mycorrhizal fungus of **P. radiata** in conventionally grown forests, was replaced by two less-common mycorrhizal fungi – **Tuber** sp. and **Scleroderma** spp. The soil fertility of the agroforestry sites is high, especially in phosphorus, and this may be the major factor affecting the change of the mycorrhizal fungal species.

Keywords: agroforestry; mycorrhizas; **Rhizopogon rubescens**; **Scleroderma bovista**; **Scleroderma verrucosum**; **Pinus radiata**.

INTRODUCTION

Forest trees have traditionally been planted on poor-quality land, with low fertility and/or steep hilly conditions, which was unsuitable or uneconomical for agricultural purposes. In recent years there has been a trend towards planting trees on better-quality land which has often previously been managed as pasture. This type of land is considered to be a more profitable investment by forest companies, and the concept of integrated agriculture and forestry (agroforestry) as a combined land use has been adopted by both forest companies and individual land owners (Tustin *et al.* 1979; Knowles & Cutler 1980).

In agroforestry management, the general practice is to apply potassic superphosphate (200–250 kg/ha) annually from the time of planting until canopy closure to maintain pasture yields. Continued grazing as the trees mature results in nutrients being actively recycled through the livestock as dung and urine. On the other hand, in management of conventionally grown forests fertilisers are applied only when needed, usually to correct soil deficiency. These management practices result in great differences in soil fertility, especially phosphorus concentration. The effects of these differences in soil fertility on tree growth have been documented by Knowles & West (1986), who showed that agroforestry sites can produce up to 40% more basal area increment than conventional forest sites.

The major function of mycorrhizal fungi of forest trees is to facilitate the maximum uptake of soil nutrients, especially phosphorus (Hatch 1937; Melin & Nilsson 1950, 1952, 1958; Harley & McCready 1950; Carrodus 1966, 1967; Morrison 1962). How-

ever, high soil fertility can reduce the activity and function of mycorrhizal fungi (Björkman 1942; Hewitt 1966; Rambelli 1967; Squire 1971; Marx *et al.* 1977) and the number of mycorrhizal roots (D. Santantonio, P. Beets unpubl. data).

The purpose of this study was to investigate whether agroforestry management practices have any effect on mycorrhizal fungi of *P. radiata* planted on agroforestry sites.

MATERIALS AND METHODS

Field Observations

From 1983 to 1986 sporocarps associated with *P. radiata* growing on a number of agroforestry sites in the central North Island of New Zealand were collected, recorded, and identified. Collections were carried out twice a year (spring and autumn) from each forest. The forests and the years when trees were planted were:

Pinnacles (Te Puke) – 1974, 1975, 1976, 1978, 1981;
Steeles Farm (Tokoroa) – 1970;
Caxton (Kawerau) – 1972;
Tasman (Kawerau) – 1977, 1979, 1981, 1982; } results combined
Tikitere Farm (Rotorua) – 1973, 1974, 1976, 1977, 1978, 1982, 1983, 1984;
Waratah Farm (Putaruru) – 1967.

Examination and Identification of Mycorrhizas

Mycorrhizal roots were collected annually from the same forests where the field observations were carried out. Root samples were collected from 10–15 randomly selected trees from each of two stands of different ages in each forest. Each sample was washed, and morphologically different mycorrhizas were separated and identified as previously described (Chu-Chou & Grace 1983).

Isolation of Fungal Symbionts and Mycorrhizas

Isolation of fungal symbionts from mycorrhizas collected from the agroforestry sites was also carried out. The isolation technique was the same as that used by Chu-Chou & Grace (1982) except that the surface sterilisation time was 10 minutes. Over 60 sets of isolations were carried out and a total of 2440 pieces of mycorrhizal roots were plated onto Hagem (Modess 1941) and modified Melin-Norkrans (Marx 1969) media. Fungi isolated from mycorrhizas were identified as described by Chu-Chou (1979).

Soil Analysis

Soil samples collected from both agroforestry sites and nearby conventional forests (with similar soil types) were analysed chemically. Concentrations of phosphorus, nitrogen, potassium, calcium, and magnesium were determined using colorimetric methods (Nicholson 1984).

RESULTS

Field Observations

Generally, very few sporocarps were collected from these agroforestry sites. The most commonly seen mycorrhizal fungi were *Suillus luteus* (L. ex Fr.) S. F. Gray,

Scleroderma bovista Fr., *S. verrucosum* Vaill ex Pers., *Laccaria laccata* (Scop. ex Fr.) Berk. & Br., and *Tuber* sp. and the less frequently seen were *Rhizopogon rubescens* Tul., *Hebeloma crustuliniforme* (Bull. ex St. Am.) Quél., *Inocybe* spp., and *Amanita muscaria* (L. ex Fr.) S. F. Gray. Sporocarps of other fungi such as *Lycoperdon* spp., *Collybia* spp., *Marasmius oreades* (Bolt. ex Fr.) Fr., *Paneolus* spp., and *Agaricus campestris* L. ex Fr. were also very common.

Examination and Identification of Mycorrhizas

Generally very few fibrous roots and mycorrhizas were observed on trees planted on farmland. Mycorrhizas identified as *P. radiata* + *Tuber* sp. and *P. radiata* + *Scleroderma* spp. were consistently found in high proportions in all root samples. *Pinus radiata* + *Suillus luteus* and *P. radiata* + Pale brown (unidentified basidiomycetes) mycorrhizas were also frequently seen. *Pinus radiata* + *R. rubescens* mycorrhizas were observed in a very high proportion in root samples collected from trees 1 year after planting, but the quantity of this type of mycorrhiza declined rapidly with the age of the trees. Only a small proportion of *P. radiata* + *Endogone flammicorona* Gerdemann & Trappe were found in root samples of trees younger than 4 years. *Pinus radiata* + *A. muscaria* were found only once in very small quantities in root samples of 11-year-old trees.

Isolation of Mycorrhizal Fungi

The results of isolation of mycorrhizal fungi from mycorrhizas of trees of different ages from different agroforestry sites are summarised in Table 1. *Tuber* sp. and *Scleroderma* spp. were the most frequently isolated mycorrhizal fungi. *Rhizopogon rubescens* was isolated in high proportions (21–100%) from the myccorhizas of 1- to 4-year-old trees, but it was isolated in very low proportions (0–11.1%) from trees older than 6 years. *Suillus luteus* was isolated from trees between 2 and 9 years of age. *Amanita muscaria* was isolated only once from mycorrhizas of 11-year-old trees. Unidentified basidiomycetes were isolated more frequently from trees older than 11 years.

Soil Analysis

The results of chemical analysis of soils collected from agroforestry sites and adjacent conventional forests are shown in Table 2. The levels of nitrogen, phosphorus, and calcium were consistently higher in soils collected from agroforestry sites. The phosphorus content was extremely high especially in the younger stands (8–23 times higher than that of adjacent forest soils). The levels of magnesium and potassium were usually lower in soils collected from the agroforestry sites.

DISCUSSION

Rhizopogon rubescens is the most common mycorrhizal fungus of *P. radiata* seedlings in nurseries and it is also commonly associated with trees of all ages in all conventionally grown forests in New Zealand (Chu-Chou 1979; Chu-Chou & Grace 1984a, b). In contrast to this, sporocarps of this fungus were rarely seen in agroforestry sites, mycorrhizas formed by *R. rubescens* were found mainly on trees younger than 2 years,

TABLE 1—Percentages of different mycorrhizal fungi isolated from mycorrhizas of different-aged **P. radiata** trees planted on five agroforestry sites

Name of forest	Age of tree (yr)	Total No. of mycorrhizal pieces plated	Total No. of pieces yielding mycorrhizal fungi	Proportion yielding (%)					
				Tuber sp.	*Scleroderma* spp.	*Rhizopogon rubescens*	*Suillus luteus*	*Amanita muscaria*	Unidentified basidiomycetes
Pinnacles	1 - 2	84	7	85.7	0	0	0	0	14.3
	3 - 4	161	19	78.9	0	21.1	0	0	0
	5 - 7	287	69	21.7	26.1	0	33.3	0	18.9
	8 - 10	133	7	14.3	28.6	0	42.8	0	14.3
	11 - 14	98	4	0	0	0	0	50.0	50.0
Tikitere	1 - 2	105	4	25.0	0	75.0	0	0	0
	3 - 4	112	8	50.0	12.5	37.5	0	0	0
	5 - 7	217	45	60.0	35.5	0	0	0	4.5
	8 - 10	233	31	3.2	35.5	0	61.3	0	0
	11 - 14	203	35	40.0	11.4	0	0	0	48.6
Kawerau (2)	1 - 2	112	53	0	0	86.8	13.2	0	0
	3 - 4	56	2	0	0	100.0	0	0	0
	5 - 7	161	14	4.4	42.8	42.8	0	0	0
	8 - 10	49	1	0	100.0	0	0	0	0
	11 - 14	49	9	0	88.9	11.1	0	0	0
Steeles	14	98	19	5.3	94.7	0	0	0	0
	16	49	2	0	100.0	0	0	0	0
Waratah	15	98	24	100.0	0	0	0	0	0
	17	49	2	0	100.0	0	0	0	0
All		2391	367	30.3	23.7	17.7	14.2	0.5	13.6

TABLE 2—Chemical analyses of soils of farm forests and conventional forests

Forests	Age of tree (yr)	Total N (%)	P (Bray ppm)	Ca (Bray)	Mg (m.e. %)	K (m.e. %)
Tikitere Farm	3	0.295	283.0	1.45	0.32	0
	12	0.347	98.5	2.41	0.34	0
Whakarewarewa Forest	4	0.107	11.9	2.78	0.96	0.250
	12	0.112	5.4	1.87	0.44	0.130
Kawerau Farms (2)	4	0.255	135.0	4.16	0.50	0
	10	0.307	153.2	3.92	0.60	0
Tarawera Forest	4	0.092	11.9	0.13	2.90	0.560
	11	0.076	5.2	0.16	2.91	1.180
Pinnacles Farm	4	0.301	93.0	2.14	0.51	0
	11	0.378	58.3	3.96	1.07	0.266
Kaingaroa Forest	3	0.178	11.8	0.49	0.16	0.542
	11	0.170	24.9	0.38	1.55	0.400
Steeles Farm	14	0.488	58.4	8.20	1.06	0.178
Tokoroa Forest	14	0.158	29.0	1.30	0.30	0.100
Waratah Farm	19	0.418	54.0	5.20	0.70	0.300
Putaruru Forest	19	0.226	13.0	2.60	1.10	0.400

and it was mostly isolated from mycorrhizas of trees younger than 6 years. From trees older than 7 years, *R. rubescens* was isolated in very low proportions (0–11.1%) (Table 1), whereas from conventionally grown forest trees of the same ages the proportion was much higher (54–79%) (Chu-Chou & Grace 1984b). Obviously, *R. rubescens,* the original mycorrhizal fungus of the nursery seedlings, did not establish well under farmland conditions. Several factors such as soil fertility, soil compaction, soil temperature, soil humidity, and competition between pine roots and grass roots may affect the establishment of *R. rubescens* on farmland. Björkman (1942) reported that the establishment and activity of mycorrhizal fungi are suppressed by high levels of nitrogen and phosphorus in the soil. Our soil analysis results showed that levels of nitrogen and phosphorus were much higher (Table 2) in soils on agroforestry sites. Also, very few fibrous roots and mycorrhizal roots were observed on trees on farm sites compared with those of conventional forests. This indicates that the high soil fertility of farmland does have a significant effect on the establishment of some mycorrhizal fungi, especially *R. rubescens.*

Theodorou & Bowen (1971) reported that in a glasshouse trial grasses grown in association with *P. radiata* or in the presence of decomposing grass roots depressed the infection of roots by *R. luteolus* Fr. – an important mycorrhizal fungus of *P. radiata* in Australia. The presence of grass roots in farm forest soil may be another important factor affecting the establishment of some mycorrhizal fungi.

Tuber sp. is another common mycorrhizal fungus of *P. radiata* in nurseries and forests, although it is far less common than *R. rubescens* (Chu-Chou & Grace 1984b). In contrast, on agroforestry sites mycorrhizas formed by *Tuber* sp. were more commonly seen and it was isolated more frequently than *R. rubescens* (Table 1). Sporocarps of *Scleroderma* spp. were infrequently seen in conventional *P. radiata* forests, and they were rarely isolated from mycorrhizas of randomly collected root samples (Chu-Chou 1979, and unpubl. data). However, in farm forests the associations (Table 1) of these fungi with *P. radiata* were much more common. It seems that *Tuber* sp. and *Scleroderma* spp. have become the dominant mycorrhizal fungi of *P. radiata* planted on farmland. The main reason for this could be the absence of competition from *R. rubescens* (a vigorous mycorrhizal former), which provides a greater chance for *Tuber* sp., *Scleroderma* spp., and other mycorrhizal fungi to colonise the roots. Also, the farmland conditions (high soil fertility, compact soil, grass roots) appeared to favour the establishment of *Tuber* sp. and *Scleroderma* spp. However, pot trial results showed that *Tuber* sp. is not as efficient as *R. rubescens* in promoting *P. radiata* seedling growth and nutrient uptake (Chu-Chou & Grace 1984b); therefore the importance of this fungus and possibly *Scleroderma* spp. in promoting tree growth and nutrient uptake under agroforestry conditions is questionable.

Sporocarps of *A. muscaria* are usually found in abundance in conventional forest stands over 9 years of age (unpubl. data), but in this field survey only one sporocarp was found in an 11-year-old stand in Tikitere Farm Forest. Apparently agroforestry conditions also do not favour the establishment of *A. muscaria.* Sporocarps of *L. laccata, H. crustuliniforme,* and *Inocybe* spp. were commonly seen in farm forests, yet none of them was isolated from mycorrhizas.

The main recognised function of mycorrhizal fungi is to facilitate the maximum uptake of soil nutrients (especially phosphorus) on low fertility sites. In agroforestry sites, although the number of sporocarps of mycorrhizal fungi and the number of mycorrhizal roots were found to be much lower than those found in conventional forests, the trees usually produce much higher levels of basal area increment (Knowles & West 1986), presumably due to high soil fertility. The change of mycorrhizal fungi under farmland conditions – from the common and efficient *R. rubescens* to the less common and less efficient *Tuber* sp. and *Scleroderma* spp. – makes it questionable whether mycorrhizal fungi have a necessary or even beneficial role under these conditions. This study also indicates that mycorrhizas are not directly implicated in the high levels of tree growth encountered on farm sites.

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