A Review of Specialised Root Systems, and Their Relevance in New Zealand Nurseries

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INTRODUCTION

It is beneficial to examine how nature endows plants with the ability to survive and grow without fertilisers and often in very impoverished soil conditions. Linderman (1978) at an I.P.P.S. conference several years ago made the point that "no organism in the natural environment can live like a hermit". This referred to the fact that plants usually live in close association with microorganisms. The objective of this review is to describe how the roots of nursery plants utilise these relationships and what considerations need to be taken into account on New Zealand nurseries

MYCORRHIZAS

The term "mycorrhiza" means fungal roots and this is a symbiotic or mutually advantageous relationship between plants and fungi associated with their roots. This topic has been studied since at least the 1840s and the name mycorrhizas was given by Frank in 1885 (Harley and Smith 1983) There have been several articles in the I.P.P S. proceedings over the years with the most recent articles discussing the propagation of mycorrhizal plants, including inoculation (St. John and Evans,1990, St. John, 1994; Galea and Poli,1994).

Most plants growing in soil have mycorrhizal fungi on their roots. These naturally occurring fungi can be found in 83% of dicotyledons and 79% of monocotyledonous plants. The simplest classification is to divide them into three groups·

The Ectomycorrhizas. These form a mantle or sheath on the outside of the root and characteristically occur on plants in the Betulaceae, Fagaceae, and Pinaceae; i e. mainly on the roots of woody plants and only occasionally on herbaceous plants. Pritchett (1979) states that there are more than 2000 species of ectomycorrhizal fungi estimated to exist on trees in North America alone. Most are Basidiomycetes, but certain of the Ascomycetes also form mycorrhizas. Other families exhibiting these microorganisms are the Juglandaceae, Myrtaceae, Salicaceae, and Tilliaceae, all of which may be either ecto- or endomycorrhizal depending on soil conditions.

The Endomycorrhizas. These fungi are the most widespread and important symbionts. They are often referred to as VA mycorrhizas because of the branched feeding organs and storage structures that may form within the plant's internal root cells. Typical host species include most crop and ornamental plants. The fungi are mainly Phycomycetes and do not produce large, above-ground fruiting bodies or wind-disseminated spores as do most ectomycorrhizal fungi.

The Ectendomycorrhizas. This is a relatively small group which has characteristics of both ectomycorrhizas and endomycorrhizas. They generally appear on roots colonised by ectomycorrhizal fungi. Within this group are the mycorrhizas found on members of the Ericaceae and Orchidaceae which may be classified separately since they, for example, do not form a fungal sheath and involve Asco- or Basidiomycetes (Harley and Smith, 1983).

OTHER TYPES OF SPECIALISED ROOT SYSTEMS

Nitrogen-Fixing Nodules on Roots. Symbiotic nitrogen (N) fixation occurs primarily within the roots of legumes in association with bacteria such as the genus *Rhizobium*. Leguminous trees like *Leucaena leucocephala* (see *L latisiliqua*) are becoming increasingly important in agroforestry (Danso et al., 1992). Non-legumes can also have N-fixing root nodules (actinorhizal symbiosis) as with *Alnus* and *Casuarina*. *Elaeagnus commutata* and *Shepherdia* spp. are further examples of actinorhizal trees and shrubs (Danielson and Visser, 1990). The microorganism in the latter case is in the fungal genus *Frankia* (Ascomycetes).

Proteoid Roots. These occur on most species within the Proteaceae and therefore are of particular significance wherever species from within this predominantly southern hemisphere family are grown. Some legumes have also been found to have proteoid roots, including *Viminaria juncea* (Lamont, 1972a) and *Lupinus albus* which is an annual (Gardner et al., 1983). The clusters of bottlebrush-like root structures that form seasonally, are not mycorrhizal and are produced by the youngest roots of the root system (Lamont, 1972b).

THE BENEFITS OF SPECIALISED ROOTS

The main benefit of specialised root systems is nutrient uptake in open-ground soils, especially where they are impoverished This contrasts with container-grown methods where high levels of fertiliser nutrients and relatively sterile media often reduce the need or appearance of these root systems.

The prime benefit of mycorrhizas and proteoid roots is the improved uptake of phosphorus The surface area of the roots is usually greatly increased. This allows plants to develop an exploitive system, as in the case of proteoid roots which occur in shallow, well aerated, high organic matter regions of the soil. These can therefore complement the normal deep explorative roots which are much less branched. Mycorrhizal fungi, like proteoid roots, provide the host plant with an improved "mechanism" for growth by providing an extensive surface area for nutrient uptake by virtue of the hyphae which reach out into great areas of the soil. Plants with a large root surface area can be expected to be less responsive to mycorrhizal inoculation than those with a smaller area; for example the native fern *Asplenium bulbiferum* was found to be nonmycorrhizal and this state was attributed to its extensive root system, copious and long root hairs and slow growth rate (Cooper, 1977). Marschner (1995) reviewed these nutritional aspects and pointed out the difficulties of interpreting the benefits related to the uptake of nutrients since there are simultaneous changes in growth, particularly root morphology and physiology, brought about by mycorrhizal colonisation. There can be improved uptake of nutrients other than phosphorus (P) but this will vary greatly with the environment and species of plant and fungus. Mycorrhizas can also benefit plants by deterring root pathogens and increasing the host plant resistance to drought and soil temperature extremes (Dangerfield, 1975).

Legumes and a few nonlegumes grown in New Zealand can benefit from nodulation on their roots In the tropics and subtropics about 200 species form actinorhizal symbioses (Peoples and Craswell, 1992). Legumes have played an important role in crop rotations for many centuries. The quantity of available nitrogen is normally the most prime or first consideration for achieving rapid growth in plants and therefore plants equipped to gather their own N can have a special place in agroforestry situations. An example of the interrelationship between two different systems is that infection with mycorrhiza (or P fertilisation) will often improve nodulation (Marschner, 1995).

NEW ZEALAND RESEARCH AND USAGE

There is no doubt that mycorrhizas are of great significance in the growth of native and exotic forest trees in New Zealand. A major group of studies were carried out by Professor Baylis and others in the Botany Department of Otago University. For example it was found that the nodule on the roots of species within the Podocarpaceae and in *Agathis australis* were considered to be an adaptation to accommodate endomycorrhizal fungi and thus be functionally equivalent to the short roots of pines (Baylis et al , 1963) Further work on kauris (*Agathis australis*) showed that these nodules have a major role in P uptake (Morrison and English, 1967). Manuka (*Leptospermum scoparium*) and rata (*Metrosideros* spp.) were shown to benefit from endomycorrhizal inoculation (Hall, 1977) and ectomycorrhizas were found on New Zealand beeches (*Nothofagus* spp.) (Morrison, 1956; Mejstrik, 1972). Smaller trees and shrubs have also been studied along with New Zealand ferns Cooper (1976) states that with few exceptions the latter are constantly mycorrhizal in natural or modified communities, even in soils with apparently high levels of P.

Crush (1973) investigated the significance of endomycorrhizas in tussock grassland in Otago. It was concluded that only two high altitude species, of the five species studied, were likely to benefit from mycorrhizas in their natural soils, although infection could be beneficial in impoverished soils or under drought stress.

Matagouri (*Discaria toumatou*) and tutu (*Coriaria sarmentosa*) are two New Zealand plants which produce actinorhizal root nodules which have been studied (Newcomb and Pankhurst, 1982a,b).

There exist many New Zealand native legumes which are also likely to fix N. Mycorrhizas on exotic forest trees including Douglas fir, eucalypts, and *Pinus radiata* have been classified and studied (Chu-Chou and Grace, 1983). *Rhizopogon rubescens* is the most common mycorrhizal (ectomycorrhizal) fungus of radiata pine seedlings in New Zealand nurseries (Chu-Chou, 1979).

In a nutrition trial studying the response of *Pinus pinea* the authors found several fungi came naturally into and onto the media, probably from existing colonisation on the seedlings or media that they were grown in. The growing medium was white with mycelium and it was found that mycorrhizal infection was significantly reduced at high liming levels and unaffected by a range of N, P, and K levels (unpublished results). In contrast proteoid root formation on *Grevillea rosmarinifolia* was significantly reduced by high rates of N or P, but not by liming (Thomas, 1981).

There are few commercial inoculants available in New Zealand for improving the specialised root systems of plants. One is used for the inoculation of pasture legumes with *Rhizobia* spp., and another was developed primarily for the inoculation of blueberries with ericoid mycorrhizal fungi. Powell (1981) discussed the need for inoculation since surveys had shown that infection in nursery and field grown blueberries was sporadic and especially low on young plants. He recommended the use of a culture of pure mycorrhizal fungus such as *Pezizella ericae* for the inoculation of cuttings or the making up of an inoculum mixture from underneath healthy blueberry bushes that could be used for new planting areas It was important that the inoculum mixture was free of any serious root-rot pathogens.

SIGNIFICANCE

Examples of the great diversity of root associations have been outlined. It is clear that in the "wild", such as in forests and where there are low soil fertility levels, these associations can provide benefit through greater nutrient uptake along with other advantages. It has even been recently postulated that plants in communities can transfer nutrients between themselves via interconnecting fungi (Miller and Allen, 1992)

Certain associations have been shown to have a very clear cut advantage and are necessary for the nursery grower to utilise. Satisfactory levels of ectotrophic mycorrhizas are a requirement for the open-ground production of forestry conifers. The trees tend to be grown in unfertilised ground and the right strains of mycorrhizal fungus confer strong benefit. Past research by the authors on ornamental conifers like *Chamaecyparis* (Thomas et al., 1994) and Leyland cypress (Thomas, 1984) have indicated the advantages of low pH and this may be related to the degree of mycorrhizal infection, as found with *Pinus pinea.* Inoculation of media with ectomycorrhizas can be quite simple, for example pine duff from pine forests is a good source or the growing of pines using cheap seed and then rotary hoeing them into the ground after a year

Proteaceous plants can be grown at relatively high plains of nutrition but it is recommended that moderately low levels of N and especially P are used. An open organic-based mix is also desirable to encourage proteoid roots and this will probably help establishment, avoid nutrient toxicities, and possibly give a longer than usual life span to the plant. Leguminous trees and shrubs could be encouraged to form nodules by avoiding very acid conditions and high N levels. Unpublished work by the authors found that the native leguminous tree, *Sophora tetraptera,* responded quite strongly to N fertilisation in a container trial. This indicates the general principle, that fertilisers can usually replace the need for all types of these specialised root systems, as an alternative to growing at relatively low nutrient levels.

Where plants are slow growing and to be grown with low fertilisation, such as with the Orchidaceae and some in the Ericaceae, the specific mycorrhizas could provide an excellent partial alternative to the total dependence on conventional fertilisers. The majority of plants which commonly depend on endomycorrhizas need to be considered according to their species and their future end use. New Zealand plants that are intended for conservation plantings and others that may be intended for impoverished sites like sand dunes, agroforestry, and native forests could be considered for mycorrhizal inoculation within the nursery.

CONCLUSIONS

- The types of specialised root systems that form on different nursery plants can be very diverse Future research can be expected to further describe this great diversity of form and function.
- Mycorrhizas and N-fixing mechanisms of New Zealand native

plants have been widely researched and shown to be often beneficial.

- Genetic engineering has already been researched to 'tailor-make' the organism's function or special host plant relationship (Lemke et al , 1995) For example there is much potential for biological disease control using beneficial microorganisms.
- All of these systems offer considerable advantage to most plants that will be planted in soils where fertilisers will not be used and especially where there are adverse conditions of low fertility.
- Well fertilised soilless container media tend to reduce the occurrence and the need for specialised roots while in the nursery. There appear to be few studies relating to the establishment of plants from this type of production into unfertilised open-ground sites.
- The significance of ectomycorrhizas in the open ground nursery production of forestry and shelter conifers is well established and generally well understood.
- All of these specialised root systems offer natural advantages to plants for their nutrition and general plant health.

There is probably much room for greater understanding by New Zealand nursery people on the potential to encourage these specialised root systems in plants. We need to consider how we can grow plants in 'natural systems' with low input of raw materials to produce plants which will establish successfully into the New Zealand environment with the specialised root systems they need.

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