FUTURE FORESTS RESEARCH

RADIATA MANAGEMENT TECHNICAL NOTE
Site Productivity

Number: RSPTN-020
Date: August 2012

A Glasshouse Study of Tree Species in Mixtures

Summary

Tree species that form ectomycorrhizae (EM) such as pines and Douglas fir (*Pseudotsuga menziesii*) have a greater ability to absorb nitrogen and phosphorus from organic sources than species that form arbuscular mycorrhizae (AM), such as cypresses and redwoods, allowing them to grow more readily under the cooler temperatures that occur at higher altitudes and latitudes, or at other sites where nitrogen and phosphorus mineralisation rates are slow. AM species grown next to EM species have been found to have higher foliar nitrogen and phosphorus concentrations than when grown alone, indicating that the nutrition of the AM species may be enhanced when grown in proximity to EM species. This raises the question, can the nutrition and productivity of AM species be improved when they are grown in mixture with EM species? If so, this may allow AM species to grow at higher elevations and latitudes, and on poorer soils than is currently the case.

To test these ideas, a glasshouse trial was undertaken to determine if growth and nutrition of the AM species of coast redwood (*Sequoia sempervirens*) and Mexican cypress (*Cupressus lusitanica*) might be improved in a soil of low fertility if grown in mixture with the EM species radiata pine (*Pinus radiata*), Douglas-fir (*Pseudotsuga menziesii*) and kanuka (*Kunzea ericoides*). When grown alone, kanuka was the fastest growing species in the trial, out-performing all of the exotic conifer species. Of the conifers, Mexican cypress grew the fastest, followed by radiata pine and coast redwood. The growth of coast redwood was suppressed rather than enhanced when it was grown in the presence of the faster growing EM species radiata pine and kanuka. The growth of Mexican cypress was enhanced when grown in mixture with Douglas-fir, but this was probably because the latter had a much slower growth rate, allowing individual cypress plants more space to grow, than when grown alone. The growth of Mexican cypress was reduced when grown in the presence of the slower growing radiata pine. Mexican cypress did, however, grow better in mixture with kanuka than when grown alone.

The good growth of Mexican cypress when grown alone, in comparison with that of the EM species, was unexpected and indicates that nutrient availability in the soil was greater than expected. Thus, nutrients appeared to be no less available to the AM species than they were to the EM species. The hypothesis that growth and nutrition of AM species might be enhanced if they were grown in low fertility soil in the presence of EM species was not confirmed by the growth of species in this pot trial. Further experimentation and results from field trials are needed before recommendations can be made as to planting species in mixtures.

Authors: Murray Davis and Graham Coker

Introduction

Foliage analysis of trees in a Scion long term site productivity trial showed that Mexican cypress trees, when growing at plot edges adjacent to radiata pine, contained higher foliage nutrient concentrations of nitrogen, phosphorus and sulphur than foliage of trees grown within the plot and not adjacent to radiata pine. We suggested that this was due to the ectomycorrhizae of radiata pine enhancing mineralisation of soil organic matter and thereby enhancing the availability of these nutrients to the cypress, which is an arbuscular AM species [2]. Growth and nitrogen nutrition of AM species of *Araucaria* (in Australia), *Fraxinus* (in North America) and *Chamaecyparis* and *Cupressus* (in New Zealand) improved when planted adjacent to pines [1]. This supports the idea that EM species may enhance nitrogen uptake of AM species. These findings suggest that nutrition of AM species may be improved when grown in mixtures with EM species. If this is the case, the productivity of AM species may also be improved, and their range extended to areas where they are normally limited by slow organic matter mineralisation and slow release of organically bound nutrients. This slow release can be caused by cool temperatures.

Two field trials have been established to study the effect of mixing species with different mycorrhizal types on nutrient uptake (see Tech. Note RTN-012). These include Mexican cypress and coast redwood as the AM species, and radiata pine and Douglas-fir as the EM species.

A glasshouse trial was undertaken to study the effect of growing species in mixtures on tree growth and nutrition in a controlled environment. The glasshouse trial would potentially yield results much earlier than

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

RADIATA MANAGEMENT TECHNICAL NOTE

Site Productivity

Number: RSPTN-020
Date: August 2012

the field trials. The glasshouse trial included the same species as the field trials, and one additional species, kanuka, which forms associations with both AM and EM. This note describes the results of the glasshouse trial.

Methods

A soil expected to be deficient in nitrogen, phosphorus and sulphur was collected from an undeveloped high country grassland site that had been partially invaded by wilding Corsican pine (*P. nigra*) and Douglas-fir. Kanuka was also naturally present. The site was at Mt Barker near Lake Coleridge in the Rakaia valley, and had not received fertiliser. To ensure that fungi that would infect the EM species used in the trial were present, soil was collected from beneath both conifers and kanuka. Soil was also collected from grassland between the woody species. It was expected that the grassland soil would provide the mycorrhizal fungi inoculum necessary for infection of the AM species Mexican cypress and coast redwood. After collection the soil was sieved to remove coarse roots, and thoroughly mixed before potting up.

Seed of the tree species was germinated in the laboratory, and seedlings were transplanted into the pots either as four seedlings of a single species, or as two seedlings each of one EM and one AM species. The treatments included each of the AM species grown alone, in mixture with each other, and in mixture with each of the three EM species. The EM species were also grown alone, but not in mixture with each other. In total there were 13 treatments, each replicated eight times. The soil was kept continually moist by watering with an automatic irrigation system that applied approximately 4 mm/day.

The trial was established in November 2009 and harvested after one year's growth (Figure 1). At harvest, shoots were cut at ground level, oven dried and weighed. Roots were weighed for the individual species when grown alone, but not when grown in mixture as it proved too difficult to separate the roots of the different species.

Figure 1: One-year-old seedlings photographed recently after irrigation in the glasshouse.

Results

When grown alone, kanuka was the fastest growing species in the glasshouse environment, out-performing all of the exotic conifer species (Figure 2). The ability of kanuka to form both AM and EM may have contributed to its rapid growth rate by facilitating nutrient or water uptake. Of the conifers, Mexican cypress grew the fastest, followed by radiata pine and then coast redwood. Compared to other species, Douglas-fir grew poorly –- the soil may have been maintained in too moist a state for Douglas-fir, which is intolerant of wet conditions.

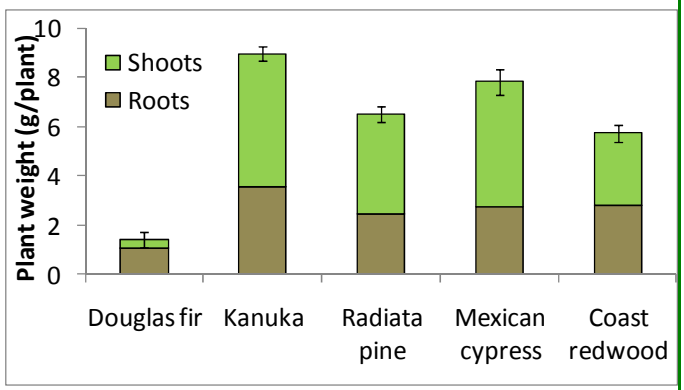

Figure 2: Shoot and root dry weights of five species grown alone in a pot trial after one year's growth. Bars show standard errors for whole plant weights.

Mexican cypress grew better with all other species than when grown alone, with the exception of where it was grown with radiata pine (Figure 3). Coast redwood, in contrast, grew more slowly in mixture than when grown alone, with the single exception of where it was grown with Douglas-fir (Figure 3).

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

RADIATA MANAGEMENT TECHNICAL NOTE

Site Productivity

Number: RSPTN-020
Date: August 2012

When grown in mixture with AM species, each of the EM species grew better than when grown alone (Figure 3). The only exception to this was with kanuka when in mixture with Mexican cypress, where it grew at a similar rate to when grown alone.

The greater growth of a species in mixture than when grown alone may be explained by differences in growth rate between it and the partner species. Where the partner species has a slower growth rate, individual plants of the dominant species have more space to grow than when grown alone. For example, all species except Douglas-fir grew faster when grown with coast redwood than when grown alone, as they had faster growth rates than coast redwood. Similarly the poorer growth of a species in mixture than when grown alone may be due to the species being suppressed by a faster growing partner species, as was likely the case for redwood with all species except Douglas-fir.

Anomalies against these trends occurred for Douglas-fir, which grew faster in mixture with the much faster growing species Mexican cypress and coast redwood; and radiata pine, which also grew faster with the faster growing Mexican cypress than when grown alone. In contrast, Mexican cypress grew more slowly when grown with radiata pine than when grown alone, despite it having a faster growth rate than the pine. The greater growth of Douglas fir and

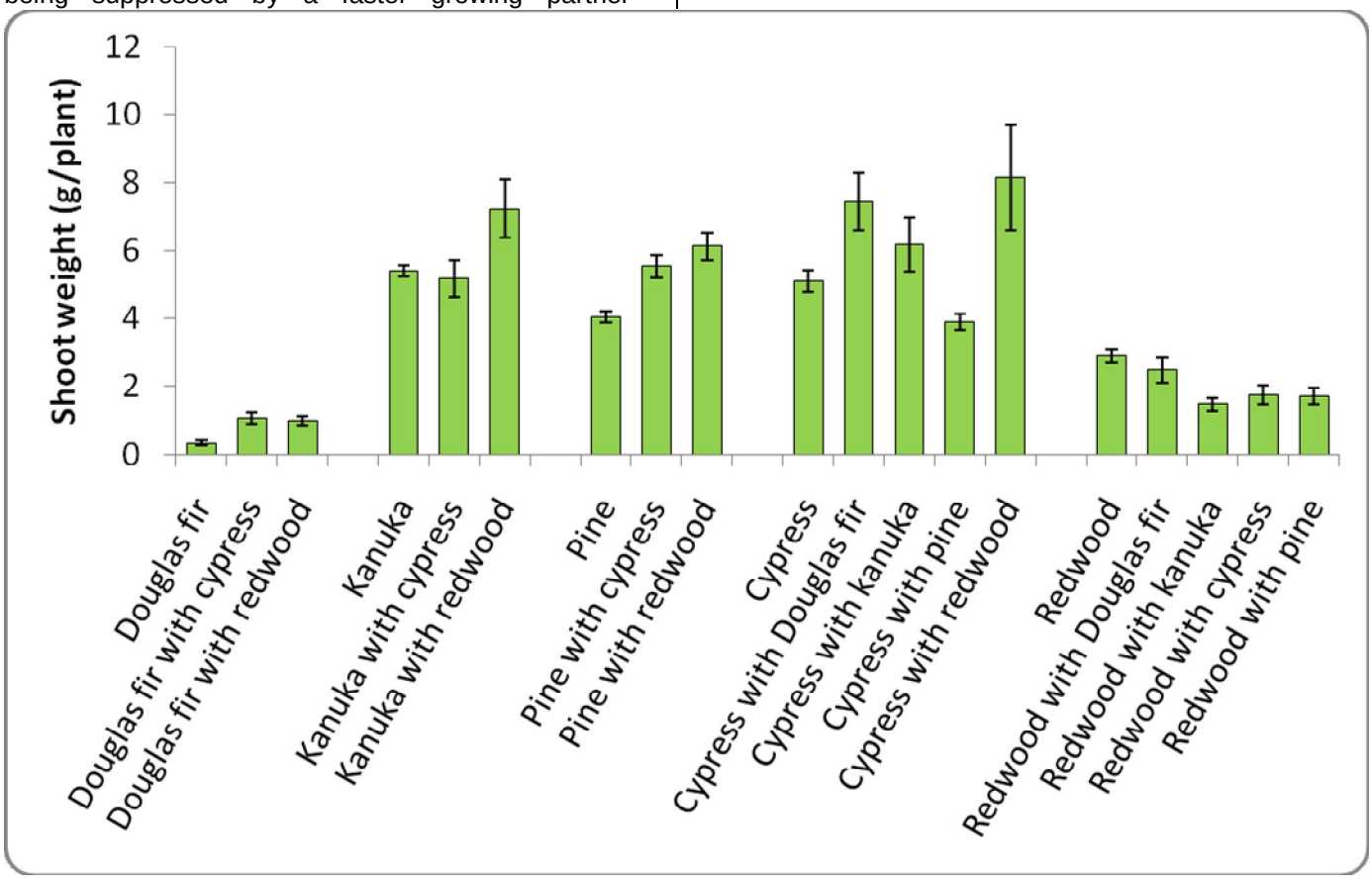

Figure 3: Shoot dry weights of five species grown alone and in mixture. Bars show standard errors.

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

radiata pine in the presence of a faster growing species may be due to the latter improving the soil environment, for example by reducing the soil water content, On the other hand, the slower growth of Mexican cypress in the presence of the slower growing radiata pine may be due to the pine reducing, rather than enhancing, nutrient availability.

The species differed in root:shoot ratio (Figure 4). Douglas-fir (not shown in Figure 4) had a very high ratio (3.8), but this is likely to be anomalous because of the very slow growth of this species. Of the remaining species, coast redwood had a substantially greater root:shoot ratio than kanuka and radiata pine. Clinton *et al*. (2009) [3] observed that redwoods are slow to establish, and queried whether the apparent slow establishment is due to trees initially allocating greater quantities of photosynthetically fixed carbon to their root systems at the expense of stem growth. The high root:shoot ratio of redwood in this study supports this suggestion.

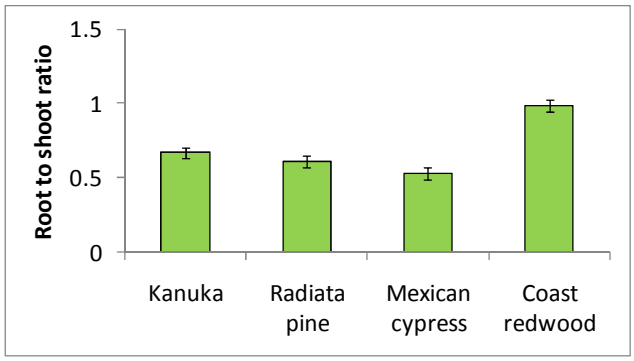

Figure 4: Root:shoot ratios of species grown alone. Bars show standard errors.

Discussion

The good growth of the AM species Mexican cypress when grown alone, in comparison with that of the EM species, was unexpected and indicates there was greater soil nutrient availability than first thought. There was no indication of chlorosis or other condition in any of the species that might indicate nutrient deficiency. Nutrients appeared to be no less available to the AM species than they were to the EM species. The hypothesis that growth and nutrition of AM species might be enhanced if they were grown in low fertility soil in the presence of EM species was therefore not confirmed by the growth of the species in this pot trial. A proportion of the soil used in the trial was collected from beneath conifers that had invaded what was originally low-productivity grassland, to ensure that the appropriate mycorrhizal fungi were present. Previous work has shown that conifer establishment in low-productivity high country soils increases nutrient availability, likely due to the activity of the associated EM fungi, and this phenomenon may account for the greater than anticipated nutrient availability of the soil used in the present study.

To explore the situation further, a new pot trial is being conducted. Soil for this trial has been collected from low-productivity grassland in the same general area as that for the first trial, but from grassland only, so it should not have nutrient availability enhanced by the presence of conifers. Inoculation of the EM species used in the new trial is being achieved by application of fungal spores and cultured mycelium material.

References

1. Stone, E. L.; Will, G. M. 1965: Nitrogen deficiency of second generation radiata pine in New Zealand. P 117-139 in Youngberg C. T. (ed.) “Forest-Soil Relationships in North America” Oregon State University, Corvallis, Oregon.

2. Watt M, Davis M, Parfitt RL. 2009. Improved nutritional status of Cupressus lusitanica when grown adjacent to *Pinus radiata*. Canadian Journal of Forest Research 39: 882-887.

3. Clinton P, Phillips C, Coker R. 2009. Redwoods – what have we been waiting for? New Zealand Tree Grower 30 (4): 3-5.