RADIATA MANAGEMENT
TECHNICAL NOTE
Site Productivity

Number: RSPTN-026
Date: February 2012

Early Growth and Nutrition of Four Species in Mixture Trials

Summary

Different tree species form different types of mycorrhizas. In field plantings, arbuscular mycorrhizal (AM) species have been found to have higher foliar nitrogen and phosphorus concentrations when grown next to ectomycorrhizal (EM) species than when grown alone. This observation indicates that interplanting the more site-demanding AM species with EM species may provide nutritional benefits to the former, potentially allowing the range of AM species to be extended into more nitrogen- and phosphorus-limiting environments than where they are now grown. Two trials were established at Hundalee Forest Canterbury, in 2009 to determine if there are nutritional benefits to either AM or EM species when they are grown together in mixtures. Hundalee Forest is a new forest being planted mainly in coast redwood (*Sequioa sempervirens*) and the trials are examining the effect of interplanting coast redwood (an AM species) with radiata pine and Douglas-fir (both EM species) and also Mexican cypress (as an AM control). The trials are located at 200 and 500 m elevation. At the low elevation site all species were planted in 2009, while at the high elevation site pine, Douglas-fir and Mexican cypress were planted into an existing two-year-old coast redwood stand. The key results were:

- Early growth measurements taken prior to the development of species mixture effects showed stem volume increment at the lower elevation site followed the order radiata pine > Mexican cypress > Douglas-fir > coast redwood.
- Growth was reduced at the higher elevation site, but stem volume increment of the species (of the same age class) followed the same order.
- Douglas-fir planting stock was two years old and larger than the other species (all one year old), and this probably contributed to its greater growth increment than coast redwood.
- Growth was reduced more in the AM species at the high elevation site (73% and 59% reduction in coast redwood and Mexican cypress respectively) than that of the EM species (22% and 24% reduction in radiata pine and Douglas-fir respectively).
- Foliage analysis showed the EM species had higher concentrations of nitrogen and phosphorus than the AM species, while the AM species had higher concentrations calcium and magnesium. This confirms results of earlier studies and indicates that there are fundamental differences in the nutrition of species which form different mycorrhizal types that could have implications for species siting and fertiliser requirements.

Species mixtures effects on growth and nutrition are not expected to show up before canopy closure.

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Background

Most plants form mycorrhizas. A mycorrhiza is an association between certain soil fungal species and plant roots, in which the plant gains the use of the fungal mycelium's very large surface area to absorb water and mineral nutrients from the soil. Additionally, mycorrhizal plants are often more resistant to soil-borne pathogens than non-mycorrhizal plants. In return, the fungus benefits from carbon compounds (energy) provided by the plant.

Several different types of mycorrhizas have been recognised, but only two are important for New Zealand tree species, namely ectomycorrhizas (EM) and arbuscular mycorrhizas (AM). Many tree species from the northern hemisphere that have become important forest species in New Zealand, including all pine species, Douglas-fir and larch, form EM. The cypresses (macrocarpa, Mexican, Lawson and Leyland cypress) and redwoods are AM species. AM species are generally restricted to warmer lower elevation sites and more fertile soils and are commonly referred to as being site demanding.

While it has long been known that mycorrhizas enhance uptake of nutrients in mineral form, especially phosphorus, research in the last 20-30 years has shown that some ectomycorrhizas can also obtain nitrogen and phosphorus directly from organic material, thus bypassing the bacterial mineralisation process. This means they are less reliant on soil bacteria and other organisms for breaking down and freeing up nutrients from soil organic compounds.

This gives EM species like pines an advantage in environments where nitrogen and phosphorus

mineralisation rates are naturally slow, and the availability of these elements is limiting. EM species therefore tend to perform better than AM species under the cooler temperatures that occur at higher altitudes and latitudes, or at other sites where nitrogen and phosphorus mineralisation is slow.

In field plantings, AM species have been found to have higher foliar nitrogen and phosphorus concentrations when grown next to EM pine species than when grown alone. Improved growth and nitrogen nutrition of AM species of *Araucaria* (in Australia), *Fraxinus* (in North America) and *Chamaecyparis* and *Cupressus* (in New Zealand) has been observed when these species are planted next to pines [4]. Results from a recent Scion study support this. In this study, foliar nitrogen, phosphorus and sulphur concentrations in *C. lusitanica* were found to be greater in trees growing next to radiata pine than in trees not adjoining the pine [5].

These observations indicate that there may be nutritional benefits to AM species when grown in mixtures with pines. To test this idea, and determine if similar benefits are conferred by EM species other than pines, two trials were established in 2009 at Hundalee Forest (North Canterbury). Hundalee Forest is a new forest planted mainly in coast redwood (*Sequioa sempervirens*), and the trials are examining the effect of interplanting coast redwood (an AM species) with radiata pine and Douglas-fir (both EM species) and also Mexican cypress (*Cupressus lusitanica*) as an AM control. The trials will also determine if EM species receive nutritional benefits when grown in mixtures with AM species.

Species mixtures' effects on growth and nutrition are not expected to show up for some years. This note presents 'baseline' data on the first two years' growth and foliar nutrient concentrations of the four species growing in common environments, prior to species effects setting in. The work is being undertaken in the Scion 'Protecting and Enhancing the Environment through Forestry' programme funded by FRST and partly by Future Forest Research.

Methods

The trials at Hundalee Forest are located at 200 and 500 m elevation and were planted in pasture. The soil at the lower site is poorly drained Hundalee Hill soil while the soil at the upper site is a well drained Hurinui steepland soil. The soils have similar chemical properties (Table 1) with low C/N ratios and moderate Olsen P values being indicative of pasture sites.

Table 1. Chemical properties of soils at the low and high elevation trial sites at Hundalee Forest.

Site	pH	C[1]	N[1]	C/N	P[2]	Ca[3]	Mg	K
Low	5.1	4.5	0.36	12.5	11	6.7	3.0	0.6
High	4.8	3.8	0.32	11.9	16	5.2	1.9	0.7

[1]C and N %, [2]Olsen extractable P (mg/kg)
[3] Exchangeable Ca, Mg, K (cmol/kg)

Species at the low elevation site were planted in 2009, while at the high elevation site pine, Douglas-fir and Mexican cypress were planted into an existing two-year-old coast redwood stand. This stand had had been blanked in 2008 and 2009, so had three age classes present when the other species were interplanted. In the lower trial, coast redwood was planted at 400 stems/ha while in the upper trial it was planted at 500 stems/ha. The species mixture treatments were applied by either interplanting coast redwood rows with radiata pine, Douglas-fir or Mexican cypress, or not interplanting (coast redwood control). Mean tree stockings in the mixtures plots were therefore 800 stems/ha in the lower trial and 1000 stems/ha in the upper trial. The Douglas-fir stock used was two years old and larger than the other species, which were all one year old.

Results and Discussion

Tree Growth

Stem volume increments for the first two years at the lower site followed the order radiata pine > Mexican cypress > Douglas-fir > coast redwood. The growth of radiata pine and Mexican cypress greatly exceeded that of Douglas-fir and coast redwood (Fig. 1).

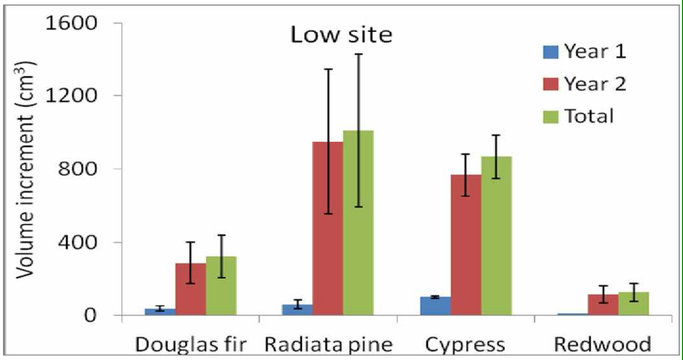

Figure 1. Stem volume increment for the first two years after planting at the low elevation (200 m) site at Hundalee forest. In this and subsequent graphs, vertical bars show standard errors of the mean.

The greater size of the two-year-old Douglas-fir planting stock was probably responsible for the better growth of this species than coast redwood at both the lower and upper (see below) trial sites. Growth was reduced at the higher elevation site, but stem volume increments of the species (of the same age class) followed the same order (Fig. 2). Growth was reduced substantially more in coast redwood and Mexican cypress at the high elevation site (73% and 59% reduction respectively) than in radiata pine and Douglas-fir (22% and 24% reduction respectively). While stem volume increment of coast redwood planted in 2009 at the high site was very small compared to the other species, the average increment of the three age classes of coast redwood combined fell between that of radiata pine and Mexican cypress (data not shown).

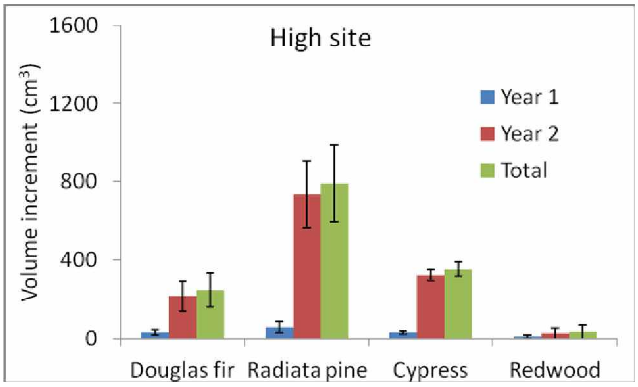

Figure 2. Stem volume increment for the first two years after planting at the high elevation (500 m) site at Hundalee forest. Growth measurements for coast redwood are for trees planted in 2009 only.

Foliar Nutrient Concentrations

At both trial sites foliar nitrogen and phosphorus concentrations were greater in Douglas-fir and radiata pine than Mexican cypress and coast redwood, as expected from their respective EM and AM mycorrhizal associations (Figs 3 and 4). Douglas-fir and radiata pine also contained greater concentrations of zinc and aluminium than Mexican cypress and coast redwood (data not shown).

In contrast, the AM species contained greater concentrations of the divalent cations calcium and magnesium (Figs 5 and 6). There were other differences between species, but these were not consistent within mycorrhizal types. The main differences were that Mexican cypress contained greater potassium, but much lower manganese concentrations than all of the other species.

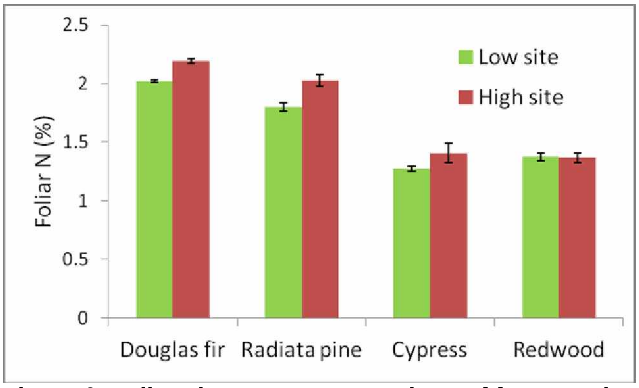

Figure 3. Foliar nitrogen concentrations of four species at two trial sites.

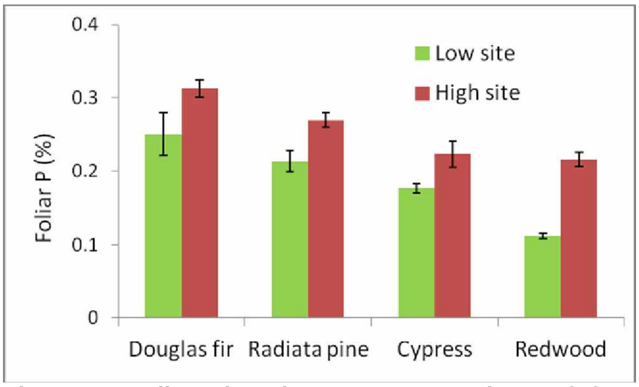

Figure 4. Foliar phosphorus concentrations of four species at two trial sites.

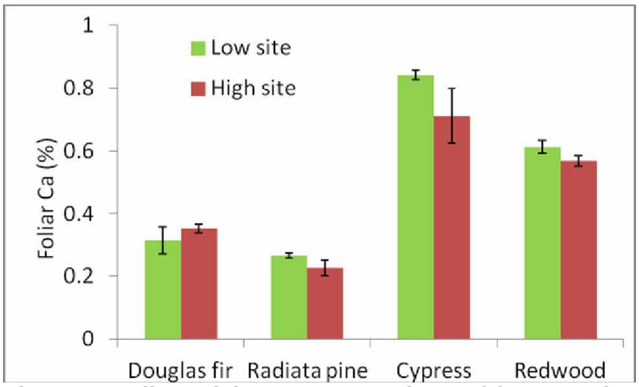

Figure 5. Foliar calcium concentrations of four species at two trial sites.

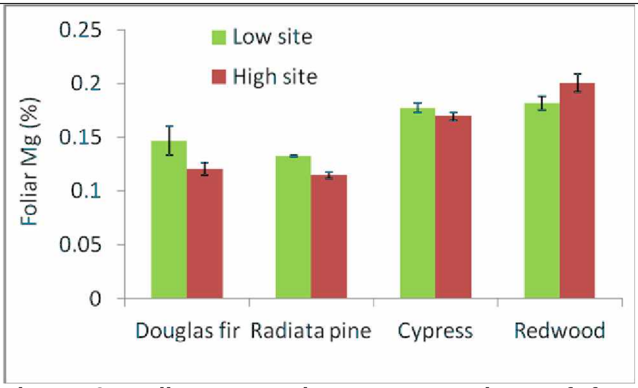

Figure 6. Foliar magnesium concentrations of four species at two trial sites.

The differences in foliar concentrations observed between radiata pine and Mexican cypress for nitrogen, phosphorus, calcium, magnesium, zinc and aluminium are consistent with those previously observed for these species in New Zealand [2] [5]. Although the differences for calcium, magnesium, zinc and aluminium are consistent for species with different mycorrhizal associations, it is not known whether these differences are due to mycorrhizal association, or some other factor. The results indicate that there are fundamental differences in the nutrition of species that could have implications for species' siting and fertiliser requirements.

With one exception, foliar nitrogen and phosphorus concentrations were always greater at the upper site than the lower site (Figs. 3 and 4). It is too early to say whether this was due to greater availability of these nutrients or slower tree growth at the upper site. Foliar nitrogen and phosphorus concentrations appeared more than adequate for growth of Douglas-fir and radiata pine at both sites [3]. Foliar diagnostic criteria are not well established for Mexican cypress, but Davis *et al*. (2010) indicate that the nitrogen concentration at the lower site (1.27%) may be below optimum, while that at the higher site (1.41%) may be just optimum. Phosphorus concentrations were adequate for Mexican cypress at both sites. Foliar diagnostic criteria are not available for coast redwood, but from comparison with other species the nitrogen concentration at both sites (1.37%) and the phosphorus concentration at the lower site (0.11%) may be below optimum.

Some argue that foliar N/P ratios are more important than tissue concentration of either nutrient in determining nutrient limitation [1]. An N/P ratio of 10 is considered to be optimum for a wide range of species, with deviations above or below indicating phosphorus and nitrogen deficiency respectively. With one exception, N/P ratios were below 10 in the present study, indicating potential nitrogen limitation (Fig. 7). The exception was coast redwood at the lower site where the N/P ratio was high as a result of a low foliar phosphorus concentration. Ratios were always lower at the upper site, indicating greater nitrogen limitation than at the lower site.

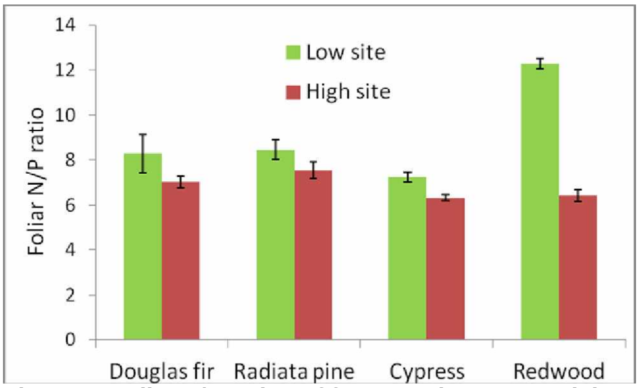

Figure 7. Foliar N/P ratios of four species at two trial sites.

At this stage it is too soon for species mixtures' effects on nutrition to become apparent. It is expected that any effects will not be manifested before canopy closure.

Acknowledgements

The authors wish to acknowledge the helpful support of the New Zealand Redwood Company for hosting the trials at Hundalee Forest.

References

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