RADIATA MANAGEMENT TECHNICAL NOTE Site Productivity

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Influence of Native Leaf Litter on the Early Stage Decomposition of *Pinus radiata* Needles

Summary

Leaf litter is a significant store of carbon and other nutrients in forest ecosystems. The process of litter decomposition is complex, and only recently have scientists begun to focus their attention on the importance of mixed litter sources (i.e., different tree species), and the effect of such mixtures on decomposition rates and nutrient cycling.

This study tested the contribution of native understory leaf litter to the decomposition rate of *Pinus radiata* leaf litter. In this study, we hypothesised that the addition of litter from native understory plant species would increase the decomposition rate of *P. radiata* needles and increase nutrient cycling rates compared with pure *P. radiata* litter.

The rate of mass loss of *P. radiata* needle litter was largely unaffected by the addition of leaf litter derived from native woody species *Aristotelia serrata* (wineberry) and *Coprosma grandifolia* (kanono); however, the addition of the tree fern *Dicksonia squarossa* (whekī) markedly slowed the decomposition of *P. radiata* litter.

At this stage we cannot determine the actual mechanism that underpins these changes in mass loss. However, we are currently examining the changes in microclimatic conditions that are associated with pure and mixed sources of litter. A final report will summarise implications of the completed work to FFR members.

Authors: M B Scott, M K-F Bader and S M Pawson; Scion.

Leaf Litter: Unlocking an Important Resource

Leaf litter decomposition is one of the primary processes driving nutrient cycling in forested ecosystems, and is an important determinant of plant productivity. Planted forests differ conspicuously from natural forests in that plantations are frequently monocultures, with leaf litter principally consisting of a single species, whereas leaf litter in natural forest is a mixture of different species.

Softwood conifers account for 98% of New Zealand's commercial production forests[1]. Needle-bearing conifers, such as *Pinus radiata*, have highly lignified leaves, resistant to microbial degradation. Only a relatively small subset of decomposer organisms, mainly fungi, has developed the necessary enzymes to break down lignin. As a result, the decomposition rate of recalcitrant (highly resistant) needles is slower than most broadleaved leaf litter types. In the absence of understory species, *P. Radiata* plantations produce a deep, uniform litter layer composed entirely of decomposing needles. Such a system can store considerable nutrients that may otherwise be recycled and made available to improve productivity.

The silvicultural benefits of a broadleaf component in commercial conifer plantations have long been postulated. Among the perceived benefits are more rapid decomposition and mineralisation, which results in improved nutrient cycling, and enhanced productivity. Only recently have scientists begun to quantify the interactive effects of mixing leaf litter during decomposition, and the few existing cases provide contradictory results.

Gartner and Cardon [2] reviewed over 30 studies that examined decomposition rates of 162 different leaf litter mixtures. In 108 cases there was a non-additive effect; in other words the change in litter decomposition rate of the mixture could not be predicted solely from the decomposition rates of each constituent part. Of those 108 cases, positive non-additive effects (i.e., a synergy) were recorded in 77 cases, where mean decomposition rate increased by 17%. However, negative non-additive effects (i.e., an inhibitory effect) of leaf mixtures were recorded in 31 cases, with a mean decrease in decomposition rates of 9%.

A number of hypotheses have been proposed to explain these non-additive effects, namely:

1) nutrients released from rapidly decaying, higher quality (nutrient rich) litter can stimulate decay in adjacent, more recalcitrant litters;

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2) higher quality litter may support a larger, more diverse soil organism community that could “spill over” onto low quality litter;
3) stimulating or inhibiting leachates may be present in particular species’ litter;
4) microclimate conditions may change, i.e., mixed litters can have a structurally more diverse litter layer that provides a more aerobic environment that stimulates biotic activity[3].

Soil Biota: Who rules who?

Soil biota is a critical element in each of these hypotheses. Understanding invertebrate interactions with leaf litter is clearly an integral part of nutrient cycling and plant productivity. The composition, abundance, and activity of the decomposing faunal community is constrained by species’ nutritional requirements and micro-environmental attributes of the leaf litter and soil surface, for example depth of accumulated litter, litter quality, temperature.

New Zealand’s invertebrate biota is interesting in that many groups have a disproportionate number of species that specifically feed on plant detritus, such as leaves and twigs[4]. This complex detritus feeding biota evolved in the presence of only a few conifer species, none of which are in the family *Pinaceae*, (e.g., pine, spruce, fir and larch) that comprise the vast majority of New Zealand plantation forest area. So, in New Zealand the indigenous biota is not specifically adapted to feed on the dominant leaf litter present in plantation forests, where the native flora is limited, or absent altogether.

This raises several interesting questions.

- What impact do native understory plants have on litter decomposition and nutrient cycling rates in plantation stands?
- How does the invertebrate decomposer fauna respond to mixtures of litter that include native understory species in these non-native forests?

Methods: The Leaf Litter Trials

To examine these questions, we established a field trial to compare decomposition rates of *P. radiata* needles with leaf litter from common understory native species *Aristotelia serrata* (wineberry), *Coprosma grandifolia* (kanono), and *Dicksonia squarossa* (whekī – or tree fern), and to test the effect of native understory plant litter on invertebrate community composition in *P. radiata* plantation forests.

We chose these native species in particular because they are common understory species present in many New Zealand plantations, and have a relatively wide range of nitrogen concentrations within their leaves. Nitrogen content is an important predictor of decomposition rates, as it is a critical element required by invertebrates, microbes and fungi in the decomposition process.

Each litter bag contained air dried litter totalling 5 g. Treatment litter proportions included bags with 100% pine and 100% native, as well as mixtures of pine with one native species at ratios of 75:25, 50:50 and 25:75. In total, we made 24 litterbags for the five litter treatments for each of the three native species (360 bags in total).Samples were pegged to the ground in four West Coast plantations, Nemona (Dyngle Bat Road, Hannah Dam), Waimea (Greenstone Road) and Mahinapua (Adair Road) on 1 October 2010 (Figures 1 and 2). Bags at each site were collected after two and six months.

We measured the mass loss of each constituent species. This was done by dry weight, litter oven-dried at 70°C.

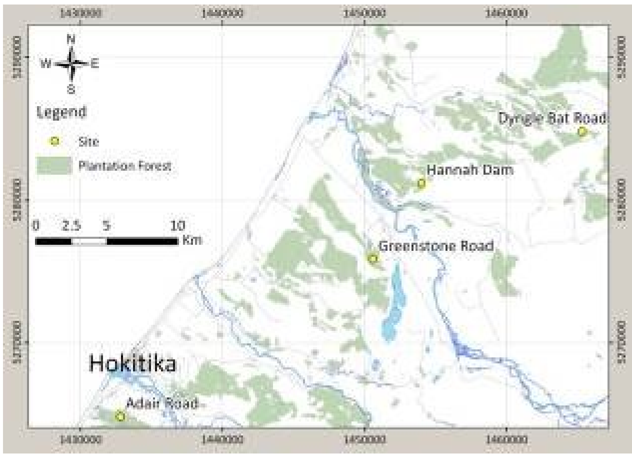

Fig. 1. Leaf litter sites on the West Coast.

Statistical Analysis

We applied linear mixed models using restricted maximum likelihood estimation to analyse litter mass loss in litter bags. The response variable was specified as relative mass loss, measured as log (final mass/initial mass). The fixed term of the models comprised ‘leaf litter species’ and ‘admixture class’ and their interaction. ‘Leaf litter species’ nested in ‘site’ were modelled as random effect reflecting the hierarchical study design.

Fig. 2. Mixed leaf litter bags of radiata pine and wineberry leaves.

Results: Pine Litter Decomposition

Mass loss of *P. radiata* needle litter ranged from 36 to 42% (Figure 3). Mass loss remained largely unaffected by the addition of leaf litter derived from *A. serrata* and *C. grandifolia*. Only when tree fern leaf litter dominated the litter mixture (25:75, *P. radiata*: *D. squarrosa*) was the decomposition rate of *P. radiata* needles affected, when it was significantly decelerated (Figure 3). This is the cause of the significant ‘litter species’ × ‘admixture class’ interaction (Table 1).

Table 1. Significance of litter species, mixture and litter species x mixture for *P. radiata* litter mass loss in pure and mixed litter bags after 6 months.

Parameter	*F*	*P*	
Litter species	9.19	0.015	*
Mixture	5.37	0.002	**
Litter species × mixture	2.28	0.041	*

Results: Native Litter Decomposition

The addition of *P. radiata* needle litter to leaf litter from *A. serrata* and *C. grandifolia* did not produce a significant effect on decomposition rates (Figure 4, Table 2). However, there was a significant ‘litter species’ effect on litter mass loss reflecting different decomposition rates of the native species irrespective of whether they were included as part of a mixture or as pure native litter. After six months, leaf litter derived from *A. serrata* and *C. grandifolia* had lost similar amounts of initial mass, between 68 and 78% (Figure 4). By contrast, the more recalcitrant *D. squarrosa* leaf litter had lost only around 20% of its initial mass (Figure 4).

Table 2. Significance of litter species, mixture and litter species x mixture native litter mass loss in pure and mixed litter bags after 6 months.

Parameter	*F*	*P*	
Litter species	240.88	<0.001	***
Mixture	0.72	0.542	
Litter species × mixture	0.71	0.641	

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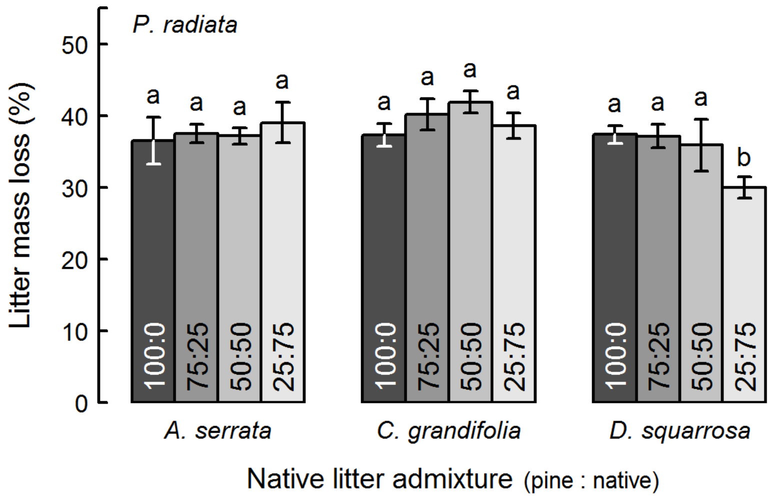

Fig. 3. Mass loss of *P. radiata* needle litter in pure and mixed litter bags. Litter mixtures are given as pine : native %. Means ± SE, n = 5. Different lower case letters indicate significant differences (multiple comparison test using Tukey contrasts).

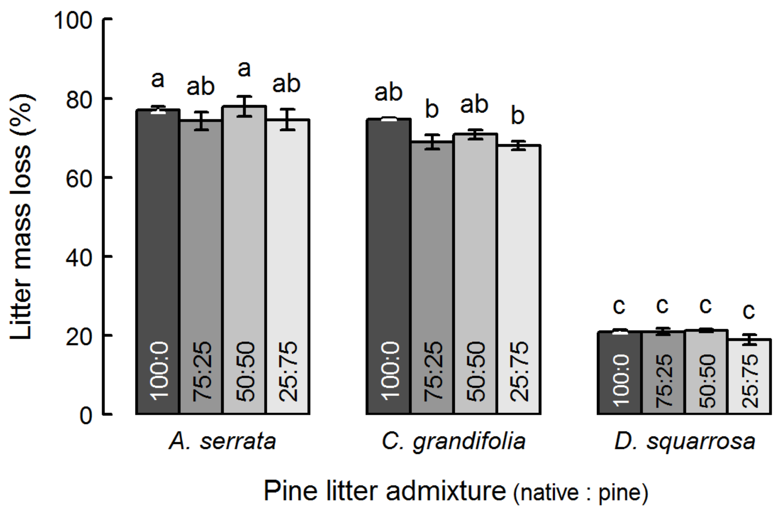

Figure 4. Mass loss of *A. serrata, C. grandifolia* and *D. squarrosa* leaf litter in pure and mixed litter bags. Litter admixtures are given as native : pine %. Means ± SE, n = 5. Different lower case letters indicate significant differences (multiple comparison test using Tukey contrasts).

Discussion

A range of litter mixing effects on decomposition processes has been reported[2, 5, 6]. The leafy native species, *A. serrata* and *C. grandifolia* decomposed almost twice as quickly as the more recalcitrant *D. Squarrosa* and *P radiata* (Figures 3 and 4). Early-stage pine litter was largely unaffected in the first six months by the presence of the native species. Only in the presence of abundant *D.squarrosa* (here 75%) was there an effect of litter mixing, expressed as a significant reduction of decomposition rate of pine litter. Pine litter, on the other hand, exerted no effect on the decomposition rate of *A. serrata*, *C. Grandifolia* and *D.squarrosa*.

A possible explanation for the leafy native species with high N levels having 'no effect' on the decomposition rate of pine is that litter from slow-decomposing species, such a *P. radiata*, with low concentrations of N and P, often contains secondary chemical compounds that may retard decomposition, or at least counteract the positive effects of high-quality litter on decomposition[5]. In addition, our study was limited to six months, which may have been too short to detect mixture effects like those that have been observed in leaf litter decomposition studies of longer time scales.

One of the main reasons for investigating the effects of mixed-species litter in plantation forests is to better understand the cycling of nutrients for improved tree growth and forest productivity. So far our results suggest that there is no understory species effect on the decomposition rate of litter. The exception is that large amounts of tree fern (>75% of the litter) in the understory may retard decomposition and therefore nutrient cycling. Our results suggest that management to increase understory plant abundance will not improve nutrient cycling in plantation forests. We hope that further work in this area will provide a more detailed understanding of the complex inter-relationships between leaf litter composition, microclimate, and the decomposer community.

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