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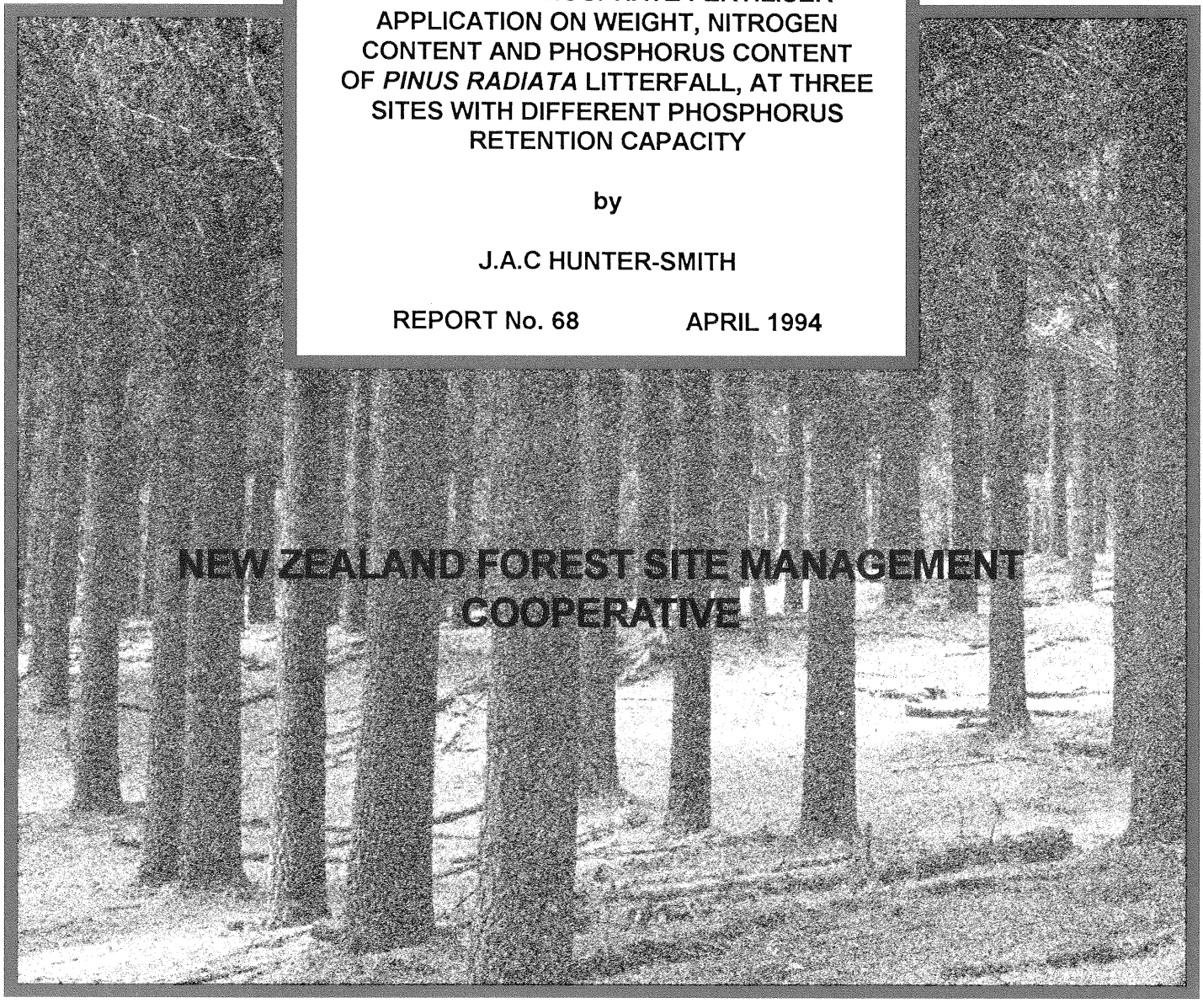
THE EFFECTS OF ROCK PHOSPHATE AND SUPERPHOSPHATE FERTILISER APPLICATION ON WEIGHT, NITROGEN CONTENT AND PHOSPHORUS CONTENT OF *PINUS RADIATA* LITTERFALL, AT THREE SITES WITH DIFFERENT PHOSPHORUS RETENTION CAPACITY

by

J.A.C HUNTER-SMITH

REPORT No. 68 APRIL 1994



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THE EFFECTS OF PHOSPHATE ROCK AND SUPERPHOSPHATE FERTILISER APPLICATION ON WEIGHT, NITROGEN CONCENTRATION AND PHOSPHORUS CONCENTRATION OF *PINUS RADIATA* LITTERFALL, AT THREE SITES WITH DIFFERENT PHOSPHORUS RETENTION CAPACITY.

J.A.C. HUNTER-SMITH

ABSTRACT

The effect of phosphorus fertiliser treatment on mass, nitrogen and phosphorus content of litterfall was estimated in three radiata pine stands at sites where soils were known to have high, medium or low phosphorus retention capacity.
The effects of superphosphate and A-Grade phosphate rock applied at a rate of 150 kg P/ha were compared at each site.
Litterfall in untreated plots varied between the three sites and ranged from 2048 to 3366 kg/ha/year. Radiata pine needles contributed approximately 99% of the total mass of litterfall.
Application of fertiliser increased litterfall at all sites and superphosphate was more effective than phosphate rock, especially at the site with zero P retention. Nutrient concentration (nitrogen and phosphorus) of litterfall was affected markedly by fertiliser treatment.
This litterfall returned up to 29.43 kg/ha/yr of nitrogen and 2.96 kg/ha/yr of phosphorus in the fertilised plots.
There was an inconsistent seasonal pattern of litterfall, which was highest during the summer months at Waipoua, and during the autumn months at Tairua. Riverhead showed no significant seasonal peak. These patterns bear little relationship to windrun.
There was, however, a consistent seasonal pattern shown with nutrient concentrations whereby litterfall tended to have the highest nitrogen and phosphorus concentrations during the summer months and lowest concentrations during the winter months.

KEY WORDS: *Pinus radiata*; nitrogen, phosphorus, phosphate rock, litterfall, superphosphate

INTRODUCTION

Three fertiliser trials were established in 1978 on phosphorus-deficient soils with different phosphorus (P) retention characteristics. The response of young radiata pine trees to various types and rates of finely-ground pelletised phosphate rock and superphosphate was followed in a series of studies.

Hunter and Graham (1983) reported a significant stem volume response to fertiliser within three years on a soil with medium P retention. Sites with very high and very low P retention gave only small volume responses. There was no difference in volume response to different fertiliser rates and types (Hunter and Hunter 1991).

Hunter and Hunter (1991) reported that phosphate fertiliser increased foliar P levels at a rate that was inversely proportional to the P retention capacity of the soil.

Switzer and Nelson (1972) stated that foliage production requires the greatest proportion of the tree nutrients, averaging 80% for all nutrient elements. Most of the nutrients taken up by the tree are transported to the foliage, which is the principle agent in nutrient recycling processes.

The aim of this study was to determine whether the total amount of *Pinus radiata* D.Don litterfall and the nitrogen (N) and phosphorus (P) concentrations in that litter were affected by site variation and phosphorus fertiliser treatments.

METHODS
SITE AND TRIAL DESCRIPTION

The three soil types were:-

Waipoua State Forest - a Tangitiki sand-Te Kopuru sand complex. P retention 0% (Sutherland *et al.* 1985)

Riverhead State Forest - a Waikare silt loam - Okaka clay and silty clay complex (Sutherland *et al.* 1980). P retention 48% in the top 10 cm of the soil.

Tairua State Forest - a clay soil derived from old deeply weathered volcanic ash. P retention 93% in the topsoil.

Table 1 presents the site and stand details for each site. Soil chemical characteristics are shown in Table 2.

TABLE 1. Site and stand details
nitrogen

	Longitude /Latitude	Alt(m) A.S.L.	1984/85 Mean Temp °C	1984/85 Rainfall (mm)	Year Planted	Stems per hectare	1978 Basal area (m^2/ha)	Mean BA/tree (m^2)
WAIPOUA	173°32'E 35°39'S	120	14.6	1361	1971	1765	6.27	0.0036
RIVERHEAD	174°32'E 36°46'S	130	14.5	1457	1974	1120	1.51	0.0013
TAIRUA	175°47'E 37°105'S	300	14.4	1544	1974	1175	3.91	0.0033

TABLE 2. Soil chemical analyses for the three sites from Hunter and Graham (1983).

SITE	Depth (cm)	Bray P (µg/g)	P retention † (%)	Total N (%)	pH
WAIPOUA	0 - 10	1	0	0.12	4.5
	0 - 20	1	0	0.12	4.5
RIVERHEAD	0 - 10	2	48	0.19	4.9
	0 - 20	1	51	0.15	4.9
TAIRUA	0 - 10	2	93	0.44	5.4
	0 - 20	1	92	0.31	5.4

† P retention is the % retained of a known added concentration to a soil

At the time of fertiliser treatment (1978) the trees in the study areas at Riverhead and Tairua were 4 years old. The study area in Waipoua was 7 years old. Height and diameter at the three sites was similar although the tree age was different. All three stands were unpruned and unthinned.

At Waipoua and Tairua there was a dense understorey of 2-3 m tall manuka scrub (*Leptospermum scoparium* J.R. & G. Forst). At Riverhead there was an understorey

(*Leptospermum scoparium* J.R. & G. Forst). At Riverhead there was an understorey of manuka mixed with native hardwoods and tall grasses (*Cortaderia selloana* (Schult.) Asch et Graeb., *Ghania sp.* J.R. et G. Forst). The understorey vegetation was beginning to be shaded out by the tree canopy when the litterfall study commenced.

Three randomised blocks of experimental plots had been established at each site in 1978. The experiment design consisted of three rates of P (0, 75, and 150 kg P/ha) and four types of phosphorus (A-grade (15.4% P) and C-grade (11.4% P) phosphate rock, Citraphos (calcined C-grade @ 14.8% P) and Superphosphate (10.8%P). The source for the phosphate rock was Christmas Island.
A subset of the fertiliser treatments was chosen for the current study. It consisted of the A-grade and Superphosphate treatments applied at 150 kg P/ha and the unfertilised control (a total of 9 plots/site).

One year after the fertiliser treatments were applied, the trees at Waipoua showed signs of nitrogen and potassium (K) deficiency. A mixture of urea (200 kg N/ha) and potassium chloride (80 kg K/ha) was broadcast over the site by hand (Hunter and Graham 1983).

FIELD COLLECTION AND LABORATORY PROCEDURE.

In March 1984, five rectangular 0.5 m^2 litter traps (78cm x 65 cm), made of a wooden frame and very fine nylon mesh on 10 cm high wooden legs, were placed at permanent fixed, randomly pre-selected coordinates in each of the nine plots per site.
Trap contents were collected monthly for one year. The samples were dried at 70 °C and weighed. The litter was then subdivided into radiata pine needles, other plant leaves, branches and twigs (all species) and pine strobili. The number of green needles was considered negligible. The proportion by weight of each component of total litterfall was calculated.

Radiata pine needle litterfall for the months March to May (autumn), June to August (winter), September to November (spring) and December to February (summer) was combined. Other litterfall components were combined for the whole year. Bulked material was finely ground using a Wiley mill. Total nitrogen and total phosphorus concentrations in each combined sample were determined using methods described by Nicholson (1984).

STATISTICAL ANALYSIS.

Site, treatment and seasonal effects and their interactions were compared by analysis of variance using SAS Statistical package (V5.16) and GENSTAT (1983). Regression analysis was used to identify the relationship between basal area increment and yearly litterfall.

RESULTS AND DISCUSSION

SITE EFFECTS

Table 3 shows the mean total radiata pine litterfall (kg/ha) that was collected for the period of one year. It shows that the amounts of litterfall varied significantly between the three sites.

TABLE 3. Mean total litterfall (kg/ha) for one year.

	CONTROL	A-GRADE	SUPER	MEANS FOR SITE
WAIPOUA	2138	2704	3248	2696 [a]
RIVERHEAD	2048	3241	3963	3084 [b]
TAIRUA	3366	3973	4278	3872 [c]
MEANS FOR TREATMENT	2517 [a]	3306 [b]	3830 [b]	

Values for treatments or sites marked with the same letter are not significantly different (P=0.05).

The analysis of variance showed that site means for litterfall were significant with Waipoua and Riverhead not significantly different from each other, but Tairua significantly higher than both of them (P=0.020).

The total litterfall results indicate that the most productive of the three sites in terms of basal area increment ie. Tairua (Hunter and Graham, 1983), produced the highest amount of litterfall. Figure 1 shows basal area increment (m^2/ha), for the period of the study as a measure of site productivity for each plot at each site, plotted against the corresponding litterfall (kg/ha) for that plot. This showed a coefficient of determination of r^2=0.35.

Figure 1. Litterfall (kg/ha/yr) vs 1984-85 basal area increment (m2/ha)

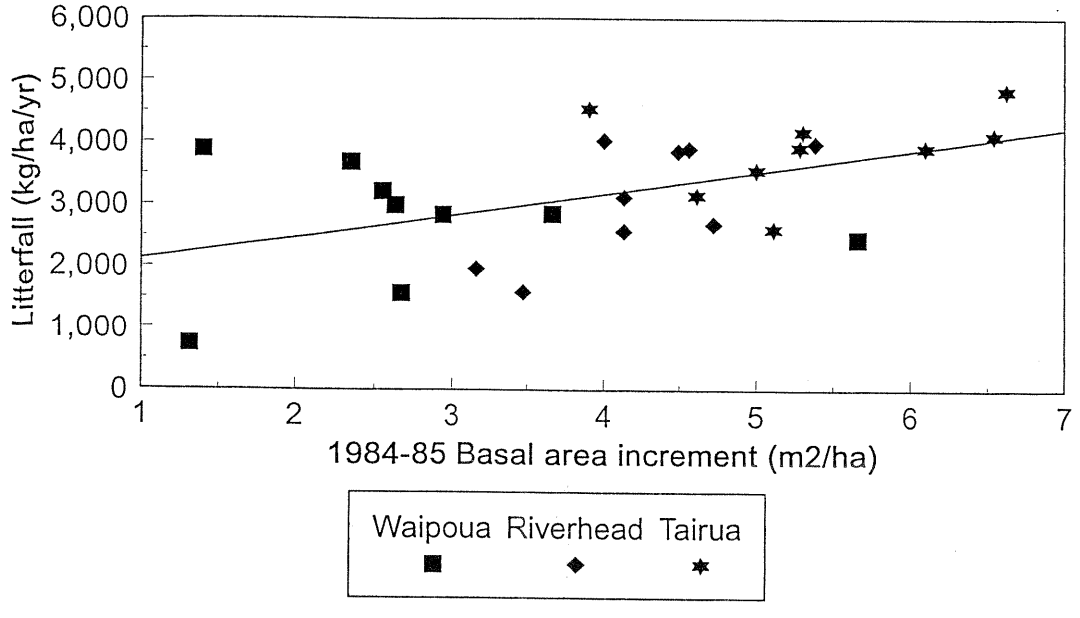


Table 4 shows that material other than radiata pine needles collected in the litter traps constituted, at most, 3% or less of the total litterfall that was collected, with leaves from other species being the highest contributor.

TABLE 4. Material other than radiata pine needle litter collected in one year (kg/ha) and compared against total litterfall (%)

	CONTROL	A-GRADE	SUPER
WAIPOUA			
Other species leaves	38.3	21.7	17.9
Pine strobili	3.5	8.8	4.4
Branches	21.2	36.4	26.3
TOTAL (% of total litterfall)	63.0 (2.9)	66.9 (2.4)	48.6 (1.4)
RIVERHEAD			
Other species leaves	12.6	12.0	11.0
Pine strobili	11.1	12.0	9.3
Branches	< 1	< 1	< 1
TOTAL (% of total litterfall)	24.7 (1.2)	25.0 (0.7)	21.3 (0.5)
TAIRUA			
Other species leaves	14.9	6.4	5.1
Pine strobili	12.0	11.3	8.2
Branches	2.6	2.0	1.9
TOTAL (% of total litterfall)	29.3 (0.9)	19.7 (0.5)	15.2 (0.3)

At Tairua and Riverhead, total litterfall expressed as a percentage of total canopy mass ie. all foliage age classes combined (kg/ha) (data from Hunter and Hunter, 1991) was similar for all three treatments (Table 5). At Waipoua a higher percentage of canopy mass was dropped as litterfall. This may have been due to the exposed nature of the site, factors such as soil moisture and wind thrashing, or to the low nitrogen status of the stand, or a combination of these factors. Beets and Madgwick (1988) have shown that low nitrogen supply can cause radiata pine to have a low canopy mass similar to those levels reported at Waipoua.

TABLE 5. Litterfall expressed as a percentage of total canopy mass

	CONTROL	A-GRADE	SUPER
WAIPOUA			
Canopy Biomass (kg/ha)†	5100	7100	5900
Total litterfall (kg/ha)	2138	2704	3248
%	41.92	38.08	55.05
RIVERHEAD			
Canopy Biomass (kg/ha)†	8900	12600	12000
Total Litterfall (kg/ha)	2048	3241	3963
%	23.01	25.72	33.03
TAIRUA			
Canopy Biomass (kg/ha)†	12000	15500	13500
Total Litterfall (kg/ha)	3366	3973	4278
%	28.05	25.63	31.69

† Data from Hunter and Hunter (1991)

TREATMENT EFFECTS

The mass of litterfall (kg/ha) varied greatly between the sites and between treatments. Table 3 shows that Waipoua yielded the lowest mass of litterfall on average for all treatments and Tairua the highest. At all three sites the Control treatment yielded the least amount of litterfall while the Superphosphate treatment produced the highest amount.

There was a significant treatment effect (P=0.013) to phosphate type with litterfall in the A-grade the highest, but not significantly different from the Super treatment, but both significantly different from the Control treatment.

Figures 2 a, b, & c show the seasonal patterns with the differences between the treatments. The greatest difference between treatments at Waipoua and Tairua was observed at the time of peak litterfall.

There was no relationship between windrun for the same period as the study and peak litterfall at the three sites. Table 6 shows that Waipoua was the most wind exposed of the three sites and that Tairua was slightly more exposed than Riverhead. It would be expected that if wind was a major factor contributing to the litterfall during this study that the amounts of green needles would have been significant enough to have been considered. Also branchfall was not generally a significant component of the total litterfall as would be expected if strong winds and storm events (Gosz *et al.* 1972) had occurred during the study, although Waipoua produced the highest amount of branchfall of the three sites (Table 4).

TABLE 6. Mean daily windrun (km/day) averaged for each season for each site (MET 1984/85)

SEASON	WAIPOUA	RIVERHEAD	TAIRUA
Autumn	297	146	152
Winter	286	157	193
Spring	322	172	203
Summer	303	129	166

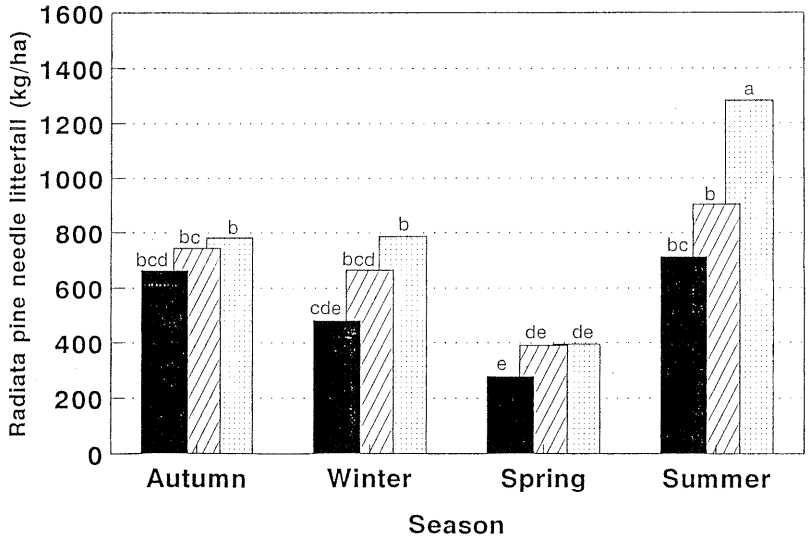
SEASON EFFECTS

Baker (1983) concluded that the peak litterfall period for radiata pine occurs in the summer months, but Will (1959) and Levett *et al.* (1984) observed peak litterfall in the autumn. From Figures 2 a, b, & c it can be seen that in this study litterfall peaked in the summer season at Waipoua but in autumn at Tairua. Riverhead showed a more consistent pattern. Averaged across the three sites there was a highly significant season effect, with the highest in autumn and the lowest in spring.

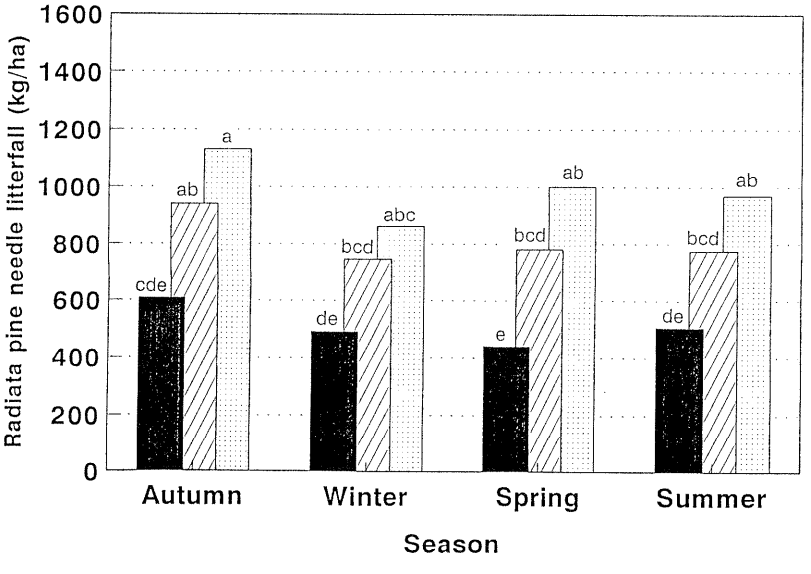
Baker (1983) found that the concentrations of N and P in dead foliage varied markedly between seasons but were consistently lowest at times of peak litterfall. Lamb and Florence (1975) also showed strong seasonal patterns in litterfall N and P concentrations. Levett *et al.* (1984) found that there was a seasonal cycle of P concentrations in radiata pine litterfall and that P levels were highest in the spring.

Figures 2 a,b,c. Seasonal differences between treatments

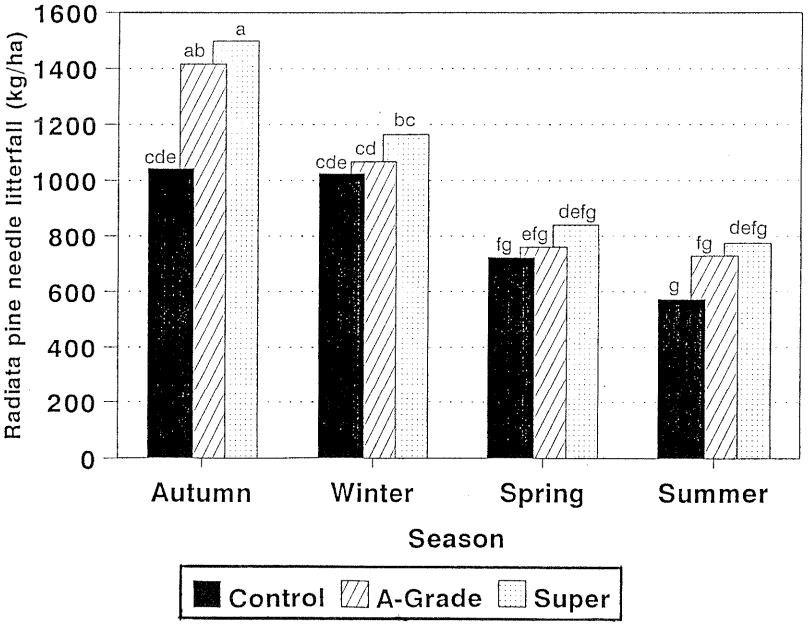
A. Waipoua Forest



B. Riverhead Forest



C. Tairua Forest



Letters with the same value were not significantly different from each other at P=0.05

This study shows that the litterfall tended to have the lowest nutrient concentrations in the autumn and winter months. Highest nutrient concentrations were observed during the spring at Waipoua and in the summer at the other two sites (Tables 7a and 7b). This shows that at times of lowest litterfall the nutrient concentrations were highest.

TABLE 7a. Seasonal variations in phosphorus concentrations (%) of radiata pine needle litterfall

	AUTUMN	WINTER	SPRING	SUMMER	MEAN	PROB
WAIPOUA						
Control	0.038	0.036	0.044	0.041	0.039	trt <0.001
A-Grade	0.083	0.077	0.090	0.107	0.089	seas<0.001
Super	0.084	0.071	0.096	0.114	0.091	trt*seas 0.123
RIVERHEAD						
Control	0.023	0.023	0.028	0.029	0.026	trt <0.001
A-Grade	0.041	0.043	0.051	0.056	0.048	seas 0.022
Super	0.054	0.057	0.064	0.066	0.061	trt*seas 0.966
TAIRUA						
Control	0.043	0.034	0.039	0.045	0.040	trt <0.001
A-Grade	0.051	0.047	0.050	0.053	0.050	seas 0.079
Super	0.059	0.049	0.053	0.065	0.056	trt*seas 0.973

TABLE 7b. Seasonal variations in nitrogen concentrations (%) of radiata pine needle litterfall

	AUTUMN	WINTER	SPRING	SUMMER	MEAN	PROB
WAIPOUA						
Control	0.459	0.493	0.555	0.529	0.509	trt 0.019
A-Grade	0.495	0.537	0.606	0.512	0.538	seas<0.001
Super	0.457	0.488	0.546	0.489	0.495	trt * seas 0.700
RIVERHEAD						
Control	0.667	0.620	0.669	0.757	0.678	trt 0.012
A-Grade	0.542	0.591	0.627	0.705	0.690	seas<0.001
Super	0.571	0.592	0.632	0.655	0.613	trt * seas 0.659
TAIRUA						
Control	0.853	0.751	0.766	0.955	0.831	trt 0.011
A-Grade	0.746	0.691	0.722	0.758	0.729	seas 0.075
Super	0.699	0.609	0.679	0.766	0.688	trt * seas 0.905

The effect of season was highly significant at both Waipoua and Riverhead, but not at Tairua.

At all three forests the fertiliser treatment effects on N concentration were highly significant. At Tairua litter in the Control plots had a higher N concentration than in fertilised plots.

Tables 7a and 7b also show that there was no interaction between treatment and season for variations in N and P concentrations.

At all three sites the treatment effect on P concentration was highly significant (from Table 7a).

season for variations in N and P concentrations.
At all three sites the treatment effect on P concentration was highly significant (from Table 7a).

Hunter and Hunter (1991) showed that foliar P concentrations in the trees in the fertilised plots were clearly related to the P retention capacity of the soil at each site. Chemical analysis of litterfall confirmed that at Waipoua, P levels had been increased markedly by application of phosphate fertiliser, to levels that were appreciably higher than at the other two sites. Litterfall P concentrations at Riverhead and Tairua were similar.

AMOUNTS OF N AND P CYCLED

Tables 8a and 8b show estimates of the amounts of phosphorus and nitrogen returned to the soil in radiata pine litterfall, seven years after the fertiliser was applied. The highest amounts of both nitrogen and phosphorus were returned in plots treated with Superphosphate, and the lowest amounts in Control plots. Waipoua returned the most phosphorus and the least nitrogen for each type of phosphate treatment.

TABLE 8a. Weight of phosphorus (kg/ha/yr) returned to the soil in radiata pine needle litterfall

	CONTROL	A-GRADE	SUPER
WAIPOUA	0.83	2.41	2.96
RIVERHEAD	0.52	1.55	2.40
TAIRUA	1.35	1.99	2.41

TABLE 8b. Weight of nitrogen (kg/ha/yr) returned to the soil in radiata pine needle litterfall

	CONTROL	A-GRADE	SUPER
WAIPOUA	10.88	14.55	16.08
RIVERHEAD	13.87	22.36	24.29
TAIRUA	17.97	28.96	29.43

CONCLUSIONS.

At the three sites investigated, the total amount of litterfall and its N and P content were increased by phosphate treatment. Superphosphate treatment increased litterfall to a greater degree than phosphate rock. This effect was observed seven years after treatment.
Trees at the site with the highest growth rate, produced the highest amount of litterfall.
Highest nitrogen and phosphorus concentrations in litterfall were observed during summer months and lowest concentrations during winter months. Nutrient concentrations tended to be highest during the periods of lowest litterfall.
The highest P concentrations in litterfall was observed in Superphosphate treated plots at Waipoua.

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