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Part 2 Giles Creek - Fertiliser response of *Coprosma robusta* and *Nothofagus fusca* seedlings

Abstract

Fertiliser trials were conducted to determine possible nutrient requirements of native forest species growing on soil and overburden materials disturbed by alluvial mining operations. The pioneer shrub, karamu (*Coprosma robusta*) responded to treatments containing urea and blood and bone, but not to superphosphate, in a field trial located on a coal mine overburden dump at Giles Creek, near Reefton. The response to the fertilisers containing nitrogen was smaller than anticipated, possibly because of nitrogen fixation by lotus prior to establishment of the trial.

In glasshouse trials with soil and gravel materials collected from stockpiles at Giles Creek, the growth of karamu and the climax tree, red beech (*Nothofagus fusca*), was severely limited when nitrogen and phosphorus were omitted from otherwise complete nutrient solution applications. Red beech showed much more pronounced yield reductions (>90%) than karamu (ca. 50%) when phosphorus was omitted from the nutrient solutions. Small yield reductions occurred in karamu, but not in red beech, when magnesium and lime were omitted from the soil, but there were no yield reductions when sulphur, potassium, or boron were omitted from either material. In the treatments where nitrogen was omitted, the leaves of both species exhibited deficiency symptoms; in karamu older leaves were yellow, while in red beech older leaves were red. For equivalent nutrient treatments, mean yields of both species on gravel were between 18% and 74% of those on soil, the differences being most marked where nitrogen was omitted, showing the value, particularly for site nitrogen levels, of stripping soil separately and respreading it on top of overburden materials.

Studies need to be initiated to examine the use of legumes for improving ecosystem nitrogen levels where it is not feasible to replace soil horizons on top of overburden materials. In the absence of a vigorous nitrogen fixing species, nitrogen fertiliser should be applied as a matter of course of native forest species planted on highly nitrogen deficient materials such as gravels. Further study of the nutrition of a wider range of potential rehabilitation species should be undertaken to improve the species selection process for land rehabilitation.

1. Introduction

Techniques for revegetating land disturbed by mining in indigenous forest areas in the West Coast region were investigated by the Forest Management and Productivity Section, New Zealand Forest Research Institute, Rangiora and Christchurch, for the Department of Conservation. The work was carried out on a DoC mining lease at Giles Creek, near Reefton, where Dunollie Coal Mines Ltd were extracting coal by opencast mining from a terrace site covered by beech forest.

The project was initiated in 1990 when two field trials were established on an existing overburden dump formed by the mining operation. The purpose was to obtain an early indication of the influence of plant stock type, fertilisers, and animal control measures on the survival and growth of native tree and shrub species. Here we report results from a fertiliser trial which examined the nitrogen (N) and phosphorus (P) requirements of the pioneer shrub, karamu (*Coprosma robusta*), on the mixed soil and gravel materials of the overburden dump. We also report results from a glasshouse trial which examined the requirements of karamu, and the climax tree, red beech (*Nothofagus fusca*), for a wider range of nutrients when grown in soil and gravel overburden materials collected from stockpiles. To our knowledge, no previous studies have been undertaken to determine possible fertiliser requirements of native forest species on materials arising from mining operations in this region or elsewhere in New Zealand.

2. Objectives

1. To determine the N and P requirements of karamu growing on an existing overburden dump at Giles Creek.
2. To determine N, P, sulphur (S), potassium (K), calcium (Ca), magnesium (Mg), boron (B), and lime requirements of karamu and red beech growing on stockpiled soil and gravel overburden materials in a glasshouse pot trial.

3. Methods

3.1 FIELD TRIAL

The trial was established on the top of an overburden dump at Giles Creek. The material capping the dump was mainly composed of finely weathered material from the granite gravels that overlay the coal seam, but included forest soil horizon and sandstone interburden material. The material was moderately acid, had low or very low levels of organic carbon (C), total N, available P (Olsen extractable), and exchangeable cations, and a low cation exchange capacity (CEC) (Table 1). Annual precipitation at Maimai, approximately 5 km south of the trial site, was 2600 mm. The elevation of the trial site was approximately 200 m.

TABLE 1. CHEMICAL CHARACTERISTICS OF THE FIELD TRIAL SUBSTRATE (0–20 CM), AND OF STOCKPILED SOIL AND GRAVEL MATERIAL USED IN THE GLASSHOUSE TRIALS.

	pH	Organic C (%)	Total N (%)	Cation exchange properties (me./100 g)				Olsen P (ppm)
				CEC	K	Ca	Mg	
field trial	5.4	0.8	0.15	7.3	0.13	0.87	0.82	3.4
stockpiled soil	4.7	2.6	0.12	14.4	0.13	0.95	0.29	1.0
stockpiled gravels	5.2	1.4	0.05	8.5	0.10	1.82	1.12	1.0

Prior to establishment of the trial the area had a herbaceous vegetation cover dominated by rush (*Juncus* spp.), lotus (*Lotus pedunculatus*), and Yorkshire fog (*Holcus lanatus*). This cover was removed by spraying with herbicide consisting of a mixture of glyphosate (Roundup®, 5 1/ha), terbuthylazine (Gardoprim®, 20 1/ha), and clopyralid (Versatil®, 3.3 1/ha) in late July 1990. Regenerating vegetation was controlled with release sprays consisting of glyphosate (2.5 1/ha) and clopyralid (0.3 1/ha), applied in May 1991, and glyphosate (2.5 1/ha) applied in December 1992.

The trial was planted with 30 cm high one-year-old bare root karamu plants in a fenced plot in early August 1990. The plants were spaced at 1 m intervals along rows one metre apart. Four fertiliser treatments were applied at the time of planting: (1) no fertiliser (control), (2) superphosphate alone (110 g/tree), (3) urea (24 g/tree) plus blood and bone mixture (150 g/tree), and (4) urea (24 g/tree) plus blood and bone mixture (150 g/tree) plus superphosphate (110 g/tree). The rates of elemental N and P applied in treatments 2–4 were as follows: (2) N=0, P=10; (3) N=20, P=7; (4) N=20, P=17. Blood and bone was used in addition to urea to supply N, to provide a slowly available organic form of N in case of rapid loss of inorganic N from urea by leaching. The fertiliser application, but without blood and bone, was repeated at the beginning of the third year, in September 1992. Fertilisers were applied by placement in a spade notch about 5–10 cm deep and 10–20 cm from the stem base. The trial was laid out as a randomised block design with five replicates, each replicate consisting of five adjacent individual plants per treatment.

Plant heights were measured at establishment and periodically thereafter to determine treatment effects.

3.2 GLASSHOUSE TRIALS

Soil and overburden gravel materials for the glasshouse trials were collected from the surface of stockpiles at Giles Creek in August 1990. Terrace soils in the immediate vicinity of the mine site are dominantly of the Ahaura series, though minor areas of Maimai, Ikamatua, and Hokitika soils also occur (Ross & Mew 1995).

The soil consisted of organic, A, and B horizons mixed in unknown proportions as stripped from the mine site after logging and subsequently stockpiled. The soil had very low levels of exchangeable cations and available (Olsen extractable) P (Table 1).

Gravels underlying the terrace soils are dominantly of granite and gneiss, though greywacke and schist materials are also present. The gravel material collected for the pot trial was less acid than the soil, and had higher exchangeable Ca and Mg levels, but lower CEC, C, and N levels than the soil. As with the soil, exchangeable K and available P levels were very low.

Soil and gravel materials were passed through 10 mm and 5 mm sieves respectively to remove coarse rock and root fragments, and thoroughly mixed before potting in 1.6 litre pots. Potential nutrient deficiencies of N, P, S, K, Mg, and B, for both red beech and karamu, were determined by applying a series of complete nutrient supplements which omitted one of the above elements at a time (see Table 2). Lime was applied to the soil, but not to the gravel, to counteract the possibility of ammonium toxicity developing from the applied ammonium nitrate. Omission of lime was included as one of the treatments. The lime was mixed throughout the soil prior to potting, while all other nutrients were applied to the soil surface in solution after potting, at the time of

TABLE 2. CHEMICALS USED AND RATES OF APPLICATION IN GLASSHOUSE FERTILISER TRIALS.

Rates given are for a single application; all nutrients except lime were applied three times over the duration of the trial.

Chemical	Rate of application		Presence in treatment							
	chemical (g/pot)	nutrient (kg/ha)	complete	– N	– P	– S	– K	– Mg	– B	– lime
NH_4NO_3	0.20	N= 40	p[1]	-	p	p	p	p	p	p
$NaH_2PO_4.2H_2O$	0.207	P= 25	p	p	-	p	p	p	p	p
K_2SO_4	0.147	K= 40, S=16	p	p	p	-	-	p	p	p
$MgSO_4$ $.7H_2O$	0.203	Mg= 12, S=16	p	p	p	-	p	-	p	p
H_3BO_3	0.019	B=2	p	p	p	p	p	p	-	p
$CaCO_3$	3.3	$CaCO_3$= 2000	p	p	p	p	p	p	p	-
KCI	0.127	K = 40	-	-	-	p	-	-	-	-
Na_2SO_4	0.117	S = 16	-	-	-	-	p	p	-	-
$MgC1_2.6H_2O$	0.116	Mg = 12	-	-	-	p	-	-	-	-
Fe EDTA	0.011	Fe = 1	p	p	p	p	p	p	p	p
$CuC1_2..2H_2O$	0.0022	Cu = 0.5	p	p	p	p	p	p	p	p
$MnC1_2.4H_2O$	0.0059	Mn = 1	p	p	p	p	p	p	p	p
$ZnC1_2$	0.0034	Zn = 1	p	p	p	p	p	p	p	p
$NaMoO_4.2H_2O$	0.004	Mo = 0.01	p	p	p	p	p	p	p	p

[1]p = present in treatment

planting in late October 1990, and in two further applications, in mid-December and in mid-February. The trials were run concurrently and adjacent to each other on the glasshouse bench, and were laid out in randomised block designs with five replicates.

Seedlings of both species were raised in a mixture of forest duff (collected from under forest at Giles Creek), sand, and peat, mixed in proportions of 1:1:1, and were transplanted (5 per pot) into the pots when they were 2–3 weeks old, and 2–5 cm in length. The trial was watered as required with a semi-automatic system employing individual drippers which delivered approximately 160 ml to each pot over a five minute interval.

The trial was harvested in early April 1991 after a period of five months. At harvest, plant shoots were cut at the soil surface, dried at 70°C, and weighed.

4. Results

4.1 FIELD TRIAL

On the overburden dump, karamu responded significantly to treatments containing urea and blood and bone (predominantly N), but not to superphosphate (P) (Table 3).

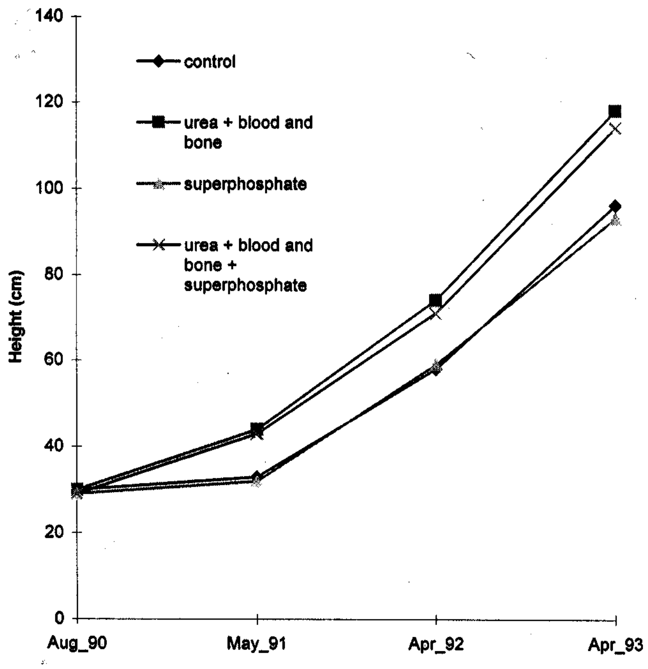
The response to urea and blood and bone was observed at the end of the first growing season (May 1991, Fig. 1), and the difference in height growth that developed at that stage was maintained throughout the remaining measurement periods, but did not increase, even after the second fertiliser application (September 1992).

It is possible that the better growth of karamu in the treatments containing N was partly due to P, as the organic form applied (blood and bone) in the first application contained some P, and there may have been some interaction between the two nutrients. However this seems unlikely because of the total lack of a response to P alone. Further, there was no additional benefit from supplying P as superphosphate over and above the urea plus blood and bone treatment.

TABLE 3. EFFECT OF FERTILISER ON THE GROWTH OF KARAMU ON AN OVERBURDEN DUMP. VALUES ARE MEANS OF PERIODIC HEIGHT MEASUREMENTS FOR ALL ASSESSMENTS AFTER FEBRUARY 1991.

Treatment	Height (cm)
control	50 a[1]
superphosphate	52 a
urea + blood and bone	65 b
urea + blood and bone + superphosphate	64 b

[1] Values without a letter in common are significantly different at $p = 0.05$ (LSD test)



Despite being located on the top of an overburden dump, the site was poorly drained, and surface water lay in low-lying microsites for long periods after rain. Plant growth was poor and mortality was high in plants established in these depressions, indicating that good drainage is likely to be important in establishing native woody species on rehabilitated mine sites in medium- to high-rainfall environments.

FIGURE 1. EFFECT OF FERTILISER ON THE GROWTH OF KARAMU ON AN OVERBURDEN DUMP.

4.2 GLASSHOUSE TRIALS

Analysis of variance of the trial results showed that there were significant differences in plant yield between nutrient treatments on both substrates.

TABLE 4. EFFECT OF NUTRIENT OMISSION ON THE MEAN YIELDS (G/POT) OF RED BEECH AND KARAMU ON STOCKPILED SOIL AND GRAVEL OVERBURDEN MATERIALS IN THE GLASSHOUSE TRIAL.

Treatment	Gravel	Soil	Gravel/Soil (%)
complete nutrients	4.98 a[1]	8.92 a	56
–N	0.57 c	3.10 d	18
–P	2.04 b	3.34 d	61
–S	5.25 a	8.41 a	62
–K	5.15 a	8.29 a	62
–Mg	5.51 a	7.41 b	74
–B	5.51 a	8.26 a	74
–lime	-	6.54 c	-
Mean species yields			
red beech	2.00 b	4.58 b	44
karamu	6.28 a	8.99 a	70

[1] Values without a letter in common are significantly different at p = 0.05 (LSD test).

On soil, the mean yield of both species was highest in the complete nutrient treatment (Table 4).

There were major yield reductions when both N and P were omitted, and smaller, but still significant reductions when lime and Mg were omitted (Table 4). There were no significant yield reductions when S, K, or B were omitted.

In the –N treatment, the leaves of both species exhibited pronounced nutrient deficiency symptoms; in karamu the older leaves became yellow, while in red beech the older leaves were red. Mean yields of karamu were twice those of red beech, and there was a significant species by nutrient interaction, indicating that the two species responded differently to the omission of nutrients. Karamu was more severely affected by the omission of N, Mg, and lime than red beech (red beech was unaffected by the omission of Mg and lime), whereas red beech was much more severely affected by the omission of P (Fig.2).

On gravel, mean yields in the complete nutrient treatment were similar to the treatments where S, K, Mg, and B were omitted (Table 4). Again, however, there were major yield reductions when N and P were omitted. N deficiency symptoms were again apparent in the –N treatment. Mean yields of karamu were three times those of red beech and a species by nutrient interaction was again present. The major difference between species in this case was limited to the much greater effect of omitting P on the growth of red beech than on karamu (Fig. 3).

In all nutrient treatments the yields of both species on soil were greater than those on gravel (Table 4, Figs 2 and 3). The differences were most marked in the treatments where N was omitted, indicating the importance of the soil horizons in supplying this element.

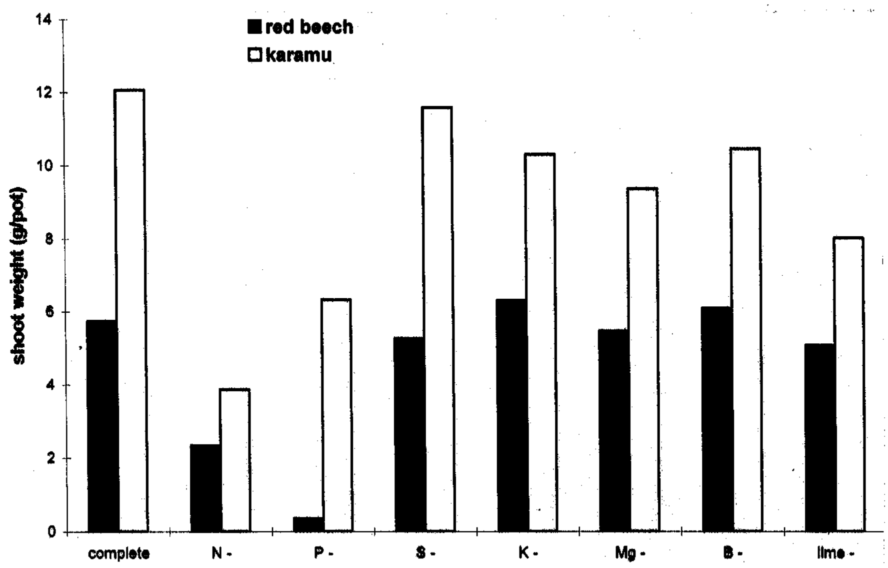


FIGURE 2. EFFECT OF NUTRIENT OMISSIONS ON THE GROWTH OF RED BEECH AND KARAMU ON STOCKPILED SOIL, GLASSHOUSE TRIAL.

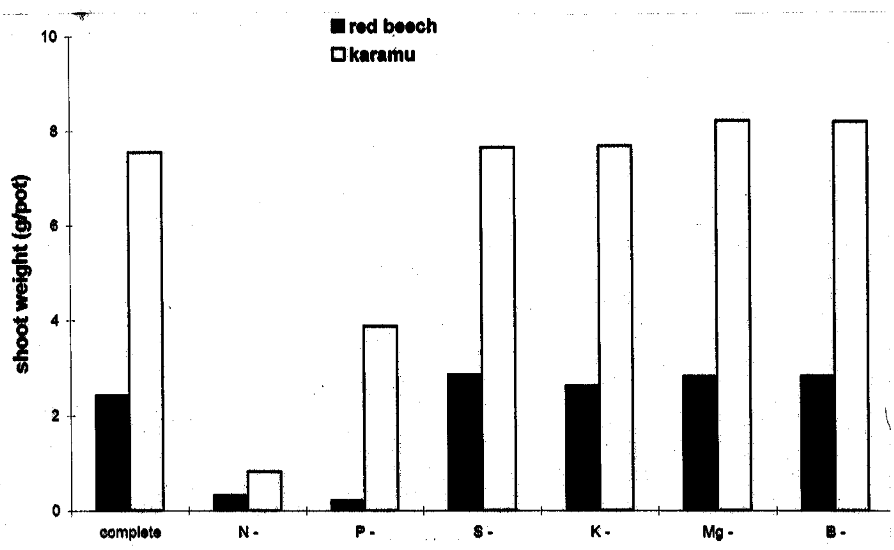


FIGURE 3. EFFECT OF NUTRIENT OMISSIONS ON THE GROWTH OF RED BEECH AND KARAMU ON OVERBURDEN GRAVELS, GLASSHOUSE TRIAL.

5. Discussion and conclusions

On mine overburden materials containing little or no soil or organic material, N is likely to be the major deficient element for plant growth. Nitrogen was deficient in the soil used in the pot trial, and very deficient in the gravel material; it was also deficient in the field trial, although there the size of the response to N was less than expected, indicating the presence of some N in the substrate. While some of this may have originated from a small amount of soil present in the substrate material, it is likely that most would have been derived from fixation by lotus, which had invaded the site prior to establishment of the trial. This result demonstrates the value of incorporating a N-fixing species at an early stage in revegetation programmes on N-deficient materials such as gravels, even if competition from that species has to be removed at a later stage by the use of herbicide, to allow the introduction of other desired species. Fitzgerald (1980) has demonstrated that a wide range of pasture legumes and other N-fixing species will grow productively on alluvial gold dredge tailings in Westland. In the absence of a vigorous N-fixing species, N fertiliser should be applied as a matter of course to native trees and shrubs growing on overburden materials, except perhaps where topsoils have been replaced on the surface of workings.

Karamu did not respond to P fertiliser in the field trial, in contrast of the glasshouse trial where omission of P from the nutrient solutions led to growth reductions on both soil and gravel materials. This difference may be explained by the fact that the substrate in the field trial contained some fine sandstone material originating from between the coal seams (interburden), which can contain high quantities of Ca-bound P (C. Ross, pers. comm.). This P is not extracted by the Olsen method for determining available P, which mainly extracts aluminium- and iron-bound forms of P.

In the glasshouse trials, red beech showed a much more pronounced yield reduction (>90%) than karamu (ca. 50%) when P was omitted from the nutrient solutions, indicating that the P present was much more available to karamu than to red beech. This may reflect differences between the species in mycorrhizal infection or requirement. The fact that P was present and available to karamu on all three substrates tested in these trials, though to different extents, may also indicate gorse, which is pioneer N-fixing species, is such an effective invader of mined-over areas.

For equivalent treatments, mean yields of both species on gravel in the glasshouse trial varied from 18% to 74% of those on soil. These results show the efficacy, particularly for ecosystem N levels, of stripping and stockpiling soils separately, for respreading on overburden materials. The stockpiled soils in the present study consisted of mixed topsoil and subsoil horizons; further advantage may be obtained by stripping and replacing topsoil and subsoil horizons separately, to avoid diluting nutrients, particularly N, which are concentrated in the top of the soil profile. A field trial to compare the growth of forest species on mixed and layered (topsoil over subsoil) horizons is in progress at Giles Creek. Advantage may also be obtained by placement of materials with a high P content, such as the interburden sandstone in this study, immediately below the topsoil horizons.

Phosphorus, S, K, and lime are all required for pasture growth on Ahaura soils (with N being provided by a legume), and B may also be required by brassica root crops (During 1972). Small responses to lime and Mg occurred on the soil used in the glasshouse trial, but there was no indication of a response to S, K, or B on soil or gravels. The responses occurred in karamu only, possibly because of the faster growth rate of this species, and were of insufficient magnitude to recommend application of Mg fertiliser or lime in field situations.

Optimum fertiliser rates have not been determined in the present study. The spot application rates used in the field trial reported here were derived from rates recommended for seedlings in plantation forestry (Ballard 1984) and are probably appropriate for correcting N and P deficiencies in native forest species at planting. In established plantings, N deficiency in plantation forestry is commonly corrected by broadcasting urea at a rate of about 450 kg/ha, while P deficiency is commonly corrected by broadcasting superphosphate at about 100 kg/ha (Will 1985), and these rates are also probably applicable to established plantings of native forest species. Where deficiencies of both N and P occur, di-ammonium phosphate (DAP) may be applied at 450 kg/ha, in place of urea and superphosphate.

6. Recommendations

1. Studies need to be initiated to examine the use of legumes for improving ecosystem N levels where it is not feasible to replace soil horizons on top of overburden materials.
2. In the absence of a vigorous N-fixing species, N fertiliser should be applied as a matter of course to native forest species planted on highly N deficient materials such as gravels.
3. The present study has shown major differences in the P nutrition of two native forest species. Further study of the nutrition of a wider range of potential rehabilitation species should be undertaken to improve the species selection process for land rehabilitation.

7. References

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