Establishing native species from seed within exotic grasslands

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Abstract

There is an increasing interest in converting existing vegetation, often dominated by exotic grasses, through to native (usually woody) plant communities. This may happen by natural processes of spread by seed, by physically planting nursery-grown seedlings, or by direct sowing of seed. We explored whether native species could be established from seed into ex-pasture grassland environments at seven sites in North Canterbury and Banks Peninsula. Particular emphasis was placed on site preparation, via management of the grass cover (grazing or mowing), soil disturbance, and the use of herbicides to control competition. Seed of twenty-three species was sown in late June 2006 in the form of locally collected pure seed and forest litter. After 1 year, almost without exception, native seedlings were only found where seed had been sown. At most sites there was a definite trend for increased seedling numbers where herbicides were applied, particularly where the grass was short, but the greatest increases occurred where ground disturbance had created a bare soil surface. The only situations where there were more seedlings in herbicide treated plots than in disturbed plots were where the grass was naturally short or had been mown. At the one site where it was known how many seeds had been sown, kohuhu (*Pittosporum tenuifolium*) had the best emergence in the short grass, followed by poroporo (*Solanum aviculare*) and broadleaf (*Griselinia littoralis*). Kohuhu also had the best mean emergence in the long grass, followed by cabbage tree (*Cordyline australis*), broadleaf and kowhai (*Sophora tetraptera*). Seedlings tended to be taller in disturbed plots. Seventy percent of the seedling numbers that were recorded in mid-season were still present at the season's end, with the best survival in the disturbed treatment. We conclude that the establishment of native species by direct seeding has potential as a cheaper technique for restoring an indigenous woody cover in ex-pasture grassland environments, particularly where large areas have to be treated. However, the results of seeding will vary between sites and seasons, and weed control after seedling emergence remains a critical factor. More research is needed in these areas.

Introduction

Many land managers (private and government) are increasingly interested in converting existing vegetation (often dominated by exotic grasses) through to a native (usually woody) plant community (Parliamentary Commissioner for the Environment 2001). This may happen by natural processes of spread by seed, as Hugh Wilson has very successfully demonstrated on land dominated by gorse (*Ulex europaeus*) at Hinewai Reserve on Banks Peninsula (McCracken, 1993; Wilson, 1994). However, the source of native seed and the vectors to carry it can be limited or non-existent. In addition, it is difficult to succeed with natural seeding processes where vigorous herbaceous species (notably grasses) are involved (Ledgard and Davis, 2004). More active management is another option, in the form of planting or direct seeding. Planting involves the establishment of nursery-grown native seedlings by hand, often followed by tending in the form of weed and animal control. It is the most commonly used native plant establishment method (Porteous, 1993), but it is time-consuming and expensive (up to NZ$45,000/ha, Bergin and Gea, 2005). Direct seeding involves artificially introducing native seed, maybe accompanied by herbicides to gain control of grasses, and initial soil disturbance or scarification to assist seed contact with mineral soil. There is an increasing interest in direct seeding, involving simple and effective techniques, which can be extensively applied and may not be as reliant on considerable inputs of funds and labour. Very similar techniques are used by many farmers to improve grazed pastures by the introduction of new grasses and legumes (Barker *et al.*, 1988; Dodd and Power, 2007).

Douglas *et al.* (2007) reviewed the current state of knowledge on the direct seeding of native species into pasture land, and concluded that direct seeding can be cost-effective as a restoration technique, but its general applicability is limited because of inadequate supplies of viable seed, lack of knowledge on appropriate sowing times and rates, unreliable field germination and seedling emergence, and frequent intense competition from existing vegetation, particularly exotic grasses. A comparison of estimated costs between spaced planting (2,500 plants/ha) and direct seeding showed the latter to be generally the cheapest option.

Ledgard and Davis (2004) successfully sowed seed of native woody species onto soil bared by a forest fire, and showed that the presence of grass significantly depressed the establishment of native plants. Researchers at Landcare Research in Hamilton looked at seedbed treatment effects on native seedling establishment in pastures, and found competitive plant cover and soil fertility were the two most important factors in seedling success (Stevenson and Smale, 2005). AgResearch scientists at Whatawhata sowed native species during autumn and spring into grazed pasture treated with herbicide, and mob-stocked with sheep to trample the seed into the soil (Dodd and Power, 2007). Mob stocking significantly improved seedling strike in the spring, but not in the autumn. After 2.5 years, two shrubs, koromiko (*Hebe salicifolia*) and karamu (*Coprosma*

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robusta), had established successfully, out of seven species sown. As did Douglas *et al.* (in press), they concluded that direct seeding of native plants can be cost-effective as a restoration technique.

Privately, some individual landowners have explored the sowing of native species. One farmer near Staveley in central Canterbury has promoted vigorous regeneration of beech alongside mature black beech (*Nothofagus solandri*) trees once the site was fenced off and the grass removed by spraying (Alan Totty, pers comm). Another landowner near Hikurangi in Northland has successfully sown manuka onto ploughed lines in pasture land (Stephen King, pers comm). King stresses the importance of carrying out a weed assessment before any native sowing to ensure that weeds are not likely to occupy any man-made niche intended for natives. To the authors' knowledge, Stephen King is the only person to have tried seeding on an extensive scale using machines.

The aim of this study was to determine whether native species could be established from seed into ex-pasture grassland environments in North Canterbury and Banks Peninsula, with particular emphasis on site preparation by means of managing the grass cover (grazing or mowing), soil disturbance and the use of herbicides to control pasture competition.

Methods

Seven trial sites located in North Canterbury and Banks Peninsula were selected for the study (Table 1). Choice was restricted to those sites offered by land owners, but the aim was to sample a range of environments, particularly relative to rainfall. All were located on pasture land dominated by an herbaceous cover usually consisting of one, or a mix of, the following common exotic species - browntop (*Agrostis capillaris*), ryegrass (*Lolium perenne*), sweet vernal (*Anthoxanthum odorata*), cocksfoot (*Dactylis glomerata*), white clover (*Trifolium repens*), yarrow (*Achillea millefolium*) and occasionally mouse-eared hawkweed (*Hieracium pilosella*).

The sites at Balmoral Reserve and Lyttelton were not included in the analyses as very few native seedlings were found. In addition, little use has been made of results from Birdlands, as even though there was a good emergence of seedlings in some treatments, the results were compromised by mortalities caused after some experimental post-establishment use of herbicides to control weeds (see Discussion).

All soils belong to the order of Pallic soils. On the sites featuring in this paper (all except Balmoral Reserve and Lyttelton), soil profiles ranged from stony and free draining with virtually no topsoil (Medbury), to fertile loams with good topsoil development at the other four sites (Kate Valley East and West, Duvauchelle and Birdlands). Other site characteristics are given in Table1.

Table 1. Characteristics of the seven trial sites in North Canterbury and Banks Peninsula.

Name	Location	Owner	Rainfall (mm)	Altitude (m)	Aspect	Slope (^{0})	Grass cover	Exposure
Medbury Reserve	Culverden Basin	Dept of Conservation	700	220	Flat	0	Ungrazed (short).	Very exposed to all winds
Kate Valley West	Omihi Hills	Transwaste Canterbury	920	300	S	10	Grazed (short) & ungrazed (long)	Exposed to south and west
Kate Valley East	Omihi Hills	Transwaste Canterbury	920	270	S	20	Ungrazed (long).	Sheltered
Duvauchelle	Akaroa Harbour, Banks Pen	Private	1200	180	W	8	Ungrazed (long).	Very sheltered
Birdlands *	Okuti Valley, Banks Pen	Private	1500	100	SW	5	Ungrazed (long).	Very sheltered
Balmoral Reserve *	Hills along S side of Culverden Basin	Dept of Conservation	700	300	N	18	Ungrazed (long).	Very exposed to west and north
Lyttelton *	Above Lyttelton Harbour	Private	800	200	SW	12	Grazed (short) & ungrazed (long)	Exposed to south

* Results not included in this paper

Figure 1a. Medbury - a hard, stony, drought-prone site.

Figure 1b. Kate Valley West - a recent pasture site with good soils

Figure 1c. Duvauchelle - a well sheltered site with good soils

Figure 1d. Birdlands - another well sheltered site with good soils

Treatments assessed in the trials were control (C), herbicide application (H), soil disturbance or cultivation (D), and seed sowing (S). These were applied to both long (except at Medbury where long grass was not present) and short grass; the short grass either having been recently grazed, or mown (to simulate grazing). In the herbicide treatments, glyphosate was applied from a knapsack at 10 mls / litre in late May, 2006, 3 weeks after any mowing and prior to sowing. Soil disturbance consisted of using a spade to turn over sods of soil (50 mm deep), to bury the grass and leave a ground surface of bare soil. Short grass was either already present, due to sheep grazing immediately prior to sowing (only at Kate Valley West), or artificially created by mowing long grass sites. Mowing was carried out in early May, 2006, using a motorised 'weed eater' which cut the grass to around 10 mm height. The cut grass was raked from the mown area.

Seed was all collected from near the trial area. It was collected either in pure form or as litter gathered from under local native forest remnants (Table 2). The species contained in the litter were determined from seedling emergence after litter samples had been sown in seed trays housed in a nursery shadehouse. At Duvauchelle, all seed was sorted and stored by the land owner, with seeds separated from any fleshy fruits, before mixing with moist sand and placing in the fridge for 2 months. For all the other sites, the pure seed was dried (after removal of any fleshy parts) and stored in large screw-top pottles in the fridge. Where litter was used (Kate Valley and Birdlands), it was collected from under bush remnants by removing the coarse material (large leaves and branchlets) on the forest floor, before scraping off the top millimetres of fine litter and loose soil. This was stored in sacks in a coolstore before sieving to remove any remaining coarse matter just before sowing.

With the exception of the seed sown at Duvauchelle, the weight and number of seed applied in each plot was not recorded. Available seed was evenly divided between the plots to be sown, and where litter was collected, 1 litre of litter was sown along with the seed into every 0.5 x 0.5 m plot. At Duvauchelle, twenty seeds of each species were sown in each plot, together with approximately 2-3 g (at c. 40,000 seeds/g) of kanuka seed. All sites were sown between June 26 and July 10, 2006.

All sown and disturbed plots were protected from animal browse and bird predation by 0.5 x 0.5 m cages made of bird netting. None of the unsown plots, with the

Table 2. Native species sown as pure seed (S) and litter (L) at the seven sites.

Species	Medbury Reserve	Kate Vly East	Kate Vly West	Bird lands	Duvauchelle	Balmoral Reserve	Lyttelton
Kanuka (*Kunzea ericoides*)	S	S/L	S/L	S/L	S	S	S
Kohuhu (*Pittosporum tenuifolium*)		L	L	L	S		
Karamu (*Coprosma robusta*)		L	L	S/L			S
Coprosma -small leaf (*Coprosma* sp)		L	L			S	
Mingimingi (*Coprosma propinqua*)						S	
Poroporo (*Solanum aviculare*)		S/L	S/L	S/L	S		
Broadleaf (*Griselinia littoralis*)					S		
Flax (*Phormium tenax*)					S		
Cabbage Tree (*Cordyline australis*)		L	L		S		
Kowhai (*Sophora tetraptera*)				L	S		
Ngaio (*Myoporum laetum*)		L	L	S	S		
Mahoe (*Melicytus ramiflorus*)		L	L	S/L	S		
Five Finger (*Pseudopanax arboreus*)		L	L	S	S		S
Kotukutuku (*Fuschia excorticata*)				L			
Flax (*Phormium tenax*)		L	L		S		
Red Mapou (*Myrsine australis*)					S		
Lacebark (*Hoheria angustifolia*)				L			
Totara (*Podocarpus totara*)				L			
Porcupine bush (M*elicytus alpinus*)						S	
Horopito (*Pseudowintera colorata*)							S
Bush Lawyer (*Rubus cissoides*)				L			
Tree Tutu (*Coriaria arborea*)				L			
Creeping pohuehue (*Muehlenbeckia australis*)		L	L	L			

exception of the disturbed plots, were similarly protected. A replicated split-plot layout was used, with three blocks each of long (except at Medbury) and short grass, within which the four treatments, plus combinations, were randomly placed. Limitations of seed meant that not all combinations were tested at all sites. The herbicide and mowing treatments were applied over 2 x 2 m areas, but seed was only sown within central 0.5 x 0.5 m plots. The disturbance treatment was only applied to the central 0.5 x 0.5 m plot.

A preliminary assessment was undertaken in February, 2007, with the main assessment in mid June 2007. The sampling was carried out using a 0.5 x 0.5 m sampling quadrat, internally divided into 0.1 x 0.1 m subplots. The quadrat was placed over the 0.5 m^2 central plot, the top left and bottom right corners of which were permanently marked with pegs to allow exact positioning. The number of seedlings was counted within each plot, and the height of the tallest seedlings recorded.

Data analysis was by analysis of variance to identify significant differences in seedling numbers between treatment levels at each site. Analyses were carried out with R (version 2.5.0, The R Foundation for Statistical Computing).

Results

Almost without exception, native seedlings were only found where seed had been sown. The one exception was at Birdlands, where five seedlings were found in unsown plots - four (one each of lacebark and kanuka, and two not identified) in short, mown grass and one (a lacebark) in rank, long grass.

Effect of herbicide

At most sites there was a definite trend for increased seedling numbers where herbicides were applied, but due to there being only three replicates with high variance between plots the herbicide effect was often not significant. At Medbury (Figure 2), for example, the average number of kanuka seedlings in the herbicide treatment was 77.3, compared to 21 in the non-herbicide sown plot, but the difference was not significant ($p=0.18$). The height of the taller seedlings was also greater at 30-60 mm in the herbicide treatment, compared to 5-10 mm in the non-herbicide. The positive herbicide effect was most evident where the grass was short; either mown or grazed, or naturally short (only Medbury). It was greatest, and significant, in the short (grazed) grass at Kate Valley West (Figure 3: $p=0.002$), and also positive, but not statistically significant in the short (mown) grass at Duvauchelle (Figure 5; $p=0.10$).

Effect of disturbance

Disturbance had the greatest positive effect on seedling numbers at three sites - Birdlands ($p<0.001$), Duvauchelle (Figure 5; $p<0.001$), and in the long grass at Kate Valley East (Figure 4; $p=0.05$) and Kate Valley West (Figure 6; $p=0.01$). Disturbance had a negative effect in the short grass at Medbury (Figure 2; $p=0.05$). At Duvauchelle, the positive effect was large in both the long grass and the short (mown) grass, dominating the smaller positive effect of mowing and herbicide application (Figure 5).

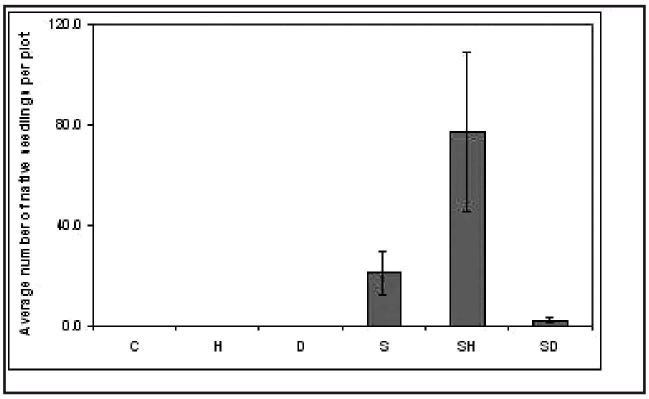

Figure 2. Seedling emergence one year after sowing in naturally short grass at Medbury (C = control; H = herbicide; D = disturbance, S = seed)

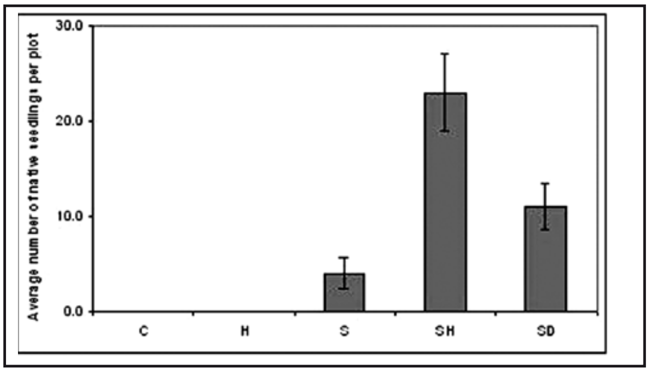

Figure 3. Seedling emergence one year after sowing in short (grazed) grass at Kate Valley West (C = control; H = herbicide; D = disturbance, S = seed)

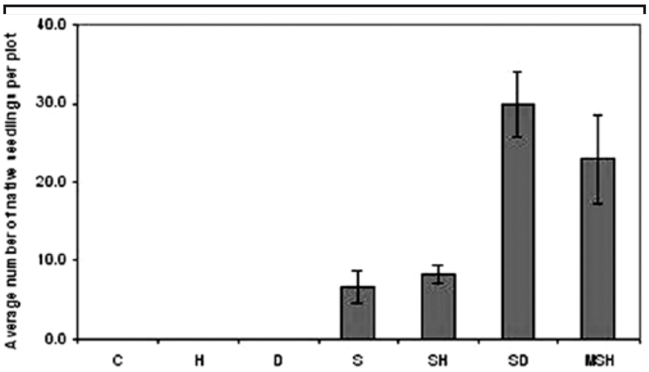

Figure 4. Seedling emergence one year after sowing in long and short (mown) grass at Kate Valley East (C = control; H = herbicide; D = disturbance, S = seed, M = mown)

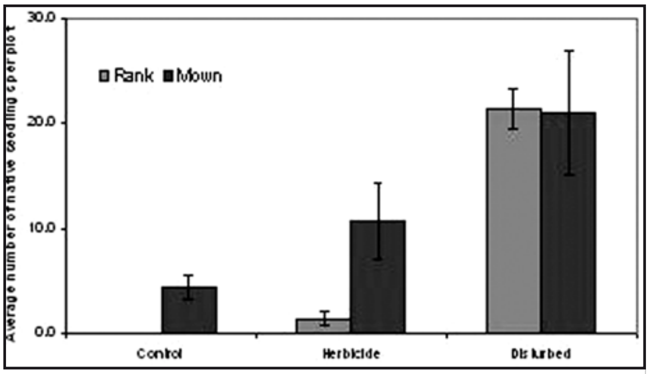

Figure 5. Seedling emergence one year after sowing at Duvauchelle.

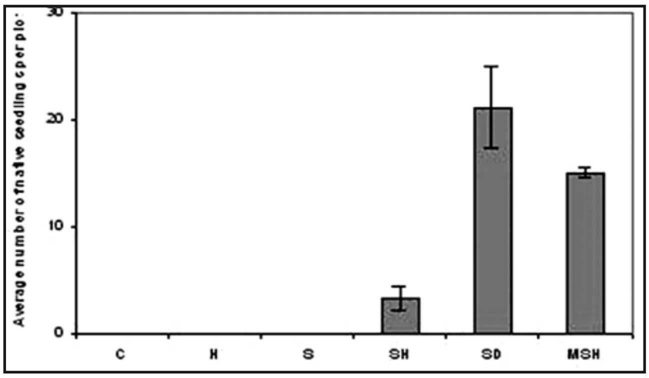

Figure 6. Seedling emergence one year after sowing in long grass and short (mown) grass at Kate Valley West (C = control; H = herbicide; D = disturbance, S = seed, M = mown)

Table 3. Emergence of seedlings of native species in short and long grass after 1 year at Duvauchelle.

Species	**Seedling emergence (% of sown seed)**			
	Short (mown) grass		**Long grass**	
	Mean *	Max **	Mean *	Max **
Kohuhu	12.9	60	16.7	50
Poroporo	10.4	45	2.5	15
Broadleaf	7.9	35	10.4	40
Flax	6.7	25	2.1	10
Cabbage Tree	5.4	20	8.3	50
Kowhai	3.8	15	7.5	40
Ngaio	4.0	5	0	0
Mahoe	2.5	10	2.9	25
Five Finger	0	0	0.8	20
Red Mapou	0	0	0	0

* Mean of all sown plots
** Maximum in any one plot (in every case this was a disturbed plot)

The only situations where there were more seedlings in the herbicide treated plots than in the disturbed plots were in the naturally short grass at Medbury (Figure 2) and in the short (grazed) grass at Kate Valley West (Figure 3).

Effect of mowing

Mowing was only used in long (rank) grass areas. As indicated above, mowing had a positive impact on seedling numbers when herbicide was used in the long grass at Kate Valley East (Figure 4;$p=0.11$) and Kate Valley West (Figure 6; $p=0.002$), and on both seed alone and seed plus herbicide treatments at Duvauchelle (Figure 5), where mean seedling numbers were increased from zero to 4.3 in the seed alone treatment, and from 1.3 to 10.7 ($p=0.10$) in the seed plus herbicide treatment. The effect of mowing prior to disturbance was only tested at Duvauchelle, where mean seedling numbers of the mown and unmown treatments were almost identical (Fig 5).

Seedling heights

After one growing season, seedlings tended to be taller in the disturbed plots. At Medbury, even though numbers were less than in the herbicide plots, the only seedlings over 10 cm tall (11 and 15 cm) were in a disturbed plot. At Duvauchelle, eighty-eight seedlings were 5 cm or taller, and seventy-eight of these (89%) were in the disturbed plots. The tallest seedlings were poroporo (five at 40-60 cm), flax (three at 20-30 cm) and cabbage tree (seven at 15-20 cm). The tallest woody tree species were cabbage tree (fifteen at 10-20 cm), kowhai (four at 10-20 cm), kanuka (three at 10-20 cm) and kohuhu (eight at 10-12 cm). Thirteen broadleaf seedlings were 5 cm or taller, but there was little difference between them, with the tallest measuring 6 cm.

Table 4. Seedling emergence of all species in sown plots at Duvauchelle, as counted in February (7 months after sowing) and June (11 months).

	Average native seedling numbers / plot	
Treatment	**February, 2007**	**June, 2007 (% of Feb)**
Long grass	0	0 (0%)
Long grass + herbicide	6.7	1.3 (19%)
Long grass + disturbance	29.2	21.5 (74%)
Short (mown) grass	8.3	4.3 (52%)
Short grass + herbicide	19.7	10.7 (54%)
Short grass + disturbance	24.5	21 (86%)

Seedling emergence at Duvauchelle

Duvauchelle was the only site where it was known how many seeds were sown of each species, with the exception of kanuka. The percentage emergence within the seeded plots in short and long grass at this site is shown in Table 3. As shown in Figure 5 above, the impact of mowing on seedling numbers at Duvauchelle had no effect in the disturbed plots, but had a significant positive effect in both the non-herbicide and herbicide treatments. For all species, the highest emergence was in disturbed plots. Kohuhu had the best emergence in the short grass, followed by poroporo and broadleaf. Kohuhu also had the best mean emergence and equal best maximum in the long grass, followed by cabbage tree, broadleaf and kowhai.

Seedling numbers declined between the time of the first assessment in February and the final count in June. Comparative figures for sown plots are presented for Duvauchelle in Table 4. No seedlings were found in the unsown plots.

Overall, 70% of the seedling numbers that were recorded in February were still present in June. Retention tended to be better in the short grass treatments than in the long grass, and consistently better in the disturbed plots.

Discussion

The results of direct seeding of native woody species at four sites in North Canterbury have been encouraging, and indicate that there are seeding techniques which could be useful for successfully establishing native species in ex-pasture sites. This endorses the findings of Stevenson and Smale (2005) and Dodd and Power (2007), although a major difference between their work and that described in this article, is the drier environment and the presence of long rank grass at many of the Canterbury sites. Rank grass is often found on pasture sites intended for native plant restoration, as prior to any work being initiated, one of the first steps taken is to remove all grazing animals. This is often done well before any revegetation is undertaken, allowing plenty of time for resident grasses to not only grow tall, but also to produce greater quantities of seed than they are likely to have done in previous years.

One of the key points emerging from the North Canterbury trials is that very few native seedlings were located in unseeded 'control' plots. In all the sites, only five were found - all at Birdlands, where mature native forest was within 20 m of the trial area. Four seedlings (one each of lacebark and kanuka, and two too small to be identified) were located in short, mown grass, and one (a lacebark) in long grass. None were found in the unsown disturbed plots, even though this treatment promoted good emergence where seed was sown, and all disturbed plots were protected by netting cages. Therefore, even close to native seed sources, the natural dispersal strategies for native seeds appear to be insufficient to create ready natural regeneration, at least during the time of the sowing trial.

At Duvauchelle, the number of seed sown (with the exception of kanuka) was known, so percentage emergence 1 year after sowing could be calculated. Six species (kohuhu, poroporo, broadleaf, flax, cabbage tree and kowhai) showed a mean emergence of >5% in the disturbed treatments. Numbers emerging were variable between plots, but in the best plots all these species, with the exception of flax, showed maximum percentages which equalled or exceeded 40%. Dodd and Power calculated the initial emergence (up to 3 months) and establishment (after 2.5 years) percentages for two species, koromiko (*Hebe stricta*) and karamu. Koromiko had an initial emergence of 24%, but this declined to <1% after 2.5 years. The trend for karamu was similar, with 18% initial emergence and 2% establishment. Seedling numbers at Duvauchelle after 7 and 11 months (Table 4) show a similar level of emergence followed by the same downward trend, although it is too early to determine final establishment figures.

Table 1 shows that sowing litter did introduce seed of native species, many of which were not sown as pure seed. These were identified from samples sown in trays housed in a nursery shadehouse. At the two Kate Valley sites, where only kanuka and poroporo were sown as pure seed, the litter contained nine other species (kohuhu, karamu, mahoe, five-finger, ngaio, cabbage tree, creeping pohuehue, unidentified small-leaved Coprosma species and flax). Only flax was not found in the field plots. At Birdlands, where six species were sown (kanuka, karamu, mahoe, five-finger, ngaio and poroporo), the litter also contained nine other native species (kohuhu, lacebark, totara, kowhai, bush lawyer, unidentified small-leaved Coprosma species, kotukutuku, tree tutu and creeping pohuehue), the last three of which were not seen in the field plots. Therefore, spreading litter is an effective way of introducing native species to properly prepared sites. At the two Kate Valley sites, the average numbers of mahoe, kohuhu, small-leaved Coprosma and five-finger seedlings found in the sown herbicide and soil disturbed plots (0.25m2) were 6.3, 1.6, 1.1 and 0.6 respectively. In the best treatments, the means were 13.3, 3.0, 1.7 and 3.0 respectively. These seedlings all emerged from one litre of litter. In theory therefore, 166 litres (one 44-gallon drum) of litter applied to properly prepared (best treatment) ground could give rise after 1 year to 2,208 mahoe, 498 kohuhu, 282 small-leaved Coprosma and 498 five-finger seedlings. Even though these figures may appear impressive, it must be remembered that they are only based on results after 1 year, and that further losses can be expected, especially if no further weed control is undertaken. In addition, litter collection is laborious and good sites could be difficult to locate, as collection must only be undertaken in areas free of weed seed. However, the option of sowing litter as a source of native plant seed deserves further attention, particularly where only small areas are being targeted. An added advantage of using litter is the possibility of introducing beneficial mycorrhizae. No attempt was made to test for any mycorrhizal effect in the North Canterbury trials.

At all sites, glyphosate was used to kill the resident vegetation (predominantly grasses) prior to sowing. The same herbicide was used by Stevenson and Smale (2005) and Dodd and Power (2007), but they only used it on short (grazed or mown) grass and had no non-herbicide grass treatment. In North Canterbury, herbicide application was particularly effective in promoting the emergence of native species where the grass was short - at Medbury (in naturally short grass) and in the grazed and mown grass at Kate Valley West and Kate Valley East respectively. The effect was considerably reduced in the long grass treatments at the two Kate Valley sites and at Duvauchelle. Overall, herbicide application did not produce as positive a response in seedling numbers as did the soil disturbance treatment, especially in the rank grass. Stevenson and Smale (2005) had similar results after sowing kanuka and karamu seed into short pasture, herbicided pasture, turf removal and topsoil removal plots. Herbicides and turf removal improved seedling numbers over the short pasture treatment (where no seedlings were found), although high variability resulted in no statistical difference between the three. The vast majority of seedlings were found in the topsoil removal treatment, which would have most closely resembled the disturbed treatment in North Canterbury.

Soil disturbance had the strongest positive effect on seedling numbers, especially where the grass was long (Figures 4, 5 and 6), although at Duvauchelle (Figure 5), soil disturbance increased the average number of seedlings in both short and long grass. The effect was much less in the short grass treatment at Kate Valley West, and was negative in the short grass at Medbury. The combination of lower rainfall (Table 1) and greater exposure makes these two sites drier than the others, which could explain why disturbance was less effective in increasing seedling numbers. In these drier conditions, seeds germinating on the soil surface would be exposed to greater extremes of moisture stress - with conditions sometimes changing rapidly over very short periods of time. Such extremes are likely to have been less beneath a cover of short dead grass (SH treatments in Figures 2 and 3), where more seedlings were counted. In much moister conditions (1635 mm rainfall), Stevenson and Smale (2005) found best seedling numbers on bare soil, especially where the topsoil was removed and soil fertility was lowest. Other authors have also found that some native species, such as manuka, can colonise low fertility sites (Grant, 1967; Porteous, 1993). However, low fertility is also likely to lead to less competition from weeds, so as pointed out by Douglas *et al.* (2007), further experimentation is needed to determine the effect of fertility unconfounded by competition effects. In Northland, Stephen King (pers com) has successfully sown manuka onto ploughed lines over many hectares of pasture land. Ploughing creates crevices between the furrows, and the indications are that seedlings can survive better in such sheltered microsites.

Mowing was carried out where grass was long in order to create short grass which could be equated to grazed pasture. It had a positive impact on the effect of herbicides when applied in the long grass blocks at both the Kate Valley sites (Figures 4 and 6). Similarly at Duvauchelle, where all treatments that were mown produced many more native seedlings per plot than those with rank grass (Figure 5). No long grass treatments were included by either Stevenson and Smale (2005) or Dodd and Power (2007), and trials involving long, rank grass are not recorded in the review by Grant *et al.* (2007). Long grass probably inhibits native seedlings from establishing by outcompeting them for both light and moisture.

Netting cages were used due to the presence of possums, hares, rabbits and birds. Even though numbers of the first three were low, without such protection, even very low pest numbers could have decimated small numbers of native seedlings emerging in small plots. Davis *et al.* (1996) looked at the effect of excluding rabbits, birds and insects from young conifer seedlings during their first year of growth from seed. In his small trial situation, rabbits were clearly the major cause of seedling failure. The cages may also have provided additional shelter, but the significance of this in terms of seedling establishment cannot be deduced, as with the exception of all disturbed plots, no unsown plots were protected.

In their review of direct seeding for establishing native plants into pastoral land in New Zealand, Douglas *et al* (2007) state that competition from existing vegetation (mostly or exclusively introduced species) is probably the greatest limitation to success. Hence seedling establishment (and in some cases, early growth rate) in the North Canterbury and Banks Peninsula trials was no doubt assisted by weed control prior to seed sowing, in the form of herbicide application and soil disturbance. However, during the first growing season after sowing, new weeds (mostly grasses and hawkweeds) appeared, and if given time, could well suppress the emerging native seedlings. Dodd and Power (2007) also noted that competition from regenerating vegetation was a major cause of reduced seedling survival over the first year of their trial. Even with much larger transplanted nursery seedlings, weed control is well recognised as necessary to ensure survival (Porteous, 1993). The removal of topsoil before sowing (Stevenson and Smale, 2005) may have reduced weed control requirements post-sowing, but it is not practical in most pastoral situations. Douglas *et al.* (2007) conclude that one of the key aspects for improving the success of direct seeding native species in the future, will be better techniques for controlling existing vegetation after sowing. Unfortunately, at this point in time, limited information is available on the effects of herbicides on native species.

At Birdlands, two herbicides were experimentally sprayed over the seedlings to control weed growth - hence, results from this site are not included above. The herbicides used were a haloxyfop isomer (Gallant) which is known to be grass specific, and glyphosate which will kill most weeds. It was found that Gallant (knapsack rate of 2.5 mls/litre) did not affect native seedlings, but the grass kill was slow and it did not control broadleaf weeds. At Birdlands, weed growth was sufficiently vigorous to form a herbaceous cover over the native seedlings, so that glyphosate could be used with low risk of the chemical actually landing on the native seedlings. At a light rate, glyphosate (Roundup in a knapsack @ 5 mls/litre) did at least partially kill both grasses and broadleaf weeds, whilst leaving the native seedlings relatively unaffected. If such a weed control strategy is employed, it is essential that the chemical be employed at the right time - when the weeds are sufficiently tall to 'protect' the seedlings, but not so lush as to have dried out the site, or deprived the seedlings of light for too long. Whatever strategy is used in the future, it is certain that weed control after seedling emergence will be a critical factor in establishing native species from seed, and more research is needed to find out the appropriate chemicals and rates.

Douglas *et al.* (2007) looked at comparative costs between native plant establishment using spaced plants and direct seeding. In each option there was a large variation in total cost, depending mainly on the plant size or species used. However the comparison showed that to attain 2,500 plants per hectare, direct seeding was generally the cheapest option, with spaced planting costing between $14,000-$23,500 / ha and direct seeding between $4,800-$14,400 /ha. Hence their conclusion, and that of Dodd and Power (2007), that direct seeding of native plants can be cost-effective as a restoration technique in ex-pasture sites.

Due to the number of factors which can influence seed survival, germination and establishment in the wild, results from direct seeding are always likely to be variable. It is for this reason that seed is more often sown in nurseries, where moisture, weeds and animals can be controlled. In the North Canterbury trials, there was much variation even within treatments, and there were two sites (Balmoral Reserve and Lyttelton) where very few seedlings were found at all. The reasons for this are unknown, but they must have involved climatic or site factors, as the sowings in the shadehouse (before fungal attacks considerably reduced numbers) indicated that plenty of viable seed had been sown. In addition to variability between sites, the success of any plant establishment procedure involving seed sowing in the field will differ from year to year, due to annual variations in climate. The late spring / early summer period (September - December) in Canterbury in 2006 was considerably moister than normal, whilst January and February (when assessments were carried out) were 20-30% drier, and the autumn was drier still. There is little doubt that the moister start to the growing season would have assisted seedling establishment. A drought year may well have resulted in no seedlings at all, and not allowed any treatment differences to be revealed. We were fortunate in that the favourable season allowed this trial to result in significant numbers of native seedlings emerging. However, it must always be accepted that, whenever seed is being used to establish native plants, variable results are likely and there is always a chance that unfavourable seasons will lead to failure. In addition, success could well be more difficult in drier environments.

In the lower middle parts of the North Island there are large areas of hill country which are currently farmed, but are regarded as too erosion-prone to remain in pasture. Ideally, they should be returned to woody species as soon as possible (Marden, 2004). Plantation forestry is an option for parts of it, but for the remainder the most preferred cover for many people is likely to be one of native species. The cost of doing this by the conventional planting of nursery seedlings would be prohibitive. The option of direct seeding deserves serious consideration.

Conclusion

As the interest in restoring native species on farmland increases, it is inevitable that large-scale techniques will be sought which are faster than natural regeneration and cheaper than the spaced planting of nursery-grown seedlings. The North Canterbury and Banks Peninsula trials, together with those carried out in the North Island, indicate that techniques involving the sowing of seed, accompanied by herbicide application and/or soil disturbance, could be successful for the cost-effective establishment of a native woody plant cover over large areas of grassland.

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NZ School of Forestry news

New staff members bring wide experience

David Evison

David joined the School of Forestry in April 2008. He is a graduate of the School and completed a PhD in forest economics at the University of Washington. His work experience includes a stint at the Forest Research Institute in Rotorua for 15 years, followed by 12 years in industry - in forestry (with Rayonier New Zealand), and financial services (with Bank of New Zealand), with some teaching on the side. His primary research focus will be in the forest economics area.

Simon Fairbrother

Born and bred in Christchurch, Simon completed a Forest Engineering degree at the University of Canterbury. He is now teaching at the School of Forestry and studying towards a PhD in Forest Engineering. Prior to life as a forest engineer, he worked for 11 years in the Royal New Zealand Air Force, travelling extensively as an aircraft navigator and was involved in project management of large-scale aircraft modification programmes. Areas of particular interest in forest engineering are the design of forest roads and harvest planning to reduce environmental impact, and the collection and utilisation of forest biomass for thermal power generation and/or production of biofuels.

Rien Visser

Rien completed a Bachelor of Engineering (Hons) in Natural Resources at the University of Canterbury in 1991. He received his Master of Engineering degree at the University of California (Davis), in 1992. He then joined the Logging Industry Research Organization (LIRO) where he studied environmental and operational issues in plantation forestry, and became program leader of the Environmental section in 1994. He completed his Dr. Nat. Tech. in Vienna in 1998. He then returned to LIRO, where he worked on operational research projects and explored radar as a means to detect internal wood properties. In 2000 he accepted a position at Virginia Tech, where he became an Associate Professor. He now joins the School of Forestry at Canterbury University in the role of Director of Forest Engineering. He is looking forward to building the Forest Engineering programme through contacts with the sector and with students.