INTRODUCTION OF NATIVE PLANTS BENEATH EXOTIC TREES PLANTED TO STABILISE PASTORAL LAND

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Abstract
Native plants offer a medium- to long-term vegetation option for pastoral hill country requiring on-going protection from soil slippage and other forms of erosion. Two trials were conducted to determine the establishment of transplanted native plants beneath variously pruned, spaced, willow (*Salix* spp.) and poplar (*Populus* spp.) trees, planted for site stabilisation. Fifteen months after planting, height of lemonwood (*Pittosporum eugenioides*) plants beneath willows was 72 cm beneath full canopies (global radiation in summer = 3 MJ m^{-2} d^{-1}) and 76 cm where the entire canopy was removed (14 MJ m^{-2} d^{-1}). Height of kohuhu (*P. tenuifolium*) plants under poplars was 98 cm beneath full canopies (12 MJ/m^2/d), which was less ($P < 0.05$) than mean plant height of 107 cm attained beneath pruned poplars with 10-15% less leaf area (11 MJ m^{-2} d^{-1}). Results are preliminary but show that the selected natives can be established satisfactorily beneath exotic deciduous trees, thereby offering a practical approach for facilitating vegetation succession and long-term land protection.

Additional Keywords: poplar, willow, succession, plant interactions

Introduction
Exotic deciduous tree species, principally poplar (*Populus* spp.) and willow (*Salix* spp.), are used extensively in New Zealand to stabilise pastoral areas subject to erosion (van Kraayenoord and Wilkinson, 1986; Wilkinson, 1995). They are short-lived species that require management to optimise their conservation functions and to ensure they do not become a hazard to land owners throughout their 20-40 year life.

In contrast, most native plants establish relatively slowly, do not produce long lengths of stem from which vegetative cuttings can be produced, and are susceptible to browsing damage, particularly when young. Consequently, native species are less favoured for primary slope stabilisation than exotic species. Once stabilised by exotic plantings, natives offer a long-term climax vegetation option for those landscapes identified as not ideal for pastoral agriculture.

There is potential to introduce native plants into pastoral areas stabilised with wide-spaced poplar and willow, where the exotic species function as "nurse crops" by providing stability, shade and shelter. Willow and poplar trees could be partially or completely defoliated to change the surrounding environmental conditions, to enhance establishment and growth of the understorey native species. Using exotics as a nurse crop or primary coloniser offers an option for extending the areas of native vegetation on farms. Presently on pastoral lands, this is limited to the retirement from grazing of native bush areas through strategic use of fencing, and efficient weed and pest management. However retirement of existing bush, and possible management of it, rarely enables an increase in the area of native vegetation on pastoral land.

This study aimed to establish local ecotypes of two native species into pastoral areas that have been stabilised with variously managed poplars and willows, to obtain information on early successional and environmental changes in this model system, and establish protocols for native plant introduction.

Materials and Methods
Sites
Two trials were conducted at AgResearch's Ballantrae Hill Country Research Station, approximately 35 km east of Palmerston North in the southern North Island of New Zealand (40° 19' S, 175° 50' E, 250 m a.s.l.). Soils are sedimentary with pH of 5.5 and Olsen phosphate of 10 mg/kg soil. The climate is temperate with mean daily air temperature ranging from 7.9 °C in June (winter) to 17.4 °C in January (summer). Average annual rainfall at the site is about 1160 mm (J. Napier, *pers. comm*.).

Trials 1 and 2 were on E (15° slope) and W (10° slope) sides, respectively, of the same hill. The paddock where Trial 1 was located comprised spaced (8-10 m apart, or 100-156 stems ha^{-1}) poplar (*Populus maximowiczii* Henry x *P. nigra* L.) trees aged 7 years in 2002, one-third of which were pruned to a mean height of 4.0 m above ground in

March 2002, retaining about 55% of leaf area per tree. Understorey pasture dry matter comprised >70% grasses (*Agrostis capillaris* auct. brit., *Holcus lanatus* L., *Lolium perenne* L.) and was grazed periodically with sheep.

Trial 2 was located on a site with relatively poor drainage, which comprised unpruned, spaced (4 x 4 m, or 625 stems/ha) willow (50:50 mixture of *Salix matsudana* x *alba* clone 'Tangoio' and *S. kinuyanagi* 'Kinuyanagi') trees aged 8 years in 2002. Botanical composition of the understorey pasture was similar to that at the other site, except for randomly distributed patches of rushes (*Juncus* spp.), and there was low pasture cover beneath a number of trees.

Native plant species
Species evaluated were *Pittosporum tenuifolium* Sol. ex. Gaertn. (kohuhu) in Trial 1 and *P. eugenioides* A. Cunn. (lemonwood) in Trial 2. *Pittosporum eugenioides* is an erect, sometimes spreading, small tree which grows up to 12 m, whereas *P. tenuifolium* is more variable in growth form, but generally grows up to 10 m (Pollock, 1986). Both species are suitable for slope stabilisation and are moderately to highly tolerant of strong or gale force winds, frost, low fertility, and seasonal water logging. They are also tolerant of browsing.

Experimental design
Trial 1: Three adjacent pruned (henceforth referred to as Poplar Pruned environment, PP) and three adjacent unpruned (Poplar Unpruned, PU) poplar trees, of similar canopy dimensions within each group, and growing on similar contour, were selected. Healthy plants of *P. tenuifolium* with mean height of 59.6 (s.e. = 2.5) cm and diameter of 28.3 (1.8) cm were planted along transects in four directions (N (directly upslope), S, E, and W) around each poplar tree at distances from trees of 0.5, 1.0, 2.0, and 4.0 m (mid-way between adjacent trees). Two similar sets of transects, each totalling 16 plants, were established in nearby pastoral areas without trees (control plots, Open). Before planting, resident pasture was spot-sprayed with glyphosate (1 l/ha) and planting was conducted three weeks later on 6 November 2002. Then, trees in the PP environment had 10-15% less leaf area than those in the PU environment. Plants/trees in PP, PU, and Open environments were then fenced to exclude livestock. Weed growth around all native plants was controlled by hand-weeding and herbicides.

Trial 2: Two environments for native plant establishment were created in mid-October 2002 by removing entire canopies of half the willow trees (trunk retained; henceforth referred to as Willow Pruned, WP), and leaving the remaining trees unpruned (Willow Unpruned, WU). Both environments were arranged in three randomised complete blocks and each plot (experimental unit) comprised 9 trees (3 rows of 3 trees). Around the tree at the centre of each plot, plants of *P. eugenioides* with mean height of 59.6 (s.e. = 0.7) cm and diameter of 28.2 (1.5) cm were planted on 6 November 2002 along transects in four directions as in Trial 1, at distances from trees of 0.5, 1.0 and 2.0 m (mid-way between adjacent trees). Two similar sets of transects of native plants (12 plants per set), transplanted into pastoral areas without willow trees, comprised control plots (Open). Pre- and post-planting management were as described for Trial 1.

Measurements
Environmental parameters: In each trial, global radiation, wind run, and air and soil temperature (100 mm depth) were measured quarter-hourly using sensors connected to a datalogger (HOBO H08 OEM 4-Channel) located in PP, UP, WP, and WU environments. Dataloggers were not used in the Open environments in each trial as conditions were likely similar to those in the respective pruned tree environments, especially the WP environment. Volumetric soil water content (VSWC; v/v) at 0-120 mm depth was determined at each planting position using a portable soil moisture probe (Spectrum Field Scout TDR 300) on 19 November 2002, and 11 February, 24 March, 12 June, 23 September, and 17 December 2003, and 3 February 2004.

Plant attributes: All native plants in both trials were assessed on the same dates as VSWC for height (cm), canopy diameter (cm; maximum value, perpendicular to transect), and vigour (plant condition scored 1 (very poor) to 5 (excellent)).

Statistical analysis
Data at each time, and differences between times, were analysed using analysis of variance and mean separation was achieved using the Least Significant Difference test at $P = 0.05$. Orthogonal linear contrasts were also used to compare environments.

Results

Environmental parameters

In both trials, total solar radiation was 2-5 MJ/m^2/d in winter and 10-15 MJ/m^2/d in summer, except in the WU environment where radiation received beneath the foliated willow trees was less than 4 MJ/m^2/d (Figure 1). Mean air temperature varied from 7 ^{o}C in July 2003 to 18 ^{o}C in January 2004, and corresponding soil temperatures were 8 ^{o}C and 16 ^{o}C, respectively.

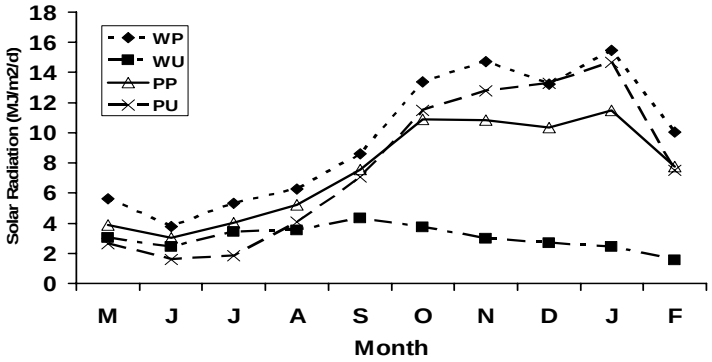

Figure 1. Total daily solar radiation received beneath pruned (PP) and unpruned (PU) poplars, and pruned (WP) and unpruned (WU) willows, near Palmerston North from May 2003 to February 2004

Volumetric soil water content at both trial sites ranged from 38-60% throughout the assessment period except in February and March 2003 when soils were very dry (6-11%). In Trial 1, negligible differences in VSWC were detected between environments, whereas in Trial 2 when the willow trees were foliated, VSWC beneath trees with entire canopies was 15-20 percentage units lower ($P < 0.01$) than under pruned willows in November 2002 and 2003, and in February 2004. There were no differences in VSWC between distances from trees in either trial at any time and VSWC only varied occasionally with direction around willow and poplar trees.

Plant attributes - Trial 1

Across all treatments, plants of *P. tenuifolium* attained an average height of 103 cm after 15 months. Since November 2002, plants in the PP (50 cm) environment had greater ($P < 0.05$) height increase than those in the PU environment (38 cm), mostly because of differences in height growth between three and seven months (late summer to early winter) after planting. Height growth of plants in the Open (45 cm) was not significantly different from that in either tree environment. Plant height in the PP environment exceeded ($P < 0.05$) that in the PU environment from June 2003 to February 2004 (Table 1).

Table 1. Mean height (cm) of two native plant species growing beneath pruned (PP), and unpruned (PU) poplars, and pruned (WP) and unpruned (WU) willows, near Palmerston North

	***Pittosporum tenuifolium* (Trial 1)**			***Pittosporum eugenioides* (Trial 2)**		
Time	**PP**	**PU**	**s.e. (n = 48)**	**WP**	**WU**	**s.e. (n = 36)**
Nov 02	57	60	0.2	56	55	1.0
Feb 03	65	66	1.3	63	62	1.0
Jun 03	76	71	0.8	69	64	1.3
Sep 03	80	74	1.3	68	65	1.5
Dec 03	93	85	2.0	69	69	2.8
Feb 04	107	98	2.4	76	72	4.3

Plant canopy diameter averaged 29 cm in November 2002, across all treatments, and by February 2004, plants in the PP environment had increased 19 cm. This was higher ($P < 0.05$) than the canopy diameter increases in the Open (13 cm) and PU (9 cm) environments, which were not significantly different. Plant vigour was unaffected by any treatment but it declined slightly from an average score of 3.9 in November 2002 to 3.4 in February 2004 because of slightly increased severity of leaf chlorosis and spotting during the intervening period.

Plant attributes - Trial 2

The average height of *P. eugenioides* plants at the final assessment in February 2004 was 74 cm. Plant height in June 2003 was higher ($P < 0.05$) in the WP (69 cm) than WU (64 cm) environment and this was the only time when a significant difference in height was detected between plants in these environments (Table 1). Between November 2002 and February 2004, the diameter of plants at 200 cm from willow trees increased 11 cm compared with ($P < 0.01$) plants at 50 cm from trees, which increased 4 cm. Plants of *P. eugenioides* in the Open environment had similar ($P > 0.05$) height and canopy diameter as those growing beneath pruned and unpruned willow trees. Average vigour score of all plants varied from 3.2 to 3.8 throughout the assessment period.

Discussion

These studies showed that the native plants *Pittosporum eugenioides* and *P. tenuifolium* can be established satisfactorily from transplants into various environments beneath spaced, exotic deciduous trees on fragile lower North Island pastoral hill country. The trees in these studies were young (7-10 years) but the approach is also likely to be appropriate for more mature trees. The optimum temporal overlap between native plant introduction and death/removal of the exotic trees, which maintains soil conservation functions, remains to be determined.

The similar average growth of plants of both native species beneath pruned and unpruned trees, and those in the Open environments, showed that growth of these species was not impaired in the treed environments. Planting the selected natives beneath established exotic trees offers potential advantages compared with planting in the open because the site is relatively stable and hence less likely to erode during storm events, and the native plants are more sheltered than in the open. Although plant growth of both native species sometimes varied significantly beneath pruned and unpruned trees, differences were small biologically. This suggests that the need for partial or complete defoliation of exotic tree canopies to facilitate satisfactory native plant establishment is not as great as first thought, which would reduce or negate labour costs for pruning.

Complete defoliation of the willow trees (WP) created significant differences in total incident radiation and volumetric soil water content between the WP and WU environments when the trees were foliated. However no differences in height or diameter growth of *P. eugenioides* were detected during the willow foliation period, perhaps because the test plants grew slowly during the 15 months since planting eg. 20 cm or less height growth. The native plants in the WP environment in June 2003 were taller possibly because of their higher exposure to radiation in the previous summer/autumn, although environmental tolerances vary between provenances and stage of maturity (Pollock 1986). The differences in growth of *P. tenuifolium* in the PP and PU environments were difficult to explain because there were negligible differences between the environments in volumetric soil water content and irradiance, and soil nutrient status was similar in both environments (Douglas *et al*. unpubl.).

Weed ingress and its management was an on-going problem in both trials. It was frequently observed that weed growth beneath unpruned willows (relatively shady; dry soil), which formed essentially a continuous canopy because of interference with neighbouring trees, was less than in the WP, PP, and PU environments. However growth of the introduced native plants was still satisfactory and it is suggested that planting in such an understorey environment, at least for *P. eugenioides*, may be the best approach for reducing herbicide use and associated application costs.

The occasional finding of native plants farthest from exotic trees being taller and having wider canopies than those nearest trees may be because of tree effects, or competition between native plants within transects, or both factors. Refined experimental design will be required to isolate these factors.

Air temperatures during the assessment period were typical of the long-term temperate climate experienced at the research station. However the site received very little rainfall in the 2002/03 summer, resulting in very low volumetric soil water contents (6-11%), which were atypical of this usually summer-moist environment.

The results in these trials are preliminary and further monitoring will determine longer-term growth patterns and enable robust recommendations to be made on optimum exotic tree management to facilitate native plant development.

Conclusion

Two native plant species were established successfully beneath variously managed poplar and willow trees on pastoral hill country. *Pittosporum tenuifolium* grew about twice as fast as *P. eugenioides* over 15 months. The approach seems a viable option for implementing vegetation successional plans for erosion-prone landscapes.

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