Indigenous sward restoration by oversowing *Microlaena stipoides* into kikuyu (*Pennisetum clandestinum*) pasture

M.B. DODD[1], B.R. BURNS[2] and I.L. POWER[3]
[1]*AgResearch Grasslands, Private Bag 11008, Palmerston North, New Zealand*
[2]*Manaaki Whenua – Landcare Research, Private Bag, Hamilton, New Zealand*
[3]*AgResearch Ruakura, Private Bag 3123, Hamilton, New Zealand*
mike.dodd@agresearch.co.nz

Abstract
Management plans for the grazed parklands of the Auckland volcanic cones call for re-vegetation to restore a more natural and historic vegetation cover. The native grass *Microlaena stipoides* has been identified as a relevant species, and a field experiment was undertaken to determine the best approach for establishing this species into existing pasture. Seed obtained locally was broadcast or hydro-seeded in May 2007 onto kikuyu pasture, at three sowing rates (100, 250 and 750 seeds/m^2) following control of the resident pasture with turf stripping or mowing and spraying, in a replicated factorial trial. After 12 months, the highest levels of *Microlaena* plant density (mean 56 plants/m^2), cover (mean 50%) and accumulated herbage mass were observed on broadcast/sprayed plots at the highest sowing rate. Recovery of the resident pasture (dominantly *Pennisetum clandestinum*) occurred to a level of ~25% after 12 months, but was inhibited at the highest *Microlaena* sowing rate.

Keywords: broadcast, hydro-seeding, kikuyu, *Microlaena stipoides*, re-vegetation

Introduction

The Auckland City volcanic cones are currently covered in pastures dominated by exotic grasses and scattered exotic and native trees, and are grazed mainly with cattle through the spring-summer-autumn period. There are concerns about the impact of erosion on sensitive archaeological sites, the compatibility of livestock with increasing public use, and the loss of indigenous vegetative character. Auckland City Council is seeking re-vegetation solutions that maintain the park-like character in the absence of livestock, restore native plant species to the cones, mitigate soil erosion and fire risks and maintain the integrity of the archaeological sites and their visibility. The non-endemic native grass species *Microlaena stipoides* (meadow ricegrass) has been identified as a valuable species in this regard, given that it has historically been prevalent on a number of the volcanic cones since human colonisation (Esler 2004).

An experiment was undertaken to investigate the potential for restoring *Microlaena* to a more substantial component of the pastures on the volcanic cones through the use of recognised re-grassing techniques. This presents an interesting counterpoint to the traditional concept of pasture improvement by attempting to replace productive exotic agricultural pasture species with slow-growing native grasses. The objective was to determine the most successful means of establishing *Microlaena* into a vigorous exotic sward of kikuyu (*Pennisetum clandestinum*) a species commonly observed on the cones.

Methods

Public sensibilities precluded experimentation on the volcanic cones. Hence, the experiment was located on a flat pasture site in the former orchards at the rear of the Unitec campus, Point Chevalier, Auckland. The pasture was almost exclusively dominated by kikuyu. The soil type was not able to be accurately determined from available maps, but is probably a red/brown loam derived from basalt lava flows (Pohlen 1964), outcrops of which occur in adjacent fields.

Seed of *Microlaena stipoides* was collected by hand from Motukorea/Browns Island during the summer of 2006-07 and tetrazolium-tested for viability using the ISTA method for *Lolium* spp. (ISTA 2003).

The experiment consisted of three factors: alteration of the ground cover prior to sowing ('residual'), sowing method and sowing rate. There were three residual treatments, two sowing methods and three sowing rates. The three residual treatments were:

1. bare ground achieved by stripping the turf and top 2 cm of soil ('bare ground');
2. existing pasture mown to 3 cm height then sprayed with Roundup® 10 ml/l plus Pulse® 7 ml/l ('short grass');
3. existing pasture sprayed as above without mowing ('long grass').

The two sowing methods were hydro-seeding and broadcasting by hand. The three sowing rates were 100, 250 and 750 seeds/m^2. The experimental design was a randomised complete block with five replicates in a full factorial arrangement, giving a total of 90 plots. The plot size was 3 m × 3 m with 0.5 m spacing between plots and blocks.

The plots were sown on 16 May 2007. Visual assessments of percentage cover in six categories (*Microlaena*, *Pennisetum*, other grasses, legumes, dicot forbs, bare ground) were made on the plots on: 27 June 2007, 42 DAS (days after sowing); 3 September 2007, 120 DAS; 20 December 2007, 218 DAS; 11 March 2008, 290 DAS; and 30 May 2008, 370 DAS. *Microlaena* plant numbers were counted in 50 cm × 50 cm sub-plots in the centre of each plot on all the aforementioned dates except March 2008, in order to calculate seedling and plant densities. These sub-plots were visually scored for cover of *Microlaena* in December 2007 and May 2008, and harvested to ~2 cm height on 29 May 2008 with percentage composition by weight determined for each sward category.

The experiment was analysed using the ANOVA directive of GenStat (10th Edition). The repeated measures analysis was carried out using the AREPMEASURES procedure of GenStat (10th Edition) with the Greenhouse-Geisser adjustment for the degrees of freedom. Count data and the *Microlaena* dry matter data were log transformed for analysis (with 1 added in the count data where required to accommodate zero values) and cover data were angular transformed for analysis. Arithmetic means are presented, with significance assessments based on analysis of the transformed data. Regression analyses of *Microlaena* measurements in the sub-plots (plant density, cover and dry matter harvested); and of cover scores in the whole plots, were conducted for each measurement date using PROC REG in SAS® (SAS® for Windows, SAS Institute, Cary, North Carolina).

Results

Seed lot viability as measured by the tetrazolium test was 40%. At the first measurement in June, *Microlaena* seedling numbers were low overall at an average of 3.7, 4.8 and 9.6 per m^2 across the three sowing rates (Table 1), representing an average emergence of 2.3% of seed sown. However, this emergence % varied between zero and 28% across all the individual plots. The highest emergence rates (mean 12.8%) occurred on the broadcast/short grass plots sown at the lowest seeding rate. The highest seedling densities occurred on the broadcast plots, the short grass plots and the high seeding rate plots (Table 1). The residual and sowing method main effects were significant in the ANOVA, while the sowing rate effect was not significant and there were no significant treatment interactions.

Across subsequent *Microlaena* plant density measurements (September 2007, December 2007 and May 2008) all three main treatment effects and the measurement date effect were significant. In addition there were significant first-order interactions between measurement date and residual treatment, and between residual treatment and sowing method. Compared with the bare ground and short grass treatments, plant densities were lowest in the long grass treatment in June, but highest thereafter (Figure 1). Plant densities in both the bare soil and short grass treatments decreased between June and September before recovering in December, whereas they increased over time in the long grass treatment. The interaction between residual treatment and sowing method indicated that the difference in mean *Microlaena* plant densities between the broadcast and hydro-seeding methods (higher for broadcast) was significant in the short grass and long grass treatments but not in the bare soil treatment (Table 2).

Table 1 Emergence of *Microlaena* (seedlings/m^2) at 42 DAS in June 2007.

Factor	Treatment main effect	Mean seedlings/m^2
Residual	Bare ground	7.6 a
	Short grass	9.3 a
	Long grass	1.2 b
Sowing method	Broadcast	9.7 a
	Hydroseed	2.4 b
Sowing rate	100 seeds/m^2	3.7 a
	250 seeds/m^2	4.8 a
	750 seeds/m^2	9.6 a

Different letter suffixes indicate significant treatment differences for P<0.05.

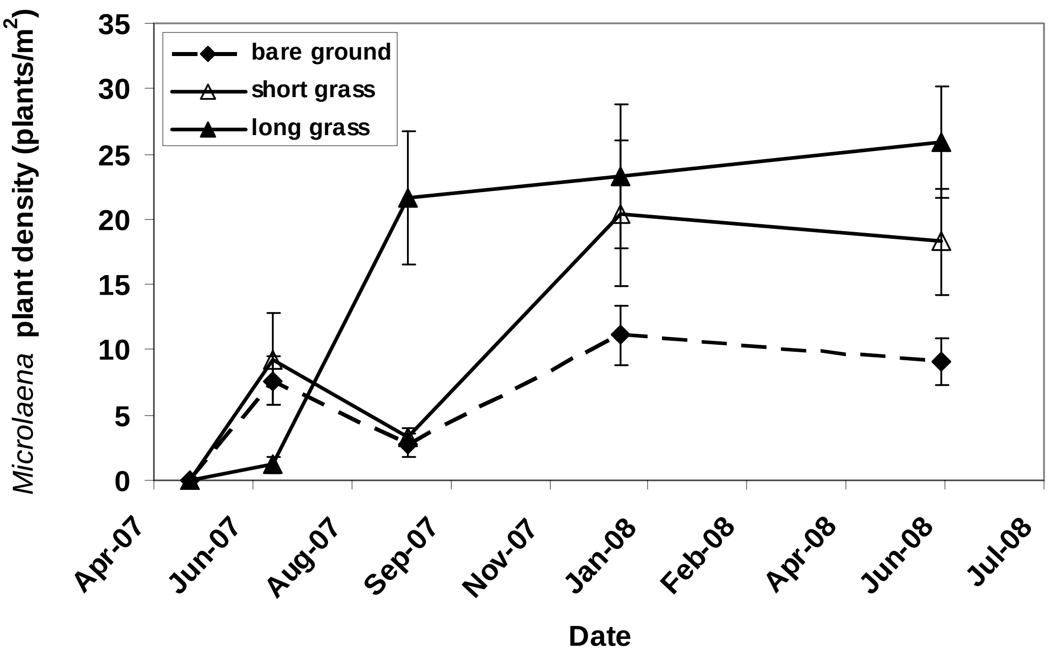

Figure 1 Interaction between measurement date and residual treatment on *Microlaena* plant density (plants/m^2). Bars represent SEM.

Table 2 Interaction between residual treatment and sowing method on *Microlaena* plant density (plants/m^2) across all dates.

Sowing method	Residual treatment		
	Bare ground	Short grass	Long grass
Broadcast	7.8 b	21.1 c	28.5 c
Hydroseed	7.4 b	4.6 a	7.5 b

Different letter suffixes indicate significant treatment differences for P<0.05.

With respect to the cover of *Microlaena* on the plots, all three main treatment effects and the measurement date effect were significant. *Microlaena* cover was higher on the broadcast plots compared to the hydro-seeded plots, except for the bare soil residual treatment (Table 3). Comparing the pre-sow residual treatments, *Microlaena* cover was not significantly different between treatments for the first two measurements but was highest on the long grass plots by December, so that there was a significant date × residual interaction. Between the three sowing rates, cover on the intermediate and high rates was not significantly different, but was greater than the low rate. The analysis of *Microlaena* dry matter harvested at 370 DAS showed broadly similar patterns for treatment differences to that of the cover on the plots (Table 4). Dry matter harvested was greatest where high seeding rates were broadcast on long grass plots, and least on bare ground plots, and where low seeding rates were applied by hydro-seeding.

The average cover of kikuyu in the plots had recovered to 3% by December 2007, 20% by March 2008 and 30% by May 2008. There were significant main effects of residual and sowing rate but no significant difference in kikuyu cover between the two sowing methods (Table 5). Kikuyu cover was significantly higher on the long grass plots compared to the short grass and bare ground plots, and significantly higher at the 750 seeds/m^2 *Microlaena* sowing rate compared to the 100 seeds/m^2 sowing rate. The analysis of kikuyu dry matter harvested at 370 DAS showed similar treatment differences to that of the cover on the plots; however none of the differences were statistically significant.

There was a significant positive relationship between *Microlaena* plant numbers in the sub-plot and % cover in the sub-plot for both measurement dates (R^2=0.53, P<0.001 in December 2007 and R^2=0.58, P<0.001 in May 2008). There was also a significant positive relationship between *Microlaena* plant numbers in the sub-plot and the amount of *Microlaena* dry mass harvested from the sub-plot in May 2008 (R^2=0.67, P<0.001). In December there was a significant negative correlation between *Microlaena* cover and the cover of other grasses (r=0.29, P<0.01).

Table 3 Percent cover of *Microlaena* at 370 DAS in May 2008.

	Sowing rate (seeds/m^2)			
	100	250	750	Mean
Broadcast				
Bare soil	1.2	3.8	3.4	2.8 d
Short grass	12.4	28.0	26.2	22.2 b
Long grass	22.2	37.0	50.0	36.4 a
Mean	11.9 b	22.9 a	26.5 a	20.5
Hydroseed				
Bare soil	1.6	5.0	12.2	6.3 cd
Short grass	4.4	12.0	6.2	7.5 c
Long grass	8.0	14.8	21.0	14.6 b
Mean	4.7 c	10.6 b	13.1 b	9.5

LSD for individual treatment comparisons = 10.3. Different suffix letters indicate significant mean differences for within-factor comparisons, $P<0.05$.

Table 4 Harvested biomass (g DM/m^2) of *Microlaena* at 370 DAS in May 2008.

	Sowing rate (seeds/m^2)			
	100	250	750	Mean
Broadcast				
Bare soil	21.4	27.4	15.5	21.4 c
Short grass	72.2	77.2	119.5	89.7 b
Long grass	75.0	157.9	263.2	165.3 a
Mean	56.2 bc	87.5 b	132.7 a	92.1
Hydroseed				
Bare soil	6.5	20.1	18.4	15.0 c
Short grass	2.4	44.7	37.7	28.2 c
Long grass	12.1	61.4	75.3	49.6 bc
Mean	7.0 d	42.1 cd	43.8 cd	30.9

LSD for individual treatment comparisons = 41.2. Different suffix letters indicate significant mean differences for within-factor comparisons, $P<0.05$.

Table 5 Percent cover of kikuyu at 370 DAS in May 2008.

	Microlaena sowing rate (seeds/m^2)			
	100	250	750	Mean
Broadcast				
Bare soil	31.0	26.0	31.2	29.4 bc
Short grass	34.6	25.0	19.0	26.2 bc
Long grass	59.0	28.0	20.4	35.8 ab
Mean	41.5 a	26.3 ab	23.5 b	30.5
Hydroseed				
Bare soil	27.8	14.6	19.0	20.5 c
Short grass	24.0	34.2	35.2	31.1 bc
Long grass	54.2	45.4	33.0	44.2 a
Mean	35.3 a	31.4 ab	29.1 ab	31.9

LSD for individual treatment comparisons = 19.1. Different suffix letters indicate significant mean differences for within-factor comparisons, $P<0.05$.

Discussion

Despite reports of successful sowing with hydro-seeding (or hydro-mulching, Whalley *et al.* 1998), emergence was poor overall with the hydro-seeding treatment (Table 1), for reasons that remain unclear: possibilities include toxins in the binding agent, and/or separation of the seed from adequate contact with soil moisture (there was an indication of the matrix drying out and contracting away from the soil/grass surface). It has been suggested that the function of the long awn on propagules of species like *Microlaena* is to orient the seed optimally as it falls onto the soil surface. This orientation would probably not have occurred with hydro-seeding as the matrix probably randomly orients the seed. In any case, the low plant populations established following hydro-seeding have persisted throughout the experiment, and current *Microlaena* cover is almost uniformly low in the hydro-seeded plots regardless of pre-sowing treatment or sowing rate.

Seedling emergence was also generally poor on bare soil, despite removal of all pasture cover that could inhibit seed-soil contact (Table 1). It is possible that higher levels of moisture loss from bare soil mean that seeds either failed to imbibe or were subject to later dessication. This species, like most grasses, is sensitive to soil moisture conditions on bare surfaces (Huxtable & Whalley 1999). It is generally recommended that *Microlaena* seeds be sown at a depth of 10-20 mm (Waters *et al.* 2001; Cole & Metcalf 2003), although an under-sowing treatment was not included on the basis of practical limitations on the highly variable topography of the cones. The same effect of seed orientation noted above may also be a factor, as the seeds were clearly observed to be lying flat on the bare soil surface. Hence smoothing of the soil surface by the turf stripper may also have hindered good positioning of the seed in the soil.

Emergence was highest where the existing vegetation had been sprayed and mowed, possibly reflecting an optimal combination of moisture retention in the soil by decomposing plant material and good seed-soil contact through the shorter sward. The longer grass, where it was not mowed, may have inhibited seed-soil contact initially, which then occurred once that cover decomposed. In any case, later germination in the long grass treatment of *Microlaena* seeds that apparently maintained viability for up to 3 months (Waters *et al.* 2001) has led to the highest plant densities – up to a mean of 56 plants/m^2 in the broadcast/long grass/high sowing rate treatment combination in May 2008. However, the variation across those five replicate plots is high, from 24-84 plants/m^2, emphasising the highly variable emergence occurring in this hand-collected seed lot.

There appears to be a fairly strong relationship between plant number and cover for *Microlaena* in these plots. This is entirely to be expected for the initial measurement dates when plants were smaller and more uniform in size. Now that the plants are larger (mean 3.6 g DM per plant with an average >100 tillers based on a sample of tagged plants) there does not appear to be any trade-off in terms of loss of smaller plants (only one of the 40 tagged plants died). The coefficient for the regression of cover vs plant density suggests that each plant covers on average an area of ~65 cm^2. There was no evidence of plants spreading by stolon growth at this point, with all of the tagged plants still confined to a single crown.

The key conclusion is that after 12 months the highest plant population and cover were achieved under the minimum management treatment, i.e., spraying and broadcasting, without any removal of herbage or soil. The only apparent drawback in this approach appears to be slightly higher recovery of kikuyu cover relative to other treatment combinations, but this may be able to be overcome by higher sowing rates (Table 4). The regression analysis of cover classes indicated that *Microlaena* was more competitive against other grasses than kikuyu. The key will be obtaining seed with a much better field emergence, perhaps through more selective harvesting methods or the use of improved germplasm. These results have positive implications for the application of an over-sowing approach to restoring *Microlaena* to the volcanic cones where establishment options are limited by public sensibilities and highly variable topography. However, the variability in *Microlaena* plant density and cover observed for the broadcast treatment in the experiment suggests some element of risk as to the results achievable in the field.

Acknowledgements

This research was funded by an Auckland City Council grant to Landcare Research and AgResearch, as part of the ACC Volcanic Cones Management Project led by Tony Hartnett. Mark Smale and Scott Bartlam provided valuable assistance in the field. Evergreen Soil Conservation Ltd, Auckland City Parks staff and Envirotech Ltd assisted in management of the site. Massey University did the seed testing. John Waller of AgResearch Ruakura performed the statistical analyses. The helpful comments of Grant Douglas (AgResearch Grasslands) and two anonymous reviewers are acknowledged.

References

Cole, I. and Metcalf, J. 2003. Management guidelines for seed production of Australian native grass cultivars. Department of Infrastructure Planning and Natural Resources, NSW Government, Australia. 23 pp.

Esler, A.E. 2004. Wild Plants in Auckland. Auckland University Press, Auckland, New Zealand.

GenStat. 2008. 10th Edition. GenStat for Windows, version 10.2.0.175. VSN International, Oxford, United Kingdom.

Huxtable, C.H.A. and Whalley, R.D.B. 1999. Emergence and survival of three native grass species sown on roadsides on the northern Tablelands, New South Wales, Australia. *Australian Journal of Botany*. 47: 221-235.

ISTA. 2003. ISTA working sheets on tetrazolium testing volume 1 agricultural, vegetable and horticultural species. The International Seed Testing Association, Bassersdorf, Switzerland.

Pohlen, I.J. 1964. Soils of the Auckland District. G.E. Orbell, pers. comm. 2008.

Waters, C.; Whalley, W.; Huxtable, C. 2001. Guidelines for revegetating with Australian native grasses. Microlaena stipoides. Retrieved 18 September, 2007 from http://www.agric.nsw.gov.au/reader/7668

Whalley, R.D.B.; Jones, C.E.; Beckers, D.J.; Earl, J.M.; Johnson, S.B.; Macandog, D.B. 1998. Commercialisation and development of an agronomic package for *Microlaena stipoides* for forage and other purposes. Meat and Livestock Australia. 84 pp.