Successful drilling of forage species during severe drought in Central Otago – a preliminary report 1998/99

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Abstract

Five plant species were established using two direct drilling techniques in a trial initiated in spring 1998 at a dryland site on Earnscleugh Station in Central Otago. The plant species were: wheatgrass (*Thinopyron intermedium*), tall oat grass (*Arrhenatherum elatius*), birdsfoot trefoil (*Lotus corniculatus*), hairy dorycnium (*Dorycnium hirsutum*) and bluebush (*Kochia prostrata*). These were established with the New Zealand Agricultural Engineering Institute/AgResearch strip-seeder drill and a conventional hoe-coulter drill. Establishment and subsequent growth during the first two growing seasons are described, and evaluation of this trial will be ongoing.

The 1998/99 summer developed into one of the driest and windiest seasons experienced in Otago, resulting from prevailing La Niña Southern Oscillation weather patterns. The extreme drought culminated in two significant grassland fires near Alexandra in late February.

Heat and drought during summer adversely affected seedling numbers as the season advanced. However, survival of plant species established with the strip-seeder drill was significantly better than that from the hoe-coulter drill. By autumn 1999, live seedling numbers were heavily reduced in all treatments (-50% and -68% for strip-seeder and hoe-coulter drills, respectively) but recovery was satisfactory during early winter. Wheatgrass, hairy dorycnium and tall oat grass in particular persisted well during the relatively mild winter. Despite a dry spring, by October 1999 these species had achieved ground coverage of 38%, 23% and 33% respectively from the strip-seeder drill (cf. 7%, 7% and 6% from the hoe-coulter drill), thus the vegetation was providing significant and earlier protection for fragile soil resources in a harsh environment.

These results are preliminary but we conclude from them that the strip-seeder technique can provide superior plant establishment on dryland sites even during adverse drought conditions. Commercial development of this technology, including simplification of the system, is recommended.

Keywords: birdsfoot trefoil, bluebush, dryland drilling, hairy dorycnium, hoe-coulter, strip-seeder, tall oat grass, wheatgrass

Introduction

Direct drilling investigations in dryland environments have resulted in the commercial development of several drills and associated establishment techniques, e.g., pre-drilling herbicide application. These have had varying degrees of success. In the early 1990s, a new drill was jointly developed by MAFTech (AgResearch) and the New Zealand Agricultural Engineering Institute (Lincoln Ventures), using strip-seeder technology. This was designed to provide a reliable, cost-effective tool for improved establishment in dry, often *Hieracium*-infested, tussock grasslands of the South Island. While this drilling system has been most satisfactory in farm-scale evaluations (Lowther *et al.* 1996), no commercial interest has been shown in it.

A trial comparing drilling techniques with several potentially useful forage species was initiated in spring 1998 at a dryland site on Earnscleugh Station in Central Otago. The trial aimed to determine the effectiveness of the strip-seeder drilling technique, compared to use of a conventional hoe-coulter drill, for establishment of these forage plants. This was preceded by an earlier investigation on Earnscleugh Station that compared the establishment of two plant species using pole harrows, a hoe-coulter drill and the 'J Tull' experimental plot drill using strip-seeder attachments (Trainor & Wills 1998).

This paper describes establishment and subsequent growth in this trial during the first year after direct drilling, which included an unusually dry spring and summer. Evaluation of this trial will continue over the next two summers.

Methods

The site selected was a northerly face (slope 5–8°) in the Omeo Gully area of Earnscleugh Station. The soil is classified as a Conroy brown-grey earth hill type, with some Becks silt loam interphases. Existing 'pasture' was very depleted and consisted largely of scabweed and haresfoot trefoil. The trial area was 1 ha,

soils and aspect were reasonably uniform across the site, and it was rabbit-proof fenced immediately after drilling.

Treatments were:

- two establishment techniques (strip-seeder drill and hoe-coulter drill)
- five plant species – hairy dorycnium (*Dorycnium hirsutum*) @ 8 kg/ha, bluebush (*Kochia prostrata*) @ 8 kg/ha, tall oat grass (*Arrhenatherum elatius*) @ 5 kg/ha, wheatgrass (*Thinopyron intermedium*) @ 5 kg/ha, birdsfoot trefoil (*Lotus corniculatus*) @ 5 kg/ha.

Cropmaster 20 fertiliser was applied to all treatments @ 100 kg/ha. Lime was applied at 25 kg/ha with the bluebush as it establishes poorly and benefits from higher soil pH levels.

Plots were 6 m x 20 m with three replicates per treatment and were assigned randomly. Two runs per plot were conducted with the strip-seeder drill and three with the narrower hoe-coulter drill. Drills were calibrated before the trial to determine equivalent seed/fertiliser application rates per coulter. A common seed source and application rate were used for each species in both drill types.

Seed of both hairy dorycnium and birdsfoot trefoil was treated with *Lotus corniculatus* inoculant before drilling. The vegetation/ground cover and soil nutrient/moisture status were determined before establishment. Drilling into unmodified pasture proceeded on 18 September 1998.

Establishment was determined by counting seedling numbers in ten 1 m transects per plot, randomly pegged within drill rows at 8, 13, 18 and 31 weeks after sowing. Plant heights were measured at the mean vegetative foliage distance above ground level (excluding flowering stalks). Changes in ground cover and plant composition were determined by point analysis at 25 cm intervals along two 10 m permanent transects in each plot. Established in January 1999, these were placed diagonally across the drill rows and were assessed the following spring and autumn. Plant phenology, pest and disease effects were also noted during these assessments.

Data were analysed statistically using a split-split plot analysis of variance with strata plots, pegs within plots and dates within pegs.

Results

Environmental conditions

During 1997/98, New Zealand's climate was predominantly influenced by the El Niño phase of the Southern Oscillation Index (SOI), bringing with it increasingly dry conditions in central and eastern parts of the South Island. The SOI rapidly changed to a strong La Niña phase during summer 1998/99 which resulted in strong westerly air-flows and severe drought conditions in South Island areas already badly affected by prolonged lack of rain. Winter 1999 was mild and dry conditions continued until mid-November when major flooding occurred in the South Island.

Monthly mean maximum screen temperatures at the Clyde meteorological station during summer 1998/99 exceeded 3°C above the long-term mean for January and February, with daily maxima reaching 35°C. Screen temperatures exceeded 25°C on 75% of days in both January and February. Both months had a mean daily wind run of about 195 km and on 28 February, when fires broke out, the wind run was 525 km with gusts exceeding 70–80 km/hr.

The 1998/99 growing season was one of the most extreme on record for Central Otago, and the species drilled in September 1998 had to endure severe drought and high temperatures for a prolonged period during their critical establishment phase.

Plant establishment and growth

The main soil nutrient changes resulting from the fertiliser addition were elevated P and S levels (Table 1). Early establishment of several of the species was satisfactory (Table 2), given the prevailing adverse environmental conditions.

Hairy dorycnium had high seedling numbers per metre of drill row with both drills (strip-seeder about 1.5-fold that of hoe-coulter) in November 1998, but these decreased as drought conditions intensified through to January 1999 (Table 2). The difference in seedling numbers between drills for each assessment date to this point was significant ($P<0.05$, LSD2). By April 1999, the difference (not significant) between the strip-seeder and hoe-coulter drilling techniques had increased to 2.9-fold. In terms of survival by the end of the summer, hairy dorycnium seedling numbers remained among the highest of the forage species in the trial, although differences were not significant.

Shrubby bluebush seedling numbers were low in November 1998, but seedling losses (both drills)

Table 1 Chemical analyses of soil in the Earnscleugh Station drilling comparison trial, January 1999, with and without Cropmaster Fertiliser (Data = Quicktest units, Cornforth & Sinclair 1984).

Sample	Ca	K	P (Olsen)[1]	Mg	Na	S[1]	pH[2]
- Cropmaster 20	8	14	15	24	2	1	6.5
+ Cropmaster 20	6	12	30	20	2	12	6.1

[1] mg/kg soil [2] 1:2.5 soil/water suspension

Table 2 Seedling counts per metre of drill row for five dryland species and two drilling techniques in the Earnscleugh Station drilling comparison trial, November 1998–April 1999.

Species	Hairy dorycnium		Bluebush		Birdsfoot trefoil		Tall oat grass		Wheatgrass	
Date/Drill	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter
Nov-1998	21.6	14.3	5.0	3.1	5.7	4.4	15.8	11.0	9.9	9.9
Dec-1998	16.7	9.3	5.9	3.2	5.0	3.4	16.6	9.2	9.6	8.6
Jan-1999	9.2	5.1	4.3	2.9	4.1	1.8	9.7	3.7	7.5	4.1
Apr-1999	5.8	2.0	3.5	1.8	3.2	1.2	5.5	3.1	6.1	3.0
Difference Nov 1998 to Apr 1999	-73%	-86%	-30%	-42%	-44%	-73%	-65%	-72%	-38%	-70%

LSD1, 5% date*drill*species = 3.7; LSD2, 5% drill*species for same date level = 2.0
note LSD does not apply to% difference.

through to April 1999 (at -30 to -40%) were less than those for all other species. Surviving plants proved quite drought-tolerant. The strip-seeder drill tended to provide better establishment and survival than the hoe-coulter drill but the differences were not significant.

Birdsfoot trefoil seedling emergence was low and seedling mortality occurred during the summer period, particularly in the hoe-coulter drill treatments. The reduction in seedling numbers from November 1998 to April 1999 using the strip-seeder drill was -44% compared with -73% for the hoe coulter drill, however the actual reduction in seedling numbers was not significant.

Tall oat grass had higher seedling numbers than wheatgrass in November 1998, but its mortality rate was also higher and the result by April 1999 was similar for both grasses. The difference in seedling numbers between drills for each assessment date to January 1999 was significant ($P<0.05$, LSD2) but that for April 1999 was not.

Wheatgrass seedling numbers were identical for both drill types in November 1998. The strip-seeder drill tended to provide better establishment and survival than the hoe-coulter drill but the differences to April 1999 were not significant. Considering survival to the end of the summer, wheatgrass seedling numbers were higher than other forage species in the trial, but again differences were not significant.

The effects of pests on the seedlings were observed to be minimal during the establishment phase, and no diseases were noted.

Seedling height was measured during the establishment period as an early indication of plant development. This generally, but not exclusively, indicated better growth from plants in the strip-seeder treatments (Table 3).

Hairy dorycnium showed typically slow, steady growth in both drill treatments and its plants had similar ($P>0.05$) heights at each assessment. At the October 1999 assessment, all other species had taller plants ($P<0.05$) from the strip-seeder treatment compared to those from the hoe-coulter treatment. This also occurred for bluebush, birdsfoot trefoil and tall oat grass at the January 1999 assessment, but not for wheatgrass which had similar ($P>0.05$, LSD2) plant height. A measurable difference in vegetative height became evident only when wheatgrass entered its reproductive phase going into the second growing season.

As the 1999/2000 growing season progressed, the advantage of the plants sown with the strip-seeder was increasingly reflected in the extension of their vegetative ground cover (Table 4a). By the beginning of the second growing season, hairy dorycnium, tall oat grass and wheatgrass, established with the strip-seeder drill, were providing 23–38% of the ground cover within their respective plots. Conversely, when established with

Table 3 Seedling height (cm) during establishment for five dryland species and two drilling techniques in the Earnscleugh Station drilling comparison trial, November 1998–October 1999.

Species	Hairy dorycnium		Bluebush		Birdsfoot trefoil		Tall oat grass		Wheatgrass	
Date/Drill	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter
Nov-1998	2.1	2.0	2.1	1.9	2.8	2.3	8.7	7.9	8.3	7.5
Dec-1998	4.7	2.4	7.9	3.3	5.3	2.9	13.3	9.1	7.1	7.1
Jan-1999	6.6	3.5	17.8	3.9	8.3	3.2	18.1	11.6	7.8	7.8
Apr-1999	10.1	7.5	16.9	3.7	9.7	6.8	11.3	9.4	10.3	8.1
Oct-1999	16.1	13.3	13.3	5.1	16.1	10.7	29.6	20.1	31.1	23.5

LSD1, 5% date*drill*species = 3.0; LSD2, 5% drill*species for same date level = 2.2

Table 4 Ground cover (%) of drilled plants following establishment for five dryland species and two drilling techniques in the Earnscleugh Station drilling comparison trial, November 1998–April 2000:

A. Date x drill x seed interaction

Species	-- Hairy dorycnium --		-- Bluebush --		-- Birdsfoot trefoil --		-- Tall oat grass --		-- Wheatgrass --	
Date/Drill	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter	Strip-Seeder	Hoe-Coulter
Jan-1999	6	1	5	1	2	0	14	6	16	5
May-1999	14	2	5	0	5	0	23	6	30	5
Oct-1999	23	7	6	0	14	1	33	6	38	7
Apr-1900	27	9	7	1	18	2	32	11	40	10

LSD1, 5% date*drill*species =7.6; LSD2, 5% drill*species for same date level = 3.6

B. Drill x seed interaction

	Drill	
Species	Strip-Seeder	Hoe-Coulter
Hairy dorycnium	14	4
Bluebush	5	0
Birdsfoot trefoil	7	0
Tall oat grass	23	6
Wheatgrass	28	6

LSD 5% drill*seed = 7.1

the hoe-coulter drill, they contributed only 6–7% of the ground cover.

Bluebush and birdsfoot trefoil contributed much lower ground cover levels, largely influenced by the low seedling numbers at establishment. The greater ground cover in strip-seeded plots remained evident with them, but was not significant ($P>0.05$).

Comparing the drill x species interaction across all assessment dates, the strip seeder drill was significantly better ($P<0.05$) with hairy dorycnium, tall oat grass and wheatgrass (Table 4b).

Discussion

This trial was established during an extreme season, one of the driest and warmest on record for Central Otago. With the trial site being on a northerly aspect, the climatic effects were accentuated and had a noticeable impact on plant survival and growth.

The two drilling techniques varied markedly in their effects on establishment and subsequent growth of the plant species. The strip-seeder drill clearly has advantages under severe drought conditions, providing greater seedling protection and a better growing environment. Although topsoil disturbance with the strip-seeder drill is initially greater than that with the hoe-coulter drill, the resulting improvement in plant establishment and growth is such that vegetation cover on the fragile soil resource is quickly and effectively restored. This is a reflection of the deeper ripping action of that drill and its fertiliser placement below the seed.

The plant species used were selected for their ability to withstand dry conditions. The initial establishment of hairy dorycnium exceeded expectation although drought quickly increased mortality of young seedlings. Post-drought recovery has, however, been good.

Bluebush had a relatively low establishment rate, in part owing to its small seed containing minimal reserves which must be used shortly after harvest to ensure good establishment. Surviving seedlings held on well through the first growing season with no significant reduction in numbers. Birdsfoot trefoil establishment was disappointing but again no significant reduction in seedling numbers occurred over the first season.

Wheatgrass, which has a large seed making for difficult drilling, was similar for both drilling techniques during establishment. No significant reduction in seedling numbers occurred over the first, drought-affected, season. It has subsequently provided the best ground cover (40%) in the strip seeder plots as the plants spread slowly via rhizomatous growth. Wheatgrass is typically slow to establish and much of its early development is underground (Wills *et al.* 1998).

Tall oat grass showed good initial establishment but, like hairy dorycnium, mortality was high during the peak of the drought. However, recovery during winter 1999 was good and ground cover with this plant was above 30% by the end of the second growing season.

The strip-seeder drill generally produced superior plant establishment and ground cover, especially with the faster-growing species which were responding to the deep soil ripping abilities and fertiliser placement of that drill. From these preliminary results, we conclude

that the strip-seeder as a drilling technique can provide superior plant establishment on dryland sites for some species even during adverse environmental conditions. Commercial development of this technology, including simplification of the system, is recommended.

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