Persistence of annual and perennial legumes 12 years after sowing in the Monaro region of New South Wales

Belinda Hackney[1, 2], Jo Powells[3], Susan Orgill[1, 2]

[1] NSW Department of Primary Industries, PMB, Pine Gully Rd, Wagga Wagga, NSW 2650
[2] Graham Centre for Agricultural Innovation, Charles Sturt University and NSW Department of Primary Industries, Pugsley Place, Wagga Wagga, NSW, 2650
[3]South East Local Land Services, Cooma, NSW 2630

Abstract
The productivity of introduced and native-based pastures across the Monaro region of NSW is often constrained by a low legume content. Full pasture renovation is frequently precluded by landscape, soil or economic constraints with producers often spreading legume seed with fertiliser in an attempt to increase the legume content of pastures. Four methods of legume introduction into an existing pastures (surface broadcasting and direct drilling with and without a pre-sowing glyphosate knockdown) at two landscape positions (north and south facing aspect) for four legume species, subterranean clover (*Trifolium subterraneum*), Caucasian clover (*T. ambiguum*), Talish clover (*T. tumens*) and lucerne (*Medicago sativa*), were investigated. Direct drilling after a glyphosate knockdown was the most successful method of introduction with subterranean clover achieving the highest seedling density. However, after 12 years, few legumes could be found on the north-facing aspect and subterranean clover had not survived on the south facing aspect. Legumes were found only in the direct drilled-glyphosate knockdown treatment; lucerne having the highest plant density and herbage availability. Where legume treatments had failed, populations of tall speargrass (*Austrostipa scabra*), a native perennial grass, had returned to their original density. *A. scabra* density was significantly lower on the south facing aspect in the lucerne and Caucasian clover treatments. There is capacity to introduce legumes into existing pastures but seed-soil contact and reduction in competition from existing pasture species at establishment is crucial to long-term persistence

Key Words
Monaro, variable landscape, lucerne, Caucasian clover

Introduction
The Monaro region of NSW is an area of diverse climatic, soil and landscape characteristics. Rainfall varies from 400 mm in the west of the region to more than 700 mm in the east with summer the wettest and winter the driest periods of the year, respectively. Winter temperatures are the coldest of the agricultural regions of Australia (Ayres and Arnott 1999). Soils are diverse with those of granite origin the most common (Ayres and Arnott 1999). Landscapes are highly diverse with the majority of the region not considered suitable for cultivation; such landscape characteristics also result in differences in microclimate which impact pasture production (Hackney 2009). Native perennial grass-based pastures are dominant across the region with *Austrostipa* spp. and *Austrodanthonia* spp. the most common in the drier localities (Ayres and Arnott 1999). These grasses have considerable capacity for recruitment as evidenced by surveys of ‘introduced pastures’ in the region, many of which had been re-invaded by native grass species; as consequence of management and environmental factors (Garden et al. 2000). Pasture legumes, predominately subterranean clover, has been introduced over time, as part of a full pasture renovation program and in less arable areas, during the process of broadcasting superphosphate by ground or air (Ayres and Arnott 1999). Maintaining useful quantities of annual legumes in the pasture system can be challenging due to the variabile and often low autumn rainfall resulting in failure to initiate germination or, if sufficient rainfall is not received until late autumn or winter, then germination and subsequent legume growth can be severely constrained by low temperature (Hackney 2009). Furthermore, the presence of perennial grasses and their capacity to effectively use soil moisture can result in germination and establishment failure even where rainfall in early to mid-autumn is favorable (Hackney 2009). Low legume content reduces nitrogen fixation, pasture production and pasture quality thereby limiting potential livestock production. Previous research has shown the potential of perennial legumes in this region, particularly Caucasian clover when sown into a fully prepared seedbed (Virgona and Dear 1996). However, use of this species has been restricted due to its very slow establishment and lack of seed availability. More recently, plant breeding programs have resulted in the development of a new Caucasian clover cultivar and domestication of a new perennial legume, Talish clover (Hall et al. 2016). Additionally, lucerne has gained increasing popularity in mixed farming zones due to the poor performance of traditional annual legumes such

as subterranean clover (Wolfe and Dear 2001) but its general adaptation to the Monaro is unknown. As native perennial grass-based pastures are the dominant pasture type in the Monaro region, the aim of this research was to assess a range of options to introduce pasture legumes into such pastures and to assess whether landscape aspect had an impact on initial establishment and long-term persistence.

Methods

The field site was located 7 km south of Berridale, NSW (36.4507 S, 148.8634E, 870 m a.s.l) in an *A. scabra* based pasture on a granite-derived soil. The site had previously had subterranean clover (*T. subterraneum*) introduced by surface broadcast with occasional application of single superphosphate although no subterranean clover had been introduced in the 15 years prior to the study commencing and no fertiliser had been applied for the previous five years. Twenty soil cores (50 mm diameter x 50 mm depth) were collected from the north and south aspect sites prior to commencement of the study to determine the background level of subterranean clover. Replicated (n=4) plot trials (individual plots 2 m wide x 6 m long) were established on both the north and south facing aspects in the paddock. Perennial grass density (plants/m^2) was assessed using a 0.5 m x 0.5 m quadrat in the centre of each plot prior to application of any treatments. Four methods of legume introduction were examined; surface broadcasting (SB), surface broadcasting following a glyphosate knockdown (SBPS), direct drilling (DD) and direct drilling following a glyphosate knockdown (DDPS). Glyphosate (360 g/L) was applied at 2 L/ha two weeks prior to sowing. Three perennial legumes were introduced into the existing pasture using the sowing methods above: lucerne (cv. Aurora), Caucasian clover (cv. Kuratas) and Talish clover (cv. Permatas). The annual legume subterranean clover (cv. Seaton Park) was used as a control. All legumes were sown at 4 kg/ha following inoculation with the appropriate strain of rhizobia. Superphosphate (8.8% P, 11% S) was applied at 125 kg/ha to the soil surface (surface broadcast treatments) or drilled for the direct drill treatments. Both sites were sown on 29th March 2007. Germination was assessed on 30th May 2007 at four random positions within each plot using a 0.5 m x 0.5 m quadrat. No further fertiliser was applied following sowing. Herbage production was assessed over the following two years (data not shown) and the sites then not monitored until spring 2018. The sites were subjected to the same management as the rest of the paddock between 2009 and 2018; no fertiliser was applied in this time and the paddock was periodically grazed with Merino sheep (~2.5 sheep/ha). On November 30th 2018, legume herbage on offer was assessed using calibrated visual assessment, eight weeks after sheep were removed. Plant density (perennial grass and legume) was assessed using a 0.5 m x 0.5 m quadrat placed in the centre of each plot. As Caucasian clover is a rhizomatous species, the number of plants could not be accurately determined and therefore assessment was made only of herbage availability for this species. Data were analysed using REML (Genstat 19th edition) fitting legume species, aspect and method of legume introduction as fixed effects and replicate as a random effect.

Results

Soils on both the north and south aspect sites were acidic with low levels of available phosphorus and sulphur, low cation exchange capacity but low levels of exchangeable aluminium. There was no difference in the general soil chemical characteristics between the north and south aspect (Table 1)

Table 1 Soil chemical characteristics (0-10 cm) of the north and south aspect positions at Berridale, NSW in 2007

	North	South
pH_{Ca}	4.8	4.7
P (mg/kg) Colwell	9.3	8.8
S (mg/kg) KCl-40	4.7	4.9
CEC (cmol/kg)	3.9	4.1
Al (% of CEC)	1.5	1.8

No subterranean clover burr or seed was recovered from the soil cores taken prior to the commencement of the study indicating a very low background level of subterranean clover. The density of *A. scabra* differed significantly between aspects (32 plants/m^2 on north aspect, 35 plants/m^2 on south aspect ($LSD_{5\%}$ = 2.4). However, there were no significant difference in perennial grass density within each aspect.

There were significant differences in germination attributable to legume species ($P<0.001$), aspect ($P<0.001$) and the interaction of aspect and method of legume introduction ($P=0.01$) (Figure 1). Germination was significantly higher for subterranean clover than all other species while the germination of lucerne was significantly higher than both perennial clover species. Germination was significantly higher for direct drilling where a glyphosate knockdown had been applied prior to sowing (DDPS) than for other methods of legume introduction and did not differ between aspects. Surface broadcasting of seed (SB) resulted in lowest germination. Use of a glyphosate knockdown prior to surface broadcasting (SBPS) resulted in a significant increase in germination compared to the SB treatment; the germination achieved was only 34% and 22% of that achieved with the DDPS treatment on the north and south aspect respectively. Direct drilling alone (DD) resulted in a significant increase in germination compared to both SB treatments on the south-facing aspect but this was only 55% of the density of the DDPS treatment on the same aspect.

Legumes were found only in the DDPS treatments in 2018 and analysis was undertaken only on this treatment group for the 2018 measurements. There were significant effects of aspect ($p<0.001$), species ($p<0.001$), method of legume introduction ($p<0.001$) and interaction of all three of these factors ($p<0.001$) on legume density and herbage on offer 12 years after sowing (Figure 2). No Talish clover, subterranean clover or Caucasian clover were found on the north-facing aspect 12 years after sowing. The lucerne population was significantly lower on the north (0.75 plants/m^2) compared to the south facing slope. Within the south-facing aspect site, the density of lucerne was significantly higher than Talish clover while no subterranean clover plants were found. In terms of herbage production, there was negligible lucerne herbage on the north-facing aspect (36 kg DM/ha). Within the southern aspect site, lucerne had significantly more herbage on offer than any other species while Caucasian clover had significantly higher herbage availability than Talish clover.

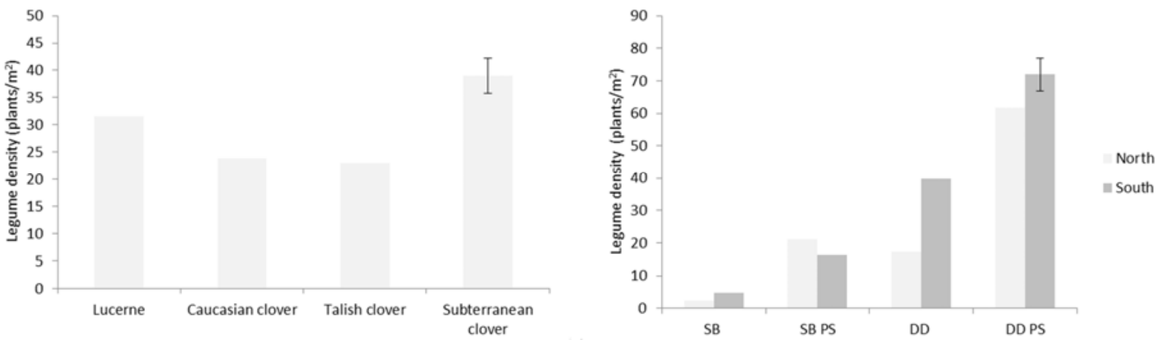

Figure 1. Germination (plants/m2) of four legume species (left); and the effect of method of legume introduction on legume germination (SB=surface broadcasting; SB PS = surface broadcasting following glyphosate knockdown; DD = direct drilling, DDPS = direct drilling following a glyphosate knockdown) on a north and south-facing aspect (right) in an *Austrostipa scabra* based pasture near Berridale NSW in 2007.

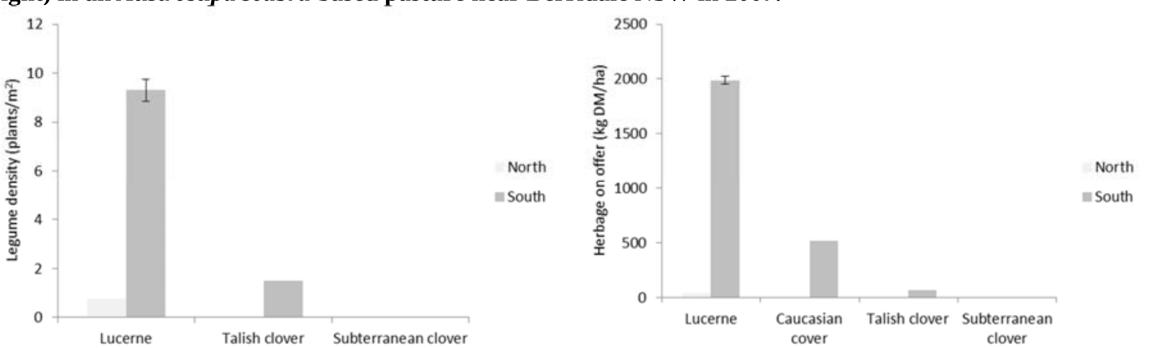

Figure 2. Legume density (plants/m2; left), and herbage on offer (kg DM/ha; right) for lucerne, Caucasian clover, Talish clover and subterranean clover in 2018 where legumes had been sown into an *Austrostipa scabra* pasture by direct drilling following application of a glyphosate knockdown. Note: As Caucasian clover is a rhizomatous species it is not possible to determine the number of plants per square metre.

There was no significant difference in *A. scabra* density in 2018 compared to 2007 on the north-facing aspect for any treatment or species combinations (av. density 33 plants/m^2). On the south-facing aspect, *A.scabra* density was significantly lower in lucerne (9 plants/m^2) and Caucasian clover (14 plants/m^2) in the DDPS treatment than for all other legume introduction-species combinations (avge 32 plants/m^2; $LSD_{5\%}$ 6.3).

Discussion and Conclusions

The improvement in establishment under direct drilling compared to surface broadcasting is similar to the findings of Dowling et al. (1971) who reported improved establishment where there was some compared to no soil disturbance for subterranean clover in the Central Tablelands region and attributed this to improvement in seed-soil contact. In our study, further improvement in the establishment of legumes was found where a pre-sowing knockdown was used and is likely due to a decrease in competition for moisture from the perennial grass. Hackney (2009), in a field trial in the Monaro region, reported increased soil moisture content in an *A. scabra*-based pasture in the autumn period, the critical period for legume germination, wherever the population of the perennial grass was lower and this was associated with an increase in annual legume content. There were no sown legumes 12 years after initial establishment on the north-facing aspect, which may be associated with microclimate conditions (lower and/or more variable soil moisture conditions and higher temperatures) that have previously been reported on north compared to south-facing aspects in the Monaro region (Hackney 2009). On the south-facing aspect and only in the pre-sow knockdown, direct drill treatment, the persistence and production of the perennial legumes lucerne and Caucasian clover were significantly higher than for the annual legume subterranean clover (which was absent) 12 years after establishment. For long-term persistence, annual legumes require conditions conducive to germination in autumn and for seed production in spring in order to maintain a seedbank over time; lower or more variable soil moisture conditions as a consequence of microclimate differences associated with aspect may have contributed to poor legume persistence on the north-facing aspect in this trial. The Monaro region is characterised by unreliable rainfall in autumn and it can also experience periods of severe moisture stress in spring, conditions that are not conducive to the long-term persistence and reliable production of annual legumes. In contrast, perennial legumes, providing they establish successfully in the year of sowing and are subsequently tolerant of moisture stress, are likely to be better able to persist long-term as they are not reliant on regular regeneration from seed which may be impacted by seasonal conditions. Both lucerne and Caucasian clover by virtue of deep and rhizomatous root systems, respectively have high levels of drought tolerance (Wolfe and Dear 2001; Virgona and Dear 1996). Virgona and Dear (1996) have previously reported long term persistence of the Caucasian clover cvv. Monaro and Alpine, in this region. Where legumes failed to persist, *A. scabra* was successful in recruiting seedlings, and had achieved a density similar to pre-treatment. Even where lucerne and Caucasian clover had persisted, the *A. scabra* had recruited but to levels that were significantly lower than the pre-treatment density. While we cannot rule out the impact of low levels of fertiliser input and low grazing pressure as a contributing factor impacting persistence in our study, we did find evidence for strong persistence of lucerne and Caucasian clover and some persistence of Talish clover under these conditions but only on the south-facing aspect. The use of these species in native perennial grass-based pastures warrant further investigation in the Monaro region with consideration given to the impacts of landscape variation on production and persistence.

Acknowledgements

The authors wish to acknowledge Mr Eric Hall (University of Tasmania) for supply of Caucasian and Talish clover seed and Dr Rowan Smith (University of Tasmania) for comments on the manuscript.

References

Ayres L, Arnott R (1999) The Monaro Region. NSW Department of Agriculture

Dowling, PM, Clements, RJ , McWilliam, JR. (1971). Establishment and survival of pasture species from seed sown on the soil surface. Australian Journal of Agricultural Research 10.1071/AR9710061.

Garden D, Dowling P, Eddy D, Nicol H (2000) A survey of farms on the Central, Southern and Monaro tablelands of New South Wales: management practices, farmer knowledge of native grasses and extent of native grass areas. Australian Journal of Experimental Agriculture 40, 1081-88.

Hall E, Reid R, Clark B, Dent R (2016) The search for alternative temperate perennial pasture species for low to medium rainfall environments in Tasmania. New Zealand Grassland Society Hill Country Symposium.

Hackney B (2009) Understanding Variation in Pasture Growth in Topographically Diverse Landscapes. PhD thesis. University of Sydney

Virgona JM, Dear BS (1996) Comparative performance of Caucasian clover (Trifoliumambiguum cv. Monaro) after 11 years under low□input conditions in south□eastern Australia, New Zealand Journal of Agricultural Research, 39:2, 245-253

Wolfe EC, Dear BS (2001) The population dynamics of pastures with particular reference to southern Australia. (In) Competition and Succession in Pastures. (Eds PG Tow, A Lazenby). pp.119-148. CAB International