A review of red and white clovers in the dryland environment

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Abstract
Red and white clovers are best adapted to areas with good soil fertility and adequate soil moisture (750 mm annual rainfall), particularly over summer (150 mm), and are therefore restricted to small areas such as the more fertile valley floors and lower shady slopes in dryland environments. To extend their range and aid survival in dry environments, grazing management and cultivar selection are critical. Continual grazing (set stocking) during spring leads to a dense grass pasture, providing protection from desiccation for white clover stolons in the following summer. White clover cultivars have an inbuilt plasticity that allows morphological adaptation to changes in grazing management. For instance, set stocking in combination with a small-leafed cultivar results in a reduction of plant size but an increase in the stolon population, leading to better plant survival through drought periods. Where drought leads to stolon death, reseeding becomes a viable mechanism for clover persistence, and grazing management has a major influence on survival of new seedlings. For red clover, there is evidence that 'creeping' types survive better than 'crown' types in hill country, but the scope for extending red clover into drier areas is more limited.

Key words: cultivars, drought, dryland, grazing management, morphological adaptation, persistence, red clover, reseeding, summer rainfall, *Trifolium repens, T. pratense,* white clover

Introduction
White clover (*Trifolium repens*), by virtue of its stoloniferous habit, is a long-lived perennial usually grown in mixed grass/clover pasture, whereas red clover (*T. pratense*) is described as a short-lived (2 or 3 years), spring and summer active, crown forming, tap rooted perennial often grown in monoculture (Smith *et al*. 1985). In recent years, selections of creeping or spreading red clovers that vegetatively reproduce by rooting at the nodes to produce plantlets (Orr & Wedderburn 1996) have shown increased persistence over crown types, but only in fertile, moist sites (Hyslop *et al*. 1996; Hyslop 1999).

White and red clovers require soils that have high to moderate fertility and are wet to moderately dry (Levy 1970), conditions more likely to be found on valley floors and flat land. The most important factor determining whether any of the red and white clovers will suit a dryland system is a minimum of at least 750 mm annual rainfall (Levy 1970; Sheath & Hay 1989), with sufficient summer rainfall to avoid permanent wilting and maintain plant viability (Greenwood and Sheath 1982). Although some progress has been made in selection to extend the range of these species into drier areas through plant breeding, it has been relatively minor compared with the magnitude of the moisture constraints of the dryland environment.

For decades, New Zealand pastoral agriculture has had a history of legume–N based pastures, and while stock pressure remained moderate, there was some degree of success using these two legumes in drier environments. We examine the cultural, environmental and management requirements that may aid persistence of white and red clovers in dryland systems.

Growth habits of white and red clover
To better understand how clovers may react to different environmental conditions, it is first necessary to examine how they grow.

White clover development from seed has three distinct morphological phases (Brock & Tilbrook 2000): 1) a rosette seedling phase lasting 1-3 months with 2-3 branches, no stem elongation and therefore no nodal root formation; 2) a taprooted expansion phase lasting 1-2 years, with rapid elongation of stem branches (300 mm spread), numerous branches (16-20) and nodal root development; and 3) a 'mature' clonal phase, as taproots die and large plants fragment into small plants of approximately 4-6 branches and 50-70 mm spread, typical of white clover in permanent pastures. Smaller-leafed, rapidly branching cultivars with smaller taproots commence fragmentation earlier than large-leaved, slower branching cultivars with larger diameter taproots (Brock & Tilbrook 2000). It has been frequently observed that after 2-3 years, when the clover population is fully clonal and more vulnerable to environmental stress, the characteristics and performance of white clover may change (Caradus & Williams 1989) and 'clover decline' commences.

Red clover has a large taproot and initial stem that produces numerous erect shoots that remain short until flowering (Langer 1973). Successive leaves on the shoots arise close to one another in a tufted arrangement, and further shoots (branches) arise from axillary buds, collectively forming a dense crown. A proportion of shoots lengthen into reproductive stems, terminating in a flower head with no further shoot extension. New shoots arise from axillary buds on older shoots from the crown-hence the term, 'crown-type'. Typically, crown-type red clover grows strongly for 2-3 years, then damage to the crown from grazing animals allows root rots to infect the taproot (Hay 1985) and the plant dies. In the quest for improved persistence, 'creeping-type' red clovers have been selected which produce prostrate shoots growing close to the ground that are not grazed and this aids plant persistence (Hyslop *et al.* 1996). An alternative strategy has seen the development of 'spreading-type' red clovers with decumbent stems that can root at the nodes to form plantlets. This feature allows the spreading to persist from daughter plants when the parent plant dies (Hyslop 1999).

White clover in dry conditions

Rainfall is the major environmental determinant of white clover performance. Even where rainfall is generally considered adequate, summer–autumn dry periods can still result in large-scale loss of white clover. For instance, in the Manawatu, a difference in average monthly rainfall over the January to April period over 3 consecutive years of 55 mm to 40 mm to 70 mm caused a change in average clover content of 25% to 6% to 22% respectively (Brock, unpub. data). Knowles *et al.* (2003) have also demonstrated a direct relationship between the severity of drought and the loss and speed of recovery of white clover in pastures. Once soil moisture falls towards wilting point in hot weather, clover leaves die, wither and disappear quickly, leaving the stolons and soil surface exposed to direct radiation, which can cause temperatures to rise to 40-50 ºC (Brock & Hay 1993). Once available soil moisture is used up, evaporative cooling ceases and stolons overheat, collapse and die quickly *en masse*. Fortunately, there are management practices that can ameliorate the more drastic effects of drought that may help extend white clover use into drier areas.

Grazing management and drought survival

In a mixed sward, the companion grass can protect clovers from high temperature damage. Loss of leaves *per se* does not kill plants, grass or clover. Unlike clover, even though the leaves of grass plant may wither and die in severe drought, they do not disappear, and together with their tiller bases, provide a cover protecting both the soil surface and clover stolons from direct radiation, lowering surface temperatures substantially by 8–10 ºC (Brock & Hay 1993).

In this regard, grazing management has a major role in 'drought proofing' pastures, primarily through the grass component. Increasing frequency of grazing, particularly set stocking with sheep, increases perennial ryegrass tiller density (>14 000 tillers/m^2) compared with less frequently grazed pastures (3–5 000 tillers/m^2) (Brock 1988). Grass of frequently grazed pastures almost completely covered the soil, while less frequently grazed pastures remained relatively open. This has a large effect on white clover survival (Table 1, Brock 1988). As the result of a severe late spring–early summer drought, white clover content fell from 12% to 3%, caused by high stolon loss in the low density rotationally grazed system. In the high density set stocked systems, clover content increased from 9% to 16% with negligible stolon loss. Cultivar morphology has some influence, in that stolon recovery was faster (1 year) for the small-leafed cultivar 'Tahora' and slower (3 years) for the large-leafed cultivars 'Pitau' and 'Kopu'. Subsequent experiments confirmed the effect of surface cover and showed that the cultivar effect was directly related to stolon density, i.e. the more stolons present at the onset of drought, the more that survived at the end (Brock & Kim 1994). The critical period for this so-called 'drought proofing' was set stocking through spring, which fits well with sheep breeding operations. The key is a uniform distribution of the grass, in which sowing method plays an important part. Broadcast sown pastures provide a more even distribution of plants than pastures that have been direct drilled in 0.15 m rows. These large inter-row spaces provide space for the clover to grow into, which is beneficial while the environment is favourable. However, in dry conditions, the open row spaces leave the clover vulnerable to overgrazing, excessive soil temperatures and possible death, similar to the open spaces of rotationally grazed pastures (Brock & Kane 2003).

Cultivar selection

Grazing management interacts strongly with white clover cultivar morphology i.e. branching density and leaf size. Small-leafed, high branching frequency cultivars (e.g. 'Prop', 'Tahora', 'Prestige') are considered less productive than the large-leafed, low branching frequency cultivars (e.g. 'Aran', 'Kopu') but this is not necessarily the case. The counterbalance between having numerous small leaves and fewer large leaves generally results in similar productivity (Brock & Tilbrook 2000). The true morphological difference between cultivars is expressed in their persistence, as illustrated in Tables 2 and 3 (Brock 1988). White clover grows best under conditions that allow sufficient time between defoliations to express its full growth potential, i.e. rotational grazing. All white clover cultivars also have an inbuilt plasticity that allows a certain level of morphological adaptation to changes in grazing management. As defoliation frequency increases (e.g. set stocking) plant organs (leaves, growing point and stolon diameter and length) reduce in size (Carlson 1966), thus avoiding overgrazing. In this way small-leafed cultivars can downsize sufficiently to survive and populations can increase, whereas large-leafed cultivars cannot as shown by the lower number of leaves/growing point (Table 2), causing larger-leafed cultivars to decline (Table 3). Selection of the right cultivar is important, relating to the trade-off between stolon size and density, and the grazing management system to be used (Brock & Hay 1996).

Table 1 Effect of drought and grazing management (RG rotational grazing, SS set stocking) in 1986–87 on white clover performance and persistence (from Figure 1, Brock 1988).

Month	Rain (mm)	Clover content (%) RG	Clover content (%) SS	Stolon (kg DM/ha) RG	Stolon (kg DM/ha) SS
September	78	12	9	540	310
October	112	6	11	300	300
November	21	6	9	240	310
December	31	2	7	100	320
January	78	0	0	50	340
February	59	2	8	40	360
March	112	3	16	30	370
$LSD_{0.05}$		6.5		118	

Table 2 Effect of management (RG, rotational grazing; SS, set stocking) on plant characteristics of 4 white clover cultivars ('Tahora', small-leafed; 'Huia', medium-leafed; 'Pitau', medium-large; 'Kopu', large-leafed) in mixed pastures (Brock 1988).

Cultivar	Area/leaf (cm^2) RG	Area/leaf (cm^2) SS	Leaves/growing point RG	Leaves/growing point SS	Stolon size (g/m) RG	Stolon size (g/m) SS
Tahora	2.09	1.30	2.90	1.72	0.48	0.46
Huia	2.75	1.15	2.87	1.71	0.63	0.56
Pitau	4.08	1.60	2.76	1.46	0.77	0.64
Kopu	5.58	1.66	2.88	1.42	0.88	0.61
S.E.M.	0.35		0.14		0.08	

Table 3 The effect of grazing management (RG, rotational grazing; SS, set stocking) on the performance of 4 white clover cultivars in mixed pastures (Brock 1988).

Cultivar	Stolon DW (kg/ha) RG	Stolon DW (kg/ha) SS	Growing points/m^2 RG	Growing points/m^2 SS	Clover content (%) RG	Clover content (%) SS
Tahora	510	680	3 750	10 480	13.3	20.6
Huia	450	370	2 750	4 720	11.0	13.1
Pitau	470	260	2 230	2 660	15.1	7.0
Kopu	420	240	1 530	1 530	19.5	7.3
S.E.M.	54		110		2.8	

Role of seedling regeneration in white clover persistence

Where there are prolonged periods of moisture stress, such as the Tablelands of northern New South Wales, stolons can die, and persistence then relies upon seedling regeneration (Archer *et al.* 1989). In the dry east coast regions of New Zealand, there are occasional summer droughts and the relative importance of clover persistence from vegetative stolons or seedling regeneration is not clear. Evidence that reseeding could be important in dryland pastures came from a white clover germplasm evaluation trial on a Templeton silt loam overlying shallow gravels at Lincoln, Canterbury. In spring 1998, 3-month-old plants of various white clover lines were planted into an ‘Advance’ tall fescue sward established the previous autumn and grazed at 6-weekly intervals all year except during winter. Clover performance was assessed each spring for 4 years (Figure 1). During the first 2 years with adequate rainfall, white clover contributed 10-30% of the pasture biomass, but severe drought in early 2001 led to a complete collapse of white clover in the low density tall fescue sward for reasons outlined above. By September 2001, recovery was poor, with a low tiller density of tall fescue and grass herbage and negligible numbers of white clover stolons (9 versus the usual 1800 stolon tips/m^2 in spring (Widdup, unpub. data)). However, over autumn/winter, a large number of clover seedlings had emerged from both buried seed (480 clover seeds/m^2 as assessed before the trial was sown) and seed fall during the trial. By December, surviving stolons and seedlings contributed 14 and 215 kg DM/ha, respectively, indicating the recovery had come principally from the high survival of new seedlings with their high potential growth rate. The wet summer of 2002 resulted in clover recovering to 45% of the pasture by April. Such rejuvenation of clover in dryland swards from seedlings is not a regular event but these results indicate that it can occur following severe droughts and in open pasture conditions. Under average summer rainfall patterns in Canterbury, stolon numbers do not decline as dramatically and vegetative recovery is more usual.

Edwards (unpub. data) found that under rotational grazing, less than 10% of white clover seed from seed drop germinated, of which 28% survived, compared with only 3% germination but 75% survival under set stocking. This raises the possibility of devising management strategies to enhance the recruitment of white clover from reseeding. This would involve:

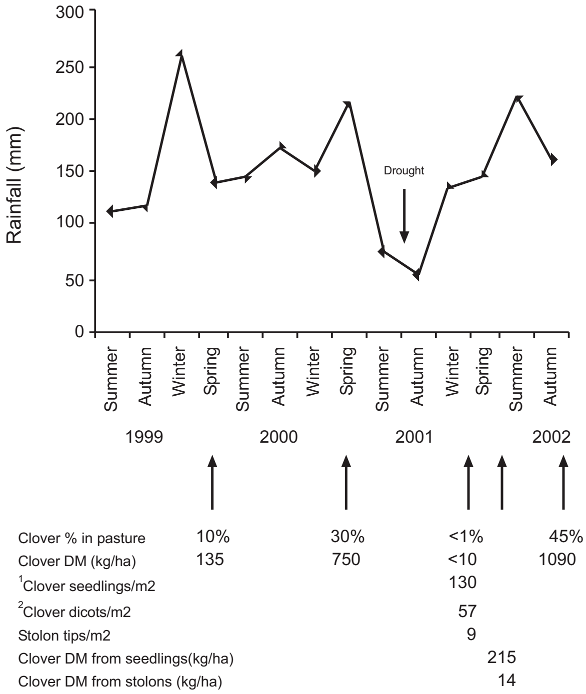

Figure 1 The performance and recovery of white clover from seedling regeneration in a tall fescue pasture following a severe summer/autumn drought in 2001 at Lincoln. The arrows indicate when key white clover performance parameters were measured.

[1] Clover seedlings with 1–2 trifoliate leaves (germinated in late autumn 2001).

[2] Clover dicotyledons emerged in early spring 2001.

1. rotational grazing in summer/early autumn to encourage seed set, seed fall and germination, then
2. set stocking after reliable rain has fallen (late autumn/winter) to encourage survival.

The prolific early flowering cultivar ‘Prop’ was developed to persist by reseeding in dry environments (MacFarlane & Sheath 1984).

Where does red clover fit in dryland systems?

Grazing management of crown-type red clovers is related to its lack of persistence (Curll & Jones 1989; Hay & Ryan 1989). These clovers suffer particularly from frequent, hard grazing which depletes the taproot of carbohydrate reserves (Hay 1985) and increases susceptibility to disease (Smith *et al*. 1985; Frame *et al*. 1998). Spring and summer moisture stress, a feature of east coast dryland systems, not only places the plant under direct stress, but also decreases the rate of taproot carbohydrate replenishment by slowing regrowth. This was also found to be the case with spreading red clover in a summer-dry environment (Hyslop 1999). A comparison of crown-type and spreading-type red clover cultivars (‘Pawera’ and ‘Astred’ respectively) under grazing frequencies of 4, 6, and 8 weeks, and grazing intensities of hard and lax (50 mm and 100 mm post-grazing heights, respectively) (Hay & Ryan 1989) was made over 17 months at Massey University, Palmerston North, with 1080 mm of annual rainfall in a randomised complete block design (Table 4). ‘Astred’ had more (P<0.01) plants remaining after two years under all grazing management options. In dryland summer environments it would be difficult to leave the recommended 100 mm residual growth when animals get to the stage of seeking any green plant material; hence, the persistency of red clover stands would be more adversely affected.

Crown-type red clovers have generally been found unsuitable for hill country sites (Hyslop *et al.* 1996), (which make up a large percentage of dryland systems), mainly due to soil infertility, moisture stress, and their lack of grazing management plasticity. Creeping red clovers do show some promise of filling this niche (Hyslop *et al.* 1996), but current studies have only been conducted under moist hill conditions (1200 mm annual rainfall). In that study, a creeping selection made up 3.2% of the total yield in a sward after 5 years, while Pawera’ had disappeared (Hyslop *et al.* 1996).

The most probable use of crown and spreading red clover types in dryland systems is for the production of high quality spring/summer forage to finish young stock. Clovers are best planted as pure swards so that winter grazing management is not compromised by overgrazing in a mixed sward. Appropriate sites are spring/summer moist areas, such as valley bottoms and river flats. Only a small percentage of the total farm area should be sown to avoid reducing the winter carrying capacity of breeding stock. Areas with warm winters can benefit by using winter active red clovers as an annual crop grown from April until November-possibly with low sowing rates of annual ryegrasses while soil moisture is available.

The economics of trying to finish young stock in dryland systems are directly related to the difference in sale price between selling store or finished young stock, and with the cost of buying/leasing more suitable land (to grow seasonal forage) to finish off young stock. As with any forage, it must fit with the rest of the system and have a sound economic benefit to the whole system. More work is required to fully test the suitability of creeping and spreading red clovers in dryland systems, particularly in hill country and winter warm areas.

Conclusions

Neither white nor red clovers are particularly suited to dryland environments, as they require moderate to high soil fertility and rainfall. For high herbage productivity, their use should be restricted to those areas where adequate conditions can be supplied (i.e. fertile valley floors and irrigation). With a wide range of morphological types, judicious use of grazing management and cultivar selection, the range and persistence of white clover

Table 4 The effect of grazing frequency and intensity on the persistence (% survival) of parent plants of ‘Pawera’ (crown-type) and ‘Astred’ (creeping-type) red clover over 18 months.

		Grazing frequency residual and height						
		4 weeks		6 weeks		8 weeks		
		5 cm	10 cm	5 cm	10 cm	5 cm	10 cm	S.E.M.
Harvest date	Cultivar							
15/6/97	Astred	68	78	78	90	69	874.55	
	Pawera	83	86	90	84	86	77	
10/1/98	Astred	51	77	69	73	65	766.26	
	Pawera	67	57	74	64	61	53	
2/11/98	Astred	26	59	52	58	47	666.32	
	Pawera	13	48	30	43	39	34	

can be extended, but at the expense of herbage productivity. Following severe droughts, white clover will rejuvenate through reseeding but success is dependent on grazing management to enhance seedling survival. Even with creeping cultivars, the scope for extending red clover into drier areas is more limited.

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