

Long-term performance of white clover cultivars oversown into summer-dry hill country

M.B. DODD, G.W. SHEATH, M.E. WEDDERBURN and I.S. TARBOTTON
AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton
E-mail: mike.dodd@agresearch.co.nz

Abstract

The performance of three white clover cultivars (Huia, Tahora and Prop) was monitored in summer-dry hill country at the Whatawhata Research Centre for 9 years. The cultivars were oversown into three steep north-aspect paddocks in autumn 1990. White clover abundance was measured every spring using line transects, and stolon fragments were sampled to determine the contribution of the cultivars to overall populations by allozyme electrophoresis on three occasions (1991, 1993, and 1994). White clover abundance declined from ~50% in the first year to ~4% in 1999. There were no significant differences in abundance between the three cultivar treatments after year 2. There were significant differences in the contribution of the cultivars to white clover populations after 5 years as follows: Huia 27%, Tahora 33% and Prop 56%. The implications of these results for introducing new white clover genotypes into summer-dry hill country are discussed.

Keywords: 'Grasslands Huia', 'Grasslands Tahora', hill country, long-term, 'Prop', summer-dry, white clover

Introduction

The performance of white clover in hill country pastures has been the subject of much study and debate over the past 20 years. It was recognised at an early stage that large-leaved types bred in lowland environments failed to persist under conditions of low fertility, close continuous grazing by sheep and slope induced drought (Forde & Suckling 1977; Charlton 1984).

During the 1980s, researchers identified two key characteristics as being important for the persistence of genotypes in the variable environment typical of hill country. Williams *et al.* (1982) showed improved performance of a small-leaved hill country selection over standard cultivars and attributed this to higher stolon density. Macfarlane & Sheath (1984) argued that an early and profuse flowering type (for greater reseeding) was better adapted for the long-term survival of populations under summer-dry conditions. These

contrasting views were undoubtedly influenced by the climatic conditions (i.e., summer moist vs. summer dry) and grazing management environments (i.e., set stocking vs. rotational grazing) in which the proponents worked.

Other than the two cultivars to come out of these research efforts ('Grasslands Tahora' and 'Prop'), there have been few cultivar releases targeted at hill country, relative to the proliferation of cultivars pertinent to more fertile lowland pastures. This probably reflects two main factors. Firstly, the lack of demand for such genotypes under the prevailing economic environment for hill country farming during the 1980s and 1990s, when there was little investment in improving uncultivable land via oversowing or fertiliser. Secondly, the inconclusive results of studies measuring changes in white clover content and production as a result of sowing new cultivars into hill country. Some trials demonstrated increases (Williams *et al.* 1982; Chapman *et al.* 1993) while many observed no change (Barker *et al.* 1988; Korte & Quilter 1990; Macfarlane *et al.* 1990; Webby *et al.* 1990; Wedderburn *et al.* 1996).

However, future interest in white clover improvement is likely to centre on developing desirable nutritional characteristics that have the potential to improve animal performance directly, over and above the benefits of increasing clover production. Examples might be genotypes with greater content of tannins or sulphur-based proteins. Thus the clover plant becomes the carrier of novel traits rather than just a source of protein and energy. In this case, consideration must be given to the contribution of new genotypes to white clover populations where resident populations exist. Three investigations of this have been made in hill country (Chapman *et al.* 1993; Wedderburn *et al.* 1996; Hopkins *et al.* 2000), all of which showed highly variable contributions by introduced material to the white clover populations.

In this paper we report the results of a 9-year field experiment designed to test the hypothesis that genotypes with small leaf size, high stolon density and increased reseeding potential would persist in the long-term, and make a significant contribution to white clover populations in a summer-dry hill country environment where cultivation was not possible.

Methods

At the Whatawhata Research Centre, three steep (average slopes $>20^\circ$) north-facing paddocks of approximately one hectare were divided into three blocks. In December 1989, the paddocks were sprayed with Versatill™ (0.7 l/ha) to kill resident clover populations and a basal fertiliser dressing of molybdenum superphosphate (300 kg/ha) was applied. The white clover cultivars ‘Grasslands Huia’, ‘Grasslands Tahora’ and ‘Prop’ were randomly allocated to the blocks and oversown into these areas in May 1990 following spraying of the resident pasture with Roundup® (1.5 l/ha). The seed mixtures consisted of one of the three white clover cultivars (3 kg/ha uncoated), high endophyte Droughtmaster and Ellett ryegrass (6 kg/ha each) and ‘Grasslands Wana’ cocksfoot (4.5 kg/ha).

In each block, 10 fixed transect lines of 10 m length were established. At 25-cm intervals along the transects, pasture species occurrence and slope class were recorded each spring from 1991 to 1999 using the 5 mm ring technique of Gillingham *et al.* (1990). Species groups were identified as white clover, other legumes, ryegrass, cocksfoot, other grasses and weeds. Micro-site slopes were identified as flat ($<10^\circ$), easy ($10\text{--}25^\circ$) and steep ($>25^\circ$).

The genetic composition of the white clover populations was determined using allozyme electrophoresis (Adam *et al.* 1993). Soil cores containing rooted nodes of white clover were removed from the paddocks in December 1989, and stolon fragments were sampled from these plants to determine allozyme frequencies for the resident populations. Further stolon fragment samples (100 samples per population, i.e., a total of 900 samples) were taken from each block in November 1991, February 1993 and October 1994.

Following a severe summer drought in 1993/94, seedling and stolon growing point densities were measured in May 1994 using 10×10 cm quadrats at 50 cm intervals along the transects. Seedling counts were repeated in May 1995 and stolon counts were repeated in November 1994 and May 1995. Flower counts were also made in January 1994 and February 1995 using 15×15 cm quadrats at 50 cm intervals along the transects.

Grazing management of the trial involved rotational grazing with sheep except for the period of flowering and seed set each year, during which time individual blocks were fenced to avoid seed transfer by animals between treatments.

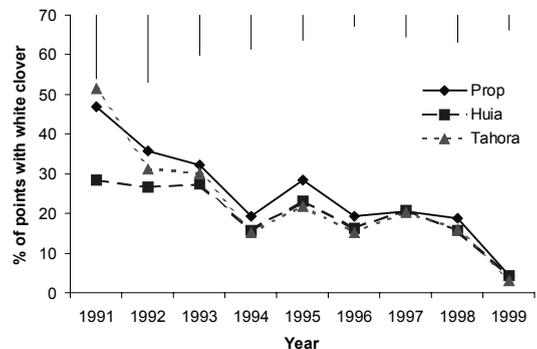
Climate data (monthly actual and normal rainfall) were obtained for the period 1990–2000 from meteorological summaries of data collected at the

Whatawhata station, located within 3 km of all paddocks (NIWA 1990–2000).

Results

The first transect abundance measures in 1991 showed that the % occurrence of white clover at sample points was significantly greater ($P<0.1$) in blocks oversown with Tahora (51%) and Prop (47%) compared with Huia (28%). During the subsequent 2 years, the abundance in blocks sown with Huia in spring remained relatively steady, while that of blocks sown with Tahora and Prop declined to reach similar levels to that of Huia (Figure 1). In 1994 following the severe drought (Figure 2), there was a substantial decrease in white clover abundance of all three treatment populations to levels of 15–20% occurrence (Figure 1). This was followed by an apparent recovery in 1995. For the following 3 years (1996–98), the abundance of all three treatment populations were similar, i.e., in the range of 15–20% occurrence. In 1999 there was another substantial decrease in abundance of all three treatment populations to 3–4% occurrence.

Figure 1 Abundance of white clover (% occurrence at transect sample points) over 9 years following oversowing in May 1990. Bars represent LSD (10%).



Within the micro-site slope categories, on only one occasion was there a significant difference between treatment populations. In 1996, the abundance of white clover on flat sites was greater ($P<0.05$) in the blocks oversown with Prop (25%) than those of Huia (15%) and Tahora (15%).

Measurements of seedling numbers and stolon densities on steep areas in May 1994 and May 1995 showed no significant differences between treatment populations (Table 1). However, in November 1994, stolon densities of blocks sown with Prop were significantly higher than those sown with Huia and Tahora ($P<0.05$). Measurements of flower numbers in

Figure 2 Percent of normal monthly rainfall at Whatawhata for 1990–2000, including the cumulative difference from normal rainfall (mm) for the December–May period each year (inside arrows). The main white clover measurement events are also shown.

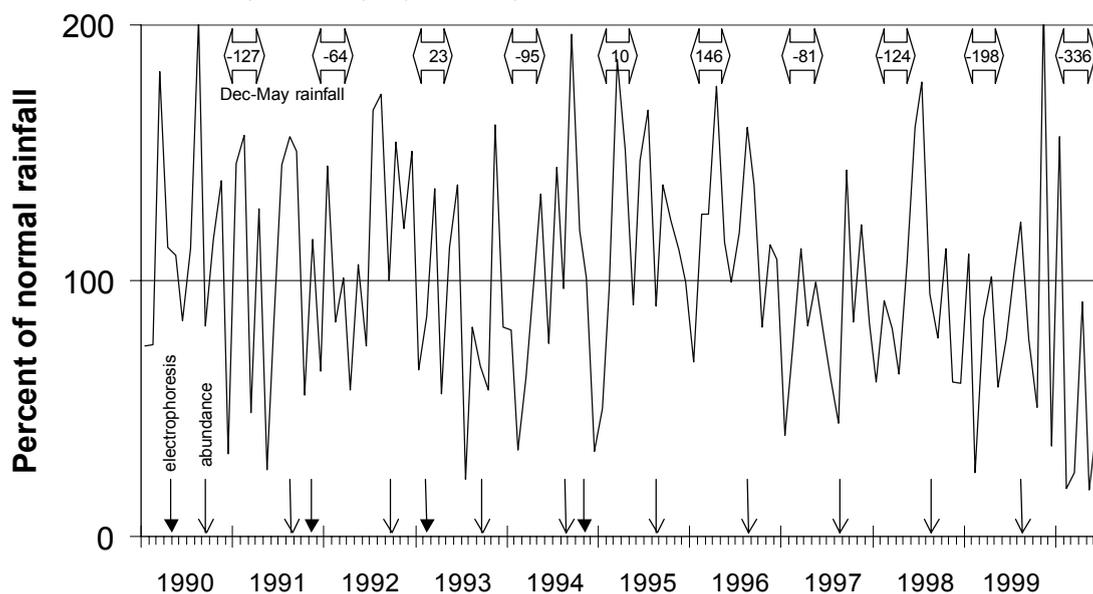


Table 1 Mean seedling and stolon growing tip counts (number/m²) for three white clover populations.

	Treatment population	May 1994	November 1994	May 1995
Seedling count	Huia	37	-	5
	Tahora	51	-	2
	Prop	69	-	3
	LSD (10%)	44	-	6
Stolon points	Huia	71	163	347
	Tahora	61	186	414
	Prop	60	225	465
	LSD (10%)	32	30	121

Table 2 Mean flower counts (number/m²) for three white clover populations.

Treatment population	January 1994	February 1995
Huia	72	49
Tahora	98	37
Prop	125	68
LSD (10%)	46	32

Table 3 Mean percentage contributions to total white clover population (based on allozyme electrophoresis) of three oversown cultivars.

Cultivar	1991	1993	1994
Grasslands Huia	43	43	27
Grasslands Tahora	64	52	33
Prop	82	43	56
LSD (10%)	45	44	22

January 1994 and February 1995 showed no significant differences between treatment populations (Table 2).

In November 1991, the proportions of oversown genotypes (as assessed by allozyme electrophoresis) within the white clover populations varied widely, but with no significant differences between cultivars (Table 3). By 1993, the contributing proportions were similar for the three cultivars (40–50%). In 1994, Prop made a significantly greater contribution (56%, $P < 0.1$) to recovering populations than Tahora and Huia (33% and 27% respectively).

Discussion

White clover abundance declined significantly during the 4-year period following oversowing onto steep summer-dry hill country. Initial levels of up to 50% occurrence, for the populations based on the two cultivars developed for hill country environments, diminished to 15–20% occurrence. In 1995 there was a brief reversal of this trend, where abundance increased by 5–8 percentage points on the previous spring. This temporary recovery coincided with a relatively high rainfall period (1995–96) following a particularly severe drought (1993–94), depicted in Figure 2. The patterns of flower, seedling and stolon counts in the summer/autumn of 1994 and 1995 (Tables 1 & 2) indicate a similar response amongst all treatments to these climatic conditions, whereby flower and seedling numbers were higher in 1994 (dry) than 1995 (wet) and stolon points

were higher in 1995 (wet) than 1994 (dry). During 1996–98, it appeared that the populations had stabilised at the 15–20% abundance level. This level was comparable to equivalent data collected from local resident white clover populations on similar slopes, which averaged ~16% occurrence between 1984–97 on the long-term fertiliser trial at Whatawhata (Gillingham *et al.* 1990). The similarities in total white clover abundance among populations of differing genetic makeup suggests that there is an environmentally determined limit of white clover content that cannot be improved on by new material. It is worth noting that it took 4 years for the populations to reach this level, raising cautions about the interpretation of the results of commonly cited 3-year evaluation trials.

A series of worsening dry summer-autumn periods from 1997 onwards (Figure 2) appears to have ultimately led to a substantial drop in the abundance of white clover between 1998–1999. Observations since the last abundance measure (1999) indicate that no subsequent recovery has occurred. The impact of the clover root weevil (*Sitona lepidus*) may have been an exacerbating factor, its arrival at Whatawhata being noted in 1996, though minimal feeding damage was observed in these paddocks. This population collapse, for whatever reason, should provide a rigorous test of the adaptive characteristics of the cultivars over the resident genotypes.

As has been noted in other experiments, the gradual recovery and eventual domination of resident genotypes over introduced material was largely confirmed in this trial, at least in respect of the cultivars Huia and Tahora. Under similar conditions (low fertility hill slopes of ~20° under rotational sheep-grazing), Hopkins *et al.* (2000) observed a 22% contribution of Huia to white clover populations 11 years after sowing. In addition, the similarity in total white clover abundance of the oversown pastures relative to local resident pastures, shows that the value of oversowing these genotypes to increase clover content in this environment is minimal. After 5 years, these genotypes contributed only ~30% to white clover populations in the field, implying that the introduction of any novel traits would have minimal effect on animal performance unless they provided large proportional benefits. However, the contribution of Prop to field populations after 5 years was over 50%. This provides some encouragement that it will be possible to establish a well-adapted cultivar as a carrier for novel traits that might be incorporated via breeding or genetic modification. However, it is important to note that in this case, the well-adapted cultivar has a strong emphasis on propagation by reseeding, in a species with a high rate of outcrossing. Therefore the maintenance or spread of any such new trait requires

that it be a dominant trait. What is clear is that any assessment of new white clover cultivars sown into resident populations must include a robust measurement of the contribution of those genotypes to clover populations in the field.

Conclusions

On steep hill country paddocks in summer-dry environments, total white clover content was determined more by environmental influences than genetic differences. Summer drought substantially decreased white clover abundance irrespective of the genetic composition of the populations. Recovery of overall populations after drought also did not appear to be influenced by genotype, although Prop contributed more to the resultant populations than did Tahora or Huia. Both seedling recruitment and stolon perenniation were important in this respect. Evaluations of the introduction of new white clover cultivars to pastures where resident populations exist should be accompanied by analysis of the contribution of those genotypes to overall populations.

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