Long-term effects of pastoral fallowing on the distribution and performance of white clover (*Trifolium repens* L.) in a hill country pasture

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Abstract

Previous work found that white clover (*Trifolium repens* L.) yield initially decreased, but subsequently increased following a pastoral fallow. The objective of this research was to quantify the response in herbage production and stolon characteristics of white clover up to 4 years after fallowing. Four treatments were used: fallowed 1990/91 (F4), fallowed 1991/92 (F3), fallowed 1993/94 (F1) and non-fallowed (F0). The fallowing period was between September and May. White clover dry matter yield (between 15/12/94 and 18/5/95) was significantly greater for the treatment F4 than F0 ($P<0.05$). Total herbage and grass production showed no statistical difference between treatments. The total stolon length (98.1 m/m^2) of F4 was significantly greater than that of F3 (45.9 m/m^2) and F0 (39.3 m/m^2). Total stolon weight and growing point density also increased significantly during the 4 year post-fallow period ($P<0.05$). The average internode length remained greater until 6 months after fallowing (2.8 mm) and declined thereafter (1.9–2.3 mm). It is concluded that the increase in white clover post-fallowing was attributed to its ability to disperse through the pasture during fallowing and re-establish in gaps in the pasture where it had previously not been present.

Keywords: hill country, pastoral fallow, stolon, *Trifolium repens*

Introduction

Low legume content (<10%) is a common feature of most hill country pasture in New Zealand and oversowing is an accepted practice to increase its proportion in the sward. However, the success rate of oversowing for legumes is low in hill country due to unpredictable weather and limitations of the technique (Awan 1995).

The fact that white clover (*Trifolium repens* L.) has patchy distribution in a mixed sward has been well recognised, although little attention has been paid to patch analysis of white clover (Edwards 1994). Production of white clover is determined by the patch density, patch size and clover mass per patch. Environmental and management factors such as season, cutting or grazing and fertilizer alter the later 2 factors rather than patch density (Edwards 1994).

The capacity of stolons to spread horizontally is an important characteristic for the competitive ability of white clover. The extent of stolon dispersion is determined by internode elongation which can be markedly decreased by defoliation (Thomas 1972; Wilman & Acuna-P 1993), but compensated by an increase in both branching and total stolon length per unit area. Wilman and Acuna-P (1993) have shown that swards should be cut or grazed closely and regularly to promote branch development in order to encourage white clover competition with grass and raise the content of white clover in the pasture. By contrast, however, other studies of the effects of alternating grazing and/or cutting management on improving the growth and content of white clover in mixed swards found that, when longer recovery intervals (over six weeks) between defoliations was imposed in white clover-depleted swards, the clover content was raised without the expense of either reseeding or oversowing (Curll & Wilkins 1985; Sheldrick et al. 1993). These conflicting conclusions may reflect the roles of different growth components, i.e. branches, active growing points or internode length.

Pastoral fallow, where pastures are not defoliated from early spring (September) to autumn (May), is a technique originally used to improve soil fertility and post-fallowing pasture production (Mackay et al. 1991). It can be considered as a prolonged rest period or interval between defoliations. During fallowing, standing herbage increases, leading to increased plant competition altering sward structure and white clover growth behaviour.

There is a need for additional information on how white clover stolons elongate and branch after a treatment of prolonged interval between grazing (or fallowing) is imposed. This paper reports the effects of a 7-month fallow on white clover growth behaviour and production for up to 4 years after the fallow.

Materials and methods

Trial site and design

The experiment was conducted at AgResearch Hill Country Station, Ballantrae near Palmerston North. The trial site was on a south (shady) aspect of moderate slope where the dominant species were low fertility-tolerant grasses such as browntop (*Agrostis capillaris* L.) and sweet vernal (*Anthoxanthum odoratum* L.). White clover constituted <10% of total annual production. The soil was a YGE/YBE intergrade (Typic Dystrochrept) of sedimentary origin. The average soil Olsen P was 12.

Twelve areas (175–750 m^2) were fenced in a randomised complete block design of 4 treatments and 3 replicates. The four treatments were: fallowed 1990/91 (F4), fallowed 1991/92 (F3), fallowed 1993/94 (F1) and non-fallowed, grazed (F0). The fallowing period was from September or October until the following May. At the conclusion of a fallow period plots were grazed twice by cattle. Outside the fallow period, in non-fallow years, and in the F0 treatment, plots were continuously grazed by sheep to prevent herbage mass exceeding 3000 kg DM/ha. All plots received reactive phosphate rock (35 kg P/ha) and elemental sulphur (14 kg S/ha) annually from 1989 to 1992, with little or no fertilizer applied in the 20 years preceding that time.

Measurements

On all plots herbage mass was measured by cutting one 0.5 m^2 quadrat to 1 cm above ground-level three times starting from 15/12/1994 to 18/5/1995. Subsamples of herbage were dissected into grass, white clover, other legume, weed and dead matter to estimate botanical composition and the dry matter of each component. Twenty 50 mm diameter tiller plugs were taken from each plot on 5/12/1994 and the numbers of grass tillers, white clover growing points, other legume plants and weeds were counted to estimate plant population density. Moss cover was scored as 0 (none), 1 (less than half of plug surface covered by moss), 2 (more than half) and 3 (full). Tiller plugs were dissected to obtain all surface and buried stolons of white clover. The stolons were washed, dried by absorbent paper and then trimmed to determine total stolon length, internode length and stolon dry matter. On 16/3/1995, a 3 m transect was trimmed to ground level by electric shears in each plot. One week later, occurrence (1) or absence (0) of active growing points and young leaves in 1 cm^2 contiguous quadrats were recorded along each transect. White clover stolon distribution pattern was analyzed by the Two Term Local Quadrat Variance (TTLQV) method (Dale & MacIsaac 1989). The squared difference between adjacent block totals was plotted against an increasing block size. The x-axis of local maxima showed the scale of pattern, i.e. average distance between the centre of a patch of white clover and the centre of a gap. The smaller peaks may reflect smaller patches of branches or irregular shape of patches. The sizes of patches and gaps was estimated by multiplying the scales of pattern with the average proportions of blocks with and without active white clover growing points.

Results

Herbage mass, botanical composition and pasture density

Significant difference in white clover yield was found among treatments (Table 1). The treatment F4 produced highest yield of white clover, 3 times that of the grazed control ($P<0.05$). Although white clover yield for F3 was increased by 76% compared with F0, the difference was not significant ($p>0.05$).

There were no significant difference for the dry matter yield of grasses, other legumes and weeds between fallow treatments. There was a trend (non-significant) of reduced dead material content with increasing years after fallowing.

As with yield, white clover growing point density declined in F1 (1520 points/m^2) from F0 and increased subsequently to over 6500 points/m^2 in F4 (Table 1). Weed density and the cover of moss showed similar trends. There was an increase in grass and other legumes in F1 from F0, but both declined subsequently. There was an inverse relationship between grass tiller density and white clover growing point density, indicating probable competition between these two components of the sward.

Table 1: Effects of post fallowing duration on pasture yield (g/m^2) from 15/12/1994 to 18/5/1995 (means of three harvests) and grass tiller and white clover growing point density on 5/12/1994.

Treatment	-------- Herbage Yield --------			-------- Density --------	
	Total	Grass	Whiteclover	Grass	Whiteclover
F4	179.6	128.9	15.3 a[1]	26,000	6520 a
F3	155.0	117.8	9.0 ab	28,000	2800 b
F1	154.6	116.8	4.8 b	36,000	1520 b
F0	172.8	125.4	5.1 b	27,000	3010 b

[1] Data with different letters indicate significant difference ($P<0.05$).

Stolon characters

Significant differences ($P<0.05$) in total stolon length were found among treatments, the sequence being F4 > F3 > F0 > F1 (Figure 1). Total stolon weight, not shown, followed the same trend. Fallowing decreased total stolon length and the F1 treatment had only 21 m/m^2 of stolons. However, internode length changed in a reverse manner to total stolon length and weight, with fallowing increasing internode length for up to 6 months after the cessation of the fallow, then gradually declined thereafter. The stolon dry matter per unit length was not statistically different between treatments, indicating stolon thickness was not altered by fallowing.

Distribution pattern

Figure 2 shows an example of distribution pattern of white clover from one replicate. There were clear patterns for F4, F3 and FO, but no clear pattern for F1 probably due to a recent substantial reduction in growing points and branches by fallowing. The ratio of gap diameter to white clover patch diameter had significant difference ($P<0.01$) between treatments, with F3 and F4 being approximately 46% lower than FO (Table 2). This reflected that the gap size in FO was significantly greater than patch size in comparison with F3 and F4. Previous fallowing increased white clover patch diameter by 25-35% and decreased the gap diameter by 19-30%. There was no significant difference for pattern scales between treatments.

Table 2: Scale of pattern, average diameter of gap and white clover patch and mean ratio of gap:white clover patch diameter

Treatment	Scale (cm) of pattern	Diameter of patch (cm) Gap	Clover	Gap:clover ratio
F4	91.7	122.1	61.3	2.0 a[1]
F3	103.3	140.5	66.2	2.1 a
F1	No pattern	-		
FO	111.7	174.3	49.0	3.8 b

[1] Data with different letters indicate significant difference ($P<0.01$)

Discussion

Little attention has been paid to detailed analyses of the spatial distribution of species within temperate grassland systems, although the fact that white clover is distributed in patches in mixed species pasture is recognised (Edwards 1994; Grant & Marriott 1989). The yield (Y, kg/ha) of white clover in a mixed sward can be described as Y = PD * PS * CMP, where PD is patch density (no./ha), PS is patch size (m^2/patch) and CMP is clover mass per patch (kg/m^2/patch). Each of the three components is positively correlated with white clover yield. Many studies (Wilman & Acuna-P 1993; Collins et al. 1991; Laidlaw & Withers 1989; Grant et al. 1991) have concentrated on the management and climate factors that influence growth of branches, growing points and leaves. This has contributed to an understanding of CMP and PS, but little of PD. This was evident from Edwards (1994) who demonstrated that increases in white clover content with various seasons and by different grazing management were predominately the result of increases in the size of clover patches with no new patches developed.

Figure 1: Total stolon and average internode length of white clover with various fallow history (Vertical bars show $LSD_{0.05}$).

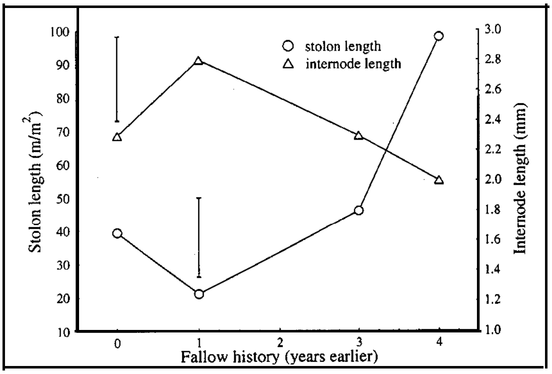
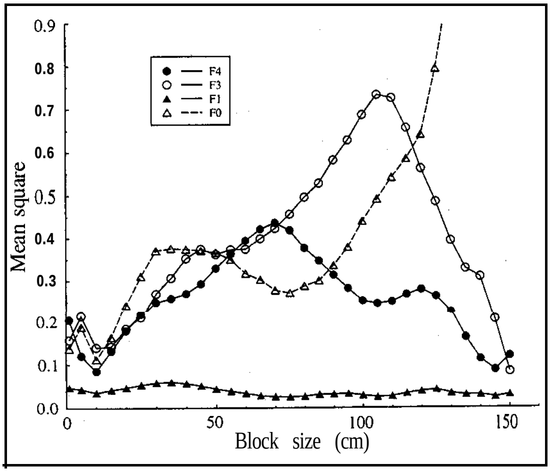


Figure 2: The distribution pattern of white clover of various treatments (TTLQV variance plot for one transect with the x-axis of local maxima as the scale of pattern for each treatment. For FO the variance at block size 150 was 2).



The patch density of white clover is initially determined by seeding rate and genotype interaction with variable surface topography. Recruitment from buried seed within established populations is rare in white clover and other communities dominated by clonal plant species (Chapman 1987). Thus, the possibility of increased clover patch density in a sward relies on stolon dispersion, unless new white clover seeds are introduced. The significance of fallow in this study was that, in spite of initial depression of clover density, it stimulated internode elongation which resulted in more extensively distributed stolons in the sward. These widespread stolons may have formed the nucleus of larger and/or new patches for subsequent expansion after grazing management had been reimposed at the conclusion of fallow. The resultant increase in white clover yield of swards fallowed 3 and 4 years earlier, was thus probably the result of both greater PS and PD. This was supported by the result of spatial pattern analysis (Table 2).

The internode length was found to be negatively correlated to the total stolon length per unit area (Wilman & Acuna-P 1993), because the increase in main stolon length by internode elongation did not compensate for the loss of secondary stolons when duration between defoliations was prolonged. Therefore, total stolon length can not be used as a criteria for stolon dispersion within a sward. For example, in the F1 treatment the total stolon length was much lower than F0 (21 vs 39 m/m^2, respectively), which was not an indication of less dispersed clover stolons in F1 sward.

Changes in sward clover content brought about by longer recovery interval of cutting and grazing management are likely to be less immediate than those from oversowing (Sheldrick et al. 1987). In this study the treatment F1 was inferior, although not significantly, to the grazed control in white clover yield, botanical composition and growing point density. This may be, in part, due to grass competition as there was a flush of grass tillers (36000 $tillers/m^2$) produced within the year after the fallow. Post-fallowing white clover regrowth is of great importance for clover recovery in the sward. In addition to grazing examined in this study, climatic, edaphic and macro-environmental factors, and the interactions between them also probably play a part in the recovery of stolon growth, branching and new patch formation after fallowing. The large difference between F4 and F3 in clover yield, growing point density and total stolon length and weight, although the order for the two treatments followed the trend along with fallow history (Table 1), may result from the interactive effect of grazing with these factors. The duration of increase in sward clover content after fallowing needs further confirmation.

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