Nitrogen fertiliser effects on white clover in dairy pastures

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Abstract

Effects of high N fertiliser rates on white clover content in the sward and clover plant morphology were monitored over two years (June1993–June 1995) at the DRC, Hamilton. The clover study was part of a farmlet trial aimed at increasing milksolids (MS) production to 1750 kg MS/ha using urea (0, 200 or 400 kg N/ha/yr) to increase pasture production at low (3.2 cows/ha) or high (4.5 cows/ha) stocking rates. On low stocked farmlets clover contents declined to 10.6% (200 kg N/ha/yr) and 2.2% (400 kg N/ha/yr) by June 1995 compared with 16.8% under no N. Decreased clover content was a result of increased competition from N-boosted ryegrass. At the high stocking rate, N application resulted in clover contents of 14.9% (200 kg N/ha/yr) and 6.8% (400 kg N/ha/yr) compared with 15.4% under no N. Pasture utilisation was better on these farmlets, suggesting the improved utilisation and control of additional feed, particularly during spring, was responsible for the higher clover content. Measurements of clover plant density supported the clover content observations. By June 1995 there were 438, 227 and 26 plants/m^2 under 0, 200 and 400 kg N/ha/yr respectively. High N rates also affected clover plant morphology; plants developed fewer axillary buds and stolons, and had lower stolon dry weights under 400 kg N/ha/yr.

Keywords: clover content, dairying, morphology, nitrogen, plant density, *Trifolium repens*, white clover

Introduction

Although white clover (*Trifolium repens* L.) can contribute, on average, 185 kg N/ha/yr (Hoglund et al. 1979) to support pasture growth, ryegrass dominant NZ dairy pastures reliant solely on symbiotic nitrogen fixation are nitrogen deficient (Field & Ball 1978). Recognition that nitrogen is essential for high pasture production together with the increased payout for milksolids (fat plus protein), has encouraged greater use of nitrogen fertiliser (N) on dairy farms. N use has increased eight-fold from 1988 to 1994 so that the average N rate is 90 kg N/ha/yr (NZ Department of Statistics) with a growing number of dairy farmers now using more than 250 kg N/ha/yr. High N rates do, however, compromise clover growth and nitrogen fixation activity. Prolonged use of high N rates may also limit clover recovery once N rates are reduced (Davies 1992).

High rates of N combined with a cereal supplement have been used in a Dairying Research Corporation trial to reach a target production of 1750 kg milksolids/ha, some 40% above previous levels of production. This farmlet trial, which ran from June 1993 to June 1995, provided an opportunity to examine the effects of high N rates on clover growth, persistence and plant morphology.

Materials and methods

Site and treatments

Seven 6.48 ha farmlets were established on ryegrass/white clover pastures at the Dairying Research Corporation, Hamilton, New Zealand. The farmlets were balanced for soil type (Horotiu silt loam, Hamilton clay loam and Te Rapa silty peat loam) and previous treatment. Farmlets (Table 1) were stocked with high genetic merit Friesian cows at either 3.24 (LS) or 4.48 (HS) cows/ha. Pastures were rotationally grazed throughout the trial at 24 (spring 1993 and 1994) to 128 (winter 1993) day intervals. N (urea) was applied in split dressings of either 22 kg N/ha on LS200 and HS200 farmlets, or 45 kg N/ha on LS400 and HS 400 farmlets after most grazings. Pastures also received 60 kg P/ha/yr and 50 kg K/ha/yr as maintenance dressings in autumn of each year. Maize grain supplement was fed as required to cows (Penno et al. 1994) on farmlets 2 to 7 while farmlet 1 served as a control. All pasture and clover measurements were conducted on farmlets 2 to 7.

Table 1: Experimental details of the farmlets.

Farmlet	Treatment	Stocking rate rate (cows/ha)	Nominal N fertiliser (kg N/ha)	Actual N fertiliser (kg N/ha)	
				1993/94	1994/95
1	Control	3.24	0	0	0
2	LS0	3.24	0	0	0
3	LS200	3.24	200	219	210
4	LS400	3.24	400	330	430
5	HS0	4.48	0	0	0
6	HS200	4.48	200	215	197
7	HS400	4.48	400	319	422

Herbage accumulation

Pasture cover (kg dry matter (DM)/ha) was estimated weekly across all farmlets by eye assessment and calibrated with ground level cuts. Net herbage accumulation was calculated from the increase in herbage mass on paddocks which were not grazed during the previous week.

Clover content and plant density

Clover content (% of total DM) was calculated from two-monthly botanical dissections. Four paddocks from each farmlet were selected to give maximum possible time between grazings and covering the range of soil types. Consequently different paddocks were sampled each time. Herbage was sampled as decribed by Harris (1994).

Clover plant density (plant number/m^2) was determined as described by Harris (1994) from tiller cores taken at random from a representative paddock on the low stocked farmlets.

Morphological characterisitics of clover plants from a representative paddock on the low stocked farmlets were measured as described by Harris (1994).

Statistical analyses

Plant density and plant morphology were measured using the same representative paddock on each of the low stocked farmlets at every sampling. Only one paddock was selected per farmlet so that each representative paddock was grazed on the same date to avoid any effects of different grazing intervals on measurements and so that soil type and management history were consistent across the paddocks. Paddocks were divided into quarters using the same system at each sampling so quarters within paddocks could be used to test for treatment differences. Analysis of clover content data, where measurements were made in four paddocks within each farmlet, with each paddock divided into quarters, showed variation within paddocks was similar to the variation between paddocks for each farmlet. This lends support to the use of a single paddock, divided into quarters, per farmlet in analysis of data examining N effects on white clover in this dairying systems trial.

Collection of plant morphology data excluded plants cut at quadrat boundaries which tended to bias the subsample population against larger plants. Consequently, these data were weighted prior to analysis using the model developed by Brock et al. (1988).

Standard error of differences (SEDs) were based on variation between quarters within paddocks. For plant morphology data, contrast comparisons, between LSO and LS200, and between LSO combined with LS200 against LS400 treatments, were also performed using the statistical package SAS.

Results

Herbage accumulation

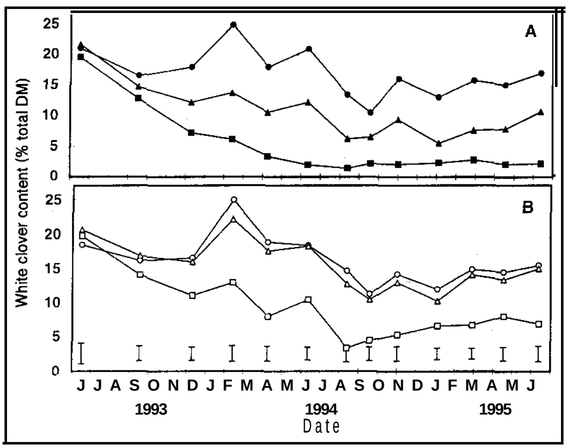
N fertiliser application resulted in large increases in herbage accumulation (Clark & Harris 1996). Averaged over the two years, annual net herbage accumulation was increased by 22% on farmlet LS200 and 23% on farmlet HS200 compared with farmlets LSO and HSO respectively. Herbage accumulation on farmlet LS400 increased by 37% but the increase was smaller (24%) on the higher stocked farmlet which received the same rate of N (HS400). Growth response to N was high during the 1993 spring (September-November) with a mean response across farmlets of 25 kg DM/kg N applied.

Clover content

Farmlets that did not receive N (LSO and HSO) had a mean clover content of 16.5% with maximum clover content in late summer (February) and minimum clover content in spring (September-November) (Figure la). Clover contents overall were higher in 1993/94 than in 1994/95. N application caused a large decrease in clover content on the low stocked farmlets. By June 199.5 clover contents on farmlets LS200 and LS400 were 10.6 and 2.2% respectively compared with 16.8% on farmlet LSO. Most clover loss on farmlets LS200 and LS400 occurred during the first six months of the trial with subsequent changes in clover content following a similar trend to changes on farmlet LSO.

N had a smaller effect on clover content at the high stocking rate (Figure lb). By June 1995 there was little

Figure 1: White clover content (% of total DM) on (a) low stocked farmlets and (b) high stocked farmlets during June 1993 to June 1995. Farmlet LSO (●), LS200 (A), LS400 (■), HSO (O), HS200 (A), HS400 (□). Error bars show the SED.



difference in clover content between farmlets HSO and HS200, 15.4 and 14.9% respectively, although clover content was lower on farmlet HS400 at 6.8%.

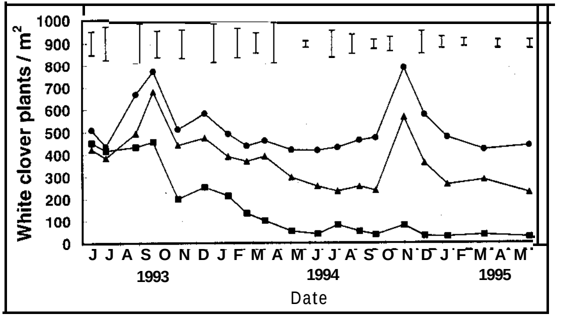
Cloverplant density

The decrease in clover content under N on the low stocked farmlets was confirmed by the decrease in clover plant density (Figure 2). On farmlet LSO the mean clover density was 514 plants/m^2. Minimum plant density was recorded in winter each year, increasing to maximum in spring. This seasonal trend in clover plant density was also recorded on farmlets LS200 and LS400 although this was combined with a declining plant density, particularly during 1993/94. At the end of the trial clover densities on farmlets LSO, LS200 and LS400 were 438, 227 and 26 plants/m^2 respectively.

Cloverplant morphology

Data describing the morphological characteristics of white clover plants on low stocked farmlets under the three N levels are presented in Table 2. When averaged over the trial, plants from farmlet LS400 were significantly different ($P<0.05$) from plants from farmlets LSO and LS200 for most morphological characteristics. However, differences were not always significant at each individual sample date due to the large variation within populations in terms of plant development ie. populations ranging from small first-order plants which formed as a result of plant break-up to mature fifth-order plants (plants with five levels of stolon branching). The 400 kg N/ha/yr treatment reduced stolon growth as shown by the lower mean stolon length and stolon DW values, as well as the lower value for internodal stolon distance (stolon length/number of nodes were 3.63, 3.55 and 3.23 for farmlets LSO, LS200 and LS400

Figure 2: White clover plant density (plants/m^2) on low stocked farmlets. Farmlet LSO (●), LS200 (▲), LS400 (■). Error bars show the SED.



respectively, SED = 0.09, $P<0.05$). Stolon branching was also inhibited at 400 kg N/ha/yr since plants on farmlet LS400 developed fewer axillary buds and therefore had fewer stolons than plants on either farmlet LSO or LS200. This effect was also apparent from differences in the mean plant order. Within all populations the proportion of first-order plants increased in spring as plants broke up. From September 1993 the proportion of first-order plants was consistently higher under 400 kg N/ha/yr than under the other N fertiliser treatments. Although mean total leaf DW and number of leaves were lower on farmlet LS400 than LS200 or LSO, this was probably associated with the lower stolon number per plant, since values for leaves per stolon and leaf size (leaf DW/leaf number) for all three populations were not significantly different. In addition, differences in grazing intensity and the time interval between grazings on the three farmlets would have affected plant leaf characteristics. There were no significant differences in either root number or root DW between N treatments.

Table 2: Morphological characteristics of clover plants on low stocked farmlets receiving different N fertiliser rates. Values show the mean for each characteristic of all plants within each population sampled over the June 1993 to June 1995 trial period. SED's and the significance level of contrast comparisons between (a). LSO versus LS200 and (b) LSO and LS200 versus LS400 treatments are given. Significance levels: ns = not significant, * = $P<0.05$, ** = $P<0.01$.

Farmlet	LSO	LS200	LS400	SED	······· Contrasts ·······	
Nominal N rate (kg N/ha/yr)	0	200	400		Ovs 200	0/200vs400
Plant order	2.13	2.08	1.97	0.05	ns	*
No. stolons / plant	5.99	5.59	4.61	0.30	ns	**
Stolon DW / plant (mg)	106.83	112.28	88.81	5.13	ns	**
Stolon length / plant (mm)	186.81	188.80	148.35	8.53	ns	**
No. nodes / plant	51.41	53.16	46.09	2.19	ns	**
No. growing points / plant	4.74	4.57	3.80	0.29	ns	*
No. axillary buds / plant	1.37	1.21	0.73	0.11	ns	**
No. leaves / plant	12.06	12.13	10.40	0.56	ns	*
Leaf DW / plant (mg)	77.43	79.54	64.95	4.20	ns	**
No. roots / plant	12.86	12.69	12.51	0.74	ns	ns
Root DW / plant (mg)	35.60	32.57	32.83	1.67	*	ns

Discussion

High N rates caused a large reduction in the % clover content on the low stocked farmlets which is consistent with a number of previous trials. In 158 trials throughout NZ, application of 100 kg N/ha/yr resulted in an average clover content of 12% of total DM compared with 18% under no N (O'Connor 1982). Similarly, application of 360 kg N/ha/yr to dairy pasture resulted in 3% white clover compared with 15% under no N (Ball & Field 1982). However, some trials

(O'Connor & Gregg 1971; Crush et al. 1982) with N rates up to 100 kg N/ha/yr showed no decrease in clover content.

N effect on clover content in mixed pastures is largely indirect. In clover monocultures receiving N, growth is usually greater than in clover pastures reliant solely on fixed nitrogen (Davies 1992). However, in mixed pasture, the grass is more efficient at taking up fertiliser N from the soil than legumes (Murphy & Ball 1985). The more efficient use of N by ryegrass leads to increased ryegrass growth and competition between the species particularly for light, but also water and nutrients is increased. Consequently ryegrass overtops clover, resulting in a reduced clover content. Brereton et al. (1985) showed white clover was suppressed in swards once a critical density of 5000 ryegrass tillers/m^2 was reached. During the current trial ryegrass tiller density on farmlet LS0 averaged 4068/m^2 and rarely exceeded 5000/m^2 but on farmlets LS200 and LS400 tillers densities averaged 6268/m^2 and 6364/m^2 respectively (Harris et al. 1996).

Most clover on the low stocked farmlets receiving N was lost in the first six months of the trial. Early spring growth of clover is slower than that of ryegrass which puts clover at a further competitive disadvantage when N is applied at this stage of the season (Murphy & Ball 1985). In addition, the response to the N applied during the 1993 spring of the this trial averaged 25 kg DM/kg N which was higher than expected, and consequently pasture cover on the low stocked N farmlets averaged 3800 kg DM during October–November 1993 compared with 3100 kg DM on farmlet LS0. The following spring, pasture cover was kept under better control on the N farmlets, mainly by increasing the amount of silage conserved. Consequently there was a much smaller effect on clover content. Davies and Evans (1990) found white clover in mixed pasture under cutting is able to adapt to increasing sward height and mass by producing leaves with longer petioles. Woledge (1988) also reported clover was not overtopped by ryegrass in irrigated swards receiving N during spring and in fact had a greater proportion of its leaf lamina in the upper, well lit layers of the canopy than ryegrass did. However, in the current trial, no clover was visible above the ryegrass canopy on farmlets LS200 and LS400 during spring 1993. Closer examination of swards suggested clover petioles had not lengthened to the same extent as ryegrass leaf, although no measurements were made.

The higher stocking rate on farmlets HS200 and HS400 meant pasture cover on these N farmlets averaged 3200 kg DM/ha during October and November 1993 compared with 2700 kg DM on farmlet HS0. The lower pasture cover during the critical spring period, compared with that on low stocked farmlets, meant more clover was able to survive competition with N-boosted ryegrass. Farmlet HS200 clearly showed it is possible to maintain clover content in pasture receiving high rates of N by ensuring additional grass grown is fully utilised. Davies (1992) however points out that high stocking rates may have negative effects on white clover in terms of increased damage to stolon growing points through increased grazing pressure, treading and burial.

Although 200 kg N/ha/yr had little effect on clover plant morphology, plants growing under 400 kg N/ha/yr were generally smaller with fewer, shorter stolons developing from fewer axillary buds. Other experiments have also shown clover growing in mixed pasture provided with N has reduced capacity to form axillary buds (Davies 1992). This occurs even when swards are kept short through grazing or cutting since individual ryegrass leaves transmit less light, particularly red light, at high N rates which in turn inhibits stolon branching. Thus this effect of N on clover plant morphology is a direct effect which cannot be completely eliminated by efficient grazing management. Wilman and Aseigbu (1982) found application of 224 kg N/ha/yr reduced stolon length by 72% and stolon diameter by 6% in a selection of white clover cultivars in a ryegrass/white clover sward. Although stolon diameter was not measured in the current trial, the ratio of stolon length:stolon DW was not affected by N treatment indicating stolon diameter underwent a proportionately similar decrease as stolon length under 400 kg N/ha/yr. Wilman and Aseigbu (1982) and Hollington and Wilman (1985) also showed high rates of N had little or no effect on leaf size which is consistent with the current trial. The absence of N effect on clover leaf size, in contrast to the increase in ryegrass leaf size under N application (Harris et al. 1996), probably adds to the competitive advantage ryegrass has over clover. More recently, Caradus et al. (1993) showed N had no effect on clover stolon characteristics in a number of cultivars until 225 kg N/ha/yr was applied. However, application of 400 kg N/ha/yr in the current trial resulted in smaller plants and reduced branching which has a longer-term effect on clover's ability to spread vegetatively and persist in dairy pasture.

The additional pasture growth resulting from N use in this trial, together with the feeding of pasture silage made on the farmlets and bought-in grain supplement, resulted in increased in milksolids production per cow and per ha compared with production on the control farmlet (Harris et al. 1994; Penno et al. 1994.). On farmlets HS200 and HS400 the 1750 kg milksolids/ha target was reached in both seasons. However, use of high N rates compromised white clover growth, particularly on the lower stocked farmlets. Given that white clover is a high quality feed for dairy cattle due to its high protein content, high digestibility and low structural fibre content relative to perennial ryegrass (Thomson 1984; Ulyatt 1981) it is possible that the low clover content on some of the high N farmlets may have reduced the potential milksolids production. Australian research has clearly shown the benefits in terms of milksolids production from high clover content diets (Rogers et al. 1982). Obviously N use to increase pasture production is the first step to increasing milksolids production but further gains should be made if N can be used to increase pasture production without reducing white clover content. The results of this trial clearly showed this is possible, providing the additional pasture grown is fully utilised, particularly during spring, so that clover is not lost from the sward. Although presence of white clover may decrease the response to N fertiliser, total annual pasture production under a given rate of N is generally greater on a mixed ryegrass/clover sward than on pure swards. Reid (1983) demonstrated ryegrass/ white clover swards produced more total herbage during a three-year cutting trial than either ryegrass or clover alone applying up to 750 kg N/ha/yr

Although this trial was not designed to determine an optimum application rate for N it has shown that for this trial site there was a greater response in terms of pasture production per kg N fertiliser applied from 200 kg N/ha/yr than from 400 kg N/ha/yr. This, together with the negative effect that the higher rate of N had on clover plant morphology, would suggest that N rates closer to 200 rather than 400 kg N/ha/yr may be more desirable for both total pasture growth and clover persistence. Similarly, in a trial measuring pasture production and composition changes under 0, 150 and 300 kg N/ha/yr, Mackenzie and Daly (1982) found 150 kg N/ha/yr produced the best balance between acceptable clover levels and herbage yield.

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