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Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

Investigation into fertiliser and pasture agronomy strategies that alleviate the impact of clover root weevil

Report to Sustainable Farming Fund

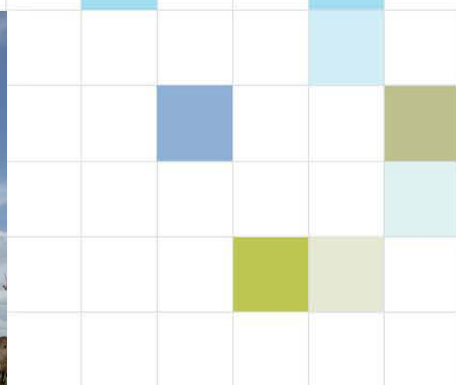
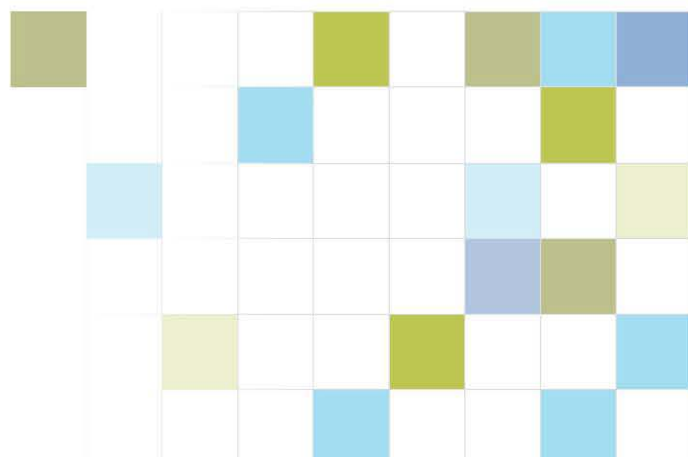
PJ Gerard, TE Eden, DJ Wilson, SA Howlett, and JPJ Eerens

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1. EXECUTIVE SUMMARY

Chronic infestations of clover root weevil (*Sitona lepidus*) severely compromise nitrogen fixation with subsequent effects on plant growth, physiology and contribution to pasture performance. The use of nitrogen fertiliser is the quickest way to ensure feed supply and maintain farm profitability in weevil-infested regions. However, little knowledge exists in regard to appropriate rates and anticipated responses when the weevils are present in pastures. A field trial was undertaken at three sites to compare pasture responses to four rates of urea (0, 100, 200 and 400 kg N/ha/annum) under two contrasting grazing management regimes.

The results from these trials show that pasture production and composition can be modified by grazing management and application of N fertiliser. However, regimes that work well under normal growing conditions can be deleterious if low soil moisture deficits eventuate. The main recommendations that can be drawn from this research are:

- Be aware that using high rates of N fertiliser may increase pasture vulnerability to drought.
- When using N fertiliser, clover content can be lifted by aiming for low post-grazing residues in spring, autumn and winter (to augment the light/shade balance between grass and white clover to maximise white clover growth) and higher residues in summer (to provide protection of growing points from the summer elements).
- When selecting field sites for multi-year trials, both farm manager and researcher should collaborate in analysing the risks associated with the site and agree on strategies to minimise them.
- Although there is insufficient data to make a firm recommendation on preferred N fertiliser rate to use in the presence of CRW, 200 kg/annum performed well at the Wilson site in terms of pasture production, N fixation, and weed content. With relatively little difference in productivity and significant risk associated with summer-early autumn N applications, it is possible that an overall lower annual rate (eg 150 kg/ha) applied in split dressings after grazing from mid-autumn to late spring would give the same benefits. This may be prove to be both economically and environmentally more sustainable since it may also increase overall clover content by shifting the competitive balance between grass and clover pasture components in clover's favour during the summer.

2. BACKGROUND

The clover root weevil (*Sitona lepidus* Gyllenhal (Coleoptera: Curculionidae) was first discovered on a Waikato dairy farm in 1996 (Barratt et al., 1996) and has subsequently become one of New Zealand's worst white clover pests (Eerens & Hardwick, 2003). It has spread throughout the North Island and has been confirmed in Nelson and Canterbury in the South Island.

There are two generations of clover root weevil (CRW) a year with adult weevils generally emerging in late spring and again in autumn (Gerard et al., 1999). The adults feed on clover foliage, favouring newly germinated seedlings (Hardwick & Harens, 2000), and making characteristic notches that are the most obvious symptom of weevil infestation. Adults live several months and female weevils can lay many hundreds of eggs during their lifetime. The soil-dwelling larvae are the most damaging stage, especially during winter when numbers typically exceed 400 larvae/m² in Waikato dairy pastures. The first instar larvae feed on nodules, then as they mature, the lateral roots and finally the nodal roots and stolons (Gerard, 2001; Gerard et al., 2004). The larvae are present throughout the year putting continual pressure on clover roots. Prior to the arrival of the weevil, no other pest species attacked clover root nodules. Therefore, while CRW competes with other pasture pests for clover roots as a food resource, it also severely compromises nitrogen fixation with subsequent effects on plant growth, physiology and contribution to pasture performance.

The use of nitrogen fertiliser is the quickest way to ensure feed supply and maintain farm profitability in CRW-infested regions. However, little knowledge exists in regard to appropriate rates and anticipated responses when CRW are present in pastures. One of the goals of SFF project 05/085 was to compare the response of CRW-infested pasture to different rates of urea in order to develop scientifically-based recommendations of how to best manage pasture in the presence of the weevil. The hypothesis was that if the pasture was grazed in a manner that prevented the grass component out-competing the clover, the addition of urea would boost both clover content and pasture production.

3. METHODS

3.1 Sites

Three replicate trials were established on farms with contrasting soil types in the Waikato region. All sites were within 20 km of each other and consisted of well-established ryegrass/white clover dairy pasture with a history of clover root weevil damage. The sites were to be grazed as part of the normal farm rotation, typically 10–12 times per year.

The sites were:

- Property of Lloyd Downing, Kuranui Road, Morrinsville. S 37° 40.941, E 175° 29.228, Clay soil. CRW abundance 1 Nov 2005 was 39 ± 1 larvae/m². Treatments commenced 8 December 2005.
- Property of Keith Holmes, Williams Road, Tauhei. S 37° 37.014, E 175° 25.144. Mineralised peat soil. CRW abundance 1 Nov 2005 was 86 ± 4/m². Treatments commenced 18 November 2005.
- Property of David Wilson, Tui Road, Hoe o Tainui. Sandy loam. CRW abundance 25 Oct 2005 was 255 ± 14 larvae/m². Treatments commenced 2 November 2005.

Note that as overwintering CRW commence adult emergence in late October/early November, the above CRW populations will be underestimates.

3.2 Design and treatments

The trial layout was four rates of nitrogen (0, 100, 200, and 400 kg/ha/year) replicated four times in a randomised block design. Each plot was split in two and randomly allocated one of two 'pasture management' treatments (Optimal and Conventional) giving a total of 32 10 x 15 m subplots.

The nitrogen (N) fertiliser used was urea (46% N) and was applied 1-2 days prior to grazing using a ride-on mower towing a calibrated Gandy 650 series drop spreader. Fertiliser was not applied when the weather forecast was for extended dry periods.

The 'pasture management' treatments were simulating contrasting grazing management regimes. The Optimal regime had low residues (1400 kg/ha) in spring, autumn and winter (to augment the light/shade balance between grass and white clover to maximise white clover growth) and high residues (1700 kg/ha) in summer (to provide protection of stolons and growing points from the summer elements). The Conventional regime simulated residues that would result from grazing relatively set periods with the same stock numbers year round. Accordingly, the intended residues were 1350 kg/ha in early spring, 1550 kg/ha in late spring/summer, 1300 kg/ha in autumn and 900 kg/ha in winter.

The Optimal and Conventional pasture residues were achieved using a ride-on mower immediately prior to grazing. Strips of pasture were mown near the trial area using each of the mower settings. A rising plate meter was used to estimate the residual dry matter of each of the mower settings and the height that gave the closest reading to the desired residue was chosen. The cut pasture was left on the plot for the incoming grazing animals and it was assumed that there was no subsequent selective grazing on any treatment plots.

3.3 Assessments

Pre-grazing standing herbage mass was assessed using a rising plate meter immediately prior to the above treatment cuts. A total of 20 readings were taken per plot and the average recorded.

Pasture composition was assessed by visually estimating percent clover, grass and weed cover within five 30 x 30 cm quadrats per plot. Calibration cuts were taken from quadrats representative of the typical range of clover levels found and the resulting herbage dissection used to calibrate the visual assessments and make corrections where necessary.

N fixation was assessed using the method described by Ledgard et al (1985). A solution of ¹⁵N -enriched ammonium sulphate solution was applied to a 1 x 3 m area of each of the 32 plots immediately after mowing. Herbage was removed from this area after 4 weeks, separated into clover and ryegrass, dried, finely ground and analysed by mass spectrometer at Lincoln University.

The data was analysed using ANOVA.

4. RESULTS AND DISCUSSION

This series of field trials had serious difficulties. The Lloyd Downing site at Morrinsville was abandoned in May 2006 after only six months data collection. While highly desirable to have a clay soil site, it proved impossible to get acceptable data from this site as planned. The very uneven surface following heavy winter pugging proved too rough for the mower and spreader to get reliable pasture cuts and fertiliser distribution, even after rolling. When wet, the mower could not move in the heavy conditions. Bruce Willoughby and Dr Han Eerens, the scientists in charge at that time, proposed dropping measurements at the site and increasing N measurements at the remaining sites to enable better interpretation of pasture data and this was accepted by the NZ CRW Action Group.

The trial at the Holmes' farm site at Tauhei showed no treatment effects over the first year. This farm was more intensive than the others and had a high input, high output approach. In February 2007, Drs Howlett and Gerard suggested that modifications relating to nitrogen application and cutting height had no effect at the site because it was already so intensively treated that it was unable to respond to further interventions.

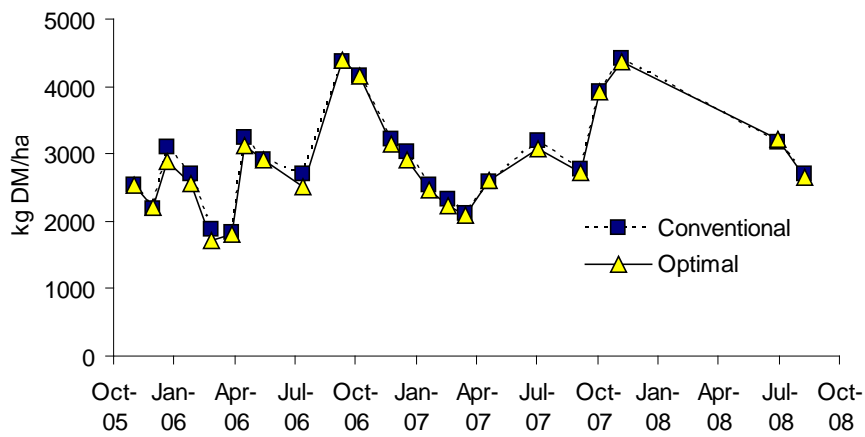
As a consequence to this report, it was discovered that there had been a break down in communication between the farm owner and the farm manager. From spring 2005 onwards the farm contractor has applied 300 units of N on top the existing trial treatment regime. This effectively negated expression of the planned fertiliser application regime on this trial. After consultation with an AgResearch agronomist (Dr Stewart Ledgard) to ascertain if any useful data could be obtained from the site, the trial was abandoned in July 2007.

The Wilson's site ran smoothly until the 2008 drought struck. The combination of hot dry conditions followed immediately by cold weather hit the pasture hard. As a consequence, the site was not grazed for over 6 months (Dec 2007 – June 2008 inclusive), no treatments could be applied and no data collected. The trial duration was then extended to allow a final treatment application to be carried out on 7 July 2008, the first grazing following the drought, and the final assessment on 18 August 2008.

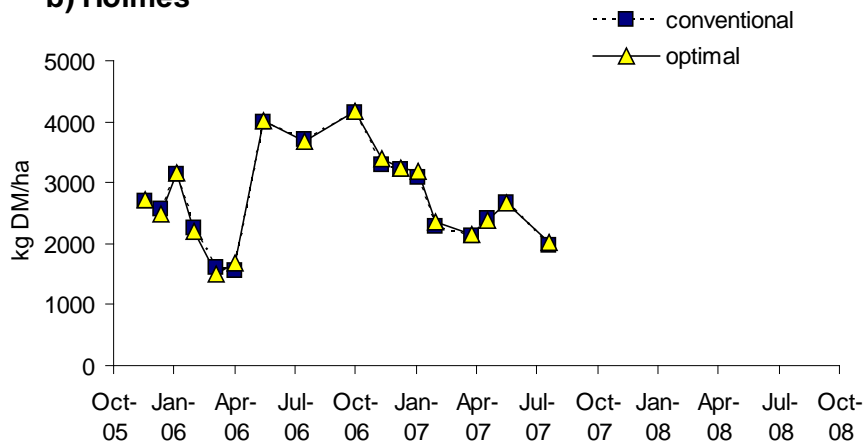
Most data from the two abandoned trials were not statistically analysed but have been reported alongside the Wilson data to show trends. The production has been analysed as pre-grazing standing herbage mass rather than production between grazings (pre-grazing standing herbage mass minus post-grazing residues) because the data set for mowing heights used, and therefore post-grazing residues, was incomplete. However, a combination of the partial data set and intended residues were used for the N response production data presented in Fig. 3. The Wilson's trial ran for 33 months and for purposes of analysis, was divided into three years (November 2005-August 2006; September 2006-August 2007; September 2007-August 2008).

4.1 Pasture production

a) Wilson



b) Holmes



c) Downing

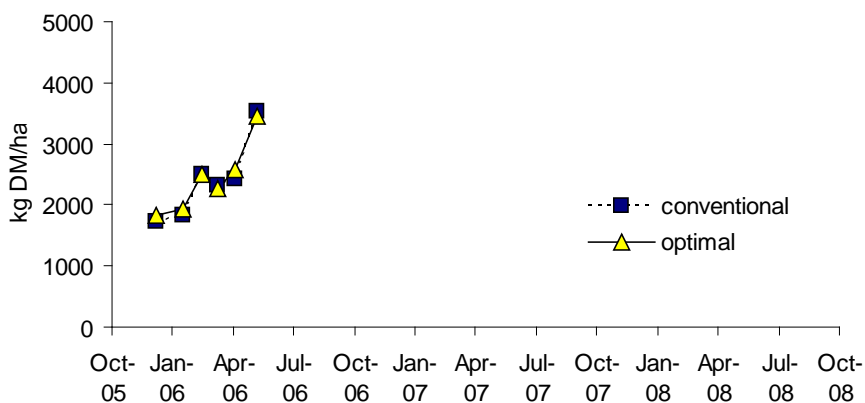


Fig. 1: Effect of conventional and optimal pasture management regimes on available standing dry matter immediately prior to grazing at three Waikato sites 2005-2008.

Figure 1 shows that pasture management regime had little overall effect on pre-grazing standing herbage mass at any of the sites throughout the course of the trial. Post-mowing plate meter readings were taken of individual plot residues on eight

occasions and analysis shows that while the intended difference between Conventional and Optimal plots should have averaged 150 kg/ha, the actual average was 79 ± 12 kg/ha (range 27-129 kg/ha). This difficulty in achieving the desired residue differences would have contributed to the overall trial outcomes in regard to the pasture management treatments. However, on three occasions at the Wilson's site, the Conventional plots had significantly higher herbage mass than the Optimal plots (December 2005 $P < 0.05$; February 2006 $P < 0.01$; October 2007 $P < 0.001$). There was no apparent relationship between these pre-grazing occasions and the previous intended post-grazing residue.

As anticipated, the amount of pasture produced increased with increasing rate of N applied over each of the three years assessed (Fig. 2). No significance should be attached to the variation between years because only in 2006/07 were samples able to be taken through a full year of 'normal' growing conditions.

The impact of N application has been presented in Figure 3 as the change in pasture herbage mass above that produced when no N was applied (N-reared pasture minus 0 N pasture).

At the Wilson site, application of 400 N gave a 9% lift of herbage mass in autumn ($P < 0.05$) and spring ($P < 0.01$) 2006, and in spring ($P < 0.001$) 2007 (Fig. 3a). There was no statistically significant difference between 400 N and 200 N on a seasonal or yearly basis and only in September 2006 ($P < 0.05$) at an individual observation basis. Pasture performance was lifted significantly by 100 N in summer 2006, and autumn and spring 2007 ($P < 0.05$ or less).

The absence of any N treatment effects can be seen at the Holmes' site where 300 N /annum had been applied across the trial site (Fig. 3b). In contrast, Fig. 3c suggests that the Downing site was showing a good pasture response to N application.

The negative pasture responses in plots to which N has been applied, that can be observed in Fig 3 at both the Wilson ($P = 0.06$) and Holmes ($P < 0.01$) sites in early autumn 2006 and at the Wilson site in July 2008, follow periods of marked soil moisture deficits. Of note is that the negative responses seem more pronounced with increasing N application rate, especially at Holmes where the 400 N plots were actually receiving around 700 N/annum. N was not applied when dry conditions were forecasted so the effect was not a direct 'burning' effect. Rather the results suggest that pasture grown under high rates of N has increased vulnerability to drought. This possibly arises because pasture plants in high N soils have no need to develop deep root systems to access nutrients but have increased foliage above ground compared to grasses on low N soil. This low root: shoot ratio would reduce the ability to access soil moisture and increase evapotranspiration, making the plants more vulnerable to drought, especially if root function was impaired by root pests. Similar increases in drought vulnerability in pasture grasses with N application have been shown in Queensland (Henzell et al 1975).

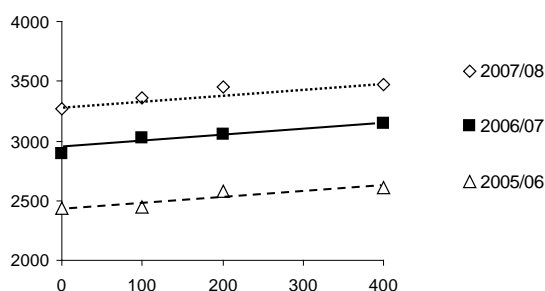


Fig. 2: Comparison of mean pre-grazing standing dry matter response to N application rate at Wilson's by year.

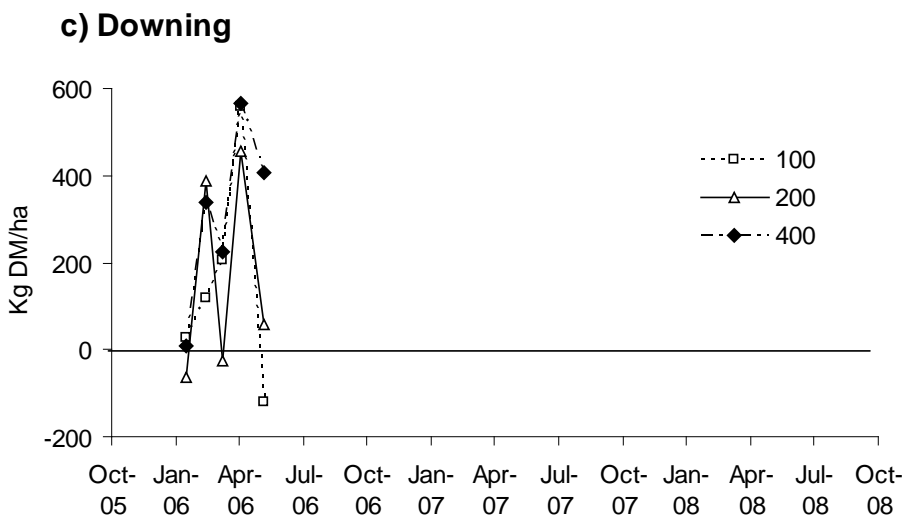
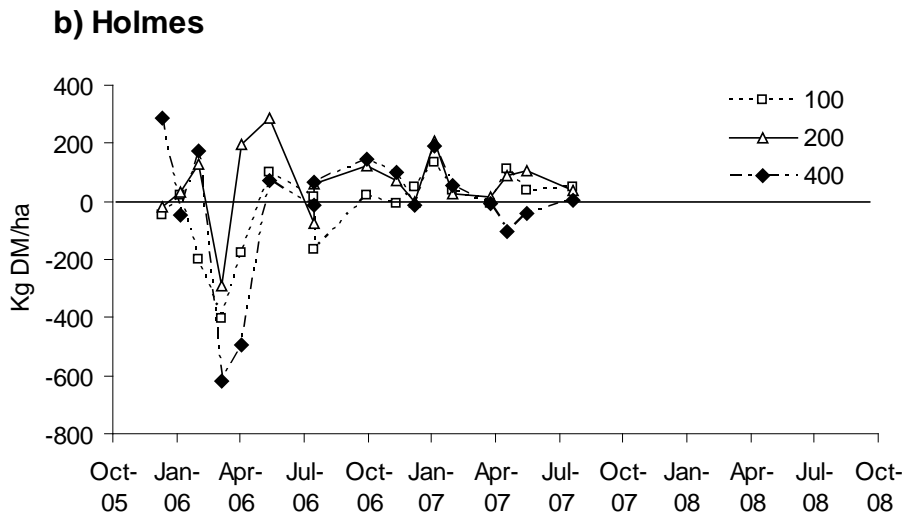
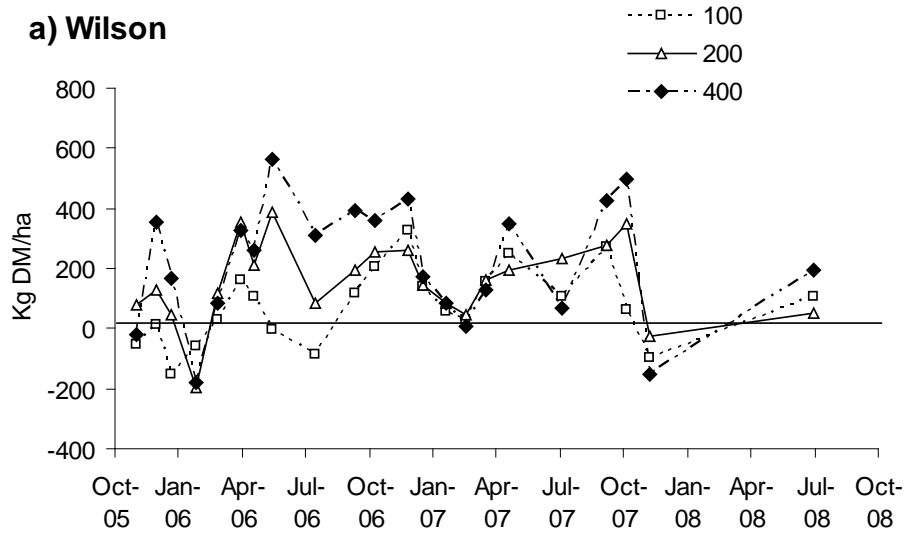


Fig. 3: Change in pasture production following application of three N rates at three Waikato sites 2005-2008. Note – additional 300 N/annum applied at Holmes

4.2 Pasture clover content

Figure 4 summarises the effect of Optimal and Conventional management regimes on the response of pasture clover to N application rate at the Wilson site. Overall, clover content was highest in the 0 N plots, with 55% more clover in 2006/07 ($P < 0.001$) and 51% more in 2007/08 ($P < 0.01$) than was present in plots receiving N fertiliser. Pasture clover content typically varies from year to year in response to a range of interacting biotic and abiotic factors. During this trial levels drifted downward, more noticeably in the plots receiving N fertiliser, and the 2008 drought wiped out resident clover plants from the trial paddock.

At the 0 N rate, plots under Conventional management averaged 33% more clover ($P = 0.015$) than those under Optimal management. However, under N fertiliser treatment, the trend appears to be the reverse, although only statistically significant in July 2007 ($P < 0.05$) in the 100 N plots and in February ($P < 0.05$) and September 2007 ($P < 0.05$) in the 200 N plots. A similar switch seemed apparent at the Downing site (Fig. 5).

When the production and pasture cover data are combined, it can be seen that clover production peaked in spring (Fig 6).

It was anticipated that clover would perform best under the Optimal management regime and the benefit to increase with increasing N rate. Clover under attack by weevil larvae will have improved growth if N is applied but unless pasture is managed well, it will become increasingly prone to be out-competed by the grasses as soil N rises. The relatively poor performance of clover under the Optimal regime and 0 N input was unexpected. There are several possible explanations. The selection of post-grazing residues for the Optimum regime may have been detrimental rather than beneficial in the growing conditions at Wilson's, especially if the intended high summer residuals could not be met when pasture is stressed by low soil moisture deficits. Also, even though the plots were mown and usually should have been too short for cows, animal grazing preferences may have varied between plots during summer when the intended Optimal residue levels were highest (1700 kg/ha). Clovers are preferentially grazed in low N pastures, especially when grass palatability drops in summer as grasses go to seed (Cosgrove et al 1996 and references therein). However, seeding is deferred and grass palatability increases when N is applied. In addition, the lower residues in the Optimal plots in late spring may also have prevented the accumulation of dead matter and again, retained palatability into the summer. Therefore selective grazing may have put more stress on clovers in 0 N Optimal plots compared to the rest.

At the Holmes site where excess N was applied, the Conventional plots appear to have higher clover content than the Optimal plots at 12 of the 16 assessment dates when N was applied at the maximum rate (Fig. 7). Also, during the 2006/07 growing season, it appears that most clover was found in the maximum rate plots. Unexpected results can occur when excess fertiliser levels are applied, as plants and soil biota vary in tolerance. If excess nitrogen is present, roots can be damaged and plants will begin to exude nitrogen from the leaf edges through guttation which can give rise to leaf burn. As clovers fix nitrogen, it is possible that they have greater tolerance for high soil N levels than grasses. It is noteworthy that researchers observed that the clovers in the 400 N plots at the Holmes site appeared healthy and had unusually large leaves, with trifoliates typically 35 mm across. Therefore it is possible that under the unusual excess N situation, these clovers were outcompeting ryegrass.

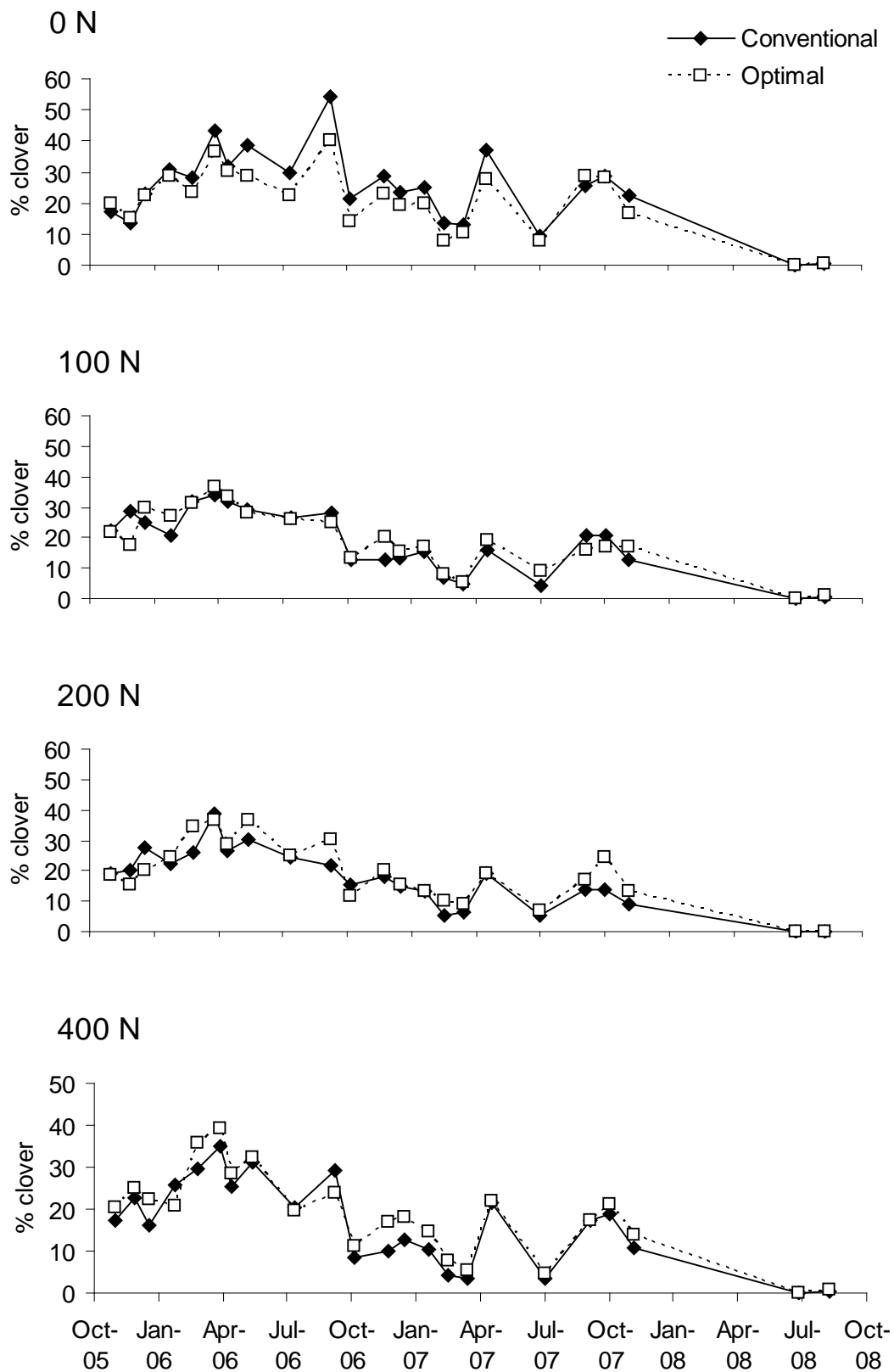


Fig. 4: Effect of conventional and optimal pasture management regimes on clover response to N application rate at the Wilson site 2005-2008

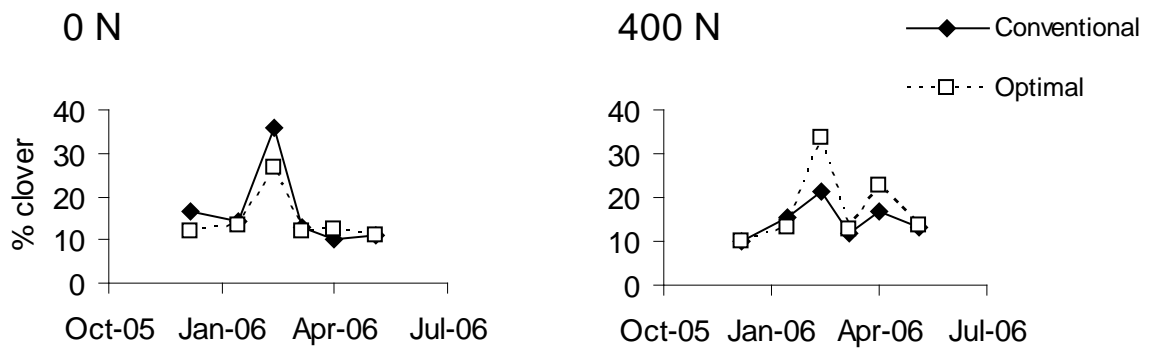


Fig. 5: Effect of conventional and optimal pasture management regimes on clover response to 0 N and 400 N application rates at the Downing site 2005-2006.

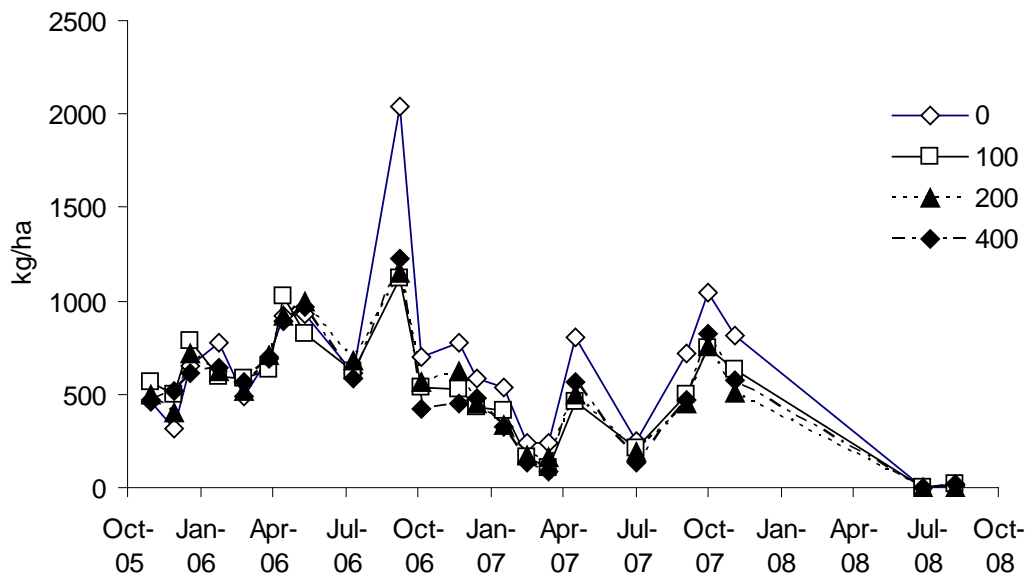


Fig 6: Effect of N application rate on in pre-grazing standing clover dry matter at the Wilson site 2005-2008

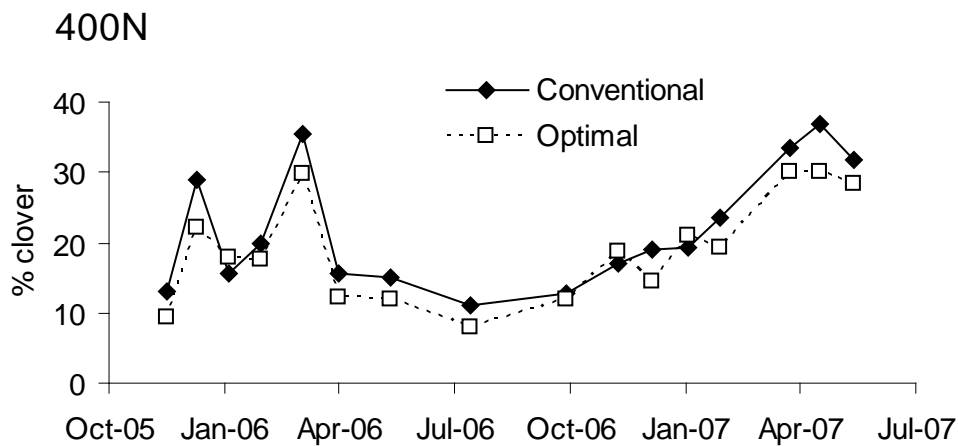


Fig. 7: Effect of conventional and optimal pasture management regimes on clover response to 400 N application rates at the Holmes site 2005-2007.

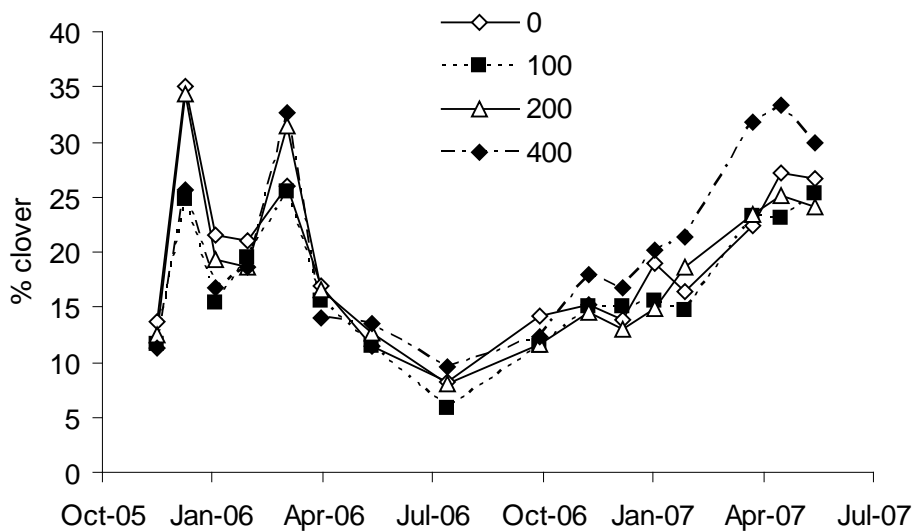


Fig. 8: Effect of N application rate on mean clover content at the Holmes site 2005-2007.

4.3 N fixation

The samples taken in December 06 showed that grazing regime had no effect on the % nitrogen fixed. Similarly, differences in N fixation under the four N treatments did not reach statistical significance (Fig 9). Superficially, this may seem contrary to the expectation that the more N fertiliser is applied, the less N clover fixes itself. However, one must also consider the clover and weevils in the system, and the history of the site.

If the clover data for the two months preceding the 15N test is averaged, the 0N plots averaged 671kg/ha/month from October to December, while the 100 N, 200 N and 400 N were 467, 530, and 469 kg DM/ha/month respectively. All clovers would be attacked by CRW, but those obtaining artificial N would have greater resources and therefore capability to replace lost nodules. This provides a possible explanation of why N fixation shows no decline with the addition of 100 and 200 N, in spite of reduced clover levels. In addition, the same reasoning would suggest the 100 N clovers would be under greatest stress (low DM and low N).

Up till September 2006, there were no treatment differences at the Wilson site, presumably because soil fertility was moderately high when the trial was established in November 2005. Compared to the 100 N plots, the 400 N plots had similar levels of clover dry matter in the pasture but fixed 23% less N (albeit not statistically significant). This may indicate that the repeated N applications are beginning to impact on N fixation.

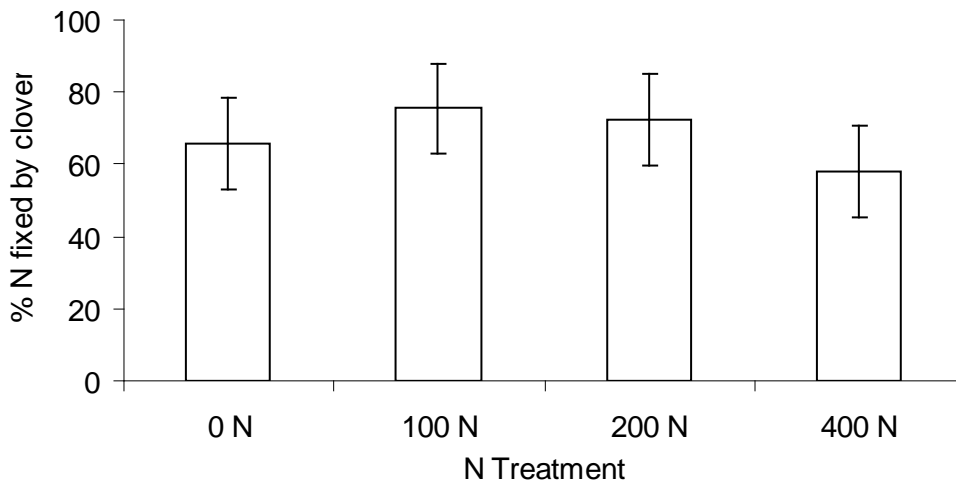


Fig. 9: Percentage of N fixed by clover under different N treatments at Wilson site December 2006

4.4 Pasture weed content

Generally weed content tended to be lowest in plots to which N had been applied at 200 or 400 kg/ha/annum (Fig. 10) although the differences were only significantly different in spring 2006 ($P=0.026$) and summer 2006/07 ($P=0.013$). As N application would have increased pasture vigour, there would have been less opportunity for weeds to establish and thrive. Weed levels peaked following the 2008 drought as the weeds were able to colonise the bare ground areas more rapidly than the desirable forage species.

The Conventional plots had more weeds than the Optimal plots in spring 2005 (9.4% vs. 5.7% $P<0.05$) but otherwise had similar levels on a seasonal basis.

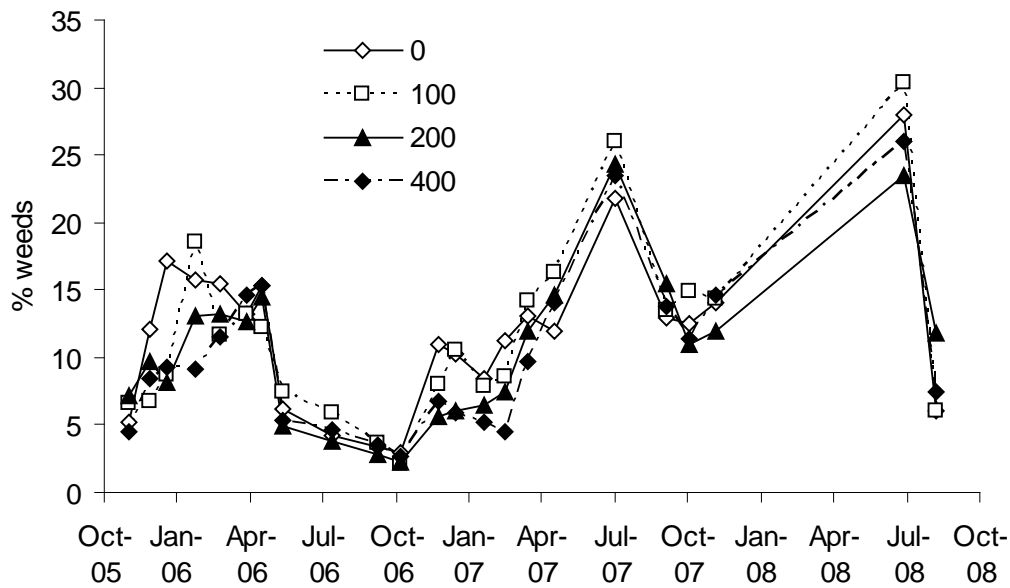


Fig. 10: Effect of N application rate on mean pasture weed content at the Wilson site 2005-2008.

5. RECOMMENDATIONS

The results from these trials show that pasture production and composition can be modified by grazing management and application of N fertiliser. However, regimes that work well under normal growing conditions can be deleterious if low soil moisture deficits eventuate. The main recommendations that can be drawn from this research are:

- Be aware that using high rates of N fertiliser may increase pasture vulnerability to drought.
- When using N fertiliser, clover content can be lifted by aiming for low post-grazing residues in spring, autumn and winter (to augment the light/shade balance between grass and white clover to maximise white clover growth) and higher residues in summer (to provide protection of growing points from the summer elements).
- When selecting field sites for multi-year trials, both farm manager and researcher should collaborate in analysing the risks associated with the site and agree on strategies to minimise them. Where a site-related risk is unavoidable and has a high chance of jeopardising trial success, both parties should be pragmatic and an alternative site located.
- Although there is insufficient data to make a firm recommendation on preferred N fertiliser rate to use in the presence of CRW, 200 kg/annum performed well at the Wilson site in terms of pasture production, N fixation, and weed content. With relatively little difference in productivity and significant risk associated with summer-early autumn N applications, it is possible that an overall lower annual rate (eg 150 kg/ha) applied in split dressings after grazing from mid-autumn to late spring would give the same benefits. This may be prove to be both economically and environmentally more sustainable since it may also increase overall clover content by shifting the competitive balance between grass and clover pasture components in clover's favour during the summer.

6. ACKNOWLEDGEMENTS

The authors acknowledge their former colleague Bruce Willoughby, and the NZ Clover Root Weevil Action Group, who had the vision and drive to instigate this project; the farmers Lloyd Downing, Keith Holmes and David Wilson for their valued co-operation and use of their farms; the students who assisted with data collection; and Catherine Cameron for the statistical analyses. This project was funded by the Sustainable farming Fund, Project 05/085 and fertiliser was supplied by Ballance Agri-nutrients.

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