Dairy grazing strategies to minimise soil pugging and compaction in the Waikato

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Abstract

This 3 year (1996–1998) study compared grazing regimes for minimising soil compaction and pugging damage. The treatments were conventional year-round dairy cow grazing, grazing for 3 hours when soil was susceptible to pugging damage, never pugged when soil was susceptible to pugging damage, and never grazed. In October 1997, macroporosity at 0–5 cm (air-filled porosity), a measure of soil compaction, was: never grazed (21.6%), never pugged (21.3%), 3 hour grazing (16.3%) conventional grazing control (12.8%). During July–September 1997, the never grazed and never pugged treatments had 35%, and 28% greater pasture yields than the control, with a similar trend in July–September 1998. The 3 hour grazing treatment had better soil physical quality than the control but this was not reflected in greater pasture production. The never pugged treatment greatly improved soil physical condition and had greater winter/spring pasture growth compared with conventional grazing so would be justified by farmers implementing "standing-off" pasture management strategies.

Keywords: compaction, pasture yield, pugging, treading

Introduction

Soil physical degradation and compaction has been highlighted in several surveys in Northland and Waikato soils under dairy farming (Singleton & Addison 1999; Singleton *et al.* 2000). Treading damage can result in under-utilisation of pasture, and reduced growth (Betteridge *et al.* 2002), so strategies to help farmers minimise pugging and compaction are therefore needed. Use of feed pads or grazing for a few hours each day when damage could occur may help reduce soil physical damage while maintaining sufficient pasture intake. Ward & Greenwood (2002) showed dairy cows consumed approximately 70% of their pasture intake in the first two hours of grazing, and 80% during the first four hours. Where "on-off" grazing was implemented, for cows "on" the pasture for 2, 4 and 12 hours, pasture yield was reduced by 19, 28 and 40%, respectively, for the following 2 months.

Conventional grazing by cows, nil, and restricted grazing during autumn/winter have been compared by de Klein (2001), showing nil grazing systems could produce up to 20% greater pasture yield annually than conventional systems. Soil physical aspects of these regimes also warrant study, so prevention and recovery of compacted soil can be investigated. Improvements in soil physical condition have been associated with increased spring pasture yield (Drewry *et al.* 2002).

The aim of this paper was to report on the effects of grazing strategies to minimise soil pugging and compaction damage on responses of soil physical properties under common winter and early lactation grazing conditions in the Waikato.

Methods and materials

Site details and treatments

The site, at Dexcel No 1 Dairy, Ruakura Research Centre, Hamilton, was on a Te Kowhai silt loam (Typic Orthic Gley Soil), which is poorly drained and susceptible to pugging. Although some details are described in Burgess (1998), this paper reports different treatment results and new data. The trial was conducted from August 1996 to December 1998. Treatments were within paddocks grazed as part of the usual grazing rotation:

(i) Conventional dairy farm grazing practice (control). In winter cows were block-grazed (confined to small areas within a paddock and shifted daily) with details given in Table 1. During lactation cows were generally grazed at 90 cows/ha unless otherwise

Table 1 Dates and soil moisture when on-off grazing treatments were imposed (for treatments see methods).

Date	Control (cows/ha)	Block or lactation grazing	G3 treatment	NP treatment	Soil moisture (gravimetric %)
Aug 1996	240	Block	Imposed	Imposed	83
Sept 1996	134	Lactation	Imposed	Imposed	77
Sept 1996	134	Lactation	Imposed	Imposed	69
Jun 1997	350	Block	Imposed	Imposed	53
Aug 1997	135	Lactation	Imposed	Imposed	57
Sept 1997	181	Lactation	Imposed	Imposed	58

specified in Table 1 (Burgess 1998).

(ii) Never-pugged, if the soil was prone to pugging (NP). This strategy avoided pugging. Similar to (i) except that when soil was deemed sufficiently wet enough for potential damage, pasture on plots was not grazed during that rotation, (i.e., simulating complete removal of cows to a feed pad). When this treatment was not grazed, herbage was trimmed and clippings returned, to simulate nutrient returns.

(iii) Grazed for only 3 hours when soil was prone to pugging (G3). This strategy minimised pugging. Similar to (i) except that when soil was deemed sufficiently wet enough for damage to occur, (if hoof prints indented soil by about 2 cm, or once bare ground appeared), then cows were removed after only three hours grazing after entering the paddock in mornings. Otherwise these were grazed similarly to the control. This treatment simulated partial grazing and partial removal to a pad only when soil was puggable.

During the first year the NP and G3 treatments were imposed 4 times, while in year 2, these treatments were imposed twice during spring (Table 1). Details of grazing during 1998 were unavailable although a similar regime was imposed.

(iv) Never-grazed (NG). Cows were completely excluded for the entire period of the trial. Pasture was trimmed and clippings returned to simulate return of nutrients.

There were two replicate blocks. The control and G3 treatments were replicated twice within each block. For the 20 year old pasture, composition (by dry matter weight) in June 1998, was 51% *Lolium perenne*, 4–5% *Pasplaum*, and 7% *Trifolium repens*. Weeds, particularly *Hydrocotyl*, were spot sprayed when required. All plots received fertiliser as applied to the farm, typically about 220 kg N/ha/yr, as six urea applications, 42 kg P/ha/yr, 100 kg K/ha/yr, and 53 kg S/ha/yr.

Measurements

Soil physical (compaction) measurements

Bulk density, percentage of pores > 300 mm (very large drainage pores), macroporosity (percentage of large drainage pores >30 mm or 0.03 mm diameter), saturated (water flow in large pores; K_{sat}) and unsaturated hydraulic conductivity (water flow; K_{unsat}), were measured using undisturbed soil cores collected in the field using 10 cm diameter stainless steel rings. K_{unsat} was measured at -0.4 kPa and –1.0 kPa to measure water flow in pores less than 750 mm and 300 mm, respectively. Soil cores were sampled at depths 0–5, 5–10, 10–15 and 15–20 cm. Preparation details are given in Singleton & Addison (1999), with particle density determined. Sampling was undertaken during October 1997, June 1998 and October 1998. Duplicate cores were taken at each of 2 sub-sample locations per depth in each plot.

Pasture dry matter yields

Pasture yield was measured every 3–6 weeks from August 1996 to February 1999 using the rate of growth technique (Lynch 1966). A rotary lawn mower was used to harvest pasture cut to 3 cm height, from one 2.3 m^2 caged area per plot, and a sub-sample collected for dry matter determination. Cages were then moved within the plot, and pasture trimmed to 3 cm.

Statistical analysis

Soil physical data were analysed by analysis of variance using the statistical package GenStat version 6. The block structure was given by depth within subsample within plot within block, and the treatment structure by treatment, depth and their interaction. Yield data were analysed in the plot stratum, by fitting treatment. Hydraulic conductivity data was analysed after a $\log_{10}$ transformation to stabilise variance.

Results

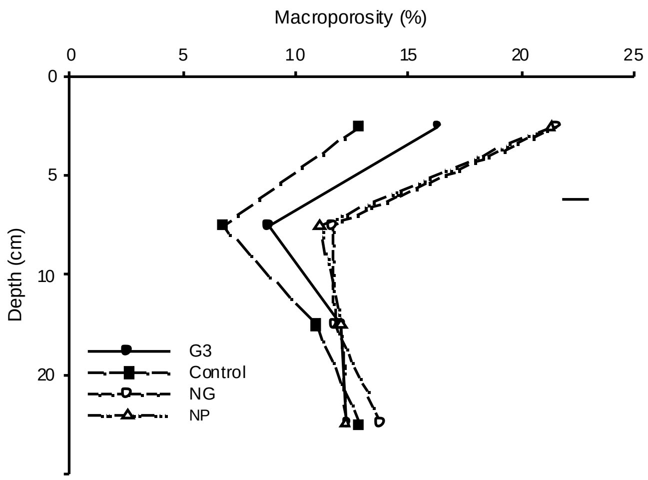
Soil physical measurements

Most soil physical measurements showed a clear and consistent pattern of treatment response at each sampling, with significantly more compaction at 0–5 cm for the more heavily grazed treatments (control and G3 treatments) than for the NP and NG treatments, but no significant distinction between the treatments at 10–15 cm or 15–20 cm. For macroporosity this is shown in Figure 1 for the October 1997 sampling, 14 months after trial commencement, and fully presented in Table 2. Figure 2 shows K_{sat} in October 1997, while Figure 3 shows $K_{unsat\ (-0.4\ kPa)}$ in June 1998, where there was a different pattern of change with depth. Significant treatment differences between the control and G3 treatments are evident from Table 2, in October 1997.

For macroporosity and percentage of pores > 300 mm, there was also a significant difference ($P<0.001$) between heavily grazed and lighter grazed treatments at 5–10 cm at each sampling, while for bulk density (data not presented) this contrast was not significant. For $K_{unsat\ (-0.4\ kPa)}$ this difference was significant ($P<0.05$) only for the October 1998 sampling.

For K_{sat} (Figure 2), however, the pattern of change with depth was quite different, with a highly significant treatment main effect ($P<0.01$), where mean values increased with depth ($P<0.001$) consistently over all treatments ($P>0.05$ for treatment x depth interaction). Averaged over all samples and depths (0–20 cm), mean K_{sat} followed the order, control (129

Figure 1 Treatment means for macroporosity (%) for soil depth (cm), October 1997. Horizontal bar represents SED.



mm/h) < G3 (238 mm/h) < NP (965 mm/h) < NG (1 897 mm/h), with each difference in sequence greater than one standard error.

In June 1998, $K_{unsat\ (-0.4\ kPa)}$ showed significant treatment effects (P<0.05) and a treatment by soil depth interaction (P<0.001) at 0–5 cm and 5–10 cm (Figure 3). At 0–5 cm, $K_{unsat\ (-0.4\ kPa)}$ was greater in the NG (48 mm/h) and NP (31 mm/h) treatments than the G3 (4 mm/h) and control (2 mm/h) treatments.

Table 2 Treatment means for macroporosity (%) at each sampling. Standard errors of the difference are given for comparisons between treatments with (a) n=4 and n=2 (SED_1), and (b) both n=4 (SED_2), at the same depth. Significance levels are given for treatment (T), depth (D) and their interaction (T.D). *, P < 0.05, ***, P < 0.001; NS, not significant.

Date n	Depth	Control	G3 4	NP 4	NG 2	SED_1 2	SED_2	P (T)	P (D)	P (T.D)
Oct-97	0–5 cm	12.8	16.3	21.3	21.6	1.26	1.03	*	***	***
	5–10 cm	6.8	8.8	11.1	11.6					
	10–15 cm	10.9	12.0	12.0	11.7					
	15–20 cm	12.8	12.3	12.2	13.8					
Jun-98	0–5 cm	11.2	14.0	19.9	22.3	2.27	1.86	NS	***	***
	5–10 cm	10.3	12.9	15.8	15.2					
	10–15 cm	14.3	16.0	17.4	14.7					
	15–20 cm	18.5	18.9	19.1	17.8					
Oct-98	0–5 cm	14.2	15.6	22.3	21.9	1.89	1.54	NS	***	***
	5–10 cm	10.7	13.0	15.2	16.8					
	10–15 cm	13.7	15.0	15.8	15.6					
	15–20 cm	16.4	18.0	17.9	18.5					

Pasture yield

The effect of the treatments on pasture yield is shown in Table 3. The NG and NP treatments had significantly greater yields than the control and G3 treatments, during the July–September periods in 1997 and 1998 (Table 3). However, during the corresponding 1996 period, there were no significant differences. During mid-late spring (October to December 1997) the NG treatment had significantly greater yield than the other grazing treatments; note the low standard error in this case.

During July–September 1997, this equated to the NG and NP treatments producing 35% (+826 kg DM/ha), and 28% (+1021 kg DM/ha) respectively, greater pasture yields than the control. During July–September 1998, the NG and NP treatments had 49%, and 39% greater pasture yields than the control. Overall, when treatment differences were significant (Table 3), the NG and NP treatments produced 39%, and 33% greater pasture

Figure 2 Treatment means for K_{sat} (mm/h) for soil depth (cm), October 1997. Horizontal bar represents SED.

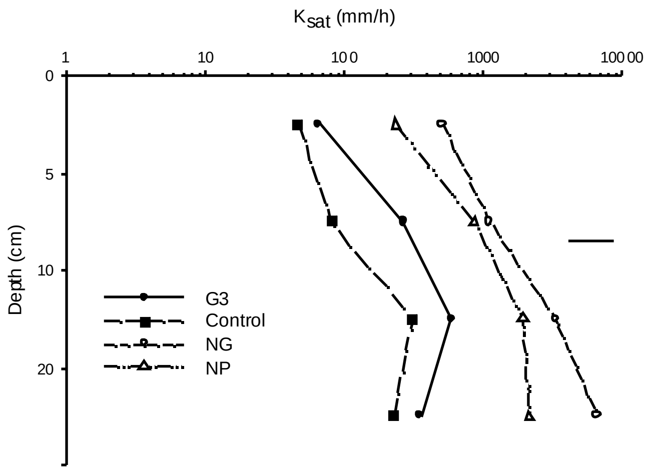


Figure 3 Treatment means for $K_{unsat-0.4\ kPa}$ (mm/h) for soil depth (cm), June 1998. Horizontal bar represents SED.

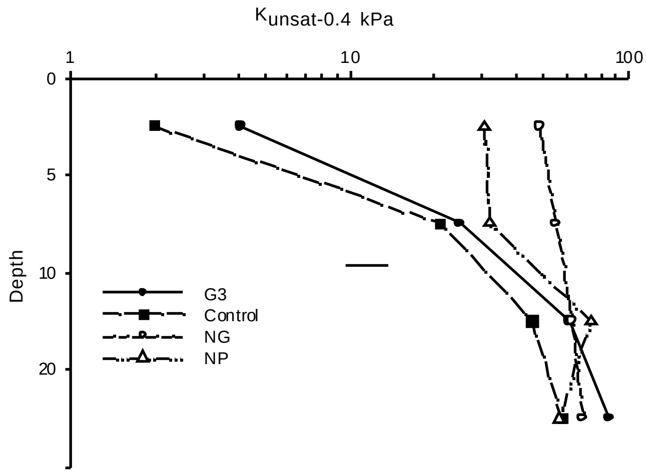


Table 3 Pasture yield (kg DM/ha) for the grazing treatments. *, P<0.05, ***, P<0.001; NS, not significant.

Period	Control	G3	NP	NG	SED	P
Jul-Sep 1996	3155	2661	3282	3492	513	NS
Oct-Dec 1996	4421	4130	3959	3956	236	NS
Jan-Jun 1997	4124	4053	3988	4306	378	NS
Jul-Sep 1997	2942	3068	3768	3963	301	*
Oct-Dec 1997	2493	2221	2446	3326	145	***
Jan-Jun 1998	4201	3778	3250	4133	794	NS
Jul-Sep 1998	1957	1935	2713	2915	293	*
Oct-Dec1998	4976	4571	4700	5115	441	NS

yields than the control. In summary, averaged over all 3 years data for the July–September periods, the NG and NP treatments produced 28% (+772 kg DM/ha), and 21% (+570 kg DM/ha) greater mean pasture yields than the control.

Discussion

This study has established contrasting levels of soil physical properties under various grazing regimes. Although not always significant between all treatments, the level of soil compaction as shown by many of the soil physical indicator measurements in the top depths were generally greatest in the order of control (conventional grazing) > G3 > NP > NG.

The G3 and NP treatments were imposed on wet soil twice during Year 2, when 5–28 mm/day of rain fell just prior to or during grazing. In contrast, these treatments were imposed 4 times in Year 1, as the soil water content was greater than Year 2, but it is difficult to relate this wetter 1996 period to soil physical status, as the first sampling was in October 1997. Overall, soil structure was in good condition, with macroporosity generally >10%, a common indicator for soil health (Singleton *et al.* 2000). Singleton & Addison (1999) indicated macroporosity at 0–5 cm was 18.7–23.6% in surveyed never trodden areas, compared with 7.5–13.3% under normal grazing. The current trial also showed similar trends. Treatment K_{sat} levels are considered adequate, being > 70 mm/h (Walker & Reuter 1996), except for the control (16–47 mm/h) at 0–5 cm, where drainage may be restricted. Soil physical improvement in the NG treatment was probably due to natural rejuvenation, particularly over summer, whereas the process was interrupted by recurring treading for the other treatments.

Although the NG treatment averaged greater pasture yield than the control, such a system may not be practical for New Zealand low-cost farm systems. The NP treatment also averaged greater winter/spring yield than the control, with both treatments having good soil physical quality, which is associated with greater spring pasture growth (Drewry *et al.* 2002). Removing cows onto a feed pad (as would be done with the NP treatment) may therefore be worthwhile during wet periods to reduce damage. The practicalities of removing cows when appropriate, and costs/benefits should be considered. The most practical option, G3, had some improved soil physical condition, although this was not reflected in greater pasture production, a contrast to the Ward & Greenwood (2002) results. Other factors not measured, e.g., tiller number, may also influence yield differences. In practice, three hour grazing also requires a feed pad or stand-off area. To help with on/off grazing decision making, a penetrometer and "Tread Ready Reckoner" (Betteridge *et al.* 2002) is being tested by farmers. The penetrometer and similar management strategies are also being evaluated by AgResearch in a 3 year trial at Tussock Creek in central Southland.

Conclusions

The level of soil compaction indicated by many of the soil physical properties, particularly at 0–5 cm and 5–10 cm was, in general, greatest in the control (conventional) grazing, followed by G3, NP, and least in the NG treatment. The G3 treatment had some improved soil physical condition, but this was not reflected in greater pasture production. The G3 treatment has some merit to reduce soil physical damage. The NP treatment greatly improved soil physical quality and increased winter/spring pasture growth compared with conventional grazing, so would be justified by farmers establishing a feed pad or stand-off area.

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