Long-term effects of pugging on soil and pasture in SW Victoria

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Abstract

A grazing trial was conducted to identify the effects of pugging by dairy cows on pasture and soil in south west Victoria. A series of pugging severities (none, light, medium and heavy) were imposed by varying the stocking density at different soil moisture levels before and after a heavy rain event. Medium - heavy pugging reduced the perennial ryegrass (*Lolium perenne* L.) tiller density by 41%, 49 weeks after the pugging, whereas light pugging did not. Heavy pugging also reduced soil macroporosity at 0-50 mm depth by 9%, 49 weeks after the treatment was imposed. The cows on the heavy pugging plots spent more time (46% of the total time) on walking, standing and lying than those on the non-pugged plots (29% of the total time). The results indicate that grazing pasture too soon after heavy rainfall that saturates the soil surface can result in major long-term pugging damage to pasture and soil.

Keywords

Plant density, perennial ryegrass, bulk density, porosity, grazing behaviour.

Introduction

Pugging of pasture by cows grazing winter-wet soils can be an important limitation for dairying in southern Victoria and Tasmania (4). A previous study (5) demonstrated that medium - heavy pugging after a heavy rainfall event in late winter had a significant adverse impact on pasture growth in the following spring. One major cause of the impact is the immediate reduction of perennial ryegrass (*Lolium perenne* L.) tiller density after pugging (5). However, the long-term impact of such pugging on perennial ryegrass density and soil condition remains unknown. An understanding of the response of pasture and soil to pugging damage in the following seasons is of practical importance in assessing the full effects of pugging damage and for the adoption of effective wet soil management strategies. The behaviour of lactating cows grazing wet pastures has not been well studied. In general animals tend to move faster towards the end of a grazing period when less pasture is available (2). Under wet soil conditions, pastures can be fouled by mud, limiting grazing by the cows (6), and increasing pugging damage to the pasture particularly with prolonged grazing. The objectives of the experiment were to compare the grazing behaviour of cows under different pugging conditions, and to investigate the long-term recovery of pasture density and soil physical condition after pugging.

Materials and methods

Site, treatment and management

The trial was conducted on a commercial dairy farm near Cobden (38?20'S, 143?05'E) in south west Victoria from 9 August 1998 to 26 July 1999. The site had a duplex soil with a 300 mm deep clay loam A horizon overlying a medium clay B horizon, giving the soil poor internal drainage. Soil fertility at the site was high with an Olsen phosphorus level of 30 mg/kg. The 76-year average annual rainfall was 866 mm. Pasture species were predominantly perennial ryegrass (*Lolium perenne* L.), and winter grass (*Poa annua* L.) in winter/spring with a small proportion of white clover (*Trifolium repens* L.) and broadleaf weeds, predominantly capeweed (*Arctotheca calendula*).

On August 6, 1998, twelve 30m*10m plots, consisting of four pugging treatments and 3 replicates were fenced in a randomised block design. The four treatments were: 1) non-pugging (NP), which was grazed when the soil moisture was below field capacity on 10 August 1998; 2) light pugging (LP), which was grazed at a stocking density of 67 cows/ha on 14 August 1998, one day after the heavy rain (24 mm on 13 August); 3) medium pugging (MP), grazed at a stocking density of 133 cows/ha on the same day as LP; and 4) heavy pugging (HP), grazed at a stocking density of 267 cows/ha on the same day as LP and NP. After 14 August 1998, pasture was grazed when the pasture mass reached 2400–2800 kg DM/ha and the soil was dry (<field capacity). The pasture was grazed down to 1200–1600 kg DM/ha at each grazing. When pasture yield measurements were completed in November 1998, the plot fences were removed and the trial area grazed as part of the normal farm rotation. The boundary of each plot area was marked for soil and pasture measurement in the following year. Full details of the site and management are given by Nie et al. (5).

Measurements

Plant population density was monitored one week before (6 August 1998), and 3 weeks (31 August 1998), 13 weeks (17 November 1998), and 49 weeks (26 July 1999) after the light; medium and heavy pugging treatments were imposed. Fifteen 80-mm diameter soil cores were collected from each plot. The numbers of perennial ryegrass tillers, other grass tillers, white clover growing points, other legume plants and weeds from each soil core were counted to estimate the density of each plant category.

On 26 July 1999 while the soil moisture was at field capacity (=35% volumetric soil moisture), six 50-mm diameter cores were collected in each plot of the NP and HP treatments to measure bulk density, total porosity and macroporosity of the soil. Cores were trimmed to remove above ground plant material, and divided into 0-50, 50-100 and 100-150 mm depths. The fresh cores were weighed, then oven-dried at 105 ?C to constant weight. Macroporosity is defined as the air-filled porosity at field capacity (3).

Grazing behaviour was observed on 10 August 1998 when the NP plots were grazed, and on 14 August 1998 when the pugging treatments were imposed. Two cows on each of the LP treatments and three cows on each of the remaining plots were marked with different coloured paint to enable quick identification of individual animals. Observations of cow behaviour were made from 08:00 to 15:00 at 10-minute intervals, and recorded as grazing, ruminating, and idling (standing, walking or lying).

Statistical analysis

Data were analysed using General Analysis of Variance model of Genstat 5 (1). A randomised complete block model was used to assess the effects of pugging on plant population density and the grazing behaviour of cows. A t-test was used to analyse bulk density, total porosity and macroporosity.

Results and discussion

Plant population density

There was a general trend that perennial ryegrass tiller density declined from late winter/early spring to late spring 1998, but increased in winter 1999 (Fig. 1). There was no significant ($P>0.05$) difference in perennial ryegrass tiller density between treatments at the beginning of the experiment (1 week before pugging treatment). Three weeks after the pugging treatment was imposed, perennial ryegrass tiller density declined considerably in HP and MP treatments, but did not in NP and LP treatments compared with their initial densities, although the difference between all treatments was not statistically different ($P>0.05$). The difference in perennial ryegrass tiller density between treatments became significant ($P<0.05$) 13 weeks after pugging. Forty-nine weeks after pugging, the average tiller density of perennial ryegrass in HP and MP was 3550 tillers/m^2, 59% of the NP treatment ($P<0.01$), whereas that in LP was not significantly ($P>0.05$) different from NP (Fig 1). Loss of plants resulting from pugging is one of the major causes of reduction in pasture yield in the following season (5). The large difference in perennial ryegrass tiller density between medium - heavy pugging treatments and the non-pugged control, 49 weeks after pugging, indicated that pugging damage had a long-term adverse effect on pasture growth and yield. There were no significant ($P>0.05$) differences between treatments in densities of other plant components. This was mostly because the other pasture components such as clovers only accounted for a very small proportion (<1%) and were variable in the plant community. The change of species composition after pugging damage requires further study.

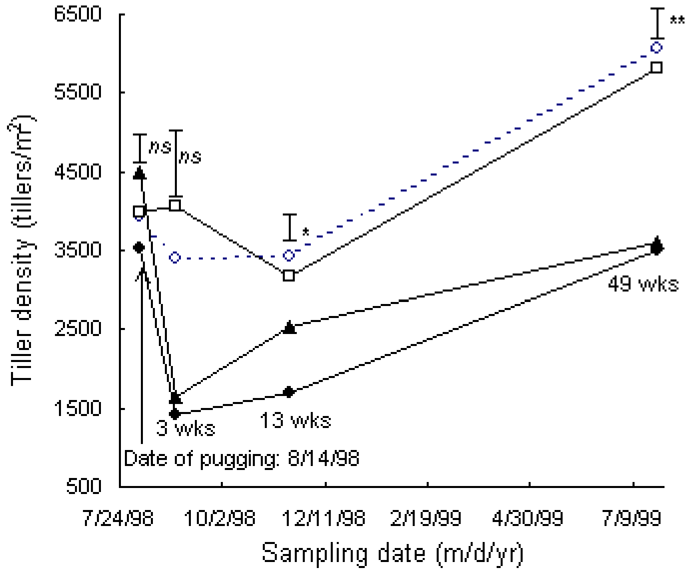

Figure 1. Change of perennial ryegrass tiller density of 1) heavy pugging (●); 2) medium pugging (▲); 3) light pugging (□); and 4) non-pugged (○) treatments 1 week before, and 3 - 49 weeks after pugging treatments were imposed (vertical bars show s.e.; *ns* - not significant; *P<0.05; **P<0.01).

Soil parameters

There were no significant (P>0.05) differences between NP and HP in soil bulk density and total porosity both at 0 – 50 and 50 – 100 mm soil depths, although there was a trend that bulk density was slightly higher in HP than in NP, and total porosity was higher in NP than in HP (Table 1). However, the effect of the heavy pugging treatment on macroporosity at 0-50 mm depth was marginal (P=0.54), compared with the non-pugged control. This suggests that pugging is likely to have compacted the layer of soil immediately underneath the animal hooves. The average depth of pug marks in the HP treatment was 43 mm (5), and the mostly compacted layer of soil would have been at the bottom of these marks, resulting in a decline in macroporosity for the 0-50 mm depth. The reduced but insignificant (P>0.1) difference between HP and NP in macroporosity further down (50 – 100 mm) indicated that this compaction probably did not occur beyond this depth. Singleton and Addison (7) studied the physical conditions of three soils and found that pugging had a long-term effect on soil physical properties such as bulk density and porosity on all three soils. The less significant effects in this study were probably attributed to the light severity of pugging which was a single, one-off pugging after a heavy rainfall event. Therefore, studies with multiple puggings during prolonged wet periods may have more profound effects on soil physical conditions. This requires further investigation.

Table 1. Soil bulk density (BD, Mg/m^3), total porosity (TP, v/v) and macroporosity (MP, v/v) under non-pugging (NP) and heavy pugging (HP) at 0 – 50 and 50 – 100 mm soil depth on 26 July 1999, 49 weeks after pugging treatments were imposed.

Treatment	Soil depth (0-50mm)	Soil depth (50-100mm)

	BD	TP	MP	BD	TP	MP
NP	1.166	0.560	0.215	1.303	0.509	0.226
HP	1.201	0.547	0.196	1.315	0.504	0.218
s.e.m.	*0.0221*	*0.0083*	*0.0095*†	*0.0141*	*0.0053*	*0.0037*

† *P*<0.1.

Grazing behaviour

The cows spent significantly (P<0.05) more time idling (walking, standing or lying without grazing) on the HP plots than on the NP plots (Table 2). However, the time spent idling for the MP and LP treatments was not significantly increased compared with the NP treatment. In contrast, the time spent grazing for the HP treatment was significantly (P<0.05) reduced compared with the NP, LP and MP treatments. The reduced time in grazing and increased time in idling by cows in HP may have been due to contamination and fouling which will limit further grazing by cows (6). There was no significant (P>0.05) difference in the ruminating time between treatments.

Table 2. The average time (min.) of grazing, ruminating and idling by cows between 0800 and 1500 under non-pugging (NP), light pugging (LP), medium pugging (MP), and heavy pugging (HP).

Treatment	Grazing	Ruminating	Idling
NP	215a	71	114a
LP	257a	25	118a
MP	223a	53	123a
HP	158b	59	185b
s.e.m.	*16.5**	*12.9*	*15.2**

P<0.05. Means within column followed by different letters are significantly different

Conclusion

Pugging damage resulting from a single pugging event in winter after heavy rainfall, still had a significant effect on perennial ryegrass tiller densities 49 weeks after pugging treatments were imposed. Heavy pugging reduced soil macroporosity at 0-50 mm depth. Cows on the heavy pugging plots spent more time on walking, standing and lying than those on the non-pugged plots. In order to better understand the impact of pugging particularly on soil, studies with increased pugging severity by multiple puggings in prolonged wet periods are necessary. On a practical level, when a single pugging occurs with no serious damage to soil structure, management options to build up the population of sown grass may be effective to restore pugged pasture.

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References

1. Genstat 5 Committee 1987. Genstat 5 Reference Manual. Oxford University Press, Oxford, UK.

2. Hodgson J. 1991 Grazing Management - Science into Practice. Longman Scientific & Technical. pp. 25-37.

3. Leeper G.W. and Uren N.C. 1993 Soil Science – An Introduction. Melbourne University Press. pp. 90-109.

4. MacEwan R 1998. Winter wet soils in Western Victoria - options for the dairy industry. Consultancy report for WestVic Dairy, Warrnambool, Victoria.

5. Nie Z.N., Ward G.N. and Michael A.T. 2001. *Aust. J. of Agric. Res.* 52 (1) (in press).

6. Sears P.D. 1956. *Proc. of the Seventh International Grassland Congress*. Palmerston North, New Zealand. pp.92-101.

7. Singleton P.L. and Addison B. *Aust. J. of Soil Res.* 37:891-902.