The effect of pasture manganese concentrations on lamb growth

L.C. SMITH[1], K. KNOWLER[1], J.D. MORTON[2] and W.D. CATTO[3]
[1]*AgResearch, Woodlands Research Station, RD 1, Invercargill*
[2]*Ballance Agri-Nutrients, PO Box 65 Rolleston Canterbury*
[3]*Ballance Agri-Nutrients, PB 12503, Mount Maunganui*
chris.smith@agresearch.co.nz

Abstract
A trial was laid down at Woodlands in Southland to investigate the effect of pasture manganese (Mn) on sheep performance. Pasture Mn concentrations were increased from background concentrations (82-98 mg/kg DM) to 192-354, 466-694 and 912-1178 mg/kg DM by the regular spray application of $MnSO_4$. These pasture concentrations were replicated four times and grazed by mobs of 10 Coopworth x Texel ram lambs. Pasture growth, botanical composition and pasture Mn concentrations were monitored. Lamb liveweights were measured fortnightly and the lambs were slaughtered after 14 weeks with the livers of six animals from each treatment sampled for vitamin B_{12}, copper (Cu), selenium (Se) and Mn concentration. Average clover content of the pastures declined throughout the trial, averaging 17%, 15% and 4% for the three grazing areas respectively. Animal growth rates averaged 180 g/day for the duration of the experiment but varied from 250 g/day during the first 2 weeks they grazed the pastures declining steadily for each 2 week period they remained on that group of paddocks to a low of <90 g/day after 6 weeks. The animal growth rates were only significantly influenced by extremely high initial Mn concentrations (>2000 mg/kg DM) or where concentrations were above 1200 mg/kg DM for the full 2 week grazing period. There was no effect of high Mn intake on liver B_{12}, Se, Cu or Mn under these conditions.
Keywords: sheep, manganese, lamb growth rates, pasture manganese concentration

Introduction
Manganese (Mn) concentrations in New Zealand pastures are generally not considered to be high enough to adversely influence pasture production (Smith & Edmeades 1983). However increased herbage Mn concentrations may affect animal performance since Grace (1973) found that sheep fed pellets with Mn concentrations in excess of 400 mg/kg dry matter (DM) had their daily weight gains decreased by about 40%. This is in contrast to overseas researchers who have reported no decrease in animal growth rates until pasture Mn concentrations exceeded 2000 mg/kg DM (Cunningham *et al*. 1966; Ivan & Hidiroglou 1980; Black *et al.* 1985a; Paynter 1987). However there is little information on whether this decrease in weight gain is gradual as Mn concentration increases.

While concentrations as high as the 400 mg/kg DM threshold reported by Grace (1973) are not common in New Zealand, they can be found in parts of Central Otago (Smith *et al.* 2004). The pasture concentration of Mn fluctuates during the year, with concentrations reported as being highest in the winter (May-August, Smith *et al.* 2004) or late summer period (January-March, Metson *et al.* 1979). For the former period, breeding stock could be adversely affected by high Mn, while for the latter period growth rates of weaned lambs would be affected.

The study reported here was initiated to assess the concentration at which Mn induced changes in animal growth rates, and the pattern of these changes.

Methods
Trial site and design
The trial was located on a Woodlands silt loam (mottled firm brown soil; Hewitt 1998) at the Woodlands Research Station in Southland. Two groups of four paddocks with similar histories in terms of fertiliser application were selected for their evenness of size and pasture cover. Paddock sizes ranged from 1.10 to 1.18 ha in the first group and from 1.19 ha to 1.25 ha in the second. Each of the four paddocks was subdivided into four equal sub-paddocks by means of temporary netting fences with treatments allocated to the sub-paddocks using a randomised block design, modified so that no treatment was favoured by being near shelter or laneways. Treatments containing different pasture Mn concentrations (Mn treatments 1, 2, 3 and 4) were created by the spray application of 0, 2.5, 7.5 and 15 kg Mn/ha as manganese sulphate ($MnSO_4$) in 300 litres water/ha respectively. These rates were calculated from a small plot trial to give herbage concentrations ranging from the background level of 82-98 mg/kg DM to 800-1000 mg/kg DM. Manganese was initially applied to the appropriate sub-paddocks in the first group on 28 January 2005, 3 days prior to the animals being placed on the appropriate treatments. The Mn treatments were re-applied every 2 weeks to maintain the appropriate herbage Mn concentrations.

Mn was applied to the second group of paddocks on 11 February, again 3 days prior to the animals being

introduced. Following the Mn application on 10 March 2005, it was discovered that the Mn concentration in the herbage had not increased to the extent required. Hence the 7.5 and 15 kg/ha rates were re-applied on 11 March Following a 6 week grazing period of the second group of paddocks, Mn was reapplied to the first group of paddocks on 22 March, 2 days prior to the animals being re-introduced to that group of paddocks.

Animals and measurements

On 31 January 2005, 160 ram lambs (¾ Coopworth - ¼ Texel born September 2004) were weighed and randomly separated into 16 mobs of 10 animals per mob. The mobs were then randomly allocated and placed on to the 16 sub-paddocks of the grazing area. The animals were weighed every 2 weeks, and placed back in their appropriate paddocks, until the trial was completed.

Initial intentions were to set stock and graze each of the two groups of paddocks for 6 weeks. However due to the high pasture mass at the start of the trial (3900 kg DM/ha) and the rapid pasture growth experienced at that time causing pasture quality concerns, the animals were removed from the first group of paddocks after 2 weeks (= grazing period 1) and shifted to the identically randomised and treated paddocks in the second group where the pasture mass was less (2400 kg DM/ha) and the quality higher. Following a 6 week grazing period (grazing period 2) for the second group of paddocks, the animals were returned to the first group for the final 4 weeks of the experiment. This group of paddocks had been grazed with a mob of ewes following the first grazing period, so that pasture mass for the final grazing period (grazing period 3) was similar to that of the second group of paddocks (2600-2800 kg DM/ha).

To prevent the animals from grazing the $MnSO_4$ salt directly, all animals were removed from the trial area for 24 hours at each re-application of the Mn treatments and held in laneways. An exception was made for the re-application of the two high Mn rates on 11 March 2005 due to rain falling at the time and the fact that the animals had just been placed on these trial paddocks.

Prior to animals commencing the grazing of these areas, and weekly, while the animals were grazing, pasture samples were collected across a set transect of each sub-paddock. These samples were divided, with one half being dried at 65°C and analysed for Mn ($HNO_3/HClO_4$ digestion; ICP-OES determination, Boumans 1980) and Fe (Nitric perchloric digest; Martinie & Schilt 1976). The other half of the herbage samples was separated into grass, clover, weeds and dead material. Additionally, on several occasions immediately following treatment application, the herbage sample was sub-divided, with one sample from each paddock washed prior to drying, so as to measure the pasture uptake of the sprayed $MnSO_4$. The herbage samples collected from the first group of paddocks on 24 March were further subdivided with one portion separated into grass and clover for Mn analysis, while similar grass samples collected on 7 April were separated into leaf and stem prior to drying and analysing for Mn concentration.

Pasture mass was measured both pre grazing and at the completion of grazing across the same transect by means of a rising plate meter (Thomson *et al.* 2001).

Following the completion of the trial the animals were sent for slaughter, with liver samples collected from six randomly selected animals within each treatment. These samples were analysed via OPTIGRO trace element protocols for B_{12}, Se, Cu and Mn.

All procedures involving the experimental use of sheep were approved by the Crown Research Institutes' Animal Ethics Committee (Approval no. INV10415; Invermay, Mosgiel, New Zealand)

Statistical analysis

All statistical analysis was done by ANOVA within GenStat v 8.11. For the animal growth rates the block structure was given by mob, and treatment structure given by Mn level applied. To assess patterns of change over time, difference contrasts between post- and pre-treatment data were analysed by ANOVA as above.

Results

Herbage Mn concentrations

Initially there was a slight decline in herbage Mn concentrations for the first group of paddocks in the weeks between spraying (Fig. 1A). Base herbage Mn concentration averaged 82 mg/kg DM for both grazing periods 1 and 3, with the treated sub-paddocks averaging 234-354, 466-692 and 1006-1178 mg/kg DM for the three rates of Mn treatments (Fig. 1A). There was little increase in the Mn concentrations for the second group of paddocks until after the re-application of the two high Mn rates with a large increase occurring at these rates on 13 and 21 March (Fig. 1B). This increase meant that the average herbage Mn concentrations for this group were 98, 192, 499 and 912 mg/kg DM for the four treatments. Prior to the double application, the concentrations only averaged 97, 208, 271 and 466 mg/kg DM for treatments 1 to 4 respectively.

Washing the samples, collected following Mn application, significantly reduced the herbage Fe concentrations on two occasions but had no effect on the herbage Mn concentrations (Table 1). This indicates that at least 90% of the Mn had been absorbed into the plant during the 24 h that animals were removed following treatment reapplication.

There was no effect of botanical fraction on herbage

Figure 1 Herbage Mn concentrations over the duration of the trial for (A) area 1, grazing periods 1 and 3, (B) area 2 grazing period 2. ▲ indicates when $MnSO_4$ was applied. Bars are $LSD_{0.05}$.

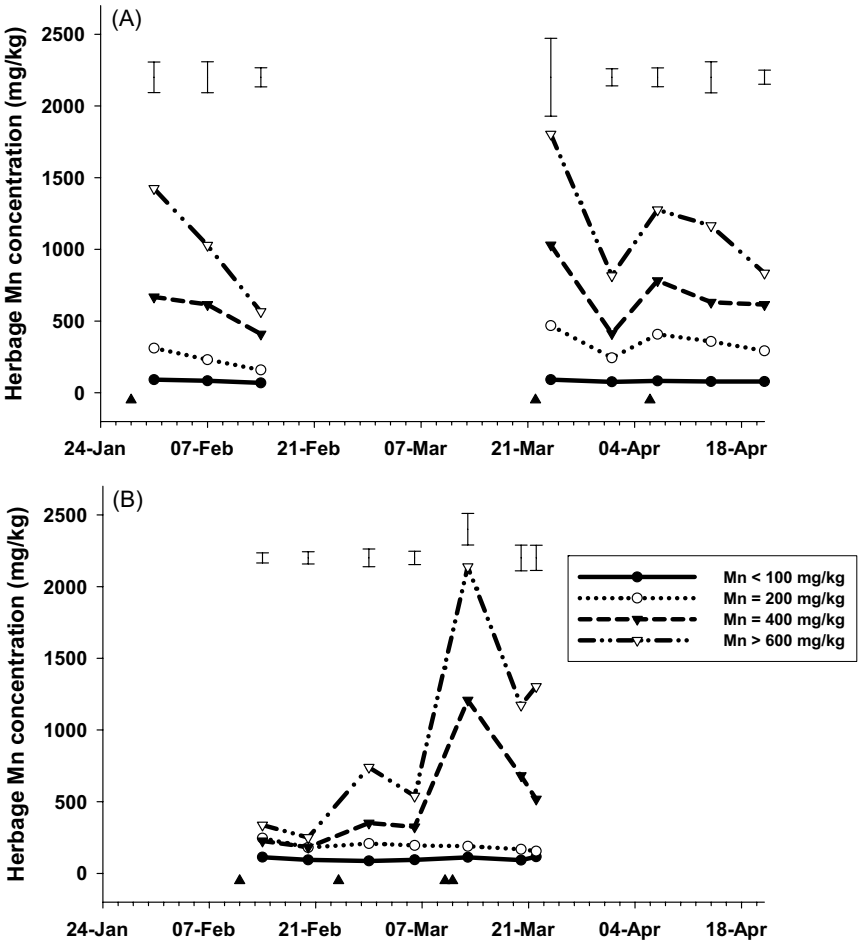

Table 1 Effect of washing on herbage Mn and Fe concentrations (mg/kg DM).

Date sampled	31 Jan		14 Feb		7 April	
Days since Mn application	3 days		3 days		1 day	
	Fe	Mn	Fe	Mn	Fe	Mn
Unwashed	126	624	137	231	182	637
Washed	82	545	122	227	112	642
$LSD_{0.05}$	13***	92^{NS}	24^{NS}	49^{NS}	22***	79^{NS}
Treat x Washing	NS	NS	NS	NS	NS	NS

Significance; NS = not significant, *** = P<0.001

Mn concentrations (Table 2) despite clover concentrations being lower in the control areas and higher in the treated areas. The grass leaves had significantly higher Mn concentrations than the green grass stems (P<0.001; Table 2).

Pasture botannical composition

The average clover content for the grazing periods was 17%, 15% and 4% for the three grazing periods respectively. The clover content of the pasture declined rapidly in the first grazing period from 34% initially to 10% 1 week later. For the second group of paddocks the clover content dropped from 25% initially to 18% after 1 week, and then declined by 2% per week. For the grazing period 3 the clover content was similar for the whole 4 week duration.

Table 2 Herbage Mn concentrations (mg/kg DM) at different rates of Mn application for grass and clover and for different components of grass.

	Rates of Mn applied (kg/ha)				Main effect
	0	0.25	7	15	
Species[1]					
Grass	88	433	995	1750	816
Clover	67	562	1218	2081	982
$LSD_{0.05}$	348^{NS}				174^{NS}
Treatment main effect	77	497	1106	1915	
$LSD_{0.05}$	246***				
Grass component[2]					
Stem (green)	83	161	310	377	233
Leaf	71	325	553	780	432
$LSD_{0.05}$	121**				61***
Treatment main effect	77	243	432	578	
$LSD_{0.05}$	86***				

Significance; NS = not significant, ** = P<0.01, *** = P<0.001
[1]Herbage sampled for species Mn analysis on 24 March, 2 days after application of Mn
[2]Grass components sampled for Mn analysis on 7 April, 16 days after application of Mn

Table 3 Daily animal growth rates for three grazing periods over the duration of the trial (g/day)

Rate of Mn (kg/ha)	Period 1		Period 2		Period 3	
	31 Jan - 14 Feb	14 Feb - 24 Feb	24-Feb - 10 Mar	10 Mar - 24 Mar	24 Mar - 6 Apr	6 Apr - 22 Apr
0	220	260	151	93	219	113
2.5	194	248	161	72	256	100
7	203	287	100	72	246	118
15	235	239	143	29	247	117
$LSD_{0.05}$	44^{NS}	66^{NS}	66^{NS}	32**	57^{NS}	43^{NS}

Significance NS = not significant; ** = P<0.01.

Pasture yield and animal intakes

Pre-grazing pasture mass averaged 3900, 2400 and 2700 kg DM/ha for the three grazing periods. These figures and the post-grazing pasture mass were used, together with the pasture growth rate, as measured at Woodlands Research Station using the moving cage technique (Radcliffe 1974), to calculate animal pasture intakes. These intakes were 2.0, 3.0 and 1.6 kg DM/animal/day for the grazing periods 1 - 3 respectively. Intakes were similar for all mobs of animals within each grazing period irrespective of Mn concentration (data not shown).

Animal liveweights

Animal growth rates were highest during the first 2 weeks the animals grazed the pastures and declined steadily for each 2 week period they remained on that group of paddocks (Table 3). For only one measurement period, 10 March to 24 March, were there significant differences in daily growth rates as a consequence of treatment (Table 3; P<0.01). It was only at the highest Mn concentration (>1200 mg/kg) in the herbage (Figure 1B; 12 – 24 March) that a significant drop in animal growth rate was measured. There was no difference between the other treatments measured.

Liver vitamin B_{12} and mineral concentrations

The concentrations of vitamin B_{12}, Se, Cu and Mn in the livers sampled were all within the ranges considered adequate for animal health and showed no significant effects of treatment (Table 4).

Discussion

High pasture Mn is known to cause decreases in animal growth rates (Cunningham *et al.* 1966; Grace 1973; Ivan & Hidiroglou 1980; Black *et al.* 1985a; Paynter 1987). However there is some debate as to the concentration at which this decrease occurs. Our study indicates that significant depressions in animal growth rates only occur at extremely high initial Mn concentrations (>2000 mg/kg DM) or where concentrations were above 1200 mg/kg DM for the full 2 week grazing period (Fig. 1B; 13 – 24 March). This threshold is somewhat higher than that reported by Grace (1973), but is similar to or lower than that reported by other workers (Cunningham *et al.* 1966; Ivan & Hidiroglou 1980; Black *et al.* 1985a; Paynter 1987). The differences in sheep growth rate responses to Mn intakes observed in the various trials (e.g. the high pasture Mn concentrations in this study cf. the study of Grace (1973)) is likely to be due to form of Mn in the

Table 4 Effect of herbage Mn treatment on liver vitamin B_{12}, Se Cu and Mn concentrations.

Mn rate (kg/ha) Adequate range[1]	Vitamin B12 (nmol/kg) >375	Se (nmol/kg) >450	Cu (µmol/kg) >95	Mn (µmol/kg) 37-81
0	543	2575	1840	38
2.5	510	3102	1720	40
7	642	2948	2572	38
15	578	2967	2005	46
$LSD_{0.05}$	183^{NS}	553^{NS}	772^{NS}	10^{NS}

Significance; NS = not significant
[1](Morton *et al.* 1999)

diet. This is in agreement with the findings of Paynter (1987) who suggested that method of Mn supplementation was the key factor, and that daily oral dosing with Mn was not equivalent to Mn supplied in feed. Grace (1973) also suggested that high levels of dietary Mn can reduce feed intake. While this has been observed in other studies, Black *et al.* (1985b) found that it was animals dosed by capsules that consumed less feed and not those where Mn was administered in the diet. There was no apparent change in feed intake due to Mn concentration in our study even with Mn concentrations up to 1500 mg/kg and hence we concur with this finding.

The period where we measured a significant decline in animal growth rates at the highest pasture Mn concentration, also coincided with the period of lowest animal growth for the whole duration of the trial (<100 g/day; Table 3). The likely reason for the drop in overall animal growth with time was a drop off in pasture availability and quality with length of time that animals were set stocked on the pasture. Hence the implication is that pasture quality had a greater influence on animal growth rates than Mn concentration in this situation.

In contrast to other studies (Black *et al.* 1985b; Grace 1973; Ivan & Hidiroglou 1980; Paynter 1987), we found no measurable effect of high Mn intake on liver Mn concentrations. This may be in part due to the form of Mn, as all the other studies had Mn supplemented as pellets or directly mixed in various forms to the feed, and not naturally absorbed in the feed as in this study. In addition, with the exception of Grace (1973) and Paynter (1987), Mn supplementation rates were considerably higher than those of this study.

These results show that on high quality pastures where herbage Mn concentrations tend to be relatively low (<250 mg/kg: AgResearch 1994), that herbage Mn is not a problem for grazing animals. Where these results may have implications, is in those areas, such as Central Otago, where pasture Mn can be high (>500 mg/kg). As this study indicated that pasture quality had a greater effect than Mn concentration, it is likely factors such as pasture quality could also be influencing animal performance in these areas, where these high Mn concentrations tend to coincide with poor quality browntop dominant pastures (Smith *et al.* 2004). The results of this study re-inforce the premise suggested earlier (Smith *et al.* 2004) that high pasture Mn could be less of a problem if pasture quality in these areas was improved.

ACKNOWLEDGEMENTS

We wish to thank Crystel Howden for collecting the pasture samples, Nigel Wood, Megan Collins and Roger Wheeler for the animal management and measurements and Roger Littlejohn for statistical advice. This work was funded by Ballance Agri-Nutrients.

REFERENCES

AgResearch 1994. Trace element status of Southland and South Otago sheep farms. A research report prepared for Southfert. 79 pp.

Black. J.R.; Ammerman, C.B.; Henry, P.R. 1985a. Effects of high dietary manganese as manganese oxide or manganese carbonate on sheep. *Journal of Animal Science 60*: 861-866.

Black. J.R.; Ammerman, C.B.; Henry, P.R. 1985b. Effect of quantity and route of administration of manganese monoxide on feed intake and serum manganese in ruminants. *Journal of Dairy Science 68*: 433-436.

Boumans, P. 1980. Line Coincidence for ICPAES Spectroscopy, (Volumes 1 and 2). Pergamon Press, Oxford, England.

Cunningham, G.N.; Wise, M.B.; Barrick, E.R. 1966. Effect of high dietary levels of manganese on the performance and blood constituents of calves. *Journal of Animal Science 25:* 532-538.

Grace, N.D. 1973. Effect of high dietary Mn levels on the growth rate and the level of mineral elements in the plasma and soft tissues of sheep. *New Zealand Journal of Agricultural Research 16*: 177-180.

Hewitt, A.E. 1998. New Zealand Soil Classification. – Landcare Research science series 1. Manaaki Whenua Press, Lincoln, Canterbury.

Ivan, M.; Hidiroglou, M. 1980. Effect of dietary

manganese on growth and manganese metabolism in sheep. *Journal of Dairy Science 63:* 385-390.

Martinie, G.D., Schilt, A.A. 1976. Investigation of the wet oxidation efficiencies of perchloric acid mixtures for various organic substances and the identities of residual matter. *Analytical Chemistry 48*: 70-74.

Metson, A.J.; Gibson, E. Janice; Hunt, J.L.; Saunders, W.M. H. 1979. Seasonal variations in chemical composition of pasture. III. Silicon, aluminium, iron, zinc, copper and manganese. *New Zealand Journal of Agricultural Research 22:* 309-318.

Morton, J.D.; Grace, N.D.; O'Connor, M.B. 1999. Use of trace elements in New Zealand pastoral farming. New Zealand Fertilisers Manufacturers' Research Association. Newmarket, Auckland.

Paynter D.I. 1987. Effects of high dietary manganese of body and wool growth in sheep. Pp. 390-392. *In*: Temperate pastures: their production, use and management. Eds Wheeler, J.L.; Pearson, C.J.; Robards, G.E.: C.S.I.R.O. Victoria. Australia.

Radcliffe, J.E. 1974. Seasonal distribution of pasture production in New Zealand I. Methods of measurement. *New Zealand Journal of Experimental Agriculture 2:* 337-340.

Smith, G. S.; Edmeades, D. C. 1983. Manganese status of New Zealand pastures. 2. Pasture concentrations. *New Zealand Journal of Agricultural Research 26:* 223-225.

Smith, L. C.; Trainor, K.D.; Catto, W.D. 2004. The use of lime to alleviate high pasture manganese in Central Otago. *Proceedings of the New Zealand Grassland Association 66:* 49-55.

Thomson, N.A.; Upsdell, M.P.; Hooper, R.; Henderson, H.V.; Blackwell, M.B.; McCallum, D.A.; Hainsworth, R.J.; MacDonald, K.A.; Wildermoth, D.D.; Bishop-Hurley, G.J.; Penno, J.W. 2001. Development and evaluation of a standardised means for estimating herbage mass of dairy pastures using a rising plate meter. *Proceedings of the New Zealand Grassland Association 63*: 149-157.