Effect of the rate of potassium chloride on dairy production in Taranaki

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Abstract
Potassium chloride (KCl) was applied at 4 rates (0, 150, 450 and 1150 kg/ha) to pasture on closed 5 ha farmlets over 3 years, and pasture and animal production and animal health measured. Friesan, Jersey and Friesan x Jersey cows were stocked at 3.2/ha on an Egmont Allophanic soil near Hawera in South Taranaki. Average soil potassium quick test (QTK) levels were 7, 8, 10 and 12 respectively from 0, 150, 450 and 1150 kg KCl/ha. There was a small significant negative linear effect of rate of KCl application on annual pasture dry matter (DM) production averaged over three years (16864 – 18359 kg/ha). The average amount of silage conserved (1369 – 2112 kg DM/ha) was consistently greater at the highest rate of KCl. Increasing rate of KCl had no significant effect on the nutritive value of grazed pasture but resulted in increased K content of silage. There was no significant effect of KCl on milksolids (MS) production (1034 –1179 kg/ha/lactation) or reproductive performance. There was a trend for the incidence of clinical metabolic disorders (8-18%) to decrease with increasing rate of KCl but this was not significant because of the low number of cows in each herd. The results from this trial suggest that soil QTK levels above the target range for optimal pasture production of 7-10 on Allophanic soils are not associated with increased dairy production and have no adverse effect on animal health.
Keywords: calcium, dairy cows, hypocalcaemia, hypomagnesaemia, magnesium, milksolids, pasture, potassium, potassium chloride

Introduction
Some 40% of the dairying in the North Island of New Zealand is carried out on Allophanic (volcanic ash) soils in the Taranaki and Waikato regions (LIC 2003). Potassium required for pasture growth is supplied in only small amounts by Allophanic soils and needs to be applied in fertiliser. Plant-available K in the soil is measured in NZ by a quick test that uses ammonium acetate as the extractant. The soil QTK has been calibrated with pasture production from a number of mowing trials on ash soils that show near maximum yield occurring within the target range 6-8 (Roberts & Morton 1999). Because K is recycled differently in mowing compared with grazing trials, it was considered worthwhile to verify this by measuring responses in pasture and MS production to soil QTK levels above the target range.

Reports from veterinarians in South Taranaki implicated the use of KCl together with di-ammonium phosphate (DAP) before calving in increases in the incidence of hypocalcaemia (e.g. Dairy Exporter, January 1996). The K status of soils, pastures and animals can affect the availability of calcium (Ca), magnesium (Mg) and sodium (Na). Morton *et al.* (2004) reported a greater amount of leached Ca and Na from increasing rate of KCl application at this site. The effect of KCl application on the pasture uptake of cations has ranged from large depressive effects (McNaught 1959 – Mg 53%, Ca 43%) to small effects, either at this site (Morton *et al.* 2004) and on sedimentary soils (Morton *et al*. 2000). Goff & Horst (1997) reported that increasing K content in the pre-calving diet from 1.1 to 2.1 or 3.1% increased the incidence of milk fever from 10% to 50% or 48% and that all cows could be classified as sub-clinically hypocalcaemic at some time within the first day after calving. Sub-clinical hypocalcaemia can result in decreased cow appetite, feed intake and milk production, and also cow reproductive performance (Stevenson *et al.* 1999). High K diets have also been reported to interfere with the ruminal absorption of Mg (Martens & Rayssiguier 1980), which can be a major source of hypomagnesaemia. Hypomagnesaemia can affect parathyroid hormone secretion that controls the mobilisation of Ca from bone and hence cause hypocalcaemia at calving (Fontenot *et al.* 1989). The association between rate of KCl application and the incidence of metabolic disorders was investigated in the three-year grazing trial reported in this paper.

Materials and methods
Site
The trial was sited on an Egmont ash (Allophanic) soil on the Whareroa Research Farm near Hawera in South Taranaki.

Trial design and treatments
A flat to undulating area was fenced into forty 0.5 ha paddocks and soil QTK to 7.5 cm measured in each paddock. The treatments were then allocated to each of ten paddocks/farmlet so that the initial mean QTK level was similar (Table 1). The treatments were:

K0 0 KCl
K1 150 kg KCl/ha applied in April 2000
K3 450 kg KCl/ha applied in April 2000 (300 kg/ha) and April 2001 (150 kg /ha)
K4 1150 kg KCl/ha applied in April 2000 (450 kg/ha), April 2001 (300 kg/ha), August 2002 (200 kg/ha) and October 2002 (200 kg/ha)

High rates of KCl were applied to K2 and K3 to achieve a wide range of soil QTK levels.

Management

The 10 paddocks in each farmlet were rotationally grazed by 3.2 Friesan, Jersey and Friesian x Jersey cows/ ha (16 per farmlet) with a 30-day grazing interval from August to April and a 100-day grazing interval for the remainder of the year. The pasture sward consisted on average of approximately 65% perennial ryegrass (*Lolium perenne*), 30% other grasses including cocksfoot (*Dactylis glomerata*), Yorkshire fog (*Holcus lanatus*) and some *Poa* species, 2.5% white clover (*Trifolium repens*) and 2.5% weeds on a DM basis. Pre-grazing pasture mass averaged 3900 kg DM/ha and post-grazing pasture mass averaged 1850 kg DM/ha across all farmlets. When post-grazing pasture mass exceeded that level, the paddock was removed from grazing and harvested for silage. Pasture silage conserved on each farmlet at 3 kg DM/cow was fed to the cows during winter and calving (until mid-August in 2000 and 2001 and late-August in 2002).

Causmag (magnesium oxide) was dusted daily on to pastures at 85 g/cow/day from early-July (pre-calving) to the end of October in 2000 and 2002. In 2001, as part of another trial, each cow was drenched with magnesium oxide (MgO), chloride or sulphate at 20 g Mg /cow/day (balanced between K treatments) from early-July until calving (mid-July) with pasture dusted with MgO from calving until the end of October as in the other two years. Superphosphate to supply 59 kg phosphorus/ha and 72 kg sulphur/ha was applied in November of each year. Urea to supply 80 kg nitrogen (N)/ha in 2001/2002 and 197 kg N/ha in 2000/2001 and 2002/2003 was applied in single applications of 22-60 kg N/ha from July to April.

Measurements

Soil

In May of each year, 15 soil cores to 7.5 cm depth were sampled (excluding visible excreta patches as per the sampling protocol for commercial dairy farms) from each paddock and analysed for QTK, Mg, Ca and Na using an ammonium acetate extraction.

Pasture

Pasture DM production was determined in each paddock by weekly visual assessment of pasture mass in grazed and silage paddocks during the lactation and two-weekly assessment during non-lactation. This assessment was corrected using calibration cuts from ten 0.1 m^2 quadrats of pasture in grazed and silage paddocks trimmed to ground level, and a sub-sample dried for 12 hours at 90°C.

The nutritive value of pasture was assessed by NIRS from monthly measurements of metabolisable energy (ME), organic matter digestibility (OMD), crude protein (CP) and acid detergent fibre (ADF) from October to December. The cation content of pasture in each paddock was also measured before being cut for silage.

Animal

During and after calving in each year, the number of cows in each group that showed the behavioural symptoms of clinical hypocalcaemia and hypomagnesaemia and received treatment using a precautionary approach, were recorded. Reproductive performance was also monitored through the recording of critical measures such as submission rate, pregnancy rate and total number of matings/cow. Milksolids production for each cow was measured twice-weekly during each lactation.

Statistical analysis

Data was analysed for linear treatment effects by ANOVA using GENSTAT.

Results

Soil

There was a significant effect of rate of KCl on soil QTK levels ($P<0.01$) in all years (Table 1). The lower QTK levels in 2002 were consistent with soil test results from the remainder of the farm and could not be readily explained.

Pasture

Pasture production

Averaged over all three years, there was a significant negative linear effect ($P < 0.05$) of rate of KCl on total pasture production (Table 2). For silage production there was a significant linear increase with increasing rate of KCl but the most consistent effect was the greater silage production from the highest rate of KCl.

Nutritive value of grazed pasture

There was no significant effect ($P<0.05$) of rate of KCl on ME (10.3-10.6 MJ/kg DM), OMD (73.9-76.6%), CP (19.8-25.0%) and ADF (26.9-29.0%).

Silage mineral content

There was a significant effect ($P<0.05$) of KCl on the K content (2.72-4.04%) of silage but no significant effect

Table 1 Effect of rate of KCl on soil QTK levels.

Year	K0	K1	K2	K3	SED	P value Linear K trend
2000	7.4	6.6	6.8	7.3		
2001	7.3	9.2	13.6	18.5	1.67	<0.001
2002	5.5	7.8	8.1	8.5	1.46	0.001
2003	7.3	8.6	10.5	15.4	2.00	0.0019

Table 2 Effect of rate of KCl on total pasture (including silage) and silage DM production (kg/ha).

Year	K0	K1	K2	K3	SED	P value Linear K trend
2000/2001						
Pasture	17118	15803	14671	16017	2803	0.317
Silage	1280	1763	1638	2141		0.382
2001/2002						
Pasture	21113	20803	19388	19904	2555	0.214
Silage	1309	1718	1354	1910		0.360
2002/2003						
Pasture	18359	16026	16533	15991	2161	0.340
Silage	1123	1472	1472	2077		0.068
Average of 3 years						
Pasture	18863	17544	16864	17304	718.2	0.024
Silage	1369	1734	1503	2112	120.4	0.002

Table 3 Effect of rate of KCl on the percentage of cows treated for clinical metabolic disorders (average of 3 years).

Year	K0	K1	K2	K3	SED	P value Treatment effect
Hypocalcaemia	12	14	8	8	6.5	0.756
Hypomagnesaemia	6	2	2	0	3.1	0.316
Total	18	16	10	8	5.6	0.317

Table 4 Effect of rate of KCl on MS production (kg/ha) in each lactation.

Lactation	K0	K1	K2	K3	SED	P value Linear K trend
2000/2001	1158	1110	1034	1120	68.3	0.538
2001/2002	1157	1119	1096	1122	74.7	0.345
2002/2003	1120	1179	1107	1154	56.1	0.887

on other plant cations (results not shown).

Animal

Incidence of metabolic disorders

The incidence of clinical hypocalcaemia and hypomagnesaemia in each farmlet herd decreased with increasing rate of KCl (Table 3). However, the small number of cows in each farmlet herd reduced the possibility of significant effects.

Milksolids production

There was no significant effect of KCl (P<0.05) measured on MS production/ha (Table 4).

Cow reproduction

Six week submission and final pregnancy rate (88–100%) and total number of matings/cow (1.30–1.89) were not significantly affected by rate of KCl (P<0.05). It is recognised that it is difficult to detect significant effects on reproductive performance unless cow numbers/group are much greater than were present in this trial.

Discussion

There have been no previous trials where results have been reported on pasture and milk production responses to K fertiliser under dairying in NZ. Although this trial was set up primarily to measure the effect of soil and pasture K status on the incidence of metabolic disorders and the effect of rate of K fertiliser on the major cations in soil, pasture and leachate (Morton *et al*. 2004), it also provided some useful information on production responses to K.

The target soil QTK test for near-maximum pasture production on Allophanic (ash) soils were determined from several small plot mowing trials to be in the range 7-10 (Roberts & Morton 1999). Since there was no increase in pasture and MS production in the farmlets where increasing rates of KCl increased soil QTK levels above the target range, this range of 7-10 was verified from these results. The maintenance of soil QTK levels for three years where no fertiliser K was applied suggested either that K cycling through urine from high stocking densities in small paddocks was very efficient or that K was supplied to the pasture from non-exchangeable pools in the soil.

The increase in silage DM production at the highest rate of KCl and soil QTK level was not expected since the K content of the pasture in the silage paddocks was within or above the optimum range for vegetative growth (2.5-3.0% – Roberts & Morton 1999). Visually assessed clover content was low (7%) in all pastures (results not shown) so the greater response to K could not be attributed to more K-responsive clover in the silage paddocks. An effect of high pasture K content (> 3.4%) reducing cow grazing preference for pasture in South Taranaki was measured in the late spring of 2000 and 2001 but no effect of K content on pasture intake was measured in 2002 (Morton *et al*. 2005). In 2001 and 2002, the measurements were carried out on this site. Therefore any possible indirect effect of cows rejecting pasture resulting in more being surplus and shut up for silage can probably be discounted.

In this trial, increasing rate of KCl only had a small depressive effect on pasture Ca and Mg contents (Morton *et al*. 2004), so there should have been no effect of K on Ca and Mg intake by cows from pasture. At calving in July, pasture Ca contents in each farmlet averaged 0.40% and pasture Mg contents averaged 0.23% (Morton *et al*. 2004). These levels were below the pasture Ca content of 0.60% and pasture Mg content of 0.28-0.35% required to avoid metabolic disorders in cows grazed outdoors and producing 1.75 kg MS/day or more (Roche pers. comm.). This would have contributed to the recorded incidences of clinical hypocalcaemia and hypomagnesaemia.

Pasture Ca content alone is not an accurate indicator of adequacy of Ca supply to the cow because Ca demand from the blood at calving and the start of lactation is so high that it relies on the withdrawal of Ca from bone or by increasing the efficient absorption of dietary Ca (Fontenot *et al*. 1989). Blood plasma Ca concentrations at calving in 2000 and the day following calving were unaffected by pasture K contents but significantly increased linearly 2 days post-calving with increasing dietary K intake (Roche *et al*. 2002). At this stage, approximately 3% of cows had plasma Ca concentrations <1.4 mmol/l indicating clinical hypocalcaemia (Roche *et al*. 2002) which was lower than the 8% of cows that were treated for hypocalcaemia in 2000. The incidence of sub-clinical hypocalcaemia (plasma Ca <2 mmol/l – Thilsing-Hansen & Jorgenson 2001) was 40% with no measured effect of KCl (Roche *et al*. 2002).

Although pasture K contents were higher in our trial (3.5-4.5%) than the highest K content of the feed (3.1%) offered by Goff & Horst (1997), the incidence of hypocalcaemia, as indicated by plasma Ca concentrations, was much lower (Roche *et al*. 2002). This difference in the effect of K on the incidence of hypocalcaemia was attributed by Roche *et al*. (2002) to be partly due to the use of more susceptible older Jersey cows by Goff & Horst (1997). Plasma concentrations of Mg on the day of calving or the two days post-calving in the reported trial (0.58 – 0.73 mmol/l) were not affected by dietary K content (Roche *et al*. 2002).

Conclusions

At this trial site, the hypothesis that high application rates of KCl are associated with an increase in the incidence of metabolic disorders in dairy cows, was not proven. The target range of soil QTK levels for near-maximum pasture production on Allophanic soils was confirmed as being in the range 7-10.

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