

# LIME AND DAIRY PRODUCTION

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## *Abstract*

In a four year grazing trial with dairy cows the application of 5000 kg lime/ ha (applied in two applications of 2500 kg/ha in winter of the first two years) significantly increased annual pasture production in two of the four years and dairy production in one year. In three of the four years lime significantly increased pasture growth over summer/autumn with concurrent increases in milk production. In the last year of the trial lime had little effect on pasture growth but a relatively large increase in milkfat production resulted.

A higher incidence of grass staggers was recorded on the limed farmlets in spring for each of the four years. In the second spring immediately following the second application of lime significant depressions in both pasture and plasma magnesium levels were recorded. By the third spring differences in plasma magnesium levels were negligible but small depressions in herbage magnesium resulting from lime continued to the end of the trial.

Lime significantly raised soil pH, Ca and Mg levels but had no effect on either soil K or P. As pH levels of the unlimed paddocks were low (5.2-5.4) in each autumn and soil moisture levels were increased by liming, these factors may suggest possible causes for the seasonality of the pasture response to lime.

## INTRODUCTION

From 1935 to 1970 more than 40 lime trials have been conducted on small plots in Taranaki and in no trial was a lime response recorded. However, in the late 1960's and early 1970's there was increasing interest by local farmers in the use of lime for the following reasons:

— deeper rooting pastures resulting in better drought tolerance and reduced pasture "pull" during grazing.

— improved soil structure and earthworm activity.

— improved stock health.

Observations trials laid down by farmers and advisers during the early 1970's showed fleeting responses to lime. Also a trial reported by McGilvary (1972) on the Inglewood soils at 670m altitude showed very marked lime responses throughout the year and the farmer on whose land the trial was situated reported a considerable increase in milkfat production following the application of 2500 kg lime/ ha.

Stimulated by farmer interest, lime trials were laid down on a rainfall sequence on the Stratford soils and increasingly consistent responses to lime were recorded in summer/autumn as rainfall and altitude increased. The greatest response (20%) was recorded at the highest rainfall site (3000 mm). A further series of trials (nine in all) encircling Mt Egmont above the 2000 mm isohyet, failed to show any responsive soils other than those previously

identified; the Inglewood and the Stratford soils at the higher altitude.

As the result, a grazing trial was laid down on the Stratford Demonstration Farm (Stratford sandy loam, altitude 350 m a.s.l., rainfall 2000mm) to determine whether the seasonal lime responses could be turned to an economic advantage in dairy production.

#### EXPERIMENTAL

A farmlet scale grazing trial comparing production of dairy cows grazing limed and unlimed pastures at two stocking rates (3.3 and 4.0 cows/ ha), was carried out over a four year period from 1972-76.

Lime was applied in two applications of 2500 kg/ ha each during winter 1972 and 1973. The objective was to raise the soil pH to 6.0 or slightly above, which was achieved with the second application.

Each farmlet comprised 12 paddocks which had been randomly allocated within blocks throughout the farm according to the variations in the following soils; Stratford hill soil, Stratford sandy loam, Stratford mottled sandy loam. Seven paddocks in each farmlet were used to monitor pasture growth, pasture chemical and botanical composition, soil quick test and soil moisture levels.

Pasture growth was measured continuously using paired cages and the rate of growth technique (Lynch, 1966) with cuts being made at three weekly intervals over the lactation period and six weekly intervals over the slower growing winter period. Soil samples for quick test (0-7.5 cm depth) were taken on a six monthly basis and for soil moisture determinations (0-10cm depth) in summer 1974 and monthly during spring, summer and autumn 1975.

Pasture samples for herbage dissection into ryegrass (*Lolium* spp), browntop (*Agrostis tenuis*), other grasses, white clover (*Trifolium repens*) and weeds were taken from within the pasture cages seasonally for the duration of the trial. In addition, pasture samples were collected on a paddock basis at monthly intervals over 18 months during 1973 and 1974 for chemical analysis of major elements. On the same day blood samples were taken from cows to determine plasma magnesium concentrations.

Milk yield and fat production was recorded monthly for each cow using the Livestock Improvement Association's Herd Testing scheme.

#### RESULTS

##### ANIMAL PERFORMANCE:

(1) Milkfat Production — (Table 1) An increase in stocking rate from 3.3 to 4.0 cows/ ha (21%) caused a reasonably consistent depression in individual cow production of 21 kg fat/cow (6%) but production per hectare was increased by 28 kg (5%). Lime increased milkfat yield in each of the four years but it was only in 1973/74 that the increase was significant ( $P < 0.05$ ).

The average increase due to lime was 9 kg fat/cow (%) and there was no indication of a lime  $\times$  stocking rate interaction. The addition of both stocking rate and lime increased the average annual production by 59 kg fat/ ha (12%).

TABLE 1: TOTAL ANNUAL MILKFAT PRODUCTION (kg/ha)

Year	Kg fat/ ha		Gain to S.R. (kg)	
	Low Stocked	High Stocked		
1972/73	No Lime	446	504	+45
	Lime	472	504	
	Gain to Lime (kg)	+13		
1973/ 74	No Lime	531	552	+20
	Lime	580	600	
	Gain to Lime (kg)	+48		
1974/ 75	No Lime	535	556	+9
	Lime	574	572	
	Gain to Lime (kg)	+27		
1975/76	No Lime	482	492	+37
	Lime	492	556	
	Gain to Lime (kg)	+32		

*Main Effects:*

S.R. +28 kg fat/ha

Lime +31 kg fat/ ha

Lime had no effect on the fat content of milk and the increase in milkfat production was due entirely to an increase in milk yield. The proportional increase in milk yield on a monthly basis as presented in Fig. 1 shows that for the first three years the major effect of lime on milk yield occurred during summer and autumn. In 1975/76 the response pattern differed from the previous years with a greater proportion of the lime response occurring over spring and early summer.

(2) Stock Health — An unexpected outbreak of metabolic diseases occurred in the first spring. Grass staggers predominated and a higher incidence of staggers occurred on the limed treatments (Table 2).

Despite the use of magnesium licks in the following two seasons, and pasture dusting with calcined magnesite in the last season, grass staggers continued to be a major problem, with a higher incidence on the limed than unlimed pasture.

TABLE 2: THE INCIDENCE OF GRASS STAGGERS AND MILK FEVER RECORDED ON THE LIMED AND UNLIMED FARMLETS (No. of Cows affected)

Season	Grass staggers		Milk fever	
	No Lime	Lime	No Lime	Lime
1972/73	5 (1)	14 (6)	3	6
1973/74	2	10	15	17
1974/75	10	12	6	6
1975/76	3 (1)	8 (1)	<i>no record</i>	
Average	5	11	8	10

( ) cows that died with cause of death positively identified as grass staggers.

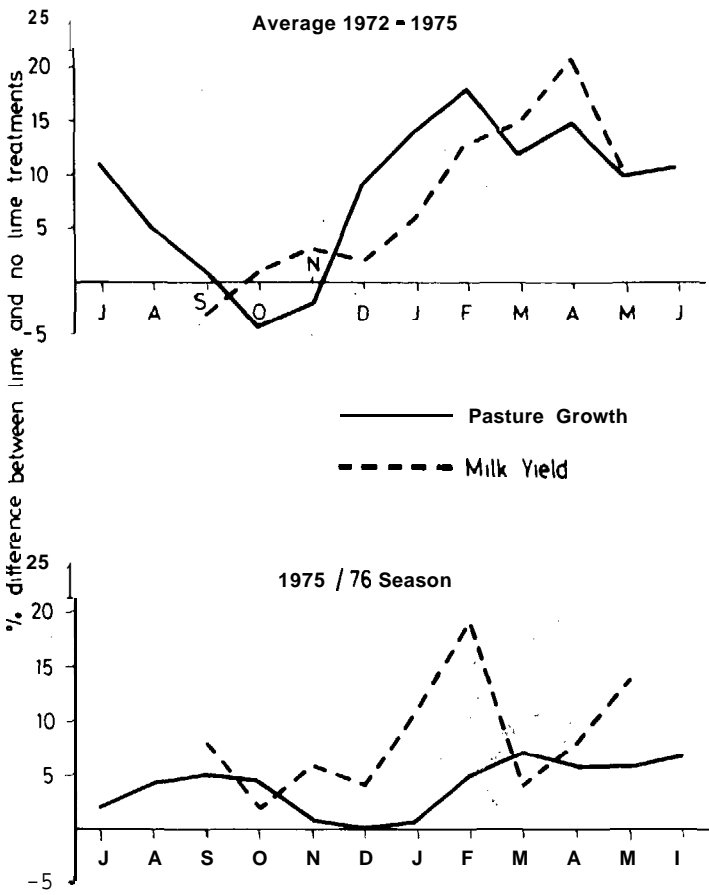


FIG. 1: *The relative effects of lime on seasonal and annual pasture growth and animal performance.*

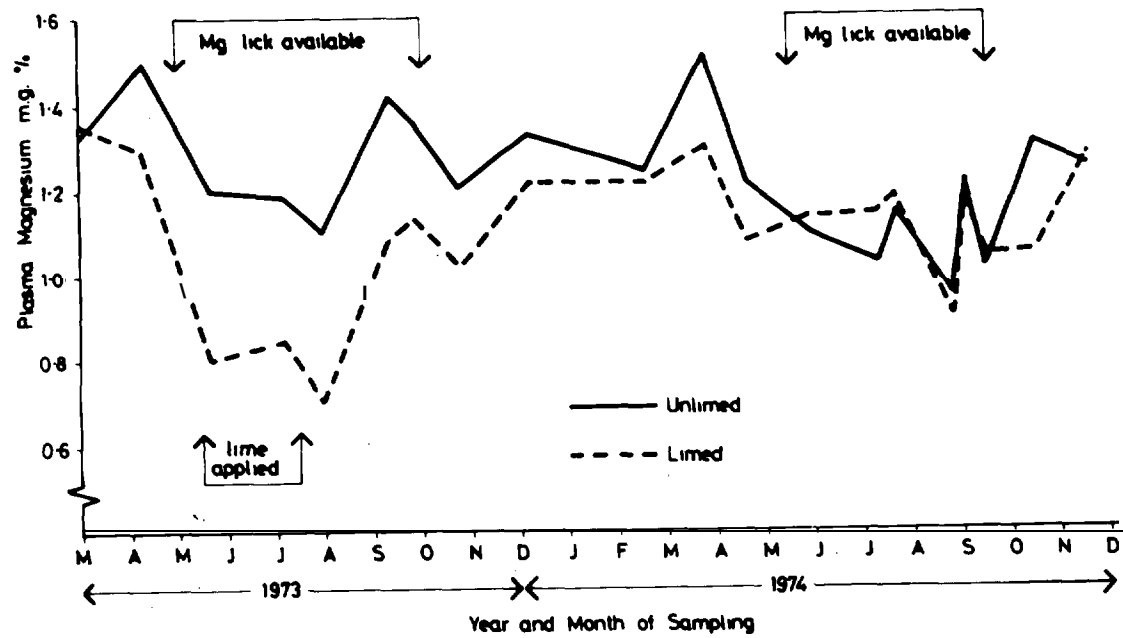


FIG. 2: Influence of lime on plasma magnesium levels.

The high incidence of grass staggers in the first spring brought about the initiation of a monitoring programme in March 1973 to measure the magnesium content of both pasture and plasma. Plasma magnesium levels were significantly depressed in cows grazing limed pastures over winter and spring in 1973 (Fig. 2), but over the next 12 months the levels in the two groups came close together and the sampling programme was terminated in December 1974 when no differences between the two groups had been recorded in four months. The effect of lime on the magnesium content of pasture was not as marked as that on plasma magnesium but in samples taken in September 1973 and in March and September 1974 significant depressions were recorded. Over the later part of the sampling period, July to December 1974, pastures were separated into grasses and clovers for chemical analysis. Significant depressions in magnesium content were recorded in both species on occasions and overall lime depressed the magnesium content of clovers by 10% and grasses by 4%.

The other major effects of lime on herbage chemical levels recorded (Table 3) throughout the trial were an increase in calcium (22%), a small increase in sodium, a depression in zinc (9%), and a large increase in molybdenum (60%).

TABLE 3: THE EFFECT OF LIME ON THE CHEMICAL COMPOSITION OF MIXED PASTURE (AVERAGE OF 12 MONTHLY SAMPLINGS)

Treatment	Element present						p.p.m.		
	N	P	Mg %	Ca	Na	K	Zn	Cu	Mo
No Lime	4.4	4.3	0.197	0.56	0.15	3.6	44	12	0.9
Lime	4.3	4.2	0.191	0.69	0.16	3.5	40	12	1.4
	NS	NS	NS	*	NS	NS	*	NS	**

Significance levels \*p < 0.05      \*\*p < 0.01

Regression analyses of the major elements present in pasture and the ratios of these elements (K/ Ca + Mg) and (K + Ca + P)/ (Mg + Na) against plasma magnesium concentrations, showed no single factor to have a significant effect, but the ratio (K + Ca + P)/(Mg + Na) showed overall a negative correlation ( $r = -0.413$ ) that approached significance at the 5% level. When examined for treatment effects the ratio was found to have a more marked effect on plasma magnesium levels for the limed ( $r = -0.530$ ) than the unlimed ( $r = -0.280$ ) treatment.

#### PASTURE PRODUCTION

Over the four years lime increased the average annual DM production by 6%, due mainly to the significant effect of lime on pasture production in the 1973/74 (+10%) and 1974/75 (+12%) years (Table 4). In the other two years lime had no effect.

TABLE 4: ANNUAL DM PRODUCTION RECORDED OVER FOUR YEARS ON UNLIMED AND LIMED PASTURE (kg DM/ha).

Season	No Lime	Lime	Increase	Significance
1972/73	10 460	10 620	160	NS
1973/74	10 230	11 230	1 000	**
1974/75	11 310	12 680	1 370	*
1975/76	15 330	15 730	400	NS
Average	11 830	12 570	740	(+ 6%)

Significance levels \* P < 0.05      \*\* P < 0.01

The pasture response to lime occurred mainly over the summer/autumn period (Fig. 1) with no response in spring and small but significant increases in winter. In the first season after the application of the first 2500 kg lime/ ha, a significant response (P < 0.01) to lime was recorded in autumn.

Regression analysis showed a positive correlation (r = 0.612\*) between the lime response in pasture and in milk production (Fig. 1). This relationship however did not hold in the 1975/76 season (r = 0.219 n.s.) when a large proportion of the total increase in animal performance occurred in spring when lime had little effect on pasture growth.

Rainfall also differed over the trial period. For the first three years the summer rainfall of 245 mm was 45% below the 30 year average of 447 mm and the summers in these years were considered by local farmers as "dry". In summer of the 1975/76 season when no pasture response to lime was recorded, 500 mm of rain fell.

Over the duration of the trial no differences in the botanical composition between limed and unlimed pastures could be detected.

TABLE 5: THE EFFECT OF LIME ON THE SOIL QUICK TEST RESULTS

		pre-trial	April 1973	August 1974	August 1976
pH	No Lime	5.54	5.24	5.69	5.76
	Lime	5.58	5.59**	6.24**	6.24**
Ca	No Lime	4.1	3.7	4.3	4.5
	Lime	4.2	6.7**	10.5**	10.3**
K	No Lime	5.2	10.4	7.2	5.6
	Lime	5.5	9.8	7.6	6.4
Truog P	No Lime	12.4	12.0	14.6	12.7 (23.9)
	Lime	12.0	14.3	16.8	15.0 (23.1)
Mg	No Lime	11.6	9.9	9.9	12.3
	Lime	12.4	12.2**	11.4*	14.3**

Significance levels \* P < 0.05

\*\* P < 0.01

( ) Olsen P test figures.

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## SOILS:

(1) Quick Test — In all of the soil samples collected, lime significantly increased both the pH and calcium levels (Table 5), but had no effect on soil potassium. The Truog phosphate test was significantly increased at one sampling in winter 1976, but an Olsen phosphate test failed to show any difference between the limed and unlimed soils.

Soil magnesium levels were increased following the application of lime and although the effect was relatively small it was consistent throughout the trial.

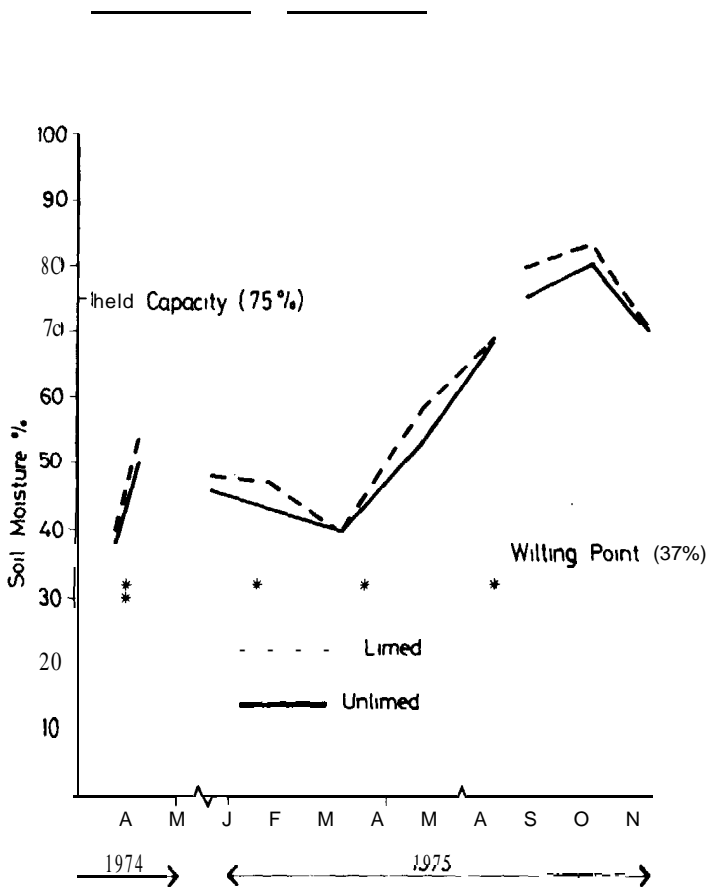
(2) Soil Moisture — Because lime increased pasture growth over the summer/ autumn period in years when summer rainfall was below average a study was initiated over the latter part of the trial to investigate the soil moisture status between the lime treatments (Fig. 3). Lime did not have a consistent effect on soil moisture but in four of the 10 samplings the soil moisture of the limed treatment was significantly higher than for unlimed soil. Over the 10 samplings the limed soil had an average moisture level 2.5% units higher than unlimed soil.

## DISCUSSION

The average production from herds tested in the Stratford area over the trial period was 149 kg fat/cow at an average stocking rate of about 2.3 cows/ ha (N.Z. Dairy Board, New Plymouth). This level of fat production was similar to the average 151 kg fat/cow achieved over the four years by the low stocked herd but at a stocking rate very much higher than district average, (3.3 cows/ ha). On a per hectare basis, the average production for the district was 343 kg fat/ ha Whilst that for the low stocked herd was 498 kg fat/ ha, 45% higher than the district average. Lifting the stocking rate to 4.0 cows/ ha or the addition of 5000 kg lime/ ha further increased production by 6%. In total, this resulted in a production from the high stocking — lime herd which was 62% above the average for the district.

The response in milkfat production resulting from the application of lime may have been restricted due to the higher incidence of hypomagnesaemia on the limed treatments. Young & Rys (1978) reported that herds with plasma magnesium levels lower than 1.5 mg % will have depressed production and will respond in terms of increased milkfat to magnesium supplementation. The data presented in Fig. 2 shows that cows on both limed and unlimed pasture were in a hypomagneseamic condition and the application of lime further aggravated the problem. Thus potential production may have been restricted especially for those cows on the lime treatments and may account for the lower production recorded from this group over early spring in the first three years of the trial. In the fourth season the results contradict this hypothesis as more than 50% of the total animal response to lime occurred in spring despite a continued high incidence of grass staggers in the lime treatments.

The association between liming and increased incidence of grass staggers' (Table 2) did not fully relate to the small depression of herbage magnesium



Significance Levels      \*  $p < 0.05$   
                                   \*  $p < 0.01$

FIG. 3: The moisture levels (gravimetric) in limed and unlimed soils at a 0-10 cm depth

due to liming (Table 3). Regression analysis on the blood and pasture chemical data failed to highlight any single major cause of the problem. However there was an indication that the ratio of the elements in pasture which are antagonistic to Mg absorption by animals (K + Ca + P) to those which enhance absorption (Mg + Na) (Butler, 1963) may relate to the depression of plasma magnesium. Of the antagonistic elements calcium was significantly increased with liming and may have been a major factor affecting hypomagnesaemia.

The significant increase in annual DM yields due to lime occurred mainly over the drier months of summer and autumn with parallel responses in milk yields (Fig. 1). This suggests that over the first three years the increase in

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milkfat production from lime was due almost entirely to an increase in pasture growth. However in the 1975/76 season this relationship did not hold as a relatively large increase in milk yield resulted from little increase in pasture growth indicating that factors other than DM yield may also be involved in determining the level of animal response from limed pasture.

The reason for the increased DM production from the application of lime can not be readily explained. From herbage chemical data and the results of subsequent lime x molybdenum trials on Stratford soil (Rys, pers. comm), it may be assumed that the correction of a molybdenum deficiency through liming was not the cause of the response.

For the duration of the trial, the pH of the unlimed soil in autumn was low (5.2-5.4) and at such low pH values an increasing soil pH through liming may give an increase in pasture growth (Edmeads *et al.*, 1979). The application of lime raised the soil pH by 0.5-0.6 units and this in itself may have been the factor causing the lime response, especially over the drier summer/autumn periods when pH levels of the unlimed soil may have been too low for optimum growth.

Liming increased soil calcium and magnesium levels (Table 5) but both were of sufficient concentration in the unlimed soil not to restrict plant growth. The increase in soil magnesium levels may reflect the reduced plant uptake (Fig. 2) caused by the antagonistic effect of high levels of calcium in the limed soil (Turner *et al.*, 1978) and not the result of lime increasing the availability of magnesium. A higher Trough phosphate level for the limed soils may not necessarily indicate an increase in plant available phosphate but may rather be an anomalous result caused by the Trough method (Grigg, 1965) and the lack of any difference in the Olsen test would suggest that in these soils the availability of phosphate was unaffected by liming.

Apart from the pH effect, increases in soil moisture levels appear to be the only other factor offering an explanation of the seasonality of lime responses on these soils. Two mechanisms have been suggested, an increase in either the water holding capacity of the soil, and/ or the "wettability" of soils. Whether, either one or both the above mechanisms were operating was not determined, but would warrant further investigation.

#### SUMMARY

- (1) The application of 5 tonnes/ ha of lime resulted over four years in a total increase in milkfat production of 124 kg/ ha or 1 kg fat for 40 kg lime.
- (2) Because of the variability of climate and response patterns in both pasture growth and milk production between years, it can not positively be concluded that the effect of lime on dairy production was entirely due to increases in pasture growth.
- (3) A higher incidence of grass staggers was recorded on the limed treatments which was attributed to the antagonistic effects of high herbage calcium levels on magnesium absorption by the cows. This may have depressed milkfat production in spring and reduced the potential production possible from liming.

(4) The responsiveness of pastures to lime over the drier summer/autumn period was considered to be due partly to an effect on soil pH and an effect on soil moisture.

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