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THE USE OF LIME! IN NEW ZEALAND PASTURES.

- by . -

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Introduction:

In this paper the word "lime" is restricted in its application to burnt lime, slaked lime and ground limestone and does not include other calcium compounds, such as phosphate or nitrate, which are applied on account of a direct manurial value. Further, any reference to the beneficial action of liming is made on the assumption that its use coincides or is followed by applications of phosphate and at the outset it should be emphasised that the use of lime without phosphate is not 'generally advocated.

The Extent of Liming:

The use of lime in New Zealand is increasing rapidly and the total quantity transported by rail last season for agricultural purposes was approximately double that carried in 1927/28.

The extent'to which lime is used in relation to the grassland area topdressed and the approximate quantities used'per acre in the various land districts of the Dominion. are shown in the following table:-

TABLE I: Grassland areas topdressed and limed and Quantities of Lime (estimated) used in various Land Districts (average of 2 seasons 1933-35).

Land District	Total area topdressed with fertilisers and/or Lime. Acres. ±	Total Area Limed. Acres. ±	Percentage of topdressed area limed. %	Deliveries of Lime Tons. **	Lime applied Cwt. per acre.,
Bth. 'Auckland	424,548	118,505	27.9	24,963	4
Auckland	906,620	338,479	37.3	46,637	3
Gisborne	29,548	3,019	10.2	-	?
Hawkes Bay	99,040	12,695	12.8	4,585	7
Taranaki	317,053	64,246	20.3	8,373	3
Wellington.	277,942	59,544	21.4	17,879	6
Nelson	25,203	**8,083**	**32.1**	1,158	3
Marlborough	**13,574**	**2,346,**	**17.3**	**14:**	1
Westland	9,402	4,942	**52.6**	1,016	4
Canterbury	64,384	27,913		**8,372**	6
Otago	50,601			22,595	23
Southland	125,724	79,104	62.9 38.5	60,010	15

± A.-& P. Statistics, 1933/34. & 1934/35.

** Deliveries of lime carried on rail to farmers less ½ cwt. for each acre of turnips sown,

The data in the last two columns are approximate only, as the tonnage is based on that of carbonate of lime delivered at officered stations and obviously'does not include a considerable quantity transported by-other means, than rail, Further, since a certain amount of-lime is applied' to arable crops, deductions have been made to allow ½ cwt.. lime for each acre of turnips..: In the case of the Otago and Southland land districts, at least, it is obvious that this deduction is insufficient..

The table serves to show, however, that Otago and Southland are by far the greatest users of lime in proportion to the amount of grassland topdressed. Moreoever, it serves to indicate the difference in practice in those districts to the remainder, in that lime is applied in large quantities of from 10 cwt. to 1 ton per acre, whereas in the north the tendency is to apply lime in smaller quantities of from 3 to 7 'cwt. per acre. It is in the North Island, however, that the increase in liming has been most apparent, an increase having taken place of 400 per cent. since 1927/28.

Reasons for Use of Lime:

In 1931 Connell(1) drew attention to the rapidly increasing quantities of lime used and suggested that lowering of expenditure in a time of financial stress was the cause which led to some of the increase. Although the diminution in the quantities of fertilizers used during the period cited lends support to this hypothesis, it should be borne in mind that certain published statements (2) & (3) on the use of lime may also. have had some influence. It is true that the reports which gave prominence to the visible effect of lime concerned the South Island but other, and probably far more telling, aspects on the use of lime in the North Island concerned the mineral content of the herbage and the effect of lime deficiency on the health Of stock -- IX factor quite as potent in some districts as increased production,

The underlying motive behind the use of lime on many farms is that it possesses a subtle influence on the chemical composition of the herbage as well as reducing the soil acidity. The cheapness of the material, often as low as 10/-per ton, is a further inducement to apply lime, and the fact that the Government encourages its wholesale use by giving free railage up to 100 miles still further develops 3 lime "complex" in the New Zealand farmer,

Actually, New Zealand farmers, apart from those in one or two districts, have less incentive to lime than farmers in the Northern Hemisphere. "Mat" on grassland, a condition requiring a large npplicntion of burnt lime for its eradication, is compurntively unknown in the Dominion.. Although clovers are generally stimulated by applications of lime in New Zealand, in some districts they thrive on soils having a lime requirement much greater than that tolerable to clovers in Europe. Much has been. said regarding the suppression of beneficial soil bacteria under acid Boil conditions, and it has been shown (4)that Azotobacter spp. in. particular were not to be found in soils having a reaction more acid than pH 6. In an examination of 15 New Zealand soils in connection with the "soil plaque" method of soil analysis Reid (5)found Azotobacter spp. to be normally present in only one sample (pH 7.5) so that. apparently Azotobacter is not well distributed in our soils,

although nitrogen fixation does not seem to suffer on that account, Scrivener (6) remarked on the apparent failure of existing methods' of determining lime requirement under, New Zealand- conditions but later (7) suggested,, a modified formula which, when applied to certain soil tests, appeared to correlate these with responses in the field,

The fact remains that in New Zealand we cannot be guided by any of the theoretical considerations, laboratory procedure or ecological conditions governing lime and its use in other countries.. Our only guide to date has been actual field trials, carried out either by the farmer or by the State..

Field Trials:

The Fields Division of the Department of Agriculture has conducted throughout New Zealand since 1924 approximately 600 simple observational trials in which lime plots (chiefly calcium carbonate) were included. Generally lime alone was compared with no lime and fertilizers - chiefly superphosphate and potash - with lime were compared with the same fertilizers on unlimed ground. -Most of the results have been published (8) but these might be here summarised briefly,

In some. of the experiments marked responses occurred, in others little or no visible benefit was derived either from lime alone or lime in combination with phosphates.

As superphosphate has been used in practically all these trials, the effect of lime might be considered relative to that of superphosphate in the following groups:-

1. Superphosphate alone gives poor or only fair results" lime alone may give fair to good results: super-phosphate with lime gives good to very good results.

Growth of both grasses and clovers is poor on unlimed ground, but lime in conjunction with phosphate induces a striking improvement in white clover which is often reflected in the health and vigour of the ryegrass. The palatability of the limed plots is generally better, as shown in the grazing. Liming is essential on this class, of land although in some cases it is quite possible that basic slag used repeatedly might obviate the necessity of liming. This is open to question, however, in districts where lime responses of such magnitude occur since,. in the majority of cases where basic slag plots were included, liming improved the appearance of the latter,' as well as the super plots.

The proportion of experiments falling in this group, together with the districts in which -the responses occurred, are as follow:-

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District.	Soils.	Percentage of experiments in Group 1.
N. Auckland	Clays or silts	**92**
"	Ironstone (laterite)	1 00 (2, experiments)
"	Volcanic	71
Marlborough	Loams and sandy loams	**33**
Westland	Miscellaneous	90
N. Canterbury	Silt loams and loams	43
Christchurch	Sandy silts, silt loams	41
Mid Canterbury	Fine sandy silts, silt loams	61
South Canterbury	Clay loams, silt loams	30
South Otago	Miscellaneous	**33**
East Southland	"	**60**
West "	"	11
Nelson		Pakihi -1 ands .

The small proportion of experiments showing relatively good responses from super plus lime as compared with super in South Otago and Western Southland - districts in which lime is used freely and in large quantities - may be. due to the fact that sufficient lime had already been applied, It should be stated that the fertilizers and lime were topdressed on existing pasture and that in the two districts last mentioned the general farming practice is to sow down to grass with one ton per acre of carbonate of lime.

In the above group might be included a trial under the mowing and grazing technique evolved by Hudson at Ruakura Farm of. Instruction, This experiment was laid down in July, 1934, on newly sown pasture and the soil may be roughly described as a pest loam. Results to 19/6/35, i.e. , for approximately 1 0 months, are markedly in favour of the lime treatments as indicated by the following:-

Treatment.	Relative Production of Dry Matter (No Manure = 100).
No Manure	**100**
Super **4** cwt. per annum	116
Super **4 cwt.** per annum + Lime. 1 ton (initial)	137
Super 4 **cwt.** per annum + Lime 10 cwt. (initial)	130

It is interesting to record that an observational trial on a true peat soil' at Ruakura suggests results in accord with the above.

2. Superphosphate gives good results, but better results are ob-tained from Superphosphate with Lime.

In the trials of this group the lime responses are generally spasmodic , i. e.. , they are obvidus only at certain times of the year,: and then chiefly in the autumn when white clover growth is more pronounced, Morecver, the experiments are, in most cases, on better pastures than those in group 1. It is indicated in these experiments that lime is not essential for the establishment and maintenance of reasonable pasture; but that lime as an adjunct to super will increase production. It does not necessarily follow that the use of lime under these conditions is profitable since it might be found that money spent in extra phosphat-e rather than in liming will give greater returns. Al so , basic slag, under certain conditions, may be a better proposition than super plus lime,

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Experimental results falling in group 2 have been obtained in most 'districts throughout the Dominion, but more especially in the King Country, South Taranaki, Wanganui, Marton, Wairarapa and Northern Manawatu districts of the North Island, and Banks Peninsula in the South Island, in addition to those districts mentioned under group 1.

In the category of group 2 may be placed a trial under the mowing and grazing technique at Marton Experimental Area, This trial was laid down in September/ 1932, and results up to 21/6/35, after approximately 2 years 9 months of trial, show 'the following:-

Treatment,.	Relative Production of Dry Matter (No Lime = 100).
No Lime	100
Carbonate of lime 2 tons per acre (initial)	112.5
Carbonate of lime 1 ton per acre (initial)	107.9

Although in this trial there is no comparison of super with no manure, other experiments on the farm show responses from super which can be classified as good,

3. The addition of Lime to Superphosphate causes no appreciable improvement

Although isolated trials in the under-mentioned -districts may show slight but fleeting responses from lime, the majority of the experiments do not indicate any improvement in the amount of growth, composition of sward or palatability of herbage. In fact, the limed plots have, on occasion, been inferior in general vigour of herbage in some of the experiments;

Districts in which no general apparent benefit has been derived from lime used. in experiments are:- Rotorua and Southern Waikato (pumice soils), Hauraki Plains (clay soils), Southern Poverty Bay, Hawkes Bay; Southern Manawatu, North Otago and Central Otago.

Haying Trials.:

During the seasons 1924 to 4929 a large number of experiments were carried out in which the production of herbage from various treatments, including lime, was cut and weighed as for a hay crop, Only 17 experiments out' of46, or 37per cent., of the trials gave any appreciable increase in bulk from the lime + super plots as compared with super alone, Most of the experiments referred to were in the South Island and in districts in which subsequent observational trials indicated that liming caused appreciable benefit, The weakness of trials in which hay weights are the sole criterion of improvement is in the fact that the hay crop represents only, a portion of the growth for the whole year and, further, that any increases- due to a particular treatment are obtained during the period of maximum production. Since,, as will be shown later,, lime tends.,.. to increase production most during periods of low production, it is considered that the results of haying trials might even be misleading when the effects of liming are under investigation.

The Effect of Lime at various Times of the year:

In the liming trial at Marton referred to previously, one of the most marked features in the increased production from liming (all plots being phosphated) was the relatively high response during periods of low production; particularly in the dry months of late summer and in autumn, and the relatively low response during periods of high grassland production. In connection with the foregoing statement regarding hay weights, the increases due to the application of 2 tons per acre of lime, in the "haying period" (taken as from 1st October to 3-l st December) as compared with the remainder of the year, are as follow:-

	Percentage increases of lime over no lime. Dry Matter.
"Haying period" 1932/33	9.2
Remainder of year 1933	16.6
"Haying period" 1933/34	11.6
Remainder of year 1934	24.1
"Haying period" 1934/35	-4.4
1/1/35 to June, 1935	9.3

The results of this- trial show., incidentally, that even where lime gives a moderate response, the effect is apparent very soon after application. It might be mentioned, also, that in another experiment alongside the above basic slag is giving results slightly inferior to those from superphosphate, and the addition of lime to basic slag has given a slight increase over basic slag without lime;

Lime Content of Herbage:

As the herbage from the above trial was periodically analysed, it has been possible to ascertain whether or not liming does affect the lime content of the herbage. For the first 8 months of the trial. the CaO content of the herbage from the no lime plots averaged **1.15** per cent. of total dry matter, while on the limed (1 ton carbonate per acre) plots the CaO content was **1.24** per cent.*

In view of the fact that the herbage from the limed plots contained a- greater proportion of white clover, which, according to Doak (9), contains almost twice as much lime (CaO) as ryegrass, the increased CaO content of the herbage due to liming is not unexpected. In discussing the effect of superphosphate on the chemical composition of herbage Hudson and Doak (10) stated "It should be remembered that the increased lime content is not wholly due to *an* increased percentage of clover in the mown herbage, but is partly due to an increased percentage of lime in both the grass and the clover."

This lends support to the hypothesis that liming increases the CaO content of the herbage, apart from the change in botanical composition, just as potash applications in another trial **(11)** increased the K_2O content of herbage without changing the sward or even increasing yield to any appreciable extent.

* Figures kindly supplied by Mr. B. W. Doak.

Aston (2) showed that liming increased the lime content of herbage sufficiently to remedy the unthrifty condition 'of sheep experienced, on the deteriorated pastures of the Mairoa district, His conclusions were that a mixture of- 5 cwt. of lime and 2 cwt, 'of super per acre enabled the farmer to successfully breed and fatten lambs on country where formerly, presumably with applications of super only, it was impossible to do so. In this investigation there was no suggestion that lime applications increased grass production to any appreciable extent. One can therefore understand to some extent the attitude which the farmer takes up in regard to applications of lime in addition to phosphate in large areas of the North . . Island in which troubles with lamb breeding are experience&

The Duration of Effect from Liming:

The effect of lime is said to persist for many years, particularly on grassland;' This idea is so Well established in Great Britain that in some districts an ingoing tenant must pay an outgoing tenant one-eighth of the 'cost of lime applied seven years previously, on the assumption that the effect of lime on grassland , lasts for 'eight years after application. As the leaching of lime from the soil will depend to a large extent on rainfall, one would expect the linie to be effective for a considerably less period in wet districts, particularly where the soil is of a light, porous nature. At Marton, in the liming experiment referred to previously; records of the free $CaCO_3$ in the top two inches of soil suggest that the latter is lost readily from this horizon, only about half of the $CaCO_3$ applied being recoverable after the first year, Since calcium compounds have so many functions in the soil, e.g.; preservation of soluble phosphate, subsequent to superphosphate applications, the alleged liberation of phosphates and potash which are hot immediately available to the plant, and the effect on the mechanical condition of the soil,, in addition to the reduction of soil acidity, it would appear that the only satisfactory method of gauging loss of lime from the soil is from actual drainage determinations. The term of years over which lime is effective depends considerably upon the initial effect on the pasture. In several of the observational trials laid down in Canterbury the effect of 1 ton of lime applied in 1928 was clearly visible in 1935, seven years after application. At Winton Experimental Farm lime applied at a ton per acre. across several paddocks in 1924 was clearly visible up to a year ago in the general improved vigour of various crops sown, particularly turnips. In this case the' effect of lime was not apparent until about two years after application.

It is hoped that some exact information as to the duration of the response to liming may be obtained from experiments under mowing and grazing at Marton and Ruakura.

Forms of Lime:

There does not appear to be *any* advantage in using burnt lime on grassland as opposed to carbonate. Burnt or slaked lime is recommended for certain purposes on arable crops, e.g., club-root control, but in view of the extra cost entailed by burning carbonate 'of lime is more economical on grassland and experimental evidence to date indicates it is quite. as efficient as burnt lime when an equivalent amount of CaO is 'applied in each case.

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Availability of Carbonate of Lime:

Much has been said regarding the extent to which limestone should be ground., In U.S.A. particularly there seems to be considerable divergence of opinion as to the best degree of fineness commensurate with cost of grinding. Grimmett & Denz **(12)** reviewed the question of fineness of grinding and other factors relating to availability in New Zealand.

Some time ago the writer and others (13) investigated the effect of various commercial samples of carbonate of lime in alleviating the germination injury to turnip seed caused by superphosphate. It was found that whereas many brands were fairly efficient in this respect, a few were extremely poor, notwithstanding the fact that they contained a high percentage of $CaCO_3$. Fineness of grinding was found to be of importance, although when each of the limestones used was reduced to a fairly high degree of fineness there still remained appreciable differences in performance which could not be explained by variations in $CaCO_3$ content or hardness of the parent rock, It is not intended to discuss this aspect of carbonate of lime further except to state that the trials referred to above focussed attention to the very considerable differences in the degree of fineness of ground limestones turned out by various quarries. Over **40** per cent, of some samples is retained on a **30** mesh sieve - which is a relatively coarse grade - while others can produce the material with less than 20 per cent. retained on a 30 mesh sieve. At the other end of the scale some commercial samples contain about **50** per cent, of material passing 120 mesh sieve and can be purchased at less cost than others containing only about 15 per cent. of this fine fraction.

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The question arises -- Are these differences. in fineness of any real moment since it is likely that the coarser particles will become ultimately available under the action of rainfall and weathering over a period of years, It has been suggested in some quarters that a fair proportion of coarser material may actually be an advantage since less leaching of lime is likely to occur. On the other hand, money spent on coarsely ground limestone represents capital lying idle for a number of years and the farmer is *getting* away from the old established custom of manuring for posterity. Quick returns from any operation are now looked for, and it is suggested that just, as one applies quick-acting fertilize-s to get a large initial response, so should frequent applications of finely ground limestone be made rather than infrequent dressings of relatively coarse material,

CONCLUSION:

The present paper is a brief survey of the practice of liming on New Zealand grasslands. It has been indicated from the results of observational trials on grassland that liming increases the efficiency of phosphates, particularly superphosphate, over wide areas of New Zealand. The resultant increased production is obtained chiefly during periods of normally low production and, where effective, is therefore another of the-means of getting a more even distribution of production over the year.

In some districts liming, in addition to applications of phosphate, seems to be necessary in order to safeguard the health of stock where calcium deficiency diseases are suspected. Even where no such troubles occur, the fact that liming increases the lime content of herbage is probably a strong incentive to the farmer to apply lime even where a good supply of phosphate is being maintained,

The effect of lime on pasture has been found to persist for several years in some districts in spite-of the frequently-made assertions that calcium carbonate is leached rapidly from the soil.

More exact information is required regarding the most desirable degree of fineness, compatible with cost of production, of our commercial ground limestones, and if the finer material is relatively more effective than coarsely ground material some definite standard of fineness shouid be advocated;

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