FERTILISER ASSOCIATION OF IRELAND

Proceedings

LIMING PRACTICE and POLICY

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No. 5 May 1971

Fertiliser Association of Ireland

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Published by the Fertiliser Association of Ireland, 54 Dawson Street, Dublin 2

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(Paper presented at the fifth meeting of the Fertiliser Association of Ireland)

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The Ground Limestone Scheme of 1951 is now 20 years old and entry into the E.E.C. may force us to modify its terms, so it seems useful at this time to review progress in liming and to try to estimate prospects for the future.

Changes in the use of limestone on a national scale, from 1953-69, are illustrated in Fig. 1. Before 1951, the use of lime was less than 0.1 m. tons per annum. Following the Ground Limestone Scheme it rose quickly to 1.22 m. tons in 1957 but this was followed by a sharp fall to 0.62 m. tons in 1960. It is difficult to understand the reason for this. Although wheat acreage fell during this period, barley acreage rose by an equivalent amount. However, liming recovered to reach 1.12 m. tons in 1964. In 1965 the standard recommendations from Johnstown Castle for liming were increased and the rate of liming increased further to 1.72 m. tons in 1969-70. This suggests that farmers are sensitive to advice and will respond quickly if the information is suitable for their programmes. The fall in the use of nitrogen (and indeed P and K) over the 1965-66 period contrasts sharply with the rise in lime (Fig. 1).

The trend in lime use in Northern Ireland has been almost the reverse of that in the Republic. In the period 1957 to 1961 rates were increasing in the North but since then, there has

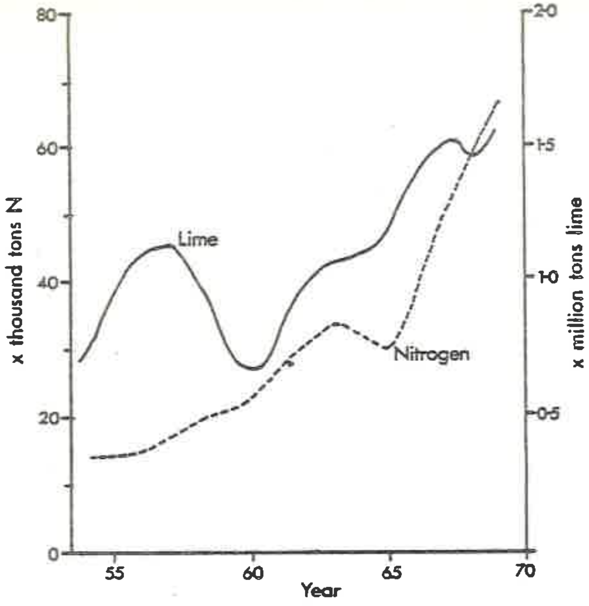

Fig. 1 : Use of lime and nitrogen 1954-1969. Data shown are for two year running averages.
Source : Department of Agriculture and Fisheries

been a steady decline (1). Despite this decline the current rate per acre of arable land in Northern Ireland at 2.7 cwt per annum is just lower than the peak figure (1969-70) for the South at 2.9 cwt per annum (see Table 1).

Table 1 : Lime use on crops and pasture

Northern Ireland 1961	8 cwt/acre
Northern Ireland 1966-70	2.7 cwt/acre
Republic of Ireland 1969-70	2.9 cwt/acre

The national statistics, however, give us very little insight into the strengths or weaknesses of the liming programme. Fig. 2 shows the distribution of lime use by county. Only two categories are shown, i.e., 2.8 cwt lime per acre of arable land or greater and 2.7 cwt or lower. The pattern is quite striking. The higher

rates occur along the east and south coasts and in Donegal (Table 2). Fig. 3, which shows the areas of intensive tillage in the country, indicates that the lime and tillage patterns are strongly related. Donegal is unusual in that the tillage rotation there is dominated by potatoes and oats and this should lead to lower than average use of lime.

The relationship (shown as a dot diagram in Fig. 4) between the amount of lime used and the area of tillage per county had a very high correlation co-efficient (r = 0.910). In Fig. 4, Offaly, Laois and Kildare are displaced from the main group in that the lime used is lower than might be expected from the amount of tillage. This is probably because these counties have a high proportion of soils derived from limestone. Although soil acidity will obviously affect the rates of lime used (see Fig. 5

Fig. 2 : Variation in lime used per county (cwt per acre crops + pasture)

for geographical distribution of acid soils) it appears that the amount of tillage is the most important determinant.

Table 2 : Lime used per arable acre (cwt) 1969

Wicklow	6.8	Cavan	2.2
Wexford	6.2	Monaghan	2.0
Cork	6.2	Galway	1.8
Waterford	5.6	Longford	1.6
Louth	5.2	Clare	1.6
Carlow	5.2	Mayo	1.6
Dublin	3.6	Laois	1.4
Donegal	3.0	Roscommon	1.4
Tipperary	2.8	Kildare	1.4
Kilkenny	2.8	Westmeath	1.2
Kerry	2.6	Sligo	0.8
Meath	2.4	Leitrim	0.8
Limerick	2.2	Offaly	0.6

Source : Department of Agriculture and Fisheries

More direct information on the relative amounts of lime used for each crop was available from the Fertiliser Use Survey 1967 by Murphy and Heavey (2). Data from this survey are shown in Table 3. Sugar beet and feeding barley receive high rates. It is difficult to understand the difference between malting and feeding barley unless the former is concentrated on limestone soils. Rates of lime used on grassland are rather low. Unfortunately, the pasture data were not separated into new pasture and old pasture but data from soil analysis quoted in Table 4 help to clarify this. Soil pH after sugar beet and

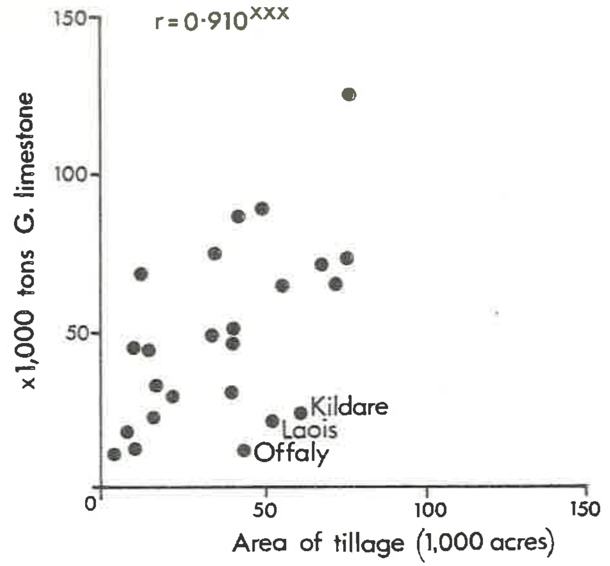

Fig. 4 : Ground limestone used vs area of tillage in each county. Cork is off scale in the diagram.

Fig. 3 : Distribution of tillage 1965
Source : Gillmor, D.A., Ir. J. agric. Econ. rur. Sociol. 2 : 135, 1969

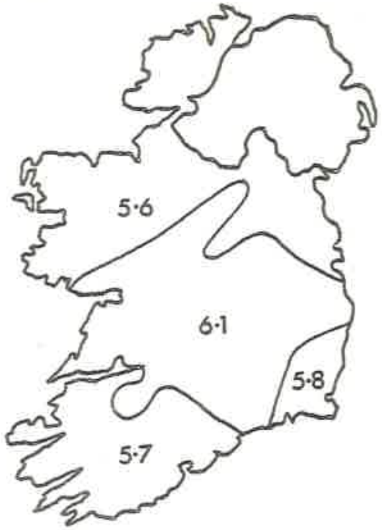

Fig. 5 : Geographical variation in soil pH

Table 3 : Average amount of lime used per crop (cwt per acre)

Sugar beet	15.6	Oats	2.9
Feeding barley	14.9	Feeding roots	2.8
Malting barley	7.6	Pasture	1.8
Wheat	5.5	Potatoes	1.3

Source : Fertiliser Use Survey 1967 (2)

Table 4: Percentage of soil samples with pH 6.0 or lower (1970)

After sugar beet	16.1	After potatoes	48.8
After barley	29.1	After permanent pasture	54.3
After wheat	31.4		
After new pasture	30.9	After oats	56.8

barley was high, in agreement with the Fertiliser Use Survey, and there was a marked difference between old and new pasture.

After new pasture, the pH was very similar to that after wheat or barley but old pasture is grouped with oats and potatoes. This indicates that the amount of lime going on old pasture is lower than that quoted for all pastures in Table 3.

The pattern of use over the year is also of interest and is shown in Fig. 6. Two peaks appear at April and October and two valley periods in June and January. If most of the lime is applied to tillage or new pasture this pattern is easily explained. It is obvious that farmers are still not keen on 'summer liming' and this is almost certainly due to a lack of interest in liming old pasture at any time of the year. The use of N, P and K on permanent pasture is also very low and well below rates used on tillage or new pasture so this suggests that the farmer must be first convinced that he should lime (or fertilise) his old pasture before the time of liming becomes relevant to him.

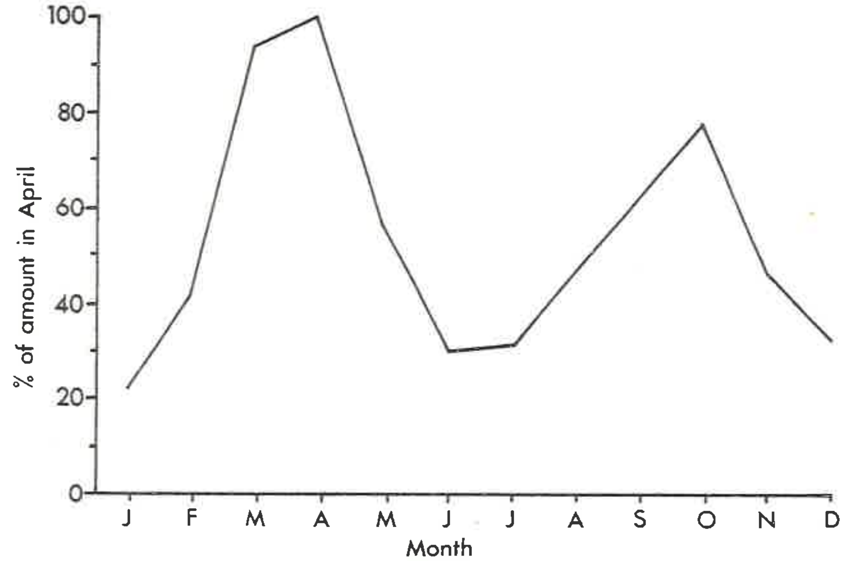

Fig. 6 : Lime used each month, 1969
Source : Department of Agriculture and Fisheries

To summarise this section covering current practice : Farmers are using reasonable rates of lime on tillage crops along the south and east coasts; if they maintain present rates, the tillage areas should reach satisfactory lime levels within 15 to 20 years; an increase to 3 million tons per annum means that a satisfactory status would be reached in tillage before 1980. Only very low levels of lime and N, P and K are being used on permanent pasture.

Crop responses to liming

The use of lime to improve soil fertility is a very old practice, yet the amount of quantitative information available on crop responses to liming in Ireland is quite limited. Because it is useful to study the effects of liming over a long period, much of the field work has been carried out on the farm at Johnstown

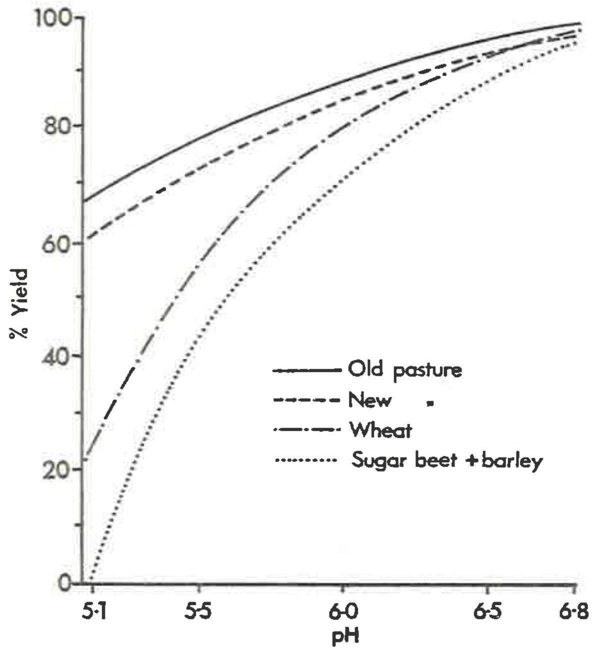

Fig. 7 : Yield vs pH

Castle. Fig. 7 illustrates some results from a current liming trial at Johnstown and responses on old pasture in Co. Louth. Wheat, barley and sugar beet all show similar patterns of yield versus pH in that all approach complete failure between pH 4.9 and 5.2, while maximum yields are achieved near to pH 7.0. Old pasture is less sensitive to acidity and will not fail completely until the pH is below 4.5. In ordinary farm practice, failures in tillage crops have been sufficiently frequent to impress farmers but failures in old pastures are virtually unknown. New pastures are a special case, for acidity often brings about a change of species as well as an overall reduction in output of dry matter. Ryegrasses will often fail to establish at pH values below 5.2 but they are usually replaced in the sward by other grasses (e.g., Agrostis tenuis), and the reduction in yield is therefore not as dramatic as with say sugar beet or barley.

If all crops followed the relationships outlined in Fig. 7 exactly, the precise value of liming would long ago have been obvious to all. Unfortunately, there is considerable variation between seasons, between areas and even within fields. An example of seasonal variation is quoted in Table 5. These

Table 5 : Effect of season on response of barley to liming

	% of maximum yield	
pH	1969	1970
5.2	32	20
5.7	75	94
7.0	95	100

results are taken from an experiment at Johnstown Castle which was laid down in 1964. The 1969 results are typical of the previous 5 years, i.e., that pH 5.7 gave less than 75% of the maximum yield of barley, but in 1970 the same plots produced 94% of potential. A similar result was observed for wheat. Possibly the dry season in 1970 influenced the results. In the same year a field in Kilmuckridge produced 33 cwt of wheat per acre at pH 5.2 while the yield of wheat at Johnstown at the same pH was only 15 cwt per acre. No data were available on response to lime on the Kilmuckridge site. Further evidence is available from the Soil Productivity Experiment which covered 19 sites and where three barley crops grown at pH 6.0 failed to respond to lime in 1970. On one site at Bunclody, liming caused a depression in the yield of barley as shown in Table 6. The cause of this was traced to manganese deficiency and treatment with 50 lb of manganese sulphate gave normal crops of wheat in 1969 and barley in 1970 without depression from the liming. Although these examples of variation show that the relationships in Fig. 7 are not very rigid, nevertheless they are a useful guide to results on commercial farms. McEnroe and Coulter (3) in a survey of 3,000 farms found that the optimum pH for sugar beet was over 7.0 and many instances of sugar beet failures have been recorded at approximately pH 5.2 or lower.

Table 6 : Depression of barley yield by liming*

pH	Yield (cwt/acre)
6.4	30.5
6.7	16.6
7.0	12.9

*Cause : manganese deficiency

All of the data available in Ireland on the response of grassland to liming have been derived from trials where yields were measured by cutting. In 1966, Murphy (4) observed a negative interaction between lime and nitrogen fertiliser on old pasture in a factorial experiment at Ballintubber. Some of the results from this experiment for 1966-68 are shown in Fig. 8. In the absence of nitrogen there was a good response to liming but at 300 lb N per acre no response was observed. The high rate of nitrogen did not increase the pH of the control. Further evidence in agreement with this observation was found in the Soil Productivity Experiment and the Incremental Liming Trial at Johnstown. Neither of these experiments had a factorial lime x nitrogen design, but soils which showed a good response to liming in the absence of nitrogen in 1970 had shown no response in 1969 when 200 lb N per acre were used.

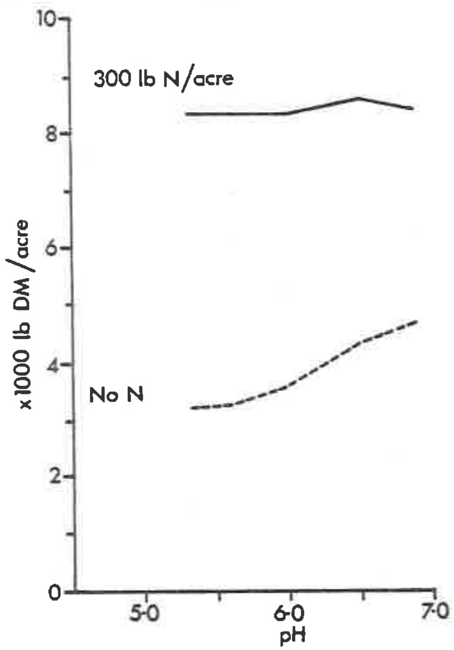

Fig. 8 : Response of old pasture to liming (Ballintubber 1966-68)

These results raise many questions on the future policy of liming grassland. Under grazing, a considerable amount of nitrogen is returned to the pasture through dung and urine but it is not spread uniformly over the area so its influence on response to lime cannot be predicted with any accuracy. Further trials are therefore needed to measure the interactions of lime by nitrogen under grazing conditions. In Britain also most of the work on liming of grass has been measured by cutting and the few long-term grazing trials reported were mostly concerned with lime x phosphorus interactions rather than nitrogen (5).

Low stocking rates in Ireland are probably the greatest restriction on fertiliser use on grassland. Should these continue to increase we might expect that the use of lime and fertiliser would rise. However, the greatest increases are likely in the use of nitrogen on grassland and this may radically alter the need for liming of grass because of the interactions discussed above. If, however, nitrogen was used as urea, ammonium nitrate or other acidifying sources (6) it seems likely that some limestone would be necessary to prevent soil pH falling below 4.5 where grass growth would be depressed even at high nitrogen rates. Current information does not permit us to predict what will happen to the liming programme of grassland in the changed circumstances of high stocking rates and high rates of nitrogen fertiliser, nor is it adequate to suggest a compromise between lime and nitrogen. Obviously further field work including trials with grazing animals is necessary.

<u>Cost of liming</u>

Current liming costs are low and indeed do not seem to have changed much for some 20 years. Lime usually costs

£1.2 per ton spread on the land so a maximum dressing of 6 tons per acre will cost £7.2 per acre. If this is written off over 10 years the cost per acre per annum is only 72p. Interest charges may bring this over £1.00, but even this is no more than the minimum maintenance cost for other fertilisers. Maintenance costs for lime should not be more than 24p per acre per annum plus interest for 2 tons per acre every 10 years. These charges depend on the application of a subsidy under the Ground Limestone Scheme and may increase should we enter the E.E.C. However, prices for agricultural products will also increase in the E.E.C. so it seems that cost should not be a major restriction on development of a liming programme.

Because of the advantages of using lime outlined above and the relatively low costs the recommendations from Johnstown Castle for standard liming practice aim at building up some reserves in the soil and maintaining these by regular dressings at 10-yearly intervals rather than waiting until crop disorders occur. For a tillage/new pasture rotation the soil should be limed to pH 6.8 and relimed when it falls back to pH 6.3. Checking by soil analysis at 5-yearly intervals should provide sufficient information for adequate control. For permanent pasture a range between pH 6.0 and 6.5 is probably adequate. Potatoes will produce full yields at pH 5.3 and may be affected by tuber blight or common scab above pH 6.0. Bergin and Golden (7) reported that liming decreased the incidence of skin necrosis on potato tubers (var. Arran Banner). Some compromise is therefore necessary in deciding on a liming policy for a particular rotation and the critical lower pH and optimum pH range are shown in Table 7.

Table 7 : Critical pH for main crops

Crop	pH for crop failure	Optimum range pH	Optimum range LR*(tons/acre)
Sugar beet	5.4	7.2-7.4	XL, XX**
Barley	5.3	6.5-7.0	1-XL
Wheat	5.2	6.5-7.0	1-XL
New pasture (perennial ryegrass + white clover)	5.3	6.2-6.8	0-2
Old pasture (Agrostis)	4.5	6.0-6.5	1-3
Swedes	4.8	6.0-6.5	1-3
Oats	4.8	5.7-6.2	2-4
Potatoes	4.3	5.3-6.0	3-6

*LR = lime requirement to bring pH to 6.8

**XL, XX = excess lime

Peats

Peats are usually acid but do not need liming to the same extent as mineral soils. This is probably because of the relatively low levels of aluminium and manganese which are present in peats. Both of these elements are more soluble and therefore available to plants at lower rather than higher pH values. As high levels of these are toxic to many plants, liming can reduce the toxic effects of acid mineral soils. However, if these elements are virtually absent from peats, liming obviously cannot be beneficial in this way. Even in peats some lime is often necessary and a pH range 5.0 to 5.5 is considered optimum depending on the crop.

Molybdenum

Liming increases molybdenum uptake by pasture and although this does not interfere with the growth of the plant it may cause disorders in the metabolism of the grazing animal if intake is excessive. Soils in some areas, notably Meath-Westmeath-Dublin-Kildare, Clonmel and Limerick-Clare (see Fertiliser Manual (8)), contain potentially dangerous levels of molybdenum. Lower rates of liming to pH 6.0 are recommended for these areas particularly for permanent grassland where pH values of 7.0 or higher may be reached in the top inch of soil after liming. However, liming is not the only factor which influences the effect of molybdenum on the animal. Clovers take up much more molybdenum than grasses, phosphate increases while sulphate depresses molybdenum uptake and young cattle are more sensitive to excess molybdenum than are older animals.

Manganese, boron, cobalt and zinc

In contrast to molybdenum the availability to crops of other trace elements particularly manganese, boron, cobalt and zinc is reduced by liming. As the lime status of the tillage areas rises over the next 10 to 20 years these elements may become more critical for plant and animal nutrition. A case of depression of barley yield by liming a manganese-deficient area has already been quoted (c.f. Table 5), and indeed cases of manganese deficiencies in cereals are well known, particularly in dry seasons on freely-drained soils.

Although there is also strong evidence that liming reduces boron uptake by plants, this effect may not be quite so important in practice since boron is already included as standard treatment in compounds for sensitive crops such as sugar beet and swedes. This precaution should be adequate even at high rates of lime.

Cobalt deficiency has been recognised in several areas of the country. Scottish workers (9) have reported that liming depresses the uptake of cobalt by herbage and extensive liming of acid soils such as the granites of Carlow and Wicklow could aggravate an intrinsic deficiency in these areas. The cost of cobalt is quite low, however, so the control of the problem should be simple and straightforward once it is recognised. Recently Gallagher and O'Sullivan (10) observed that zinc deficiency in onions was increased in the presence of lime. It is unlikely that this interaction will be important on mineral soils as no other case of zinc deficiency has been reported in Ireland. Nevertheless, it is one more illustration that the effects of lime on a crop are complicated and interactions occur with many other factors, physical, chemical and biological. It is not likely, however, that these complications will have a major influence in restricting or stimulating the national liming programme. Constant monitoring of trace element supply will be necessary but remedies are available should any widespread need arise.

Liming materials

Ground limestone is the main source of lime used in Ireland, accounting for approximately 90% of the total which includes sugar factory sludge, sea sand and basic slag fertiliser. Its quality as a liming material is measured by its total neutralising value and its fineness, and both of these properties are controlled by law. Work at Johnstown Castle and elsewhere has shown that coarse material (5 to 20 mesh) reacts very

slowly with the soil and is never as effective as material which is finer than 40 mesh. The Irish statute which prescribes that 35% must pass through a 100 mesh sieve should guarantee a suitable material for farming. This standard is important since one of the disadvantages of lime compared with other fertilisers is the slowness of its action, e.g., nitrogen may show an effect in weeks but lime may need a year or more.

The magnesium content of a limestone is also of interest. A dolomitic limestone raised the magnesium content of herbage from 0.2% to 0.4% at the 8-ton per acre rate in an experiment at Johnstown Castle. This may be of value in the control of grass tetany but is not a guarantee of its prevention. It can only be recommended where the soil needs lime and a convenient source of dolomite is available.

Conclusions

It is obvious that tillage dominates the pattern of lime use. At current rates - 2 million tons per annum - the tillage areas will have reached a satisfactory lime status before 1990, probably by 1985. If 3 million tons per annum were used in the same proportions between grass and tillage this position would be reached before 1980. Any extra lime over the current rates must, therefore, be applied to grassland. Lime and fertiliser use on grassland is currently very low. Although fertiliser use will probably increase on grassland as stocking rates rise, lime use may remain low because of a substitution effect between lime and nitrogen. Further information is needed on the effects of lime on output from grazing animals at high and low levels of nitrogen. Should acidifying forms of nitrogen fertilisers (e.g., urea) be used, limestone may still be necessary even at high rates of nitrogen.

Continuous monitoring of the trace element supply to crops and animals will be necessary as the lime status of our soils is increased. This, however, is not likely to be a serious obstacle to the use of lime.

ACKNOWLEDGMENTS

I would like to acknowledge the help of W. E. Murphy in preparing this lecture particularly in providing the data for Fig. 8, M. Ryan provided some of the data used in Fig. 7, M. O'Keeffe carried out statistical analysis, J. Lynch prepared slides and J. Parle prepared the diagrams. The statistics on lime use were received from the Department of Agriculture and Fisheries. The help of the technical staff in the management of the field experiments is also gratefully acknowledged.

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