A REVIEW OF THE POSITION RELATIVE TO GRASSLAND MANURING IN NEW ZEALAND.

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" To a very real extent grassland is singularly independent of the virginal character of the soil " states Professor Stapledon(1) in his latest book, but he adds, " good management and adequate manuring can lead to the development of tolerably good grassland on any soil, while bad management will mask the virtues of the most beneficent soil. " This noted British grassland authority is referring to Home conditions, but his remarks apply equally well to New Zealand ; in this country manuring pastures gives better returns than in Britain, and returns which can hardly be paralleled in any other country, provided sound management, practices are associated with top-dressing. . Whilst the fertilizer-bag is the -greatest single factor-within the control of farmers-for the improvement of New Zealand grasslands, still it is only one of the factors, and it must always bc viewed in relation to the others, more especially those of pasture composition and grassland management.

THE PAST.

The first importation of fertilizer was 459 tons of guano in 1867. Up to 1915 all the New Zealand imports of fertilizers were under three heads only-bonedust, guano, and unenumerated. It is generally agreed that top-dressing began in the Waikato in the " eighties " of last century. The manure applied was mainly a mixture of bonedust, superphosphate, and rock prosphate. Guano was also used. Farming in the " eighties " was at a low ebb. Kefrigeration had not yet come, in and did not influence returns from animal products until the early " nineties." The top-dressing wave, therefore, moved very gently over the landscape in the early years.

The first top-dressing at the Ruakura State Farm took place in **1891.** In 1892 the first shipment of basic slag arrived in Auckland. By **1900** top-dressing was well under way in the Waikato, going hand in hand with progress in dairying. Up to that time bonedust was the chief fertilizer used, superphosphate being applied in limited amounts only. The State commenced top-dressing trials in 1904 at Ruakura, and later at other experimental farms. Some of these were on the basis of live-stock increases, and it is rather a pity that they-were not maintained, as it is this type of experiment which, if difficult to carry out, is most informative and appeals to farmers. By 1909 top-dressing was being practised on a moderately wide scale in the Auckland Province and had spread to Taranaki. In the early years, and up to comparatively recent times, nearly all the top-dressing was done on dairy pastures.

In **1909** New Zealand imported 70,000 tons of 'fertilizer, mostly phosphatic. A certain amount of this, together with fertilizers made in New Zealand, went on to dairy pastures ; but in the South Island and in the sheep areas of the North Island top-dressing was still almost an unknown quantity. In the next five years the fertilizer tonnage increased by 50 per cent., with top-dressing absorbing its share of the increase, but the total area top-dressed was still limited. During

the war years basic slag was practically unobtainable. This led to the more extensive use of superphosphate and to the realization that this was a most effective type of phosphatic top-dressing manure., In 1921 imports of superphosphate rose 'to 40,700 tons, the peak year for superphosphate imports. Since 1923 practically the whole of the superphosphate requirements of the country have been manufactured in the Dominion. It was about 1922–23 when top-dressing began to expand at an accelerating rate in this country, but still it was mainly devoted to dairy lands, 'and this largely in the North Island ; top-dressing developments came much later in the South Island than in the North.

The establishment of the Canterbury Soils Improvement Committee in 1923 and the experiments conducted by it and by the Department of Agriculture subsequently were major factors in getting top-dressing started in Canterbury. The year 1923 is a landmark in New Zealand top-dressing history. This was the year in which the Dominion, because of sufficient manufacturing capacity; became independent of outside supplies of super-phosphate. In 1926 Cockayne(2), surveying twenty-five years of New Zealand agricultural progress, said that manure sales had increased from 25,000 tons in 1900 to 200,000 tons in 1925, and that 150,000 tons of this last figure were for top-dressing, and over half that amount was superphosphate. The fertilizer was applied- at that time to about 1,000,000 acres, or 5 percent. of the sown grasslands of the country. Incidentally, Cockayne predicted a trebling of the figures in the next ten years, and this has just about been accomplished,. as 15 per cent. of the sown New Zealand grasslands are now top-dressed. The actual fertilizers carried by rail nearly doubled between the years 1926 and 1928, and increased a further 25 per cent. by 1929. After that the slump caused a decline in figures, but the 1929 amounts are likely to be again attained this year (1936). A survey of 200 dairy-farms in 1926–27 by Fawcett(3) showed that high per-acre fertilizing is associated with : (a) high per-acre production, (b) high carrying-capacity, (c) high herd-average of butterfat, and (d) reduction in cost of producing butterfat.

Potash, first introduced in 1888, has been used all along to a certain degree on pastures. The recent experimental work. in Southland, Taranaki, and other areas, combined with the propaganda of the potash interests, has in recent years developed 'an annually increasing use of potassic fertilizers on grassland.

The use of nitrogenous fertilizers on grassland in New Zealand was negligible prior to 1929 ; up to that time it had- been applied as blood and bone, or inorgani; nitrogenous fertilizer incorporated in extremely small amounts in mixtures applied, to pastures. The advent of synthetic sulphate of ammonia, combined with new grassland concepts, were undoubtedly leading factors in the trials of nitrogenous fertilizers, begun in the Dominion some nine years ago by the Department of Agriculture and Cawthron Institute, acting in co-operation with Imperial Chemical Industries, Ltd. To-day, however, the use of inorganic nitrogen on pastures is tending to increase, and in the 'main it is used as ammoniated superphosphate (2 parts superphosphate to 1 part sulphatc of ammonia) on the better-class pastures for what is termed "out-of-season" grass.

The development of liming grassland in this country was fully discussed at the 1935 Grassland Conference by Mr. Woodcock (see *N.Z. Journal of Agriculture*, January, 1936).

THE PRESENT POSITION.

The following table indicates the acreage of grassland top-dressed in New Zealand in 1935 :-

District.	Acres Top-dressed.	Area of Sown Grassland.	Percentage of Top-dressed Land of Acreage of Sown Grassland.
			Per cent.
North Auckland	441,120	1,686,610	26
Auckland	987,693	2,275,346	43
Gisborne	40,366	2,069,133	2
Hawke's Bay	152,068	1,431,888	10
Taranaki	329,776	1,143,857	29
Wellington	344,227	3,510,712	10
Nelson	23,517	309.925	7
Marlborough	13,268	359,326	3
Westland	92935	144,476	9
Canterbury	73,641	2,053,770	3
Otago	69,624	1,244,388	5
Southland	198,879	1,158,743	19
	2,684,114	17,388,174	'5

* This includes lime as well as fertilizers.

Unfortunately, the figures do not give the clearest of pictures, *as* there is no separation of the total amount of fertilizers used alone on pastures-that is, apart from lime. There is also possibly a certain duplication which would make the actual acreage less than that indicated in the table. The percentage of sown grassland top-dressed in each land district shows a marked variation from district to district.

Generally speaking, top-dressing is heaviest in the North Island ; heaviest in the dairying districts ; heaviest in the districts of lightest soil and high rainfall-subject to the reservations, that it is. heaviest in areas where rail and transport facilities are most favourable and where application is easiest. Connell(4) pointed out some little time ago that the practice of top-dressing was maintained best over the worst years of the slump in districts where it had been practised longest and where its value was most appreciated. It was noticeable, also, how many sheep-farmers dropped top-dressing the first year of the slump just when they had begun to apply fertilizers. Auckland maintained its top-dressing tonnage best during the slump years.

The following table indicating the stock carried in relation to top-dressing is based on the assumption that each cattle beast is equivalent to five sheep :--

District.	Number of Sheep carried to the Acre too-dressed.
North Auckland	10
Auckland	6
Gisborne	120
Hawke's Bay	27
Taranaki	9
Wellington	26
Canterbury	60
Otago	59
Southland	15

TYPE OF FERTILIZER APPLIED.

Phosphate.—Top-dressing fertilizers are predominantly phosphatic, with superphosphate the chief form used to-day. The 'main. trend in recent years has been towards an increase in the amount of water-soluble phosphate applied. In 1929 there was large imports of North African rock phosphate, which were applied directly to grassland, but the figures were not sustained. Basic slag is being used this year (1936) in larger quantities than for several years past. This is mainly due to a lowering in its price combined with a strong selling campaign. A question on which further information is needed is the economics of farmers buying large quantities of basic slag, especially at a price substantially above that of superphosphate. A study of New Zealand top-dressing experiments reveals extremely few instances where basic slag gives better results than- those of superphosphate plus lime, or, in many instances, of superphosphate alone.

The Auckland district has used more than half the basic slag imported into New Zealand during recent years. Mr. P. W. Smallfield, surveying eighty experiments 'carried out in the Auckland Province in 1928-34, writes in the New *Zealand Journal of Agriculture,* April, 1935, as follows : " The results of the top-dressing trials confirmed general farm practice. Superphosphate is generally the cheapest and most efficient phosphate for pasture top-dressing, but on some soils lime is necessary to enable the best results to be obtained from superphosphate. Slag is also quite efficient, but it' is not superior to superphosphate, or super-phosphate and lime. Rock phosphates are generally inferior to superphosphate or slag." Early experiments—1906–11 at Moumahaki, Taranaki-where wool and mutton increases were registered on top-dressed and untop-dressed areas, showed that superphosphate was superior to slag to the extent of &1 16s. per acre.

Potash.-Mr. Woodcock (see pp. 146-152) has surveyed the position in regard to the present use of potassic manures on grassland. I wish to sound a note of warning in regard to -drawing hard-and-fast conclusions from trials where to the eye responses from potash are inconsiderable, especially where full stocking is not practised on the treated areas.

Other Minerals.-As the question of mineral deficiencies is being dealt with by Dr. Hopkirk, I will not discuss this matter at any length. Another reason for brevity is the paucity of information available on the subject ; possibly mineral deficiency in foods is being credited with some troubles due more to insufficiency of stock-foods and errors in stock management. So far the-question-of mineral deficiency-has-been confined almost solely to the pathologic&l areas of the country-e.g., where bush-sickness prevails-but from an economic standpoint the financial losses on the more normal soil types with the much greater numbers of stock carried may be much greater even if the percentage of stock loss is relatively low. The annual loss in New Zealand of £6,000,000, due to stock diseases, as indicated by Dr. Marsden(5), is surely big enough for steps to be taken to secure a much better understanding of the disease position and of any possible relationship to mineral deficiency in soil and plant. I am sure the fertilizer industry will co-operate

within economic limits to improve the plant-nutrition status of the fertilizers supplied. The possibility of supplying necessary minerals per medium of stock-licks must also be considered.

Nitrogen.-The question of applying inorganic nitrogen to pastures has been discussed at previous conferences. Trials were commenced in 1929—the technique employed did little more than cloud the issue, a matter for which no blame is attributable to the, investigators. Over four years ago, Connell (see *Journal of Agriculture*, January, 1932) showed that the method of testing nitrogen on pastures being used at that time had distinct weaknesses.

The trials referred to have been discontinued, and, unfortunately, since then little has been done to get greater definition on the economics of nitrogenous manuring of pastures, which in reality is a difficult thing to do by ordinary experimental technique.

Many New Zealand farmers, however, apply to pastures inorganic nitrogen usually combined with superphosphate--i.e., ammoniated superphosphate. (More recently lime has been incorporated, and the combination of 2 parts superphosphate and 1 part sulphate of ammonia and 1 part carbonate of lime is termed " neutral " ammoniated superphosphate.) Most of the applications go on in the very early spring to bring forward early-spring grass, and the extent of the practice with each individual farmer is governed by the spring-feed outlook. The combined nitrogen/phosphatic fertilizer is also used on pastures intended for silage and hay. However, the most interesting development is the application of nitrogen, usually as ammoniatcd superphosphate, in late autumn to grow " winter 'grass " for rationing to early calving cows and to encourage grassiness in certain swards as a preventive of bloat in cattle and taint in cream. The late autumn applications are growing in popularity as, at this time, especially when pasture is allowed to grow and is not hard-grazed, nitrogen gives its maximum effect with the minimum of disadvantage.

Some Observations on White Clover.-Top-dressing with phosphate, potash, and lime is really an indirect method of giving more nitrogen to grassland, since the above-mentioned materials stimulate clovers, which secure the atmospheric nitrogen. Levy has put it well when he states " the main propelling force in initiating pasture progress is phosphate, and the machinery by which this force is applied is largely the clover of the sward "(6). Whilst fully appreciating the essential role of white clover in a sward, I still maintain that there may be a strong case against its overdominance on some swards, and more especially at a particular time of the year-e.g., early spring.

Professor Stapledon(7) recently set down these views : " The cornerstone of land improvement in all parts of the world is the leguminous plant ; however, the grasses, taken as a whole and considered in terms of the -final attainment of the land-improver, are probably of greater value than the clovers, they are more productive under constant-grazing, and they afford a longer grazing season, but the clover is the first step. Start with the legume appropriate to the conditions and end with the best grass appropriate to the conditions." The relationship of grasses to clovers in a sward is one of the major problems in grassland-development. It would be interesting to ascertain the number of rye-grass plants a white-clover plant can effectively nourish.

Some authorities advocate a two-to-one relationship of grass to clover, but, this, of course, will vary in percentages. over the season. One, rather wonders if the vigorous New Zealand No. 1 white, ' instead of. wet-nursing, say, two rye-grass plants, may not,, under favourable treatment, overlay its charges and monopolize the sward. "It does suggest the necessity of selecting, breeding, and feeding of rye-grass strains in a manner adequate to allow this grass to hold its place with the New Zealand No. 1 white clover.

Time of Application of Fertilizer.—It 'is only within recent years that there has been much top-dressing other than spring top-dressing. Spring dressings are probably still most popular on most grasslands in the South Island, although autumn applications are increasing at a. fairly fast rate even there. In the North Island autumn is now the main season of application, although the following figures, based on a large proportion of the North Island fertilizer output over a nine-year, period, show that some manure goes on every- month of the year and the dominance of autumn top-dressing is not as great as many people imagine, even in the North :—

Monthly Percentage of Fertilizer Deliveries' in the North Island for Nine-year Period 1927–1935.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
5	7	14	12	9	8	10	12	9	6	4	4

Farmers would get better returns were they on the whole to top-dress earlier in the autumn, to top-dress more in autumn irrespective of the seasonal growth, and to put on the minimum quantities in the "dead" winter months. This applies to phosphate and potash. Nitrogen is mainly used- for getting "out-of-season" grass, and here I think more attention can be paid to the April to May dressings. In regard to sowing down to grass, there is scope for greater quantities per acre than is usually applied ; in fact, far too great an acreage gets no fertilizer at seeding-down. Further every new pasture should have a second dressing during its first year-that is, autumn-sown grass should have a second manuring in the following spring. In this way the pasture is helped markedly when all the species sown have the best chance of making their full contribution to the sward. This also helps in weed-control. Hudson has suggested that summer applications of super-phosphates increase phosphate content of pastures at a time when this may be low. On country liable to suffer from phosphate-deficiency in autumn-this is specially desirable.

Quantities per Acre.-The usual practice is to apply 3 cwt. per acre of fertilizer, mainly phosphatic, on dairy pastures and 2 *cwt.* -on sheep pastures. In the drier areas-e.g., Canterbury-the dressing is often not over 1 cwt., a figure too low even in a low rainfall area : 3 cwt.- per acre is the equivalent of 1 oz. per square yard, and this is put on irregularly even with the best top-dressers, human and mechanical. One -of. the main lessons, experience will teach,us is the profitableness of applying even heavier dressings than is now current practice, perhaps .not

at one time, but within the year, and especially with the initial building-up of a sward. On many North Island dairy-farms 5 cwt. to 6 cwt., Sometimes even greater amounts, of phosphates are applied per acre, usually in two applications per year, autumn and spring. On the poorest North Island soils-e.g., raw pumice-three applications .of a phosphate fertilizer, totalling 10 cwt. per acre, may be given in the first twelve months. Generally speaking,. dairy pastures get the 3 cwt. already indicated-some areas are treated in the autumn, some just prior to closing for silage and hay, and some just after the silage is cut. Sheep pastures get varying amounts-from 1 cwt, to 3 cwt., and most of this goes on in the autumn. Potash is applied at the rate of 1 cwt. to 2 cwt. per acre, usually at the same time as phosphate and in the form of 30-per-cent. salts. Sulphate of ammonia goes on at the rate of 1 cwt. per acre, although some farmers give 1½ cwt. for autumn dressings. Ammoniated superphosphate is usually applied at the rates of 3 cwt. to 4 cwt. per acre on dairy pastures, and 2 cwt. to 3 cwt. on sheep lands.

Method of Application.—The major portion of top-dressing material is applied by machine, but much hand top-dressing is carried out even on areas suited to a mechanical top-dresser. Recent developments are in the direction of top-dressing by contract. In the South Island there is an increase in the number of carriers who attach top-dressing machines to their trucks 'and cart eithe from depot or rail and apply fertilizers at a contract price. In the North there is a movement developing to get teams of top-dressers who move, as do shearers, from farm to farm, and who pack out and apply fertilizers by hand to hill country. Developments along, both lines-with trucks and with teams of men—should be encouraged.

FACTORS ASSOCIATED WITH TOP-DRESSING.

Harrowing.—At one time it was thought by many that an essential accompaniment to top-dressing was drastic pasture harrowing. It is now known that surface application of fertilizers, especially of the water-soluble type, quite soon shows an effect in pasture growth on unharrowed land, provided there is not an overburden of "foggage." There is no evidence that, at least on good rainfall areas, any method of inserting fertilizers into grassland would be an improvement in the present method of surface spreading. This does not eliminate the possibility, even probability, of improved results from the incorporation of fertilizers into soil prior to sowing down to grass on the drier soil areas—e.g., Canterbury. A drastic harrowing is advisable, where it is necessary, to tear out any "mat" or to remove "foggage" prior to top-dressing, but in good rye-grass - white-clover swards the necessity for severe harrowing-or anything other than dung spreading, and this is even less necessary on good swards than others-is very doubtful.

Pasture - management in Relation to *Top-dressing.*— -Improvement of pastures, apart from botanical composition of the sward, is very much wrapped up in sound grazing practices. More and more we are realizing the very great importance of pasture-management in grassland-improvement work.

Amount of *Leaf at Time* of Top-dressing.-The old dictum about always close-grazing pastures prior to top-dressing may be quite unsound

-so much depends on the time of -fertilizer applications. When manures are applied at times of the year when growth is rapid, it matters little what previous grazing treatment has been practised. It is different in late autumn; early winter, or early spring. Although very little, work has been done on this point, all the evidence points to the desirability of having, at the times indicated; a certain amount of leaf on the pasture plants-certainly of not having them bare-grazed. Unless there is some leaf-growth, a plant takes up little of the applied fertilizer-that is, at the colder periods of the year. This is a matter of vital importance in regard to the. applications of nitrogenous fertiliiers, but it is also important in regard to phosphatks and even potash. The position is that if it is desired to get a quick response to any fertilizer treatmept it can best be done by having quite a substantial amount of leaf-growth at the time the pasture is top-dressed-also in subsequently spelling the pasture from stock to allow the plants full scope to utilize the applied -fertilizer.

THE ECONOMICS OF TOP-DRESSING.

Unless top-dressing had proved profitable it would not have developed to its present position. Yet definite information on the economics of top-dressing is extremely limited. It can only be secured by a consideration of farm results, and even when these are available other factors interact with top-dressing. In practically no other country in the world does top-dressing give such a high return over and above the cost of fertilizer as is the case in New Zealand. This is difficult to prove, but actual statements received this year by the writer from a large number of farmers certainly indicate that top-dressing is exceedingly profitable over a wide area of this country.

In 1929 Cockayne(9) said : " It is hard to estimate the actual profits that the prosaic manure-bag holds in store for New Zealand grassland farmer, but from past. experience it can be said that every pound spent on top-dressing returns at least threefold that amount, and, in addition to this, helps to build up a soil-fertility reserve which can be viewed as a capital and permanent improvement." Any calculation to-day with a lower price for fertilizers and at least a moderately good return from dairy and sheep products indicates returns no less than those previously indicated by Mr. Cockayne. Of course, it is not possible to estimate profits definitely since so much depends on a number of variables,. not the least important being the farmer himself.

THE FUTURE.

The future of top-dressing in New Zealand will involve probably-

(1) An increase in the amount of fertilizers used on acres now in the top-dressing programme.

(2) A better use of the fertilizers so applied by-(a) application of a greater quantity at the best times ; (b) manuring better swards ; (c) improved management ; (d) greater knowledge as ascertained through research and from farmers' experiences.

(3) An extension of top-dressing on areas not yet treated by--(a) better appreciation by farmers of the profits obtainable through, top-dressing ; (b) improved credit facilities ; (c) contract top-dressing programmes ; (d) sound investigational and educational methods aldng lines here suggested.

THE NEED FOR RESEARCH ON SOILS AND FERTILIZERS.

Whilst it may be true,. as. stated by a high' New Zealand, Government official, that over large areas of New Zealand grassland " the margin between cost of top-dressing and the returns secured is So wide as to be almost beyond 'belief," that does not mean that we should not conduct research on fertilizer problems so as to ensure even greater returns' from any unit of expenditure. Our knowledge, as distinct from mere opinion; on the best method of fertilizing pastures is very limited, and there is considerable scope for research in this country on the following problems:—

(1) Lime.-The role of lime in increasing the efficiency of fertilizers is not fully understood. For instance,, Mr. Rigg states : " Certain New Zealand soils have high fixing power for soluble phosphatic manure, others well supplied with lime have not this feature so strongly developed. Dr. Grange states : " There is a high absorption of phosphate by the soil types with a low silica-sesquioxide ratio and a very small absorption. by the gumland soil with. a high ratio." He considers that the soils with low ratios require heavy dressings of lime on account of the phosphate fixation. There is considerable scope for research work on the use of lime in relation to fertilizers on various soil-types.

(2) *Phosphate.*—As suggested in (1), there is much to learn on what happens to phosphate when applied to different soil-types. This suggests, too, the relative efficiency of various types of phosphate applied to pastures. In the case of water-soluble phosphates what, for instance, are the relative merits of finely divided as compared with granulated fertilizers. Doak has published the results of some interesting research on some aspects of what happens to phosphate in soils-a continuation of this type of research has much to commend it, We have much to learn, too, on such questions as-" What is the best rate of phosphate application for any soil type ? " " When should manures be applied, and how often ?"

(3) *Potash.*—Is itsound to judge the efficiency of potash manuring merely by (1) observation, or (2) increased yield of herbage, without regard to quality ? We need much more knowledge on the relationship of potassic to phosphatic and nitrogenous manures, and the real significance of balanced manuring as a sound, long-term procedure in pasture top-dressing over wide areas.

(4) Trace-elements.- What is the deficiency in trace-elements of different soil types ? What practical means can be adopted to make these good by *(a)* additions to present-day fertilizers, (b) through suitable stock licks?

(5) ***Soil*** *Biology.*—Our knowledge of soil biology and its relationship to liming and fertilizing pastures is negligible.

(6) Pasture Plants and Fertilizers.-We need more research work on the efficiency of fertilizers in relationship to types of pasture plants-

(7) The Place of *Temporary Pastures.*—A matter of considerable importance is the place of temporary pastures, especially long-term rotational keys-as contrasted with permanent pastures-if maximum returns are to be secured from fertilizing grassland.

(8) *The* Animal *in Relation* ***to Pasture*** *Manuring.*—We must not lose sight of the role of the animal in any research work.concerned with top-dressing problems. If this is difficult in small-scale experiments, can

we not intensify our research of what is happening on farms where we have top-dressing associated with stocking under actual farm conditions.

(9) *Economic Considerations.*—Our research must finally include economic considerations and investigations on the net returns from fertilizer applications to grasslands. This must be conducted mainly in association with farm-management surveys.

(Abbreviated.)

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(9) Primary Producers' Annual, 1929. Published by the *Dominion,* Wellington.