THE MINERAL CONSTITUENTS OF PASTURES

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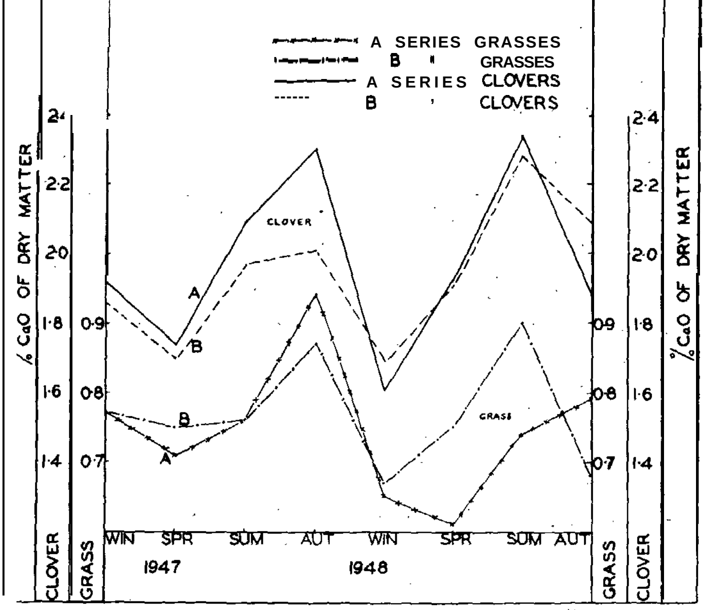
INTRODUCTION

I cannot claim any originality in the title of this paper, since during the past hundred years dozens of papers have been written under the identical heading and hundreds -have been written on the same topic. In the hour that is allotted to me I propose to discuss, not the mineral status of pastures grown under all the environmental conditions possible in New Zealand, but one or two small trials which have been under way in Palmerston North during the past 3 years. The reason for this intense specialisation will, I hope, become clear as the lecture proceeds, but briefly we are concerned with principles which will be applicable regardless of the environmental conditions rather than with applications which relate only to one particular climate or one particular soil.

And if we are going to be interested in general principles, it is essential that we ask the simple question, "What is the justification for spending a great deal of time and money on investigating the mineral constitutents of pasture plants? Why undertake these laborious field trials and these hundreds of analyses for lime, potash, phosphate, and nitrogen?" The answer I think is equally simple: The mineral elements 1 have mentioned together with a number of others are essential for the growth of plants. These plants derive their minerals entirely from the soil and if one or more minerals are deficient in any particular soil, the deficiency has to be made good from the fertiliser bag. And finally, despite all the work that has been done on this subject, we are still a very long way from being able to say, simply from an analysis of pasture herbage, whether or not an application of lime or phosphate or nitrogen will produce a greater yield. That is one half of the answer and the half to which I shall devote all my time. The other half is, of course, that animals also require minerals for growth, but they do not require them in the same proportions or in the same amounts as do plants. Since pastures furnish practically the whole diet of our sheep and 'cattle populations, it is obviously of prime importance to know the quantities of minerals available in the herbage at different times of the year and under different environmental conditions.

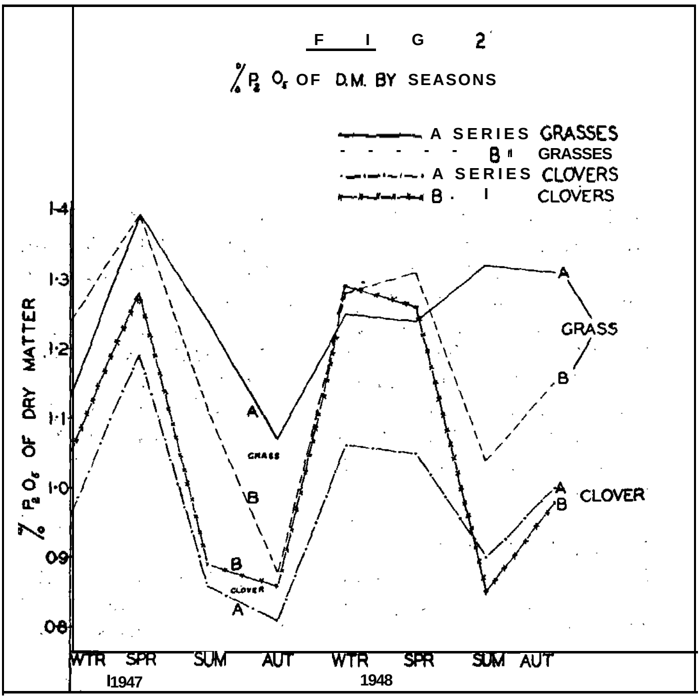
FIG 1

% CaO OF D.M. BY SEASONS



There is just one further point I wish to make in this introduction. The authorship as shown in the programme is quite inadequate. If justice were to be done there would be over half a dozen names of which that of Melville would be last. As you will see later, the field work which'was necessary before any sample came into the laboratory was enormous, and this field work was carried out by Mr Sears and his team in Grasslands Division :-Mr Goodall, Mr Fitzgerald, Miss Owen, and several others. Then the chemists in the audience will appreciate the hundreds of man hours involved in the 700 odd analyses on which I shall base my argument. Those analyses have been the soie responsibility of Mr Turner of my staff, who has personally carried out over 90 per cent.. of them. I therefore wish to emphasise that I.am acting only as mouthpiece and. interpreter for -the large group of 'Workers who are actually responsible.

Now as to the trial itself, it is necessary. first of all -to describe the field side and outline the aims and



objectives which Mr Sears had in mind before the plots were laid down in the autumn of 1946. Briefly they were to determine the effect of clovers in 'the sward under a number of different root environmental conditions (Table I.). Thus the first plot was sown to grass, and legumes have been excluded throughout the trial. The second plot was sown to a standard grass-clover mixture, as were also plots 3, 4, and 5. Plot 2 received no fertiliser or lime, plot 3 received phosphate 'only, plot 4 received lime only, while plot 5 received both lime and phosphate. These were applied at a rate calculated to make good the losses of lime and phosphate in the herbage of the highest producing plot. Finally plot 6, like plot 1, was sown to grass only, but unlike 1 has had the same' dressing of lime and phosphate as plot 5. Defoliation has been by motor mower, and the whole series is shown in the table as the "A" series.

Then the plots are repeated in every detail except that dung and urine are returned to the plots in amounts proportional to the yields from each plot. Thus if plot 1 yields 2000. lb dried herbage/ac/annum and plot 5 yields 12,000 lb, then dung and urine will be returned at 6 times the rate for the second as for the first. This series which we have called the "B" series is again under mowing.

Now to complete the story on the field side, the series is repeated twice more, again in exactly the same manner as described, except that sheep do the defoliation instead of a mower. In the first repetition the dung and urine are not returned to the pasture, so that the series is a duplicate of the "A" series. The only difference is that in the "A" series the mower is used, while in this one the sheep is used. Finally on the 4th. series defoliation is similarly by bagged and bottled sheep, the dung and urine being returned to the plots in proportion to their productive capacity.

The trial is therefore a fairly comprehensive one, and the information to be derived from it may be summarised as follows :-

1. The effect on the sward of the grazing animal separated into its components, viz., the effect of animal droppings, the effect of trampling by hooves as compared with consolidation by the mower, and the effect of defoliation by the grazing animal as compared with defoliation by the mower.

2. The effect of the addition of lime and phosphate on pure grass swards and on grass-clover associations under the different systems already outlined.

3. The contributions made by legume and non-legume in the sward to the amount of minerals available to the grazing animal.

That then is the background to layout and objectives, and it is my opinion that in this trial is the nucleus of the methods which will be used to solve a large number of the outstanding problems of pasture growth. But you may well ask where the chemist comes in on all this. There are three answers to'that question. First, the. pasture ecologist must know as accurately as possible the turnover of minerals which occurs in pastures under the different systems of management, and in particular he needs information about the turnover of these elements through the grazing animal. For such studies chemical analyses are essential. Secondly, we in the laboratory who are interested in. what happens inside the green leaf felt that here was an excellent opportunity to gain information about mineral levels in 'pasture herbage from. closely controlled plots under a wide variety of root environmental conditions and over a reasonably long period of time. Thirdly, continued analysis on really high-production pastures do not exist. The best available ones come from the Marton trials, where maximum yields of about 10,000 lb D.M./ac/annum were recorded. We know from several, seasons measurements at Palmerston North that the capacity of the newer strains is of the order of 50 to 60 per cent. higher than this at about 16,000 lb D.M., and we wished to be able to provide authentic figures for certain elements. And finally of 'equai interest to both collaborating institutions was the determination of the separate roles played by legume and non-legume in the mineral cycle.

Chemical analyses have been confined to the first two series which I described earlier, i.e., the plots under mowing. Cuts are taken whenever the grass on the fastest-growing plots reaches the 4 to 6 inch stage, which involves between 1'2 and 16 cuts per year. The. samples for botanic&l dissection- and chemical analysis are taken by hand shears at each cut over the whole area of the plot. These samples are dissected into grasses and clovers, and the separations are rapidly dried in a well-ventilated oven. Analyses are done on 3-monthly bulkings of individual cuts, not because the value of more frequent analyses was not appreciated, but because our analytical resources do not run to the huge number' of analyses which 'would have been required. As it is, the total number of analyses on this trial alone since its inception is over 700. Methods of analysis for nitrogen,, calcium, potassium, and phosphorus, the only elements studied, were along well-standardised lines.

When I first worked on this paper I intended to confine the discussion to the levels of the different elements in grasses and clovers under different management conditions and at different seasons of-the year, but I found that this was like presenting the bare bones without any covering of flesh. It is essential that leaf. levels of the elements should be set in the background provided by total yields and botanical composition of the various plots, and I propose to devote the-next 5 minutes or so to these topics.

The story on yields is shown in Table II. as well as for the 1948-49 year in Table I.

Total production figures in the first part of the table are shown to nearest 500 lb of dry matter.

A full consideration of this yield table would take up my whole hour, and I merely wish to draw your attention to the salient points:-

1. The biggest single factor in 'increasing yield has been the white clover plant, as can be seen from 'a comparison of 1A with 2A, or 1B with 2B.

2. The addition of phosphate to a clover-deficient sward has no effect in increasing yield,. as can be seen by a comparison of 1A with 6A and 1B with 6B.

3. The potentialities' of present strains of grass and. clover. can be' seen in the 1948-49 se&son, when 16,000 lb D.M./ac/annum was achieved in the B series. That was an excellent year for growth and has to be compared with the 1947-48 year, when the Manawatu suffered the nearest approach to drought which is ever likely to happen. In this case the yield was just over 12,000 lb D.M.

4. Next to clover the grazing animal is the major factor in increasing yield.

5. Additional phosphate gives significant increases in yield in the A series where dung and urine are not returned, but it is of the greatest importance that in the B series there is no phosphate response.

6. Lime has had no apparent effect on yield:

The differences in botanical composition- are almost as spectacular as are the differences in yield. The ratios between grasses and clovers for the '1948-49 season are shown on the chart, and I would draw your attention to the- overwhelming effect of the grazing animal in promoting grass growth.

There is, however, another aspect than gross clover to grass ratio. There is an interesting difference in the grass species which go to make up the total grass Component, and this is shown in Table III. For simplicity I have chosen 4 -representative plots, viz., 1A, 2A, 5A, and 5B, and shown the percentage of ryegrass in the total amount of grass in each sward.

All plots started off with -approximately the same percentage of ryegrass; although the yield of grass in 5B was already in 1947 nearly double that in the plots 'where' animal residues are not returned. 'This percentage of about 85 is-held in 5B, but the plots of the A series show marked decline in ryegrass proportion. Further, the ability of ryegrass to hold in those plots where it is growing in association with white clover is very marked in comparison with the deterioration which has taken place in 1A. This deterioration is reflected in the marked decline in grass yield from 1A.

I shall return to these yield and botanical data again in the more detailed consideration of the elements, but I think it is essential that you should have this background.

It is neither necessary nor desirable to swamp this meeting with a mass of figures. The detailed analyses are available to anyone who has specific points to raise. I propose to avoid the use of single figures and will use only averages or weighted averages, drawing such conclusions as are justifiable and pointing out the gaps in our knowledge as we go along.

CALCIUM

The first point which emerges very clearly from the trials is that lime levels in white clover are more than double those in the associated grasses. Thus in plot 2A the average lime content expressed as CaO is 0.73 per cent. for grass and 1.93 per cent. for clover. In plot 5B the figures are 0.79 per cent. for grass and 1.95 per cent. for clover. The high lime content of clovers has, of course, been known for many years, but I think the matter is worth re-emphasising. It is of importance to note that in our high-production pastures where the ratio of grasses to clovers is about 70:30, the clovers will contribute at least half the total lime available to the grazing animal. Further any management practice which decreases or increases the clover content of the sward will have a very marked effect on the calcium intake by the animal.

The question of lime response is naturally one of prime concern in a study such as this, i.e., Do the plots which receive lime show increased lime levels in the herbage ? Lime responses in both clover and grasses are small, and, again taking average values as a convenient method of expressing results, Table IV. shows the picture over the past 3 years.

In view of the very small, differences due to treatment, no long analysis of the results is called for. It is of interest to note that the grass in 2A is slightly but consistently lower in lime than, that from 5A or

4A. Similarly where grass growth is stimulated due to return of dung and urine, there is a slight calcium response, although the degree of differentiation is somewhat lower. On grasses, therefore, we can point to some small response to liming as determined by leaf levels under the particular conditions of this experiment. I would stress that last phrase -"under the particular conditions of the experiment." We at Palmerston North are working under favourable soil conditions and all our experience with fertilisers on our area have shown minimal lime responses. Had these trials been performed on land known to give increased yields with lime, I have no doubt that the lime response as measured by leaf levels would have been marked.

The response in clovers is a little more obvious than in the grasses. Herbage from plots 4A and 5A is consistently higher in lime than that from 2A, while there also appears to be some response from the calcium added in the superphosphate applied to 3A.

From the figures which have been shown on the last slide no indication is given of seasonal variations, which are much more striking than differences due to liming procedures. In Fig. 2 are shown graphs of the seasonal variations in both grass and clover. The values are obtained by averaging the grass and clover analyses for plots 2A, 3A, 4A, and 5A, and 2B, 3B, 4B, and 5B. In general you will note a similarity in all the curves, i.e., when clovers are high in calcium the grasses are likewise high and vice versa. Further, high values may be expected in summer and autumn with low values in winter and spring. The pattern, however, is by no means a regular one, as can be seen by comparing the autumn values for the years 1948 and 1949. There is a very marked peak in both clovers and grasses in the former year, while in 1949 after quite high summer values there is a pronounced decline into the autumn for all components except the grass in the A series. A clue to this irregular behaviour is, I think, to be found in weather conditions. The summer and autumn of 1948 were extraordinarily dry, only about half the normal rainfall being recorded between November and April. It has been noted by many investigators that drought conditions lead to high leaf calcium levels, and this appears to be a reasonable explanation of the autumn peak of 1948. In 1949, on the other hand, growth conditions over the whole year were as nearly optimum as is ever likely to be achieved, there, was practically no -water deficiency at any time, and autumn. pasture growth. closely resembled spring growth.,

I would particularly draw your attention to the magnitude of the seasonal variations. As shown on the graphs of average values, the variation is from 0.61 per cent. to 0.94 per cent.; 'the absolute variation being from 0.57 per cent; to 6.96, per cent., i.e., differences of over 50 per cent.. calculated on the minimum figures. Similar ranges from 1.5 per cent. to 2.5 per cent. are to, be found in the clovers. Moreover, it must be, remembered that these values are drawn from 3-monthly bulkings, and, that if analyses had been carried out more frequently, even larger variations would almost certainly have appeared.

We have been considering thus far seasonal variations in the grass and clover components taken separately. The position is even more interesting when the two are taken together and the seasonal variations in the. mixed pasture herbage are considered. In late winter the. ratio of grass to clover may be as-high as 80:20, while in autumn it falls as low- as 30:70. Bearing in mind that autumn values are high, that winter values are- low, and that clover contains more than twice as much calcium as ryegrass, it is obvious that the lime in the diet will vary through a wider range than is the case when the species. are considered separately. By using. these ratios and taking average figures of lime. levels from the graph, we arrive at the conclusion that a high-production winter pasture will contain about 0.9 per cent. of lime, while the same pasture in summer. will contain 1.9 per cent. Such differences are of obvious importance to the animal nutritionist who is concerned, with the mineral. requirements- of grazing animals.

One point emerges for which we have no -ready explanation, viz., there -is a significantly higher. lime level in plots 1 and, 6 (which contain no clovers) than in the grass component of-any other plots in the series. Thus to take, an example at random the average lime content of the grass in 5A is 0.79 per cent., whereas that of 6A is 0.93 per cent. Two possible explana-, tions come to. mind., First, as I pointed. out earlier, plots 1 and 6 have deteriorated to a dominantly browntop-chewings fescue association with relatively little ryegrass, whereas the latter has held reasonably well. in the -plots where, clover. is. present. It may well be that. these low-fertility grasses have a higher. lime content than does ryegrass. The second explanation lies in the low production levels of the- plots where clover is absent, a condition simulating drought conditions where leaf lime levels are normally high.

PHOSPHATE

When we proceed from lime to phosphate we have on the whole a much more clearcut picture, and I shall deal with the various points in the same order as I did in the case of lime. First, the species difference in phosphate levels is not nearly so great as is the case with lime. Grasses contain significantly higher amounts of phosphate than do clovers growing in. association with them. In 28 grass and 28 clover samples from the B series, the average P_2O_5 content of 'grass is 1.18 per cent. as against 1.07 per cent. for clover. Out of 56 plot samples over 3 years only 3. cases have been found where this trend is reversed, and in every case the difference was practically within experimental error. Secondly, there. is a marked difference in the response to phosphatic fertilisation on the A and B series. respectively, as reflected in leaf phosphate levels.. Table V, in which the grasses and clovers are averaged over a S-year period, illustrates this point very well.

In the A series where dung and urine are not returned there is a marked response to phosphate in both clovers and grasses: 2A and 4A are much lower than 3A and 5A. But when we come to the B series where dung and urine are returned phosphatic responses are both smaller in extent and less regular in incidence. Taken in conjunction with the fact that herbage yields in 2B, 3B and 4B, and 5B are essentially the same, the inference is that under Palmerston North conditions and at this level of fertility there is no necessity for phosphatic fertilisation to maintain yields. This is a point of the greatest importance,' particularly in the present and future phosphate shortage, and further data are required on a wide variety. of soil types to determine under what-conditions and at what levels of production the soil-plant-animal phosphate -cycle reaches equilibrium in respect to phosphate. It may well be, for instance, that the-drain of phosphate through a milking animalwould be just sufficient to upset the equilibrium as established in this series, and hence the necessity may arise for phosphatic fertilisation to maintain yields. It is highly desirable. to know what proportion of total production may be skimmed off and still leave enough phosphorus in the cycle to maintain equilibrium.

While we are on this question of species differences a point emerges which is not sufficiently widely recognised, viz., that in a high-production ryegrass-white clover pasture in which ryegrass produces about 70 per cent. of the total herbage yield, then of the phosphate which is extracted from the soil by the growing plants about 75 per cent. is taken'up by ryegrass and the remaining 25 per cent. by clover. Too frequently we think of phosphate as a stimulant for clover growth and leave out of account the high demands made by the grasses on the available phosphate in the soil.

Seasonal variations are again very marked, amounting to well over 50 per cent. for both species within anv single treatment. Thus the variation for grass in 2E is from 0.87 per cent. to 1.39 per cent., while that for clover is from 0.82 per cent. to 1.36 per cent. Seasonal variations of average P_2O_5 levels for plots 2, 3, 4, and 5 are shown in Fig. 2. It will be noted that, as with lime, the curves for clover and ryegrass follow a fairly similar course. From median values for the winter of 1947, there is a sharp rise in spring, an even sharper drop through summer to the autumn of 1948, rising again to the winter and spring of that year. An irregularity now develops in that there is a sharp fall in the clovers, and in the grass. of the E series, followed by an autumn increase. In the grass of the A series there is a slight summer rise followed by an even smaller drop to the autumn value.

It is of interest that the seasonal curves for lime and phosphate are more or less mirror images of one another. That is, phosphate is generally high in each species when lime is low and vice versa. Another minor point which appears from the analytical data is the apparent interaction of lime and phosphate. If we compare 3A, which has added phosphate, with 5A, which has added phosphate and lime, both without return of dung and urine, we find that the grass component of 3A is consistently lower in phosphate than is that of 5A, indicating a somewhat better utilisation of this element when lime is added. A similar trend can be seen in the clover component, but the effect is much smaller. In the corresponding dung and urine series lime appears to exert no effect whatever an either the clover or grass phosphate levels.

POTASH

The potash story is a much simpler one than either lime or phosphate, because no potash was added artificially. The comparison is therefore the A series as a whole against the B series as a whole, since dung and urine provide all the potash which. is applied to any plot. It is of interest here to state that of the potash excreted by the animal about 75 per cent. is returned in soluble and highly available form in the urine, while 25 per cent. is returned in insoluble form in the dung. Plot averages are given in Table VI.

The first point is that grass contains about 25 per cent. more potash than does the clover growing in association with it.

Secondly, the effect of dung and urine is very marked in raising the potash percentages in both clover and grass, and values up to 5.2 per cent. have been recorded for the latter species. Since over many experiments during a long period no potash response has been obtained on the Palmerston North area, it is believed that the higher potash values for the B series represent luxury consumption.

Thirdly, seasonal variations are low as compared with lime and phosphate and do not normally exceed 20 per cent. The tendency is toward high values in spring and low values in autumn.

Fourthly, as might be expected, there is no effect of the addition of lime and phosphate on potash concentrations.

NITROGEN

I have left the most difficult element, viz., nitrogen, to the last. It is difficult because the original source of practically, all the nitrogen in this trial, as in normal grasslands farming practice, is derived from the air. Moreover, that nitrogen is derived from the air, not by one main mechanism but by two-the first by free-living micro-organisms in the soil, the second by the micro-organisms in the nodules of clover plants. The effectiveness of these two -types of organisms can, be seen quite clearly from this trial, and in order to get a clear picture it is necessary to consider both yields and nitrogen levels in the herbage. Let us consider plots 1A where grass is grown without clover and 2A where grass is grown in association with clover, for the period May, 1947 to May, 1948. In both cases the plots are under mowing, so that there is no return of animal droppings. The yield of dry grass from plot IA was 1600lb of dry matter/acre containing 2.1 per cent. N, so that one acre of this pasture has extracted 33lb of nitrogen from the soil. The sources of that nitrogen are the free-living nitrogen-fixing bacteria, as well as the decomposition of organic residues present in the soil before the trial began.

In plot 2A the total yield of dry matter is 9500lb with a nitrogen content of 4.3 per cent., so that one acre of this pasture has extracted from the soil 412lb of nitrogen or nearly 13 times as much as the all-grass plot. Unless the presence of clover has in some way stimulated the activity of free-living nitrogen-fixing bacteria, and this is unlikely, then the 13-fold increase is due to the activity of the nodule bacteria. Those figures illustrate excellently the relative effects of free-living as against symbiotic bacteria.

But another point arises when we compare grass yields and composition from the two plots. Plot 1 produced 1600lb of dry grass with a'nitrogen content of 2.1 per cent., or a total nitrogen yield of 33lb. Plot 2 produced 2700lb of grass with a nitrogen content of 3.3 per cent. or a total nitrogen yield of 90lb. Thus not only is more grass produced when it grows in association, i.e, in competition, with clover, but the nitrogen content is also markedly increased. There appears to us to be only one logical conclusion: the almost threefold increase in nitrogen yield' is due to transfer of nitrogen from clover roots to grass roots. There is a quite definite -and considerable transfer of nitrogen underground. We are accustomed to thinking of overground transport through the grazing animal as the sole means of nitrogen transport from clover to grass in the sward, but it is obvious from these results that underground transport has also to be. taken into account. Under certain circumstances which cannot -be discussed here we believe that this underground transport of nitrogen is- of considerable importance.

When we come to a consideration of overground transport we must again think in terms of total yields and botanical composition as well as of nitrogen levels within the herbage. Just to remind you of the earlier part of the lecture in which I touched on these matters, I can summarise as follows:—

1. Yields of the best plot in the A series last year were 12,000lb D.M./acre/annum against about 16,000lb for all four plots in the B series.

2. In the A series the grass to clover ratio is about 40-60, whereas in the B series it is 70-30 over the whole year.

3. Plot 5A produced 5,000lb of grass and 7,000lb of clover, whereas 5B produced 11,000lb of grass and 5,500lb of clover.

This summary shows the enormous importance of animal droppings on the yield and composition of pastures, and I have presented it again because we are convinced that the key to the explanation lies in nitrogen supply. Other factors are unquestionably involved, but all our -experience over the past 10 years goes to show that the nitrogen contained in the dung and urine outweighs them all.

Now to go on to considerations similar to those adopted for the other elements (Table VII), we find that the clovers are consistently higher in nitrogen than are the associated grasses. This is most marked in the A series where there *is* no return of dung and urine and, to take a typical example, the average nitrogen content of the grass in 5A is 3.72 per cent., while that of the clover is 4.46 per cent., a difference of about 20 per cent. in favour of clover. This difference decreases when 'animal residues are returned and where the grass is in a better state of nitrogen nutrition. Thus in 5B the grass contains 4.0 per cent. N as against 4.42 per cent. for clover.

Secondly, there appears to be no consistent, difference in nitrogen levels between clovers which receive animal residues and those which do not. This does not necessarily mean that the clover plants in' a mixed sward do not take up nitrogen from dung and urine voided on the soil. The evidence from overseas workers is that they do take up nitrogen from the soil and that while extraneous nitrogen is available the nodules tend to adopt a go-slow policy, only returning to full activity when those extraneous sources are exhausted. The tendency from this trial appears to be that clover will absorb nitrogen only till a certain level is reached in the leaf. The addition of extraneous nitrogen, as in urine, will not increase the leaf level and, as I have already indicated, the probability is that the nodules decrease in -activity.

Thirdly, an interesting interaction between nutrients appears in the no-return series. If we compare the nitrogen content of the grass in 2A to which no additions are made with that in 5A to which both lime and phosphate are applied, we find slightly but consistently higher nitrogen values in 5A as against 2A. The reason for this appears to be largely in the added phosphate, since where lime only is added there is no definite increase throughout the course of the trial, whereas where phosphate is added the picture is much the same as for both additions.

The effect of added phosphate and lime on the nitrogen level of clovers follows approximately the same course as it does with the grass, and again the slight increases in leaf level seem to be attributable to phosphate. I think we may say that protein synthesis in dover is at a maximum only when phosphate supplies are adequate, and that the underground transfer of nitrogen from legume to non-legume is greater where the legume is not limited for phosphate.

These phosphate responses disappear in the B series where animal droppings are returned.

The responses in this case as in other eases mentioned earlier are small, as is their apparent significance. But I am not so sure that their true significance is so small. If leaf levels of a certain element may be taken as an index of efficiency of the uptake and metabolism of that element, then it is possible that these small differences may be significant. Moreover, this trial has been going for only 3½ years and it is possible that small differences now may become much larger differences in the future.

There is another digression in this direction which must be made at this point. You have possibly had the thought in mind that the A series which is under mowing is entirely divorced from normal farming practice. I would agree, provided that you leave out the word "entirely," and that proviso is added because of the excretory habits of grazing animals. To take wethers as an example, we have determined over the course of several years the average quantity of urine passed by a sheep, the number of times it urinates, and the area of ground affected by a urination. With that information we can calculate the frequency with which any piece of pasture is likely to become a urine patch. Even with the high stocking rate possible on the pastures of the B series, i.e., about 10 mature sheep the whole year round, the probability is that the period between urinations on any patch of pasture is nearly a year. This period, of course, would go up with decreasing pasture production and decreased

TABLE L-LAYOUT, GROSS BOTANICAL COMPOSITION, AND YIELDS FOR 1948-49 SEASON.

	A. SERIES-NO DUNG OR URINE.						B. SERIES—DUNG AND URINE ADDED.					
Plot No. . .	1A	2A	3A	4A	5A	6A	1B	2B	3B	4B	5B	6B
Fertiliser .	Nil	Nil	Phosphate	Lime	Phosphate +Lime	Phosphate +Lime	Nil	Nil	Phosphate	Lime	Phosphate +Lime	Phos. phate +Lime
Pasture . . .	Grass	Grass+ Clovers	Grass+ Clovers	Grass + Clovers	Grass+ Clovers	Grass	Grass	Grass+ Clovers	Grass+ Clovers	Grass + Clovers	Grass+ Clovers	Grass
Per Cent. Grass	99	47	45	44	41	98	97	69	70	66	66	98
and Clover	0	53	55	56	59	0	0	31	30	34	34	0
Total Dry Matter, Production 1948.49	2000	9500	11500	9.500	12000	2000	6500	16500	16500	16000	16000	6500
Per Cent. Crude Protein. 1948-49 .	15.9	26.5	27.7	26.6	28.4	15.0	20.0	28.4	28.0	29.0	28.8	20.5

stocking rate. We do not know for how long a urine patch is effective, but on present indications it is less than three months. For the rest of the year, or 15, or 18, or 24 months as the case may be, that patch is under the same conditions as the A series of plots, and it is for this reason that I have'stressed the behaviour of grass and clover in the A series.

Seasonal variation in nitrogen levels of clovers is not particularly marked-from a minimum over all samples of 4.4 per cent. to a maximum of 5.6 per cent. The variation in grass is considerably greater-from 2.9 to 4.7 per cent. in the A series and from 3.2 per cent. to 5.2 per cent. in the B series. As would be expected values are high in spring for both species and low in summer and autumn. What is rather surprising is that the highest values recorded occur in winter. The highest value recorded for grass was 5.3 per cent. in the winter period of 1948, this figure corresponding with 33 per cent. crude' protein. 'It is of interest that the highest value of crude protein ever recorded for pasture herbage, viz., just over 40 per cent. protein, was also from a winter sample. This value was reported by workers from the Soil Fertility Research Station at Hamilton some three or four years ago. From another trial on this area average nitrogen content of grass for the period from June till August was 6 per cent., representing a crude protein content of 37.5 per cent.

CONCLUSION.'

In this brief paper I have tried to summarise the main results emerging from this trial which. is now well into its fourth year, and for every question that. has been answered five new questions have arisen. Some 'of these questions will, we hope,. be answered by the results of duplicate trials which are now in progress at Lincoln and Gore, while new experiments arising out of the present trial have been laid down at Palmerston North. I should like to see the critical parts of the trial, particularly as they relate to phosphate turnover through the grazing animal, on a very much poorer soil than that. at Palmerston North.

The final point I should like to stress is that in all pasture work we are dealing with soil,, plant, and animal, and that any changes induced in one component of this complex is reflected in the other two. And the chief factors in bringing about an increase in pasture production is first the clover plant and 'secondly the grazing animal.

TABLE II

GROSS YIELDS EXPRESSED AS LBS DRY MATTER PER ACRE

	1946-7	1947-8	1948-9
2A	40.00	1500	2000
3A	12000 11500	11000 9500	11500 9500
4A	11500	10500	9500
5A	11000	11000	12000
6A	3500	1500	2000
1B	5000	3500	6500
2B			
3B	11000 11500	12500 12500	16500 16500
4B	11000	11500	16000
5B			
6B	11500 6000	12500 3500	16000 6500

TABLE III

GROSS GRASS YIELDS, AND RYEGRASS EXPRESSED AS A PERCENTAGE OF TOTAL GRASS COMPONENT.

Period	lb D.M./ac	% ryegrass	Period	lb D.M./ac	% ryegrass
	1A			2A	
-2/47	3150	90	-2/47	3330	88
2/47-2/48	1800	63	2/47-2/48	2840	63
2/48-2/49	1500	21	2/48-2/49	3890	46
	5A			5B	
-2/47	3260	90	-2/47	6210	87
2/47-2/48	3260	65	2/47-2/48	6450	79
2/48-2/49	4610	49	2/48-2/49	9130	87

TABLE IV

AVERAGE CaO FIGURES EXPRESSED AS PERCENTAGES : 1946-9.

	Grass	Clover		Grass	Clover
1A	0.91		1B	0.87	—
2A	0.70	1.93	2B	0.74	1.86
3A	0.72	1.96	3B	0.77	1.92
4A	0.77	1.97	4E	0.78	1.93
5A	0.76	2.10	5B	0.79	1.95
6A	0.93		6B	0.96	

TABLE V

AVERAGE P_2O_5 FIGURES EXPRESSED AS PERCENTAGES : 1946-9.

	Grass	Clover		Grass	Clover
1A	0.99	—	1B	1.17	—
2A	1.14	0.03	2B	1.16	1.06
3A	1.26	1.01	3B	1.20	1.10
4A	1.17	0.92	4B	1.17	1.02
5A	1.34	1.05	5B	1.18	1.10
6A	1.14	—	6B	1.24	—

TABLE VI

AVERAGE K_2O FIGURES EXPRESSED AS PERCENTAGES : 1946-9.

	Grass	Clover		Grass	Clover
1A	2.5	—	1B	3.24	—
2A	3.87	3.2	2B	4.77	3.94
3A	4.04	3.18	3B	4.74	4.00
4A	4.00	3.27	4B	4.70	3.89
5A	4.2	3.02	5B	4.60	3.91
6A	2.61	—	6B	3.21	—

TABLE VII

AVERAGE N FIGURES EXPRESSED AS PERCENTAGES : 1946-9.

	Grass	Clover		Grass	Clover
1A	2.42	—	1B	2.94	—
2A	3.56	4.24	2B	3.98	4.38
3A	3.71	4.39	3B	4.03	4.46
4A	3.59	4.22	4B	4.05	4.38
5A	3.72	4.46	5B	3.98	4.42
6A	2.40	—	6B	2.98	—