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PASTURE UTILISATION BY THE ANIMAL.

by

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The title of this paper is one which has been a matter of some controversy. The original title proposed by Professor McMeekan was "The Measurement of Digestibility and Intake in the Grazing Animal". It seemed to us that this gave a somewhat erroneous conception of the objects of the experiments which are in progress at our respective institutions in Palmerston North, while it predicated a knowledge of ruminant nutrition to which we do not profess. The title as set down in the agenda paper is also misleading since pasture utilisation has a specific meaning to the pasture ecologist which is different from what we wish to discuss. We felt that to call the paper "Pasture Utilisation by the Animal" represented a fair compromise.

One of the outstanding achievements of the Grasslands Division has been the introduction by selection and breeding of better strains of ryegrass and clover. The results of the work of Mr Bruce Levy and associates in this direction and the increasing areas which have been sown with certified seed are matters which are too well known to require further description before this audience. But with the enormous increase in productivity of much of our pasture, has arisen a host of other problems. The idea is firmly fixed in the minds of many farmers and others that stock disease increases disproportionately with the increase in carrying capacity. The ryegrass-white clover association is one with its own growth peculiarities, and difficulties of management not infrequently arise which prevent the best final return in terms of animal products. This is particularly true of pasture in the stage of rapid growth during spring and autumn.

It is obvious that any institution which is concerned with the growing of pasture to suit a wide range of grazing requirements under the limitations imposed by soil and climate must take stock of these problems; it must interest itself in the value to the animal of the grasses and clovers which it recommends. To take a specific instance it seems probable from recent results obtained by Mr Corkill that a clover plant could be bred which would have a sufficiencly high content of glucoside and corresponding enzyme to cause HCN poisoning in stock. No matter how desirable may be the growth characteristics of such a plant, its economic use is out of the question.

One further point must be made in this introduction and for us it is a rather important one. The question might be asked why the information we are trying to gain about pasture utilisation should not be obtained from one or other of the grazing experiments which are running throughout the country. The answer is that we believe it to be impossible. In nearly every grazing layout the animal is regarded as sacred and every endeavour is made to see that it thrives and pays as well as possible. It is our contention that fundamental work on the effect not only of pasture on the animal but of the animal on pasture cannot be superimposed on such a programme. A time must come when there arises a difference of opinion between the pasture investigator and the animal investigator as to the management procedure to be adopted, and no compromise is satisfactory to both sides. In the utilisation experiments now under way the needs of the pasture will be met even at the possible cost of the animal.

This sharp line of cleavage is, of course, ultimately deleterious since the soil-plant-animal system is merely a biological complex, each member of which reacts to changes in the other. But what we plan is an experiment along the lines of experimentation hallowed by long tradition, viz., the intensive study of one part of the complex under the imposition of controlled changes in the other two. We believe that the information thereby derived is necessary for a study of the most important part of the problem which is the achievement and maintenance of the maximum yield of animal products per unit area.

The work which we are doing may be divided into two sections: (1) Measurement of pasture growth in such a way that the quantity of material consumed by the grazing animal may be calculated. (2) Measurement of feeding value of the pasture eaten.

The measurement of pasture growth has been the subject of study by many investigators over a long period of time. The methods which have been used are many and varied but the following summary represents the main lines of approach.

(1) Observations in the field. Farmers and pasture investigators are well aware that different species have different growth characteristics according to the month of the year, and to locality. By a process of trial and error good results can be achieved on any one farm by an intelligent use of such observations.

(2) The bucket method. The farmer is primarily interested in the number of gallons of milk or alternatively the number of fat lambs which can be produced per unit area, and his appraisal of various paddocks and of the value of the pasture associations within them are directly related to his cash returns.

(3) Yields of hay and silage. This has obvious limitations in that the pasture is allowed to produce its maximum dry matter yield at one time of the year. We know that the better the pasture the higher will be its yield of hay and silage, but no information can be deduced from such studies as to nutritive values under grazing conditions throughout the year.

(4) Simple mowing trials on ungrazed plots. This method has yielded results of great utility in the past and because of its simplicity is still valid for certain experiments. It does not take into account the two main functions performed by the animal viz. consolidation by trampling and return of dung and urine, while defoliation by the mower is quite different from defoliation by the animal.

(5) Mowing and grazing trials. These represent the best method to date for accurate determinations of the rate of growth of pasture. They allow of a suitable number of replications and are straightforward insofar as technique is concerned. There is, however, some controversy as to the effect of transference of fertility through the grazing animal.

(6) Self-contained block trial coupled with frames. This method guards against transference of fertility and enables stock measurements on any particular manurial or strain treatment to be made. It is admittedly expensive but represents the high water mark of pasture experimentation. The most difficult point lies in the determination of the size of the paddock. If too large sampling and grazing difficulties increase enormously; if too small, the rate at which stock is rotated is too great.

Even with the limitations briefly outlined above these methods have all been used at one time or another at the Station, while several have also been used in field work away from Palmerston North. Two points must be mentioned as being essential for all pasture productions experiments. First; Yields of pasture must be expressed on a dry matter basis. Results based on fresh weight are quite valueless for accurate investigation. Second: Botanical analyses on all herbage samples should be performed since it is obvious that the value of total dry matter yields are much enhanced by an accurate knowledge of the part played by the constituent species. We are endeavouring in all current trials to carry out chemical analyses of the separated species in order to get a more complete picture of the role played by each in the conglomerate which we call "nutritive value".

I think it will be obvious from the very short description given of methods of estimation of the food available to and eaten by the animal that the most controversial point is the effect of the grazing animal on the pasture. During the past year an experiment has been in progress to determine one isolated effect of the animal, viz. the effect of dung and urine on the yield and botanical and chemical composition of pasture. One acre of land was sown with a complex mixture and divided into ten paddocks. Four different types of management were applied. In one the animals grazed normally, dung and urine being returned to the pasture in the usual way; in the second the urine was collected and only the dung returned; in the third the dung was collected and only the urine returned; while in the fourth neither dung nor urine was allowed on to the pasture. Collections of excreta were made by means of harness to which the collectors could be attached, the dung collector being a rubber bag and the urine collector a modification of that devised by Messrs. Webster and Hutchinson of Massey College. We have used a metal container which we believe gives more satisfactory results than the original model.

Some interesting results have been obtained on the excretory capacity of the two tooth Romney wethers used throughout the trial. The largest volume of urine excreted during 24 hours was 14 litres which is well over 2½ gallons; while the lowest was 2 litres. The average excretion is 4 to 5 litres. The average amount of faeces per 24 hours is about 3 lb. but it is very noticeable that within a day of going on to new feed the amount goes up to 5 lb. while when feed becomes scarce at the end of the grazing period it drops to 2 lb.

I do not propose to deal in detail with the botanical changes which have taken place as a result of the various treatments. The graphs tell the story sufficiently well.

The quantitative collection of urine and faeces from the grazing animal permits of many determinations of interest to the animal and plant physiologist. As an indication I might quote some of the figures already obtained. The amount of food eaten by the animal was determined by the method of frames which were put in the paddocks just prior to grazing and clipped after the sheep came out (a period not exceeding 3 days). The nitrogen, potassium, phosphorus and calcium content of the herbage was determined, while the same elements were determined in the urine and faeces collected during grazing on the nil return plots. For the 6 months period from December, 1940, to June, 1941, the herbage contained 239 lb. of nitrogen, the urine 165 lb. and the dung 66 lb., a total excretion of 231 lb. The corresponding figures for calcium were 88 in the herbage and 88 in the dung and 1.4 in the urine; for phosphorus 56.8 in the herbage, 69.0 in dung and 1.2 in urine; and for potassium 204.1 in herbage, 27.4 in dung, and 173.7 in urine. For potassium, calcium and nitrogen ingestion and excretion tally within 3%. For phosphorus there is a difference of 20%. I do not propose to comment on the results beyond saying that in spite of the apparently large discrepancy in the phosphate balance, the results have encouraged us in the belief that our pasture measurement is along the correct lines and that with due care, quantitative collections of dung and urine can be made from the grazing animal.

Another result arises from the urine return experiment. Here the herbage ingested contained 300 lb. of nitrogen (calculated from pasture growth measurement). The dung contained 80 lb. of nitrogen giving a coefficient of digestibility for crude protein of 78%, a figure which agrees with other figures obtained from penned animals fed on similar type pasture.

But there is also another side to the picture and I do not want you to think that all our balance sheets work out to order. I have already mentioned one rather inexplicable result where potassium, calcium, and nitrogen intakes and excretions tally excellently indicating indeed a standard of accuracy of which the technique is incapable. But the phosphorus figures on the same samples of feed and excreta show a 20% discrepancy.

Again on the urine return paddocks a discrepancy occurs between the amounts ingested and obtained in the faeces. During the period December to June, the animals according to pasture measurement consumed 2700 lb. of dry matter. Hence the coefficient of digestibility of the dry matter would appear to be 66%. But in the light of our experience with other pasture herbage the digestibility coefficient should be of the order of 75-80%. Or to put it in another way: the amount ingested by the animals as determined by pasture measurement is 7600 lb.; the amount ingested as calculated from the faeces and a digestibility coefficient of 75% is 10,800, a difference of 30%.

I may say that we are not unduly perturbed by these discrepancies. We know that our technique is deficient in that the animals are on any one plot for a very short period and that no account is taken of the carryover in the animal at the beginning or end of the grazing period. This can and will be overcome by grazing on self-contained blocks. We believe that by modification and refinement of our technique results of very real value in the utilisation of pasture will be obtained. One obvious development would be the working out of a manurial mixture which would supply to a plot under mowing conditions, equivalent nutrients to those which would be returned by an animal grazing on it. Such a development would be of the greatest utility to the plant breeder in testing new lines under field conditions without the use of animals.

One further point which I think will be of interest to all. From the figures obtained from our first year the total return of essential nutrients to a high production pasture would correspond with over a ton of sulphate of ammonia, 6 cwt. superphosphate, 2½ cwt. of carbonate of lime and of 15 cwt. 30% potash salts. These are conservative figures in that the pasture will probably produce more in the coming year than in the last, but a slight overestimate where losses due to milk or fat lambs produced are taken into account.

So much for our attempts to measure pasture growth or, if you prefer it, the intake of the grazing animal. I wish to spend the rest of the time allotted to me to a consideration of the value to the animal of the food ingested. There are two main approaches to this problem, one by chemical analysis of the feed and the other by feeding trials with animals.

There can be few analyses which can compare in venerable old age with the conventional analyses whereby rations for live stock are evaluated. The separation into ash, crude protein, ether extract, crude fibre and nitrogen free extract is based on the work of two German agricultural chemists, Henneberg and Stohmann. In 1865 they published their methods which are used today with only slight modification in the thousands of feed analyses appearing in modern scientific publications.

Ash, crude protein and ether extract need not detain us although each presents its own problem to the nutritionist, but I should like to dwell on the crude fibre and nitrogen free extract for a little. These together may be designated as the carbohydrate fraction and in pasture herbage comprise from 50-80% of the dry weight of the feed. For the benefit of those who are unfamiliar with the methods employed for the separation of the carbohydrate fraction, I shall briefly describe the procedure. The dried feed is freed from fats, waxes and pigments by exhaustive extraction with ether. The extracted material is refluxed for exactly 30 minutes with 1.25% acid and then with alkali of the same strength for the same time. In this way the proteins, starch and sugars are quantitatively removed, leaving as residue most of the cellulose and other complex polysaccharides along with some mineral matter. The loss on ignition of this dried residue is taken as the crude fibre. The nitrogen free extract which comprises the sugars, starch and a large part of the ill-defined material classed as hemicelluloses is determined by difference. It is represented by the figure obtained when the sum of the ash, protein, fat and crude fibre of a feed is subtracted from 100. It obviously includes the cumulative errors of other determinations and is not a precise value, and yet in herbage analyses this fraction seldom amounts to less than 40% of the total feed.

A more unsatisfactory state of affairs from the point of view of the plant chemist can hardly be imagined. The fractionation achieved by the conventional method of analysis bears no relation to the structure or function of the leaf, and although with experience the chemist can deduce some information from the analytical data as to stage and rapidity of growth they are useless for studies in plant metabolism.

To sum up the criticisms which can be directed against the conventional fractionation of the carbohydrate fraction I can hardly do better than quote Professor Norman formerly of Rothamstead and now of Iowa: "It would be an important advance if the determination of crude fibre and its use in expressing pasture composition were abandoned as inadequate, unreliable and misleading."

But the defender of the conventional analysis of feed does not claim that the methods are of use in plant physiological studies. He does claim that they offer a very useful and satisfactory index to the nutritive value of any feed and he may point with pride to the standards of feeding value which have been set up as a result of tens of thousands of such analyses. He might also point out that the separation of the carbohydrate fraction into crude fibre and nitrogen free extractive does make a distinction, although not an absolute one, between the more and the less digestible carbohydrates.

As a plant chemist the least that I should like to see in any analyses of the carbohydrate fraction, would be figures for cellulose, lignin and the hemicelluloses, with further differentiation if possible of the last fraction. The analytical methods for these materials are not entirely satisfactory but they do give infinitely more precise information regarding the composition of the cell wall than is given by the crude fibre figure. Recent results of a number of investigators would indicate that lignin is almost entirely undigested by omnivorous or herbivorous animals, that cellulose is digested to a marked degree through the action of bacteria in the rumen and that the hemicelluloses are also fairly highly digestible.

As I have already said this would be more satisfactory from the point of view of the plant chemist, but would it also be an advance insofar as the nutritionist is concerned? My own vote would be cast with those who prefer the more precise determination even though I recognise the difficulties in the way of its general acceptance. These difficulties are many but it seems to me that the three main ones are: (1) All feed analyses where a starch equivalent or net energy value has been arrived at would have to be repeated and factors, similar to that used now with crude fibre, would have to be calculated for lignin and cellulose; (2) Analytical methods for the new determination are more tedious and analyses would be more expensive; (3) The determination of lignin, cellulose and hemicellulose may still leave us with considerable uncertainty as to the fate of these separate chemical entities in the alimentary tract of ruminants. The reason for this is not clear unless something is known of the structure of the cell wall in leaves, and that is not a subject which I propose to deal with here. It is sufficient to say that the progressive increase in lignin with increasing age of the leaf means not only that a totally indigestible fraction is increasing but that through the incrustation of cellulose by lignin, the digestibility of the cellulose is decreased by purely mechanical means. It is the ultimate aim of all this work to replace feeding trials on animals with a chemical analysis which will tell exactly the same story.

We are a long way from that goal and we still have to use digestibility trials to get a reasonable picture of nutritive value.

of pasture herbage. And that brings me to my final section, viz. the trials which have actually been run at Palmerston North.

The method used relates almost entirely to sheep, although isolated trials have been carried out with calves and milking cows. The sheep are pen fed in a shed which will take four animals. Collection of dung is made by means of the same apparatus as for the trials already described. Feeding has been on the ad. lib. basis and results obtained have to be interpreted in light of this. As a result of our experience gained through 15 trials on duplicate animals in each case, we believe that the following points are important if good results are to be obtained.

(1) The feed must be clean and free from dung and dead bottom. Any unpleasant odour in the feed causes rejection by the animal. The importance of this factor cannot be overemphasised and numerous illustrations can be seen in any paddock, where the grass round dung pats is left severely alone. A recent illustration occurred on a newly sown block at the Station. The pasture had become muddy through trampling and was eaten bare along fence lines where trampling had not occurred.

(2) The sheep must not be disturbed during feeding, since disturbance always leads to spreading of the feed over the floor.

(3) Length of herbage does not seem to matter, but sheep object to wilted herbage so that care must be taken to see that the sun does not shine directly on the feed.

(4) We were successful in feeding silage provided that it was not too wet and that it was not compacted.

(5) An arrangement to catch rejected feed and to prevent it falling on the floor has proved its great value.

(6) It is essential that results for the food offered and rejected be reduced to a dry matter basis.

Five feeding trials with sheep on pasture at different stages of growth were conducted during the spring months. In every trial the sheep were given a five day pre-feeding period and a ten-day experimental period. In all pasture trials the sheep ate at least 3 lb. of dry matter per day, the highest recorded amount being 5-6 lb. by an animal which had eaten about 3 lb. on the previous days. All sheep gained weight during the experimental period, the increase varying from 3-7 lb.

In the silage trials difficulty was experienced at first in inducing the sheep to eat, but, except with certain samples which were known to be of poor palatability, successful feeding was always achieved. Dry matter ingestions in six trials averaged $1\frac{1}{2}$ lb. per day, the highest daily intake being $2\frac{1}{2}$ lb. In two cases only did sheep lose weight, while one sheep had to be removed after 7 days because it was obviously not doing well. The remainder held their initial weight and tended to gain slightly in some cases. Considering the known difficulties of feeding silage to sheep these results are encouraging.

Everybody who has studied digestibility investigations knows the way in which analytical figures pile up, and we believe that even summaries of digestibility coefficients would take too much time to present, even in the sketchiest manner. The details are, however, available for anybody who wishes to pursue the matter further.

The chief point of interest in both the silage and pasture trials were the high levels of digestibility as compared with European and American figures. Dry matter digestibilities in four out of five pasture trials were over 80% with correspondingly high values for the separate fractions of the feed. In the fifth trial the material was at an advanced stage of growth and was 18" - 24" long. Even here the digestibility coefficient for dry matter was 73%.

Dry matter digestibility coefficients on silage were of a lower order than those on pasture and varied between 65 and 74% according to the type of silage. One interesting feature was the high apparent digestibility of the crude fibre which was in all cases over 80%, and was always the most digestible fraction. The implication in light of our criticism of the crude fibre determination is obvious.

I think it will be realised that these experiments are at a very preliminary stage. We have raised more questions than we have answered and this perhaps is the most important part of our contribution. It is our hope that the scattered and uncoordinated results which we have been able to present justify your invitation to present them.

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