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GRAZING MANAGEMENT*

C. P. McMEEKAN

Ruakura Animal Research Station, Hamilton.

AT THE 6TH INTERNATIONAL GRASSLAND CONGRESS, our American colleagues honoured me with the invitation to deliver the plenary paper on the pasture/animal complex. In New Zealand, the 7th Congress provided the opportunity of again advancing the view so often neglected, that pasture production cannot be considered independently of animal production. That the 8th Congress should have asked me to open a session on grazing management would suggest that modern pasture specialists are now keenly aware of the symbiotic association of plant and animal production in practice.

To one interested mainly in animal production from grassland, this is encouraging. Yet it is disappointing still to read so many dissertations on the production and use of grass, where the animal is regarded almost entirely from the viewpoint of its harmful or beneficial effects on the pasture complex.

Thus, a prominent British leader of grassland research wrote recently (Davies, 1958): "The production and use of grass is quite complex, and its proper exploitation often demands an appreciation of the underlying principles of plant growth and an understanding of the effects the grazing animal has upon the pasture." To me this is but half the story, since the use of grass involves just as much an understanding of the principles of animal physiology, of animal nutrition, of animal husbandry, and of animal health. That this is so is well illustrated by the many problems associated with grazing management in its widest sense.

At the outset I must re-state the three basic factors upon which the efficiency of conversion of pasture to animal products depends (McMeekan, 1956). These are:

(1) The amount, quality and seasonality of the pasture crop.

(2) The proportion of this crop actually harvested by the animal.

(3) The efficiency of conversion within the animal of the fodder consumed.

*Previously delivered to the 8th International Grassland Congress, 1960, and reproduced with the permission of the Congress Committee.

Each of these is affected by grazing management. The selection of the grazing method, the number of animal units employed in harvesting, and the kind of animals used in terms of their physiological state and their inherent productive merit, interact not only with each other, but with the quantity and quality of pasture feed grown, its seasonality of output, the percentage harvested by stock, and the efficiency of conversion to animal products. Over-riding all of these, on occasions, is the efficiency of animal husbandry, since poor animal management can nullify completely the benefits of potentially superior grazing systems. If this paper gets no further than to secure still greater recognition of the need for plant and animal specialists to join forces in fact as well as in theory in the search for better pastures, better used, its major function will have been fulfilled.

A pasture has been defined as a biotic climax (Tansley, 1939) and it is with the complex inter-dependence of the plant community and the grazing animal that the problem of achieving maximum output of animal products from grassland is concerned. I do not propose to burden you with an analysis of how, on a broad scale, the relative inflexibility of pasture growth in relation to environment controls the stratification of animal industry, nor how, within each stratum, the pasture and animal factors can be manipulated by species selection, cultural practices, conservation techniques and grazing methods on the one hand and through control of animal number, genetic merit, reproductive state and nutritional status on the other, to get the optimum degree of integration of the two (McMeekan, 1952).

My special responsibility here, concerns the impact of grazing management, which I have argued on so many occasions as comprising three components controllable by man—the grazing method, the stocking rate and the kind of stock used (McMeekan, 1956).

In practice, it is our task in seeking maximum production from grassland within any particular system of animal production, so to manipulate the grazing factor that the maximum yield of animal products is obtained without upsetting adversely the equilibrium of the pasture complex. Aspects of the grazing factor that can be manipulated most easily by the three components listed are the severity of defoliation and the frequency of defoliation.

It is not unexpected, therefore, that pasture specialists seeking improved grazing methods should have concentrated upon studies of the precise role of frequency and severity of defoliation on pasture productivity. It is also reasonable that, having established the reality of such effects, measured almost always in the absence of the grazing animal, they should have proceeded to recommend grazing systems involving the animal with little, if any, attention to necessary intermediate steps.

It is only of recent years that experimental verification of the various theories underlying different methods of grazing, and involving animal products as a criterion of effects, has been attempted on any scale. It has been somewhat disconcerting to find that methods, apparently soundly based in terms of pasture yield measurements, have had either negligible or small effects on animal production.

It is not proposed to review the extensive literature on the effects of severity and frequency of defoliation upon the botanical composition of the sward and its quantitative and qualitative yield. All grassland workers are familiar with the significant contributions. It will be agreed that the great bulk of early studies demonstrated an inverse relationship between the yield of pasture dry matter and both the severity and frequency of defoliation. Conversely, the theoretical nutritive value of pasture dry matter was found to be positively related to both severity and frequency of cutting, so that some compromise was argued as being necessary to achieve the maximum production of high quality herbage from a sward.

In the main, two explanations of the adverse effect of severe and over-frequent defoliation upon yield, gained general acceptance. On the one hand the cumulative effects of depletion of root reserves through energy transference to new growing points of the plant following cutting and on the other hand the reduction in the quantity of light intercepted by the defoliated plant, combine to reduce recovery rate and lower total yield. Botanical changes in a beneficial or harmful direction were demonstrated as due to the different response of different species and strains to defoliation and to competition hindered or aided by the light interception factor. Changes in the chemical composition, and hence in assumed nutritive value, were attributed to ageing effects within the plant as its flowering stage approached as well as to variations in the leaf/stem ratio of herbage cut at different stages of growth.

In these circumstances, and since it was plausibly expected that the total dry matter yield of the sward must govern its animal productivity, it was logical that grazing methods involving the principle of intermittent defoliation should have been accepted as scientifically sound, and in consequence should have been widely advocated. Alternate spelling and grazing at intervals appropriate to the environment and to the specific pasture type would increase pasture yield and effect a satisfactory compromise between quantity and quality from the animal viewpoint. In contrast, continuous grazing was condemned as harmful to both pasture yield and animal output.

Recently, the major experiments contrasting continuous and intermittent grazing in a wide variety of environments throughout the world have been ably reviewed (Freer, 1959). Of 15 separate studies, rotational systems of one form or another showed to small advantage over set stocking in only two instances. Set stocking was slightly superior in two cases, while results were indefinite or showed no difference in the remaining eleven studies.

Set stocking or continuous grazing can involve the use of a single field grazed by all stock at all times, or a diurnal shift between a day and a night paddock, or the use of these two in conjunction with a young stock or dry stock area. Intermittent or rotational grazing can describe a multitude of systems ranging from a daily shift around three or four fields to a shift around thirty or more, or from weekly alternation between two fields to weekly shifts around six or eight paddocks. It can even mean stepping up the intensity of grazing on a "strip basis" to provide stock with one, two, or even more new strips per day. When all these possible variations in set stocking on the one hand and rotational grazing on the other are remembered, it is hardly surprising that no universal agreement has been reached on the best method of grazing in any particular situation. This becomes even less surprising when the multiplicity of possible pasture types, stocking levels and classes of stock used are considered.

While these arguments are sound enough to explain the general lack of agreement as to the best method of grazing, other causes must be sought for the widespread failure of rotational systems relative to set stocking when these have been contrasted under experimentally controlled conditions. It is rather necessary that such reasons should be sought, since the superiority of grazing methods based upon alternate grazing and spelling has been widely accepted in practice in the more intensively used grassland areas of the world. There are many possibilities:

(1) It is obvious that of two pastures, similar in nutritive quality and utilized and converted by the animal with equal effici-

ency, that which yields the most dry matter per acre should give a greater output of animal products. However, it may be that in attempting to approach maximum production of herbage something may be lost in terms of quality, efficiency of utilization and efficiency of conversion. It may not, therefore, be axiomatic that a grazing method which grows the most grass is the superior method. Evidence produced later supports this hypothesis.

(2) Despite the evidence from cutting experiments, it is not necessarily true that a system involving alternate spelling and grazing does result in a greater total herbage yield from a pasture than do continuous grazing systems. The introduction of the animal into the complex brings to bear a series of interacting forces that can upset predictions. From studies to be described, it will be clear that this possibility can become a reality.

(3) The "root reserve" theory which is basic to the concept of more grass under alternate spelling and grazing may be unsound, or at least of less importance than hitherto believed. The theory has been challenged recently by Australian workers (May and Davidson, 1958) who claim that the precise role of carbohydrate reserves in plants after defoliation is still a matter of speculation. There has been tacit acceptance of the importance of reserve substances in determining regrowth, but no critical work on the fate of root reserves or stem base reserves has been carried out. These workers claim that the majority of the carbohydrate reserves are used for plant respiration and only to a minor extent as substrate for synthesis to new growing points (May and Davidson, 1958).

(4) On closer examination, the "light interception" theory can be used to support set stocking rather than rotational grazing under specific conditions. Recent studies have shown that both close defoliation and long rest periods (through shade effects) can reduce the production of a sward (Brougham, 1956; Davidson and Donald, 1958; Mitchell 1955a, 1955b, 1956). It is not impossible to maintain the L.A.I. approximating the optimum under continuous grazing (Donald, 1956). Indeed it may be easier to do this with a dense sward continuously grazed than with one that is more open and erect due to lenient intermittent grazing.

(5) It is probable that the importance of the reproductive phase to the total annual and seasonal production of herbage grasses has not been sufficiently recognized. It is during this phase in New Zealand that dry matter per acre increments rise rapidly from 30 to 40 lb per day to 80 to 100 lb or more. Destruction of the apical meristem at this critical phase by over-grazing which can occur very easily under a rotational plan owing to bad timing, can seriously reduce pasture yield (Davies, 1956; Anon, 1956; Campbell, A. G., pers. comm.).

(6) Most set stocking versus rotational grazing experiments have been conducted on a schematic basis, arising primarily from a desire for a neatly designed experiment amenable to standard statistical analysis. Such designs have ignored basic facts involved in the biology of pasture growth and animal needs. Pastures do not grow uniformly so that fixed time intervals between successive grazings are unrealistic in terms of and are in conflict with principles underlying intermittent grazing. Their recovery rate after defoliation is influenced by a wide variety of environmental variables such as temperature, moisture status, fertility level, contour, etc., as well as by the previous grazing history in relation to these factors. Any system of rotational grazing management which ignores the effect of variable recovery rate is basically artificial and unsound. Similarly, animals do not respond efficiently to uncontrolled variations in intake (McMeekan, 1956). They can benefit from rationed feeding at times, which often coincide with critical periods of normal pasture growth (Wallace, 1959). Such control of intake is not possible under any schematic rotational grazing plan. It is of interest to note that the system of rotational grazing management universally practised with all classes of stock in New Zealand and which is associated with very high per acre output on a continuing basis is not a schematic system but a controlled one, characterized by orderly disorder in the grazing pattern.

(7) Most major experimental studies have operated with fixed stock numbers or variable numbers added to or subtracted from the experiment by judgment according to the observed or expected feed supply. They have not involved pasture conservation, which surely is an inseparable part of any rotational grazing system in practice. When stock numbers

are held constant throughout the year, or even when attempts to vary them are made, much feed is wasted under both set stocking and rotational grazing when conservation is not practised. A widely quoted Australian experiment with sheep which failed to show any advantage of rotational grazing suffered from this defect (Moore *et al.*, 1946). It has been pointed out that the proportion of herbage consumed in this study was 100% of that grown for only 4 weeks and averaged 9% during the spring flush, when 80% of the total seasonal growth was made. Obviously no marked difference between grazing techniques could be expected under such conditions (Davies, 1946).

(8) The moisture status of the pasture, particularly during dry summer weather, can be better under dense swards more typical of set-stocking systems than under the more open and upright swards characteristic of rotational methods. We have observed this to be so in New Zealand studies of these two methods under dairy cow grazing (Campbell, A. G., pers. comm.).

(9) Differential winter pugging effects upon pasture yield are likely to occur to the advantage of set stocking in many environments. While critical experimentation with this variable is necessary, field observations suggest strongly that most rotational systems can suffer adversely from the influence of pugging.

(10) The precise role of dead material build-up, especially that which occurs in summer dry periods, has not been assessed under different grazing methods. Its magnitude could complicate seriously the relative merits of the two basic systems under discussion. New Zealand data show this dead material to assume proportions in summer as high as 50 to 60% of the total dry matter. In absolute terms this is greater in laxly grazed pastures (Campbell, A. G., pers. comm.) Much of this material is rejected by stock; much rapidly disappears. This factor has been ignored in cutting experiments contrasting various defoliation procedures.

(11) It is a fallacy that normal set-stocking methods necessarily involve close continuous defoliation. It is equally a fallacy that rotational grazing methods necessarily avoid this condition. Where stock numbers, apart from natural increase, are static, as is necessary in any practical applica-

tion of either system, set-stocked pastures can be very laxly defoliated in spring and early summer, since the overall stock numbers must be determined by and adjusted to winter carrying capacity. On the other hand, a rotational plan, especially when this involves fodder conservation as a logical and inescapable part of the cycle, can lead to closer defoliation than desirable when too large areas are withdrawn from the grazing cycle for conservation in spring or when the interval between grazing is abnormally lengthened in autumn and winter.

(12) The nutritive quality arguments underlying advocacy of one system or the other may be unsound. It is no news that we still have no reliable method of assessing the true value of pasture as a food for livestock. The need for this before the results from past and future grazing experiments can be evaluated is well illustrated by New Zealand studies which have demonstrated that a pound of digestible organic matter varies in its milk-producing function over the year, even when cows are grazed on pasture on a rotational plan, so that the herbage so far as is practicable, is at a comparable stage of growth.

(13) Because of the carry-over effect upon animal production of previous feeding treatments, and because of the differential expression of these under different pasture intake levels at critical periods (McMeekan, 1956), schematic comparisons of grazing methods can yield different and extremely confusing results. Where such experiments involve pasture feeding for only part of the year or supplementary feeding with non-pasture concentrates during the progress of a grazing experiment (Voisin, 1959), confusion is worse confounded in the eyes of any animal man.

(14) Efficiency of conversion of feed to animal products by the ruminant is not necessarily directly proportional to level of intake. There is much evidence that greater efficiency is associated with lower intakes than maximal, even when these result in lower per animal yields. It is thus likely that maximum response from any grazing method requires more delicate adjustment of feed supply and animal needs in an efficiency sense than has been achieved in any of the experiments conducted so far. It is in this field that stocking rate and kind of animal are probably such key factors.

All these possibilities add up to three main conclusions:

(a) It is not necessarily true that systems based upon rotational grazing do grow more grass of greater nutritive value.

(b) Verification of the theoretical expectations of a rotational regime can fail because of poor experimental design which ignores basic biological aspects of both pasture growth and animal requirements.

(c) Much more critical experimentation, both basic and applied, is essential before it will be possible to develop optimum grazing methods, soundly based and adapted to specific environments and to specific purposes.

From this general background I must move on to describe the more recent stages of my own attempts to evaluate some of the issues involved in grazing management, and, in particular, the interactions between grazing method and stocking rate.

Those who were present at the 7th International Grassland Congress when my analysis of the relative importance of grazing method, kind of stock and stocking rate was presented, will remember the criticisms evoked from all quarters of the globe. These arose from the natural reluctance of most grassland specialists to accept the relatively small superiority of rotational grazing systems over set stocking in practice. The main argument was that I had restricted the potential effect of more intensive grazing methods by comparing them always under the same stocking rates.

Critics insisted that rotational techniques must result in the production of more feed which could not be taken advantage of unless more stock were carried. My reply was to point to our data, which showed quite conclusively that, under precisely the same method of grazing, the number of stock used per acre or per hundred acres materially affected the efficiency of pasture use. (McMeekan, 1956; Walker, 1955; Lambourne, 1956; Hancock, 1953.). I also argued that no one had ever insisted that stock numbers have to be increased in order to take advantage of the benefits of rotational grazing methods. I suggested, too, that the same critics would have been the first to have complained had I designed the experiments in such a way as to use differential stocking rates predetermined by the hypothesis that rotational grazing in fact produced more feed. Obviously, such a design would be unsound, since it would not sort out the conflicting contribution of method of grazing and numbers of stock.

The "war" waxed fast and furious. In the end we agreed that there was a very definite need for experiments so designed as to study not only the individual contribution of the two variables, but also the interaction between them.

Accordingly, I re-designed the Ruakura Number 2 Dairy experiment on which I had been contrasting set stocking and controlled rotational grazing for so many years. I accepted the suggestion that the number of stock under rotational grazing should be stepped up to make full use of the more grass theoretically to be grown. An arbitrary increase of 30% was decided upon. Since it is rather unfair and certainly not completely informative to run two rotationally grazed farms at two different stocking rates and a set stocked farm only at the lower stocking rate, I decided also to increase the number of cows under set stocking by the same proportion.

It will be noted that this design gave four farms, two of which are managed on a set stocked basis and two on a controlled rotational basis. Under each grazing method, one carries a "low" rate of stocking and the other a rate 30% higher. Since land restriction limited cow numbers, and in order to avoid the presence of young stock which would complicate comparisons, I decided to run the new experiment with milking cows only. I believed that this would increase precision.

In this re-designed experiment it was also my object to maintain the two original farms and treatments as closely as possible to what they had been for the previous 12 years. To this end, we calculated from our pasture intake data the number of milking cows that would have to be added to the "low" stocking rate farms to approximate the same grazing pressure as had operated when both were run on a self-maintaining herd basis. This figure worked out at 25% increase in cow number per farm. Thereafter the number of cattle placed upon the "high" stocking rate farms was lifted by another 30%.

In practice this meant that we started off three years ago carrying 40 milking cows per 42 acres on each of the low-stocked farms and 40 cows on 33½ acres on each of the high-stocked farms. These rates were maintained for two years, after which two more cows were added to each farm. During the last year, therefore, the two low-stocked farms have carried 42 cows per 42 acres and the two high-rate farms 42 cows per 33½ acres. All four farms have been completely self-contained in feed provision. What have been the results to date?

TABLE 1: PER COW AND PER ACRE YIELDS OF BUTTERFAT AND MILK FROM THE FOUR TREATMENTS (MEAN OF THREE YEARS)

Grazing Method/ Stocking Rate	*Yield per Cow* Fat lb	Milk gal	*Yield per Acre* Fat lb	Milk gal
Controlled/light	431	947	417	916
Controlled/heavy	402	878	488	1,067
Set stocked/light	414	910	401	881
Set stocked/heavy	355	784	431	952

Table 1 averages the production figures of each farm for the three years. Such summarization is not strictly permissible because of the increase in stocking rate which was made on all farms at the end of the second year. I believe, however, that the figures do illustrate the principles involved in a more understandable way than is possible from the mass of data on a separate year basis. The data show that the results are in accord with predictions. Increased stocking rate under both grazing systems reduced per cow production but increased per acre output. Controlled grazing was superior to set stocking under both high and low stock density.

The data are noteworthy for the high per cow and per acre outputs recorded. The average output for the three years of 488 lb butterfat and 10,668 lb milk per acre from controlled grazing in combination with high stocking is impressive by any standards. This is specially so since grass yield data from the four farms averaged between 10,000 and 11,000 lb of herbage dry matter per acre per annum, which is substantially less than that obtainable from better soil types with better quality swards.

Returning to the comparative angles, these are probably most easily seen from Table 2 where the plus or minus differences of each system in relation to the others are set out. Six comparisons are possible.

The first point emerging (comparison 1) is the closeness of the results both per cow and per acre between controlled grazing and set stocking at the lower stocking rate of 40 to 42 cows per 42 acres. The mean difference of 4% in favour of controlled grazing is so small as to be negligible. The superiority of controlled grazing, however, is several times greater (comparison 2) when both systems are compared at the higher stocking rate of 40 to 42 cows per 33⅓ acres, the advantage averaging 57 lb of butterfat per acre, or 13%. Since all three years were good grass-producing years, the relative small overall advantage of the controlled system in both cases is in line with the results pre-

TABLE 2: MEAN DIFFERENCES BETWEEN TREATMENTS IN YIELD OF BUTTERFAT PER COW AND PER ACRE.

Comparison	*Yield per Cow* Actual lb	*Yield per Cow* Percentage	*Yield per Acre* Actual lb	*Yield per Acre* Percentage
1. Controlled *v.* set stocking at lower rate	+17*	+4	+16	+4
2. Controlled *v.* set stocking at higher rate	+47	+12	+57	+13
3. Controlled at higher rate *v.* set stocking at lower rate	−12	−3	+87	+22
4. Higher rate *v.* lower rate under controlled grazing	−29	−7	+71	+12
5. Higher rate *v.* lower rate under set stocking	−59	−14	+30	+7
6. Higher rate under set stocking *v.* lower rate under controlled grazing	−76	−19	+14	+3

*All differences are those obtained when the production of the second treatment is subtracted from that of the first treatment set out in the comparison column.

viously reported from the ten-year comparison of these two grazing systems. Then, the effect of rotational grazing was small or even zero in years when ample grass was grown.

The second point justifies the suggestion that the full benefits of controlled rotational grazing may not be obtainable unless associated with increased stocking rate. Comparison 3 summarizes the results where this was done. Here controlled grazing at a high stocking rate was superior to set stocking at a lower stocking rate by 87 lb of butterfat per acre or 22%. This result was achieved despite a fall in per cow yield of 12 lb of fat or 3%. This result must be considered in relation to the good grass years experienced. The difference could be expected to be considerably higher in years when marked variability in growth of grass tends to penalize a set-stocked system.

Comparisons 4 and 5 measure the effect of stocking rate under each of the two grazing methods. The most interesting feature is that increasing the stocking rate had a greater effect (71 lb of fat per acre or 12%) under controlled grazing than it had under set stocking (30 lb of fat per acre or 7%). This difference is due, obviously, to the large drop in per cow yield (59 lb of fat or 14%) with increased stocking rate under set stocking. The reduction in cow yield was substantially less (29 lb of fat or 7%) under controlled grazing.

From the picture so far drawn, two conclusions seem reasonable. They are:

(1) Controlled grazing must be associated with high stocking rates to exploit fully the greater efficiency of the more intensive grazing method.

(2) Increasing stocking rate will not be accompanied by as large increases in per acre output under set stocking as it will under controlled grazing. Further data which extend this latter point come from the third year of the experiment.

In this year stocking rate was stepped up still higher to see what would happen if a point could be reached under set stocking where the increased stocking rate no longer increased per acre yield. I have argued previously that the law of diminishing returns probably applies to stocking rate as it does to increasing intensity of grazing method. This situation eventuated as will be seen from the comparisons in Table 3.

TABLE 3: PER COW AND PER ACRE YIELDS OF BUTTERFAT AND MILK, 1959/60 SEASON.

	Per Cow		*Per Acre*	
Grazing Method/ Stocking Rate	*Fat lb*	*Milk lb*	*Fat lb*	*Milk lb*
Controlled/light	456	9,973	456	9,973
Controlled/heavy	417	9,056	522	11,354
Set stocked/light	429	9,391	429	9,392
Set stocked/heavy	337	8,081	422	9,314

These figures cover the results of the last year, with 42 cows per farm. It is clear that increasing cow numbers by a mere 5% on top of the already high rate of 40 per 33⅓ acres has "bust" the set-stocked system. The drop in per cow yield was so large that production per acre was not as high as that with the same number of cows on the 40 acres. This is the first time in many studies at Ruakura that we have succeeded in pushing stocking rate to the breaking point. In contrast, all the other farms increased in their per acre output with a record yield of 522 lb of fat or over 1,100 gal of milk per acre from the controlled grazed farm at the higher stocking rate.

Finally, it is clear that differences in herbage yield do not explain the differences recorded. A 5-acre pilot area, set up within the experiment on a replicated basis and which duplicated both grazing method and stocking rate differences of the major experiment, yielded the estimates of herbage yield over the last two years given in Table 4 (Campbell, A.G., unpub. data).

TABLE 4: PASTURE YIELDS (TWO-YEAR AVERAGE)

Grazing Method/ Stocking Rate	*Dry Matter per Acre (lb)*
Controlled/light	10,750
Controlled/heavy	11,250
Set stocked/light	11,150
Set stocked/heavy	11,100

Obviously more grass was not produced under rotational grazing, and equally obviously the large per animal and per acre differences in output are not due to differences in total herbage yield.

While the complete story remains to be unfolded by further work, while the study raises more problems than it solves, and while, in particular, many more experiments of the same type are highly desirable under different environmental conditions and with stock of poorer quality, and if possible with adequate replication within each year as well as in time, I believe that the general relationships of grazing method and stocking rate to the efficient conversion of grass to milk which have emerged, will stand the test of time.

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