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A THEORETICAL BASIS FOR GRAZING MANAGEMENT

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SUMMARY

It is observed that *ad hoc* research into grazing management has produced apparently conflicting results. Some reasons for the conflict are discussed.

It is claimed that, in a grazing situation where little flowering of grasses is allowed, pasture dry matter production has a linear association with digestible organic matter production and, by implication, with potential animal production. It is further claimed that maximum dry matter production will be achieved only by understanding how the grazing animal modifies the physiological processes of pasture plants, and their micro-environment, and then applying grazing pressures in such a way as to enhance pasture production. The physiological developments and environmental pressures which may be of cardinal importance at different stages in the life cycle of a pasture plant, are discussed in relation to grazing management and pasture productivity.

TO THE CASUAL OBSERVER it must seem that any scientific basis for grazing management has been as much obscured as illuminated by the results of *ad hoc* experimentation.

Numerous comparisons of rotational grazing with set stocking and strip grazing have been made. The term "rotational grazing" has been used to cover a multitude of systems from daily shifts to monthly shifts, from 3 paddock systems to 30 paddock systems. The pasture species used have been diverse. They have included, and still do include, species or strains well recognized as being unsuited to one at least of the systems imposed. Thus, set stocking of lucerne pastures is an excellent way, if one wishes, to discredit set stocking.

Such has been the scope of this type of experimentation. The results have not been unanimous. They have only been less numerous than the number of the experiments because system A can only be better than, the same as, or worse than system B.

Apart from the diversity of interpretation which can be placed upon such terms as "set stocking" and "rotational grazing", and apart also from the multiplicity of species involved in such comparisons, some of the confusion has arisen from the methods of evaluation employed. In experiments which have relied solely on animal production measurements as the criterion of the efficiency of two grazing systems, and which show no difference between the systems, the only conclusion that can safely be drawn is that pasture utilization in neither was sufficiently complete to allow the system growing least pasture to be identified. More serious perhaps is the Ruakura observation that differences in animal output between different grazing systems, can be directly contrary to total pasture production. Ivins (1959) has observed that "Techniques of grassland evaluation with livestock measure whichever potential, animal or grass, is lower." This dictum would have been more complete had he included management (within any one grazing system) as a third factor having a highly variable potential.

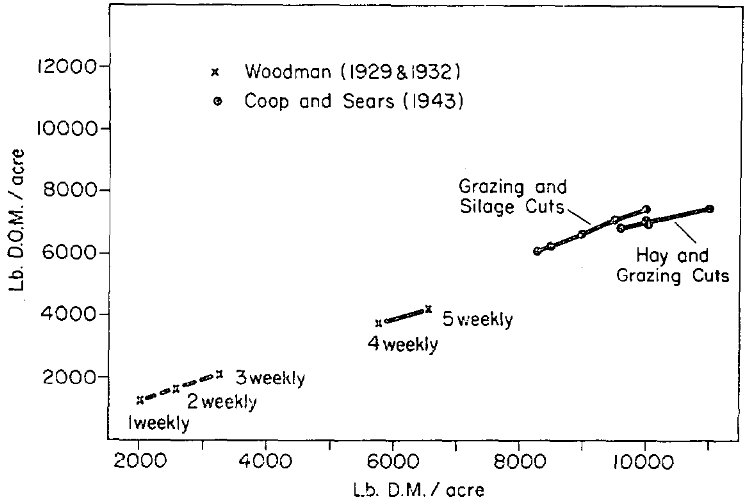
In defence of animal output as the criterion, it has been claimed that, since animal production is what matters in the long run, the animal must be the final arbiter in deciding the efficiency of any system of grazing management. But only concurrent pasture measurement can uncover differences in pasture utilization, and so it must be the final arbiter in deciding the efficiency of the grazing manager.

A third, and probably the most grave deficiency of animal output, used as a sole criterion for evaluating grazing systems, is that it seldom if ever provides reasons for the differences found between systems, and so the next step forward to an even better grazing system cannot be taken on any logical basis.

Recently a suggestion has been made that a combination of systems of set stocking and rotational grazing might be best (McMeekan, 1959). This suggestion undoubtedly has merit, but, if adopted with too great enthusiasm and too little fore-thought, the way will be open for the entry of further permutations and combinations into the *ad hoc* arena. Grazing management, on any scientific basis at least, could then become a considerably greater nightmare than was ever endured by the average football pool investor!

It would appear, then, that no amount of *ad hoc* work, particularly if evaluated only by reference to animal production, is likely to pin-point the ideal grazing management system for any situation with any certainty, for no matter how many permutations within or between existing systems may be compared there will always, in practice, remain many more untried permutations any one of which might be the *ne plus ultra* which we seek. Moreover, an appeal solely to animal output neglects the fact that animal and managerial potentials may be lower than those of the pasture, and that such evaluation cannot clearly point the way in which further progress can be made. How else, then, apart from the *ad hoc* approach, can we hope to find the ideal grazing management system?

The objective in seeking the ideal system is to achieve the maximum per acre output of animal products from pasture,



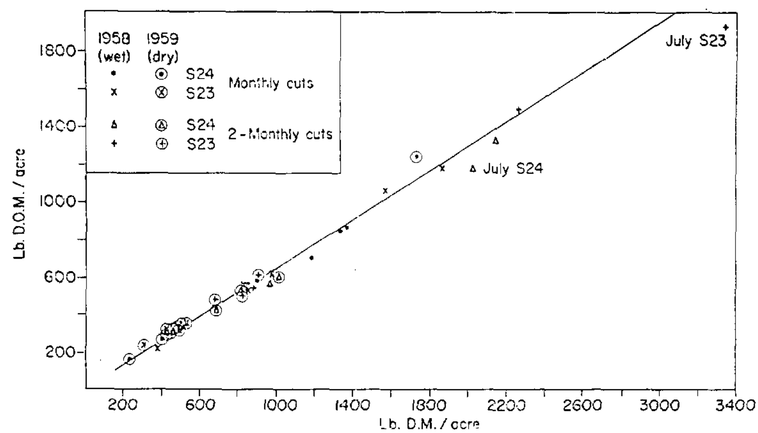


Fig. 1: The relationship between dry matter production per acre and digestible organic matter production per acre.

Top: *Derived from the data for 1-, 2-, 3-, 4-, and 5- weekly cuts by Woodman* et al. *(1929 and 1932), and the grazing and silage cuts of Coop and Sears (1943).*

Bottom: *Derived from the data of Minson, Raymond and Harris (1960).*

without causing permanent damage to that pasture. This objective will be reached by a system of grazing and conservation which allows the highest level of pasture utilization (proportion consumed of amount grown), while giving maximum pasture yield of the minimum quality necessary to sustain a reasonable level of per animal output. It will be legitimate not to seek the highest possible level of per animal output by growing pasture of the highest nutritive quality, if to do this demands any considerable reduction in total yield of digestible pasture nutrients, just as it has already proved necessary to waive maximum per animal production in the interests of a high degree of pasture utilization (Wallace, 1956).

A generally linear relationship can be established between pasture dry matter production per acre and digestible organic matter per acre from the data of Woodman (1929, 1932) and Coop and Sears (1943) and more recently Minson, Raymond and Harris (1960) (Fig. 1). It seems reasonable, then, as a starting point in a grassland environment where most of the pasture is grazed *in situ,* to seek the grazing system which will give maximum pasture dry matter yield and then, through modification of the system, to sacrifice as little as possible of that gross yield to animal requirements of nutritive value per unit of intake, to the seasonality of stock needs, and to the managerial problems associated with maximum utilization of the pasture grown.

The pathway to achieving maximum pasture yield will most logically be found by understanding first of all how the physiological and related morphological developments within pasture plants can influence their yield, and then understanding the ways in which the grazing animal inpinges upon the constituent pasture species to vary the speed or extent, or change the direction of these fundamental processes. Truly rational grazing management must be geared to these processes if a maximum output of pasture is to be obtained. Since these physiological and morphological developments do not correspond to statutory seasons, it is necessary to consider them month by month as they arise.

October-November : Spring Flush—Silage

Without much doubt, although it has not been stated in the context of grazing management, the greatest productive force within a grass plant arises directly from the reproductive force (Langer, 1958). It is not fortuitous that, at the time when the incremental growth of pastures is increasing from 40 lb of dry matter per acre per day to around 100 or 120 lb, the main grass constituent of the sward is thrusting up its flowering head. Nor is it fortuitous that incremental growth rate falls abruptly when the flowering process is complete.

The source of this reproductive urge lies in the apical meristematic tissue, the growing tip of the grass tiller (Fig. 2a). When the tiller is vegetative, this meristem is very small and is situated within the enfolding leaves close to or slightly below ground level. In this state it is unlikely, in most common species

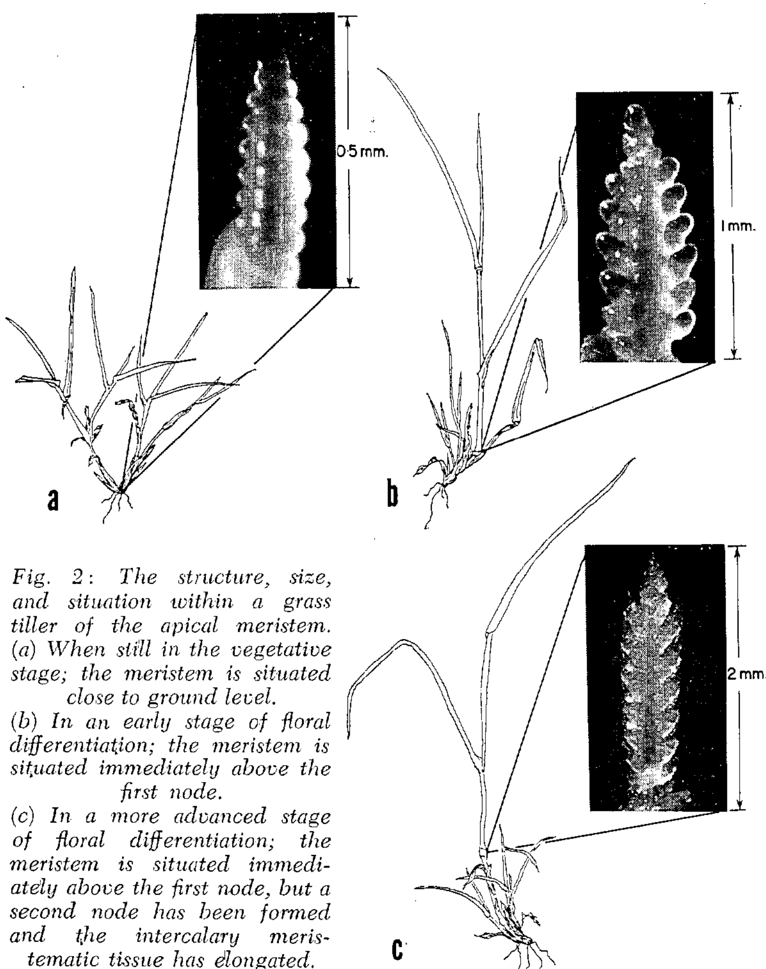


Fig. 2: The structure, size, and situation within a grass tiller of the apical meristem. (a) When still in the vegetative stage; the meristem is situated close to ground level. (b) In an early stage of floral differentiation; the meristem is situated immediately above the first node. (c) In a more advanced stage of floral differentiation; the meristem is situated immediately above the first node, but a second node has been formed and the intercalary meristematic tissue has elongated.

of pasture plants, that the apical meristem will be damaged by grazing.

Under various external influences, first low temperature, then a specific daylength, the apical meristem ceases to be vegetative and differentiates flowering parts (Fig. 2b). Under conditions of adequate light and temperature (Evans, 1960), moisture and fertility, the underlying intercalary meristematic tissue elongates rapidly, thrusting the now floral primordium upwards. Leaves initiated prior to floral differentiation continue to grow alongside the developing flower head (Evans and Grover, 1940; Cooper, 1951).

At the stage shown in Fig. 2c the apical meristem rapidly ceases to be protected from the grazing animal. Once this apical meristem is grazed off, the tiller bearing it will develop no more. Growth of intercalary meristematic tissue appears to stop on removal of the apical meristem. If the apical meristem is destroyed when it is one inch above the ground, the additional yield of dry matter which it would have produced had it been allowed to grow further towards maturity will be forfeited.

New growth will come from vegetative tillers at the base of the tiller destroyed, but this is a relatively slow process (Davies, 1956) and their growth is unlikely to compensate for

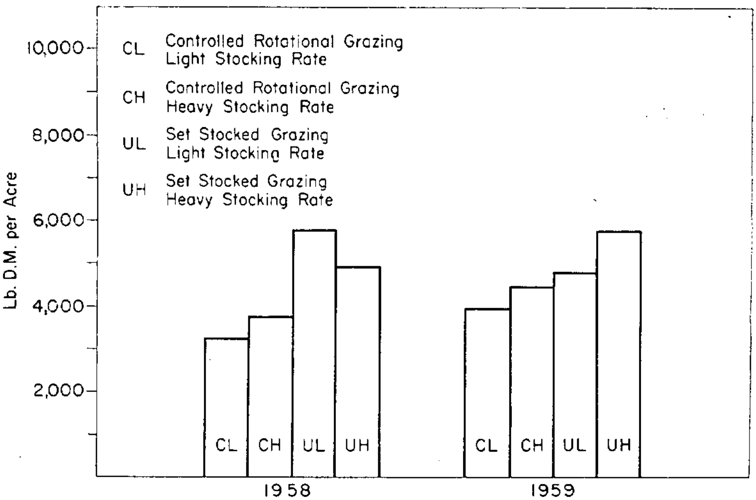


Fig. 3: The net pasture dry matter increments measured between October 1 and December 15 in 1958 and 1959 from a trial comparing rotational grazing with set stocking at two stocking rates.

the yield of the reproductive tiller which has been destroyed (Langer, 1957 and 1959a).

It may be important that in some years during this phase of growth greater pasture yields have been obtained at Ruakura from a system of set stocking than from a system of rotational grazing round 15 paddocks (Fig. 3).

Since the reproductive process is triggered off by a specific day-length, the majority of fertile tillers of the main grass component of the sward tend to be at the same stage of development at the same time—at least in the perennial strains of pasture grasses to which we are accustomed (Cooper and Saeed, 1949). A system of rotational grazing involving fairly uniform defoliation may tend to destroy the apical meristems, also with fair uniformity, paddock by paddock. The set stocked animal, however, being more selective in its grazing, may well avoid areas of pasture as they become progressively more mature, and as their maximum productive potential comes to be more nearly realized.

In this context it is necessary to note for what it is the fallacy that set stocking automatically involves close and continuous grazing. Woodman (1931) in his now classical work at Cambridge demonstrated the defects of continuous close grazing. But to equate this with set stocking in an environment where stocking rate is seldom more than a cow to the acre, and where pastures produce more than 30 lb of dry matter per acre per day for six or seven months of the year is wrong, except perhaps for three months in the winter.

From Ruakura experience it seems probable that at least some forms of rotational grazing, associated with the closing of substantial areas of the farm for silage, may reduce pasture yield severely on the grazed areas of the farm.

A triangular situation may be involved, and depending upon which corner of the triangle serves one as a vantage point the conclusions will vary (Fig. 4).

$$\begin{tikzcd}
\text{Area Closed} \arrow[rr, leftrightarrow] \arrow[dr, leftrightarrow] & & \text{Time of Closure} \arrow[dl, leftrightarrow] \\
& \text{Grazing Pressure} &
\end{tikzcd}$$

Fig. 4: The possible relationship between grazing pressure, area closed, and time of closure for silage.

(i) If too large an area is closed too soon, excessive grazing pressure may damage production on the grazed area.

(ii) By delaying time of closure it may be possible to close a larger area without increasing the grazing pressure sufficiently to do serious harm.

(iii) If grazing pressure is too great in early to mid-October, closure may best be delayed, or the area closed reduced, or both.

Since daily dry matter increment is increasing exponentially right through this period, a delay of two weeks or so in closing paddocks for silage will not necessarily mean a similar delay in cutting the crop. The productive advantages of such a delay for the grazed area of the farm may be important.

Again from Ruakura experience, it would seem that the grazing system by which the grazing pressure is applied is more important than the stocking rate. In other words, set stocking at a heavy stocking rate has allowed of greater pasture production than rotational grazing at a lower stocking rate.

This discussion must not be construed as advocating set stocking during this phase of growth. The intention is only to call for recognition of the reproductive phase as potentially valuable, to suggest that grazing management can influence the realization of that potential, and to suggest that further study needs to be made of this growth phase in relation to grazing management, animal needs, and subsequent productivity of the pasture.

December : Seed Setting — Haymaking

Mention has previously been made of the sharp decline in daily dry matter increment when flowering ceases. At Ruakura the decline is from over 100 lb of dry matter per acre per day to about 40 lb. It occurs abruptly, usually about the second week of December in our predominantly ryegrass pastures. Presumably the older tillers have run their distance, and the younger tillers are still in the toddling stage.

The common practice of making hay in mid-January rather than in mid-December seems, therefore, agronomically if not managerially unsound.

A crop cut at the later date will not gain much by standing in the paddock during late December and early January. It will probably decline in feeding quality, and the increasing soil moisture deficit which is normal at this time is likely to be detrimental to aftermath regrowth.

JANUARY-FEBRUARY : DROUGHT — HIGH LIGHT INTENSITY — DEAD MATERIAL

At this period the effects of increasing soil moisture deficit become apparent. Measurements at Ruakura confirm other observations (Mitchell and Closs, 1958; Mitchell, 1959) that soil moisture is conserved better under long pasture than under short pasture. What this means in terms of pasture productivity is not clear. Begg (1959) in the Armidale environment has shown that moisture deficits are greater under highly productive sown pasture than under less productive natural pasture. Does a lower moisture deficit under long pasture then indicate potential for still greater growth, or simply a lower rate of previous growth? However, drought effects, though important, are products of the local environment and need not be further discussed here.

More important in this context is the report that the high light intensity of these summer months can reduce pasture growth (Mitchell, 1959). The physiological mechanism involved may not yet be understood, but if mutual shading by leaves within the herbage of a longer pasture can help to alleviate this depression, there would seem, in this environment, to be two good reasons for grazing management which will maintain a fairly bulky cover of pasture over as large a proportion of the farm as possible, for as long as possible, at this time.

A disturbing feature of pastures in January and February is the tremendous accumulation of dead material which takes place. At Ruakura, where the sampling technique involves cutting as close to ground level as possible, it has been found that in both closely and laxly grazed swards dead material increases at this time until it accounts for about half of the total dry matter. In absolute terms, the laxer the grazing the greater the weight of dead material there will be present. Not only is this material probably of very low nutritive value, it is assiduously avoided by the grazing animal. Perhaps more correctly, being mainly in the bottom of the sward it is less accessible for grazing. Certainly much of it must be completely lost through decay in the humid autumn months.

The need in these summer months would seem to be for a grazing system combining the soil moisture and possible mutual shading benefits of lax grazing with the lower absolute loss, through death and decay, of more severe grazing. These requirements may seem to be mutually exclusive, but this may not necessarily be so.

MARCH-APRIL : TILLERING — AUTUMN FLUSH

It is necessary to emphasize that spring flush and autumn flush arise from widely different physiological sources. Both are dependent to a great extent on an improvement in the environmental influences of soil moisture and improving conditions of light and temperature, but, whereas the spring flush arises largely from the development towards maturity of fertile tillers, the autumn flush arises from the vegetative growth of an increasing number of tillers. That this response is to an extent independent of grazing management or soil fertility has been demonstrated for meadow fescue (*Festuca pratensis*) and timothy (*Phleum pratense*) (Langer 1958, 1959a, 1959b). With several other species, including perennial ryegrass, Ruakura evidence shows a similar trend, although in this case it is not possible to distinguish between a natural increase in tiller numbers and one induced by late summer grazing pressure. A similar pattern of spring and summer decline has recently been shown for stolon numbers in certain strains of white clover (Crowder and Craigmiles, 1960).

It follows that the grazing management system needed to enhance the autumn flush is not necessarily the same as that required to enhance the spring flush.

Appreciation of the fundamental difference between the spring and autumn flushes may be helpful, but it does not point directly to the grazing system required to raise pasture productivity in autumn.

Up to the point of complete light interception, and at any one level of soil fertility, tiller numbers are probably important at this time. Periodic close grazing may stimulate tillering in short-rotation ryegrass by preventing basal shading (Mitchell and Coles, 1955; Brougham, 1959) but persistent close grazing may have the opposite effect with this and other species (Jacques, 1937; Brougham, 1959). However, under close grazing Leaf Area Index will be reduced, and light interception will suffer. It may be that close grazing is inevitable towards the end of the previous, summer period and that this will be sufficient to stimulate the desirable degree of autumn tillering.

It may even be wise to consider means other than grazing management to stimulate tillering. Here nitrogen is known to be effective (Stapledon and Milton, 1930; Podsivalov, 1938; Cooper, 1951), but the value of phosphate is still rather equivocal (Jacques, 1943). The usefulness of clover as a source of the necessary nitrogen may be noted here. Its proportion in mixed swards is normally high at this time. Grazing at regular intervals, by reducing light competition, and through actual defoliation itself, has been shown to induce a rapid turn-round of nodule nitrogen (Butler, Greenwood and Soper, 1959).

These arguments are based on the assumption that high tiller numbers are important for autumn flush pasture production. This may be only relatively true since tiller number and tiller size must be equated. Even so, in the case of many perennial species it would be prudent to recognize that these autumn formed tillers, which will be vernalized by low temperature during the winter, probably provide the bulk of the fertile tillers which contribute to the spring flush of the following year.

JUNE-JULY-AUGUST : AUTUMN-SAVED PASTURE

Visible signs of physiological change within the plant at this time are absent, and little is known about their existence or importance, apart from the well recognized and powerful effects of vernalization through cool temperature (Gassner, 1918) which is necessary for the subsequent development of most perennial species.

We must note the suggestion that, in the case of short-rotation ryegrass, appreciably more total dry matter will be utilized if pastures are grazed off leniently, at regular intervals of about six weeks in the course of the winter period than if grazed severely at irregular intervals or utilized as one crop of autumn-saved pasture towards the end of the period (Brougham, 1956a).

This work is also valuable in highlighting the need at all stages in the pasture growth cycle for compromise between animal needs and maximum pasture productivity. In this instance, the agronomist has demonstrated the grazing management likely to grow most pasture dry matter at this season. But the animal nutritionist refuses to sacrifice the large bulk of autumn-saved pasture, conserved as immediate pre- and post-calving feed, to the Moloch of maximum pasture production.

Pugging or poaching of pastures is a problem at this time. This has long been recognized, and is at present being investigated (Edmond, 1958).

Two comments seem opportune. First, the effect of winter pugging is immediately apparent, but its whole influence on pasture productivity is not necessarily short term. Among other things, it will result in the destruction of potentially fertile tillers and so *may* influence the spring flush five months ahead. Edmond's (1958) work with short-rotation ryegrass suggests, on the contrary, that more fertile tillers may be established under severe sheep treading. It may be wrong, however, to transpose this finding to the pugging of other pasture species with heavier stock.

Second, since normal winter pugging will affect potentially fertile tillers, be it adversely or beneficially, the results of experiments where pugging is induced artificially at other times of the year cannot be projected to forecast the probable effects of winter pugging.

Rotationally grazed pastures have been observed to suffer more damage from pugging than those set stocked. But whether this is due to increased stock movement, greater restlessness of stock, or to variations in pasture tiller density, is not clear (Suckling, 1956). Again, a cover of long pasture has been found to reduce pugging damage (O'Connor, 1956), though one would expect much immediate wastage of pasture nutrients in these circumstances.

Late August-September : Spring Growth

At this season the limiting effects on pasture productivity of low temperature, and particularly of low light intensity, are wearing off. It is convenient at this time to refer to the importance of light in pasture growth.

Certainly light controlled photosynthetic activitity is fundamental to pasture growth and productivity at all seasons. Light is important in the context of grazing management, both at the whole pasture level and at the individual species level.

At the whole pasture level, light falling on the soil surface is largely wasted in terms of pasture growth. It has been demonstrated that a Leaf Area Index of about 5 (*i.e.*, 5 acres of leaf per acre of ground surface) will provide optimum light interception for maximum rate of pasture regrowth in a sward of short-rotation ryegrass, red and white clover (Brougham, 1956b).

But there is nothing magical about a Leaf Area Index of 5. It is not the universal optimum for all crops nor, presumably, for all pastures nor even for the same pasture at different seasons of the year; neither is 100% light interception by a sward a sufficient criterion of its efficiency as a medium for utilizing incident light. It appears that green plants cannot make much use of light intensities greater than about 2,000 foot-candles, and the maximum efficiency of light use occurs at about one half of this intensity—round 800 to 1,000 foot-candles. Thus, a pasture plant having leaves which grow relatively upright so as to distribute incoming light of high intensity over a large area of leaf at a lower intensity will, theoretically, be more efficient in the use of light energy per unit area of ground covered than another pasture plant having leaves which grow horizontally, even though percentage light interception may be equal in both cases.

This concept of leaf orientation and efficiency of light use may explain the fact that, given two grass strains of widely differing flowering dates, maximum daily dry matter increment tends to occur about the time of flowering of each species, irrespective of day length.

But, leaving these theoretical considerations for future illumination, from the grazier's point of view, it is probably more difficult to obtain and retain good light interception at some seasons of the year than at others. In early spring, for example, tiller numbers may be tending downwards, and pastures will have been opened up by winter pugging, or over-long closure for autumn-saved pasture followed by severe grazing. In summer, light interception may tend to fall once more below a desirable value, but soil moisture may be limiting at this season.

Management, then, must aim to retain this desirable but, as yet, indefinable amount of cover over as much of the farm as possible so that incident light is not wasted and growth rate is maintained at a maximum.

At the individual species level there is a broad distinction between legumes and grasses in their ability to withstand shading. Legumes are more depressed in growth rate than grasses by reduction in light below normal daylight intensity. But even within the Gramineae and the Leguminosae there are differences in shade tolerance (Black, 1957). Even in default of specific aid from the scientist, grazing managers can undoubtedly influence these light relationships at all seasons, but perhaps to greatest effect in early spring.

CONCLUSION

At all seasons it may be useful to consider that there is a relationship between residual pasture, remaining after grazing, and the rate at which regrowth will subsequently take place. The amount of the optimum residue will not be the same at all seasons. It will depend upon the pasture species employed, upon the physiological state of the pasture plants at some times, and at others upon their micro-environment. For example, the residue necessary to permit survival and development of apical meristems in spring (if this be deemed valuable) may differ from that necessary to provide mutual shading from the high light intensities of summer, or to permit complete light interception at all seasons, and the residue necessary to retain soil moisture in summer may be very different from that required to enhance autumn tiller production.

The extent and nature of physiological processes within pasture plants, the environmental pressures upon the pasture, and the way in which these can be influenced by the grazing animal are still only very incompletely understood as the deficiencies of this paper will have made abundantly clear. The sites of the elaboration of and response to plant hormones, their inter-relationships, and particularly their antagonisms, offer many interesting possibilities for speculation in regard to grazing management (Hayashi and Murakami, 1954). Even so, matters known or half known are themselves sufficiently complex to be going on with.

The intention of this paper has not been to recommend a grazing system or even a combination of systems. Rather has it been to set out in some sort of chronological order known stages in pasture plant growth and development which must be considered when decisions are taken about grazing management. It is perhaps not too much to assert that a grazing system based on a recognition of these stages, and an awareness of the grazing animal's part in their modification, will have much wider applicability than any recommendation for or against set stocking, rotational grazing, strip grazing, or any other grazing system which largely ignores the fact that the pasture plant, as much as the grazing animal, is a complex physiological entity.

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