Sward conditions, herbage allowance and animal production: an evaluation of research results

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ABSTRACT

The evidence on the influence of herbage allowance and sward characteristics upon animal performance and herbage production is reviewed briefly, with particular reference to the prediction of animal performance, the use of decision rules in grazing systems and understanding of animal/sward interrelationships. Attention is concentrated on evidence from temperate grasslands, with particular reference to New Zealand results.

Simple management rules based on herbage allowance or residual dry matter indices have made a major contribution to improvement in the efficiency of grazing management. However, their use as general indices is restricted by the interdependence of the effects of variation in allowance and sward conditions upon animal performance. Furthermore, allowance-based studies make only a limited contribution to understanding of the factors influencing the links between the plant and animal components of grazing systems. It is suggested that more attention should now be concentrated on the causative effects of variation in sward characteristics upon both herbage production and animal performance.

Keywords Sward; herbage allowance; grazing management; herbage mass; sward height; herbage intake; animal performance; herbage production

INTRODUCTION

Over the last 20 years there has been a steady stream of papers dealing with aspects of the influence of herbage allowance on the performance of many classes of grazing animal. A substantial proportion of them have appeared in New Zealand journals in the second half of the period. The purpose of this review is not to make comparisons between published results, rather it is to assess briefly the evidence on:

1. The value of herbage allowance as a predictor of the performance of grazing animals.
2. Its use as an aid to decision making in grazing systems.
3. Its contribution to understanding of animal/sward interrelationships and hence to a better appreciation of the scope for control and manipulation in grazing systems.

Attention is concentrated primarily on New Zealand evidence, with reference to information from other temperate countries where this helps the argument.

Herbage allowance is defined here as the weight of herbage present per animal at a point in time, measured to ground level. Expression in absolute terms rather than relative to live weight can make for difficulties in comparing results between and within animal classes, but this is the form of expression most commonly used in New Zealand publications and it is convenient to use it here. Herbage allowance finds its most useful application in management procedures involving short grazing periods of 1 to 3 days, where it provides a measure of the daily ration of herbage from a sward of known mass and the contribution of concurrent herbage production can be largely ignored. It is more difficult to use where grazing periods are longer and where herbage production during grazing makes a significant contribution to the herbage supply. Under continuous stocking management the term is probably meaningless and a more satisfactory means of describing feed rationing is the F/D ratio of Hart (1972), which in essence describes the balance between herbage production and demand over a defined (and usually prolonged) period of time.

1. HERBAGE ALLOWANCE AND ANIMAL PERFORMANCE

Animal performance usually increases at a steadily decreasing rate towards a maximum value as herbage allowance increases (Jagusch *et al.*, 1979; Rattray *et al.*, 1982a; See Fig. 1), reflecting the influence of allowance on the amount of herbage consumed. Intake

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normally approaches a maximum at allowances 3 to 4 times greater than the amount eaten, but only starts to decline markedly when the allowance is less than twice intake (Le Du *et al.*, 1979). A reduced allowance may also depress the digestibility of the herbage consumed (Geenty and Sykes, 1982), but this will usually have a smaller impact on performance than the direct limitation to herbage intake.

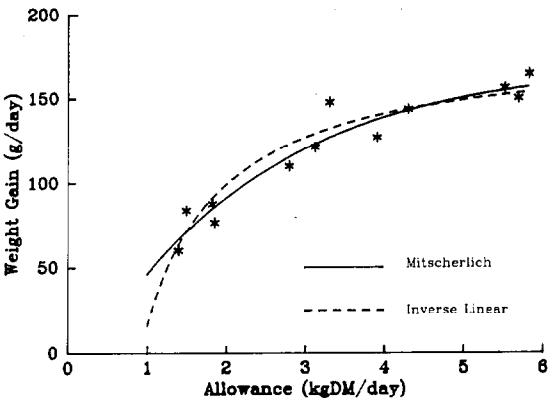

FIG. 1 The relationship between herbage allowance and weight gain in weaned lambs. The Mitscherlich and inverse linear functions shown in the figure were fitted to the data of Jagusch *et al.* (1979) by Pringle and Wright (1981); see text.

The pattern of the production response will depend upon the sensitivity of the parameter in question to the current level of herbage intake. For example, the weight change of lactating ewes is likely to be more sensitive to change in herbage allowance than is the weight gain of their lambs because the milk supply of the ewe, sustained at the expense of body reserves at low allowance, helps to protect the lamb from the direct effect of herbage rationing (Rattray *et al.*, 1982b).

Several different curvilinear functions have been used to describe the shape of the relationship between herbage allowance and either herbage intake or animal performance. Some of these have been compared in statistical terms (Pringle and Wright, 1981), but the biological and practical implications of the alternative models have not been considered in detail. Given the limited range of herbage allowance in most grazing studies and the inevitable variability in the results there is seldom an objective basis for choosing a particular curvilinear function, but the choice of model can have an important influence upon the interpretation of the results. Variations in the prediction of maximum animal performance will not necessarily be of practical significance, but variations in the areas of main animal performance sensitivity are of potential importance. For example, the Mitscherlich and inverse linear functions used by Pringle and Wright (1981) fitted the data of Jagusch *et al.*, (1979) equally well, but the herbage allowances predicted by the 2 equations to sustain a lamb growth rate of 120 g/d differed by 12% (Fig. 1).

Variations in sward conditions pre-grazing (e.g. differences in total or green herbage mass, or contrasts between plant species) generally influence the level of animal performance achieved at non limiting allowances and the rate of response over a range of limiting allowances (Rattray *et al.*, 1980). There have been significant interactions between the effects of herbage allowance and sward conditions on animal performance in some studies (Rattray *et al.*, 1982b; see Fig. 2) but not in others. Critical examination of this topic is inhibited by practical limitations to the ranges of allowance and sward conditions possible within a single study and by the difficulties of dealing with curvilinear functions. Use of the reciprocal of allowance, resulting in an approximately linear relationship with intake or animal performance (Trigg and Marsh, 1979; Pringle and Wright, 1981), offers more scope for the appraisal of possible interactions if it is acceptable in biological terms.

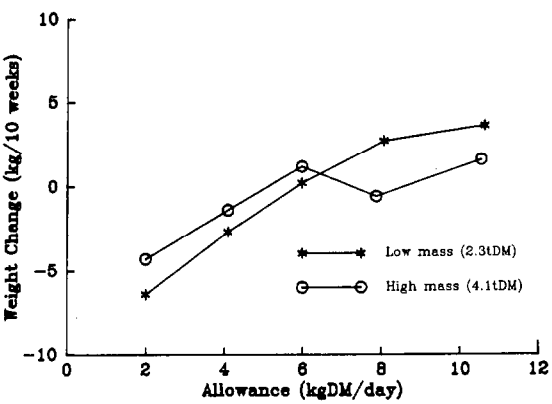

FIG. 2 The influence of herbage mass on the relationship between herbage allowance and weight change in lactating ewes; an example of an interaction between the effects of sward condition and allowance on animal performance (from Rattray *et al.*, 1982b).

The results of some studies suggest that residual herbage mass or stubble height (Le Du *et al.*, 1979; During *et al.*, 1980) or grazing efficiency (= herbage consumption/herbage allowance) (Thompson *et al.*, 1980) may be more useful than herbage allowance as general predictors of herbage intake and animal performance. However, correlations are likely to exist between any or all pairs of the parameters shown in Table 1, and the conclusions drawn from a particular study will be influenced by the ranges of variation and particularly the degree of independent variation achieved in these parameters.

TABLE 1 Interacting sward variables in herbage allowance studies.

Per unit area	Per animal
Initial mass	Area
Animal numbers	Allowance
Herbage eaten	Herbage intake
Grazing efficiency (utilisation)	Grazing efficiency
Residual mass	

Definitions of the effects of herbage allowance and sward conditions on animal performance are interdependent (e.g. Reardon, 1977) and in the final analysis it is optimistic to expect that any one parameter will act as a satisfactory general predictor of performance (Rattray *et al.*, 1980). A better appreciation of the degree of generalisation possible is dependent upon a better understanding of the ways in which grazing animals respond to variations in sward characteristics (see Section 3).

2. MANAGEMENT DECISIONS

The potential benefits of grazing management practices involving a clear appreciation of the feed requirements of grazing animals, regular monitoring of swards and feed budgeting to plan for and adjust to seasonal variations in herbage supply and demand need no emphasis here. Within this framework relatively simple rules based on estimates of herbage allowance (Thompson and Jagusch, 1981) or residual dry matter, RDM (Milligan, 1983) can provide an effective and objective basis for management decisions. Two aspects of their application in grazing systems deserve consideration, however.

General Predictions

The conclusions at the end of the preceding section imply that no single parameter is likely to provide a reliable basis for predicting animal performance unless it is applied within well defined constraints. Current recommendations for grazing control take this into account by defining levels of allowance or RDM appropriate to specified sward conditions (Thompson and Jagusch, 1981; Milligan, 1983). However, the relative shortage of evidence from comparative sward studies makes it difficult to predict the limits within which recommendations of this sort can apply, or the extent to which allowance or RDM standards need to be modified over the range of sward conditions to be expected on farms.

A system of varying allowances over a range of swards will inevitably be arbitrary in nature, and it is argued later (see Section 3) that decision rules based primarily on sward conditions will provide a more effective basis for manipulating sward and animal performance. To this extent a system based on RDM may be more robust than one based on herbage allowance, though it seems likely that neither can be divorced from the need to specify pre-grazing sward conditions in addition. These arguments are most appropriate to management procedures during the spring and summer when herbage is relatively plentiful and sward control may be a major consideration. In these conditions the difficulties of applying decision rules based on sward conditions are likely to be greater under rotational grazing managements, where sward changes during a grazing period are rapid and substantial, than under continuous stocking management where they are slow. In contrast, strict rationing systems involving fixed herbage allowance under intermittent grazing management are particularly appropriate to periods of feed shortage.

Implications to Grazing Systems

Current recommendations, particularly those involving herbage allowance, tend to be animal-orientated. They are usually related primarily to target levels of animal performance and are based largely on the results of relatively short-term studies in which animal performance was the primary measurement. In order to use them effectively in pastoral farming systems these recommendations need to be tempered with knowledge of their potential impact on sward conditions and herbage production in both the short and long term, and on whole-system performance.

The available evidence indicates that herbage production may be relatively insensitive, within limits, to variations in herbage allowance or RDM in established swards (Brougham, 1959; Campbell, 1966; Baars *et al.*, 1981), though the effects on botanical composition are of potential importance (Boswell and Crawford, 1978; Baars *et al.*, 1979) particularly in developing swards. The issue is particularly relevant, however, to managements designed to maintain near-maximal levels of herbage intake and animal performance, which are likely to involve grazing efficiencies of only

TABLE 2 Spring grazing management, herbage production and composition (from Holmes and Hoogendoorn, 1983)

	Management	
	Hard	Lax
Herbage production (t DM/ha)		
1 September-15 December	6.9	6.3
16 December-31 March	3.4	2.6
December sward:		
Herbage mass (t DM/ha)	2.5	5.3
% Leaf	45	29
Clover	17	12
Stem	24	41
Dead material	10	17
Digestibility (% DM)	73	65

25 to 30% with the consequent high levels of herbage wastage, declining nutritive value and reduced sward vigour. Examples are the management of spring swards for dairy cows at peak production and of summer swards for weaned lambs, where recommended herbage allowances are likely to lead rapidly to deleterious sward changes unless stock with lower nutrient demands are available for clean-up grazing (e.g. Holmes and Hoogendoorn, 1983; Table 2).

The need for compromise between animal and sward requirements in order to maintain whole-system viability is no doubt well appreciated. However, objectivity in determining the appropriate compromises is limited by the shortage of data from studies involving measurements on both sward and animal, particularly in a systems context.

3. UNDERSTANDING SWARD/ANIMAL RELATIONSHIPS

One of the main objectives of grazing research is to provide the grazier with a firm set of decision rules which he can use to manipulate herbage and animal production to meet desired targets. This depends upon an understanding of the factors which determine sward and animal responses and the scope for controlling them.

Animal Performance

Variations in sward conditions and in herbage allowance both influence animal performance through their effects on the amount and nutritive value of the herbage consumed. The need now is to seek a common basis for these effects.

There is growing evidence that within limits, daily herbage intake is directly related to the amount of herbage ingested per grazing bite. Increases in biting rate or grazing time can seldom compensate adequately for reductions in intake per bite, which itself appears to be directly related to sward conditions at the time and, in particular, to variations in grazing height and in the density and morphology of herbage in the grazed horizons (Hodgson, 1982). In one series of studies the effects of variations in initial sward height and herbage allowance upon herbage intake have been reconciled in a simple linear relationship between grazing height and intake per bite or rate of intake (Hodgson, 1981; Fig. 3).

This approach needs to be repeated in different circumstances and in any case is too simple to be likely to apply generally. However, it suggests a way of looking at total herbage intake (or mean daily intake) over a period of time as the integrated response of rate of intake to changing sward conditions over the same time. In this sense herbage allowance is seen to affect herbage intake indirectly, through its influence on the rate of change in sward conditions, rather than to determine intake directly. It follows that the accurate prediction of herbage intake is likely to require information on initial sward conditions, target residual sward conditions, and the rate and pattern of change from one to the other. This may be regarded as a counsel of perfection and it is clear that at present the parameters needed to describe sward state cannot be defined with accuracy. However, in order to acquire a proper understanding of the basis for controlling animal performance in grazing systems it will probably be necessary to follow some of these arguments through to a conclusion. That is not to say that there is no place for herbage allowance studies in future research programmes, but there is a real need for a more flexible approach to both the design and conduct of grazing studies. This will allow for a more critical appraisal of the importance of alternative sward characteristics (Bryant, 1980), and a sharper definition of short-term patterns of animal response than are possible in conventional designs.

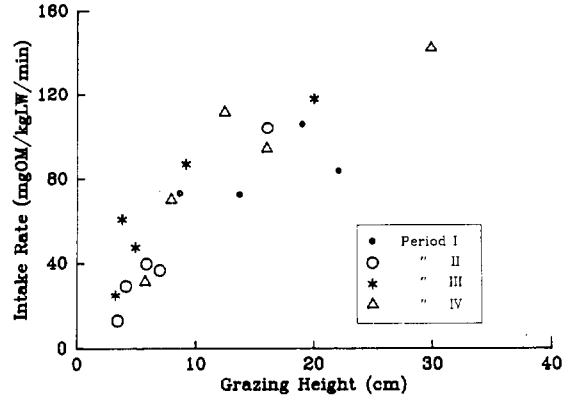

FIG. 3 The relationship between grazing height and rate of herbage intake in grazing calves, combining the results from 4 swards each grazed at several levels of herbage allowance (from Hodgson, 1981).

Herbage Production

Essentially the same arguments apply to a consideration of herbage production, which reflects firstly the effects of tiller/stolon populations and the amount of green leaf on the rate of growth of new plant tissue, and secondly the effect of the amount of mature and senescent tissue on the rate of loss to death and disappearance (Hodgson *et al.*, 1981). Variations in the frequency and severity of defoliation or in herbage allowance will influence these sward characteristics, but are means to an end rather than ends in themselves.

Rates of net herbage production (=growth − senescence) in established ryegrass or ryegrass/white clover swards in the UK may be depressed by the effects of hard or lax grazing upon rates of herbage growth and senescence respectively but in general,

appear to be relatively insensitive to quite substantial variations in sward conditions under both intermittent grazing and continuous stocking managements (Parsons *et al.*, 1982a, b; Bircham and Hodgson, 1983; Grant *et al.*, 1983). These results would not necessarily apply to developed New Zealand swards with greater growth potential in winter and, possibly, greater heat and drought stress in summer, or to developing swards in either country. However, there is a need for a better understanding of sward responses and limits of tolerance in terms of the important sward characteristics (Korte, 1982; Holmes and Hoogendoorn, 1983) rather than arbitrarily defined variables like frequency of defoliation or herbage allowance.

CONCLUSIONS

Information from the herbage allowance studies carried out in New Zealand over the last 10 to 15 years has clearly provided a firm factual basis on which to build sets of management guidelines, and the widespread use of this information in the management of grazing systems should provide an object lesson for pastoral industries elsewhere in the world. However, these studies have done less to improve our understanding of grazing systems and the scope for manipulating them than is desirable because they have been largely animal oriented and because of the conceptual limitations to herbage allowance as an experimental variable which were outlined earlier. The need now is for a greater diversification of grazing studies to allow investigation of the causative relationships between sward conditions and animal or plant performance, in addition to the applied management studies which have always been the strength of pastoral research in New Zealand.

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