THE NEED FOR ALTERNATIVE TECHNIQUES OF PRODUCTIVITY ASSESSMENT IN GRAZING EXPERIMENTS

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ABSTRACT

The fixed stocking rate design for grazing experiments offers a simple method of contrasting pasture treatments at different grazing intensities, but the rigidity of the design restricts the opportunity to manage pastures, especially those with legumes. Also subdivision of results into seasonal or forage yield classes is subject to a number of reservations including those related to carryover effects such as compensatory gain in cattle, or excess forage. Short-term experiments will reduce the confounding of seasonal production with carryover effects, and also have less within treatment variation in forage yield over time. Consequently they are better suited for investigating relations between pasture and animal productivity.

Forage yield is a better measure of forage supply than forage allowance or grazing pressure. The forage yield should also be qualified on its availability which includes both accessibility and acceptability. There is a need for a further understanding of what constitutes available forage and results from agronomic experiments should then be compared in these terms.

INTRODUCTION

Two considerations have had a dominant influence on the design of grazing experiments in Australia. Firstly, the importance of stocking rate (SR) in determining the efficiency of pasture utilization and animal production (McMeekan 1956) has led to most pasture treatments being repeated at a number of SR. Secondly, fixed SR have been used because of the experimental simplicity and because farm SR are essentially constant throughout the year.

A range of fixed SR treatments has often been used to quantify the animal productivity of pastures in various districts and to examine the effect of various grazing intensities on both pastures and animals. Whilst our level of understanding of these processes has advanced, experimental designs with a range of fixed SR treatments continue to be the cornerstone of pasture utilization research. My aim in this paper is to highlight the need in future experiments for more control over the balance between forage available and animal requirements.

DEFINITION OF TERMS

The following definitions are used in the paper:

Grazing intensity. A generic term to describe the overall balance between forage available and animal requirements. It is not defined in specific terms.

Forage yield. The instantaneous measure of the amount of forage per unit area of land.

Forage production. The total amount of forage produced per unit area over a certain period; i.e., it is the integral of forage growth rate over time.

Stocking rate. The instantaneous measure of the number of animals per unit area of land.

Grazing pressure. The instantaneous measure of the number of animals per unit amount of available forage (based on Mott 1960).

Forage allowance. The instantaneous measure of the amount of available forage per animal. It is the reciprocal of grazing pressure. Greenhalgh, Reid, Aitken, and

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Florence (1966) originally defined herbage allowance as the quantity of herbage allotted for an interval of time; in their case for one day. They used herbage allowance to describe the presentation yield per animal at the beginning of a day. However, their definition does not distinguish between situations where the presentation yield may be the same initially but then vary over the defined interval. Defining forage allowance as an instantaneous measure is more precise, and retains it as an exact reciprocal of the grazing pressure. If forage yields fluctuate during a period, it may be sufficient to express forage allowance as the mean of several values.

Decision interval. The time lag between the initiation of a management practice which will alter the grazing intensity and the actual change in grazing intensity. It may be a few days as when animals are sold or supplements are fed, approximately a month with the use of nitrogen fertilizer or irrigation, and considerably longer when new pastures or forage crops are sown. It is proposed that the decision interval defines the minimum period for which SR must be held constant in experiments which relate to a whole-farm.

GRAZING INTENSITY

The relation between forage available and animal production has been a frequent goal of researchers. Its clarification would aid the interpretation of experiments, the extrapolation of results to areas with different levels of forage production, and would indicate the best measure of forage production in agronomic experiments. The relation has many facets and for simplicity this paper will not consider the effects of changes in pasture quality on animal production.

Liveweight gain per animal (GPA) of non-lactating, young, growing animals provides the simplest measure of animal production. Whilst it is a sensitive and reliable measure for the prevailing set of conditions, there is a need for more refined measures of animal production to aid extrapolation to other classes of animal production, to regions with different conditions, or to explain inconsistencies in results (Lambourne 1968).

Currently, no measure of forage availability for tropical pastures can be accepted with the same reliability as GPA provides for measuring animal production. The basic problem is what constitutes available forage. Some investigators have used grazing pressure or forage allowance as a measure of the feed supply. These terms weight the forage yield according to the SR, and are used with the concept that forage yield must be partitioned between the number of animals grazing it. However, social effects aside, it is a reasonable assumption that the intake of an animal at a point in time is determined by the pasture offered to it, irrespective of how many animals are grazing alongside. Thus, forage yield, and not grazing pressure or forage allowance, ing distorts the data and that forage yield is the best expression of forage supply.

Two year's data from an experiment (Mears 1973) with kikuyu (*Pennisetum clandestinum*) pasture fertilized with 336 or 672 kg N year^{-1} were used to contrast forage yield, forage allowance and grazing pressure as indices of the feed supply. The pastures were grazed at fixed SR of 4.9, 7.4, 11.1 (336 kg N), or 7.4, 11.1, 16.6 (672 kg N) animals ha^{-1}. The values used were means for periods of approximately 12 weeks, and were taken from the second replicate which was kikuyu dominant. Forage measures were based on the yield of green coloured, kikuyu leaf expressed on a dry matter basis. This use of data from long-term, fixed SR experiments is subject to a number of reservations to be discussed later. Consequently only these selected observations were used in order to minimize the reservations.

The grouping of values for each SR has been indicated by straight line relations (Figure 1). For simplicity, only the relations for all SR of the 336 kg N treatments, and the 16.6 SR of the 672 kg N treatment, are given. The unequal weighting at different SR caused the forage allowance and grazing pressure relations to vary more between SR than relations based on forage yield. It is my contention that this weighting distorts the data and that forage yield is the best expression of forage supply.

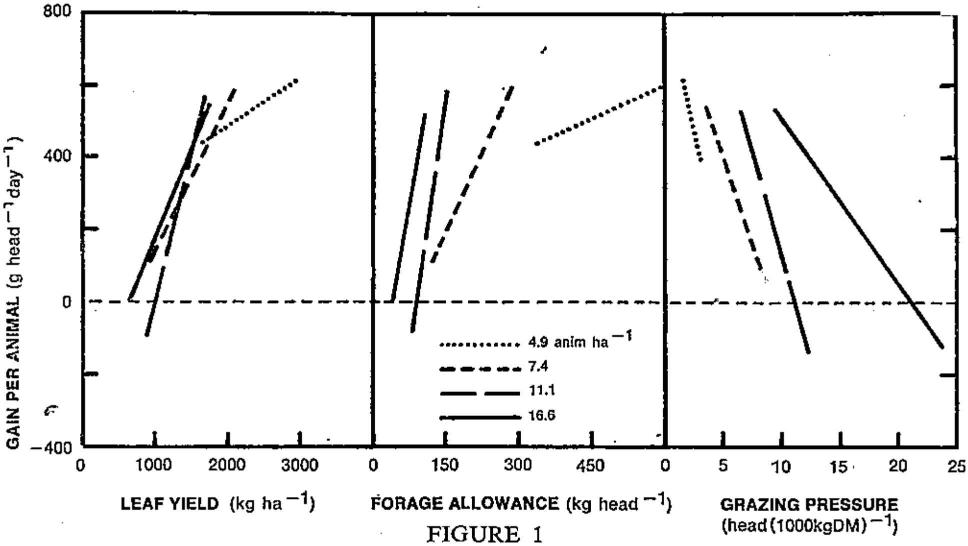

FIGURE 1

The relation of gain per animal with leaf yield, forage allowance, and grazing pressure for different stocking rates on nitrogen fertilized kikuyu pasture.

AVAILABILITY OF FORAGE

Clarification of what determines the availability of forage is a more intractable problem. In some studies, the GPA has been better related to the amount of green material, than to the total of dead and green (Willoughby 1959; 't Mannetje 1973; Mears 1973). However, the reverse has also been observed (Capriles and Hodgson 1974).

The problem can be considered in a more exact way by partitioning availability as:

availability = accessibility × acceptability

The accessibility of forage relates to an animals' ability to prehend it. Stobbs (1973b) has shown that bite size will be reduced if a pasture is short with a low yield, or if a mature sward with a high yield has a high stem content. Although increased grazing times or biting rate can compensate for a low bite size, fatigue sets an upper limit for such compensation (Stobbs 1973a).

In agronomic experiments, forage yields are usually expressed as the total production per unit area, and without details of sward characteristics it is difficult to predict animal production. Results can be biased if forage accessibility for grazing varies between treatments, particularly when yields or stem contents are high. Qualification not only on component fractions, but also on their distribution with height can be useful (Stobbs 1973b).

The acceptability of forage relates to an animals' willingness to eat it. Some species are simply unpalatable, but palatability can sometimes alter once an animal becomes accustomed to the feed. Soiling of forage by dung is a more ubiquitous source of poor acceptability, and estimates of the reduction in intake resulting from pasture soiling have varied from 11 to 47% (Brockington 1972). Urine has only a minor effect on acceptability (Norman and Green 1958). Soiling effects are more pronounced at a medium grazing intensity. At a low grazing intensity SR and hence the frequency of soiling is usually low, whilst at a high grazing intensity animals are forced to eat the less acceptable forage. Forage soiling is very important in the experimental context when one attempts to relate forage and animal production, and forage yields are inflated because soiling has reduced the acceptability. Viewed in another manner, forages with the same yield but different acceptability, provide different grazing intensities. For example Greenhalgh and Reid (1969) found a nine per cent reduction in organic matter intake, when similar amounts of soiled and clean pasture were fed to dairy cows.

There is a pressing need to define characters which describe the availability of forage. Experiments with such aims should be of a short duration so that a uniform forage supply can be maintained. Consequently a rapid animal measure such as bite size and rate of biting, intake, or milk production should be used. No one measure of availability will apply to the whole sward. Rather we must envisage that a sward yield will be partitioned into fractions of different availability. The distribution of yield over these different availability classes will have important implications for the rate at which a pasture can be "eaten out", or for the rate of change in animal production when the rate of pasture removal exceeds its growth rate.

STOCKING RATE DESIGNS

The use of fixed or variable SR provides a clear demarcation between the two major groups of SR designs (Wheeler, Burns, Mochrie, and Gross 1973). The designs can be further subdivided as follows, according to the duration of the experiment and the method of selecting variable SR.

Fixed stocking rate experiments. The SR are fixed at pre-determined levels for at least one year.

Short-term, fixed stocking rate experiments. The SR are fixed at predetermined levels for experiments of less than one year's duration.

Put-and-take experiments. The SR are varied according to an uncontrolled but measurable criteria.

Seasonally altered stocking rate experiments. The SR are varied to pre-determined levels during a year, whilst the experiment has a minimum of one year's duration.

Fixed stocking rate experiments

The fixed SR design is used extensively in grazing experiments in tropical areas of Australia. Major advantages of the design are its simplicity, ease of operation, and the ability to conduct stocking rate treatments without error. These are important advantages if experiments are sited at isolated locations or if little is known about the potential animal productivity of the pastures. However with increasing knowledge, as we have today for many areas, the rigid management of the fixed SR design becomes a disadvantage. Fixed SR designs abstract the treatment response from the dynamic nature of animal production on farms where a variety of management practices are used to aid animal or pasture production (Mauldon 1968). Furthermore, although SR may be held constant throughout the year, many biologically important variables fluctuate markedly (Table 1).

Results from fixed SR experiments are often subdivided to give animal production in each season. The results in Table 1 are typical with the GPA in winter being 16% of the summer rate. Evans and Bryan (1973) found the mean winter GPA on a tropical grass-legume pasture at a medium SR was 28% of the summer rate. This subdivision of GPA is useful for indicating the likely gain in different seasons when interpreting the total system. However all summer values, regardless of SR, are usually obtained from a low grazing intensity, and all winter values from a high grazing intensity. Hence, any attempt to use seasonal values to relate animal production to forage available includes substantial confounding with seasonal trends (Scharringa 1969). Seasonal effects may alter pasture quality (Evans 1969; Minson and McLeod 1970), and botanical composition (Mears 1973; Bryan and Evans 1973). Also carryover effects between seasons such as compensatory gain in animals, and unused forage will add to the confounding. This confounding can be avoided by using short-term, fixed SR experiments, where uniform pastures and animals are used at the commencement of the experiment.

TABLE 1

Variation between seasons in mean pasture and animal measures in a fixed stocking rate experiment

	Absolute values				Relative values			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Stocking rate (anim ha^{-1})	7.4	7.4	7.4	7.4	100	100	100	100
Liveweight (kg)	208	240	246	296	100	115	118	142
Liveweight gain (g $anim^{-1}$ day^{-1})	542	77	263	494	100	14	49	91
Maintenance requirement (Nat. Res. Counc. 1970) (MJ day^{-1})	29	32	33	38	100	110	114	131
Maximum voluntary intake* (Conway 1973) (kg DM $anim^{-1}$ day^{-1})	5.3	6.0	6.2	7.1	100	113	117	134
Pasture yield (kg leaf DM ha^{-1})	1860	1017	1240	1688	100	55	67	91
Forage allowance (kg leaf DM $anim^{-1}$)	251	137	168	228	100	55	67	91
Grazing pressure (anim (1000 kg leaf $DM)^{-1}$)	4.0	7.3	6.0	4.4	100	183	150	110

Data from Mears (1973) for a kikuyu pasture fertilized with 336 kg N ha^{-1} $year^{-1}$; animals replaced with six month old weaners at the beginning of each autumn.

*Organic matter digestibility of kikuyu taken as 0.65.

Short-term, fixed stocking rate experiments

The large seasonal variation in biologically important variables such as pasture yield, and the non-linear relations between pasture attributes and animal response (Morley 1966a, 't Mannetje 1973) can cause long-term mean values to obscure important facits of the pasture-animal relationship (Morley 1966b). For instance, whilst there may be a linear relation between mean GPA and SR (Jones and Sandland 1974), data from individual plots may show a grazing intensity threshold above which liveweight will plunge (Morley 1966a). Shortening the experimental period to span a relatively constant set of conditions will provide a sounder basis for investigating pasture-animal relations.

The grazing intensity on individual paddocks is often altered for 3-6 month periods for a variety of management reasons. Examples include situations where the persistence of a legume can be improved by reducing the grazing intensity with the trailing types (Jones and Jones 1971, Bryan and Evans 1973), or increasing the grazing intensity to reduce grass yield with white clover and *Lotononis bainesii* (O'Brien 1971, Bryan and Evans 1973); where bite size and hopefully intake can be improved by increasing the grazing intensity to increase the leaf : stem ratio (Stobbs 1973b), the grazing intensity is lowered by supplementary feeding, or the grazing intensity is increased by removing an area of pasture for cultivation or spelling another pasture (Morley and Spedding 1968). Short-term (3-6 months) experiments offer a means of investigating such situations whilst using constant SR. Also the potential range of SR within a season can be examined, without being restricted by the level of pasture production in other seasons. Such information is essential for rational management decisions to be made during a season and relates to management on a paddock rather than a farm basis (Lamond 1968). However the integration of the seasonal management into a long-term, whole-farm strategy requires supplementary information on the consequences of management decisions for part of a farm, on the whole-farm productivity (Morley and Spedding 1968). The clear understanding of when compensatory gain can be expected, and the rate of deterioration of carryover pasture are two important considerations in this regard. Eventually the various components should be combined to give systems which can be investigated as a whole (Spedding 1970).

One disadvantage of short-term, fixed SR experiments is that variable amounts of pasture may remain at the conclusion of the experiment and will have implications for production in the following season, especially when moving into winter. A complete understanding of a year-round grazing system will require some assessment of the value of such carryover feed.

Put-and-take experiments

Put-and-take techniques provide a further experimental refinement towards obtaining constant herbage availability. Stocking rates can be adjusted so that all herbage produced during the experimental period is consumed and there is no problem in evaluating carryover feed. However put-and-take experiments are subject to objectivity and time involvement limitations (Wheeler *et al.* 1973).

It is sometimes argued that the put-and-take technique is invalid because SR on a farm are essentially constant throughout the year. This argument ignores the fact that the grazing intensity can also be altered by supplementary feeding, forage cropping or changing pasture production by fertilizing. Nor do considerations which affect a farmer's ability to alter the grazing intensity disqualify the put-and-take technique as a valid means of obtaining constant conditions when investigating basic pasture-animal relations. The direct applicability of put-and-take procedures to commercial conditions depends on the range of management practices available, their decision intervals, and the frequency with which SR are altered in the experiment. The applicability gap may be quite small for many dairying situations, and with intensive beef production where management techniques with a short decision interval, e.g., nitrogen fertilizer, are used.

Seasonally altered stocking rate experiments

A smaller degree of partitioning into component processes is provided by seasonally altered SR experiments, which can run continuously over a number of years, with SR being altered in a pre-determined fashion to suit some management system. Such experiments have the advantage of being able to measure long-term trends, whilst using a better management system for a particular forage than is provided by fixed SR. However, treatment contrasts will include confounding due to differences in the amount of compensatory gain, in animal weight and in forage carry-over between seasons.

Few results are available from seasonally altered SR experiments. On temperate pastures, Conway (1968) found that whilst fixed SR treatments had a large effect on GPA, the seasonal GPA on a high-low SR treatment were similar to those on the corresponding fixed SR treatment for each season. The results suggest the carryover effects were unimportant for GPA, or alternatively opposing effects balanced out. Norman (1963) found that compensatory gain was more pronounced in cattle of 3 years and older. There is a need to clarify the importance of carryover effects for typical fluctuations in grazing intensity on tropical pastures.

CONCLUSIONS

In many areas of tropical Australia, there is a need for a second generation of grazing experiments to investigate finer details of the forage-animal complex than can be studied with the classical, long-term, fixed SR designs. Experiments must accommodate pasture management practices where SR can be altered to investigate the best grazing intensity for pastures or animals in different seasons. If the primary aim is to establish relations between forage and animal productivity, short-term experiments with a minimum of variation in grazing intensity within a treatment, should be used. The animal productivity should be related to the yield of available forage, where the yield is qualified according to its quality, availability and accessibility for grazing.

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