NEW METHODS AND CURRENT NEEDS IN PASTURE RESEARCH

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ABSTRACT

New methods for pasture research are reviewed and areas highlighted where improved methodology is required. Techniques to measure "states" (e.g. yield) are generally adequate but those for measuring rates (e.g. growth and decay, intake) are less satisfactory. Attention is also drawn to the need for measuring and interpreting variability within pastures. Gaps between research methodology and commercial use of pastures are discussed. The use of new statistical methods has often been resisted, and possible reasons for this are discussed together with some new statistical techniques.

INTRODUCTION

This paper on methods in pasture research considers measurements of plants, soil and animals, on-farm-testing, and data analysis. It examines recent developments and current needs. However improved methodology only complements, but does not replace, the need for imaginative thought in defining and solving problems.

METHODS OF MEASURING PLANTS, SOILS AND ANIMALS

Pasture yield, growth, and botanical composition

The main plant attributes recorded in Australian grazing trials with tropical pastures have been presentation yield and botanical composition. The BOTANAL package, using visual estimation methods, (Tothill *et al*. 1978; Jones and Hargreaves 1979) is now widely used for this and further changes have been suggested (O'Rourke *et al*. 1984). Hand held computers for field entry of data can eliminate the need for card punching (Hargreaves 1983). The disc meter (Stockdale 1984) has rarely been used in Australian tropical pastures. This is partly because it may not give as good a relationship with yield as can be obtained by visual estimation (authors unp. data), and partly because visual estimation of yield is part of BOTANAL.

For many years research workers in temperate areas have used paired quadrats with exclosures to measure pasture growth and decay (e.g. Hunt 1971). More measurements of growth (Bruce and Ebersohn 1982) will be required if accurate models of growth and utilisation of tropical pastures are to be developed and validated. Experience suggests that visual estimation of yield is not accurate enough to measure pasture growth rates. Non-destructive measurements by the 'new' electronic pasture meters (Burns *et al*. 1981; Vickery 1981) may offer scope. Field measurement of photosynthesis by gas exchange has been successfully used to measure growth in temperate pastures (Korte 1984), but this highly technical procedure will only be used for specific purposes. The greater heterogeneity in most tropical pastures, as compared with temperate pastures, will present extra difficulties in making and interpreting all these measurements.

Where pasture attributes are being related to animal production, there is increasing interest in subdividing plant biomass into green or dry and leaf or stem. There is no adequate yet rapid technique for doing this. Some workers use the dry-weight-rank component of BOTANAL, treating the plant components as if they were separate species, despite the caution of Tothill et al. (1978).

It can be misleading to relate percentage of a species or plant part in the total sward to the percentage in the diet. Stratified cutting down the sward profile, followed by separation into leaf or stem and green or dry, is still the only way of accurately describing that part of the sward presented to the grazing animal. If there is patchy grazing it may even be misleading to relate the diet of animals to the top of the sward, as sampled over the whole pasture area, without considering patchiness.

There is increasing realisation of the importance of spatial heterogeneity of pastures in plant/animal relationships (Keogh 1984; Taylor 1985). Patches can be large scale (McCown et al. 1977) or small scale, as with dung patches, (Jones and Ratcliff 1983). Patches can be permanent or transient and may relate to changes in botanical composition. Pasture heterogeneity in part, tended to be overlooked in the past because of the failure to recognize its importance and reluctance to accept results of non-random sampling. Also, with the exception of pasture height, the methods available were not well suited to take the large number of samples required to document variation in yield and composition. The BOTANAL package is currently being modified so that variability within a pasture can be documented from routine field measurements (J. Kerr, J.N.G. Hargreaves and R.M. Jones, pers. comm.). Large scale heterogeneity can be measured by remote sensing and aerial photography.

Agronomists tend to lump ecologically unrelated species into groups such as "miscellaneous weeds" and "other native grasses". While this is often justified, the "other species" can have quite different ecological and/or agronomic attributes and should be separated in some way. The supplementary use of floristics (the relative frequency of occurrence of all species) can provide insight into the ecological effect of different treatments (Tothill 1984).

There are no major problems in measuring presentation yield and botanical composition, but it is more difficult to partition yield into plant parts and to describe their spatial distribution and rates of growth, utilisation and senescence. These measurements should not become routine but will usually be restricted to those grazing trials where there is an emphasis on measurement of rates rather than states, for example, relating pasture growth to animal production. Such experiments may require a combined input from several scientists with different expertise (Parsons 1985). In other grazing experiments, simple measurements of presentation yield and botanical composition will be adequate, and a half-hearted attempt to measure a few more detailed pasture attributes would not be justified.

Ecophysiology

Demographic studies in pastures can be very time consuming. Jones (1985) suggested that demographic measurements should not be used routinely in all grazing trials whereas observing and thinking about demographic changes should be. Quantitative models of persistence have been developed for mixtures of annual species (Rossiter et al. 1985) but this will be more difficult for perennials (Jones 1985).

In temperate pastures, there has been increasing interest in the intensity of defoliation and the initiation and death of individual leaves and tillers (e.g. Chapman et al. 1984). Similar studies are commencing in tropical pastures, although there are extra difficulties with twining tropical legumes such as Siratro (R.J. Clements, pers. comm.). Because of the time required to take these measurements they will never become standard and will only be made where it is necessary to describe how and why pastures and animals interact.

Competition between pasture plants has been studied extensively in pots where the effects of root and shoot competition can be isolated by using subdivided containers (Snaydon 1979). In the field, Cook and Ratcliff (1984) have successfully used in situ steel tubes to study competition between seedlings and established plants. Larger tubes (30-50 cm diameter) may be useful for studying root and topgrowth competition between established plants.

There has generally been inadequate appreciation of the importance of root competition in pasture plants and this may lead to more measurements of root density or use of optic fibres. There is potential for separation of tropical grass and legume roots by using the ^{13}C technique (Ludlow et al., 1976). In ecophysiological studies there has generally been inadequate use of parallel experimentation in different environments, as used by Mott et al. (1981).

Fertilizer needs and responses

No major changes are foreseen in methods of plant and soil analysis, though the existing trends in automation, use of multi-element analyses and refining the interpretation of results will continue. Spatial variability in soil will always present problems in interpreting soil analysis, but use of fixed sampling sites reduces variability when examining long term trends (Vallis 1973).

There is increasing interest in cycling of nutrients in temperate (Hunt 1983) and tropical pastures and thus in developing methodology, particularly using radioactive isotopes (Anon, 1983). Understanding of cycling may lead to more efficient use of nutrients especially if nutrient flows can be modelled quantitatively. Preliminary information on nitrogen status in brigalow soils has already suggested possibilities for manipulating N flows by rotating crops and pastures (Catchpoole 1983) or by renovating grass pastures (Catchpoole 1984).

There is increasing evidence that some of the apparently poor relationships between pasture attributes and animal production are due partly to over-riding nutrient limitations for animals (Hendricksen et al. 1985). Relevant techniques are discussed by Gartner et al. (1980).

Microbiology

By using mutants of Rhizobium strains that are resistant to antibiotics it is now possible to follow survival of individual Rhizobium strains in the soil (Bushby 1983). This should aid in commercial availability of strains better able to persist in soil. Short term field responses to applied mycorrhiza have been measured in tropical pasture plants on infertile soils (Jehne 1980) but long term benefits of mycorrhizal application have yet to be demonstrated and the practical problems of field inoculation resolved. The successful culturing and distribution of bacteria capable of breaking down DHP, a toxic metabolite of mimosine, has raised the possibility of similar solutions for problems associated with other toxic plants grown outside their area of natural distribution (Jones and Hegarty 1981).

Forage quality

Cellulase is replacing rumen liquor for measuring in vitro digestibility, reducing the variation between laboratories and eliminating the need for maintaining rumen fistulated sheep. Near infra-red reflectance (NIRR) shows some promise for predicting several attributes of forage quality (digestibility, intake and protein content) but early studies did not adequately consider the bias introduced by differences in grass species, age of regrowth, plant part (leaf or stem) and form (chopped or pelleted) (Minson et al. 1983).

There is still no really satisfactory method of predicting intake from small samples of forage. The good relationship between intake and digestibility may be adequate for selection within a plant species, but not between species. There is some possibility based on the resistance of plant particles to breakdown by grinding (Zoot and Reed 1981).

Preliminary Evaluation of Pasture Plants

Conceptual stages in agronomic evaluation of pasture plants have been outlined by many authors (e.g. Jones and Walker 1983). However, these procedures are not always followed in practice and successful pasture plants in a given environment will often show up regardless of the "system", e.g. Vigna parkeri (Jones 1984). We foresee no major change in the cooperative procedures currently used by the State Departments of Agriculture and CSIRO for introduction, description and classification of tropical forage plants, although more use could be made of overseas screening for pests and diseases.

Although there has been a swing away from evaluation by cutting in recent years, this may have gone too far. Cutting height x frequency experiments (e.g. Jones 1974) have given reasonable predictions of a species' reaction to grazing pressure. Perhaps their main drawback is that they have given less satisfactory prediction of plant recruitment than of plant survival. When evaluating pastures under grazing, improved methodology will not substitute for duration of testing. Pasture persistence and productivity after three years can be quite misleading if extrapolated to longer time spans (Jones 1985).

Plant/animal interface

Pastures which differ in structure, botanical composition and presentation yield often give similar liveweight gains and the reasons for this are not understood. This suggests that we do not know enough about the plant/animal interface. Simple observations may be adequate for some purposes. Oesophageal-fistulated animals are sometimes used to determine what species or plant parts animals are selecting, but the results obtained from small groups of animals, introduced to different pastures for a short period of time, may not be the same as from animals regularly grazing the same treatment (D.B. Coates, P. Schachenman and R.J. Jones, pers. comm.).

Seasonal changes in palatability and selective grazing can have a considerable impact on pasture stability, legume persistence, and animal production. Analysis of cuticle fragments in faeces can be used to distinguish between different grass species in the diet but not with dicotyledons where the cuticle is less resistant to digestion (Slater and Jones 1971). However, it is possible to correct for differences in digestibility of ingested species (Leslie et al. 1983). Other possible ways of determining the percentage of species in the diet include measuring indigestible hairs from legume leaves which are recovered in faeces (Jones and Slater 1986), and utilising the difference in carbon isotope uptake by C_3 and C_4 plants through analysis of extrusa, faeces, hair and other tissues (Jones 1981). Both these approaches have limitations; the former depends on legumes having distinguishable and indigestible leaf hairs, and the latter is difficult to interpret when there are several C_3 plants grazed in the pasture, and also requires access to a mass spectrometer. Searches could be made for chemical markers in faeces which could reflect the percentage legume in the diet.

Methods of measuring intake have been reviewed by Leaver (1982). Intake of grazing animals is usually measured with the standard chromic oxide technique and new slow release capsules show promise. Intake can be measured by weighing animals before and after grazing and collecting and weighing excreta during grazing (Penning and Hooper 1984). The use of weight-sensitive boots fitted to cattle (Horn 1981) could be difficult in practice. Because the bolus size swallowed by grazing animals is relatively constant (Stuth and Angell 1982), it may be possible to estimate intake by counting the number of boli swallowed by attaching a sensory device to the animal's neck . This may overcome the problem of variability in bite size noted by Chacon et al. (1976), Hodgson (1982) and Penning et al. (1984).

Intake in grazing trials can be calculated from liveweight gains of animals of a specified weight (Baker 1982). This approach has been extended by D.J. Minson and C.K. McDonald (pers. comm.) who have assumed different levels of digestibility of ingested feed based on daily liveweight gain. This back calculation may be quite adequate for many purposes, e.g. to assess intake of feed as a percentage of pasture productivity, but is of little value for short term studies.

GRAZING EXPERIMENTS AND ON-FARM-TESTING

Agricultural research aims to produce information or technology that can be used by managers to improve the stability and/or productivity and/or efficiency of agriculture. Hence the farm is the final testing site. This has not always been fully appreciated by researchers, e.g. there have been more difficulties with Siratro persistence on farms than on research stations (Brown 1983).

Part of the problem may lie with the relevance of the typical grazing trial. There are many differences between commercial grazing and set stocked and continuously grazed experiments. Any rigid management system involving "put and take" grazing or fixed rotations is likely to be equally far removed from the reality of beef enterprises, though perhaps more relevant to dairy farms. Fire is excluded from most grazing experiments but may be normal practice on properties. The effect of fire on Siratro seed reserves (Mannetje _et al_. 1983) may partly explain the apparently poorer persistence of Siratro in commercial plantings (Jones _et al_. 1983, Brown 1983).

Murtagh (1975) has suggested we need "second generation" grazing trials which could involve, for example, changing stocking rates (or grazing pressures) with seasons. Flexible stocking rates have been used successfully (Jones 1984; Lodge and Whalley 1985), but there need to be sound reasons for deciding when to change stocking rates. If the interest is in changes in pasture composition and productivity with time, and not with animal production, smaller grazed paddocks under rapid rotational grazing appear adequate (e.g. Jones _et al_. 1980).

These "second generation" trials should encompass variables closely related to farm pastures, i.e. underfertilization, fire, seasonal changes in stocking rates and integration with other feed sources. Some of these variables could possibly be studied in secondary small plot experiments laid out within grazing trials. Farm surveys on the ground (Rees _et al_. 1972; Carter 1981; Morley 1981; Cook _et al_. 1985), or by remote sensing (Vickery _et al_. 1980), and documentation of farm experience (Vera _et al_. 1984; Edye and Gillard 1985) can also suggest subjects for future research.

More attention could be paid to "on-farm testing". This is not just putting research plots on farms, but involves seeing how new technology (e.g. improved pastures) fits into the whole farm operation. With the projected increase in cropping in Queensland (Weston _et al_. 1981) there will be greater need for a whole farm approach and increased interaction between graziers, extension workers, research agronomists and specialists (e.g. modellers, economists). On-farm testing of pastures will be more difficult than it is for crop research because of larger areas involved and the time required to evaluate new species or management practices.

DATA ANALYSIS

Agricultural research provided the catalyst for the revolutionary advances in the design and analysis of experiments developed by Fisher and Yates in the 1920s and 30s. So successful were these methods that agricultural research seems reluctant to contemplate improved statistical procedures. The standard techniques of analysis of variance and multiple comparisons of treatment means are powerful tools when correctly used. However, they are often blindly applied when more appropriate analyses exist. A prime example is where treatment levels are quantitative, and the interest really lies in the shape of the response function rather than in the significance of treatment differences (Mead and Pike 1975; Gandar and Kerr 1980).

Another common shortcoming in agricultural literature is the concentration on statistical significance at the expense of practical significance. Given sufficient replication, any two treatments can be shown to be different, but is the magnitude of the difference of practical importance? In statistical parlance, there should be more emphasis on estimation and less on hypothesis testing (Chew 1980). There are many useful techniques which have not found their way out of statistical literature into applied disciplines. We discuss a few which are of particular relevance to pasture research.

Ranking and selection

In plant breeding or evaluation trials, the aim is usually to identify the best variety (e.g. in terms of dry matter production, seed yield, nutritive value), or to reduce a vast number of varieties to a group of promising ones. Analysis of variance is not the appropriate procedure and ranking and selection procedures, such as the "indifference zone" approach (Bechhofer 1954) and subset selection (Gupta 1965), are more appropriate. These methods are described in detail by Gibbons *et al*. (1977), and Edwards (1985) has released an interactive computer package which performs ranking and selection analyses.

Spatial analysis

When observations are taken over an area, e.g. soil or plant samples from a paddock, the mean and standard deviation do not provide a complete summary of the data. For little extra effort the location of each sample can be noted, and the spatial variability over the area examined. Spatial information is often useful in interpreting results. Different soil properties or vegetation patterns can be "mapped" over the area and their inter-relationships examined. Sample values, particularly those located close together, may not be independent and should be accounted for through spatial autocorrelation between sample points. The effect of autocorrelation can be reduced by sampling on a regular grid rather than randomly (McBratney & Webster, 1983). Spatial analysis can be used to delineate homogeneous areas for future experimentation. It is often informative to investigate spatial variability at several scales (Mead 1974). Spatial methods are described by Ripley (1981) and Diggle (1983).

Analysis of field trials can incorporate information from the yields of neighbouring plots. Such "nearest neighbour" models have been claimed to be substantially more efficient than conventional randomized block designs. Various competing methods of nearest neighbour analysis are appearing in the statistical literature (e.g. Wilkinson *et al*. 1983, Besag and Kempton 1985, Green *et al*. 1985).

Fertilizer response models

Much work has been done on the response of monocultures to applied nutrients. Similarly, competition between pasture plants has been extensively studied, often via the de Wit (1960) replacement series model. Less attention has been paid, however, to the response of a mixed pasture to applied nutrient, despite the general principle that "the behaviour of mixed stands is not predictable from the behaviour of pure stands" (Harper 1964).

A recent model (Sinclair and Probert 1985) combines elements of plant growth analysis and the de Wit model to examine the response of a mixed grass-legume pasture to applied phosphorus. The approach, which extends to the response of any multicomponent system to a quantitative input, provides insight into the changing competitive situation in the pasture. Recommendations, for example, as to the optimal level of fertilizer to maximize legume yield in the pasture can be obtained.

Informal and graphical methods

There has been a trend in statistics in recent years toward more informal methods of data analysis. Tukey (1977) has paved the way for a variety of ingenious techniques which are not hamstrung by the assumptions underlying much of classical statistics (e.g. normality and constant variances). Doubts about the validity of these assumptions have led to the development of the promising "bootstrap" and "jackknife" methods of data analysis (Efron and Gong, 1983).

A picture can be worth a thousand words in the presentation of research results. Interesting graphical techniques for statistical analyses are given by Gnanadesikan (1977), Barnett (1981) and Chambers *et al*. (1983) and, in the agricultural sphere, Russell (1984).

Resistance to new methods

While pasture research literature is not completely devoid of innovative statistical analyses, and has been prominent in development of pattern analysis (Williams 1976), new techniques are generally not filtering through from the statistics journals. Why? The statistical profession must bear some of the blame. Esoteric articles in theoretical statistical journals earn greater rewards than excellent expository articles in applied journals. Thus statisticians lack the incentive to make practitioners aware of the latest advances. Agricultural scientists, on the other hand, often regard statistics as a necessary evil giving apparent legitimacy to their research results. They need to be convinced of the value of unfamiliar methodology. Finally, agricultural journals are conservative and reluctant to publish unconventional analyses.

Pasture research can only benefit from the adoption of improved statistical methods. Advanced statistical packages such as MINITAB and GLIM are now readily accessible but improved methods do not do away with the wisdom of consulting with a statistician during design and analysis of experiments.

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