A summary of grazing trials carried out by CSIRO in northern Australia from 1950-2000: treatments imposed and attributes measured

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Abstract

The published records of 73 grazing trials that measured pasture and animal production, carried out by CSIRO in northern Australia from the 1950s to 2000, have been collated. They have been grouped into 5 geographical regions: coastal subtropical Queensland, subcoastal subtropical Queensland, tropical Queensland, the Northern Territory and northern Western Australia. No CSIRO experiments of this type are currently in progress. The duration of each trial is given and also an indication of whether it included native pastures, oversown native pastures and/or fully improved pastures. The treatments imposed, e.g. stocking rates, tree killing, introduction of legumes, use of supplements, fertilisation (N, P, K or lime) and burning, have been tabulated for each trial. This format makes it easy to find all the trials that have examined the effects of any particular variable. Many trials have measured attributes other than cattle liveweight gain and pasture yield and composition, including: demography, biodiversity, seed contents of faeces, pasture quality, carcase quality and economics, dietary composition, run-off following rainfall and soil fertility. The extra attributes measured in each trial are also listed, making it possible to determine which trials have information on any specified attribute. No experimental data are presented in this paper; rather it is a record of where experimental data can be found. Similar pasture information is given for a further 12 trials where grazing treatments were imposed but no measurements made of animal production.

Some comments are made about regional differences in the emphasis placed on native pastures as compared with fully improved pastures. It is suggested that inadequate emphasis was given to burning and to grazing management, other than stocking rates, as variables and also that there has been inadequate use of grazing trials as a resource in which to measure how attributes such as biodiversity and soil properties have been affected by the treatments imposed. It is also pointed out that writing up the results of grazing trials for the conventional scientific paper has resulted in the loss of data that could be useful in model development and validation. Some comments are made about attributes which could have been measured, at least in some trials, but were not. Finally, it is stressed that the value of many grazing studies, in terms of measuring changes in botanical composition, has been limited by their short duration.

Introduction

CSIRO has played an important part in developing improved pastures and an understanding of how to manage improved and native pastures in northern Australia. Almost all of this CSIRO research has been conducted by scientists in the Division of Tropical Pastures (1959-1972), Division of Tropical Agronomy (1972-1975), Division of Tropical Crops and Pastures (1975-1996) and CSIRO Tropical Agriculture (1996-2000). This work sometimes involved grazing experiments, where the impacts of different pasture species or management practices on cattle production and/or pasture productivity were measured. As CSIRO currently has no experiments of this type, it is an opportune time to summarise all the published information from such studies in terms of the treatments imposed and the attributes measured. With the increasing interest in the use of modelling, it is also important to alert scientists to sources of published data on animals and plants, which might be useful in the development or validation of models.

This paper provides details of all CSIRO trials where liveweight gain and/or reproduction of beef cattle and pasture composition were measured under controlled grazing. In the majority of cases, only 2-4 head, usually steers, grazed each treatment. Short-term trials carried out in the

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1970s using dairy cattle have not been included; a complete list of publications describing these trials can be found by looking under “Stobbs” in the list of CSIRO publications compiled by Thompson (1982). With one exception (Roe and Allen 1993), CSIRO has not reported on any grazing trials with sheep in northern Australia, apart from one instance where sheep were used in an endeavour to assess quality differences in different accessions of buffel grass (*Cenchrus ciliaris*) (Minson and Hacker 1995) and another where sheep were used as grazers in an evaluation study in the coastal lowlands (Bryan and Evans 1971a). Other state-based government departments, especially the Queensland Department of Primary Industries (now Queensland Primary Industries and Fisheries), and some universities have also made major contributions in the fields of pasture improvement and animal production, but their contributions were not included in this paper. However, some of the studies reported here were made by workers outside of CSIRO but were on CSIRO experiments (e.g. Orr et al. 2004a; 2004b).

Grazing trials with annual forage crops, such as those with forage sorghum or oats in the Ord River valley (Blunt and Fisher 1973; 1976) or with oats in central Queensland (Coaldrake and Smith 1967) have not been included. The experiments carried out on Townsville stylo (*Stylosanthes humilis*) at Katherine Research Station during the 1960s have not been included. Most were short-term trials, lasting less than 2 years and/or grazed for only part of the year. For further information on these trials, refer to Norman and Phillips (1970) and Norman and Begg (1973).

This paper outlines what treatments were imposed and then lists the types of data collected. It does not give actual results, but refers to publications where these data are presented. In the vast majority of the experiments considered, the data are available in published papers. A few of the experiments listed have not been formally written up, but some of the key data have been summarised in annual reports and conference papers, so they have been included in this paper. Three Ph.D. thesis studies, conducted within listed long-term grazing trials, have been included, even though the results of these studies have not been published. This paper complements the publication of Hasker (2000) that presents information from trials and producer-demonstration-sites under headings such as weaners, supplementation etc. within northern Australia. Day et al. (1997) have also summarised the results of 10 grazing trials on native pastures within Queensland.

**Methods**

The published papers were examined to determine what treatments were imposed, and which attributes were measured other than animal production and basic pasture yield and composition.

**Results**

*Location of trials and treatments imposed*

Details of the trial sites, including location, rainfall and soil type are listed in Table 1. Soil types have been listed using the terms in the relevant published papers, so several different forms of nomenclature have been used. In some cases, where no soil type is given in the original publication, soils have been described using general terms such as “clays”, based on personal knowledge of the site.

Table 2 gives details of each trial, which is allocated a number. Where a trial ran for a number of years but was then appreciably modified, the different phases have been indicated by use of the letters a, b and c after the same trial number. In cases where the same experimental site has been re-used, but with completely different treatments in the second trial, the second trial has been given a new number. Table 2 lists the site name and the duration of the trial in years, and the pasture types, designated by an ‘x’, have been grouped into 3 classes: native pasture, oversown native pasture and fully improved pasture. The table then uses an “x” to indicate the types of treatments imposed in each trial, under the following column headings:

- **SR** Stocking rates - the trial included 2 or more stocking rates
- **Gs** Grazing systems - the trial compared 2 or more grazing systems. Most trials had continuous grazing only.
- **N** Nitrogen - there were 2 or more levels of nitrogen fertilisation
- **P** Phosphorus - there were 2 or more levels of phosphorus fertilisation
- **K** Potassium - there were 2 or more levels of potassium fertilisation
Ca Calcium - there were 2 or more levels of lime or calcium fertilisation
Gr Grass - 2 or more grasses were compared as different treatments
Le Legumes - 2 or more legumes were compared as different treatments
Tr Trees – the effects of tree killing were examined
Ha Hay - 1 treatment included conserving excess feed during the growing season and feeding this in winter
Bc Breed comparison - productivity of 2 or more cattle breeds was compared
Su Supplements - the effects of nutritional supplements such as P and N were examined
Bu Burning - the effects of burning stand-over feed were compared with not burning

A very brief description of each trial is given, with the key reference to that trial. The only exception is that the key reference to trial 36 is a particular issue of Tropical Grasslands. This is because the results of that trial were presented, along with the results from other grazing trials on the same topic, in 6 different papers within the one journal issue.

Attributes measured

Trials 1-82b all contain some data on animal production, although the level of detail varies widely. Almost all of these trials have some data on pasture yield and botanical composition. Trials 101-112 contain data on yield and composition only. The plot sizes in these trials were adequate to give controlled grazing but not large enough to enable measurement of animal production.

Table 3 lists attributes other than liveweight gain, pasture yield and botanical composition data that have been measured in these trials. It refers to trials by the same numbering system used in Table 2. In some instances, where many extra attributes have been measured, 2 or more lines have been used in Table 3 to list all the attributes measured in the 1 experiment.

Other attributes measured in these trials are listed under the following column headings:
Sf Soil fertility - includes attributes such as pH, available P, total N, total C
Ro Run-off - includes measurements of run-off and soil loss
De Demography - includes plant survival, seed-set, seed banks, seedling recruitment
Fs Faecal seed - seed levels in cattle faeces
Bi Biodiversity - plant biodiversity or species richness
Ec Economics - economic analyses were carried out comparing different treatments
Pq Pasture quality - measurements such as N%, P% and digestibility
Cg Carcase grade - carcase grades of animals from different treatments
Am Animal measurements - includes P in blood and bone, thyroxine in blood
De Dietary composition - from oesophageal fistula or analysis of C isotopes of faeces
Gr Grass - includes measurements of grass leaf/stem and green/dry components, etc.
Re Reproduction - includes measurements of grass leaf/stem and green/dry components, etc.
Pe Pests - includes ratings of insect damage

Following the individual columns for these attributes, the next column gives very brief details of what was measured. Phrases in this column separated by a semicolon indicate they relate to different areas of study. For example, the first phrase may relate to measurements of demography and faecal seed, whereas the next phrase relates to measurements of animal reproduction. The order of phrases is, as far as possible, the same as in the headings Sf to Pe, as given above. Appropriate references follow. If there are 2 references separated by a semicolon, the first refers to the first phrase in the previous column.

Obviously, not all entries have the same amount of information about that attribute. For example, one of the entries with an ‘x’ for biodiversity could have a large amount of information with complete listing of all species present. Others might have much less information, yet still present enough to warrant inclusion. In contrast, papers that had only a sentence or two about “other important species” were not given an ‘x’ for biodiversity.

Details on pasture quality

Further details of any pasture quality and animal measurements are given in Table 4. Using the same trial numbers as previously, the first 2 columns indicate whether measurements were made on cut samples, which were usually taken from herbage samples cut to 10 cm above ground level, or were plucked by hand to simulate what animals might eat. The next 4 columns indicate if samples were from native grass, sown grass, legume or a mixture. The following 12 columns
describe what elements (N to Mn) were measured in at least some of the samples, while the next column indicates if measurements of \textit{in vitro} digestibility were taken. The final column of plant attributes indicates that some measurements were made of leaf:stem ratios or of green and dry leaf in at least some of the samples. The next 9 columns relate to measurements of animal bone P, blood, faeces or saliva. Appropriate references are then listed, using semicolons as described previously.

\section*{Discussion}

It is not the purpose of this memorandum to present or review data. However, some general observations can be made about the types of experiments used and on the attributes measured.

Firstly, there is an interesting difference between the pasture types used for experimentation in southern Queensland and those used in north Queensland and the Northern Territory. In southern Queensland, most experiments have been on fully sown pastures rather than on oversown or undisturbed native pastures. This is presumably partly due to historical changes in thinking and partly to practical considerations. When many of the grazing trials were set up in the 1960s, it was assumed that pasture improvement would be more important than it has actually been. For example, Davies and Eyles (1965) estimated that $\approx 58$ M ha of Queensland could be improved, whereas more recent estimates (Walker and Weston 1990) suggest a figure of 22 M ha. Similarly, native pastures were perhaps undervalued by CSIRO policy makers, so it is not surprising that there was less emphasis on native pastures in the 1960s. Furthermore, much of this early research work was done in the coastal and brigalow areas, where there were usually no or insufficient useful native grasses to quickly colonise the newly cleared areas. Consequently, the emphasis was on sown pastures. Despite this, there was some work on native pastures in southern and central Queensland in the 1950s-1970s, primarily at Narayen, Westwood and Rodds Bay. In contrast to southern Queensland, experiments in northern tropical Australia, with the exception of those under irrigation at Kununurra in Western Australia, focussed on undisturbed or oversown native pasture.

Secondly, there has been little research on burning, although burning is a topic of considerable interest in relation to pasture composition (Winter 1987; Orr \textit{et al.} 1991). Burning was a variable in one trial in the northern Territory (70d), and in two medium-term experiments at Narayen Research Station (34b; 37) and some opportunistic observations were made after an accidental burn in sown pastures in experiment 33 at Narayen. In addition, the effects of tree clearing have been investigated in only 4 experiments.

Thirdly, very few trials have looked at grazing management other than set-stocked year-long grazing. While this form of management has the distinct advantage of reproducible simplicity and is well suited for initial grazing studies, there has been very little attempt to move further. This would involve the examination of the effects of short- or long-term resting, deferred grazing or even seasonal changes in grazing pressure (column Gs or grazing system in Table 3). This is despite the early scientific demonstration of the major impacts that these factors can have on pasture composition (\textit{e.g.} Jones 1933) and of the improvements claimed by graziers who have used these strategies on their own properties (\textit{e.g.} Lansberg 1993). It is also interesting to reflect that, while many of the treatments imposed have resulted in overgrazed pastures at the heaviest stocking rate, little effort has been made to investigate how to restore these overgrazed pastures. Even the simple use of small exclosures or cages on such pastures can provide very useful information on recovery (Jones 1992). There are very few instances of where grazing treatments have been deliberately imposed on poor or degraded pastures with the objective of restoring them (\textit{e.g.} Jones 1984; Ash \textit{et al.} 2001; Jones and Jones 2003).

Fourthly, a considerable amount of information has been collected on nutrient concentrations in forage. This was collected to provide data to enable better interpretation of results of animal growth. With the exception of the detailed work on P in plants, soils and animals (\textit{e.g.} experiments 36, 53 and 70c), it is questionable how much of this has been useful, particularly from cut samples. It is very difficult to relate the data from the many ‘whole plant’ samples (cut to ground level) to material being selected by grazing animals. There is abundant evidence of the ability of animals to select a higher quality diet than the mean
of the pasture on offer, even in intensively grazed and high quality temperate pastures (Jacobs et al. 1999), where selection is unlikely to be as critical as it is in extensively grazed tropical pastures. While the whole plant analyses describe broad changes in overall pasture quality with season or species, they may be of little practical use. The data on plucked samples, taken to simulate what animals are actually eating, are more likely to be of use in explaining results or in modelling studies. However, it is uncertain how representative plucked samples are of the material that animals are ingesting. Similarly, caution is needed in extrapolating measurements of diet selection, as measured by oesophageal-fistulated animals, to free-grazing animals (Coates et al. 1987b; Clements et al. 1996). While there is considerable value in measuring nutrient content if this can be related to true pasture yield, and then to nutrient status of the pasture system, these parallel measurements were not made in any CSIRO trials.

Fifthly, comparatively few studies have taken advantage of the opportunity that is afforded to take extra measurements of other variables such as species diversity, plant demography and soil fertility that can be measured in grazing trials. The advantage of taking such measurements is that they can be placed in the context of controlled variables such as fertiliser and stocking rates and known rainfall and pasture composition. It is then possible to gain insight into how the different management treatments affect the ecology of the whole grazing system. For example, some environmentalists argue that sowing of species such as buffel grass reduces species diversity. Yet, in the many experiments sown to buffel grass, records have been taken of the complete species list of associated species only in experiment 34 (although they are as yet largely unpublished) and, to a much lesser extent, experiment 35. Thus, the opportunity to ascertain how species floristics have been affected by the use of buffel grass has been lost. There was not even one instance of where measurements were made of how treatments affected below- or above-ground grassland invertebrates. Similarly, there has been very little use of exclusion cages to measure how applied grazing treatments have affected true pasture growth and decay. Such measurements are particularly useful in pasture modelling. Likewise, there have been only rare instances, such as McIvor et al. (1995) and Orr et al. (2004a), where the basal area of perennial grasses has been measured, although this can be a very useful attribute in rangeland research. These statements, however, are not to imply that such extra measurements (O’Reagain et al. 2008) should be taken in all trials, as the merit of taking them depends on many factors, such as the importance of the pasture types being investigated. This concept of making more use of grazing experiments by measuring extra variables has been discussed in more detail by Jones et al. (1995a).

Sixthly, valuable information on pastures has been obtained by using small paddocks that enabled different stocking rates to be imposed, yet were not large enough to measure animal production. This applied to trials 101-112, particularly to 107 and 108, where many ecological processes, such as colonisation and tree regrowth, were investigated. There is good evidence that such small plots can give realistic stocking rate effects, as shown by the comparable effects of heavy grazing on Setaria sphacelata pastures in very small paddocks (<0.1 ha) (Jones 1979) and larger paddocks of 1-3 ha (Jones and Jones 2003) and on commercial pastures in the same region. In all cases, the tussock grass setaria was replaced by prostrate grasses such as Digitaria didactyla. However, caution may be needed in using small plots to compare different grazing systems owing to the small number of animals used in small plot studies (Norton 1998). The limitations of small plots may also be greater in rangeland research compared with intensively grazed improved pastures, owing to greater spatial and temporal variability (Ash and Smith 1996).

Finally, many of the grazing trials carried out in the 1960s-80s collected vast amounts of data on pastures and animal liveweight changes at regular 4-8 weekly intervals. These data could be of considerable use in model development and validation, but with two exceptions (McCaskill 1992; McDonald et al. 1995) were not published. As published data on long-term trials are often presented on an annual basis, or even as the mean of a number of years, this detailed information is lost unless it is specially presented in another form. However, it must also be acknowledged that much of the regular information collection occurred in the early years of the trials, before many of the important changes in botanical composition took place (e.g. Jones et al. 1995b; Jones and Jones 2003; Jones 2003). This highlights a potential problem in short-term grazing studies, particularly if carried out for less than 5 years;
it is quite likely that such studies could provide a misleading indication of long-term pasture persistence. The difficulties associated with documenting long-term botanical changes in grazing studies and possible ways of overcoming them have been discussed in more detail by Jones et al. (1995a).

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