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Utilising faecal NIRS measurements to improve prediction of grower and breeder cattle performance and supplement management

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Abstract

For decades a major limitation to applying nutritional science to the management of grazing cattle has been the difficulty in estimating the intake of nutrients from pasture. Faecal near infrared reflectance spectroscopy (F.NIRS) is a novel technology which provides this information. The project developed technology for northern producers to utilise F.NIRS. It examined F.NIRS to measure diet quality and growth of cattle in a number of northern pasture systems (e.g. speargrass, Mitchell, Leucaena), and the responses of cattle grazing Mitchell grass to nitrogen (N) supplements. F.NIRS measurements of dietary crude protein (CP), digestibility (DMD) and the proportion of legumes, forbs and browse selected by grazing cattle were generally consistent with expectations, although the intake of forbs was often high. Cattle appeared to respond to urea supplements when the ratio DMD/CP was greater than 8-10. F.NIRS could be used to predict breeder herd productivity. 'Proof-of-concept' was demonstrated that F.NIRS calibrations could be expanded using digested forage residues from nylon bags instead of faeces. This will greatly reduce costs of expanding some F.NIRS calibrations. Producers will benefit from knowledge of the reliability of F.NIRS technology for growing and breeder cattle, from improved knowledge of cattle responses to urea supplement, and the value of N supplements for cattle grazing Mitchell grass pastures.

Executive Summary

A long-standing limitation to the application of science to improve nutritional management of cattle grazing the extensive pastures of northern Australia has been the difficulty in estimating the quantity and balance of nutrients selected by the animal from the pasture. Faecal near infrared reflectance spectroscopy (F.NIRS) is a novel technology, far superior to any current alternative, to measure the diet selected by grazing cattle. F.NIRS allows many characteristics of the diet selected by grazing cattle to be measured rapidly and economically from dung samples collected in the paddock. Project NBP.302 (NIRS Task 2), in collaboration with NIRS Tasks 1 and 3 (*NAP3.121, Improving faecal NIRS calibration equations* and *NBP.303, Delivery of faecal NIRS and associated DSS as a management tool for the northern cattle industry*), developed technology to allow northern producers to more effectively utilise F.NIRS to improve the nutritional management of their cattle by:

(i) determining the reliability of F.NIRS to predict diet quality and liveweight change of young cattle and breeders,
(ii) determining animal responses to nitrogen (N) supplements particularly in the Mitchell grass downs and developing criteria to use F.NIRS to predict responses to supplements, and
(iii) setting up a F.NIRS analysis system in Rockhampton, developing a laboratory based system to expand F.NIRS calibration equations, and experimentation to improve use of F.NIRS to measure voluntary intake and selection of cattle grazing tropical pastures.

The major project activities included:

(i) a trial examining the responses of cattle grazing Mitchell grass pastures to N supplements and testing F.NIRS in this context,
(ii) trials to test the ability of F.NIRS to measure diet quality and animal performance in the northern and southern speargrass environments, the north-west Mitchell grass downs, and on Leucaena-grass pastures. Measurements were also made in other regions (Mitchell grass near Longreach and Richmond, buffel and Indian couch pastures near Charters Towers, arid browse-grass near Charleville). F.NIRS was related to other nutritional indices and responses to N supplements,
(iii) testing F.NIRS for nutritional management of breeders,
(iv) transfer of F.NIRS calibration equations to an NIR instrument in Rockhampton, development of a laboratory-based procedure to expand F.NIRS calibration equations and development of F.NIRS to measure additional components of pasture, and
(v) experiments to generate diet-faecal pair samples for F.NIRS calibration equations in the NIRS Task 1.

Low rainfall caused difficulties at all sites and the animal and F.NIRS measurements during the project tended to represent low rainfall years. F.NIRS measurements of crude protein (CP) content, digestibility (DMD) and proportion of non-grass in the diet selected by cattle were usually consistent with the rainfall patterns, the available pasture, and the expected annual cycles. The proportion of non-grass (i.e. forbs, and/or sometimes browse) was often higher than it was expected would be selected by grazing cattle. On Mitchell grass pastures the diet CP concentration was often maintained until the late dry season, apparently by the forb component.

The ratio DMD/CP, measured by F.NIRS, provides a better criterion than diet CP to predict when cattle will respond to rumen degradable N supplements such as urea. Animals appeared to respond when the DMD/CP ratio was greater than 10 in the Mitchell grass pastures, but greater than 8 in the northern speargrass pastures. F.NIRS measurement of DMD/CP provides an important decision support system to better manage the timing and quantity of urea supplements.

F.NIRS measurements of diet quality were not affected by pregnancy or lactation. In animals fed loose mineral mix or low levels of cottonseed meal F.NIRS measured the quality of the forage ingested; estimates of the diet CP of supplemented animals need to be adjusted for the N in the supplement.

F.NIRS predictions of liveweight (LW) change depended on calibrations entirely independent of those for diet quality. The established NIRS mathematical procedures used restricted the calibrations to young growing animals, and hence the calibrations cannot be applied directly to mature or supplemented animals, or lactating breeders. Predictions of cumulative LW change of young growing animals over extended intervals were generally acceptable for the speargrass pasture regions, but not for Mitchell grass. Error in prediction of LW change from a single faecal sample was too large for this measurement to be generally useful. A modified calibration for LW change predicted Leucaena-grass pasture acceptably at one specific site, but this calibration was likely not to be suitable for general application.

It was demonstrated that F.NIRS can be used to satisfactorily measure the diet quality and nutritional status of lactating breeder cows. Liveweight (LW) change of the non-lactating breeder grazing northern speargrass pastures at one site (Swans Lagoon) was well predicted by F.NIRS. Estimation of the LW change of lactating cows from F.NIRS measurements would require adjustment for the effects of lactation.

F.NIRS calibration equations were transferred from the NIR spectrometer in Davies Labs, Townsville, to that in CQU Rockhampton. 'Proof of concept' was demonstrated that (i) it is possible to use digested forage residues as proxy faecal samples to expand F.NIRS calibration equations for diet quality, and (ii) that F.NIRS can be used to measure plant species and the leaf-stem ratio in the diet of tropical pastures. Trials were conducted to generate diet-faecal pair samples for 43 diets using cattle fed in pens, or oesophageally fistulated cattle, to contribute to NIRS Task 1.

Producers in the northern cattle industry will benefit immediately from this project by the ‘proving’ of F.NIRS technology, and in particular by:
(i) knowledge of the reliability of F.NIRS across many of the important pasture systems,
(ii) development of the DMD/CP, measured by F.NIRS, as a criterion expected to be better than dietary CP to predict when cattle will respond to urea N supplements,
(iii) knowledge of the effectiveness of N supplements for cattle grazing Mitchell grass pastures,
(iv) knowledge of how to apply F.NIRS to the breeder herd.

It is recommended that further R&D resources be invested in the following activities:

i. Support for the maintenance and ongoing validation of F.NIRS calibration equations, and the necessary skill base. Calibration maintenance is a necessary aspect of NIRS. This will require access to samples from appropriate cattle experiments conducted for other reasons, resources for NIRS analysis, and for the conduct of animal experiments to generate diet-faecal pairs and for growth performance.
ii. Further develop F.NIRS calibration equations for pasture systems not adequately represented in current equations. There is limited data for many pasture systems, including Mitchell, buffel, Leucaena, arid zone and improved pastures. Browse diets, and the effects of the condensed tannins present in many browses, need to be addressed.
iii. Experimentation to more closely determine the diet DMD/CP ratio at which cattle respond to urea supplements under various circumstances and pasture systems.
iv. Further develop F.NIRS calibrations to predict forage quality where molasses, protein meal and cereal grain supplements are fed.
v. Develop F.NIRS technology to measure the plant species and plant components which grazing cattle select from the pasture to improve understanding of the impacts of grazing cattle on rangeland vegetation.

vi. Further develop F.NIRS to measure metabolizable energy intake and thus LW change of grazing cattle.

Contents

1 Background

1.1 Project team

The NIRS_Task_2 project was a major project involving collaboration with two other NIRS projects - Tasks 1 and Task 3. The collaboration with Task 1 was with Mr David Coates and colleagues in CSIRO Sustainable Ecosystems, who made a major and essential contribution to the present project, particularly by undertaking the NIRS analysis of the majority of the faecal samples. Collaboration was also with the DPI&F staff of the NIRS_Task_3 project team, led initially by Peter Smith and subsequently by Ms Desiree Jackson, and which also extensively involved DPI&F staff Dave Smith, Michael Jeffery, Felicity Hamlyn-Hill, Ross Dodt, Bernadette Lyttle, Trevor Hall, Alistair Brown and Russ Tyler.

The Task 2 team included:

Rob Dixon, DPI&F, Swans Lagoon and Rockhampton
Dave Smith, DPI&F, Charters Towers
Mick Sullivan, DPI&F, Mt Isa
David Coates, CSIRO Sustainable Ecosystems
Steve O'Connor, DPI&F, Toorak Research Station
Trudy Obst, DPI&F, Toorak Research Station
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1.2 Acknowledgments

A large number of people made major contributions to this project and the project could not have been conducted in its present form without their help, advice, assistance and cooperation. The project team would like to express their thanks to North Australia Program Industry Committee (NAPIC) and the Western, Northern and Central Qld Regional Beef Research Committees for supporting the project. We would like to acknowledge and thank the DPI&F staff Peter Martin, Keith Reichmann, Keith McGuigan, Adam Pytko, Ian Brock, Brian Burren, Alan McManus, Peter Verhoeven, Stu McLennan, Michael Yee, Don Myles, Peter Connelly, Taoufik Ksiksi, Christopher Holloway, Dennis McLachlan, David Mims, Wayne Ehrlich, Neil Cooper, Michael Leake, Alan Laing, Geoffry Fordyce, John Compton, Bob Mayer, Swans Lagoon Research Station staff and Brian Pastures Research Station staff. Cattle producers Dick Cribb, Alister McClymont and John Brownson made possible the trial sites on commercial properties, and Peter Finlay and Rick Seirer and staff made possible and managed other trial sites. CSIRO staff Bevan Robertson, Mike Nicholas, Kylee Verry, Lindsay Whitman and David Poppi contributed to sampling and analysis. I would like to thank Central Queensland University staff Kerry Walsh, Mirta Golic, Christo Liebenberg, Phul Subedi, and DPI&F staff member John Guthrie, for assistance with development of NIRS analysis in Rockhampton. Ms Marthe Vivant, L'Isara Lyon University in France and visiting CQU, conducted the experimentation examining NIRS to measure plant species composition as a student project.

Peter Smith (formerly DPI&F, later WADA) made a major contribution to the development and design of the project, to the early work program, and collaborated with a parallel project in northern WA.

1.3 Background to the project and the industry context

A long-standing limitation to the application of nutritional science to cattle grazing the extensive pastures of northern Australia has been the difficulty in estimating the quality and the quantity of the diet selected by the animal from the pasture. The principle limitations to the growth and productivity of cattle grazing tropical pastures (including across northern Australia) and the principal biological mechanisms involved are usually considered to be understood (e.g. the general changes in the nutritive value of pasture through the seasonal cycle, the nutritional demands of animals in various physiological states and the increased demands of lactation and growth). However, application of knowledge of the science of ruminant nutrition in specific circumstances requires estimates of the amounts and balances of nutrients which the animal is obtaining from grazed pasture. The difficulties of estimating the diet ingested by ruminants grazing tropical rangelands, particularly where selection of pasture is intensive such as at low stocking rates and with patch grazing, are well known. The diet selected is rarely the average of the pasture on offer, and is usually much higher in nutritional quality. Thus evaluation of the pasture available usually gives only limited information on the quality of the diet selected by the grazing animal. Each of the established technologies to measure the diet selected by grazing animals (e.g. oesophageally fistulated animals, faecal markers, histological analysis of faeces, plucked pasture sampling) involves serious disadvantages, all involve large error and none are suitable for routine use on commercial cattle properties.

A technology to measure the diet selected by grazing cattle with reasonable accuracy, reliability, simplicity and cost, and with acceptably low imposition on the animal and operator, would be extremely valuable for many facets of the cattle industry to understand and manipulate nutrition of cattle for improved production and rangeland management. Such information would likely be used by managers of commercial cattle properties, for numerous aspects of R&D related directly or indirectly to the nutrition of the animal, for training of personnel in the cattle industry, and for management of grazing livestock with acceptable consequences for the soils and vegetation of rangelands. Faecal NIRS technology meets many of the above requirements as a technology to understand the diet selected by grazing cattle.

NIRS (near infrared reflectance spectroscopy) is widely used for analysis of the nutritive value of feedstuffs (such as forages and grains) and in the food industries. It is also widely used for process control in manufacturing such as pharmaceuticals, textiles and the petrochemical industries. The physical and chemical basis of NIRS and the mathematical treatment of spectra to measure the constituents of feedstuffs have been described in many reviews (Norris *et al.* 1976; Murray 1993; Givens and Deaville 1999; Deaville and Flinn 2000). Usually the NIR spectra of samples are related to the concentration of a feed constituent in the sample. Sets of samples of known composition are used to generate calibration equations, and these are used to predict the composition of unknown samples. Development of calibration equations usually depends on mathematical pre-treatment of the spectral data followed by multivariate modelling involving, for example principal component and partial least squares analysis, to relate an independent variable (constituent concentration) to absorbance at various wavelengths. These are empirical relationships and it is usually not possible to relate the spectral data to specific chemical constituents. Large data sets which encompass the full range of sample types of interest are required to generate robust calibration equations. A calibration equation can only be applied legitimately to predict the composition of an unknown sample if the spectra of the latter is reasonably similar to the samples in the calibration set. To test this spectral similarity the Mahalanobis distance method is usually used to determine whether a specific unknown sample can be adequately predicted by a calibration equation and to provide a cautionary indicator when predictions are likely not to be reliable (Shenk and Westerhaus 1993). The goodness of fit of a calibration equation, or of prediction in an unknown sample, is described in terms of the standard error of calibration (SEC), the standard error of cross-validation (SECV), the standard error of prediction (SEP) and the coefficient of determination (R^2).

NIRS analysis of faeces (F.NIRS) to predict dietary characteristics of grazing herbivores involves an unusual approach for NIRS technology. For most applications NIRS measurements are made on the material of interest and the same material is also analysed by conventional laboratory procedures to relate the NIRS measurements to a chemical composition. However, in F.NIRS the spectra of the faeces are usually related directly to characteristics of the diet or to the animal (e.g. intake, growth). It depends on the assumption that the NIR spectra of faeces reflect the composition or other characteristics of the diet which are of interest. Pen-fed or oesophageally fistulated animals are usually needed to obtain representative samples of the diet ingested, and to measure voluntary intake, to allow NIRS measurements in faeces to be related to the equivalent diet. F.NIRS can also be used to directly measure characteristics of the faeces (e.g. nitrogen (N) concentration, delta carbon or $^{13}C/^{12}C$ ratio, starch concentration, ash concentration) where these attributes are important.

F.NIRS was first reported by Brooks *et al.* (1984), and has since been developed for grazing cattle, in particular by teams led by Jerry Stuth in Texas and by David Coates in northern Australia. These groups have shown that F.NIRS can be used reliably to measure many attributes of the diet of grazing ruminants. Advantages of F.NIRS include that the measurement is based on faeces which represent the diet actually selected by the grazing animal, and the simplicity, speed and cost of NIRS analysis once calibration equations are established. Mr David Coates introduced F.NIRS to northern Australia and over the last decade has developed calibration equations for a number of diet characteristics of cattle ingesting pastures typical of northern Australia. The MLA-supported project CS.253 developed F.NIRS calibration equations for diet crude protein, digestibility and non-grass based on 164 forage diets from the Townsville, Charters Towers and Mareeba regions of north Queensland, thus establishing the validity of F.NIRS in the northern Australian environment. This was followed by the MLA-supported project NAP3.121 project which developed more robust F.NIRS calibration equations with an increased number and diversity of forage diets (Coates 2004). The likely roles of F.NIRS in the northern cattle industry have been discussed by Coates (2000, 2001, 2002). F.NIRS appears far superior to any other existing or emerging technology to measure the diet selected by grazing cattle.

Project NBP.302 (NIRS_Task_2) was undertaken to develop the technology, additional to the NIRS_Task_1 (NAP3.121 above), required by northern producers to confidently utilise F.NIRS to improve the nutritional management of their cattle. It was undertaken concurrently and in collaboration with the NIRS_Task_1 project, it provided many samples for Task 1, and undertook some feeding experiments to provide diet-faecal sample pairs for Task 1. The latter project focused on improving the faecal NIRS (F.NIRS) calibration equations to predict diet quality (Coates 2004). NIRS_Task_2 was also undertaken in collaboration with NIRS_Task_3 (NBP.303) which is focussing on extension of F.NIRS technology on commercial cattle properties.

Application of scientific knowledge in ruminant nutrition obtained from F.NIRS measurements for the nutritional management of grazing cattle requires a series of steps. It requires estimation of the current intake of nutrients and the extent and timing of changes in intake of specific nutrients to achieve a required outcome. For a specific group of cattle the main steps to apply knowledge of ruminant nutrition are:

(i) estimate the current nutrient intake, animal status (e.g. as liveweight and/or body condition) and likely animal productivity (eg. as growth or reproductive rate) if intake of nutrients is not modified,
(ii) estimate how much of which nutrients are needed to increase productivity to a specified level, and

(iii) know how to provide the required additional nutrients most cost-effectively (e.g. supplementation technology).

The improvement and refinement of the F.NIRS calibration equations in the NIRS_Task_1 project made a major contribution towards step (i) above to provide best estimates of the balance and quantity of nutrients ingested by grazing cattle. However, this information clearly needs to be related to knowledge of the nutritional requirements of the animal to conclude which nutrients are limiting and to decide how much of which nutrients need to be supplied in addition to the current pasture to achieve a targeted level of production. The principal role of F.NIRS in this context is to better understand the current nutrition of herds in a specific set of circumstances, and to use this knowledge for improved nutritional managerial decisions. This clearly requires, in some manner, the estimation of the three steps indicated above. These decisions may be guided by decision support systems of various levels of complexity from 'back of the envelope' calculations to use of computer-based quantitative models of the intake and utilization of various classes of nutrients. In addition, if producers are to use faecal NIRS as a management tool, they need to have confidence that the information is sufficiently accurate and reliable to improve the decision process.

The NIRS_Task_2 project addressed a number of aspects of the application of F.NIRS technology to improve understanding of nutrition and to use scientific knowledge to improve the nutritional management of cattle as follows:

(i) Limitations to use of F.NIRS for young growing cattle. Monitor herds with growing cattle undertaken for other projects and where F.NIRS measurements made have provided a description of the variation in the quality of the diet ingested and the ability of F.NIRS to predict LW change. However, since this has been done largely on an opportunistic basis, there was generally little continuity through years, or selection of the most suitable pastures. The present project expanded the range of pasture systems, particularly to provide information under conditions not adequately represented. For example we anticipated that prediction of LW change would be erroneous when pasture availability is low. In addition F.NIRS measures were examined in relation to other field measures of animal status.

(ii) Application of F.NIRS to the breeder herd. Although F.NIRS will often be applied to the breeder herd and breeders clearly constitute a large proportion of the cattle in northern Australia, no validation of F.NIRS or framework to apply F.NIRS measurements of diet quality to the breeder herd was available. Such a framework needed to be developed to accommodate the cyclical nutrient demands of the breeder herd through the annual seasonal reproductive cycles and to relate nutrition to fertility.

(iii) An important application of F.NIRS technology across northern Australia is likely to be to improve the cost-effectiveness of N supplementation by improving decisions on when and how to provide urea supplements, and the animal responses which can be expected. Considerable information is available on the responses of cattle in the northern speargrass to urea supplementation (Winks 1984; Dixon and Doyle 1996), but no experimental results are available for any other pasture system of northern Australia. NIRS_Task_2 addressed this issue for the Mitchell grass Downs region and the Charters Towers area. The PhD project of Jim Gibbs (formally part of NIRS_Task_1) addressed the development of F.NIRS calibration equations when concentrate supplements (cereal grains and protein meals) are used.

(iv) Use of F.NIRS to better manage urea supplements requires a generalised decision process to make the decisions of when and how much supplementary urea to provide and the expected animal response i.e. a decision support system is needed which can be applied across a variety of pasture, animal and property circumstances. This has been discussed in the North American context by Stuth *et al.* (1999) and in the Western Queensland context by McLennan *et al*. (1999). Estimates must be made of the likely sequence of limiting nutrients and the amounts of additional nutrients required as supplements most likely to be economically optimal. Although these decisions can be made on the basis of experience and 'back of the envelope' calculations, decision support systems provide a means to integrate on a quantitative basis complex and interacting information. The NUTBAL decision support system was discussed by Stuth *et al*. (1999), and the GRAZFEED decision support system by Stuth *et al*. (1999) and more recently by McLennan (2005).

(v) Experimentation was undertaken with the NIR spectrometer jointly owned by the DPI&F and Central Queensland University and located in Rockhampton. Firstly, the Rockhampton instrument was set up to conduct F.NIRS analysis so that the technology is no longer entirely dependent on the CSIRO Davies Laboratory in Townsville. Second, experiments were undertaken to examine whether a laboratory-based procedure could be used to expand F.NIRS calibration equations to alleviate the need for costly trials with pen-fed or oesophageally fistulated cattle. Thirdly, experiments were undertaken in order to develop NIRS analysis of pasture, and if possible of faeces, to measure the morphological components and species composition of the pasture ingested by cattle. The leaf content of tropical grass pastures is much more important than digestibility as a determinant of voluntary intake (Minson 1990; Rafiq *et al*. 2002), but there is currently no practical method available for routine measurement of the leaf content of the pasture selected by grazing cattle. NIRS can be used to measure the leaf content of temperate pastures.

In conclusion, by providing a practical field method for measuring the diet selected, F.NIRS offers enormous potential to understand and manipulate the nutrition of grazing cattle. However, effective utilization of this technology requires knowledge of the validity and reliability of current F.NIRS calibration equations across a wide variety of circumstances, and an understanding of the nutritional requirements of cattle and the animal responses to the provision of limiting nutrients in the northern Australian environment which has not previously been necessary. F.NIRS technology will allow a degree of understanding and manipulation of the nutritional management of grazing cattle which has never previously been possible, but also requires improved knowledge of cattle nutrition. NIRS_Task_2 was designed to contribute to this knowledge.

2 Project Objectives

The project was intended to provide the technology, additional to the faecal NIRS calibration equations, which is essential for the effective utilisation of faecal NIRS for cost-effective nutritional management of cattle in Northern Australia.

The objective was to develop a system based on NIRS technology to allow producers to improve their ability to identify nutritional needs for their cattle, as follows:

- Determine the accuracy and reliability with which faecal NIRS (F.NIRS) can predict diet quality, growth of young cattle and (in conjunction with body condition scoring) the performance of breeder herds.
- Determine the accuracy and reliability with which F.NIRS can predict the magnitude of animal responses to urea-based or low levels of protein meal supplements in northern Australia, particularly the Mitchell grass Downs of Western Qld.
- Set up an NIRS instrument in Rockhampton for F.NIRS analysis with transfer of calibration equations, develop a laboratory-based procedure using digested forage residues to expand faecal calibration equations, and examine whether NIRS can be used to measure morphological components in tropical pastures.
- Determine the reliability with which F.NIRS analysis can be used as an input to improve presently available decision support systems for prediction of performance of grazing cattle, particularly for prediction of the responses of animals to supplements. Identify what needs to be done to modify and improve existing decision support systems for cattle management in the seasonally dry tropics.

3 Methodology

3.1 Toorak supplementation experiment in the Mitchell grass downs

3.1.1 General

Six 128 ha paddocks in a trial set in open Mitchell grass downs pasture situated on Toorak Research Station, 50 km south of Julia Creek, NW Qld, were used for the experiment. The water supply was good quality bore water. The paddocks had been only moderately grazed preceding the experiment and represented NW Qld Mitchell grass pastures in good condition.

Three supplementation treatments were compared in a randomised block experiment. The six paddocks were, on the basis of soil type and position, considered as 2 blocks, and the 3 paddocks within each block allocated to one treatment in each year. During the experiment each treatment was allocated to each paddock for one year, except that the same allocation was used for Draft 3 and Draft 4. The paddocks were grazed by 4 drafts of steers during the 4 years of the experiment. Draft 1 of the experiment commenced with the steers entering the paddocks on the 3 August 2001, and supplementation treatments commenced on the 27 August 2001. Draft 1 cattle were replaced with Drafts 2, 3 and 4 in March 2002, 2003 and 2004, respectively. Draft 4 was terminated in March 2005. Due to severe drought during Draft 3 the trial paddocks had to be destocked from June 2003 to March 2004; thus supplement treatments could not be compared for Draft 3 steers although F.NIRS measurements were continued with the designated Nil treatment steers grazing (without supplements) an adjacent similar paddock with adequate forage.

All of the cattle used in the experiment were *Bos indicus x Bos taurus* cross steers (Swans Lagoon genotype, F*n* and about 5/8 *Bos indicus*) which had been relocated to Toorak 2-4 months before being introduced into the experiment. It was initially intended to use 2 age groups of steers in each draft. This was possible for Draft 1 (12 yearling steers and 6 steers one year older in each paddock) but with low pasture availability in subsequent years only a single age group of yearling steers were used (12 for Draft 2, 12 for Draft 3 and 18 for Draft 4 per paddock). The stocking rate was modified at the commencement of each draft in March and as it was calculated to ensure sufficient pasture on offer through until the following February, was conservative for the region.

Measurements of the pasture available and the species composition of the pasture were made at the end of the wet season (May) and in the late dry season (October) using standard Botanal procedures (Tothill *et al*. 1992). Photographs of pasture were taken monthly at a fixed site considered representative of the paddock. Each month the steers were mustered to yards, weighed, body condition score estimated (9-point scale, NRC 1996), and faecal samples obtained by rectal sampling. Faecal samples were also obtained in the paddock midway between these musters, or during Draft 4, weekly. Faecal samples were bulked within paddocks, dried, ground and scanned by NIRS in the Davies Laboratories.

The three supplementation treatments consisted of no supplement (Nil), loose mineral mix (LMM) urea supplement, and cottonseed meal (CSM). The LMM contained (g/kg air dry) 350 cottonseed meal, 300 urea, 290 salt and 60 ammonium sulphate. During an introductory period (weeks 1-2) LMM supplement was mixed with additional salt to reduce the risk of urea toxicity, or during weeks 2-6 with additional CSM if the intake of LMM was sub-optimal. Voluntary intake of LMM was measured. A restricted amount of CSM supplement (400 g air dry/head.day equivalent) was offered twice weekly and was invariably consumed promptly.

The Draft 2 steers were blood sampled late in the dry season (September and November) to examine nitrogen and phosphorus status. Samples of the stock water supply were taken on

3 occasions and analysed in the DNR laboratories, Indooroopilly, for a wide range of constituents important to water quality.

3.1.2 F.NIRS calibrations used for prediction of diet attributes

F.NIRS predictions of dietary attributes were calculated using the calibration equations developed during the NIRS_Task_1 project and as described in detail by Coates (2004) except where otherwise indicated such as with measurement of the proportion of Leucaena in the diet of steers grazing Leucaena -grass pasture. Samples were predicted for diet crude protein concentration using both the lnit1441 and dnit1441 calibration equations, and the value for the lnit1441 prediction accepted if it was ≤ 8% crude protein, and the dnit1441 prediction was accepted for the remaining samples > 8% crude protein. In vivo DM digestibility was calculated from the feedivd3 calibration with conversion of the in vitro DM digestibility prediction to the in vivo estimate by: [(InVitro%) * 0.508] + 30.2 (Coates 2004).

Liveweight change was calculated as daily weight gain (DWG), and as cumulative liveweight change through the interval of the draft of cattle. A number of calibrations for DWG were used, and were the adg1441 calibration described by Coates (2004), or modifications of this calibrations developed by inclusion of additional data. The approach used for the Toorak site was as follows: First, the general adg1441 calibration of Coates (2004), less the data derived from Toorak, was used to calculate the DWG. Second, a calibration for DWG was calculated from a data set which consisted of the Coates (2004) data set plus all of the data from unsupplemented yearling steers in the present study at Toorak (adg_TrkA). Third, to examine the predictions for DWG at the Toorak site but where the samples being predicted were a population external to the data set used to develop the calibration, 4 calibrations were calculated from data sets which comprised the Coates (2004) data, less samples from Toorak, plus samples from (i) drafts 2, 3 and 4, (ii) drafts 1, 3 and 4, (iii) drafts 1, 2 and 4, and (iv) drafts 1, 2 and 3. The calibrations calculated from these data sets were used to predict the DWG for Drafts 1, 2, 3, and 4, respectively. These 4 predictions were combined as the adg_TrkB predictions. Cumulative predicted LW measured with F.NIRS was calculated from the mean steer LW at the commencement of the draft plus the summation of F.NIRS measurements of LW gain in fortnightly increments through the measurement interval for each draft.

3.2 Swans Lagoon growing heifer experiment in the northern speargrass

Five paddocks were selected on Swans Lagoon Research Station, Millaroo, Ayr, Qld, to represent a range of pastures representative of northern speargrass-based pastures in Eucalyptus woodland. Two paddocks (B..TT and C..TT) (each 40 ha) were in an area with low fertility soil of poor water-holding capacity. Two other paddocks (E..LH and F..LH) (each 24 ha) were on medium fertility soil which had been fertilized with phosphate fertilizer 10-20 years previously and where there had also been considerable invasion of seca and verano stylo from surrounding paddocks in which these species had been planted. One of the paddocks on each soil type was grazed at a moderate stocking rate (10 heifers) and the other paddock was grazed at a high stocking rate (20 heifers). A fifth paddock (Poddy)(41 ha) consisted of speargrass pasture with a 1.1 ha swampy area dominated by para grass and growing on medium fertility soil; this was selected as a paddock with 2 distinct grass pasture areas of contrasting quality and quantity available through the annual cycle. This latter paddock was stocked with 10 heifers.

From May 2002 measurements of the pasture available and the species composition of the pasture were made at the end of the wet season (May) using Botanal procedures (Tothill et al. 1992). The amount of pasture DM on offer in the late dry season (October/November) was estimated with reference to photographic standards. In addition, photographs of pasture were taken monthly at a fixed site considered representative of the paddock. During the 2002/03 summer the E..LH and F..LH pastures were severely damaged by insects (army worms and grasshoppers).

The cattle used throughout the experiment were *Bos indicus x Bos taurus* cross heifers from the Swans Lagoon station herd, F*n* and about 5/8 *Bos indicus,* and were about 12-15 months of age when introduced into the experiment. Draft 1 heifers were introduced into the paddocks in late December 2000 and were continued in the paddocks until March 2002 (i.e. for 15 months). These heifers were replaced with Draft 2 heifers in March 2002, which in turn were replaced by Draft 3 heifers in March 2003, and Draft 4 heifers in March 2004. The experiment was terminated in September 2004 so that the Draft 4 heifers were measured for only 7 months from the late wet season through to the late dry season.

The design of the trial was that no supplements would be fed except as a measure to alleviate excessive liveweight loss, and thus the risk of mortality of heifers, during the dry season. The low rainfall in some years of the trial and the high stocking rate for some paddocks meant that action to alleviate excessive liveweight loss of some heifer paddock groups had to be taken with 3 of the 4 drafts. For Draft 1 molasses-urea (M8U) was fed to B..TT and C..TT herds from mid-July, and to the E..LH and F..LH herds from mid-September, through to the seasonal break in mid-December 2001. For Draft 2 molasses-urea was fed to the B..TT, C..TT and F..LH herds from late October 2002 to mid-February 2003. For Draft 3 no molasses-urea supplement was fed. However the B..TT, C..TT, E..LH and F..LH herds were each relocated from their allocated paddock to an adjoining similar paddock from June to December 2003, and also because of the severe insect damage to the pastures in the E..LH and F..LH paddocks these herds were reduced to 6 and 12 head respectively. For Draft 4 it was not necessary to either provide supplement or to relocate any of the heifer groups.

Each 4-5 weeks the heifers were mustered to yards, weighed, body condition score estimated (9-point scale, NRC 1996), and faecal samples obtained by rectal sampling. Blood samples were obtained by venous puncture and urine samples obtained by manual stimulation of the vulva of all of the heifers in the low stocking rate paddocks, and in 10 selected sampler heifers in the high stocking rate paddocks. These sampler heifers were designated when each draft of heifers was commenced and represented the range of heifer LW within the paddock. Blood samples were immediately chilled in iced water and later centrifuged to separate plasma which was stored frozen. Urine samples were immediately acidified with 10M hydrochloric acid to pH <4 and chilled, and later bulked on an equal volume basis within paddocks. Plasma samples were subsequently analysed for concentrations of urea and inorganic phosphorus. Urine samples were subsequently analysed for concentrations of purine derivatives and creatinine by HPLC (to measure microbial protein synthesis) and urea (to measure urinary urea excretion). Faecal samples were also obtained in the paddock midway between these musters. Faecal samples were bulked within paddocks, dried, ground and scanned by NIRS in the Davies Laboratories. Samples of the stock water supply were taken on 15 occasions and analysed in the DNR laboratories, Indooroopilly.

F.NIRS predictions of diet crude protein, digestibility and non-grass were made using the Coates (2004) calibrations as described in Section 3.1 above. Measured daily weight gain (DWG) was calculated as the tangent to the fitted polynomial relationships of animal liveweight with time. F.NIRS predictions of heifer DWG were made using the Coates (2004) ADGSGBA calibration. Cumulative predicted LW measured with F.NIRS was calculated from the mean heifer LW at the commencement of the draft plus the summation of F.NIRS measurements of LW gain in fortnightly increments through the measurement interval for each draft.

3.3 Brian Pastures, Gayndah, monitor herd grazing Leucaena - grass pasture

3.3.1 General

A monitor herd of growing steers grazed an established Leucaena-grass pasture at Brian Pastures Research Station in the southern Speargrass region near Gayndah, Qld, to evaluate

F.NIRS for cattle grazing Leucaena-grass pastures in a set-stocking context. The 11.0 ha paddock (Browns-1) was on a brown clay – black earth soil of basaltic origin and classified in the Nursury Unit by the Brian Pastures Soil Survey of Reid and Sorby (1968). Leucaena (cv Cunningham) had been established in 1976 in 3 m rows. During the 25 years before the present trial commenced the paddock had been used for a variety of trials, the Leucaena had tended to spread from the original rows, and some areas of the Leucaena in the drainage lines had been severely damaged by frost. The grass between the Leucaena rows was principally green panic (*Panicum maximum*).

Bos indicus cross steers (Swans Lagoon genotype) were used for each of the 3 drafts of the monitor herd. Draft 1 commenced in July 2002 with 14 steers 14-17 mo of age and averaging 216 kg. With lower than average rainfall during the September-December interval, 6 steers were removed from the paddock in December to reduce the grazing pressure. The draft was continued through to March 2003. Draft 2 commenced in August 2003 with 7 steers 8-11 mo of age and average LW 197 kg, and were continued until June 2004. Draft 3 commenced in August 2004 with 8 steers 8-11 mo of age and average LW 178 kg, and were continued until May 2005. When each new draft of steers was introduced to the Leucaena paddock a group of mature steers adapted to Leucaena for at least several months grazed an adjacent Leucaena paddock and shared a water trough with the trial herd. This procedure was adopted as it was expected to be a generally effective management practice to allow transfer of the specialist rumen microorganisms providing DHP resistance to cattle grazing Leucaena (Jones and Megarrity 1986). In addition, Draft 3 steers were drenched with inoculum of rumen bacteria able to degrade DHP soon after the steers entered the paddock. No symptoms of mimosine or DHP toxicity were observed in the trial steers.

Steers were mustered each month, weighed and faeces obtained by rectal sampling. Faecal samples were also obtained in the paddock about mid-way between musters. Faecal samples were analysed by NIRS in Davies Laboratories.

3.3.2 Modifications to the Coates (2004) F.NIRS calibrations used for these Leucaena diets

Predictions of diet quality and LW change were made initially with the Coates (2004) F.NIRS calibration equations. Difficulties were associated with the application of these calibration equations, which were based principally on diets of grasses and improved legume forages, to the diets in the present study usually containing a substantial proportion of Leucaena. The data set used to develop the Coates (2004) calibrations for crude protein content and DM digestibility of the diet contained only 5 Leucaena diets (one diet of 100% Leucaena and 4 containing 25-50% Leucaena) of the 350 diets in the data set. The Coates (2004) calibrations for δC content of faeces (used to calculate diet non-grass proportion, i.e Leucaena in the present study) was based on conventional mass spectrometry analysis of δC in faeces, and therefore acquisition of additional data to expand the calibration equations does not have the same limitations as for the forage constituents cited above where diet/faecal pairs of samples are needed for the calibration. The data set for these calibrations contained 210 reference samples from Leucaena diets of the 1501 in the data set used to calculate the calibration equations for δC, but 182 of these 210 samples were obtained from one site and during one season and therefore represented highly specific circumstances. The data set used to develop the animal liveweight change calibrations did not contain any Leucaena diets. From experience with use of NIRS in measurement of other agricultural materials such as forages it is not unexpected that NIR spectra from Leucaena diets would differ appreciably from those of conventional forage diets, and therefore that prediction errors are likely to be larger than with conventional forage diets.

The ISI software package (Intrasoft International, Foss NIRSystems, Silver Spring, MD, USA) was used in the present project for chemometric analysis to develop calibration equations, and then to use these calibrations to predict constituent concentrations or attributes of unknown samples from the spectra. This chemometrics package uses a procedure to examine the similarity of the NIR spectra of an unknown sample with the spectral population used to construct the calibration; if the spectra of the unknown sample is not reasonably similar to that of the calibration population then the error of prediction may be larger than indicated by the calibration statistics. ISI uses the GH distance, also known as the Mahalanobis distance, to evaluate the homogeneity of spectra (Shenk and Westerhaus 1993). A GH value higher than either 3 or 4 for a sample is usually considered to indicate that the prediction result for that sample should be considered with caution. Occurrence of high GH values does not indicate that NIRS technology is inappropriate, but rather that the calibration equations may not adequately encompass the unknown sample.

The average global H values for the predictions of diet CP and DMD were 4.7 (s.d. 3.5) and 5.1 (s.d. 3.2), respectively, and indicated that some caution in the interpretation of the predicted values is warranted. The percentage of samples with GH values >3, and thus conservatively considered as spectral outliers, was 74% for diet CP, 67% for diet DMD, 24% for δC and Nil for faecal N concentration when the Coates (2004) calibrations were applied to the samples from the 3 drafts of cattle. In the absence of any reference values for the actual values of diet CP% or diet DMD in the present study it was not possible to directly address this problem further for these variables. Revised calibration equations for the prediction of faecal δC for Leucaena diets were calculated following 2 approaches. First, a data set was identified where all of the faecal samples were derived from cattle grazing Leucaena-grass pastures and where the δC has been measured by mass spectrometry. Most of these samples in this data set (n 256) were derived from the studies of Galgal (2002) (187 samples), Streeter (2005) (12 samples) and P. Shotton (unpublished results) (42 samples), and included 15 faecal samples from the present studies. A calibration equation (MPLS, 700-2500 nm range, SNV+Det and 1,4,4,1 data treatment) was developed from this data set and had excellent calibration statistics (R^2 0.96, SECV 0.75 δC units, RPD 3.9). However when this calibration equation was used to predict the faecal δC in the Leucaena diets of the present study, 25% of the sample spectra were not well described by the calibration model with GH >3. We considered that this likely occurred because the data set used did not represent sufficient diversity of Leucaena -grass pastures, because the data set was small in relation to the general data set used for the Coates (2004) calibration, and because the Brian Pastures site of the present study was not extensively represented in the data set. Thus the specialist calibration for Leucaena diets did not offer advantages, and indeed may have been less reliable, for prediction of δC and therefore of Leucaena proportion on the diets of the present Brian Pastures study. A second approach was then examined to develop an improved calibration equation. The faecal samples from the studies described above where cattle ingested Leucaena diets were added to the data set used to develop the Coates (2004) calibration to provide a data set with 1825 samples. A calibration equation was developed from this data set (MPLS, 700-2500 nm range, SNV+Det and 1,4,4,1 data treatment) and also had highly acceptable calibration statistics (R^2 0.92, SECV 0.91 δC units, RPD 3.5), albeit not as good as that calculated from the Leucaena diets data set. When this calibration equation was used to predict the faecal δC in the Leucaena diets of the present study only 18% of the sample spectra were not well described by the calibration model with GH >3, and thus this appeared to be an improved calibration to predict samples from the present study at Brian Pastures. It is likely that the third calibration was more satisfactory and robust than the second, even though the calibration statistics were not as good, because it was a much larger and more diverse data set. The results presented in this report were calculated using this third calibration equation.

The percentage of faecal samples with GH values >3 was high for predictions of LW change using the Coates (2004) calibrations; 72% when LW change was predicted from the adg1441 calibration, and 97% when predicted from the adgsgba calibration. However, since actual liveweight change was measured by weighing the animals regularly during the present study, it was possible to examine the consequences of inclusion of LW change results from cattle grazing Leucaena-grass pastures in the present study to revise and improve the calibration equations for this variable. Two approaches were used. First the faecal NIR spectra collected from Drafts 1, 2 and 3 were, with their respective animal LW change reference values calculated from weighing the animals, added to the data set used to calculate the adg1441 LW change calibration (n 1191) to develop a modified calibration adg_LeucA. This calibration was then used to predict the LW change of the steers at each sampling time, and then to calculate the cumulative LW of the steers through the interval of each draft. Second, 3 modified calibrations were calculated by inclusion of spectra from (a) Drafts 1 and 2, (b) Drafts 2 and 3, and (c) Drafts 1 and 3 with the adg1441 data set. Each of these 3 modified calibrations was then used to predict the LW change of the steers for the draft not included in the data set to calculate the modified calibration. These latter predictions of LW change for the 3 drafts were combined and considered as the adg_LeucB predictions. Although neither of these approaches was considered sufficient to develop a satisfactory general LW change calibration for cattle grazing Leucaena pastures, they provide evidence about whether it is possible to develop such calibrations for Leucaena pastures as well as for tropical grass and grass -legume diets as developed by Coates (2004).

3.3.3 Calculation of estimated metabolizable energy (ME) intake of the steers

The estimated ME intake of the steers at each sampling time was calculated from the measured LW and LW change at the time following SCA (1990) procedures and as described by Dixon and Coates (2007) (Appendix 3). Standard reference weight was assumed to be 550 kg. The LW change of the steers at any specific time was calculated as the tangent to the fitted polynomial regression of measured LW with time for each draft. The DM intake was calculated from the DM digestibility measured by F.NIRS and by assuming (SCA 1990) that digestible DM contained 18 MJ ME/kg. The intake of Leucaena DM was calculated from the total DM intake and the F.NIRS measure of the proportion of the diet consisting of Leucaena.

3.4 Brian Pastures, Gayndah, monitor herd grazing southern speargrass native pasture

Three age groups of steers with 3 head per age group grazed a native pasture paddock. The 30 ha paddock consisted of a hill paddock with generally shallow soils consisting of brown clay/black earths and of basaltic origin. The main grass species were native grasses of the southern speargrass, consisting primarily of black speargrass, Burnett blue grass and Indian couch. In the mid dry season of each year (May–August) the oldest age group of steers were removed and were replaced with yearling steers; thus steers remained in the paddock for 3 years. The steers were *Bos indicus* cross but the origin of the various age groups varied with availability of replacement yearling cattle; the cattle were from local commercial properties or from Swans Lagoon. Draft 1 steers were measured from October 2001–August 2002, draft 2 steers from August 2002–June 2003, draft 3 steers from June 2003–June 2004, and draft 4 steers from June 2004–May 2005. The yearling steers in Draft 4 were removed from the paddock from August to October for treatment of scouring which was suspected to be due to a coccidiosis; these steers lost LW during this interval. The steers were mustered each month, weighed and faeces obtained by rectal sampling. Faecal samples were bulked within each age group of steers. Faecal samples were also obtained in the paddock about mid-way between musters. Faecal samples were analysed by NIRS in the Davies Laboratories.

Since actual LW change was measured by weighing the animals regularly during the present study, it was possible to examine the consequences of inclusion of LW change results from cattle grazing the Mount Bambling pastures in the present study to revise and improve the ADG1441 and ADGSGBA calibration equations for this variable. Two approaches were used. First the faecal NIR spectra collected from Drafts 1, 2, 3 and 4 (n 74) were, with their respective animal LW change reference values calculated from weighing the animals, added to the data set used to calculate the adg1441 LW change calibration (n 1191) to develop a modified calibration adg_MtB9. This calibration was then used to predict the LW change of the steers at each sampling time, and then to calculate the cumulative LW of the steers through the interval of each draft. Second, 3 modified calibrations were calculated by inclusion of spectra from (a) Drafts 1, 2 and 3, (b) Drafts 2, 3 and 4, and (c) Drafts 1, 3 and 4, (d) Drafts 1,2 and 4 with the adg1441 data set. Each of these 4 modified calibrations was then used to predict the LW change of the steers for the draft not included in the data set to calculate the modified calibration. These latter predictions of LW change for the 3 drafts were combined and considered as the adg_MtB6 predictions.

3.5 Morungle Station, Richmond, monitor herd grazing mixed downs/forest country

A monitor herd was set up at Morungle Station located 40 km north of Richmond on what is termed locally as “frontage country” where black soil downs meets open woodland country. This is an important pasture system in NW Qld. The site commenced in September 2001 and continued until February 2003, when it had to be terminated due to a failed 2003 wet season and drought conditions. Local responsibility was taken by Ms Felicity Hamlyn-Hill (DPI&F, Charters Towers), Mr Dick Cribb (Manager, Morungle Station) and Mr Alister McClymont (Owner, Morungle Station).

The black soil half of the 280 ha paddock contained pasture species typical of downs (Mitchell, Flinders and *Digitaria* grasses and herbage), while the vegetation on the red soil included white speargrass, forest Mitchell grasses, and some buffel and stylo, and woody vegetation of whitewood, pebbly gidgee, conkerberry and dogwood. The water supply was from a bore and also from a creek during the wet season. The paddock had been conservatively stocked, the pasture condition was good, and there was initially substantial pasture available. The trial commenced in Sept 2001 with a herd of 17 #0 steers (350 kg, CS 5-6) and 24 #1 steers (178 kg, CS 4-5) consisting of high grade Brahman and Brahman cross animals. In April 2002 21 head of #2 steers (156 kg, CS 3.5-6, and recently weaned) were added to the herd and in June 2002 the #0 steers were removed. About each 5 weeks the cattle were mustered, weighted and faecal samples obtained. Thus Draft 1 was from September 2001 until July 2002, and Draft 2 from August 2002 until February 2003.

3.6 Croxdale, Charleville, monitor herd grazing arid grass-browse country

A monitor herd was set up at Croxdale Research Station close to Charleville as a site representative of some low rainfall grass-browse pasture systems in SW Qld. Local responsibility was taken by Mr Michael Jeffery (DPI&F, Charleville). The trial commenced in November 2001 with Draft 1 of the cattle grazing a 300 ha paddock consisting of Coolibah flats of black/grey clays and loams, and red sands with Mulga/turkey bush vegetation. Major plant species on the Coolibah flats were Queensland bluegrass, Mitchell grasses and kangaroo grass. Major species on the red sands were mulga oats, mulga Mitchell, Kangaroo grass, Mulga, wilga, and wiregrasses. In July 2002 Draft 2 commenced and the herd was moved to another 430 ha paddock with similar soil types and vegetation. The cattle were supplemented with cottonseed meal (0.7 kg /head.day) from July to September, and then with Uramol (30% urea) feed blocks which were continued through to April 2003.

Initially the herd comprised 19 steers (6-9 months, 251 kg, CS 4.5-5.5) (Draft 1). These cattle were crossbreds of about ½ *Bos indicus* content. As the steers ranged widely in LW they were divided into light (L) and heavy (H) sampler groups with mean LW of 233 and 281 kg respectively. In June 2002 for Draft 2 the group of H steers was removed and replaced with 5 weaner steers (183 kg) and 21 weaner heifers (177 kg). The trial terminated in April 2003. About each 5 weeks the cattle were mustered and weighed and faecal samples obtained from the rectum of designated sampler steers. Faecal samples were bulked within the 'light' and 'heavy' groups of steers.

3.7 Forest Home, Mingela, paired monitor herd at to examine urea supplement response on Indian couch pastures

A supplementation experiment was established on Forest Home Station, between Mingela and Charters Towers. The country is typical of the Goldfields country around Charters Towers and where Indian couch (*Bothriochloa pertusa*) has completely replaced the original native grasses. The experimental site of approximately 80 ha was subdivided into 2 paddocks of roughly equal area. Two treatments were applied: (a) a control treatment where the 10 head received no supplement, and (b) a supplemented treatment where urea and ammonium sulphate were fed through the drinking water. Steers were mustered and weighed fortnightly, and the groups of steers changed between paddocks at each weigh day. The watering facilities were arranged so that the experimental treatments were maintained when the groups of steers were alternated between the paddocks. Faecal samples, bulked within treatment and age group, were collected per rectum when the steers were weighed. Also plucked samples of Indian couch from each paddock were collected, the method of harvesting intended to simulate the material selected by the grazing animal. The trial was managed by Mr David Coates and staff of CSIRO Davies Laboratories, Townsville.

The trial commenced on August 2001 with 5 #0 and 5 #9 high grade *Bos indicus* steers from the Forest Home herd in each paddock. The #9 steers were removed in June 2002, and were replaced with 5 #1 steers. The trial terminated in January 2003 with a failed 2002/03 wet season.

3.8 Fletcherview RS, James Cook University, Charters Towers – paired monitor herd to examine urea supplement response on buffel grass pastures

A 2-paddock supplementation trial, similar in design to the trial established at Forest Home described in Section 3.3.7 above, was established on basalt soil at Fletcherview RS 20 km north of Charters Towers. Local responsibility was taken by Mr Peter Finlay, Manager of the station.

The trial site consisted of two 50 ha paddocks with predominantly buffel grass pasture. Two herds each consisting of 10 *Bos indicus* speyed heifers grazed the 2 paddocks and were exchanged between the paddocks each 2 weeks and were weighed monthly. Faecal samples were obtained each 2 weeks. The control herd was given free access to a loose mineral mix (LMM) supplement (g/kg: 472 salt, 472 calcium phosphate and 57 elemental sulphur) following the routine management on the property to meet suspected deficiencies of sodium, sulphur and phosphorus. The N supplemented treatment was offered a loose mineral mix containing (g/kg) 275 salt, 275 urea, 175 limestone, 125 cottonseed meal, 125 monocalcium phosphate (Kynophos) and 25 elemental sulphur.

Two drafts of cattle were measured. Draft 1 (mean initial LW 279 kg) commenced on the 16 August 2001 and was continued until the 19 September 2002, while Draft 2 (mean initial LW 307 kg) was measured from the 11 October 2002 until the 20 October 2003 with 10 heifers in each paddock.

3.9 Longreach Pastoral College – paired monitor herd to examine urea supplement response on Mitchell grass downs pastures

A supplementation experiment was established on Mitchell grass Downs pasture on Longreach Pastoral College, 5 km from Longreach. The experimental site of approximately 360 ha was subdivided into 2 paddocks of equal area. Two treatments were applied: (a) a control treatment which received no supplement, and (b) a supplemented treatment where a loose mineral mix was fed ad libitum. The watering facilities were arranged so that the experimental treatments were maintained when the groups of animals were alternated between the paddocks. The groups of animals were changed between paddocks about each month, and the animals were mustered to yards and weighed each 1-2 months. Faecal samples were collected per rectum when the animals were weighed, and also in the paddock between weighings. The trial was managed by Mr Rick Seirer and other staff and students of the Longreach Pastoral College, Longreach.

There were 2 drafts of cattle. Draft 1 was from September 2002 until May 2003 when the paddocks had to be destocked due to low rainfall in the 2002/03 summer, low pasture availability and because the animals were losing LW at an unacceptable rate. Draft 1 involved 7 heifers per paddock initially 273 kg mean LW. The LMM supplement fed to Draft 1 contained (g/kg) cottonseed meal 400, salt 375, urea 120, calcium phosphate 74, ammonium sulphate 30 and trace minerals 1. Voluntary intake averaged 780 g/head.day. Following good rain in the 2003/04 summer Draft 2 was commenced in July 2004 and was continued until April 2005; low rainfall in the 2004/05 summer resulted in low pasture availability and by April 2005 the animals were losing LW at an unacceptable rate. Draft 2 consisted of 8 Santa Gertrudis weaner steers in each paddock. The LMM supplement fed to Draft 2 animals contained (g/kg air-dry) cottonseed meal 350, urea 300, salt 290 and ammonium sulphate 60.

3.10 Swans Lagoon breeder cow experiment

A breeder monitor herd was set up at Swans Lagoon RS in order to examine the relationships between performance of breeder cows and the predictions made from NIRS analysis of faeces in a northern speargrass environment The herd contained both non-pregnant non-lactating (NPNL) and pregnant (and later lactating) breeders to allow direct measurement of the consequences of the reproductive cycle.

A 200 ha paddock was selected on Swans Lagoon Research Station as representative of northern speargrass native pastures in open Eucalyptus woodland. The paddock was stocked with a small herd of young breeder cows during the 4-year trial. Draft 1 was introduced in December 2000 and was replaced by Draft 2 in September 2001, by Draft 3 in August 2002, and by Draft 4 in August 2003. Draft 4 was terminated in September 2004. The breeders used were, when introduced to the experimental paddock, about 3 YO for Draft 1, or at 2.5 YO for the later drafts. The breeders used were *Bos indicus x Bos taurus* cross from the Swans Lagoon station herd, F*n* and about 5/8 *Bos indicus,* which had been weaned and managed as normal for the station herd until they entered the present trial. These breeders had been joined as 2 YO heifers for 3 months from late January, and thus were expected to calve from November to January. Of the 52 breeders in each draft, 8 were selected to be non-pregnant and 44 were selected to be pregnant. After calving (November – January), the herds was joined with 2 bulls from late January until May. The cows were pregnancy tested by rectal palpation in May and July. For Draft 1 and 4 half of the calves were weaned in May and the remainder in July or August. For Drafts 2 and 3 all of the calves were weaned in May due to the difficult dry season conditions.

Each 4-5 weeks the breeders were mustered to yards, weighed, body condition score estimated (9-point scale, NRC 1996), and faecal samples obtained by rectal sampling. During Draft 1 faecal samples from all sampled animals were analysed individually by NIRS for 4 sampling times representing the range in pasture quality during the annual cycle. There were no differences between the lactating and dry cows, or between the early and late weaned cows, for the F.NIRS predictions of diet quality. Therefore faecal samples were bulked within the 3 groups (i) non-pregnant non-lactating, (ii) lactating cows, and (iii) cows which had calved but lost the calf. Faecal samples were also obtained in the paddock midway between these musters, or during Draft 4, weekly. Calves were not sampled. Faecal samples were dried, ground and scanned by NIRS in the Davies Laboratories.

The changes in LW and body condition of the breeders were considered within the framework of the flow model developed by Dixon (1998) to relate breeder LW and body condition status to reproductive rate. This flow model provides a framework for comparing and evaluating management options for improving the nutrition and body condition status of breeders (e.g. supplements of phosphorus and urea, M8U, timing of weaning).

3.11 Transfer of F.NIRS calibration equations to the Rockhampton NIRS instrument

The NIR spectrometers in CSIRO Davies Laboratories, Townsville, and in Rockhampton are both NIRSystems 6500 scanning monochromators using Intrasoft International software. This facilitated comparison of instruments and transfer of the calibration equations. Firstly, a large number of faecal samples from diet-faecal pairs (about 1200) which had been scanned in Davies Laboratories were rescanned on the Rockhampton instrument and calibration equations developed. Secondly, a set of faecal samples selected on the basis of the GH values (a measure of the Mahalanobis distance) to represent subsets of standards with similar low GH, or with the full range of GH values from 0.0 up to 3.0. These samples were scanned on both the Davies Lab and the Rockhampton NIR spectrometers, using the Intrasoft International software, allowed comparison of the 2 instruments and correction of the Rockhampton instrument to the Davies Lab instrument following established procedures.

3.12 Development of a laboratory-based procedure for expanding F.NIRS calibration equations

3.12.1 Experiment 1

Three hays representing low quality tropical grass hay, high quality grass hay and a high quality legume (panic, rhodes and lucerne hays respectively) were fed to 3 rumen fistulated steers, and the same hays were incubated in synthetic fibre bags in the rumen for 48, 72 or 96 hours. Samples of each of the hays, the hay washed with water, the residues of hay following digestion in the rumen for the various intervals, and faeces, were scanned using the NIR spectrometer in Rockhampton.

3.12.2 Experiment 2

Three rumen fistulated steers were fed a low quality grass hay and 47 forages were incubated in synthetic fibre bags in the rumen of each of the steers. These forages consisted of 27 forages which had been used in previous pen-feeding experiments for NIR calibrations and 20 forbs (19 dicotyledonous and one monocotyledonous species) sampled from the Mitchell grass and northern speargrass pasture regions. NIR spectra of the residues obtained following incubation in the synthetic fibre bags were measured and examined as a means to expand faecal NIRS calibration equations to predict diet quality.

3.13 Developing NIRS to measure morphological components and plant species present in pasture diets

3.13.1 Experiment 1

Samples (n 346) of 3 tropical grass species (buffel, rhodes and panic) were harvested from sites at Belmont R.S. during each of 2 years, and separated manually into leaf and stem components. Amounts of dried leaf and stem were determined and NIR analysis of these samples of known leaf/stem conducted using the Rockhampton NIR spectrometer. Calibration equations were developed to predict the proportion of leaf in the sample using the established procedures. The accuracy and precision of these calibration equations were then tested against samples of grass forages harvested at Toorak and Swans Lagoon.

3.13.2 Experiment 2

Samples of a mixed buffel grass – speargrass – seca stylo pasture were harvested at intervals and separated manually into leaf and stem components of each of the plant species. NIR analysis (n 405) of these separated components, and also mixtures containing known proportions of leaf and stem of the various species, was conducted using the Rockhampton NIR spectrometer. Calibration equations were developed to predict the proportion of leaf and of each plant species in the sample using the established procedures. This experiment was conducted as the research project of a visiting French agricultural scientist student, Ms M Vivant, and was conducted in parallel with, but independently of, the NIRS_Task_2 project.

3.13.3 Experiment 3

Samples of extrusa (n 87) obtained from oesophageally fistulated steers grazing at Galloway Plains between 1993 and 1998 were provided by the DPI&F scientists responsible for that project. The samples had been analysed for total N and the proportions of the various plant species present, and the leaf-stem proportions, had been measured using conventional procedures. NIR analysis of the extrusa samples was conducted to examine whether this technology could be used to measure the proportions of plant species and plant parts in oesophageal extrusa samples.

3.13.4 Experiment 4

Samples (n 42) of leaf blade or stem, or mixtures of known leaf blade content, obtained from Experiment 1 of the series, were incubated in synthetic fibre bags in the rumen of a steer consuming low quality grass hay. NIR analysis of these samples of digested leaf or stem or known leaf/stem proportion was conducted using the Rockhampton NIR spectrometer. Calibration equations were developed using the established procedures to predict the proportion of leaf in the forage or using the digested residue as a proxy for faeces.

3.14 Development of a decision support procedure for timing and quantity of urea supplements using F.NIRS outputs

A comprehensive review of the literature and of feeding standards was undertaken and a framework developed to use the F.NIRS outputs as criteria for whether an animal is likely to respond to urea-based supplements. Experimental results obtained in the Toorak, Forest Home and Swans Lagoon trials was used to support the development of these criteria.

3.15 Trials to generate diet-faecal pairs for faecal calibration equations

3.15.1 Pen feeding trials

These were conducted by feeding fresh pastures, harvested daily with a forage harvester, to heifers held in individual pens. The standard protocol was to muster and weigh the animals on a Monday and establish them in individual pens, and to immediately commence feeding the designated fresh forages. Heifers were held in the pens through to the following Friday (i.e. for 11 days). Forage intake was measured daily, and samples of forage offered, forage refused and voided faeces obtained each day. Between 3 and 5 heifers per diet were measured, and the 10 day feeding interval ensured that the heifers had time to adapt to the forage and reach a stabilised voluntary intake. Trials were conducted at the following sites:

i. Swans Lagoon. Pen-feeding trials were conducted with 16 forages harvested through the late wet season and early dry season; these were selected to represent a variety of native grass pastures in various stages of maturity. In addition 6 diets were fed in a trial with dry season pasture either fed without supplement or with 5 levels of supplementation with good quality chopped lucerne hay.

ii. Toorak Research Station. A pen feeding trial was conducted during the late wet season (March and early April) with 4 forages chosen to consist primarily of Curly Mitchell grass, Bull Mitchell grass, Flinders grass and a mixture of grasses and forbs from a flood-out area.
iii. Croxdale Research Station, Charleville. A pen feeding trial was conducted with young cattle fed low quality hay and 4 levels of freshly harvested mulga.

3.15.2 Oesophageal fistulated (OF) animals

A group of 4 OF steers at Brian Pastures Research Station were used through one summer. Small paddocks of Rhodes grass or Green Panic were grazed and samples of OF digesta and equivalent faeces obtained near the end of the fortnight interval. Three samples of each grass species were sampled, and were selected to represent these pastures during the interval when the nutritional quality is high. Thus 6 diets were measured. Samples of forage or OF extrusa and of faeces were analysed by David Coates in the Davies laboratories as part of Task 1 and are reported therein.

3.15.3 Faecal samples

Faecal samples were taken on an intensive basis from cattle in pen experiments fed low quality tropical grass hay and supplements (molasses-urea, cottonseed meal, cereal grain) in experiments of Dr Stu McLennan (at Brian Pastures) and of Dr Bevan Robertson and Dr Bob Hunter (Rendall Laboratories). Faecal samples were analysed used the NIR spectrometer in Rockhampton and were used in the calibration equations.

4 Results and Discussion

4.1 Toorak supplementation experiment in the Mitchell grass downs

4.1.1 Rainfall

Rainfall during the summer preceding the commencement of Draft 1 (i.e. Oct 2000 to Mar 2001) was 509 mm and greater than the long-term mean of 439 mm (Table 4.1.1). In contrast rainfall was only 236, 200, 308 and 319 mm in the 4 subsequent years, and was thus 54%, 46%, 70% and 73%, respectively, of the long-term mean. There was negligible winter rainfall through the trial. The seasonal break during Draft 1 was on the 12 December 2001, during Draft 2 on the 3 March 2003, during Draft 3 on the 9 January 2004, and during Draft 4 on the 8 January 2005.

Table 4.1.1. *Rainfall (mm) at the trial site*

Month	2000/01	2001/02	2002/03	2003/04	2004/05	Long-term mean
Jul	0	1	0	0	0	9
Aug	0	0	0	0	11	4
Sept	1	0	0	0	5	5
Oct	51	41	0	0	10	15
Nov	94	13	0	9	12	30
Dec	201	54	0	35	66	62
Jan	28	68	17	166	110	111
Feb	67	51	41	98	81	102
Mar	68	9	142	0	0	64
Apr	0	0	0	0	0	15
May	0	0	0	0	24	16
Jun	0	0	0	0	0	7
Total	509	236	200	308	319	439
Date of break	12/12/00	17/12/01	03/03/03	09/01/04	08/01/05	

The seasonal break was defined as the first rainfall event of at least 50 mm over 3 days.

4.1.2 Pasture

Table 4.1.2. *Availability of components of the pasture. Values are the means for the 6 paddocks used in the trial*

Measurement	Draft_1	Draft_2		Draft_3	Draft_4	
	May 01	May 02	Oct 02	May 03	May 04	Sept 04
Yield (kg/ha)						
Mitchell grasses	1685	946	983	261	684	186
Flinders grasses	820	49	43	29	328	0
Other grasses	96	72	55	6	50	38
Legumes	23	2	0	23	23	9
Non-leguminous forbs	12	15	14	119	224	34
Litter & inert	0	27	53	1	121	139
Total	2636	1111	1148	439	1430	406

Table 4.1.3. *The frequency (%) of forb species which, on average for the 6 paddocks, were present in at least 1% of quadrats on one of the 6 sampling occasions is given. Values are the means for the 6 paddocks used in the trial*

Forb species	Draft_1	Draft_2		Draft_3	Draft_4	
	May 01	May 02	Oct 02	May 03	May 04	Sept 04
Leguminous species						
Alysicarpus rugosus	6.5	4.9	0.7	11.7	0.3	0.6
Cullen cinereum	0.5	0.0	0.0	1.0	1.0	0.0
Desmodium spp.	1.0	1.8	0.0	0.0	0.2	0.0
Glycine falcate	1.1	0.6	0.2	3.8	0.2	0.0
Indigofera spp.	0.3	0.5	0.2	4.3	0.6	0.2
Rhynchosia minima	12.9	1.8	0.6	3.7	3.4	0.2
Other legumes	0.8	0.5	0.7	8.0	0.8	0.2
Non-leguminous species						
Abutilon spp.	0.1	0.2	0.1	1.5	0.2	0.0
Amaranthus mitchellii	0.0	0.3	0.0	2.1	2.9	1.7
Boerhavia spp.	0.1	6.1	3.9	14.4	21.6	12.5
Cleome viscose	0.1	0.2	0.0	10.5	28.9	18.5
Commelina ensifolia	0.0	0.2	0.0	0.0	0.0	0.0
Flaveria australasica	0.1	0.1	0.5	5.9	2.5	1.2
Goodenia spp.	1.2	6.3	5.0	0.7	0.6	1.7
Ipomoea & Polymeria spp.	1.7	5.1	1.7	16.5	25.5	8.7
Malvastrum americanum	2.6	2.5	1.1	12.0	1.0	0.3
Phyllanthus spp.	0.1	1.7	0.1	0.1	0.0	0.0
Sesbania spp.	5.3	0.1	0.0	3.5	4.7	2.4
Sida spp.	4.6	17.8	5.0	36.5	11.1	10.9
Solanum spp.	0.1	1.0	0.4	7.5	0.2	0.0
Streptoglossa adscendens	6.0	0.5	0.3	15.1	12.1	9.8
Tribulus terrestris	0.0	0.5	0.0	16.0	2.2	0.9
Trianthema triquetra	0.0	0.0	0.0	0.0	5.8	0.2
Other non-leguminous species	1.0	7.7	11.5	56.1	16.2	7.4

As consequences of the high rainfall during the 2000/01 summer and light grazing of the trial paddocks, pasture availability in May 2001 was high (2636 kg DM/ha) and, in the absence of grazing, remained at about this amount until the commencement of Draft 1 on the 3 August 2001 (Table 4.1.2). Most of this pasture was Mitchell grasses (64%, which was predominantly curly Mitchell) or Flinders grass (31%), with only 1.3% consisting of forbs. The latter (Table 4.1.3) consisted principally of *Rhynchosia minima*, *Alysicarpus rugosus* (chain pea), *Streptoglossa adscendens* (mint weed) and *Sesbania*. Associated with the moderate summer rainfall during 2001/02 and 2003/04, pasture availability in May was 1111 and 1430 kg DM/ha, respectively. Forbs comprised 1.5% of pasture DM in May 2002, but 17% of total pasture DM in May 2004. These tended to be the same forb species as observed in 2000/01, but also *Boerhavia* spp. (tar vines), *Sida* spp., *Cleome viscose* (tickweed) and *Trianthema triquetra* (red spinach). In May 2003, following low summer rainfall of only 200 mm, total pasture available was 439 kg DM/ha and 32% of this consisted of forbs. Thus, following the good or moderate summer rainfalls in 2000/01 and 2001/02, forbs comprised 35 and 17 kg DM/ha and 1.5% of the pasture DM in the early dry season. Following the very low summer rainfall of 2002/03, the density and viability of tussocks of the dominant perennial curly Mitchell grass appeared to be severely reduced. These observations were in accord with measurements of the effects of severe droughts on the density of Mitchell grass tussocks elsewhere on the same research station (Orr 1998; D M Orr, unpublished results). At this time (May 2003), and also in May 2004 following a summer of

Figure 4.1.1. *Pasture at a representative site in Paddock P4 (not supplemented treatment) for Draft 2 during 2002/03*

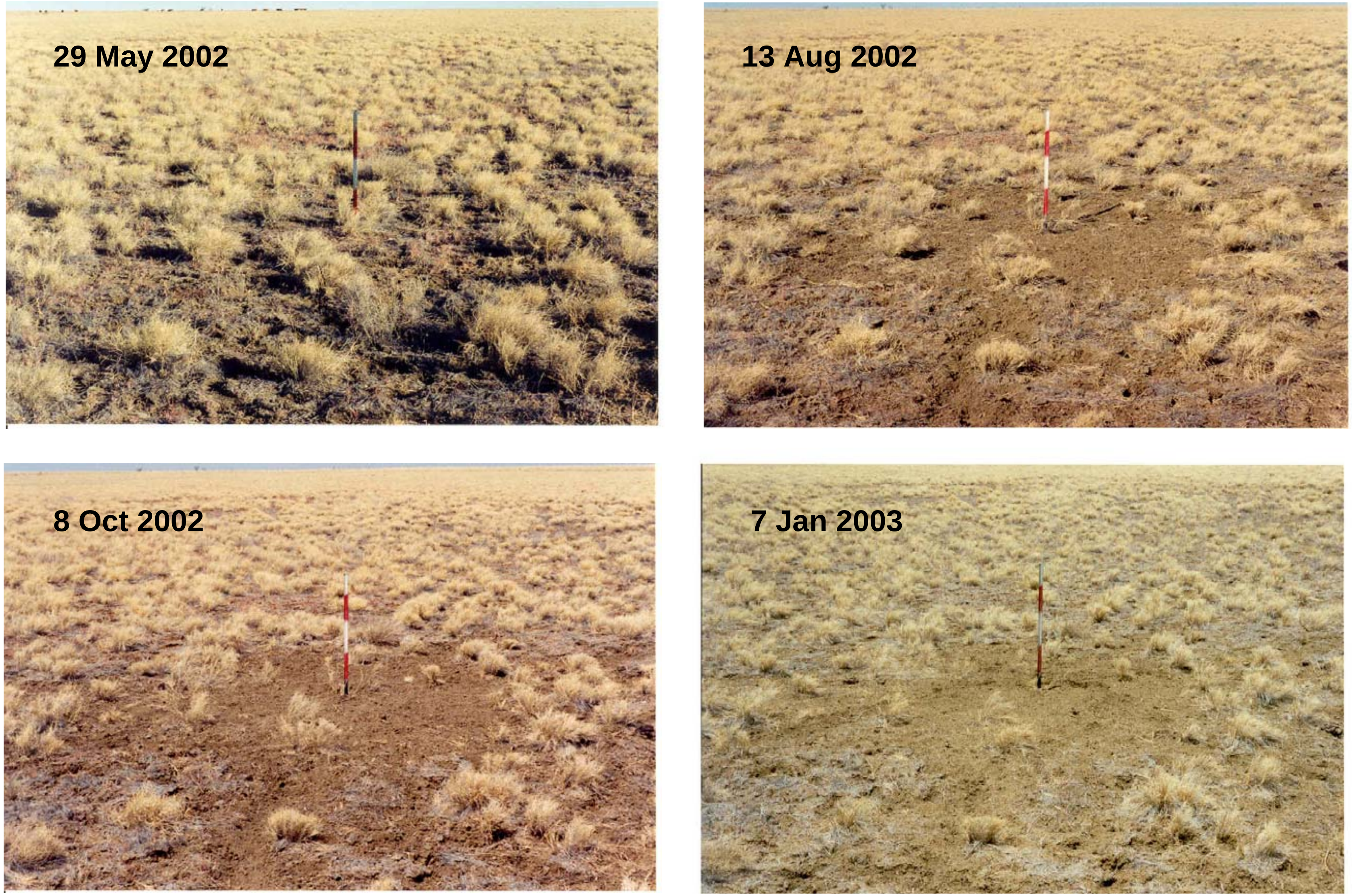
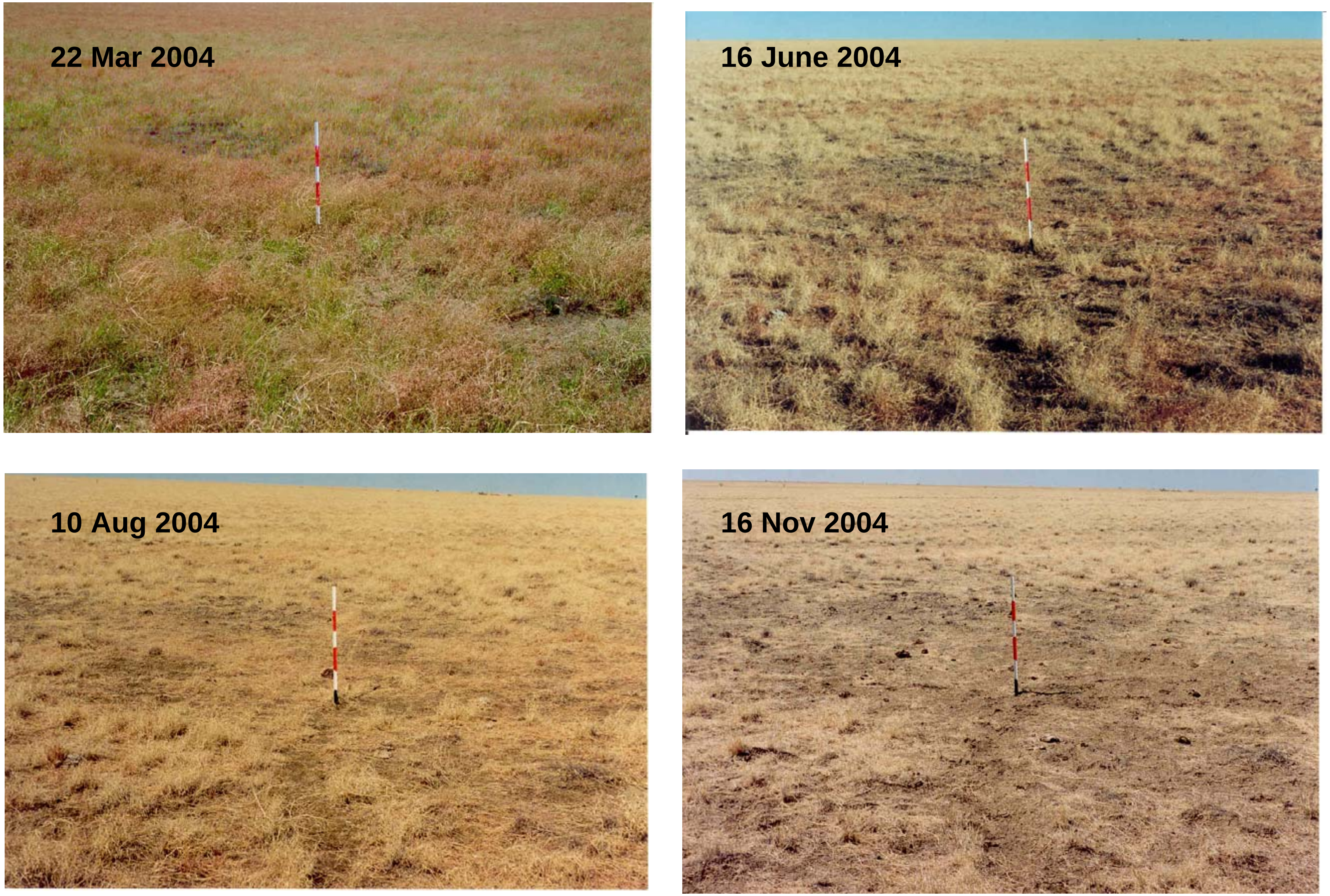


Figure 4.1.2. *Pasture at a representative site in Paddock B7 (not supplemented treatment) for Draft 4 during 2003/04*



moderate rainfall, there were greatly increased amounts and frequencies of forbs (142 and 247 kg DM/ha, respectively) which comprised large proportions (32% and 17%, respectively) of much lower amounts of pasture DM on offer.

Photographs of the pasture at fixed points chosen to be representative of the non-supplemented paddocks for Drafts 2 and 4 are shown in Figure 4.1.1 and 4.1.2. It was evident that by May-June, early in the dry season, the pasture was almost entirely senesced and the amount of pasture available declined as the dry season progressed. These observations were typical of all of the trial paddocks. Water quality was high (Appendix 4) and was not likely to have constrained pasture intake or liveweight gain of the steers.

4.1.3 Supplement intake and diet selected

Generally the steers readily consumed all of the CSM supplement offered and thus consumed 28.1–29.4 g supplementary N per day in the CSM. Up to about 4 weeks was required for each new draft of steers to consume substantial amounts of LMM, and mixing additional protein meal with the LMM was only partially successful to increase LMM intake. Voluntary intake of LMM was generally low throughout all of Draft 1 feeding, and for the first 3-4 months of feeding of Drafts 2 and 4 (Figure 4.1.3 and 4.1.4). However, in Drafts 2 and 4 the voluntary intake of LMM increased progressively through the dry season, and in the late dry season averaged about 300 and 250 g DM/steer.day in Draft 2 and 4. Voluntary intakes of LMM supplement sometimes fluctuated widely between weeks, and decreased abruptly following rain. Intake of N from the LMM supplement averaged 12.0 and 16.2 g N/steer.day for the 2 paddocks of Draft 1 and thus averaged 48% of the N provided by the CSM supplement. For Drafts 2 and 4 the LMM provided less supplementary N than the CSM until August, but during the late dry season about 52 and 43 N/steer.day for Drafts 2 and 4, respectively, i.e. almost twice as much supplementary N as the CSM supplement provided during the same interval.

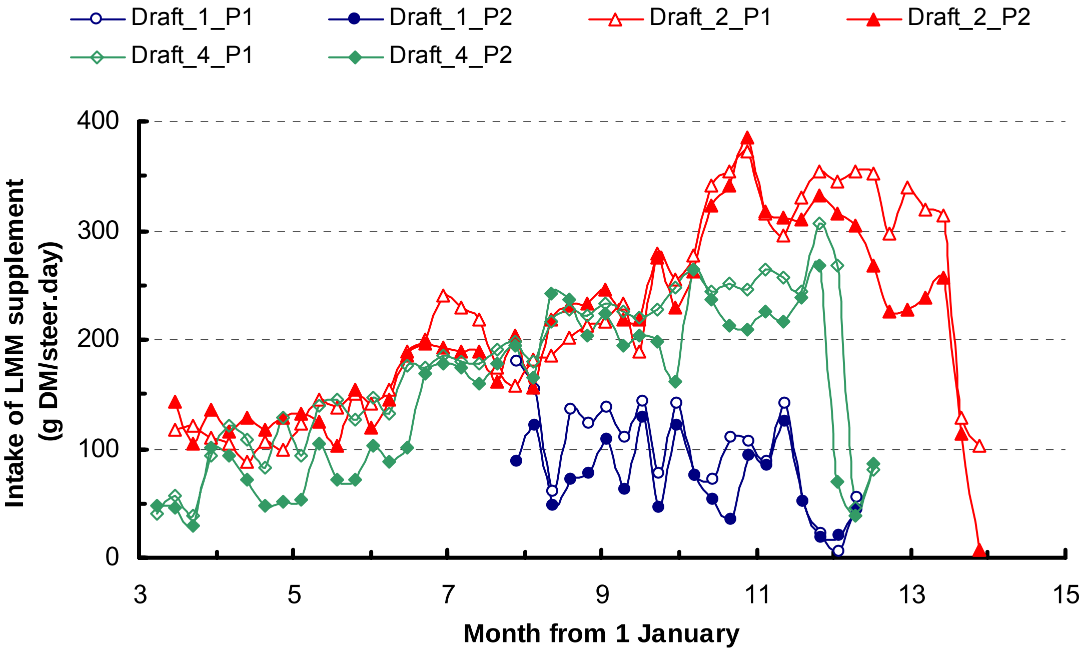


Figure 4.1.3. *Voluntary intake of the DM of loose mineral mix (LMM) supplement for each paddock group of each draft of steers. The steers given the CSM treatment consumed 360 g CSM DM/day.*

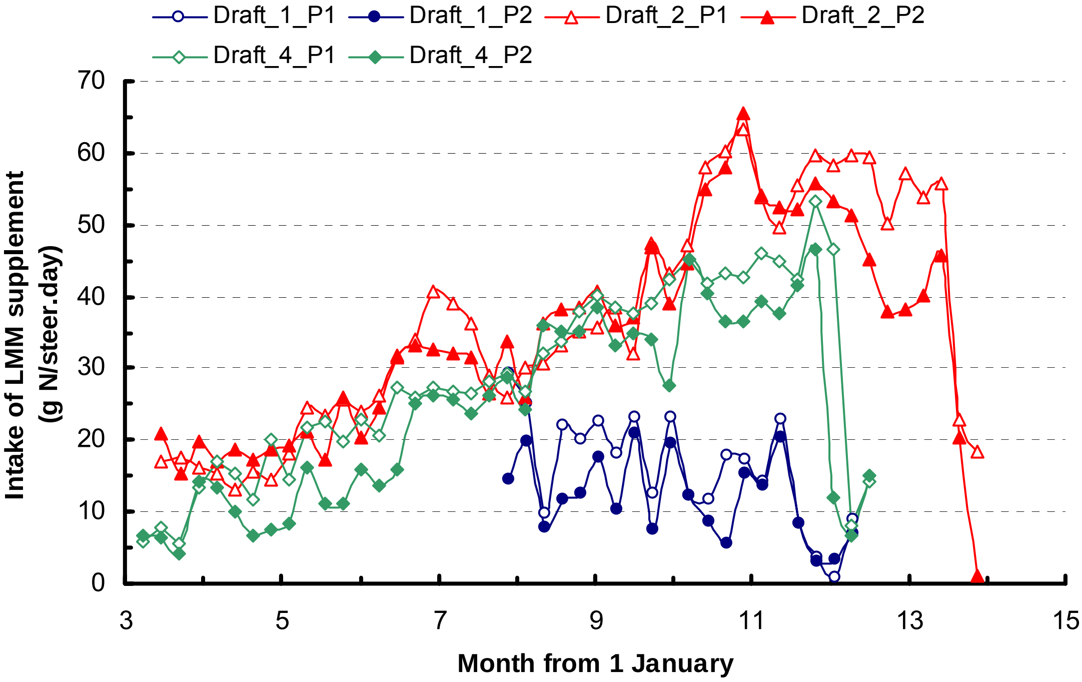


Figure 4.1.4. *Voluntary intake of the N of loose mineral mix (LMM) supplement for each paddock group of each draft of steers. The steers given the CSM treatment consumed 29 g CSM N/day.*

The F.NIRS measurements of the quality of the diet selected by the cattle grazing the unsupplemented paddocks are shown. As no browse or C3 grasses were present, the non-grass component measured by F.NIRS would have consisted of forbs. In each of the years of the trial the non-grass initially contributed a high proportion of the diet, indicating that there was a very high degree of selection for this component of the pasture (Figure 4.1.5). In Drafts 3 and 4 the non-grass was initially about 40-60% of the diet, and this declined to the range 30-50% of the diet for most of the dry season. This high proportion of forbs selected was consistent with the large amounts of forbs available during the dry season for both of these drafts of cattle. The proportion of dietary non-grass was initially high in Draft 1, most obviously because the paddocks had been only lightly grazed since the previous wet season and before this draft was commenced in August. However, by late October the Draft 1 steers were ingesting a diet with less than 10% forbs, presumably because the small amount of forbs present in the pasture initially had been selectively removed by the grazing cattle. Similarly, in Draft 2 the proportion of dietary non-grass declined from 20-30% in April-May to 10-20% from June to December.

The CP content of the diet selected, and the changes in this dietary characteristic through the seasonal cycle, were generally as expected (Figure 4.1.6). For Drafts 2 and 4 the diet CP declined to 6-7% by April and subsequently in the mid to late dry season to 5-6%. Diet CP was lower for Draft 1 (less than 4% in the late dry season) and higher for Draft 3 where diet CP did not decline until August. Diet CP increased sharply after the seasonal break to 10-25% CP with the new pasture growth. Diet digestibility (not shown) was for all drafts, 55-60% in March-April and declined to 50-55% through the dry season. The DMD/CP ratio (Figure 4.1.7) followed a general pattern of values of 4-8 in the wet season, increasing with the transition to the dry season and as the dry season advanced. For Draft 2 the DMD/CP during the dry season was generally in the range 10-11. For Draft 4 this ratio was in the 8-10 range for the 7 mo April - October, and over 10 for the remainder of the dry season. Similar values were observed for Draft 3 except that the increase to > 8 did not occur until August. The DMD/CP for Draft 1 was much higher (12-13) during September-October.

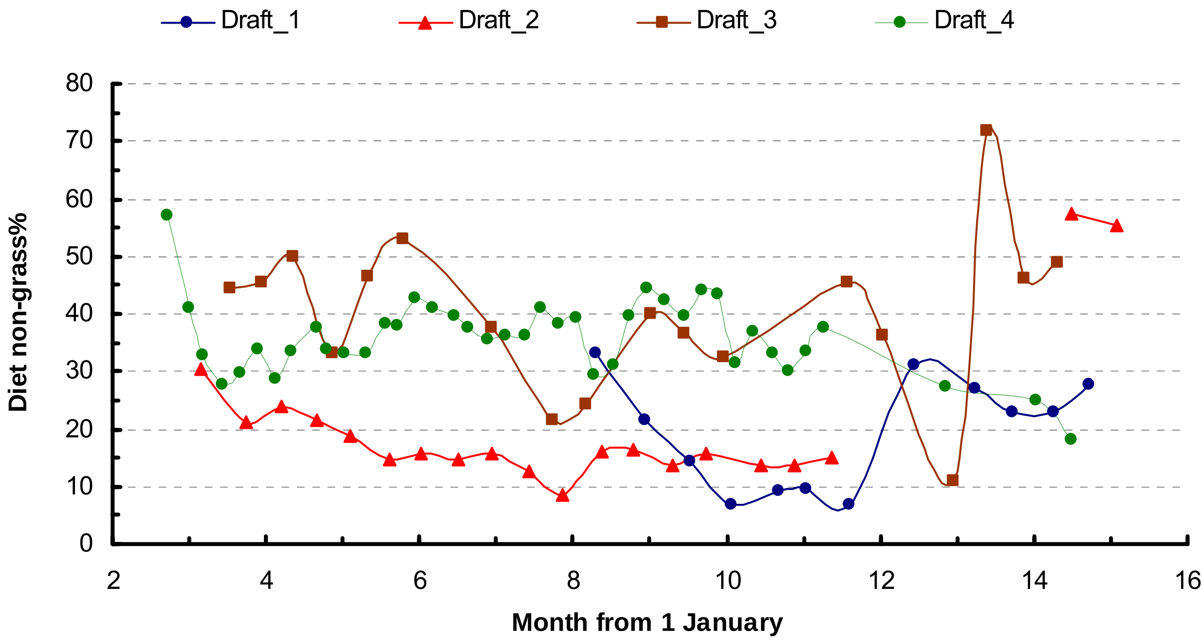


Figure 4.1.5. *F.NIRS measurements of the percent non-grass in the diet selected by unsupplemented steers grazing Mitchell grass pastures during each of 4 annual cycles.*

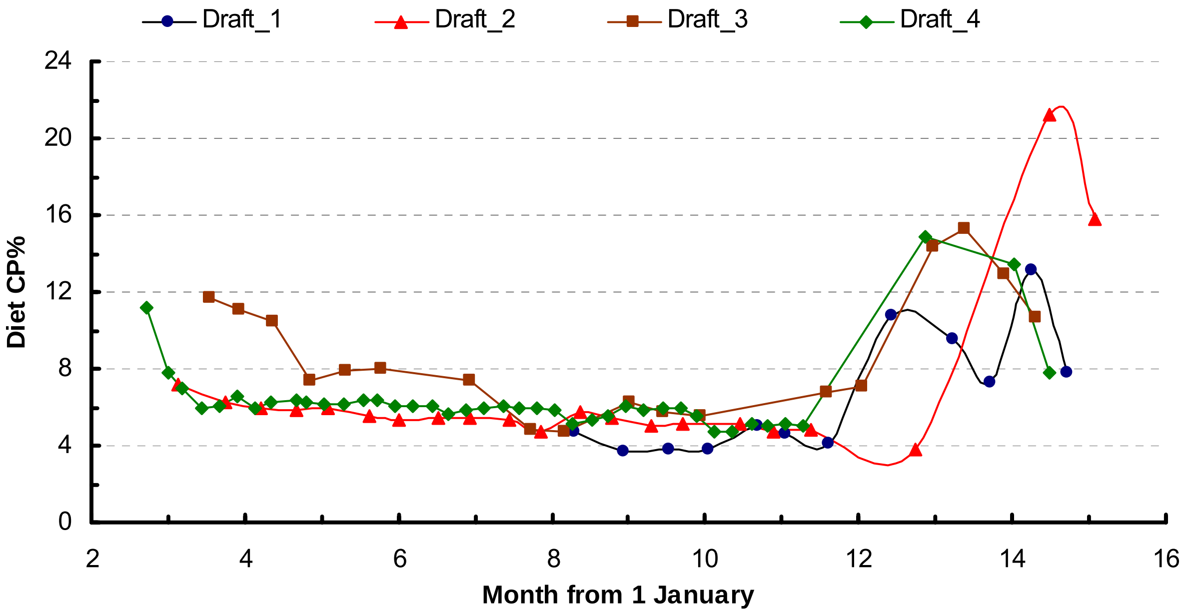


Figure 4.1.6. *F.NIRS measurements of the crude protein (CP) content (%) of the diet selected by unsupplemented steers grazing Mitchell grass pastures during each of 4 annual cycles.*

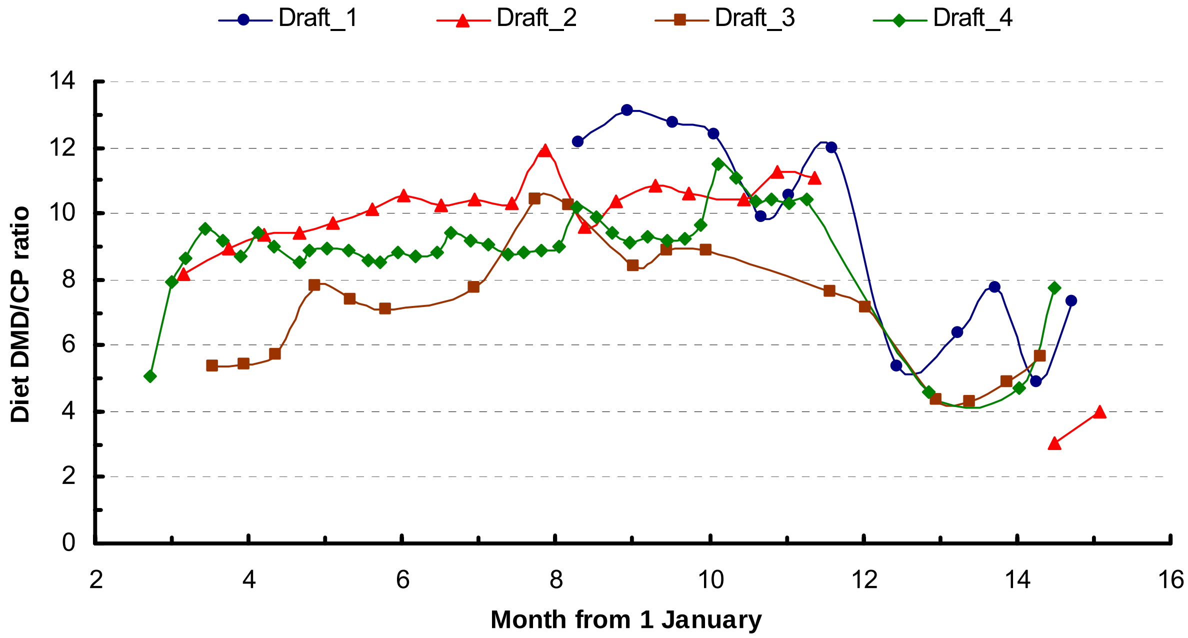


Figure 4.1.7. *F.NIRS measurements of the ratio DM digestibility/crude protein (DMD/CP) in the diet selected by unsupplemented steers grazing Mitchell grass pastures during each of 4 annual cycles.*

4.1.4 Steer performance

The Draft 1 unsupplemented steers lost LW and BCS from the commencement of measurements in early August through to late October, with LW losses of 15 and 31 kg in the yearling and mature steers, respectively (Tables 4.1.4 and 4.1.5). Rapid LW gains occurred after the seasonal break through to the following March. Compared to the unsupplemented steers, the urea supplement improved the LW of the steers by 20 and 22 kg, and the CSM supplement improved the LW of the steers by 39 and 34 kg in the yearling and mature steers, respectively, in November shortly before the seasonal break. Much of the LW benefit was retained through the wet season, being on average 15 kg for the LMM supplement and 25 kg for the CSM supplement (Table 4.1.4).

Steers in the later drafts gained LW through the dry season until January (Draft 2), October (Draft 3), or November (Draft 4) (Table 4.1.6). LW gains of unsupplemented steers were 117, 228 and 162 kg per annum for Drafts 2, 3 and 4, respectively. Unsupplemented steers lost 28, 20 and 49 kg during the late dry season until the seasonal break, followed by rapid LW gain during the wet season. BCS reflected the changes in LW (Table 4.1.5 and 4.1.7).

Table 4.1.4*.* *Initial liveweight and cumulative liveweight change of steers in Draft_1 which commenced in August 2001*

Measurement	Months[a]	Yearling steers			Mature steers		
		Nil	LMM	CSM	Nil	LMM	CSM
Initial LW (kg)	-	229	229	229	405	405	404
LW gain to Sept	1.8	3	4	13	-7	0	6
LW gain to Oct	2.9	-15	1	18	-31	-12	4
LW gain to Nov	3.9	-1	19	38	-19	3	15
LW gain to Jan	5.3	23	44	62	-12	12	27
LW gain to Feb	6.6	71	87	104	29	47	53
LW gain to Mar	7.6	104	118	133	58	74	80

[a], Months from the entry of the steers into the paddocks an commencement of the draft.

Table 4.1.5. *Body condition score (BCS) of the steers in Draft_1 which commenced in August 2001*

Measurement	Months[a]	Yearling steers			Mature steers		
		Nil	LMM	CSM	Nil	LMM	CSM
BCS, Aug	-	4.8	4.7	4.8	6.3	6.3	6.1
BCS, Oct	2.9	4.0	4.4	5.0	5.8	6.1	6.0
BCS, Feb	6.6	4.4	4.2	4.6	5.4	5.3	5.3
BCS, Mar	7.6	5.2	5.2	5.9	6.3	6.0	6.8

[a], Months from the entry of the steers into the paddocks an commencement of the draft.

Table 4.1.6. *Initial liveweight (LW) and LW change of yearling steers in Drafts 2, 3 and 4 given no supplement (Nil) or given a urea supplement (LMM) or cottonseed meal (CSM). Due to drought conditions during Draft 3 only Nil steers were continued through the annual cycle in an adjacent paddock and at a low stocking rate. Measurements were commenced in March 2002, 2003 and 2004 for Drafts 2, 3 and 4, respectively. The yellow highlight indicates the interval during the late dry season when the steers were losing liveweight*

Measurement	Draft_2			Draft_3	Draft_4		
	Nil	LMM	CSM	Nil	Nil	LMM	CSM
Initial LW, Mar (kg)	238	240	239	176	229	229	229
LW gain to Apr	14	17	12	31	21	25	22
LW gain to May	35	40	35	60	37	39	31
LW gain to Jun	50	55	48	84	45	50	44
LW gain to Jul	59	64	62	103	55	57	50
LW gain to Aug	70	75	74	134	64	69	61
LW gain to Sept	86	87	85	146	73	78	70
LW gain to Oct	95	104	100	156	83	91	86
LW gain to Nov	104	115	111	151	93	103	95
LW gain to Dec	112	133	120	136	70	90	75
LW gain to Jan	113	132	126	136	44	72	52
LW gain to Feb	95	118	116	182	88	112	94
LW gain to Mar	85	111	112	225	134	152	130
LW gain to Apr	121	143	142	-	172	185	161

Table 4.1.7. *Body condition score (BCS) of yearling steers in Drafts 2, 3 and 4. Further information on these drafts of steers is given in the header of Table 4.1.6*

Measurement	Months	Draft_2			Draft_3	Draft_4		
		Nil	LMM	CSM	Nil	Nil	LMM	CSM
BCS, Mar		4.6	4.7	4.5	3.4	3.1	3.1	3.1
BCS, May		4.7	4.5	4.7	4.0	3.6	3.8	3.5
BCS, Aug		4.6	4.6	4.7	4.5	3.9	3.9	3.9
BCS, Oct		5.0	5.1	5.1	3.3	2.9	3.0	2.8
BCS, Dec		4.4	4.7	4.7	3.2	3.9	4.3	4.1
BCS, Feb		4.0	4.4	4.5	4.0	4.1	4.6	4.1
BCS, Apr		4.3	4.5	4.6	4.5	4.3	4.3	4.2

4.1.5 Other nutritional indices

The concentrations of inorganic phosphorus in plasma (mean 4.2 and 2.6 mmol/L) of Draft 2 steers in September and November 2002, respectively, of unsupplemented steers indicated that these animals were adequate in phosphorus status (McCosker and Winks 1994). Also, the observation that the steers were gaining LW at this time, plasma urea concentrations (1.5 and 1.1 mmol/L) suggested that N was not likely to be severely deficient.

4.1.6 Response of the steers to the LMM supplement

The effect on the LW of yearling steers of providing rumen degradable N in the LMM supplement during the later part of the dry season was substantial, being 20, 26 and 28 kg shortly before the seasonal break, and 14, 22 and 13 kg at the end of the following wet season in March for Drafts 1, 2 and 4, respectively. This is comparable with the magnitude of the response to feeding urea-based supplements during the entire dry season in the northern speargrass. In this latter environment the reduction in LW loss by young growing cattle averaged 18 kg across 12 experiments, although the response ranged from Nil in benign dry seasons to 36 kg in harsh dry seasons (Dixon and Doyle 1996). When the larger LW benefits were observed in the latter studies, about one-third of the LW benefit was lost during the following wet season to compensatory growth effects. No other studies of responses of cattle to dry season N supplementation are available for the Mitchell grass regions of Northern Australia. However, the losses in the LW benefit due to compensatory growth during the wet season in the present study (30%, 15% and 54% for Drafts 1, 2 and 4, respectively) were comparable with those for the northern speargrass region (Dixon and Doyle 1996). The generally low N content and high digestibility of hayed-off grasses during the dry season in the Mitchell grass Downs region, at least until any damage by winter/spring rain, could be expected to lead to large responses to N supplements during the dry season. Thus when cattle are grazing senesced Mitchell grass pastures with high grass and low forb contents and are given N supplements for the entire dry season, the animal LW responses may be large. This is consistent with the large animal response per month to LMM supplement in Draft 1 when forbs were no longer available in the pasture, and are also consistent with anecdotal reports and producer experience of excellent responses in some circumstances to N supplements fed to cattle in the Mitchell grass downs (McLennan *et al.* 1999).

The observation that the LW response to N supplements did not occur until very late in the dry season for Drafts 2 and 4, and that the LW effect was modest even though the DMD/CP ratio was >10, suggests that the N component of the forbs in the diet may have been more available to provide rumen degradable N than the grass component of the diet. The proportion of N consisting of rumen degradable N in senesced native tropical grasses may well be low, although experimental data is lacking. However the proportion of N consisting of rumen degradable N in forbs, even when senesced, may be substantially higher than for the tropical native grasses and explain why an animal response to the LMM supplement apparently did not occur until the DMD/CP was a much higher value than for northern speargrass pastures.

4.1.7 Response of the steers to the CSM supplement

The reduction in liveweight loss of the yearling steers through to the seasonal break of 39, 27 and 8 kg for Drafts 1, 2 and 4 due to feeding CSM supplements was much greater than for the LMM supplement for Draft 1. However, in Draft 2 the responses were similar, and in Draft 4 the response to CSM tended to be lower than that to the LMM. Generally a lower animal response would be expected to a urea N supplement than to the same amount of supplementary N provided as a protein meal such as cottonseed meal due to less efficient use of the N in urea than that in CSM as a rumen substrate, and also in some circumstances to the benefits of increased supply of absorbed amino acids to the animal. However, in the present experiment the lesser response of the LMM with the Draft 1 steers may have been due to the low voluntary intake of the LMM supplement since it provided only about 60% of the N provided by the CSM supplement. This occurred even though the LMM contained about 30% CSM and would be expected to be more palatable for cattle than most of the supplements of this type used in the northern cattle industry. This result emphasises that delivery systems remain a major limitation to effective use of urea-based supplements by the extensive cattle industry in northern Australia.

4.1.8 F.NIRS predictions of diet quality

The ingestion of the LMM or the CSM supplement had no discernable effect on the F.NIRS measurements of the characteristics of the diet. This is in agreement with results from a number of other studies (Appendix 1, Dixon and Coates 2005) indicating that when F.NIRS calibration equations based on forage-only diets are applied to diets which contain some concentrate from loose mineral mixes or a small amount of cottonseed meal, the predictions are those of the forage component of the diet and not the total diet. In the present studies only the F.NIRS measurements of the Nil treatment paddocks have been presented, and these measurements likely provide the best estimate of the forage diet selected in this experiment.

The dietary crude protein content and digestibility were within the range expected. The use of the DMD/CP ratio to indicate the RDN status of the animal and as an index of when cattle are likely to respond to urea supplements has been discussed comprehensively by Dixon and Coates (2005) (Appendix 1). That the DMD/CP ratio was, during the mid to late dry season, in the range when an animal response to RDN supplement would be expected, and that the N supplements did improve steers LW in the present studies, support the hypothesis that the DMD/CP ratio is useful as an index of the response of an animal to RDN supplements. However, it should to be pointed out that during some intervals in the present study when the DMD/CP was > 10 there was no discernable response to N supplement. Possibly this was associated with sub-optimal intake of the LMM supplement or provision of more rumen degradable N than expected from the forb component of the diet.

The faecal N concentration was curvelinearly related to the dietary CP% as shown in Fig. 4.1.8. Faecal N concentration of 1.3%, as proposed by Winks *et al*. (1979) to be the faecal N concentration below which responses of cattle to urea supplements can be expected with speargrass pastures, corresponded to a dietary CP content of 6.9%. However, as Winks *et al*. (1979) pointed out, this threshold is likely to be specific for the pasture system, and the 1.3% faecal N criterion observed for the northern speargrass may not necessarily apply to Mitchell grass pastures. The threshold dietary CP below which animal responses to supplementary urea N occur is likely to be between 5 and 6% as discussed elsewhere in this report. Thus it appears that the threshold faecal N concentration below which supplementary N responses occur is different (and lower) for Mitchell grass pastures than for the northern speargrass pastures.

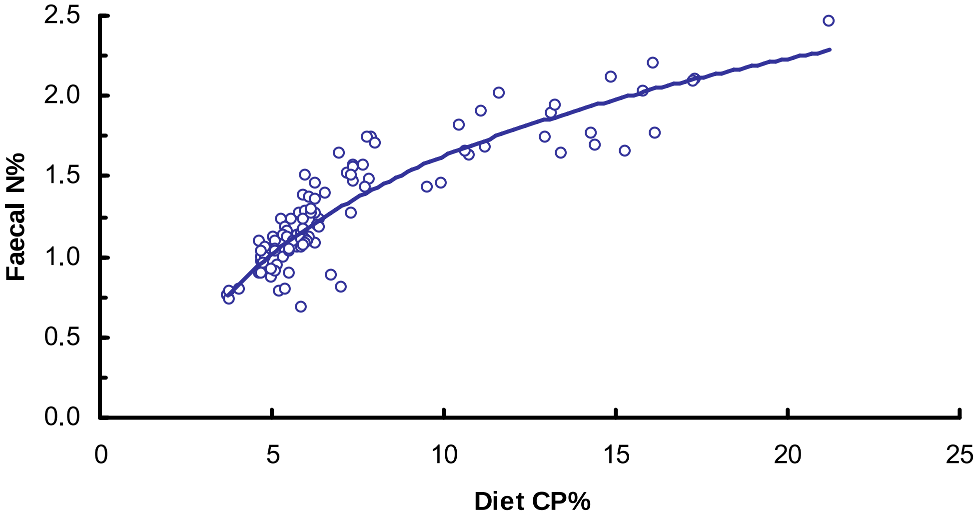


Figure 4.1.8. *The relationship between dietary crude protein and faecal N concentration both measured with F.NIRS in unsupplemented steers grazing Mitchell grass pastures during 4 annual cycles. The relationship was: Y = 0.877 Ln (X) - 0.39 (n 104, R^2 0.82).*

The high proportions of dietary non-grass observed in the present experiment is in accord with previous experimentation reporting extensive selection by sheep for forbs in the Mitchell grass pastures (Lorimer 1978; McMeniman *et al*. 1986; Pritchard *et al*. 1986), and also with F.NIRS measurements in cattle at Rosebank, Longreach (D. Jackson, unpublished results) indicating that cattle grazing Mitchell grass pastures selected extensively for forbs and could sometimes obtain the majority of their diet as forbs. The high proportion of non-grass (25-50% of the diet) selected by the Draft 3 steers through the dry season provides a likely explanation for the high LW gains of these steers (0.84 kg/day from March to early September) despite the very dry seasonal conditions. The low stocking rate of these Draft 3 steers presumably contributed to this selectivity of the diet.

4.1.9 F.NIRS predictions of liveweight change of unsupplemented yearling steers

The calibration equations for DWG calculated from the Coates (2004) data set and all of the data for the unsupplemented yearling steers from the present Toorak site (adg_TrkA) had acceptable calibration statistics with an R^2 0.82 and an SECV 219 g/day. These are similar to the calibration statistics reported by Coates (2004) for the adg1441 and other more specific calibrations for DWG. However, prediction of DWG of the Toorak samples involved large error, regardless of whether the Toorak samples were included as part the sample population used to calculate the calibration. First, where the Toorak samples from the unsupplemented yearling steers were included with the Coates (2004) data set, the standard error of prediction (SEP) of the Toorak samples was 423 g/day and the R^2 of prediction 0.60. Second, although the calibration statistics for the 4 calibration equations contributing to the adg_TrkB composite calibration were similar to those for the Coates (2004) adg1441 calibration, with the R^2 0.83-0.84 and the SECV 203-214 g/day, prediction of DWG from the adg_TrkB composite calibration when the 4 drafts were considered as separate populations also involved large errors. The SEP's ranged from 267-503 g/day and averaged 381 g/day, and the R^2 of prediction ranged from 0.56-0.81. When these

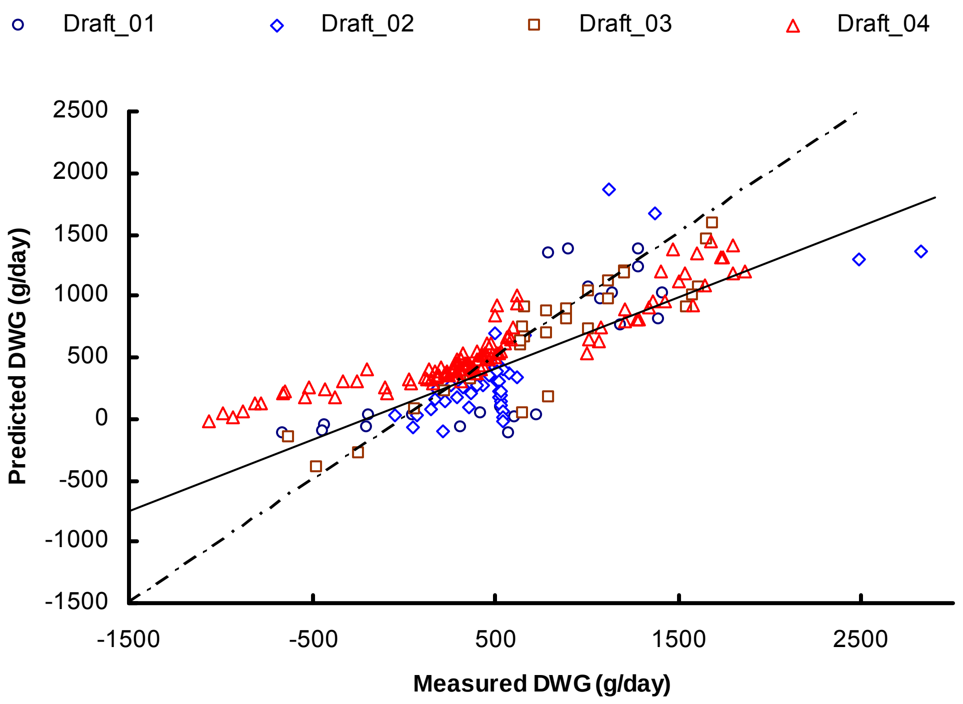


Figure 4.1.9. *The relationship between the measured DWG (g/day) and DWG predicted from the F.NIRS calibration adg_TrkB in unsupplemented yearling steers grazing Mitchell grass pastures during 4 annual cycles. The relationship was:* $Y = 0.54X + 235$ *(n 194,* R^2 *0.66).*

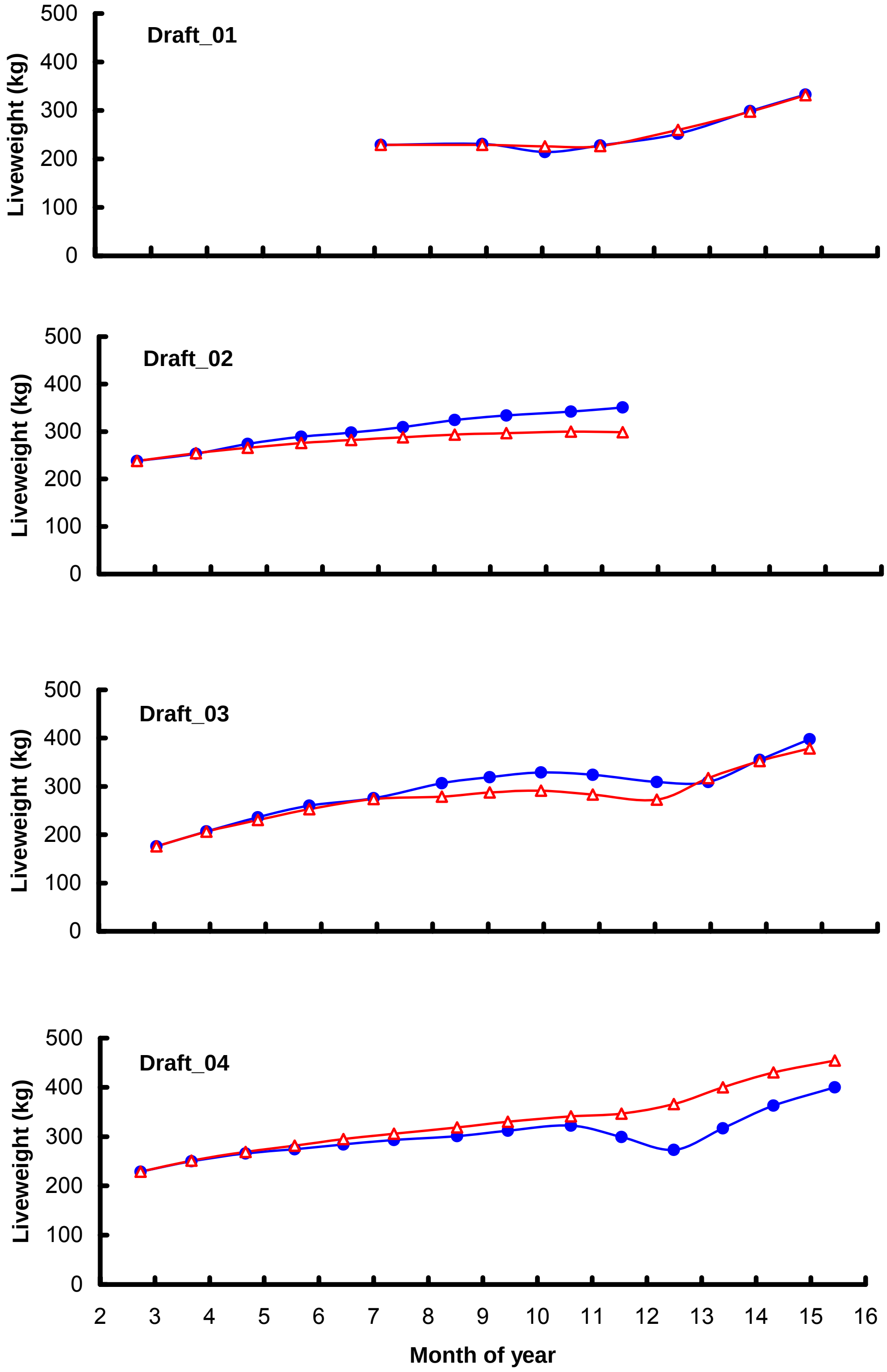


Figure 4.1.10. *The measured LW (●) and cumulative predicted LW (Δ) calculated from the F.NIRS calibration adg_TrkB for unsupplemented yearling steers grazing Mitchell grass pastures during each of 4 drafts.*

data were combined there was a poor relationship between the measured DWG and the predicted DWG (Fig 4.1.9). As shown by this relationship the F.NIRS prediction severely underestimated LW loss during intervals of high LW loss, and severely underestimated LW gain during intervals of high LW gain. Third, when the Toorak unsupplemented yearling steers were predicted from a calibration calculated from the adg1441 data set (less some samples derived from Toorak) (i.e. a DWG calibration with no representation of the Toorak site), the SEP was 453 g/day and the R^2 of prediction 0.57.

The poor relationship between the measured and predicted DWG for the unsupplemented yearling steers in the present study (Fig 4.1.9) is likely to be due in large part to error in the original measurement of DWG in this experiment rather than in the NIR technology to predict DWG. Examination of the Fig 4.1.9 indicates that there were many measurements of DWG > 1.3 kg/day, and values ranged up to 2.83 kg/day. There were also many measurements of LW loss exceeding 0.5 kg/day and up to 1.1 kg/day. These estimates of the measured DWG were calculated from the tangent to the fitted polynomial of steer LW with time as the best estimate of animal DWG. The very high positive or negative values for measured DWG were probably associated with large changes in digesta load, body energy content and compensatory growth known to occur in grazing cattle through the annual cycle in the seasonally dry tropics. That the ME intakes that would have been necessary to achieve animal tissue gain or loss of the measured DWG would have been outside the range possible for the experimental animals provides strong evidence that there were large errors in the measurement of DWG. These errors would be expected to cause an under-estimation of the slope of the regression relationship, and explain why the observed slope was much less than the expected slope of 1.0.

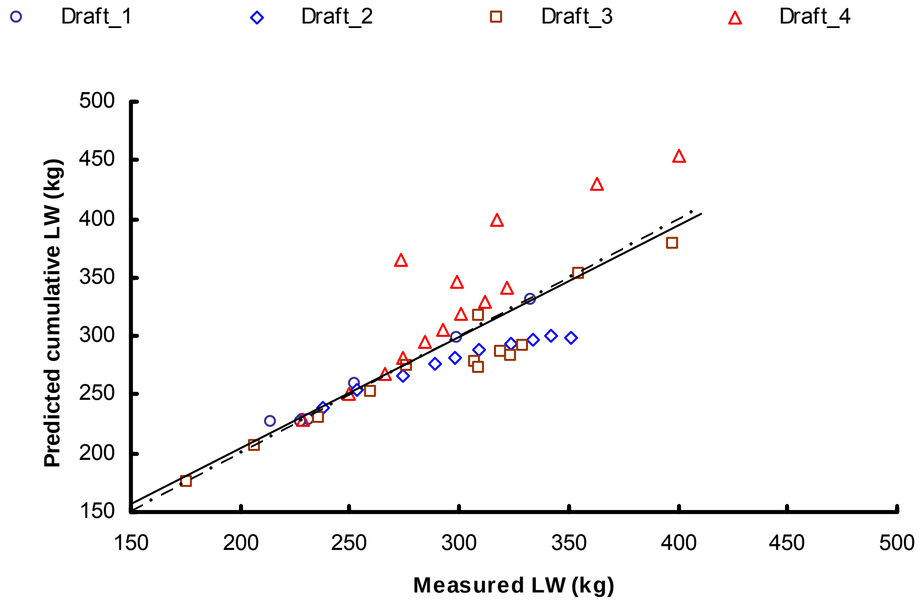


__Figure 4.1.11.__ The relationship between the measured LW and cumulative predicted LW calculated from the F.NIRS calibration adg_TrkB for unsupplemented yearling steers grazing Mitchell grass pastures during 4 annual cycles. The regression relationship was:
Y = 0.97 X +9 (R^2 0.71, n 44).

The measured LW and the cumulative predicted steer LW (calculated from DWG and the steer LW at the commencement of the draft) in each of the drafts are shown in Fig 4.1.10. Agreement was excellent in Draft 1, but not in Drafts 2, 3 and 4. In Drafts 2 and 3 the F.NIRS underestimated LW during the second half of the dry season, but in Draft 3 (where measurements were available through the following wet season) it was evident that over-estimation in the early wet season compensated for the under-estimation during the dry season. This under-estimation and over-estimation may have been a consequence of changes in digesta load. In Draft 4 F.NIRS severely over-estimated LW during December and January (the months corresponding to the very late dry season and when digesta load may have decreased), but there was only partial compensation during the following wet season. The maximum difference within a draft ranged from 12 kg in Draft 1 to 93 kg in Draft 4, while the difference at the end of the draft ranged from 12 kg in Draft 1 to 54 kg in Draft 4. Also, as expected from the poor prediction of DWG when samples were considered as a population external to the calibration population and these differences described, there was a poor relationship between the measured steer LW and the predicted cumulative steer LW (Fig 4.1.11).

It is of interest that when there was adequate grass pasture on offer and the proportion of forbs in the diet was low in Draft 1, predicted cumulative LW agreed well with the measured LW. In Drafts 2 and 4 the pasture DM on offer was only 1.1 and 1.4 tonnes/ha in May, and in Draft 3 was much lower (0.4 tonnes/ha). Also forbs were selected extensively and comprised a large part of the diet in Drafts 3 and 4. The poor F.NIRS prediction of cumulative LW appears to have been associated with lower availabilities of grass pasture and high selection of forbs.

4.1.10 F.NIRS predictions of liveweight change of mature steers and supplemented yearling steers

NIRS chemometrics fundamentally involve the development of calibration equations as empirical mathematical relationships between the NIRS spectra (i.e. in F.NIRS the NIR spectra of faeces) and the characteristics of the sample (in F.NIRS, for example faecal N concentration, diet crude protein concentration, animal DWG, etc). For development of calibrations for DWG the Coates (2004) data sets, and the present NIRS_Task_2 project, have depended as far as possible on an animal model consisting of a young growing *Bos indicus* type animal in the absence of factors which would constrain growth other than diet DM digestibility and diet crude protein content. Such factors which would be expected to affect animal growth include disease, parasites, nutritional deficiencies such as phosphorus, supplements, compensatory growth, pregnancy and lactation and pasture DM on offer. Animals influenced by these latter factors have been excluded as far as possible from the calibration data sets since such factors are known to affect voluntary DM intake and / or LW change, but for reasons which are not likely to change the characteristics of the NIR spectra of faeces. In ruminants ingesting forage the NIR spectra of faeces appears, during calibration for most variables, to be measuring the undigested plant material in faeces rather than endogenous material of animal origin.

A consequence of the origin and development of the calibration data sets for liveweight change as described above is that if, as in the present study, it is not possible to measure DWG of unsupplemented yearling steers grazing pasture from the F.NIRS calibrations, it will not be possible to directly predict from the calibration equation the DWG of cattle in a different physiological state (e.g. the more mature #9 steers in Draft 1 of the present study) or being fed supplements (e.g. the LMM and CSM supplemented treatment steers in the present study). The relationships between the measured DWG (X) and the predicted DWG (Y) using the adg_TrkB calibration actually appeared better for the LMM and CSM supplemented steers, than for the unsupplemented steers, in the present study. The regression relationships were as follows:
Nil: $Y = 0.54 X + 235$ (n 194, R^2 0.66) (as given in Fig. 4.1.9),
LMM: $Y = 0.79 X + 104$ (n 166, R^2 0.75)
CSM: $Y = 0.72 X + 134$ (n 166, R^2 0.71).
However, the obvious reason for the observed improvement in the regression statistics is that both supplements reduced the measured liveweight losses during the dry season, and for the present data set this increased the slope of the linear regression relationship. Thus the improvement towards the 1:1 relationship between the measured and the predicted DWG for the treatments where the supplements were provided was fortuitous, and does not have general application to improve predictions of DWG in supplemented steers. Prediction of the DWG of supplemented animals, or animals differing in physiological state to the young growing *Bos indicus* type animals used to develop the calibration equations, is likely to have to depend on

prediction of the 'standard' unsupplemented animal and then adjustment made for the effects of supplementation or physiological state. Although it should be possible to develop F.NIRS calibrations to measure the DWG of cattle in a different physiological state or fed a specific type of supplement, etc, the data sets required would presumably have to contain many hundreds (or thousands) of observations to develop calibrations of comparable accuracy and robustness. This is clearly impractical. This is discussed by Dixon et al (2007) in the context of reproducing breeders (Appendix 4).

In conclusion, it was not possible to obtain acceptable F.NIRS calibrations for DWG at this Toorak site during the present experiment. This was the case even when the Toorak samples were included in the calibration data set and the predictions were made as part of the sample population used to develop the calibration. We cannot provide an explanation why acceptable F.NIRS calibrations for DWG could be developed for each of the other pasture systems investigated in this NIRS_Task_2 project (as discussed later in this report), but not for the Mitchell grass pastures at Toorak. However, we suggest that the problems are more likely to be associated with the size and robustness of the data set to adequately encompass the diversity of Mitchell grass pasture systems and especially through erratic rainfall years, rather than any fundamental difference of Mitchell grass pastures which prevents application of F.NIRS to measure DWG.

Summary. Four drafts of *Bos indicus* cross steers (initially yearlings 176-239 kg, or for one draft also 2.5 YO steers 405 kg) grazed Mitchell grass pastures in a replicated supplementation experiment. Treatments consisted of no supplement, or N supplement as a loose mineral mix containing urea or cottonseed meal fed through the dry season. Pasture availability and species were measured twice annually using Botanal techniques. Frequent measurements were made of animal liveweight and faeces were sampled fortnightly for F.NIRS measurements. The patterns through the annual cycle of animal liveweight and of the quality of the pasture selected (measured with F.NIRS) were generally as expected for the pasture system and region. Steers often selected a high proportion of dicot forbs, and the crude protein content and digestibility of the diet (as measured by F.NIRS) was maintained until the late dry season. Steers responded to the N supplements in the late dry season, but some of the liveweight benefit of the supplement was lost due to compensatory effects during the following wet season. F.NIRS did not provide acceptable measurements of animal liveweight change or cumulative liveweight through the seasonal cycles.

4.2 Swans Lagoon growing heifer experiment in the northern speargrass

4.2.1. Rainfall

The 2000/01 summer rainfall (Table 4.2.1) was similar to the long-term average for the site, but in the 2001/02 summer was only 63% of average, in the 2002/03 summer 46% of average and in the 2003/04 summer 69% of average. Also in the 2002/03 summer the seasonal break was not until February 2003 and thus was very late for this region.

Table 4.2.1. *Rainfall (mm) at the Swans Lagoon trial site. The bars indicate when Draft 1 commenced, when the Drafts of heifers were changed, and the termination of Draft 4*

Month	2000/01	2001/02	2002/03	2003/04	2004/05	Long-term mean
Jul	0	5	0	0	0	15
Aug	4	0	20	0	3	19
Sept	0	6	0	0	6	9
Oct	66	10	3	29	35	30
Nov	176	7	0	2	24	67
Dec	176	161	18	150	53	123
Jan	91	92	32	218		195
Feb	112	231	236	153		187
Mar	45	34	36	22		114
Apr	21	0	11	30		44
May	3	2	5	0		40
Jun	7	2	36	0		18
Total	701	550	397	604		871
Date of break	6/11/00	12/12/01	24/2/03	13/12/03		16 Dec

The seasonal break was defined as the first rainfall event of at least 50 mm over 3 days.

4.2.2. Pasture

Pasture availabilities (Table 4.2.2) generally reflected the rainfall and the grazing pressure during the previous 12 months, and were generally as expected. At the start of the trial in December 2000 there was a large amount of pasture on offer in each of the trial paddocks, reflecting the early seasonal break and that the trial paddocks had been destocked, or only lightly stocked, before the trial commenced. In April 2003 pasture availability in each of the paddocks was lower than in the other years, due to the late seasonal break and the low total rainfall during the preceding summer. Also, in each year pasture availability was much lower in the high stocking rate paddocks (C..TT and F..LH) than in the equivalent moderate stocking rate paddocks (B..TT and E..LH, respectively). The extremely low pasture availability in E..LH and F..LH in April 2003 was associated with the severe damage by army worms and grasshoppers to these paddocks late in the 2002/03 wet season. Stylos, native legumes and forbs constituted a much larger proportion of the pasture in the medium fertility paddocks (E..LH, F..LH and Poddy) than in the low fertility paddocks (B..TT and C..TT). In April 2004 these comprised 21-32% of the available pasture in the E..LH, F..LH and Poddy paddocks, but only 6-8% in the B..TT and C..TT paddocks.

Water quality was high (Appendix 4) and was not likely to have constrained pasture intake or liveweight gain of the steers.

Table 4.2.2. *Yield of components of the pasture (kg/ha)*

Measurement	Paddock				
	Low fertility		Medium fertility		
	B..TT	C..TT	E..LH	F..LH	Poddy
April 2002					
3P grasses	1818	474	1748	690	1971
Annual grasses	6	0	62	25	497
Undesirable grasses	356	67	125	196	131
Stylos	0	0	125	5	62
Native legumes	0	0	0	0	9
Forbs	37	8	99	23	135
Sedges	5	9	0	0	71
Total	2222	558	2159	939	2876
November 2002					
Total	1400	540	1800	400	1540
April 2003					
3P grasses	1129	849	405	213	1112
Annual grasses	191	92	840	818	748
Undesirable grasses	41	85	19	65	205
Stylos	0	0	107	27	6
Native legumes	25	14	66	36	100
Forbs	65	37	182	148	466
Sedges	71	58	17	25	60
Total	1522	1135	1636	1332	2697
November 2003					
Total	928	490	672	356	1050
April 2004					
3P grasses	2493	1547	1156	995	1409
Annual grasses	112	60	630	688	420
Undesirable grasses	79	18	187	193	101
Stylos	0	0	338	57	55
Native legumes	119	51	94	74	171
Forbs	135	57	535	401	704
Sedges	185	164	120	79	200
Total	3123	1897	3060	2487	3060

Composition groups of pasture:
3P grasses; *Bothriochloa ewartiana, Bothriochloa pertusa, Brachiaria mutica, Chrysopogon fallax, Dicanthium spp., Eragrostis spp., Eulalia aurea, Heteropogon contortus, Heteropogon triticeus, Panicum spp., Paspalum dilatum, Sorghum plumosum, Themeda triandra, Urochloa moambicensis.*
Annual grasses: *Brachiaria spp., Dactyloctenium radulans, Digitaria ciliaris, Echinochloa colona, Paspalidium spp*., others.
Undesirable grasses: *Aristida, Bothriochloa decipiens, Chloris spp*., others.
Stylos; Seca (*Stylosanthes scabra)* and Verano *(Stylosanthes hamata)*.

4.2.3. Animal liveweight and liveweight changes

***Table 4.2.3.** LW and LW changes of the 4 drafts of heifers through the annual cycles*

Measurement		Paddock				
		Low fertility		Medium fertility		
		B..TT	C..TT	E..LH	F..LH	Poddy
Initial LW (kg)	mean	196	196	196	196	194
	range	165-215	163-215	163-215	165-215	162-211
Maximum dry season LW (kg)	mean	263	251	280	264	281
LW gain (kg) to maximum	mean	67	56	84	68	87
	range	37-99	24-91	53-112	35-87	40-111
Month of maximum dry season LW	range	Apr-Aug	Apr-Jul	May-Sept	May-Oct	Jun-Aug
Minimum dry season LW (kg)	mean	235	218	246	228	255
Month of minimum dry season LW	range	Aug-Dec	Aug-Dec	Dec-Feb	Dec-Feb	Dec-Jan
LW loss from Max to Min (kg)	mean	31	38	37	41	36
	range	17-46	33-46	9-66	26-56	15-56
Final LW (kg)	mean	329	296	314	288	336
Annual LW gain (kg)	mean	139	106	125	99	148
	range	126-157	75-138	92-157	83-117	127-161

The expected pattern of gain in LW by the heifers through the late wet season and the early dry season, loss in LW during the late dry season, and rapid LW gain following the seasonal break (Winks 1984) was observed for each of the 4 drafts of heifers. Initial mean LW ranged between drafts from 162 to 215 kg as a consequence of seasonal and management effects on the heifers during the preceding season. For the 4 drafts of heifers the average gain in LW to the maximum LW during the dry season ranged between paddocks from 56 to 87 kg, and between years within paddocks ranged from 24 kg in paddock C..TT for Draft 4 to 112 kg for paddock E..LH for Draft 1 (Table 4.2.3). The month when the maximum dry season LW was observed ranged widely between paddocks and between years (April to October), and this usually occurred 2 months earlier in the low fertility TT paddocks than in the medium fertility LH and Poddy paddocks. Within paddocks, the month of the maximum dry season LW ranged between years by 2-5 months.

In general, the heifers continued to gain weight longer into the dry season when there was stylo or paragrass present in the pasture. Pasture type had a greater effect than the imposition of high stocking rate. The LW loss of herds during the late dry season varied between paddocks by 31-41 kg, but varied between years by up to 59 kg. However, since some paddock groups of heifers were supplemented with molasses-urea, or were transferred to adjacent paddocks, to alleviate dry season LW loss, the measured differences would have underestimated the true differences between the paddocks if no such intervention had occurred. Annual LW gain ranged from 75-161 kg and varied widely between years. The mean annual LW gain was reduced by 26 and 33 kg by the increase from moderate to high stocking rate in the medium (LH) and low fertility (TT) paddocks, respectively.

4.2.4. Diet selected by the heifers

The proportion of non-grass in the diet, measured by F.NIRS, varied widely between paddocks. The results for Draft 1 are shown in Figure 4.2.1, and the results for the other drafts followed a similar pattern. In the low fertility (B..TT and C..TT) paddocks, where only a low proportion of the available pasture consisted of forbs and legumes, non-grass comprised about 10-15% of the diet in the wet season, and generally less than 10% during the dry season. However, in the medium fertility paddocks with high availability of stylo and other forbs (E..LH and F..LH), the non-grass increased from the wet season through to the early dry season, and in the moderate stocking

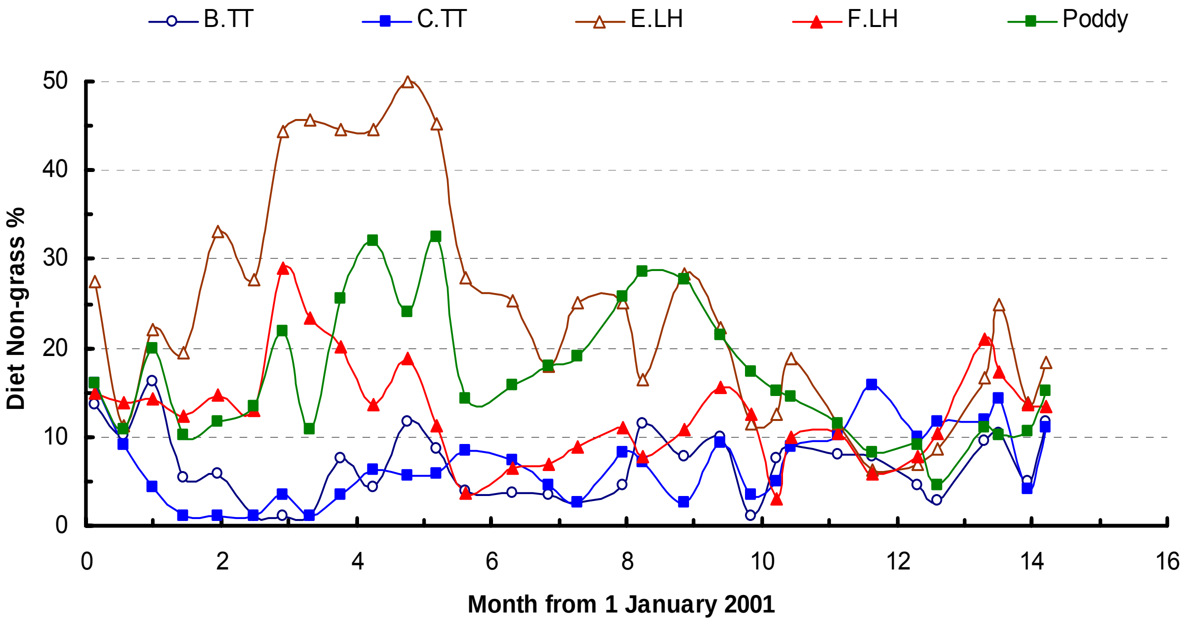


Figure 4.2.1. *F.NIRS measurements of the percent non-grass in the diet selected by the heifers grazing each of the 5 experimental paddocks during 2001 and early 2002 (Draft_1).*

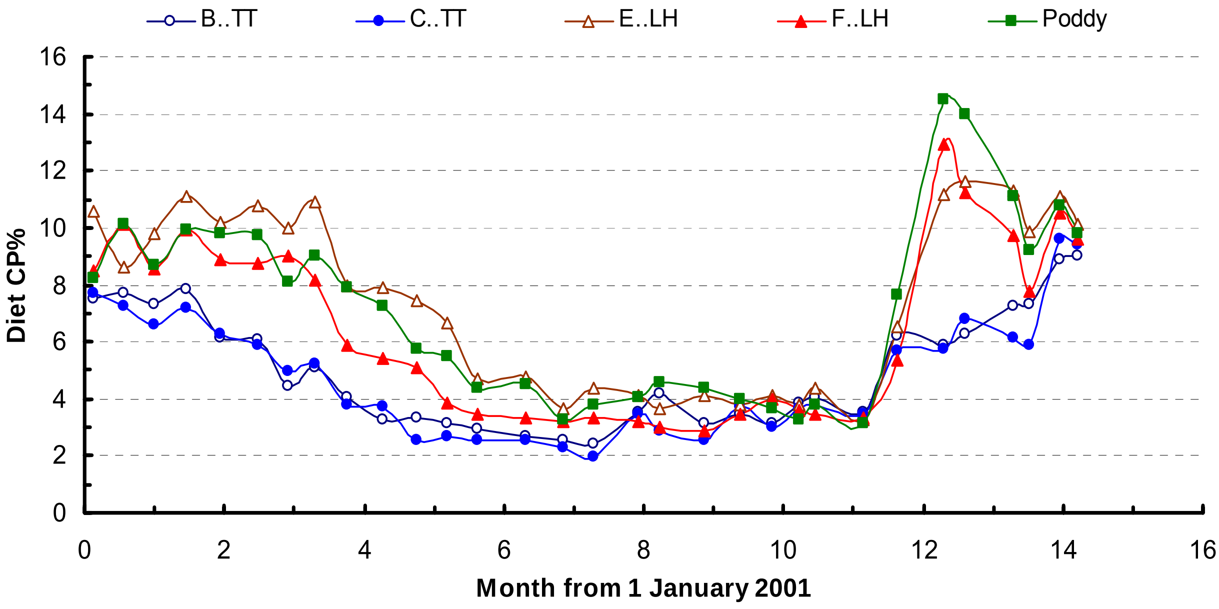


Figure 4.2.2. *F.NIRS measurements of the crude protein content (CP%) of the diet selected by the heifers grazing each of the 5 experimental paddocks during 2001 and early 2002 (Draft_1)*

rate paddock comprised 40-50% of the diet for an extended interval. The lower proportion of diet non-grass in the high stocking rate medium fertility paddock (F..LH) was presumably because there was less stylo and other non-grass material available due to their selective removal during previous grazing by the heifers. The high proportion of non-grass in the Poddy paddock with the area of para grass presumably reflected selection by the heifers of forbs, and possibly also browse. The latter was not recorded in the Botanal measurements. There was a range of dicot species present in the paddock, including substantial amounts of a *Crotolaria spp* and Noogoora burr (*Xanthium pungens*) and Acacia and Eucalyptus species of browses. Although none of these latter species would generally be considered palatable, selection of these or other dicot species apparently occurred for the measured non-grass to comprise up to 32% of the diet.

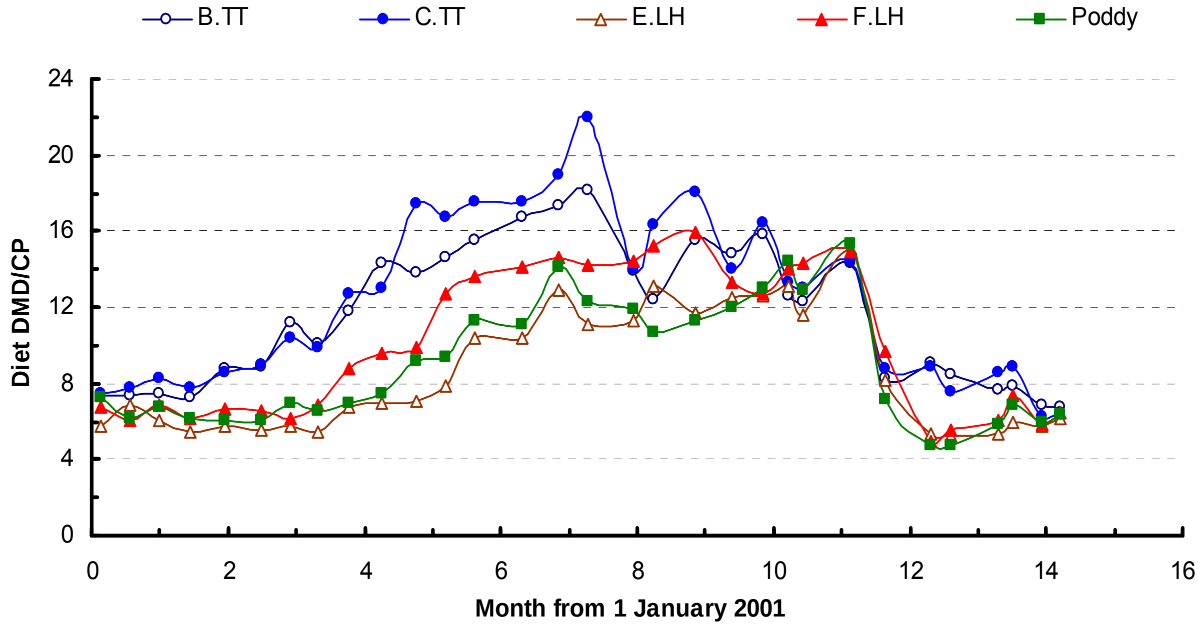


Figure 4.2.3. *F.NIRS measurements of the ratio DM digestibility/crude protein (DMD/CP) of the diet selected by the heifers grazing each of the 5 experimental paddocks during 2001 and early 2002 (Draft_1)*

Dietary CP% measured by F.NIRS followed the expected pattern of high dietary CP% in the wet season which declined as the dry season commenced and progressed (Figure 4.2.2). During the wet season the diet CP% was consistently higher in the medium fertility (E..LH and F..LH) paddocks with stylo, and in Poddy paddock with the paragrass, than in the low fertility (B..TT and C..TT) paddocks. Also the decline in dietary CP% occurred later, and decreased to only about 4% dietary CP% in these former paddocks rather than 2-3% dietary CP% in the B..TT and C..TT paddocks.

The ratio DMD/CP (Figure 4.2.3) followed an inverse pattern to the dietary CP% though the annual cycle. This was a consequence of the decline of the diet DMD%, from the wet season into the dry season, being proportionally much lower than the decline in dietary CP%. As discussed elsewhere in this report (Appendix 1), a DMD/CP ratio value of about 8 appears to be a critical threshold for speargrass pastures; above this value an animal response can be expected to urea supplements. For Draft 1 the DMD/CP increased to >8 in late February–early March for the low fertility (B..TT and C..TT) paddocks, but not until late March to late May for the medium fertility paddocks with substantial amounts of stylo or para grass. The month when DMD/CP increased to be greater than 8 in all paddocks and for all drafts (Table 4.3.4.) demonstrates the variability between paddocks and years, the month ranging from February to October. The liveweight change (LWΔ, g/day) of the heifers was related to the ratio DMD/CP in the diet as shown in Figure 4.2.4. The polynomial equation given described a higher proportion of the variance than the exponential relationship (R^2 0.57).

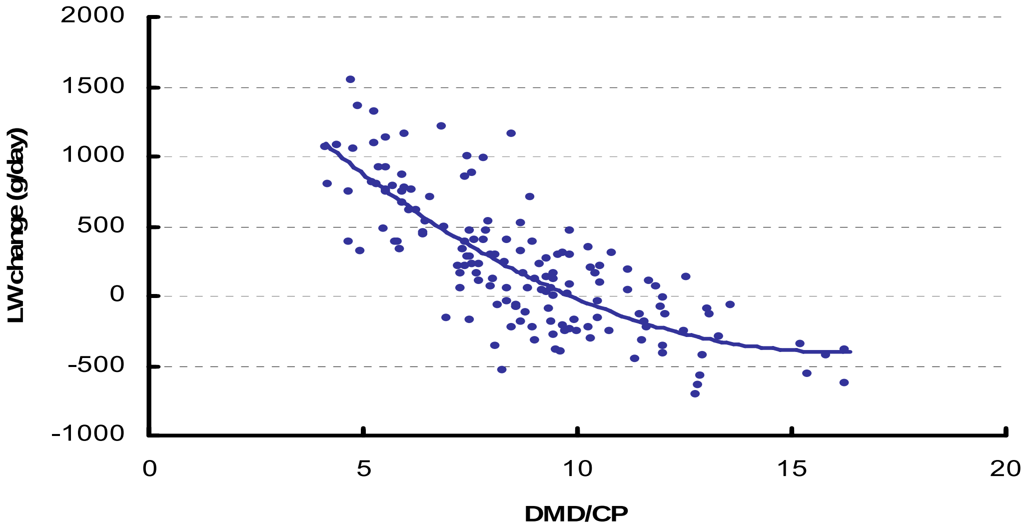


Figure 4.2.4. *The relationship between the ratio DM digestibility/crude protein (DMD/CP) of the diet selected by the heifers and the measured liveweight change (LW∆) of the heifers. The equation was:* $LW\Delta = 10.6\,(DMD/CP)^2 - 338\,(DMD/CP) + 2303$ *(n 152,* R^2 *0.62).*

Table 4.2.4. *The month when, from F.NIRS measurements of the diet, the dietary DMD/CP ratio was greater than 8 in each paddock for each of the 4 draft*

Heifer group	Year	Paddock				
		Low fertility		Medium fertility		
		B..TT	C..TT	E..LH	F..LH	Poddy
Draft_1	2001	Feb	Feb	Jun	Apr	May
Draft_2	2002	Mar	Mar	May	Apr	May
Draft_3	2003	May	May	Oct	May	Sept
Draft_4	2004	Apr	Mar	Jul	Jun	Jul

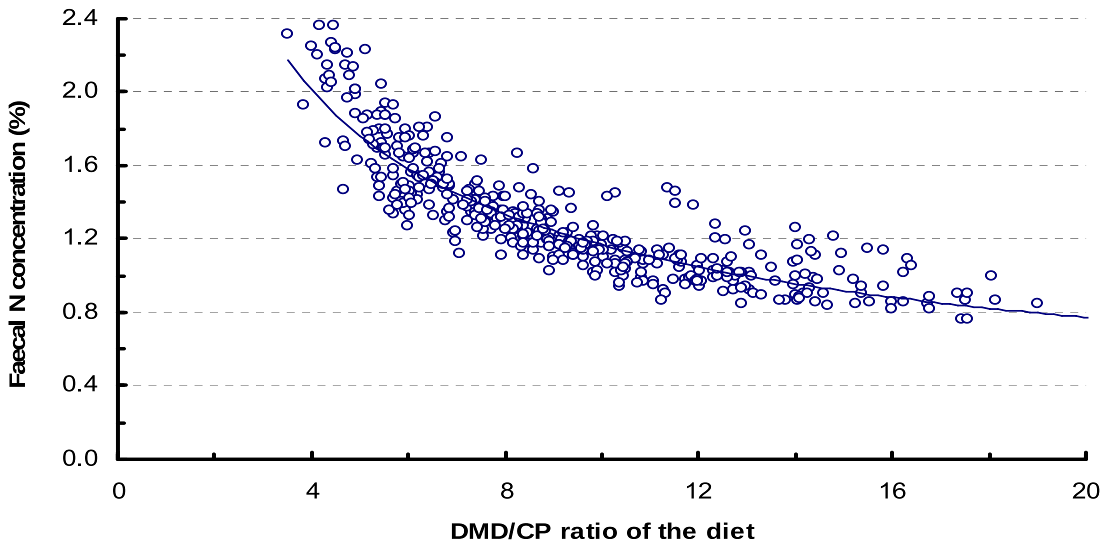


Figure 4.2.5. *The relationship between the DMD/CP ratio of the diet measured by F.NIRS and the faecal N concentration (Faecal N%). The relationship was described by the equation:* $\text{Faecal N (\%)} = 0.0085\,(DMD/CP)^2 - 0.26\,(DMD/CP) + 2.87$ *(n 454,* R^2 *0.80)*

The concentration of N in faeces has been used as an indicator of when cattle are likely to respond to urea supplements, and Winks *et al.* (1979) suggested that, at least for northern speargrass pastures, an animal response to urea supplements can be expected when the faecal N concentration decreases to <1.3%. Faecal N concentration is accurately measured by F.NIRS. In the present data set from Swans Lagoon, the faecal N concentration was linearly related to the dietary crude protein concentration as follows:

Faecal N(%) = 0.095 (Diet CP%) + 0.65 (n 454, R^2 0.87)

Therefore a faecal N concentration of 1.3%N corresponded to a dietary protein concentration of 6.8%. In addition, the faecal N concentration was curvelinearly related to the DMD/CP ratio of the diet (Figure 4.2.5), and this relationship indicated that a concentration of 1.3% N in faeces corresponded to a DMD/CP ratio of 8.5. The polynomial equation provided a slightly better description of the relationship than the exponential equation (R^2 0.78). However, it is important to note that there was considerable error associated with the prediction of dietary CP% or DMD/CP ratio from the faecal N concentration. Given that the availability of degradable N in the rumen is clearly dependent on the N in the diet rather than in the faeces, the direct measurement of diet from faecal NIRS spectra is likely to be a much more reliable indicator of the nutrient status of the animal.

4.2.5. Microbial protein synthesis and metabolites

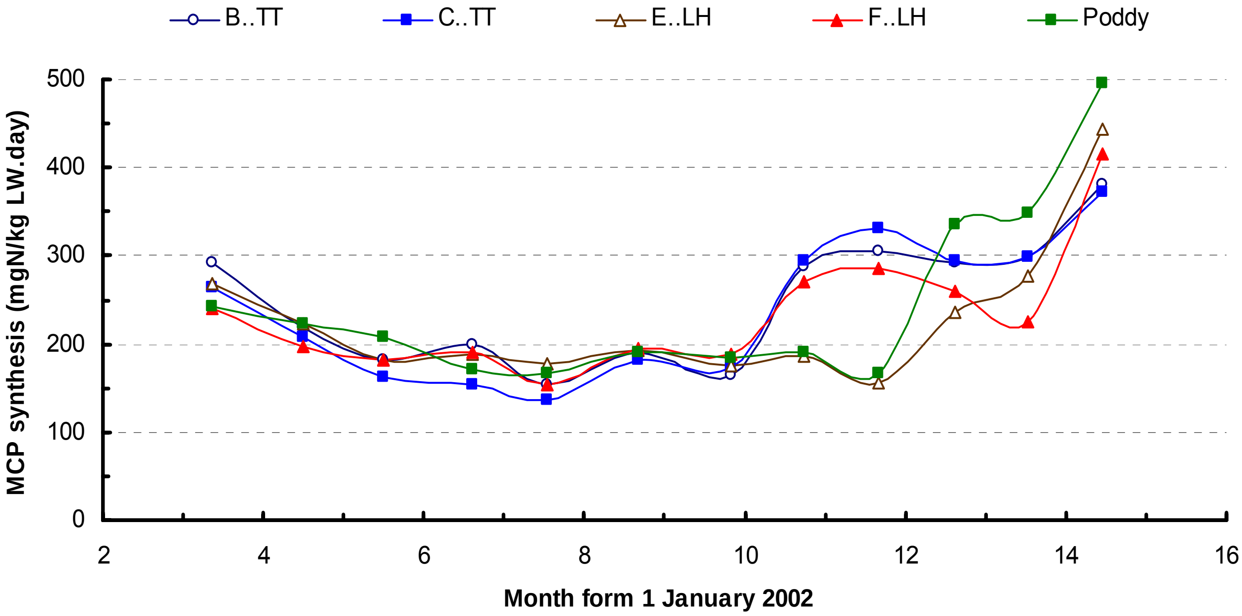


Figure 4.2.6. *The synthesis of microbial crude protein (MCP, mg N/kg LW.day), measured by excretion of purine derivatives in urine and use of creatinine as a marker of urine volume, by heifers grazing each of the 5 experimental paddocks during 2002 and early 2003 (Draft_2). Molasses-urea supplements were fed to paddocks B..TT, C..TT and F..LH from late October to mid-February 2003.*

The synthesis of microbial crude protein (MCP) in the rumen, measured by the excretion of purine derivatives in urine, followed a seasonal pattern as would be expected; the results for Draft 2 are shown in Figures 4.2.6, and the results for other years were similar. MCP was 250-400 mg N/kg LW.day in the late wet season, declining to about 200 mg N/kg LW.day during the dry season and increasing to 350-450 mg N/kg LW.day during the peak pasture quality of the wet season. It would be expected that MCP synthesis would be determined primarily by the intake of metabolizable energy except perhaps when RDN became limiting for rumen microbial activity. Thus there was possibly a reduced efficiency of MCP synthesis during the dry season.

However, there was little evidence that the MCP synthesis differed markedly or consistently between diets. The changes in MCP synthesis are consistent with the expected changes in the intake of total pasture DM and metabolizable energy through the annual cycle, and with changes in LW gain of the heifers measured directly or predicted by F.NIRS. LW change (LWΔ, g/day) of the heifers was related to the microbial protein synthesis (MCP, mg N/kg LW.day) as follows:

$$LW\Delta = 5.28\,(MCP) - 1077 \quad (n\ 152,\ R^2\ 0.63)$$

There was also a quadratic relationship between the microbial protein synthesis and the DMD/CP ratio of the diet, but the relationship explained only 38% of the variance.

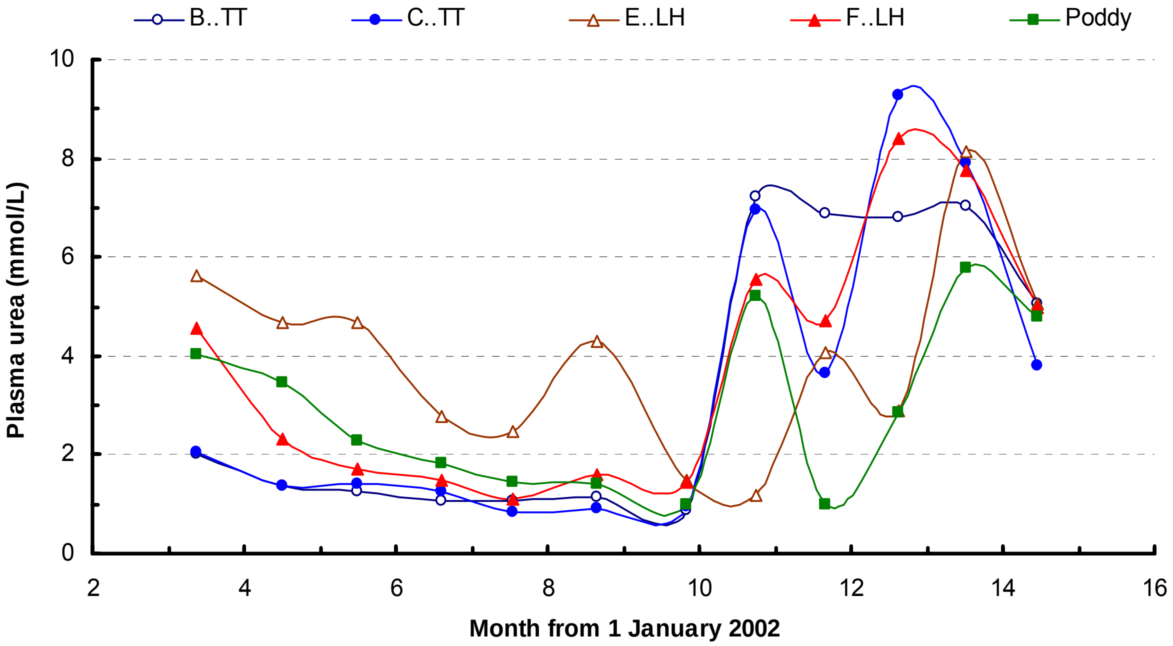


Figure 4.2.7. *Urea concentration in plasma (mmol/L) by heifers grazing each of the 5 experimental paddocks during 2002 and early 2003 (Draft_2). Molasses-urea supplements were fed to paddocks B..TT, C..TT and F..LH from late October to mid-February 2003.*

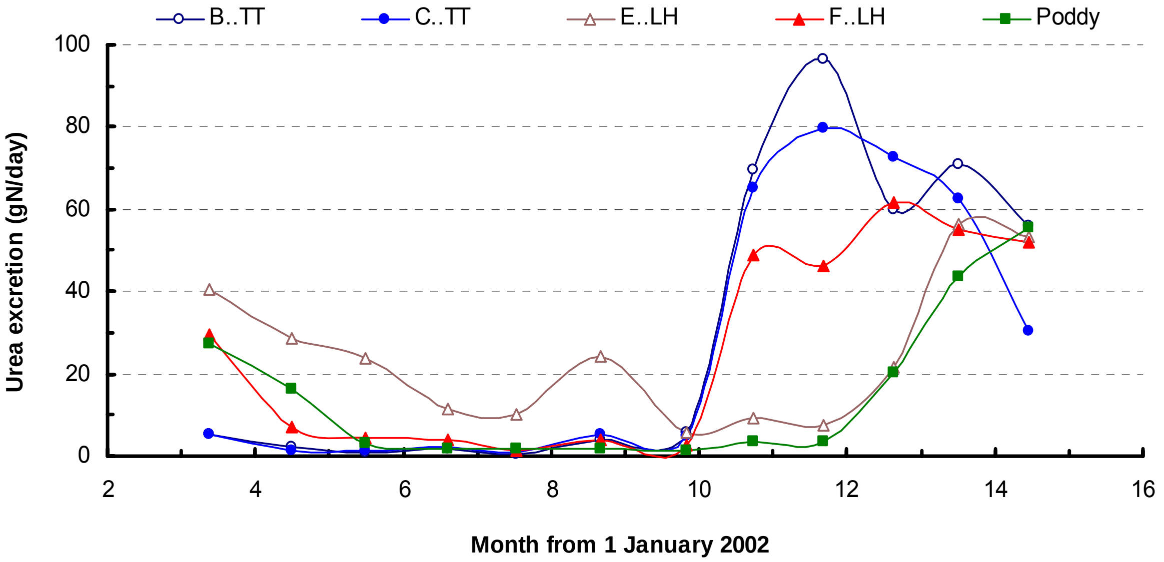


Figure 4.2.8. *The excretion of urea in urine, measured using creatinine as a marker of urine volume, by heifers grazing each of the 5 experimental paddocks during 2002 and early 2003 (Draft_2). Molasses-urea supplements were fed to paddocks B..TT, C..TT and F..LH from late October to mid-February 2003.*

The concentration of urea in plasma (Figure 4.2.7) followed a similar pattern to the MCP synthesis with a decline from the late wet season through into the dry season, and large increases in the concentrations late in the year. However the increase in plasma urea concentration may have been associated with mobilization of muscle tissue during LW loss and with molasses-urea supplementation in the B..TT, C..TT and F..LH herds from late October 2002 to mid-February 2003, as well as the changes in the diet. Nevertheless the plasma urea concentrations during the dry season before commencement of this supplementation indicated that the N status of the heifers in the two TT paddocks was much lower than in the other paddocks. Excretion of urea in urine (Figure 4.2.8) followed a similar pattern to the plasma urea concentrations. The decline in urea excretion by the heifers in the B..TT and C..TT paddocks to negligible amounts in the mid to late dry season is in accord with the hypothesis that these heifers were in a N deficient status. Urea excretion in urine was also correlated with the DMD/CP ratio of the diet (R^2 0.54) and to the microbial crude protein synthesis (R^2 0.47).

The concentration of inorganic phosphorus in plasma provides an indicator of the phosphorus status of animals, the most critical time of the year being in the late wet season when the animals are growing and any body stores of phosphorus have been depleted (McCosker and Winks 1994). The concentrations of inorganic phosphorus in plasma of heifers after they had been grazing the trial paddocks for 9-11 months (Table 4.2.5) suggested that the heifers in the E..LH and F..LH paddocks were probably marginal or deficient in their P status for part of the annual seasonal cycle during this trial. Estimation of the consequences of such marginal phosphorus status on LW change is difficult. Other trials on Swans Lagoon where the responses of heifers in similar phosphorus status to phosphorus supplements have been measured (R M Dixon, unpublished results) suggest that LW gain would have been reduced by such marginal phosphorus status by the equivalent perhaps to 3 kg/month.

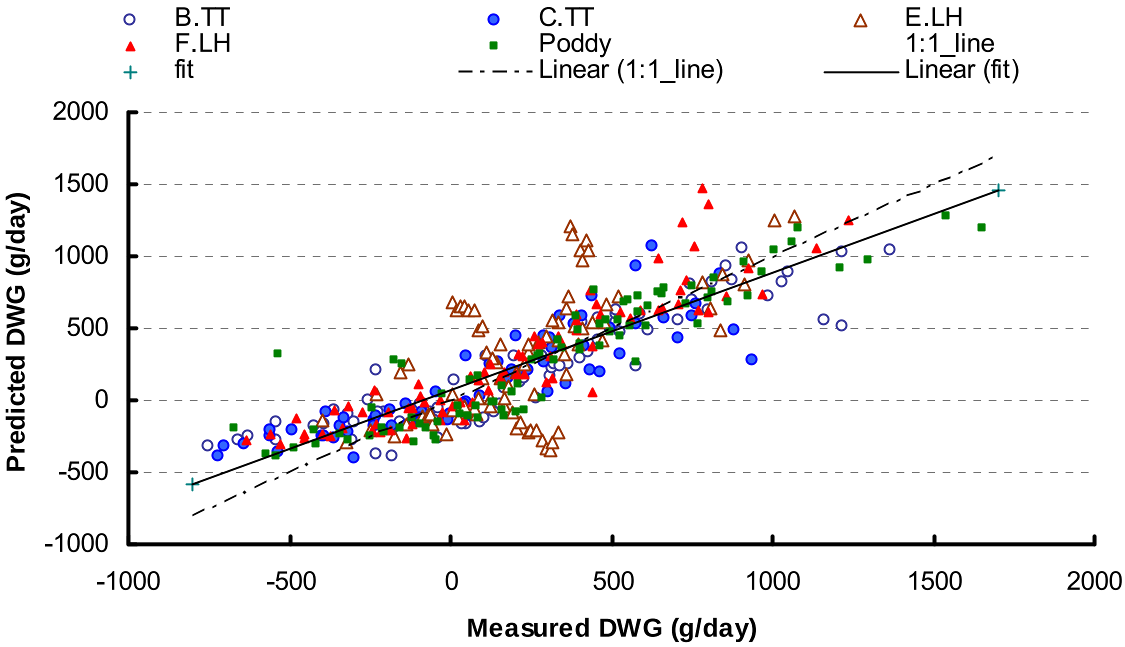
Table 4.2.5. *Concentrations of inorganic phosphorus in plasma (mmol/L) during the wet season (January, February and March) of heifers grazing the 5 experimental paddocks. Values are the mean of 6-10 heifers per paddock measured on 2 or 3 occasions*

Heifer group	Year	Paddock				
		Low fertility		Medium fertility		
		B..TT	C..TT	E..LH	F..LH	Poddy
Draft_1	2002	2.3	2.6	1.4	1.3	2.0
Draft_2	2003	1.7	1.4	1.5	0.9	2.1
Draft_3	2004	2.0	1.9	1.8	1.6	2.1

Concentrations of inorganic P in jugular plasma are indicative of the phosphorus status of non-lactating growing animals grazing wet season pastures as follows: 0.9-1.25 mmol/L, deficient; 1.25-1.6 mmol/L, marginal; >1.6 mmol/L adequate (McCosker and Winks 1994). The yellow highlight indicates the paddocks likely to be deficient.

4.2.6. Prediction of LW change

The relationship between the measured DWG and the DWG predicted by F.NIRS is shown in Fig. 4.2.9 with separation of the results based on paddock in part A and separation of the results based on draft in part B. As observed in the Toorak results described above, it appeared that the measured DWG over-estimated the true DWG at high growth rates, and underestimated the true DWG when heifers were losing liveweight rapidly. The reasons are likely to be the same; that measured DWG during high LW gain or loss was associated with changes in digesta load, body energy content and compensatory growth known to occur in grazing cattle particularly in the seasonally dry tropics. As in the Toorak data (Section 4.1), these errors would be expected to cause an under-estimation of the slope of the regression relationship. A further source of error



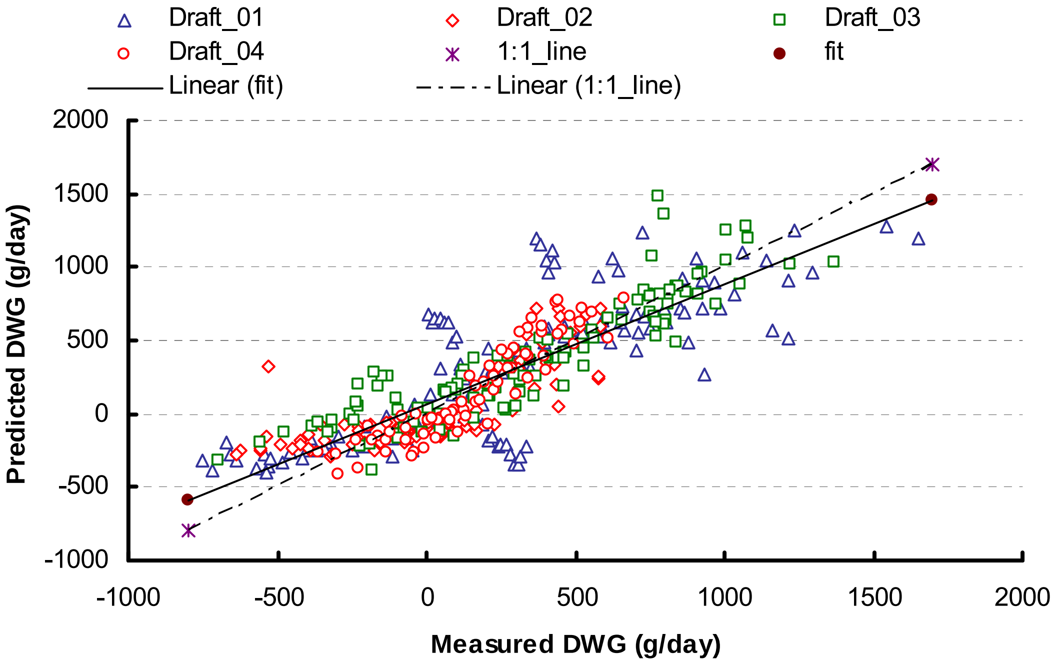
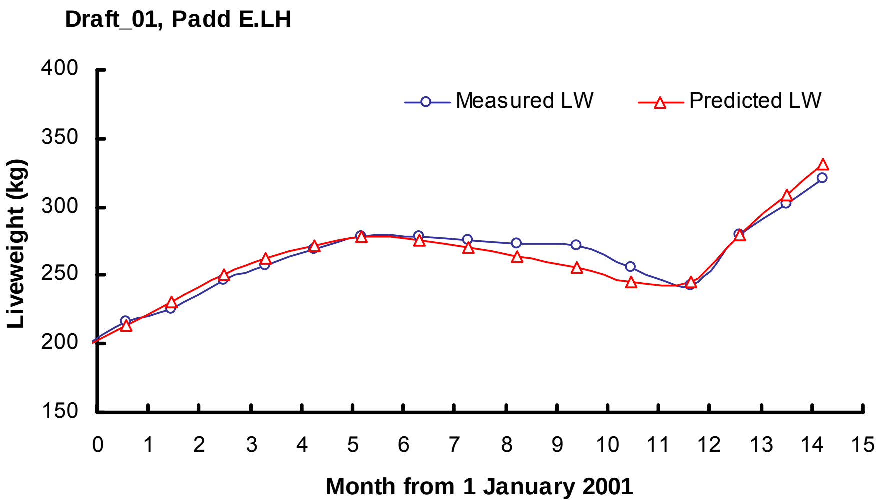
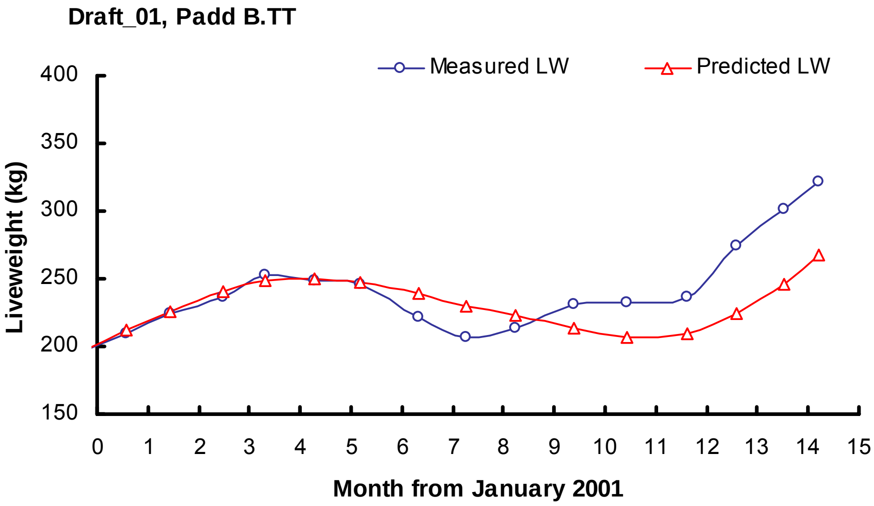


Figure 4.2.9. *The relationship between the measured DWG and the DWG predicted from the adgsgba F.NIRS calibration equation for the 4 drafts of heifers in the 5 paddocks at Swans Lagoon, showing the relationship (A) by paddocks, and (B) by draft. The regression equation was:* $Y = 0.819 X + 69$ *(n 393,* R^2 *0.71).*





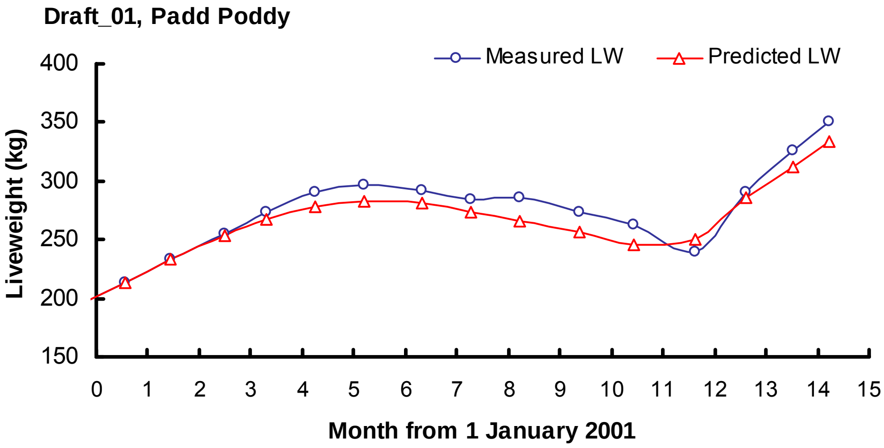
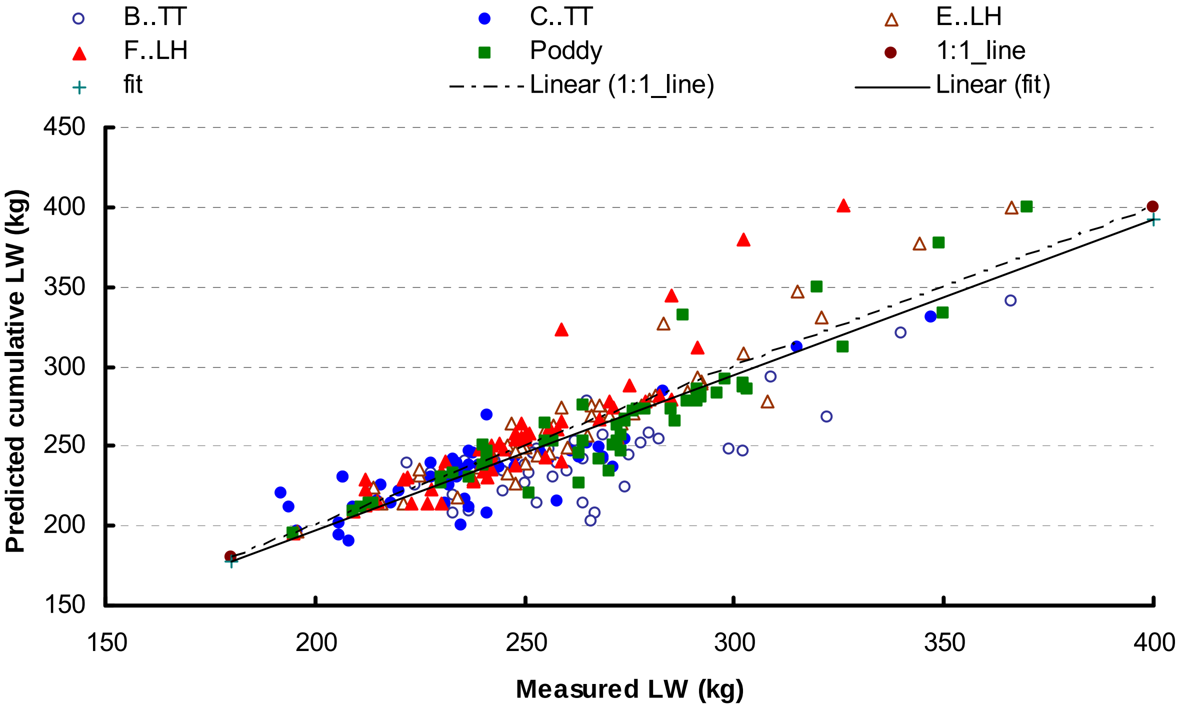


Figure 4.2.10. *The measured liveweight pathway and the liveweight pathway predicted from the initial LW and F.NIRS measures of LW change for the Draft 1 heifers in 3 paddocks. Molasses-urea supplement was fed from mid-July in paddock B.TT and from mid-September in paddock E.LH until mid-December 2001, but was not fed in Poddy paddock. These paddocks were representative the good (E.LH and Poddy) or poor (B.TT) agreement observed during the experiment between measured and predicted liveweight through the annual cycle.*



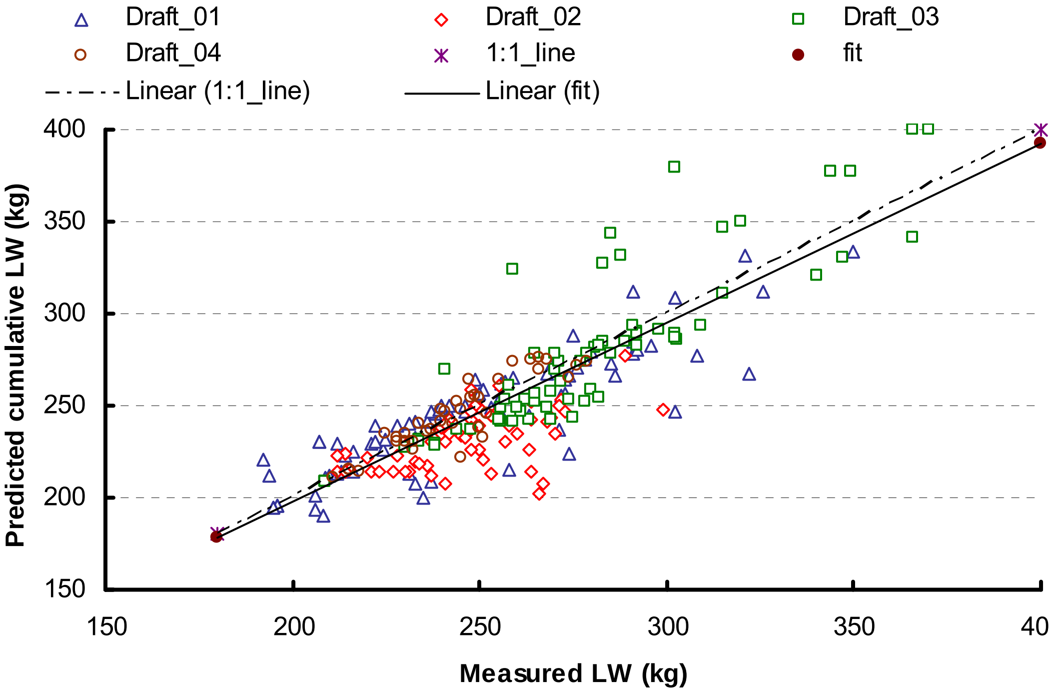


Figure 4.2.11. *The relationship between the measured liveweight and the cumulative LW predicted from the initial LW and F.NIRS measurements of LW change for the 4 drafts of heifers in the 5 paddocks at Swans Lagoon, showing the relationship (A) by paddocks, and (B) by draft. The regression equation was:*
$Y = 0.972 X + 3.1$ (n 255, R^2 0.75).

in the present study was that molasses-urea supplements were fed for intervals during the late dry season to at least some paddocks in 3 of the 4 years. As described and discussed by Dixon and Coates (2005), current F.NIRS predictions become unreliable when cattle are ingesting more than minor amounts of molasses supplement. Thus additional error may have been introduced into the F.NIRS prediction of DWG during those intervals when molasses-urea was fed. The standard error of prediction (SEP) of these DWG predictions in the present study was 237 g/day.

The heifer LW actually measured when the heifers were mustered monthly and the predicted LW was calculated from the initial LW and the F.NIRS predictions each 2-3 weeks are shown in Fig. 4.2.10 for 3 representative paddocks from Draft 1 of the 20 paddocks measured through the 4 drafts. Paddock Poddy represented the situation where no supplement was fed and there was good agreement between measured and predicted liveweight, paddock E.LH where molasses-urea was fed in the late dry season and there was good agreement, and paddock B.TT where there was poor agreement but molasses-urea supplement was fed for 5 months. Individual herds varied considerably in the extent to which the actual and predicted LW agreed during the annual cycle. Importantly, the error in the F.NIRS prediction of liveweight was a summation of the errors associated with the predictions in 2-3 week increments through the 12-15 months interval during which the draft was measured, and thus there was potentially a very large effect of any bias error in the prediction of DWG. In addition, the relationship between the measured and predicted cumulative LW for all of the herds during the experiment is shown in Fig. 4.2.12. This relationship indicated that the F.NIRS provided reasonable and unbiased estimates of the cumulative LW, despite the magnitude of the SEP and the potential bias errors associated with the feeding of molasses-urea supplement for at least some interval to the majority of the drafts of heifers examined.

These results support the hypothesis that F.NIRS predictions of LW change were sufficiently reliable in cattle grazing speargrass pastures to be useful for many management purposes, even when stocking rates were high and pasture availability was low. However, it should however be noted that the F.NIRS calibration equation equations used for these predictions was derived from data sets containing many measurements in the northern speargrass pasture region, and the predictions for these heifers at Swans Lagoon are likely to be more reliable than predictions for animals grazing other pasture systems.

Summary. Four drafts of *Bos indicus* cross yearling heifers (initially 163-215 kg) grazed native pasture low fertility soil at moderate or high stocking rate, or native pasture-stylo pasture on medium soil fertility at moderate or high stocking rate, or native pasture with a small area of para grass for 4 years. Frequent measurements were made of animal liveweight, of metabolites in the rumen, plasma and urine, and also faeces were sample fortnightly for F.NIRS measurements. Patterns through the annual cycle of animal liveweight and of the quality of the pasture selected (measured with F.NIRS) were generally as expected for the seasonally dry tropics. The month when diet measurements indicated that the heifers would respond to N supplements varied widely between years and between paddocks. F.NIRS provided acceptable measurements of animal liveweight change and cumulative liveweight through the seasonal cycles.

4.3 Brian Pastures, Gayndah, monitor herd grazing Leucaena – grass pasture

4.3.1 Rainfall and season

The annual rainfall, the time of the seasonal break and the long-term averages for the site are given in Table 4.3.1. Rainfall in the 2002/03 summer from October to March for Draft 1 (332 mm) was only 64% of average. However, this lower than average rainfall was alleviated by higher than average rainfall in the preceding August (91 mm) sufficient to cause the seasonal break which was also earlier than usual. The distribution and total during Drafts 2 and 3 were more similar to the long-term averages. The amounts of Leucaena and grass forage varied widely with the stage of the seasonal cycle and grazing, and the extremes are indicated in Figure 4.3.1. Quality of the stockwater supply should not have constrained animal intake or productivity (Appendix 4).

Table 4.3.1. *Rainfall (mm) at the Brian Pastures trial site*

Month	2000/01	2001/02	2002/03	2003/04	2004/05	Long-term mean
Jul	5	46	0	17	1	33
Aug	3	1	91	41	1	29
Sept	0	38	0	9	22	30
Oct	171	33	64	60	92	63
Nov	80	174	24	46	76	77
Dec	65	52	58	179	182	100
Jan	7	18	0	142	46	103
Feb	138	164	113	91	68	96
Mar	120	60	63	109	30	66
Apr	32	5	61	28	10	36
May	53	49	43	11	44	39
Jun	1	70	10	5	96	29
Total	675	710	527	738	668	702
Date of break	30 Oct 00	10 Nov 01	22 Aug 02	6 Dec 03	18 Oct 04	

The seasonal break was defined as the first rainfall event of at least 50 mm over 3 days.
The yellow highlight shows the months when Drafts 1, 2 and 3 measurements were made.

4.3.2 Measured LW change and ME intake of the steers estimated from LW change

The Draft 1 steers gained, on average, 0.76 kg/day for 8 months and were 398 kg at termination in March 2003. Drafts 2 and 3 steers gained on average 0.83 and 0.59 kg/day and were 436 and 348 kg, respectively, at termination of these drafts in May 2004 and 2005, respectively.

The LW gains and the estimated ME intakes of the steers are shown in Figs 4.3.2 a, b and c. In Draft 1 the increasing LW gain from July to October 2002 was presumably a consequence of the 91 mm rain in August 2002, and the decrease in LW gain from over 900 g/day in November 2002 to about maintenance in March 2003 due to declining amounts of forage on offer. The LW gains of Drafts 2 and 3 steers were consistent with rainfall and the amounts of forage on offer at various intervals during these drafts. In Draft 2 LW gains were initially about 1 kg/day but declined steadily to about 700 g/day at the end of the draft. In Draft 3 the increase in LW gain from maintenance initially in September 2004 to gain 1000 - 1100 g/day in December 2004 to February 2005, and subsequent decline through to May 2005, reflected low initial forage availability followed by growth of forage during the summer months and later insufficient forage through into the autumn months. Since the estimated ME intakes were calculated from the measured LW changes of the steers, the differences within drafts between the plots for

Browns-1 Leucaena, 31 December 2004

Browns-1 Leucaena, 9 June 2005

Figure 4.3.1. *Examples of the amount of Leucaena-grass pasture available during the summer following a flush of growth (a) and during the winter following extensive grazing (b).*

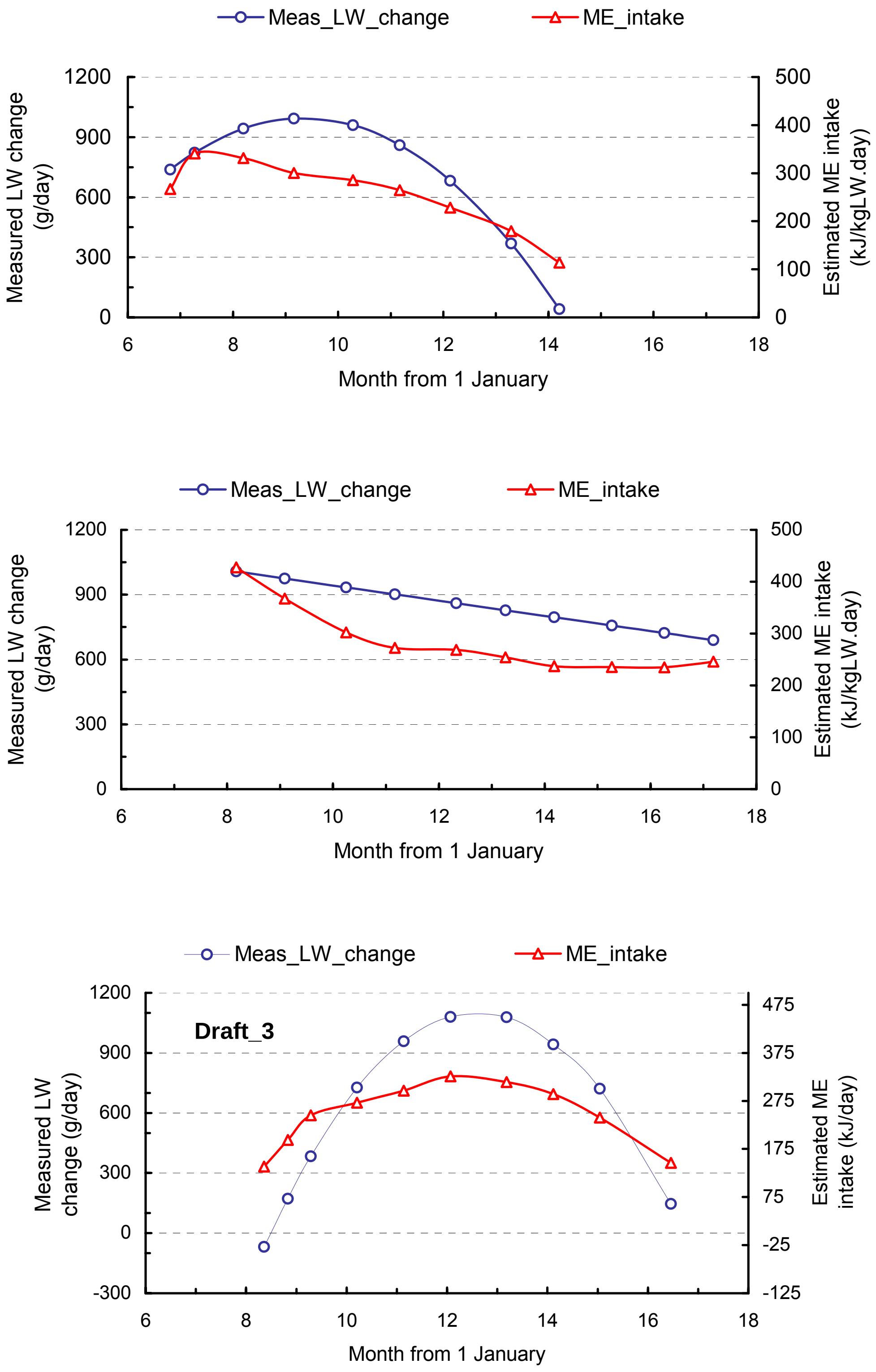


Figure 4.3.2 a, b and c. *The measured LW change (g/day) and the estimated ME intake calculated from LW change (kJ ME/kg LW.day) of steers grazing Leucaena-grass pasture during each of Drafts 1, 2 and 3.*

measured LW change and estimated ME intake were associated with the greater liveweights, changes in k_g calculated from DMD, and increasing net energy content of LW gain as the steers within each draft matured.

4.3.3 Dietary selection by the steers of Leucaena and intakes of total DM, Leucaena DM and grass DM

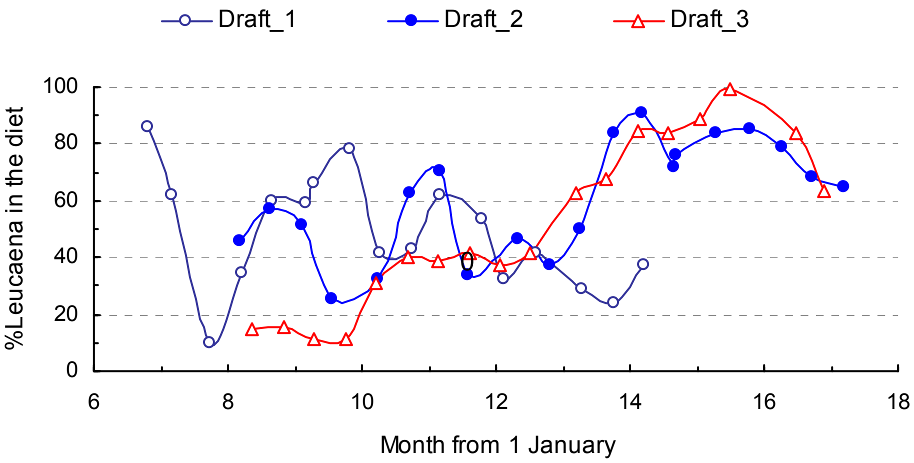


Figure 4.3.3. *F.NIRS measurements of the percent Leucaena in the diet selected by the steers in each of 3 drafts grazing Leucaena-grass pasture.*

The proportion of Leucaena in the diet (Figure 4.3.3) varied through a wide range which usually appeared to reflect the amount of Leucaena forage on offer. This proportion was initially high for the Draft 1 and 2 steers (86% and 46-52%, respectively). The proportion then declined to between 7 and 34% during the next 2-3 months of grazing, due presumably to a decrease in the Leucaena forage available. In Draft 1, with rain and summer growth, the proportion of Leucaena in the diet tended to increase, but then to decline by January 2003. In Draft 2 the % Leucaena in the diet from late February to May 2004 was high and averaged 83%. Draft 3 steers selected a low proportion of Leucaena initially (11-15% of the diet), most obviously because there was little Leucaena forage available when this draft commenced. However, with rain and summer growth the proportion of Leucaena in the diet increased progressively and averaged 84% of the diet from March to May 2005.

The intake of Leucaena (g DM/kg LW.day) was related to the %Leucaena in the diet as follows: $Y = 25 - 28e^{-0.016X}$ (n 55, R^2 0.70). LW gain was related asymptotically to the %Leucaena in the diet $Y = 0.82 - 0.97e^{-0.029X}$ (n 55), but the R^2 was only 0.12 (Fig. 4.3.4 a). LW gain was asymptotically related to the intake of Leucaena DM (R^2 0.45) (Fig. 4.3.4 b), and it appeared that LW gain approached the asymptote when the steers ingested about 8 g Leucaena DM/kg LW.day. It is of interest that high LW gains (> 0.7 kg/day) occurred across a wide range (10-91%) of %Leucaena in the diet, establishing that high LW gain could occur with only low proportions of dietary Leucaena. The three data points in Draft 3 where the %Leucaena and Leucaena intake were high (64, 84 and 99% of the diet; 6.8, 11.7 and 19.3 g DM/kg LW.day) but LW gain was low (-0.08, 0.15 and 0.56 kg/day, respectively) occurred during April-May 2003 when the amount of both Leucaena and grass forage on offer was low. These observations clearly differ from the remainder of the population, and this may have been associated with low forage availability.

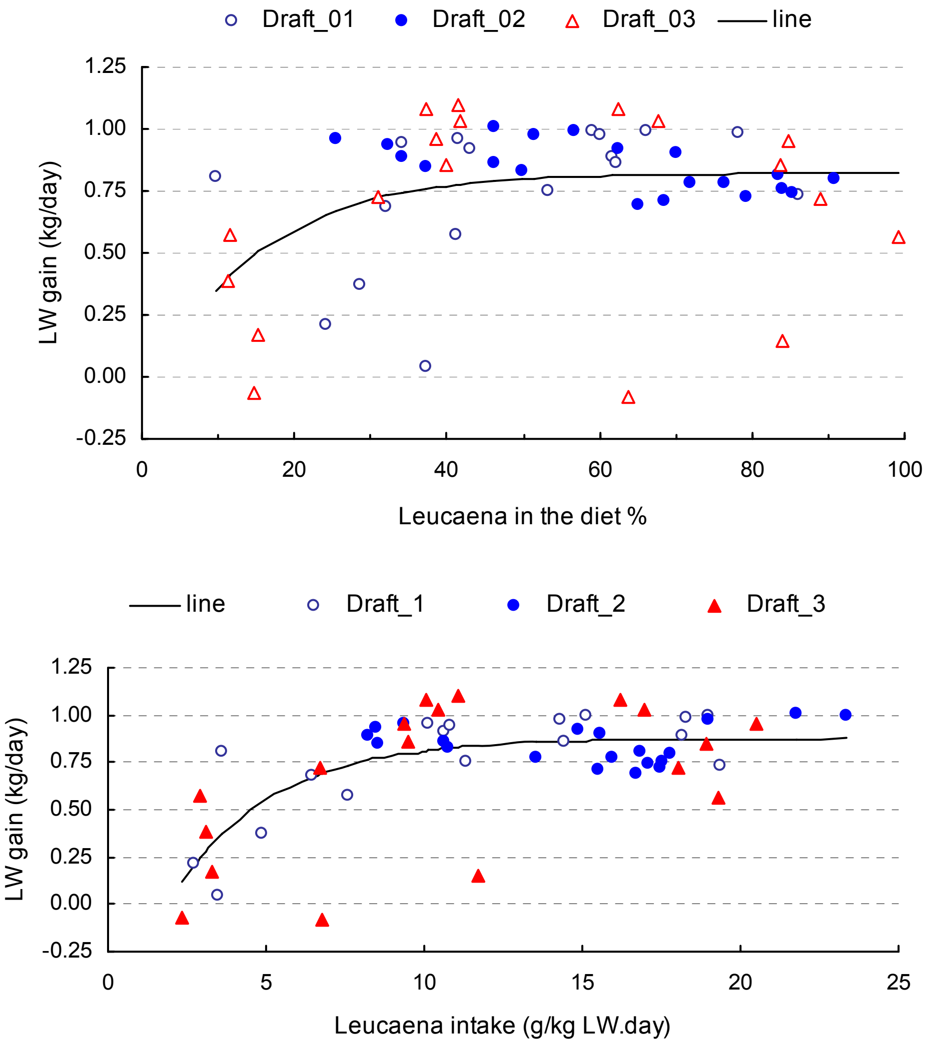


Figure 4.3.4 a and b. *The percent Leucaena in the diet (X1) and the measured LW change (Y)* ***(a),*** *or the amount of Leucaena ingested (g/kg LW.day) (X2) and measured LW change (Y)* ***(b),*** *for the 3 drafts of steers grazing Leucaena-grass pasture. The equations were as follows:*
(a) $Y = 0.82 - 0.97\ e^{-0.074X}$ *(n 55, R^2 0.12),*
(b) $Y = 0.88 - 1.60\ e^{-0.32X}$ *(n 55, R^2 0.45).*

The intakes of Leucaena, grass and total DM in each of the 3 drafts are shown in Fig 4.3.5a-c. Total DM intake exceeded 30 g DM/kg LW early in Drafts 1 and 2, and declined to less than 15 g DM/kg LW late in Drafts 1 and 3. The latter is consistent with the low measured LW gains during the same intervals. Leucaena DM intake was higher in January - June in Draft 2, and January-April in Draft 3, consistent with the high %Leucaena in the diet during these intervals and the high LW gains of the steers during these intervals.

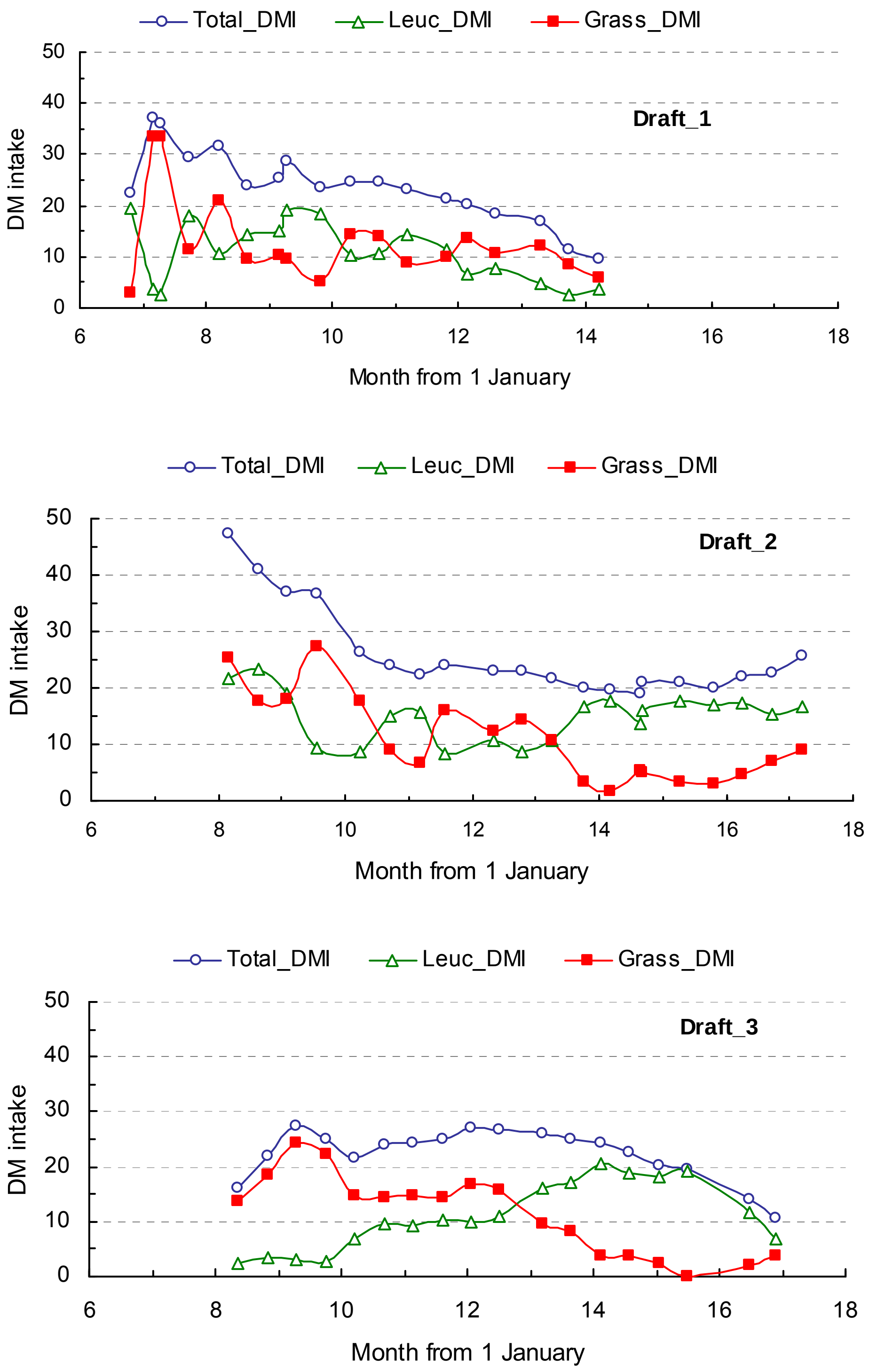


__Figure 4.3.5 a, b and c.__ The intakes of total DM, Leucaena DM and grass DM (g/kg LW.day) for the 3 drafts of steers grazing Leucaena-grass pasture. Total DMI was calculated from the estimated ME intake required for the measured LW change of the steers and the DMD of the diet, while the Leucaena and grass intakes were calculated from the total DMI and the % Leucaena.

4.3.4 Diet CP and DM digestibility

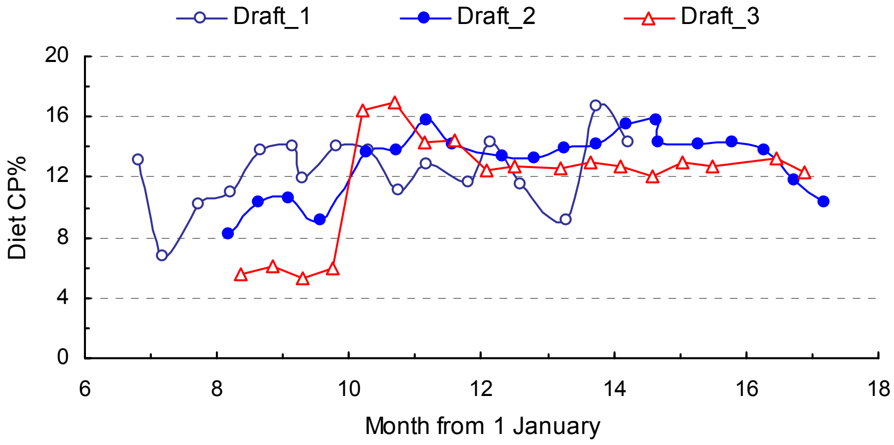


Figure 4.3.6. *F.NIRS measurements of the protein content of the diet selected by the steers in each of 3 drafts grazing Leucaena-grass pasture*

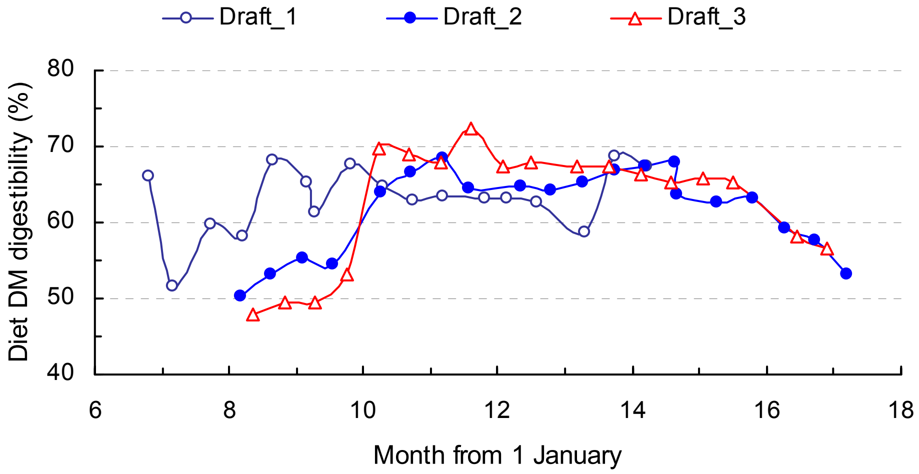


Figure 4.3.7. *F.NIRS measurements of the DM digestibility of the diet selected by the steers in each of 3 drafts grazing Leucaena-grass pasture*

The concentration of crude protein and the digestibility of the diet selected (Figures 4.3.6 and 4.3.7) tended to follow a similar pattern to the diet %Leucaena through the grazing interval for each draft except that during the months November to January the diet CP% and DMD were high (>11% and >63% DMD, respectively) irrespective of the %Leucaena in the diet. This was most likely because the new season growth of grass in these months soon after the break of the season would have been high in CP and DMD, thus allowing a high quality diet. Dietary CP% (Y1) and DMD% (Y2) were asymptotically related to the %Leucaena in the diet (X1) as follows:

$Y1 = 13.2 - 27.1\ e^{-0.115X1}$ (n 55, R^2 0.48),

$Y2 = 63.9 - 48.9\ e^{-0.113X1}$ (n 55, R^2 0.33).

In addition, the dietary CP% was asymptotically related to the Leucaena intake (g DM/kg LW.day) (X2), as follows:

$Y1 = 13.0 - 20.5\ e^{-0.528X2}$ (n 55, R^2 0.24),

Dietary DMD% was not related to the Leucaena intake. Except for about 6 weeks early in Draft 3 the DMD/CP ratio was >8 indicating, as expected for a high-legume pasture, that N for rumen digestion was seldom limiting. The CP content (X) and the DM digestibility (Y) of the diet were linearly related as follows: $Y = 1.91\ X + 38.6$ (n 56, R^2 0.78).

4.3.5 Prediction of LW change with F.NIRS calibrations

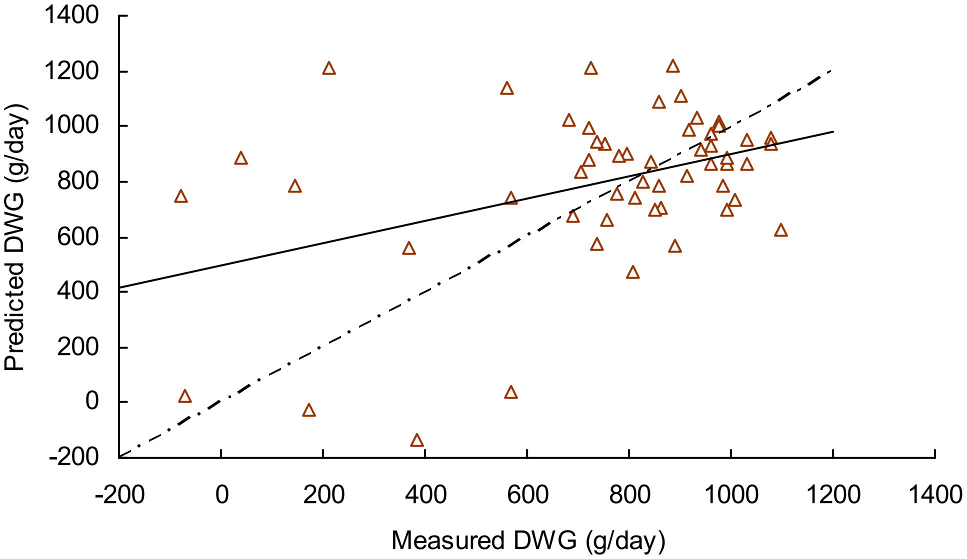


Figure 4.3.8. *Measured daily weight gain (DWG) and DWG predicted using the ADG_leucB F.NIRS calibration for the 3 drafts of steers grazing Leucaena-grass pasture. The linear regression was: Y = 0.40 X + 498 (R^2 0.16, n 52).*

The DWG predicted by each of the F.NIRS calibrations was poorly related to the measured DWG of the steers. This relationship for the DWG predicted from the ADG_LeucB calibration is given in Figure 4.3.8. However, as is evident from this figure, the data for measured DWG is not evenly distributed along the X axis, and there are a number of samples with X values ranging from -100 g/day to 400 g/day which would have had large leverage in the regression relationship and do not represent the steers with moderate to high growth rates while grazing Leucaena. As described above, these low measured DWG (including LW loss) were often associated with low amounts of Leucaena-grass forage on offer in the paddock, creating a situation where forage availability was sufficiently low and to be expected to limit DM intake by the steers. F.NIRS cannot be expected to predict DM intake or animal LW gain is the constraint is availability rather than quality of the forage. The second problem with fitting the relationship was that most of the X values were in a narrow range from about 700-1100 g/day. The much more important criteria to evaluate the error associated with the prediction of DWG was the standard error of prediction (SEP) as is commonly used and applied in mainstream NIRS chemometrics. The SEP from the ADG_LeucA calibration where the Leucaena samples were part of the population used to calculate the calibration equation was 0.33 kg/day. The SEP from the ADG_LeucB calibration where the Leucaena samples were external to the population used to calculate the calibration equation was 0.40 kg/day. These SEP's were about twice those for cattle grazing conventional grass and grass-legume pastures in northern Australia (Coates (2004). With an SEP of 0.4 kg/day it is not possible to measure the LW gain of the cattle from a single faecal sample. The 95% confidence interval is ± 2* SEP.

The measured animal LW, and the cumulative LW predicted with the Coates (2004) ADG1441 and ADGSGBA calibration equations for the 3 drafts of steers are shown in Figure 4.3.9 a, b and c. In addition, the relationships between the measured and predicted LW calculated from the ADG1441 and ADGSGBA calibrations are shown in Figure 4.3.10 a and b. The relationships in the latter figure indicated that the LW gain predicted by the ADG1441 and ADGSGBA calibration equations were, on average, 1.7 and 1.2 times the actual LW gain of the steers. Thus both of these F.NIRS calibrations severely over-estimated LW gain of the steers. However, when the results from steers grazing Leucaena-grass pastures in the present study were included with the

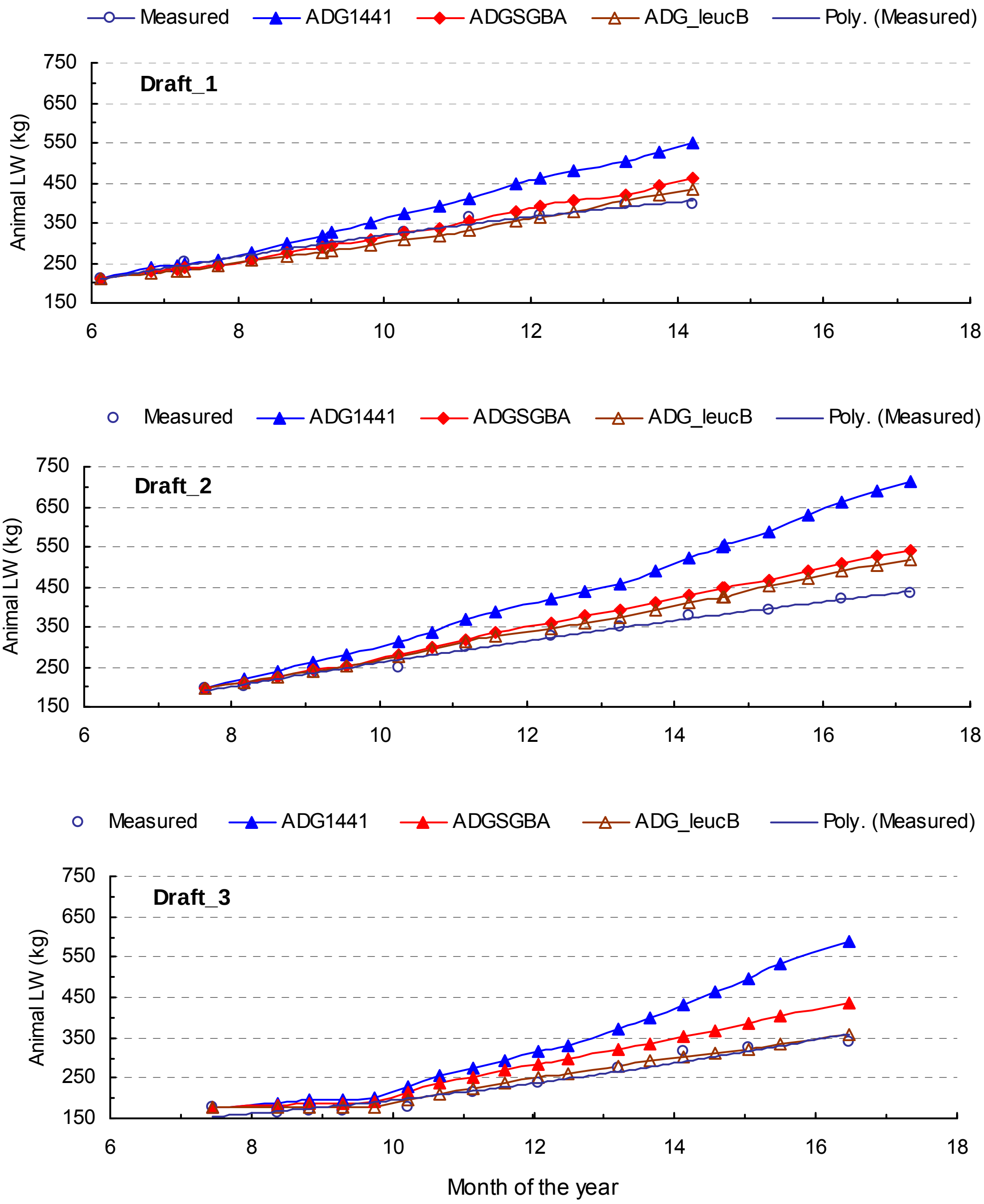


Figure 4.3.9 a, b and c. *Measured LW and the cumulative LW predicted using the ADG1441, ADGSGBA and ADG_leucA F.NIRS calibrations for the 3 drafts of steers grazing Leucaena-grass pasture.*

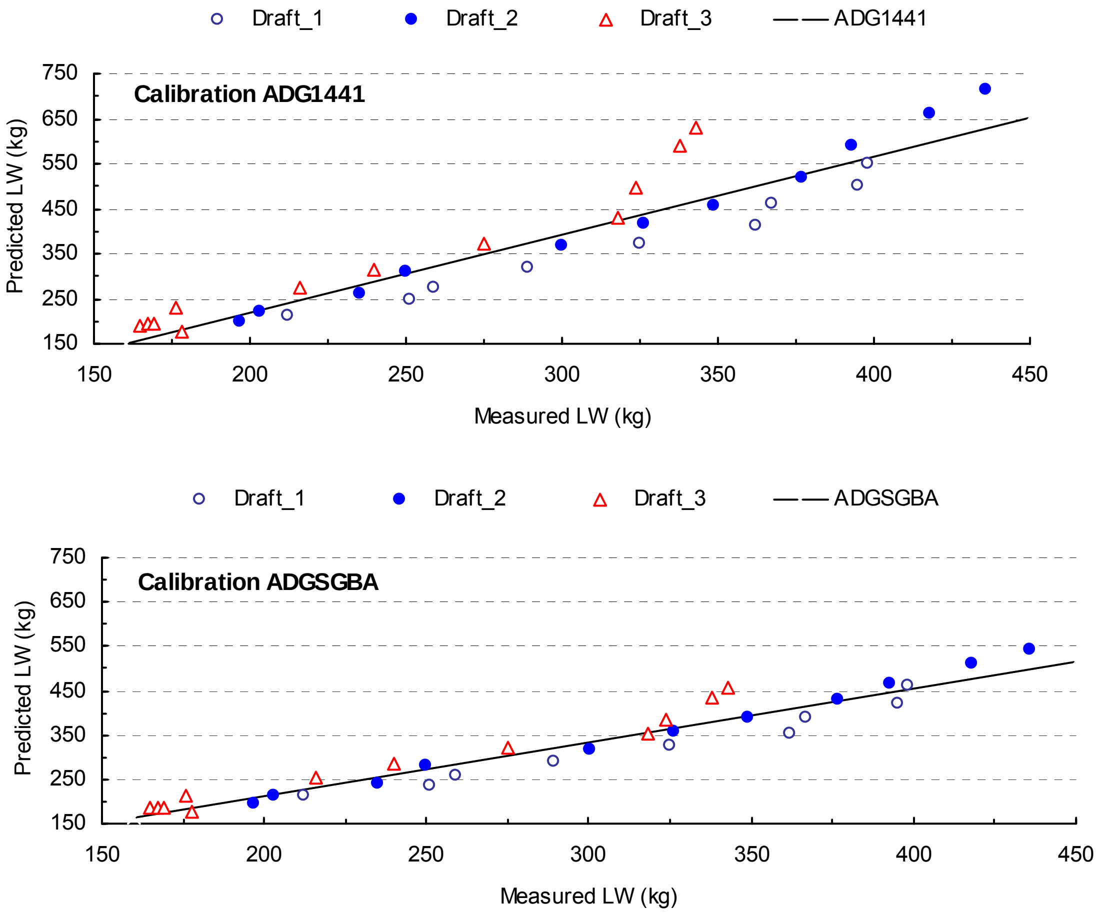
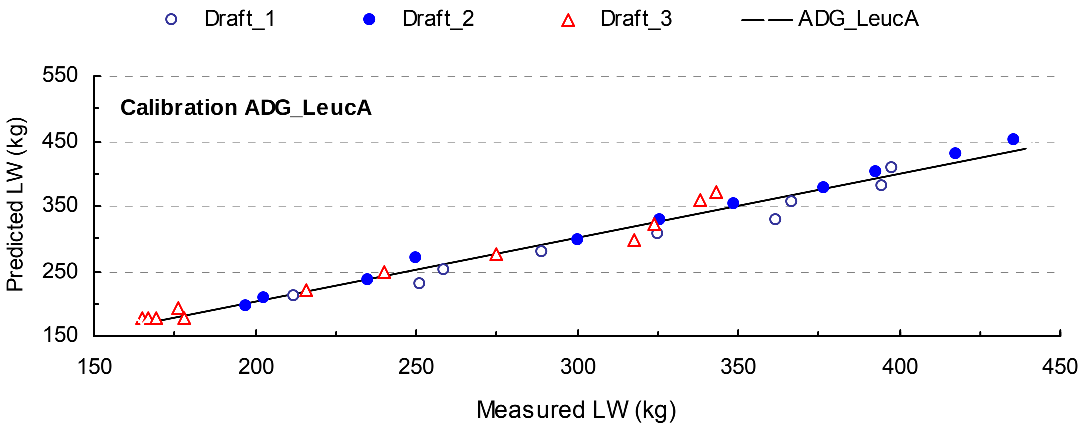


Figure 4.3.9 a and b. *Measured LW and the cumulative LW predicted using the ADG1441 and ADGSGBA F.NIRS calibrations for the 3 drafts of steers grazing Leucaena-grass pasture. The respective equations were as follows:* $Y = 1.73\,X - 125$ *(n 32,* R^2 *0.90),* $Y = 1.22\,X - 32$ *(n 32,* R^2 *0.94).*



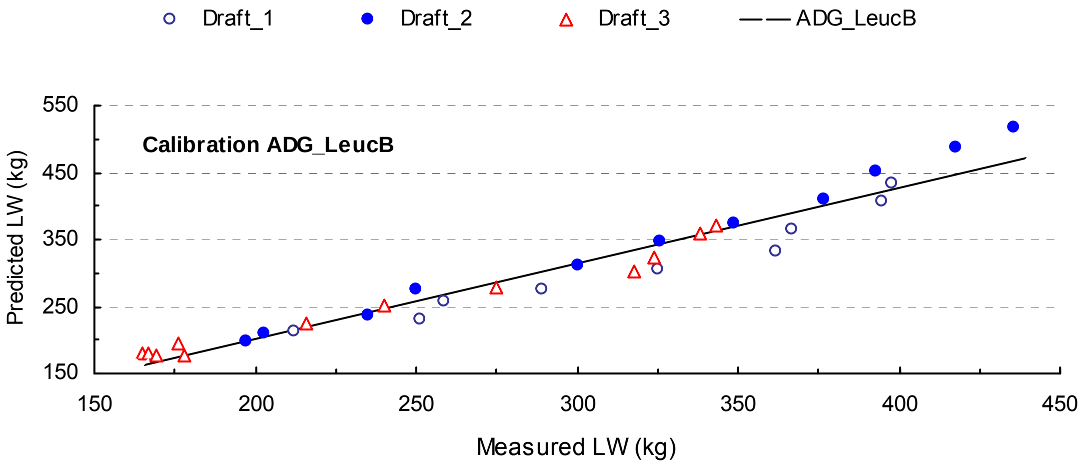


Figure 4.3.10 a and b. *Measured LW and the cumulative LW predicted using the ADG_LeucA and ADG_LeucB F.NIRS calibrations for the 3 drafts of steers grazing Leucaena-grass pasture. The respective equations were as follows:* $Y = 0.98 X + 7$ *(n 32,* R^2 *0.97),* $Y = 1.13 X - 26$ *(n 32,* R^2 *0.95).*

Coates (2004) data set to calculate the revised ADG_LeucA calibration, and the LW change predictions were then being made within a sample population, it was clear (Figs 4.3.11 a, b) that LW change could be predicted with excellent accuracy. The prediction of LW change from the composite calibrations presented as ADG_LeucB considers the samples for prediction as a separate population to that used to calculate the calibration equation, and therefore provides a more conservative indication of the reliability of the LW gain prediction for these Leucaena pastures from F.NIRS. There appears to be an over-estimation of actual LW gain by about 1.1 which was equivalent to about 10-20 kg after 8 months (i.e. <100 g/day over-estimation). We consider that the ADG_LeucB calibration is not likely to be suitable for general use to predict LW gain of cattle grazing Leucaena-grass pastures since it is likely to be specific for the Brian Pastures site where the measurements were made. Nevertheless, it demonstrated that even a small number of samples from LW gain with Leucaena-grass pastures substantially improved the F.NIRS calibrations, and provides strong evidence that F.NIRS can be used to predict LW gain of cattle grazing Leucaena. The large errors associated with the use of the ADG1441 and ASDGSGBA calibrations were likely primarily associated with the lack of representation of Leucaena diets in the Coates (2004) calibrations, rather than any fundamental limitation of the application of F.NIRS to measure LW change of cattle grazing Leucaena-grass pastures.

4.3.6 General Discussion. Application of F.NIRS calibrations to Leucaena-grass pastures

The present studies were intended to examine whether F.NIRS technology, and specifically the Coates (2004) or revised calibrations, could be used to measure the quality of the diet and LW gain of cattle grazing Leucaena-grass pastures. This was done firstly by examination of whether faecal spectra from cattle grazing Leucaena-grass pastures were acceptably similar to the faecal spectral populations measured in cattle grazing conventional grass-based tropical pastures, secondly through comparison of the measured LW change and that predicted by F.NIRS in the steers, and thirdly whether the F.NIRS measurements of diet quality and intake were consistent with previous information.

It was clear from the first and second criteria above that the F.NIRS calibrations for LW change developed by Coates (2004) did not provide acceptable measurements of LW gain. Given the botanical dissimilarity of Leucaena-grass pastures and conventional tropical pastures, and experience with application of NIRS technology to forages and foods (e.g. hays, grains and fruit) (Shenk and Westerhaus 1993), this was not unexpected. However, the inclusion into the Coates (2004) data set of a relatively small number of faecal spectra from the present study was successful to develop a modified calibration which predicted LW gain satisfactorily for Leucaena-grass pasture, at least at the Brian Pastures site during the years of the present study. It is of interest that the revised calibrations for LW gain provided reasonable predictions of the actual LW through each draft even though the amounts of Leucaena and grass forage on offer were, during some intervals, low and likely limited voluntary DM intake. Since the present study was limited to a single site, the calibrations which were developed (adg_LeucA and adg_LeucB) were probably not sufficiently robust to predict reliably across the variety of Leucaena-grass pastures which occur in northern Australia. However, the present study demonstrated that even a small number of faecal samples with LW gain measurements substantially improved the F.NIRS calibrations, and provides strong evidence that it is possible to develop F.NIRS calibrations for LW gain of cattle grazing the wide variety of pastures which occur in rangeland systems. It should be possible to develop robust and reliable calibrations for Leucaena pastures in northern Australia if measurements similar to those in the present study are obtained in herds representing the variety of such pasture systems.

The Coates (2004) F.NIRS calibrations to measure faecal N concentrations were satisfactory for these Leucaena-grass pastures. Those to measure δC (to calculate the %Leucaena of the diet) were initially not satisfactory, but improved with inclusion of the additional data available from cattle grazing Leucaena-grass pastures into the Coates (2004) calibrations. Further data would be highly desirable to increase the robustness and reliability of these calibrations. F.NIRS calibrations for diet CP% and diet DMD% were not entirely satisfactory since during prediction of unknown samples from spectra the GH values were unacceptably high in a majority of samples. Additional experiments to generate diet-faecal pairs for Leucaena-grass diets are needed to improve these calibrations. The greatest need would seem to be for Leucaena-grass diets where the Leucaena is providing a N source to balance other low N forages in the diet such as senesced pasture or maize silage, and where it is important to measure diet CP% and DMD/CP ratio accurately and reliably. Although desirable, more accurate F.NIRS calibrations for diet CP% in cattle ingesting diets with high proportions of Leucaena forage will usually be less important. When Leucaena constitutes a large proportion of the diet the dietary CP is usually high, and animal responses to additional rumen degradable protein (RDP) are unlikely. In the present study the DMD/CP ratio of the diet exceeded 8 for only about 6 weeks during September - October 2004 during Draft 3. Since RDP is likely to be limiting only when the DMD/CP ratio exceeds 8-10 (Dixon and Coates 2005), the present study supports the hypothesis that Leucaena-grass pastures are rarely deficient in RDP, as indeed is to be expected for any pasture containing a high proportion of legume. Reliable measurement of the undegraded dietary protein (UDP) intake in high Leucaena diets will be important, but there will also be substantial errors from other sources involved in predicting UDP supply and whether animal responses could be expected to additional absorbed amino acids supply. These other sources of error would also need to be addressed. Similar arguments would apply in relation to development of improved F.NIRS calibrations to predict diet DM digestibility.

4.3.7 General Discussion. Diet selected and LW gain of the steers

Leucaena made a substantial contribution to the diet selected by the steers in the present study, and was usually >30% of the diet. This was expected given that Leucaena is generally considered a highly palatable forage, and only limited grass was usually available between the narrow 3 m Leucaena rows in the pasture used. It is also consistent with the observations that in steers grazing irrigated Leucaena pastures in the Ord the Leucaena forage usually comprised 40-60% of the diet selected (Petty 1997). In the present study diet CP and DMD were generally high (overall means 12.3% and 63%, respectively) compared to diets usually selected by cattle grazing tropical grass pastures, and this was presumably due to the high CP% and DMD% of Leucaena leaf and because N concentration of grasses in established Leucaena-grass systems is expected to be increased by the legume.

Although in the present study diet CP and DMD increased as the %Leucaena in the diet increased up to about 20-30% of the diet, and LW gain increased up to about 8 g DM intake/kg LW.day as Leucaena DM intake increased, the % Leucaena in the diet was poorly related to LW gain. Furthermore high growth rates of the steers (> 0.7 kg/day) occurred as Leucaena ranged from 10-91% of the diet. This contrasts with the report of Petty (1997) of a relationship between Leucaena intake and LW gain, and of Galgal (2002) that steer LW gain increased by about 200g/g Leucaena DM intake.kg LW.day in the range 2-10 g Leucaena DM/kg steer LW.day. In general, selection of Leucaena forage and the %Leucaena in the diet is obviously a function of the quality and the availability of both the grass and Leucaena components of the forage on offer. In the present study the degree of selection of Leucaena was presumably strongly influenced by the availability and palatability of the inter-row grass, and there would have been much more grass of higher quality available during the summer months as a consequence of the rain and summer temperatures. The absence of the general relationship in the present study is likely simply a consequence of the much greater range in quality and quantity of amounts and proportions of Leucaena and grass forage on offer through the interval when measurements were made than in the previous studies. In the experiments of Petty (1997) and Galgal (2002) the relationships between % Leucaena and diet CP were made in a single pasture over a few weeks and as the amounts of forage available were changing rapidly with heavy grazing pressure. In the experiment of Quirk *et al.* (1990) where % Leucaena was associated with LW gain, measurements were made under widely different availabilities of Leucaena in circumstances where there was excess grass pasture available. Regardless of the reasons for the differences between experiments, we conclude from the present study that caution should be applied in any general recommendation for producers, as suggested by Dalzell *et al.* (2006), that cattle should be ingesting 30% of their diet as Leucaena to achieve high growth rate of >1kg/day. The situation is far more complex. If high quality grass pasture is available during the wet season then high LW gains are likely to be achieved with low %Leucaena in the diet, whereas if only low amounts of total forage are available then animal LW gains are likely to be poor even if the diet selected contains a high proportion of Leucaena.

In conclusion, the present study demonstrated the utility of F.NIRS to measure the amount and quality of the diet selected by cattle grazing Leucaena-grass pastures, including the contribution of Leucaena forage at various times of the year. Such information is essential to develop optimal grazing management strategies. Advantages of F.NIRS include the simplicity, low labour and low cost of analysis compared to established alternative techniques to understand the nutrition of grazing ruminants, and its suitability for commercial property situations.

Summary. Three drafts of *Bos indicus* cross steers (initially 178-216 kg) grazed Leucaena-grass pasture (cv Cunningham in 3 m rows with green panic) from late winter through to autumn during 2002-05 at Brian Pastures, Gayndah. LW gain of the steers was generally 0.7-1.1 kg/day during the summer months. The %Leucaena in the diet varied widely (7-99%) and was asymptotically related to diet CP% and DM digestibility. LW gain was asymptotically related to the intake of Leucaena. F.NIRS calibrations satisfactorily measured %Leucaena in the diet. Calibrations developed with tropical grass pastures overestimated LW gain, but a revised calibration which included reference values from these steers grazing Leucaena predicted LW gain correctly. This indicated that general F.NIRS calibrations for LW gain of cattle grazing Leucaena can be developed.

4.4 Brian Pastures, Gayndah, monitor herd grazing southern speargrass pasture

The rainfall during the trial is given in Table 4.3.1 above. The amounts and distributions were generally as expected from the long-term average for the site.

The F.NIRS measurements of diet quality did not differ between the three maturity groups of steers (Table 4.4.1). This was consistent with the absence of any differences in F.NIRS predictions of diet quality with age of steers at the Toorak site (see Section 4.1 above), or with reproductive status (see Section 4.10 and Appendix 3). These observations support the hypothesis that the faecal NIRS calibration equations to measure diet quality can be used for animals of a range of ages and maturities with introduction of little error into the prediction.

Table 4.4.1. Effect of maturity of the steers on the F.NIRS measurements of diet quality and animal LW gain

Measurement	Age of steers			s.e.d.	Prob.
	Yearling	Steer	Bullock		
Diet crude protein %	6.7	6.8	6.9	0.47	n.s.
DM digestibility %	52.8	52.7	52.5	0.84	n.s.
Non-grass in diet %	6.1	6.9	8.2	3.07	n.s.
Faecal N concentration %	1.19	1.19	1.14	0.061	n.s.
LW gain (g/day)					
adg1441 calibration	513	572	591	91	n.s.
adgsgba calibration	575	575	553	88	n.s.

The yearlings, steers and bullocks were approximately 1 YO, 2 YO and 3 YO at the start of the draft.
s.e.d., standard error of the difference; Prob, probability.

F.NIRS measurements of the proportion of non-grass in the diet (Figure 4.4.1) fluctuated widely between samplings, but was generally in the range about 5-15% and rarely exceeded 20% of the diet. Diet non-grass averaged 11 (s.d. 5.9)% during the summer months (November-March), and 9 (s.d. 4.7)% during the winter months (April - October). Since no browse was available in the paddock, all of the non-grass component of the diet must have been derived from the forbs and native legumes in the pasture. The low proportion of non-grass in the diet was consistent with the observation that there was little native forb or invasive legume species in the pasture. The crude protein content of the diet averaged 8.4 (s.d. 2.1)% in the summer and 5.8 (s.d. 1.2)% during the winter months (Figure 4.4.2). DM digestibility averaged 56 (s.d 3.3)% in the summer months, and 51 (s.d. 2.6)% in the winter months (Figure 4.4.3). The DMD/CP ratio was generally in the range 8-11(average 9.1 s.d. 1.5) during the mid to late dry season, and average 7.1 (s.d. 1.3) during the summer and the early dry season. The higher diet CP and DMD, and lower DMD/CP, during November to March is consistent with most rainfall occurring during these summer months (Table 4.3.1), and the expectation that due to temperature constraints there would be limited plant growth from any winter rainfall. As discussed elsewhere (Appendix 1) cattle grazing northern speargrass pastures appear likely to respond to urea supplements when the DMD/CP ratio is greater than 8, although such responses do not seem certain until the DMD/CP ratio is greater than 10. These results suggest that in the southern speargrass pasture system such as at the present site there are likely to be some animal response to urea supplements during the mid to late dry season in many years, although the values for the DMD/CP ratios also suggests that, compared to the northern speargrass, only small amounts of urea supplement will required and the animal response will be less than in pasture systems such as the northern speargrass.

Faecal N% (Y) was positively related to diet CP% (X_1), and negatively to diet DMD/CP (X_2) as follows:
$Y = -0.0049\ X_1^2 + 0.19\ X_1 + 0.12$ (n 82, R^2 0.87), and
$Y = 0.014\ X_2^2 - 0.36\ X_2 + 3.13$ (n 82, R^2 0.83).
The measured LW change was positively related to diet CP%, and negatively related to diet DMD/CP, but the relationships were poor (n 34 and R^2 0.26 for each).

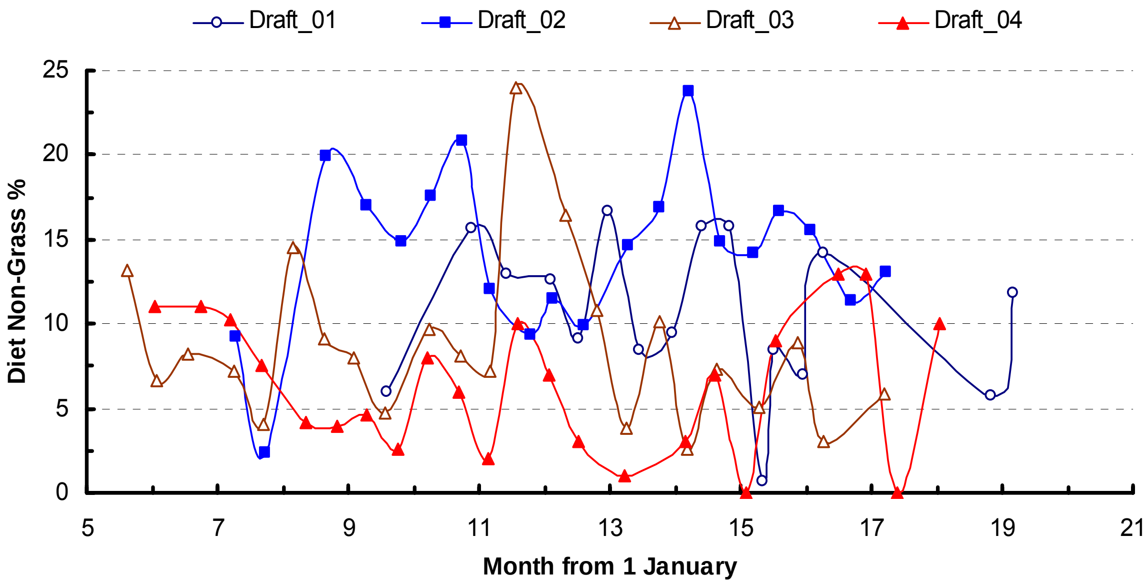


Figure 4.4.1. *F.NIRS measurements of the percent non-grass (i.e. native forbs) in the diet selected by each of 4 drafts of steers grazing native pasture*

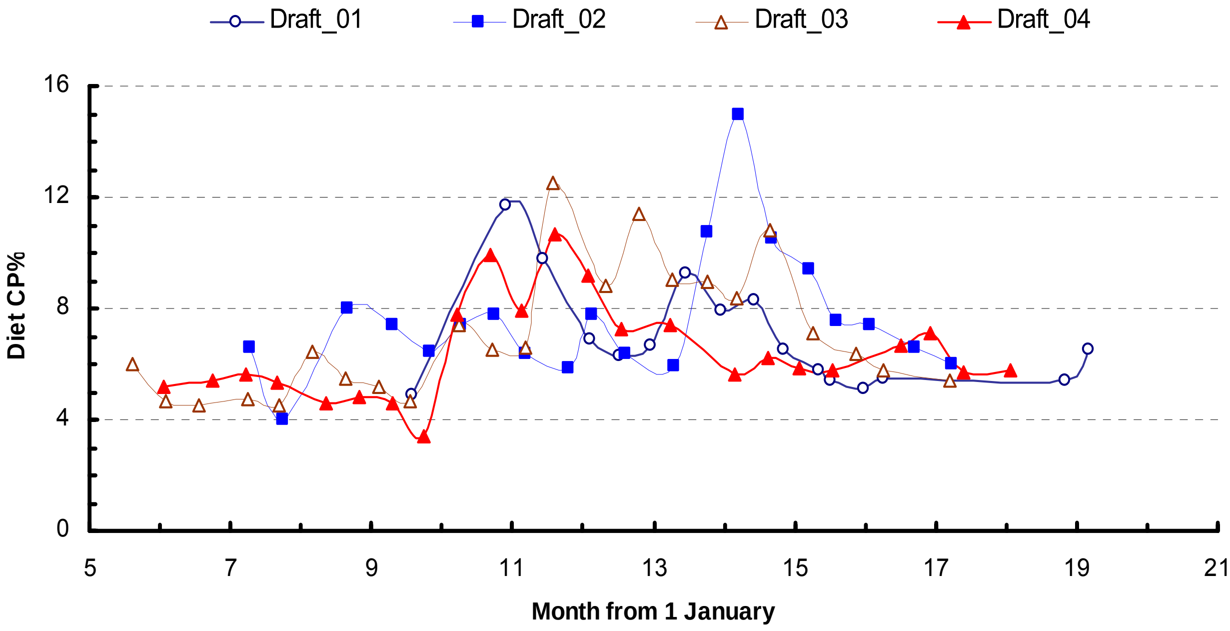


Figure 4.4.2. *F.NIRS measurements of the crude protein content of the diet selected by each of 4 drafts of steers grazing native pasture.*

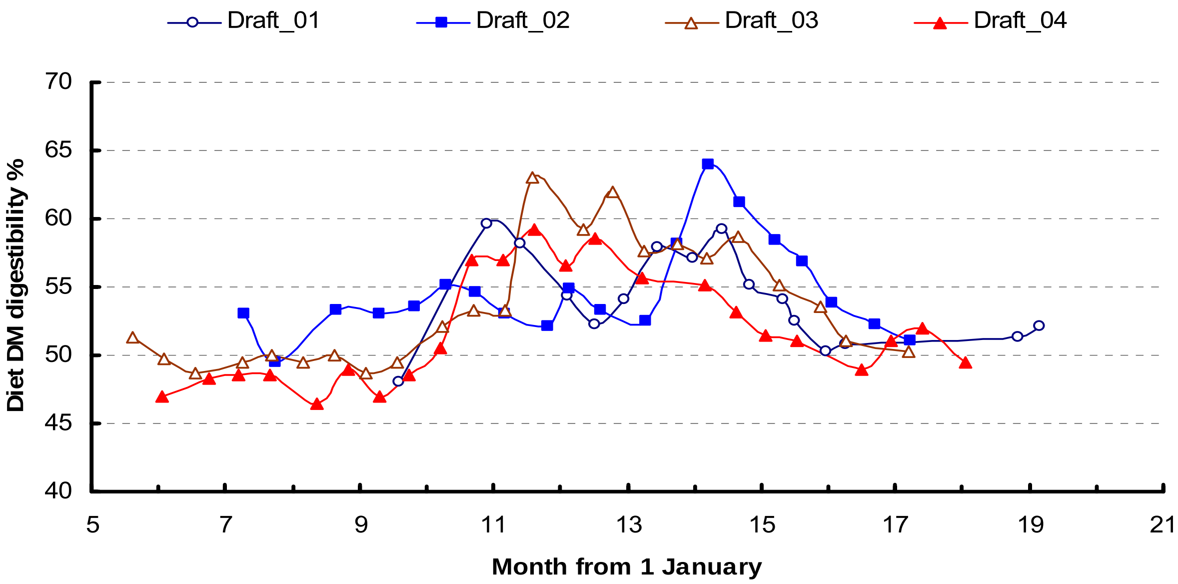


Figure 4.4.3. *F.NIRS measurements of the DM digestibility (DMD) of the diet selected by the steers in each of 3 drafts grazing native pasture*

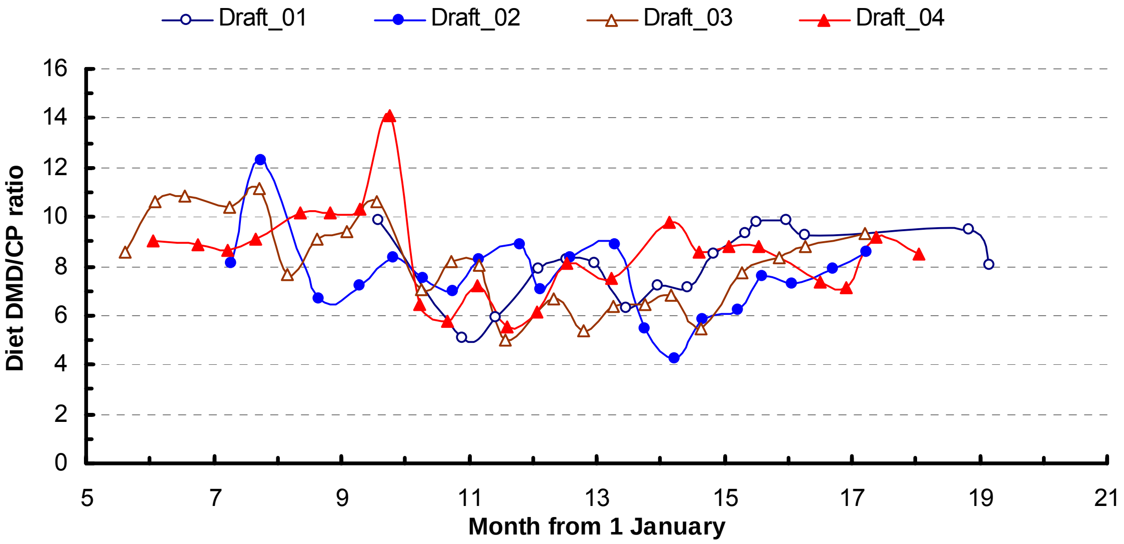


Figure 4.4.4. *F.NIRS measurements of the DMD/CP ratio of the diet selected by the steers in each of 3 drafts grazing native pasture*

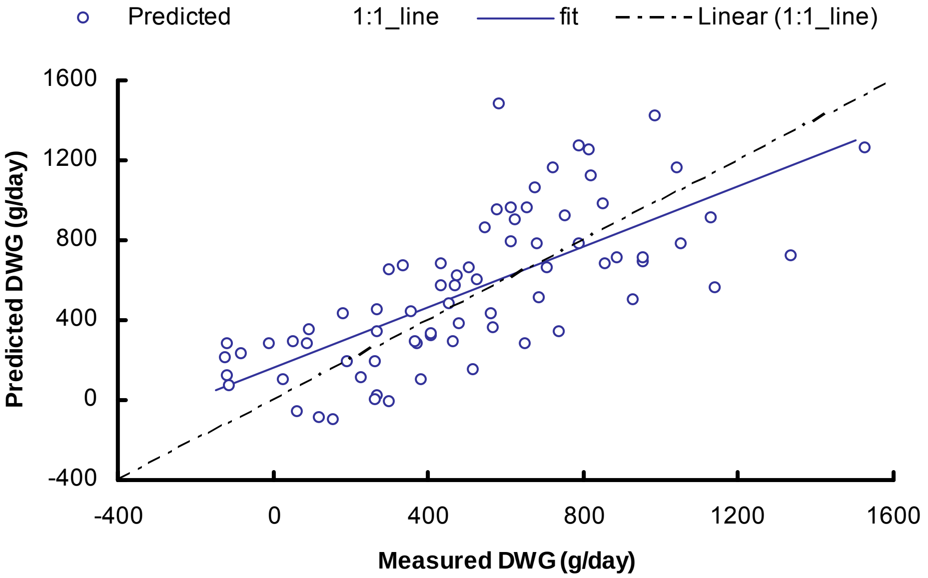


Figure 4.4.5. *Measured daily weight gain (DWG) and DWG predicted with the ADG_MtB6 calibration equation for the yearling maturity group of steers of Drafts 1 to 4. The regression relationship was as follows:* $Y = 0.76 X + 160$ *(*R^2 *0.50, n 80).*

The calibration statistics for the ADG_MtB9 equation (n 1247, R^2 0.81, SECV 209 g/day; RPD 2.2) were similar to those for the adg1441 equation. Calibration statistics for the 4 equations which were combined as the adg_MtB6 equation were almost identical, but because the samples in the draft being predicted were not included within the calibration (but as a validation set) the latter calibration equation provides a more conservative estimate of the error associated with the prediction of LW change. The SEP of samples from the combined adg_MtB6 was 283 g/day, and thus was comparable with the SEP with the general Coates (2004) calibrations for LW gain. The relationship between the measured DWG and the DWG predicted from the adg_MtB6 calibration is shown in Figure 4.4.5. The measured LW of the yearling subgroup of steers and the cumulative LW predicted with the ADG1441, ADGSGBA and ADG_MtB6 calibration equations are shown in Figure 4.4.6. At the site of the present monitor herd the ADG1441 and ADGSGBA calibrations overestimated LW gain 3 of the 4 drafts (Drafts 1, 2 and 4). The ADG_MtB6 calibration provided excellent estimates of the cumulative LW in drafts 1 and 2, underestimated in draft 3 and overestimated in draft 4. Since the ADG_MtB6 calibration included information for the specific site, although not in the specific year, it was to be expected that this calibration would provide improved estimated of the LW change variable.

The regression between the measured and predicted LW for all 4 drafts of the steers is shown in Figure 4.4.7 and 4.4.8; the R^2 indicated a close association but as shown in the plots of the individual drafts, on average the ADG1441 calibration overestimated the LW gain of the animals by about 10% or about 30 kg after 12 months in a 400 kg animal, but the ADG_MtB6 calibration provided an excellent estimate.

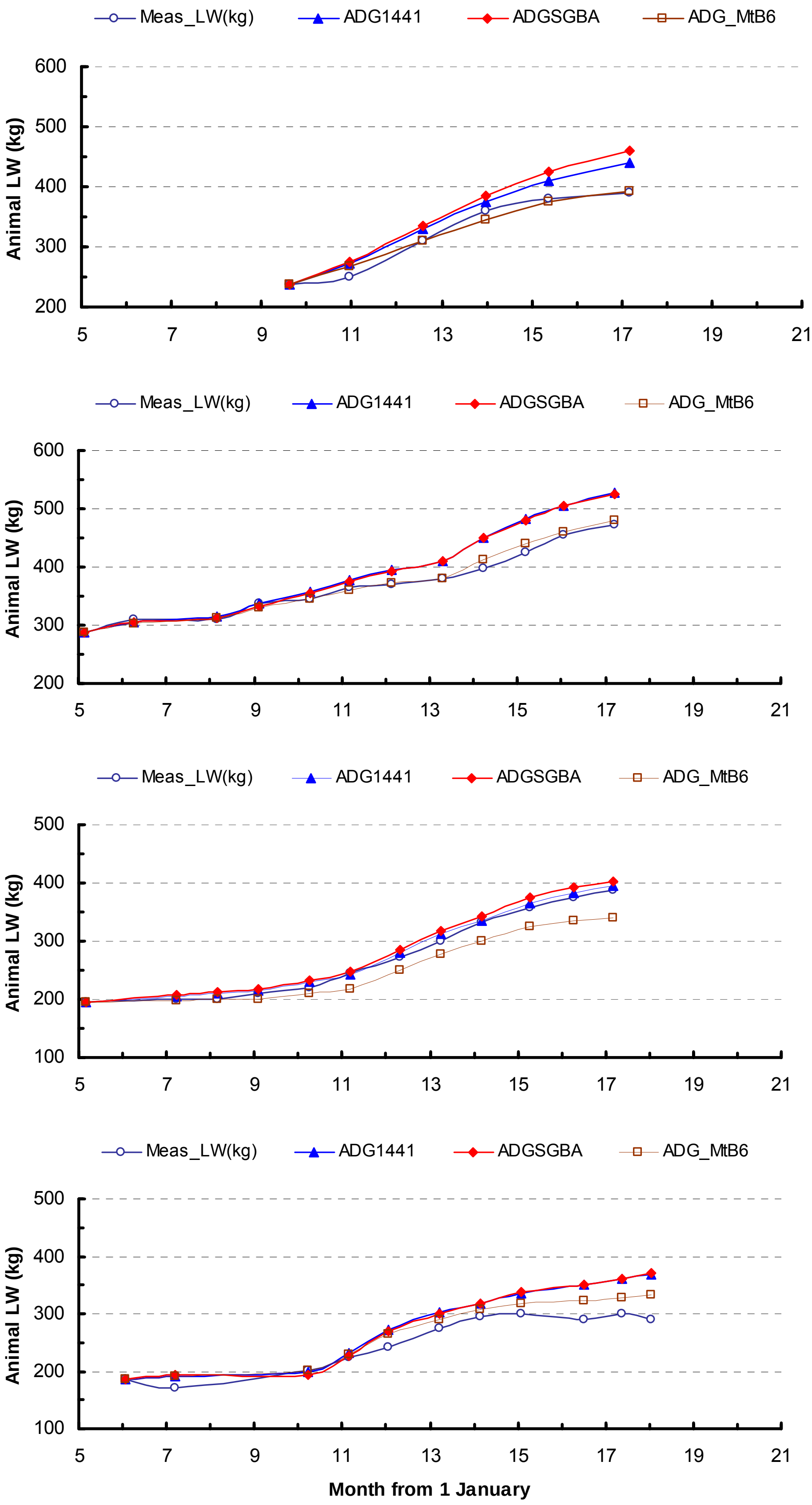


Figure 4.4.6. *Measured LW and cumulative predicted LW with the ADG1441, ADGSGBA and ADG_MtB6 calibration equations for the yearling maturity group of steers of Drafts 1 to 4, respectively.*

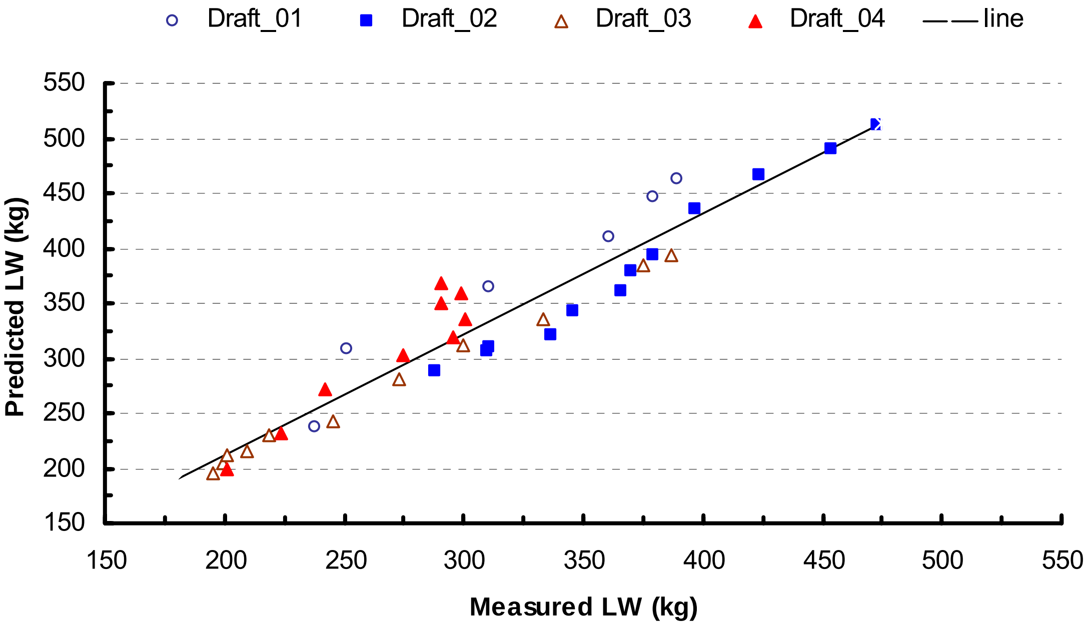


Figure 4.4.7. Relationship between the measured liveweight of the yearling maturity group of steers and the cumulative predicted liveweight using the ADG1441 calibration equation for Drafts 1 to 4, respectively. The relationship was as follows: Y = 1.10 X - 8.5 (n 39, R^2 0.93).

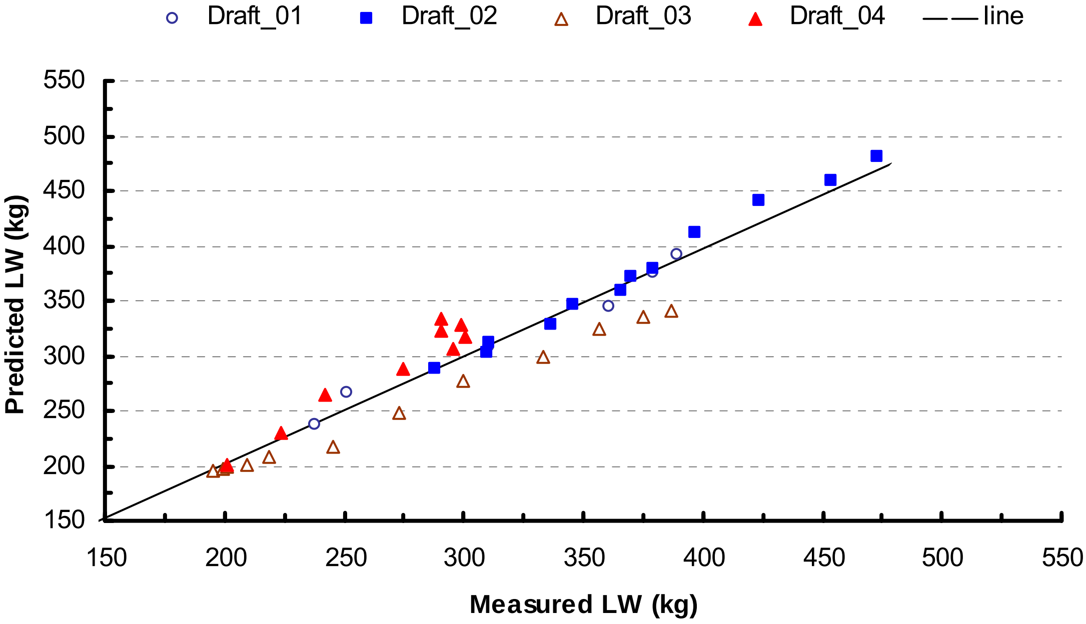


Figure 4.4.8. Relationship between the measured liveweight of the yearling maturity group of steers and the cumulative predicted liveweight using the ADGMtB6 calibration equation for Drafts 1 to 4, respectively. The relationship was as follows: Y = 0.98 X + 5.7 (n 39, R^2 0.94).

The annual LW gain, from July to June, of the 3 maturity groups of steers are shown in Table 4.4.2. Annual LW gain was markedly influenced by maturity, with the LW gain of initially 2 YO steers and 3 YO bullocks being only 84% and 69%, respectively, of that of the initially 1 YO yearling steers. Such a decrease in annual LW gain with increasing maturity is to be expected from well-known principles of growth and maturity as outlined by, for example, SCA (1990).

Table 4.4.2. *Annual liveweight gain (kg) from June to June of the 3 age groups of steers in the Mt Bambling herd measured by monthly weighing or predicted from the initial LW and the F.NIRS predictions of LW change using the ADG1441 calibration equation through the year*

Draft	Measured annual LW gain			Predicted LW gain
	Yearling	Steer	Bullock	
1	161[a]	84[a]	88[a]	-[a]
2	185	164	148	224
3	192	153	112	199
4	-[b]	96	42	184
Mean of Drafts 2 & 3	189 (1.00)	159 (0.84)	130 (0.69)	

[a] since the F.NIRS measurements were not commenced until October a cumulative predicted LW gain for the 12 months could not be calculated.

[b] the yearling steers were removed from the paddock from August until October due to health problems.

F.NIRS predictions of LW gain were calculated using the ADG1441, ADGSGBA and then the ADG_MtB6 calibration equations as described above. Since all of these calibration equations for LW change were based on reference data sets of measurements in young growing animals, from the principles on which NIRS calibration equations are calculated it is to be expected that the calibrations would predict the LW change of the yearling animals rather than the LW change of more mature steers. The ADG1441 calibration overestimated the annual LW gain of yearling steers by 10% or about 20 kg per annum, and because of the lower LW gain of the more mature steers would have overestimated the annual LW gain of the steers by 50 kg and the bullocks by 80 kg. These results support the hypothesis that the current F.NIRS calibrations for LW change should only be applied to young growing animals, and adjustments would need to be made for the known lower LW gain of more mature animals.

Summary. Three maturity groups of *Bos indicus* cross steers grazing a native pasture paddock for 4 years at Brian Pastures R. S in the southern speargrass pasture region. Diet non-grass proportion averaged 10 (s.d 5)% and fluctuated widely. Diet CP% and DMD% were generally higher during the summer months and the DMD/CP ratio indicated that rumen degradable N was seldom likely to be limiting. F.NIRS measurements of diet quality and LW gain were not affected by maturity of the steers. Annual LW gain was lower for bullocks than for steers, and lower for steers than for yearlings. F.NIRS predictions of LW gain based on Coates (2004) calibrations over-estimated LW gain of the yearling steers by about 20 kg after 12 mo. However, when calibrations were modified with results from the experimental site, predicted LW was within 4 kg of the measured LW after 12 mo.

4.5 Morungle, Richmond, monitor herd grazing mixed downs – forest country

Rainfall during the 2001/02 wet season totalled 975 mm and was reasonably spread from November to February. There was no rain during the 2002 dry season, and the 2002/03 wet season failed with a total of 25 mm rain. Approximately 4000 kg pasture/ha was available in September 2001 at the start of the trial, and about 3000 kg/ha of dry pasture in May 2002. The amount of pasture available declined progressively and the paddock had to be destocked in February 2003 following the failure of the 2002/03 wet season. For Draft 1 the #0 and #1 steers gained 157 and 160 kg, respectively from September 2001 until June 2002 (i.e. LW gain of 0.6 kg/day) when the #0 steers were removed. For Draft 2 there was little LW gain by the #1 steers from June to December 2002, and a 43 kg LW loss from December to February 2003. The #2 steers gained 38 kg from April to December 2002, but lost 24 kg from December to February 2003.

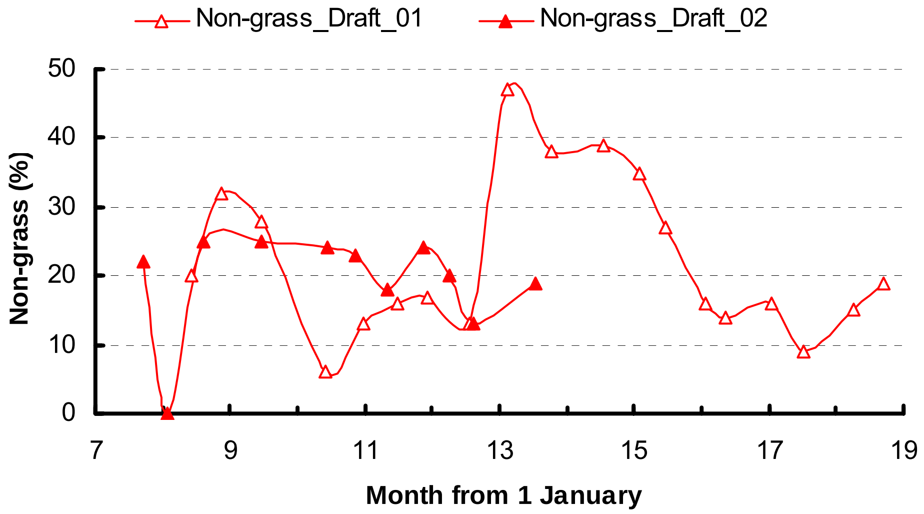


Figure 4.5.1. *F.NIRS measurements of the non-grass content of the diet selected by each of 2 drafts of steers grazing a mix of Mitchell grass downs and open woodland country.*

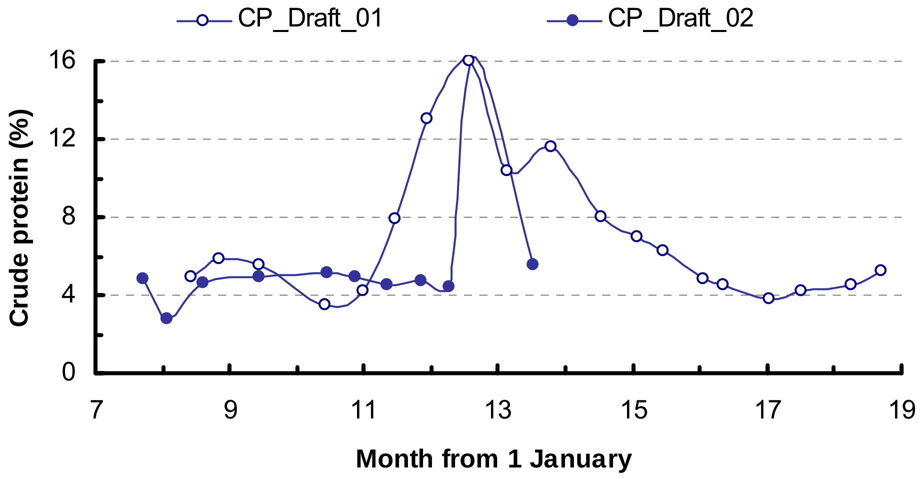


Figure 4.5.2. *F.NIRS measurements of the crude protein content of the diet selected by each of 2 drafts of steers grazing a mix of Mitchell grass downs and open woodland country.*

The proportion of dietary non-grass (Fig 4.5.1) was generally 15-30% during the late 2001 dry season, increased to the range 38-47% during the 2001/02 wet season, and then declined to 10-20% during the 2002 dry season. Diet CP was 4.9-5.8% in September-October 2001 and decreased to 3.5-4.2% during November (Fig 4.5.2). With the onset of the wet season the diet CP increased, to 16.2% in mid-January, before declining progressively to the concentrations observed during the previous dry season (6.2% in April to 4-5% late in the dry season). F.NIRS measured DMD declined from 48-51% in September-October 2001, increased up to 67% during the wet season, and then declined to values similar to the previous dry season. The DMD/CP ratio was generally in the range 8.7-10.4 in Sept until mid-Oct 2001, and increased to >13 in November and until the onset of the 2001/02 wet season (Fig 4.5.3). Following the low values (<8) during the wet season, the DMD/CP increased progressively and was >10 from May 2002 through the 2002 dry season. These results are comparable with those observed at Toorak RS where the non-grass (i.e. forbs) comprised a substantial part of the diet and the diet CP did not decrease to very low concentrations, or the DMD/CP increase to very high values, which are often observed for the northern speargrass pastures. This supports the hypothesis that cattle responses to urea supplements are likely to occur less frequently on the Mitchell grass Downs than in the northern speargrass, and that the availability of forbs in the pasture appears to be the important difference.

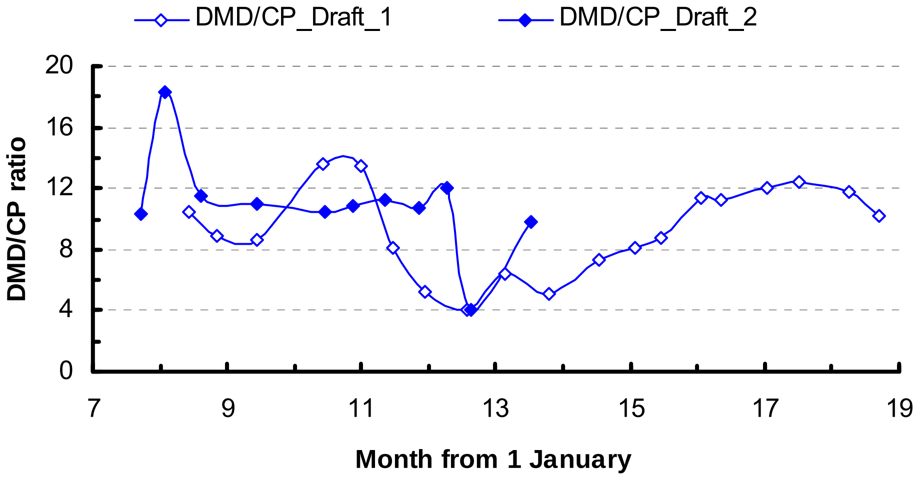


Figure 4.5.3. *F.NIRS measurements of the DMD/CP ratio of the diet selected by each of 2 drafts of steers grazing a mix of Mitchell grass downs and open woodland country.*

The F.NIRS measurements and the animal LW changes were generally in accord with expectations from the rainfall pattern and the quality and quantity of pasture available at various times. Among the various calibration equations to predict accumulative LW change, the adgmitch equation was similar to the actual LW, particularly for Draft 1. The adg1441 equation gave a better prediction than the adgsgba equation. For Draft 1 the deviations of the predicted LW gain from the actual LW gain of 159 kg for these 3 calibration equations were +3, -9 and -29 kg over the 10.3 months interval. The regression relationships between the measured LW, and the cumulative LW predicted using each of the F.NIRS calibrations, is shown in Figure 4.5.6. Both the adgmitch and the general adg1441 calibrations provided good predictions of the LW of the animals.

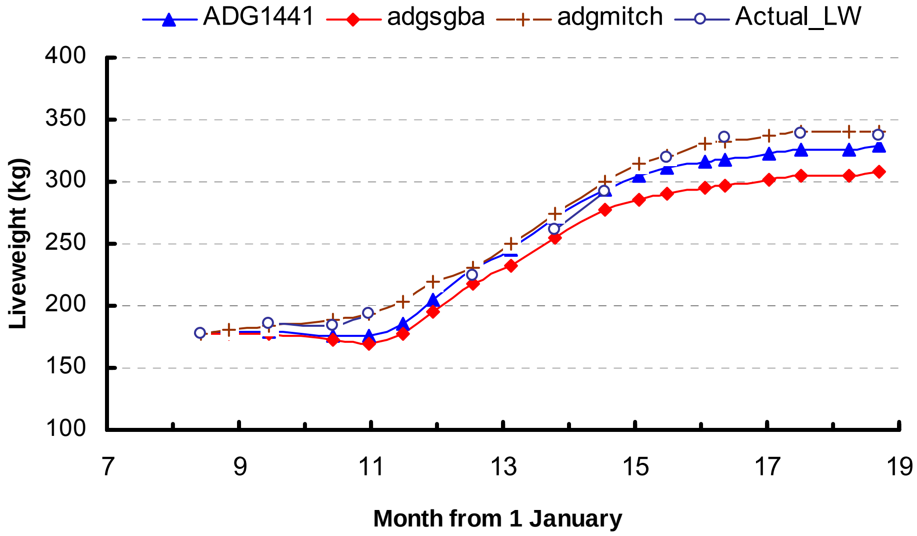


Figure 4.5.4. *Draft _01. Comparison of actual LW of the steers and that predicted from F.NIRS measurements using 3 different calibration equations.*

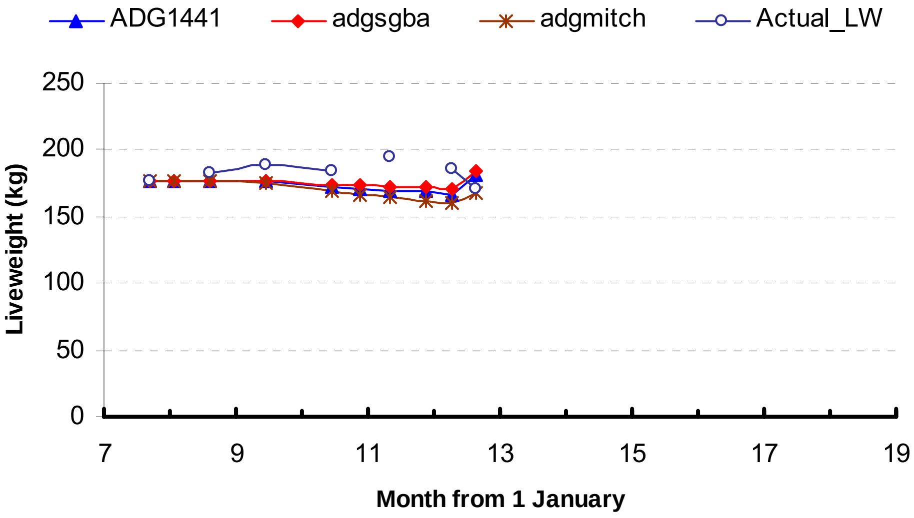


Figure 4.5.5. *Draft _02. Comparison of actual LW of the steers and that predicted from F.NIRS measurements using 3 different calibration equations.*

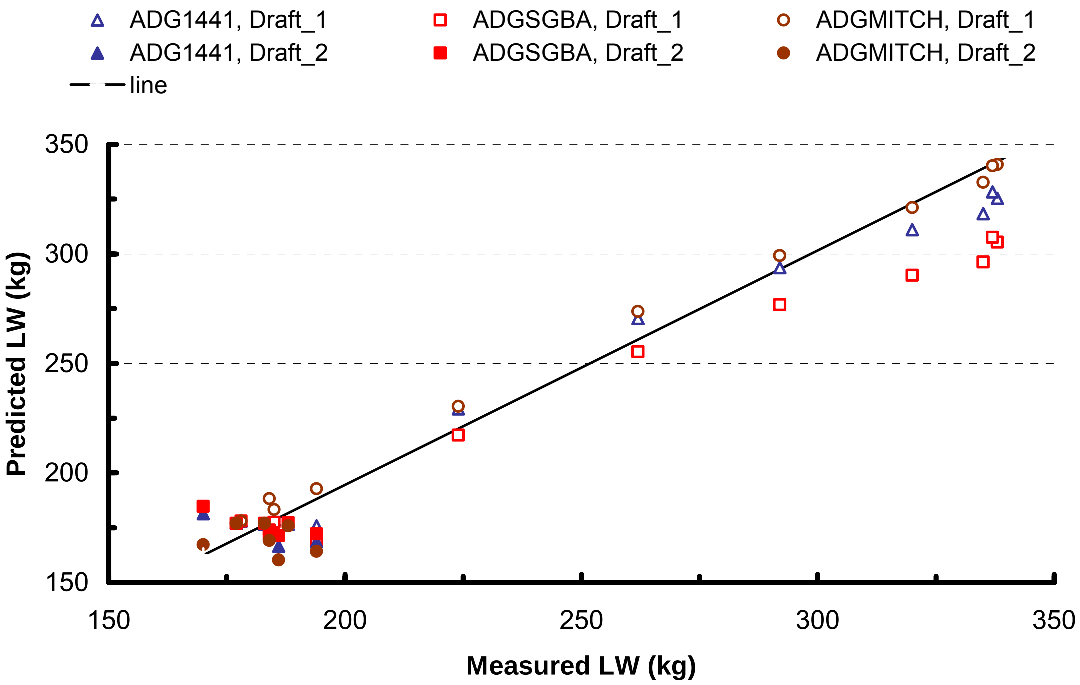


Figure 4.5.6. *The relationship between the measured LW and the cumulative LW predicted with the ADGMITCH calibration. The regression equation was as follows:*
$Y = 1.08 X - 20$ (R^2 0.98, n 18).
The regression relationships (not shown) for the measured LW and the cumulative LW predicted with the ADG1441 and ADGSGBA calibrations, respectively, were as follows:
$Y = 0.99 X - 5$ (R^2 0.98, n 18)
$Y = 0.84 X + 22$ (R^2 0.97, n 18).

It was not possible to continue this trial site with further drafts of cattle.

4.6 Croxdale, Charleville, monitor herd grazing arid grass-browse country

At the commencement of the trial in November 2001 about 1000 kg green pasture DM/ha was available. There was considerable rain from November 2001 until mid-February 2002 (total 365 mm) and the amount of available pasture was about 1000 kg/ha until July 2002 when the cattle were moved to the second paddock. In this second paddock the pasture available was about 1000 kg/ha in July 2002, and in the absence of appreciable rain this declined progressively to about 400 kg/ha by April 2003.

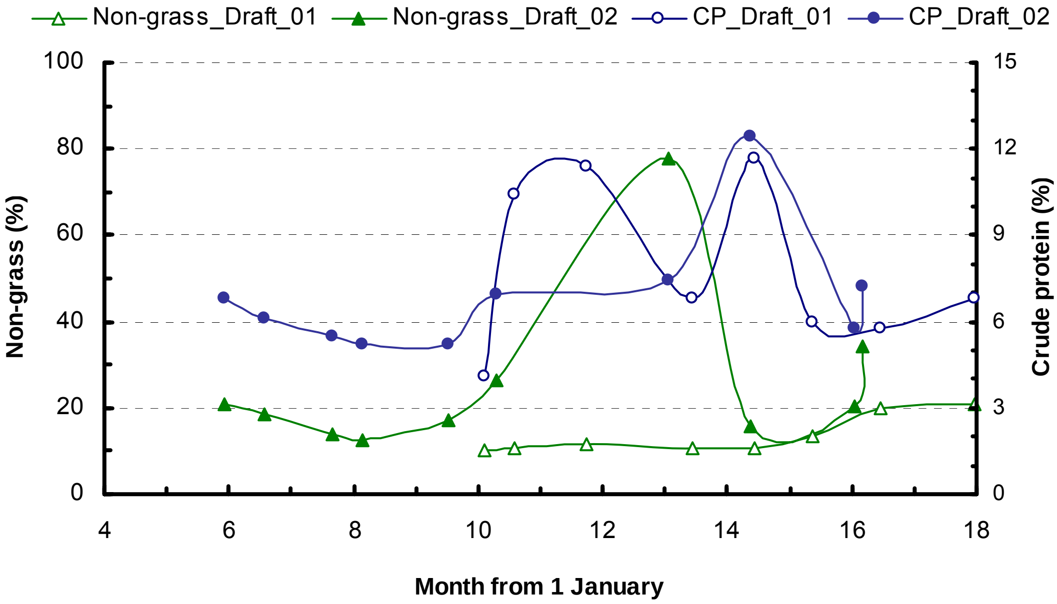


Figure 4.6.1. *The percentage of non-grass in the diet, and the crude protein content of the diet, selected by the 'light' animals in 2 drafts of steers grazing mixed grassland-Mulga vegetation at Croxdale near Charleville.*

The Draft 1 steers gained 146 kg LW from November 2001 until June 2002 (i.e. 0.6 kg LW/day), but the Draft 2 steers only 25 and 44 kg (0.1-0.2 kg/day) for the light and heavy groups, respectively, from June 2002 through to March 2003. F.NIRS measurements of diet quality did not appear to be affected by LW group of the steers. For Draft 1 the diet CP was 4.1% in early November 2001 and increased to 10.4-11.4% in late November and December 2001 (Figure 4.6.1). This increase in the crude protein content of the diet selected by the steers was presumably due to pasture growth associated with the rain during these months, while the absence of a concurrent increase in the non-grass% indicated that the animals were selecting new growth of grass rather than forbs during this interval. Diet CP% declined in February 2002, increased in March 2002, and then declined again in April and May 2002. Diet DMD (not shown) was 48% in November 2001, increased to 53-62% from December 01 to April 02, but was declining in May and June 02 to 53%. The proportion of non-grass in the diet of Draft 1 steers fluctuated between 10 and 21%; the higher levels occurred in April/May 2002. The proportion of non-grass in the diet tended to be inversely related to the estimated CP content and DMD of the diet, suggesting that the cattle were consuming more browse as grass pasture quality declined. For Draft 2 steers the diet CP ranged from 5.2 to 6.9%, and non-grass from 12-21%, from June to November. Non-grass and diet CP contents both increased briefly in January or March (to 12.4% and 78%, respectively) presumably due to growth of pasture including forbs following rain, before declining again in April and May.

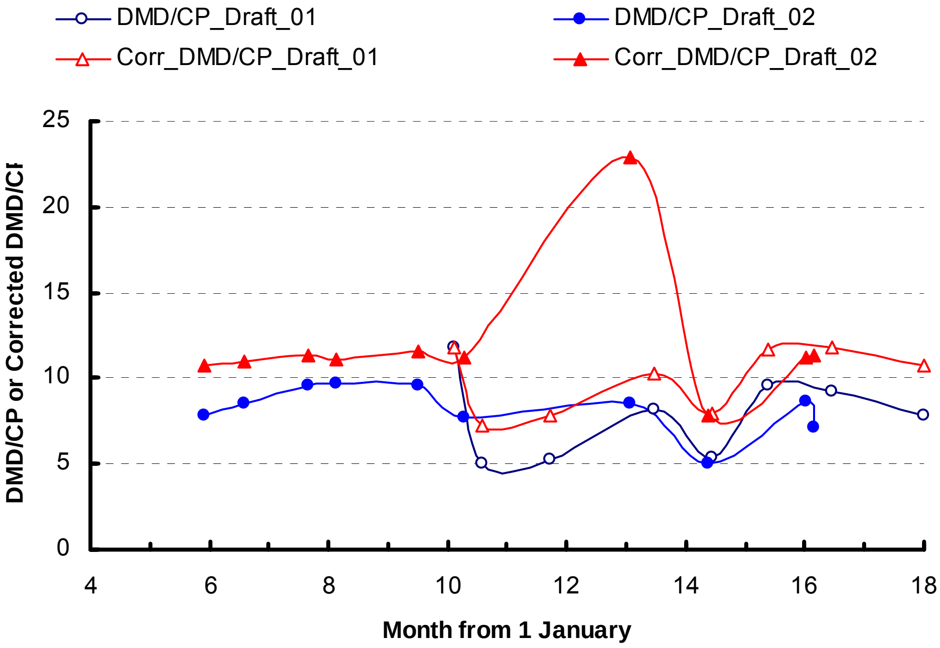


Figure 4.6.2. *The ratio DMD/CP (dry matter digestibility to crude protein of the diet) predicted by F.NIRS, or the same ratio following correction for the expected indigestibility of the browse component of the diet in the 'light' animals of 2 drafts of steers grazing mixed grassland-Mulga vegetation at Croxdale near Charleville. The correction is only appropriate where the non-grass component consists of browse, and not when the non-grass consists of forbs after rain.*

These F.NIRS measurements of cattle grazing in circumstances where, during some intervals, a substantial proportion of the diet may have consisted of browse are more difficult to interpret than F.NIRS measurements in cattle grazing conventional pastures. As discussed elsewhere (Appendix 1) the existing F.NIRS calibration equations include few diets containing substantial amounts of tannins, and other secondary metabolites, expected to be present in browse such as the mulga leaf. Inclusion of more diets containing browses such as mulga in the NIRS calibration equations is highly desirable to ensure reliable calibration equations for environments where browse is an important dietary component such as that where this trial was done in SW Qld.
A procedure for correcting the F.NIRS measurements of diets containing substantial proportions of browse and where the availability to the animal of the protein is low due to condensed tannins and possibly other secondary metabolites, has been described (Appendix 2). It assumes that only 50% of the browse protein is available. However, the corrected DMD/CP value is only appropriate where the non-grass selected consists of browses rather than herbaceous forbs. Since current F.NIRS calibrations cannot distinguish between browse and forb non-grass components, the decision on whether to apply the corrected or uncorrected DMD/CP depends on evaluation of the pasture to estimate the source of the non-grass. Figure 4.6.2 shows the DMD/CP ratio calculated directly from the F.NIRS measurements, and also the DMD/CP ratio corrected for an expected low availability of dietary protein. The corrected DMD/CP ratio was greater than 10 for much of Draft 2 of the present trial, but the corrected DMD/CP ratio' of 23 in month 13 (January) was likely an aberration with the non-grass consisting of forbs rather than grass.

The LW of the 'light' group of steers determined from the regular weighing, and the LW predicted from the initial LW and the summation of LW change predicted using the adg1441 F.NIRS calibration equation is shown in Figure 4.6.3. There was remarkably good agreement between the observed and the predicted LW (Figure 4.6.4), increasing confidence in the reliability of the adg1441 calibration to predict LW change of young growing animals.

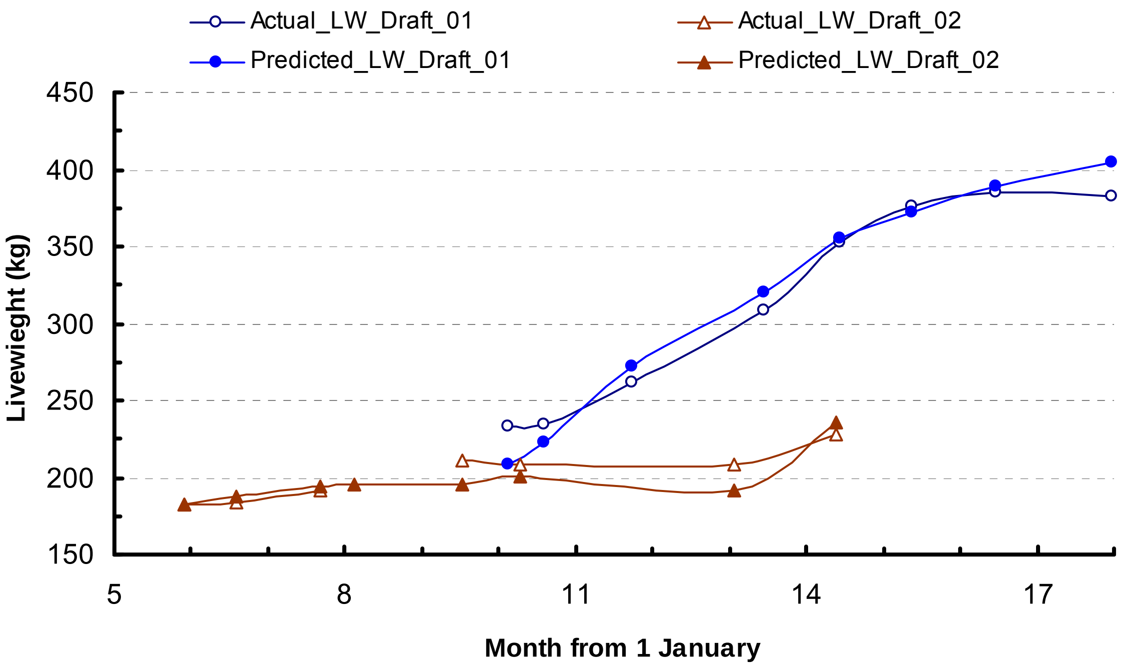


Figure 4.6.3. *Comparison of actual LW of the 'light' group of steers and that predicted from the initial LW and the F.NIRS predictions of LW change using the adg1441 calibration equation for the 2 drafts of steers. The steers grazing mixed grassland-Mulga vegetation at Croxdale near Charleville.*

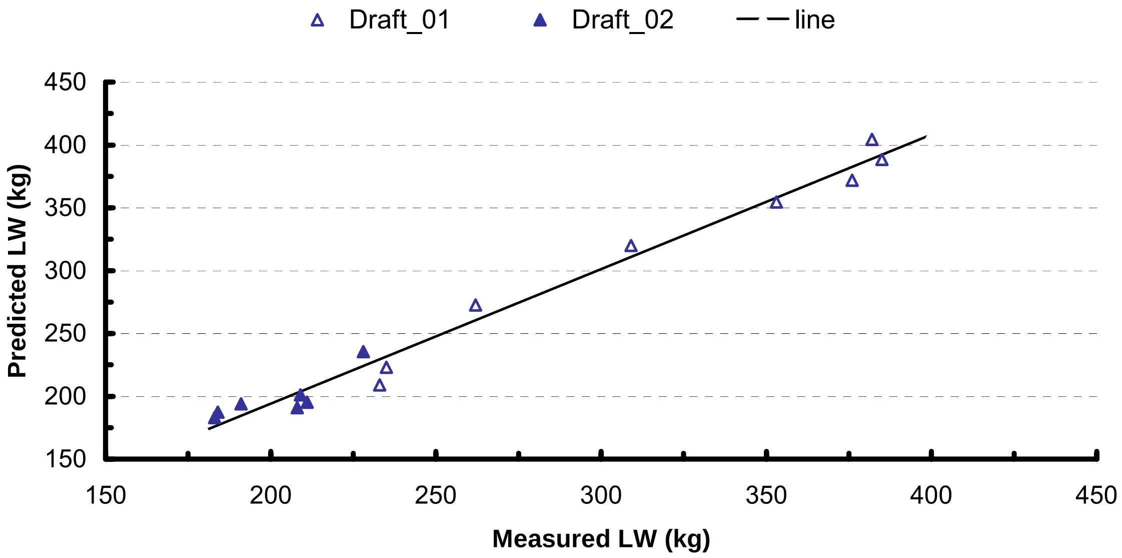


Figure 4.6.4. *Comparison of measured LW and the LW predicted with the ADG1441 calibration for the 'light' group of steers for the 2 drafts of steers. The steers grazing mixed grassland-Mulga vegetation at Croxdale near Charleville. The regression relationship was as follows:*
$Y = 1.07 X - 20$ (R^2 0.98, n 15).

With the continuing drought conditions at the site the Draft 2 animals had to be terminated earlier than scheduled and the paddock destocked.

4.7 Paired monitor herd at Forest Home, Mingela, to examine urea supplement responses on Indian couch pastures

There was 425 mm on rain from November 2001 through to January 2002. However there was negligible rain through the 2002 dry season and little rain in the 2002/03 wet season. On average the supplemented steers ingested 21 g urea per day in the drinking water although this varied from 3 g/day in March to 40 g/day in September, the low urea intake being associated with low water intakes.

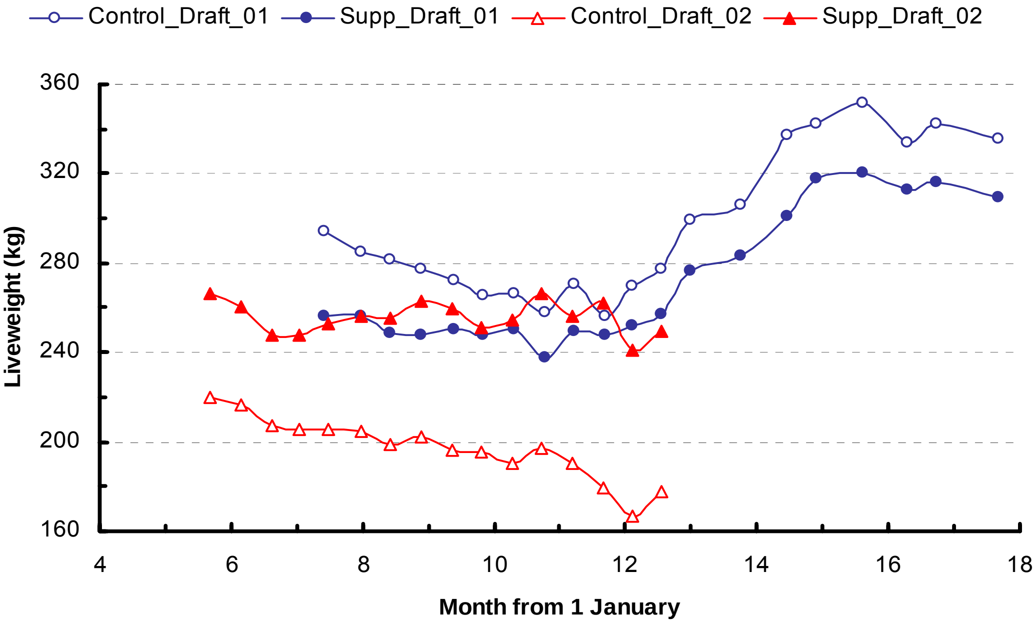


Figure 4.7.1. *The measured LW of the younger age group of steers in each of drafts 1 (#0) and 2 (#1) through the experimental interval. Control steers (open symbols) grazed pasture alone while the supplemented steers (solid symbols) were a given urea and sulphur supplement.*

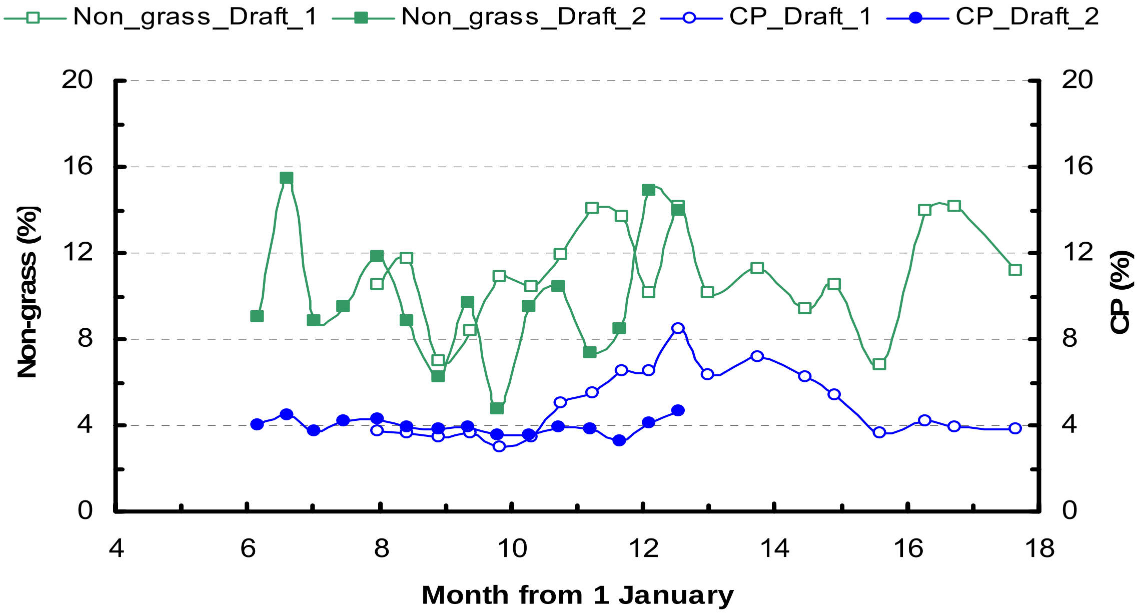


Figure 4.7.2. *The percentage of non-grass, and the crude protein content of the diet, selected by the 2 drafts of steers.*

The #9 and #0 steers were initially, in August 2001, 348 and 256 kg LW respectively. The #9 steers were 392 kg in June 2002 when they were removed from the trial and had therefore gained 44 kg during the 10 month interval. When they entered the trial in June 2002 the #1 steers were mean LW 273 kg. When the trial was continued until January 2003 and the #0 and #1 steers weighed 288 and 269 kg. The results showing the difference in liveweights between the control and the urea supplemented steers are shown in Figure 4.7.1, and also in the Recent Advances in Animal Nutrition paper in Appendix 1. All of the steers lost LW from August 2001 through to the seasonal break in November, although the urea supplement alleviated this LW loss. The steers gained LW through the wet season but the overall gain to June 2002 was only 43 or 44 kg LW in the 2 age groups. From August 2001 to June 2002 the LW benefit of the urea supplement during the dry season was eroded by compensatory growth during the wet season such that there was no net benefit, by June 2002, of the urea supplement. This compensatory effect was not observed between June 2002 and January 2003, but also was not expected as there was no wet season with high quality pasture for compensatory growth effects to occur.

The proportion of non-grass was generally in the range 7-15% of the diet (Figure 4.7.2), which was in accord with observations that there were few forbs or native legumes present in the pasture. During the late 2001 dry season the diet CP and DMD were about 3% and 45-47%, respectively (Figure 4.7.2). The values for plucked pasture were even lower at 0.8-2.3% CP and 38-43% DMD indicating that even in these Indian couch pastures the steers selected a diet of appreciably higher quality than the pasture on offer. Diet CP and DMD increased to 7-9% CP and 50-60% DMD during the wet season, but declined rapidly so that by May 2002 it was similar in quality to that observed during the previous dry season. This low dietary CP and DMD continued, in the absence of rain, through to January 2003 when the trial was terminated. The increase in LW due to the urea supplementation appeared to occur when the DMD/CP ratio was greater than about 11, and when the DMD/CP decreased to less than 10 compensatory growth with control steers growing more rapidly than supplemented steers, was observed (Figure 4.7.3). A consequence of this compensatory growth was that by the end of the wet season there was little net LW benefit from the urea supplementation during the previous dry season.

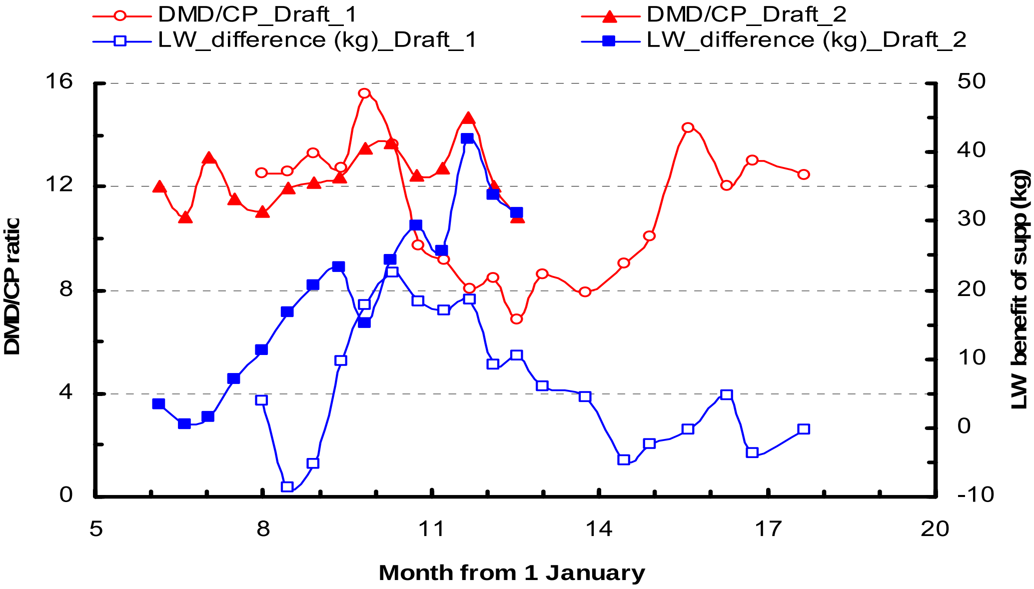


Figure 4.7.3. *The ratio DMD/CP (dry matter digestibility to crude protein of the diet) predicted by F.NIRS, and the difference in LW between the control and the supplemented animals, for 2 drafts of steers*

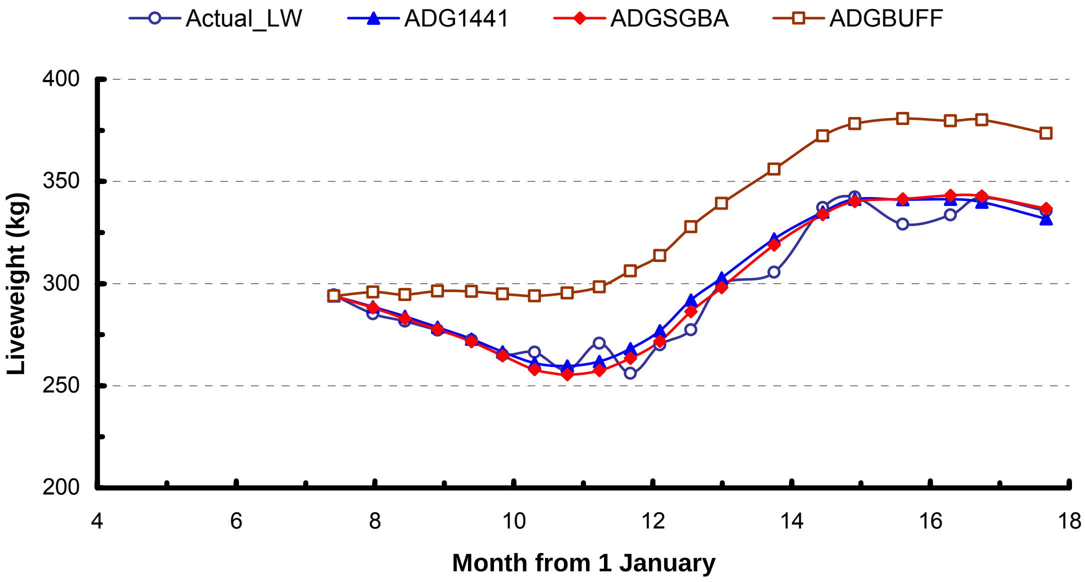


Figure 4.7.4. *Draft 1. Comparison of actual LW of the younger age group unsupplemented control steers and that predicted from F.NIRS measurements using 3 different calibration equations.*

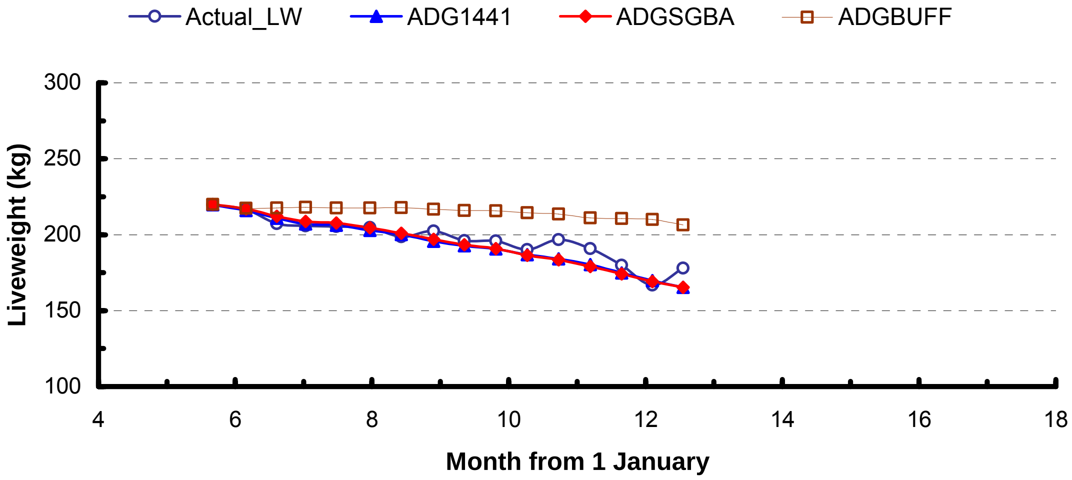


Figure 4.7.5. *Draft 2. Comparison of actual LW of the younger age group unsupplemented control steers and that predicted from F.NIRS measurements using 3 different calibration equations.*

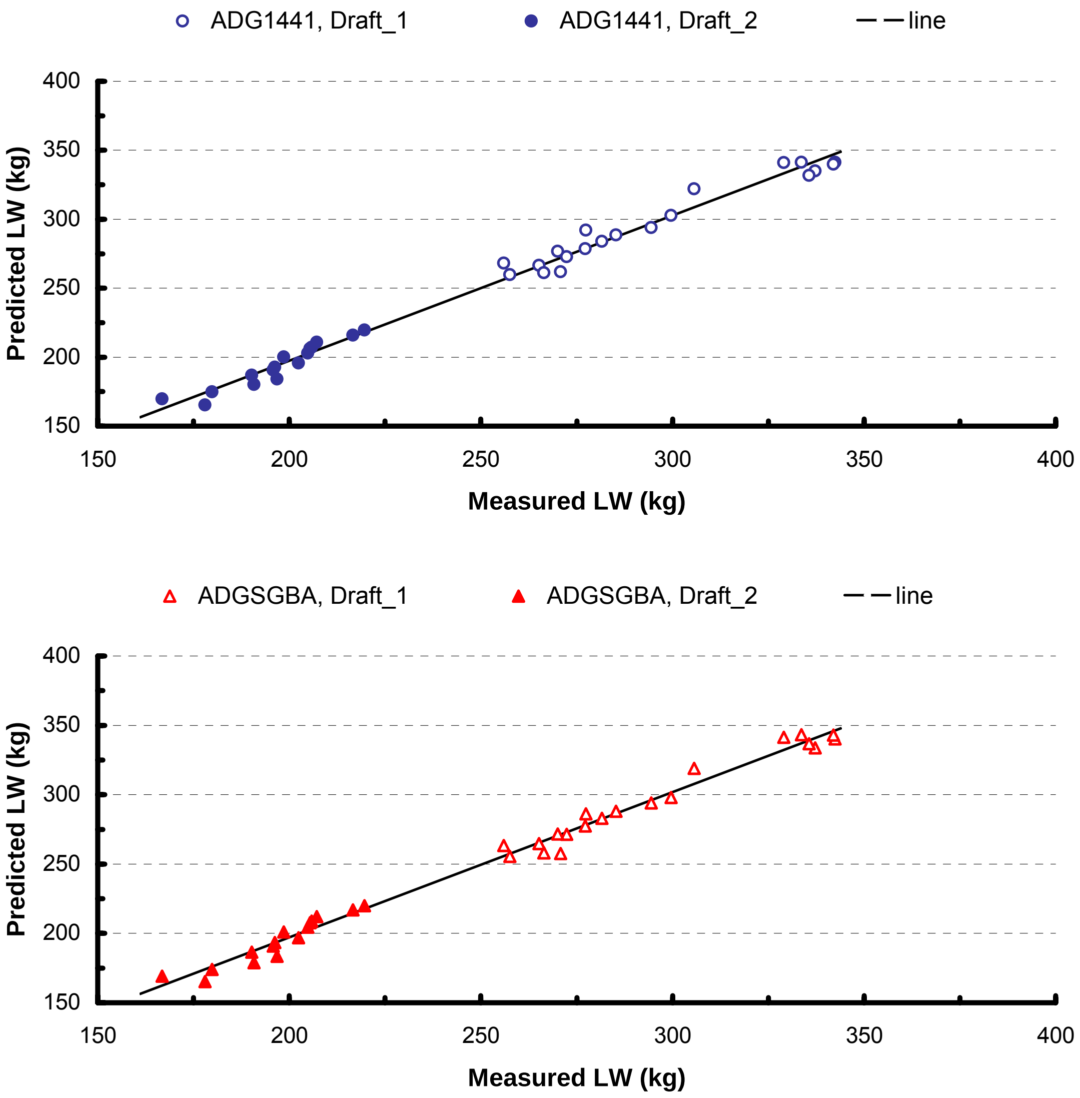


Figure 4.7.6 a and b. *Measured LW and the cumulative LW predicted using the ADG1441 and ADGSGBA calibration equations for the younger age group of 2 drafts of steers grazing Indian couch pastures. The equations were as follows:*
Y = 1.052 X - 13 (n 36, R^2 *0.99),*
Y = 1.047 X - 12 (n 36, R^2 *0.99).*

When the actual measured LW of the younger age group of steers in each draft was compared with the accumulated LW calculated from each of 3 calibration equations it was observed that the calibrations ADG1441 and ADGSGBA provided excellent predictions of the LW of the steers (Figure 4.7.4 and 4.7.5). The relationships between the measured and predicted LW for each of these calibrations is shown in Figure 4.7.6. Substantial over-estimation of the LW gain occurred for both drafts of steers if the calibration developed for buffel pastures (ADGBUFF) was applied to these steers grazing *Bothriochloa pertusa* dominant pasture.

4.8 Paired monitor herd at Fletcherview, Charters Towers, to examine urea supplement responses on buffel grass pastures

Total rainfall from 1 July 2001 – 30 June 2002 was 544 mm, from 1 July 2002 – 30 June 2003 was 411 mm, and was negligible from I July 2003 until the termination of the Draft 2 heifers in October 2003. Annual LW gain of the Draft 1 heifers was 123 kg, and of the Draft 2 heifers was 106 kg.

Table 4.2.1. *Rainfall (mm) at the Fletcherview trial site. The bars indicate when Draft 1 commenced and when the Drafts of heifers were changed.*

Month	2000/01	2001/02	2002/03	2003/04
Jul		6	0	0
Aug		0	22	0
Sept		0	0	0
Oct		11	0	14
Nov		73	2	
Dec		77	24	
Jan	61	137	18	
Feb	72	215	284	
Mar	67	9	21	
Apr	2	0	1	
May	0	10	23	
Jun	11	8	17	
Total		544	411	
Date of break[a]		13 Jan 02[b]	24 Feb 03	

a, The seasonal break defined as the first rainfall event of at least 50 mm over 3 days.

b, This was preceded by 40 mm of rain on the 11 November 2001, and 151 mm in smaller falls between the 11 November and the 13 January 2002.

Draft 1 heifers were supplemented from August 2001 through to late November 2001, and from April 2002 until this draft was terminated in October 2002. Intake of the LMM containing urea through September - October was about 140 g/day and thus supplied about 38 g urea/day. Intake of urea declined to about half these amounts in November with the onset of the wet season which commenced with 40 mm on 11 November 2001. On average across both treatments the heifers lost 19 kg LW during this interval (Figure 4.8.1). There was no evidence of any effect of the N supplement on the LW of the heifers during the interval mid-August 2001 to mid-April 2002, and supplemented heifers actually lost up to 17 kg more LW than control heifers during this interval. Supplemented heifers subsequently gained more LW during the 2002 dry season so that they were 6-12 kg heavier in August-September 2002.

Draft 2 heifers were fed supplements from October 2002 until late January 2003, and from mid-March 2003 until this draft was terminated in October 2003. From October 2002 until 1 January 2003 the Draft 2 heifers not fed N supplement lost 32 kg while the N supplemented heifers lost only 17 kg (i.e. 15 kg LW benefit of urea supplement) (Figure 4.8.1). However, although there was this evidence that the urea supplement reduced the LW loss of the heifers late in the dry season, the difference in LW between the treatments decreased during the following wet season. Again supplement intakes were lower than expected and provided only low amounts of urea. After the 1 January 2003 heifer LW increased with rain even though the seasonal break (defined as 50 mm in 3 days) did not occur until late February. The LW gain of the control and supplemented heifers late in the 2003 dry season was similar with a difference of only 8 kg LW between the groups.

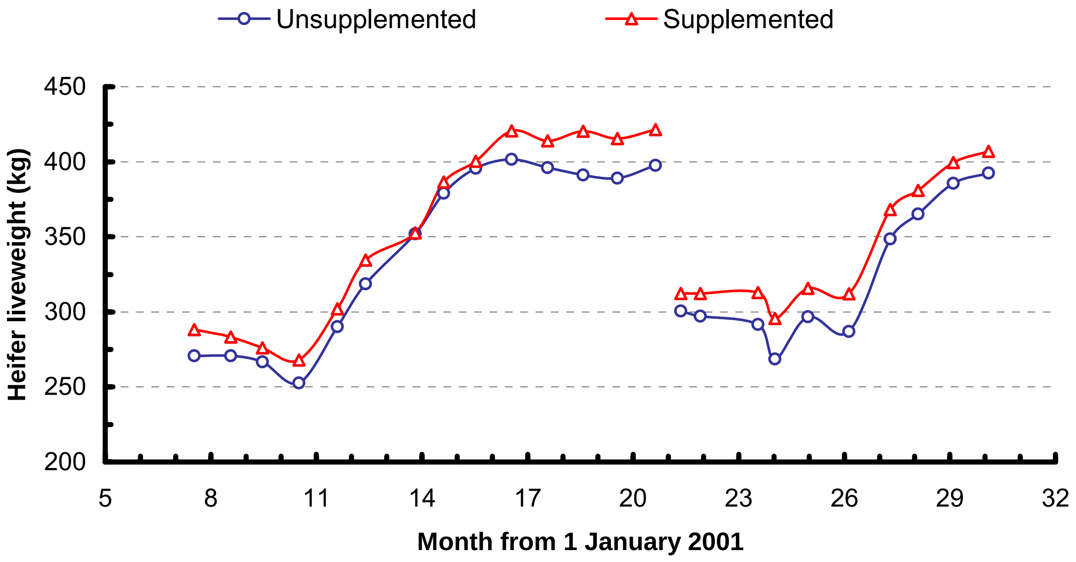


***Figure 4.8.1**. The liveweights of 2 drafts of heifers, without or with a urea supplement, grazing predominantly buffel grass pasture at Fletcherview, Charters Towers*

In both drafts of heifers the proportion of non-grass in the diet was generally 10 to 25% of the diet, and the fluctuations did not appear to be related to the season (Figure 4.8.2). These proportions of dietary non-grass were appreciably higher than observed during the same years at Swans Lagoon and the Forest Home sites which are located in the same region (See sections 4.2. and 4.7 of this report). At Fletcherview there was some seca stylo and edible browse (Bauhinia spp) available in the pasture, and their presence may explain the higher dietary non-grass.

During the dry season months (August - November 2001, May-December 2002 and May-October 2003) the diet CP averaged 5.2% (range 3.5 – 6.4%) (Figure 4.8.3). These dietary CP values are, as for the diet non-grass, higher than for the Swans Lagoon and Forest Home sites where it seldom exceeded 4% CP. DMD was generally in the range 48-53% (Figure 4.8.4). The DMD/CP ratio averaged 10.8, and ranged from 8.8 –13.2 (Figure 4.8.5). The LW benefit associated with the supplement is also shown in Figure 4.8.5. With the DMD/CP greater than 10 at intervals, an animal LW response was expected to the N supplement (Appendix 1). However, as described above, although a LW response to the supplement occurred in late 2002 in the Draft 2 heifers, only a modest LW response to the supplement was observed in the Draft 1 heifers in the mid 2002 dry season or in the Draft 2 heifers in the late 2003 dry season. We cannot provide a complete explanation for this small response to urea supplement. The small response seemed surprising given that: (i) the pasture was completely senesced, (ii) faecal N concentrations were usually less than 1.2% N, and (iii) observation and experience in the region suggested that liveweight responses to urea supplements would be expected. We speculate that the absence of a response to urea supplement was due to the substantial proportion of non-grass in the diet. A higher rumen availability of the CP in this non-grass component than in grass component of the diet, and perhaps in buffel grass than in the native grasses of the northern speargrass region, may have contributed to rumen degradable N supply and alleviated the need for supplementary urea. Under such circumstances an animal response to urea supplement may require the DMD/CP ratio is substantially greater than 10 for prolonged intervals. Two further considerations are that (i) intake of supplementary urea was low, and (ii) the heifers were introduced into the trial in the mid (Draft 1) or late (Draft 2) dry season; possibly the pasture grazed before introduction to the trial was higher in N and led to sufficient labile N reserves in the heifers to alleviate the effects of the low CP pasture.

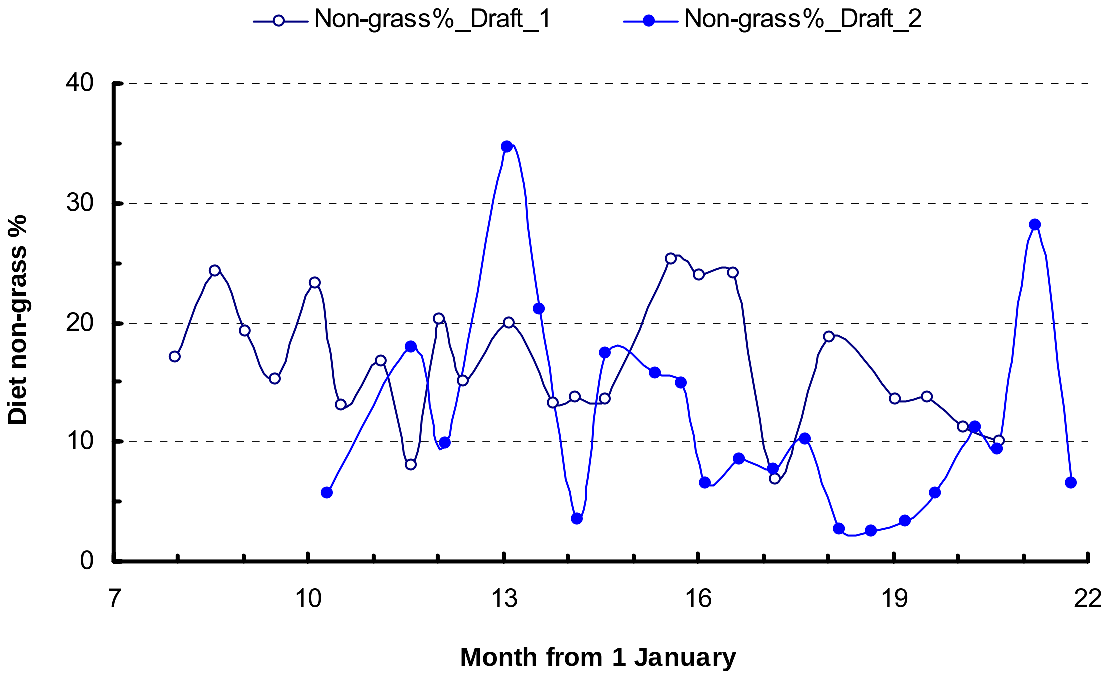


***Figure 4.8.2**. The proportion of non-grass in the diet predicted by F.NIRS for the 2 drafts of heifers at Fletcherview, Charters Towers*

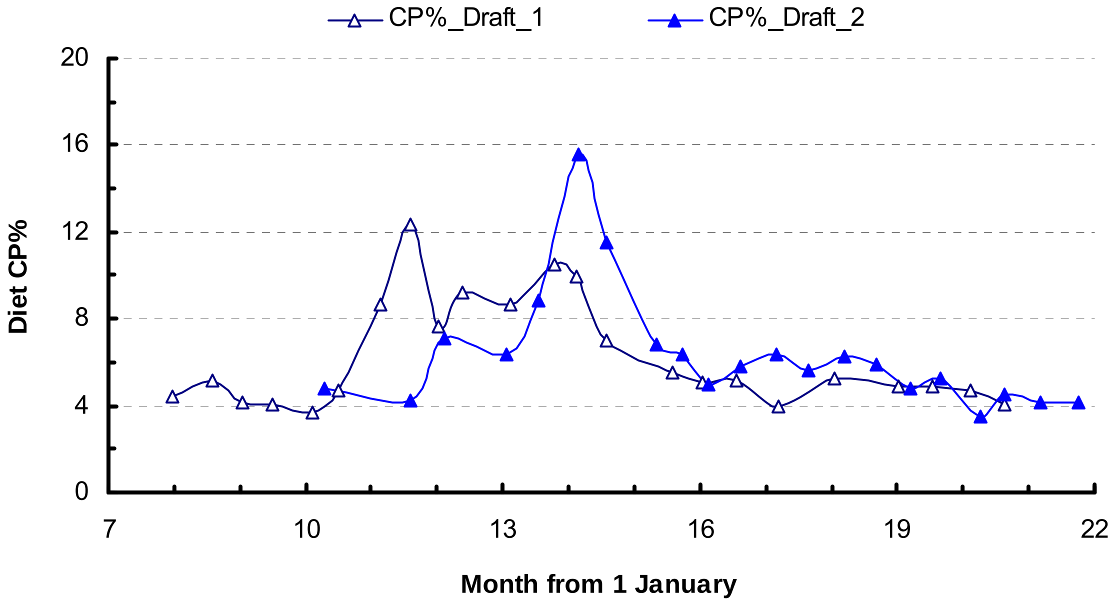


***Figure 4.8.3**. The crude protein content of the diet predicted by F.NIRS for the 2 drafts of heifers at Fletcherview, Charters Towers*

The LW of the unsupplemented heifers determined from the monthly weighings, and the LW predicted from the initial LW and the summation of LW change predicted by each of 3 F.NIRS calibration equations (ADG1441, ADGSGBA and ADGBUFF) are shown in Figures 4.8.6 and 4.8.7. As can be observed from these figures, most of the deviation between the actual and the predicted LW occurred during the dry season when the heifers were losing LW. The ADGSGBA appeared to give the most reliable prediction of LW, the ADG1441 the next most reliable, and the ADGBUFF the least reliable of the 3 calibrations examined. This seems surprising given that the pasture at Fletcherview was predominantly buffel grass. However, the ADGBUFF calibration

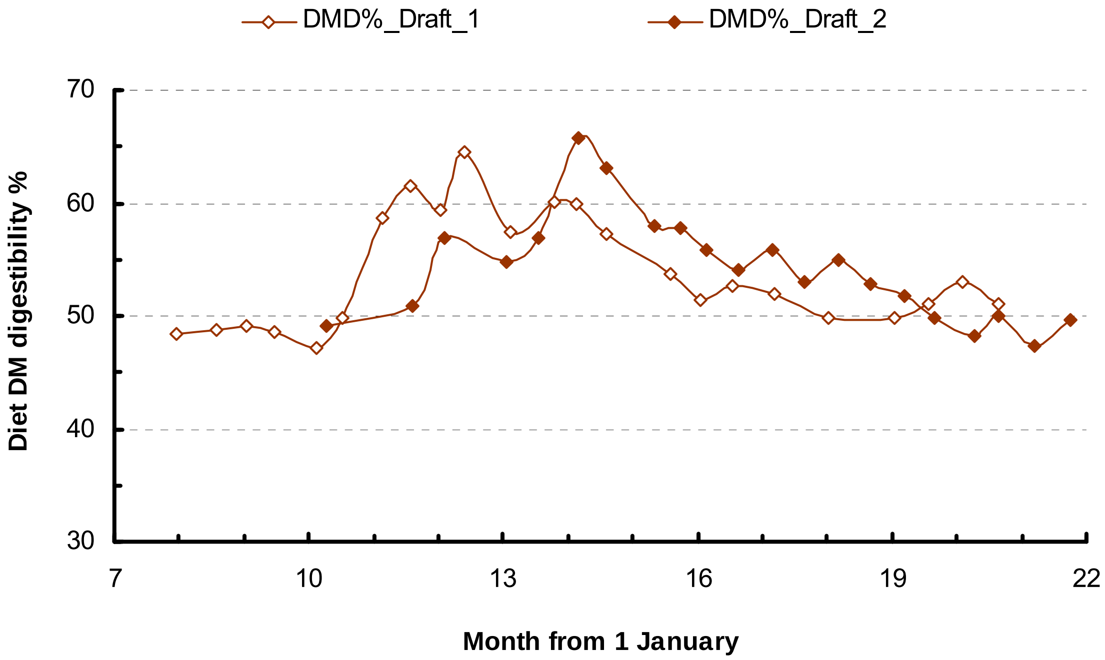


Figure 4.8.4. *The in vivo DM digestibility of the diet predicted by F.NIRS for the 2 drafts of heifers at Fletcherview, Charters Towers*

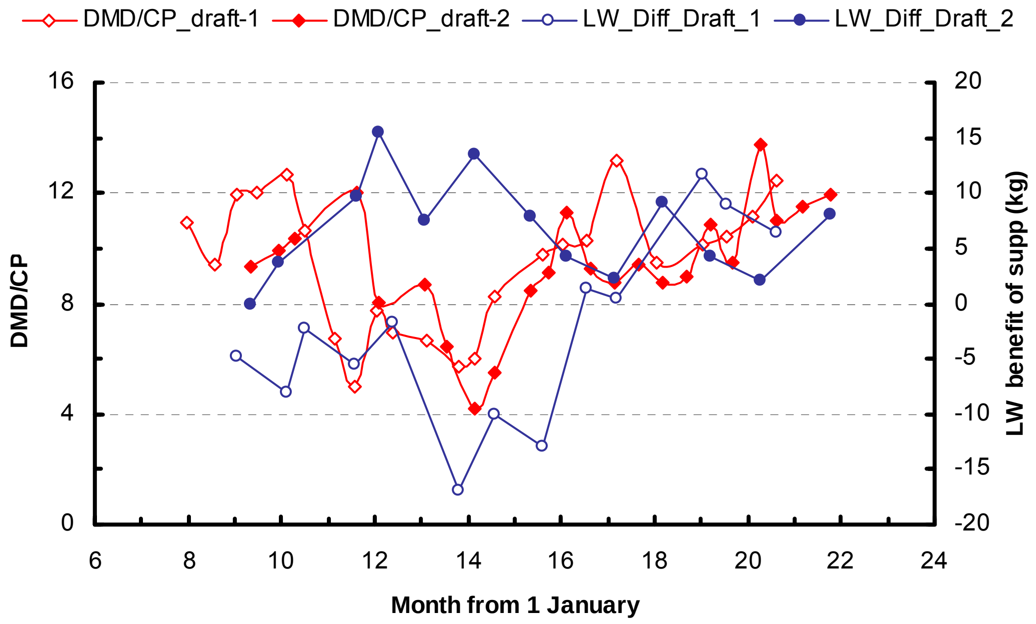


Figure 4.8.5. *The ratio DMD/CP (dry matter digestibility to crude protein of the diet) predicted by F.NIRS, and the LW benefit associated with the urea supplement, for the 2 drafts of heifers at Fletcherview, Charters Towers.*

was based principally of measures in herds grazing buffel pastures on Brigalow soils in Central Qld, whereas the other 2 calibrations were derived from herds in the northern speargrass and *Aristida-Bothriochloa* pasture systems in NE part of Qld and within about 100 km of the Fletcherview site, and were therefore in some respects similar to the present trial site. Possibly the grass species is less important than the soil types and climatic aspects in influencing the various calibration equations for LW change.

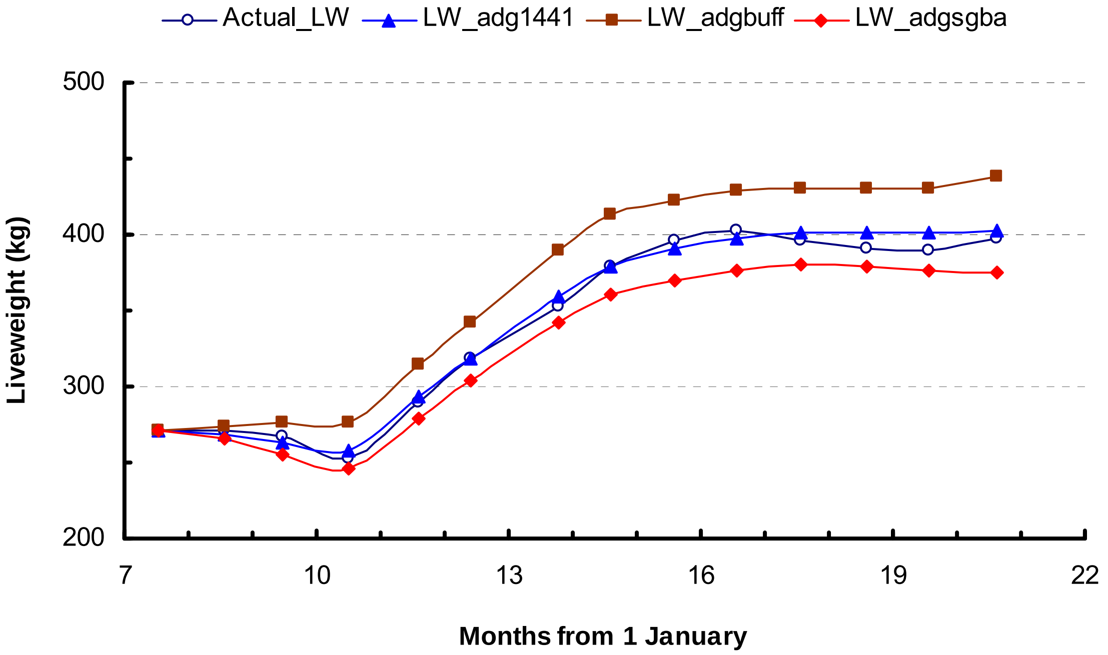


Figure 4.8.6. *Draft 1. Comparison of actual LW of the unsupplemented heifers and that predicted from F.NIRS measurements using 3 different calibration equations.*

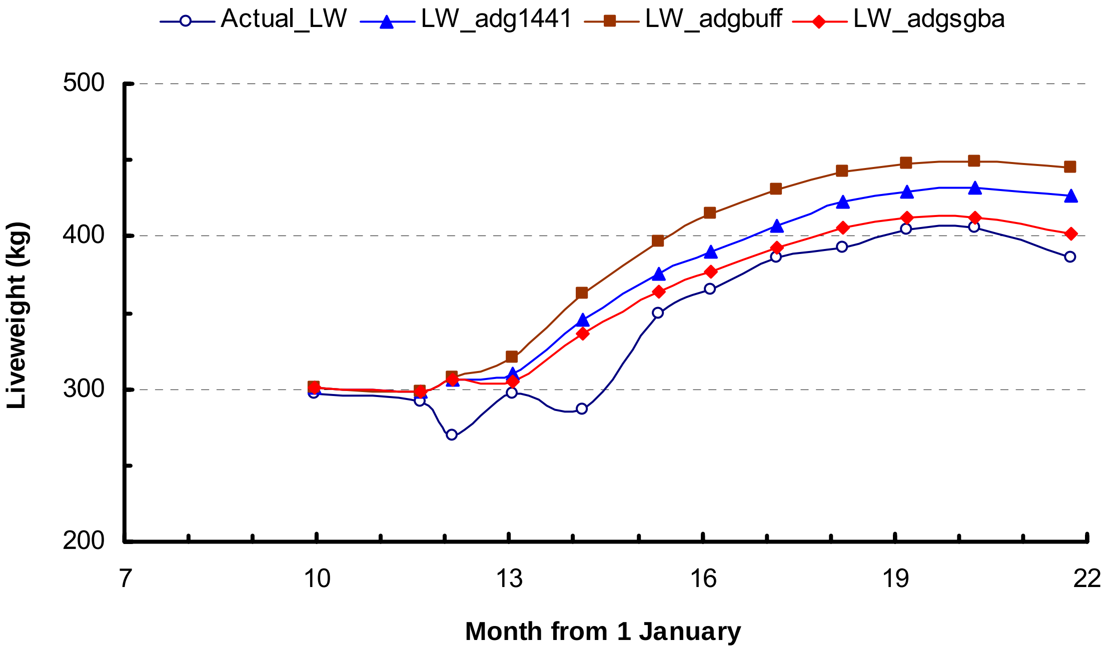


Figure 4.8.7. *Draft 2. Comparison of actual LW of the unsupplemented heifers and that predicted from F.NIRS measurements using 3 different calibration equations.*

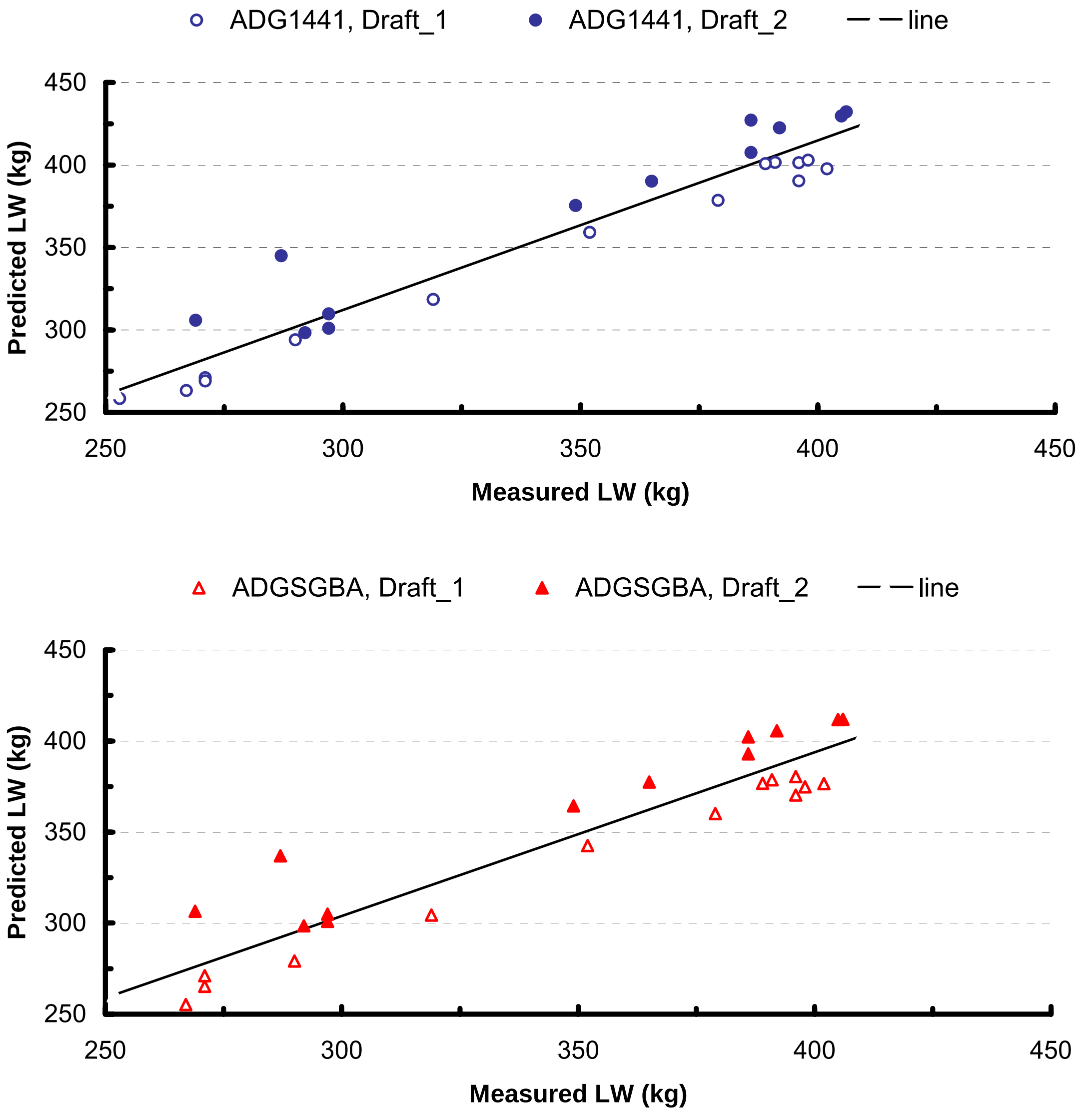


Figure 4.8.8 a and b. *Measured LW and the cumulative LW predicted using the ADG1441 and ADGSGBA F.NIRS calibrations for the 2 drafts of steers at Fletcherview, Charters Towers. The equations were as follows:*
$Y = 1.027 X + 4$ (n 26, R^2 0.92),
$Y = 0.899 X + 34$ (n 26, R^2 0.89).

The relationships between the measured and predicted liveweights (Figure 4.8.8) emphasis the excellent prediction of the measured animal liveweight by the AGD1441 and the ADGSGBA calibration equations.

4.9 Paired monitor herd at Longreach Pastoral College to examine urea supplement responses on Mitchell grass downs pastures

Rainfall during the 2001/02 summer before Draft 1 commenced was 282 mm. During Draft 1, from 1 July 2002 to 30 June 2003, rainfall was 261 mm or 58% of the long-term average for the site. Draft 1 heifers were on average 273 kg in September 2002 and gained 99 kg in the 8.4 months through to May 2003. There was no apparent effect due to the provision of supplements on LW gain through this interval. The proportion of non-grass in the diet during the dry season and until the seasonal break (May 2002 - February 2003) was high and averaged 29% (range 22-37%) (Figure 4.9.1). During the same interval the diet averaged 5.5% CP (range 4.7–5.8%), 56% DMD (range 53-57%) and the DMD/CP averaged 10.2 (range (9.7–11.2). With the seasonal break the diet non-grass increased to 42-51%, diet CP% to 16-19%, and DMD to 64-68%.

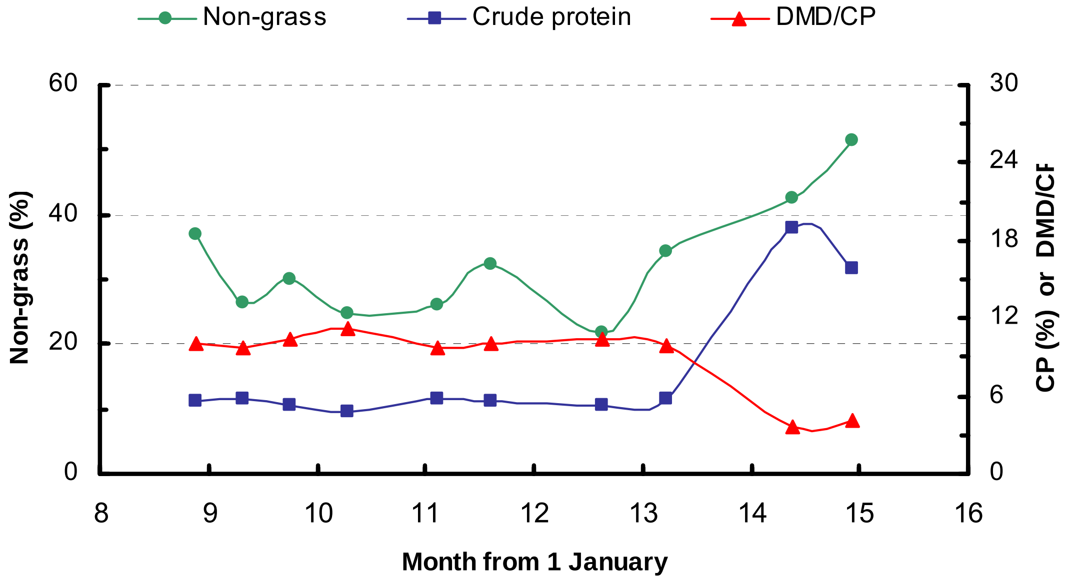


Figure 4.9.1. *Draft 1. F.NIRS measurements of diet quality at the Longreach Pastoral College site (2002/03).*

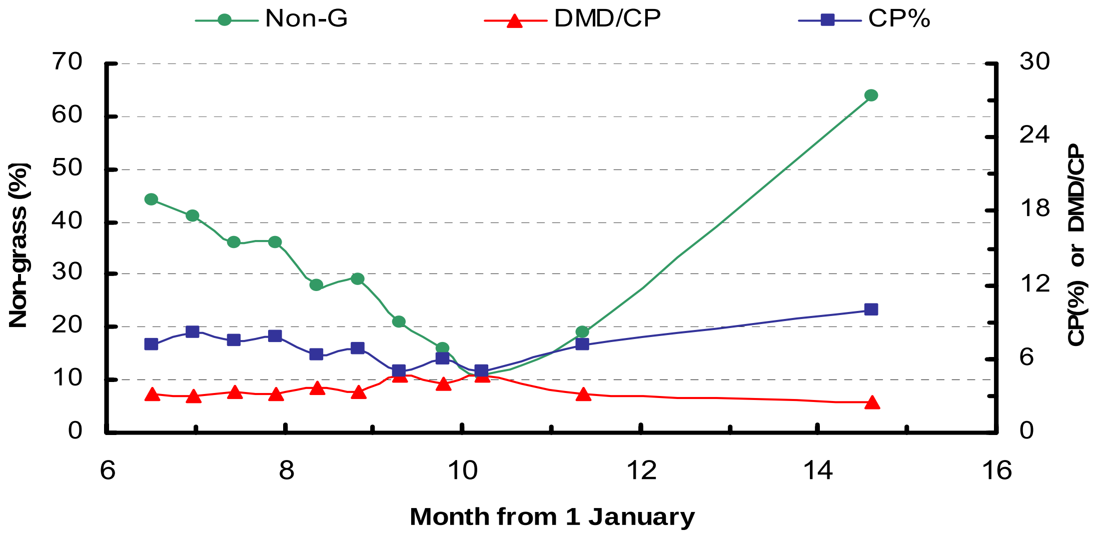


Figure 4.9.2. *Draft 2. F.NIRS measurements of diet quality at the Longreach Pastoral College site (2004/05).*

During the 2003/04 summer preceding the commencement of Draft 2 the seasonal break occurred on the 14 January 2004 and there was 375 mm rain. However there was only 234 mm rain through the 2004/05 summer and thus there was limited pasture growth. Draft 2 had to be terminated in April 2005 due to low pasture availability. Draft 2 steers were on average 228 kg LW in July 2004 and gained on average 148 kg during the 8.8 months through to April 2005. There was no effect of the N supplement on LW gain through this interval. Non-grass comprised 44% of the diet in July 2004 and declined progressively through to November when it was 11% of the diet (Figure 4.9.2). The average non-grass through this interval was 29%. From July to November diet CP averaged 6.6% (range 4.9–8.2%). DMD averaged 55% (range 52–58%) and DMD/CP averaged 8.5 (range 7.1–11.0). With the summer rain the diet non-grass increased up to 64%, CP to 9.9% and DMD to 56%.

Although the pastures were entirely senesced at the commencement of each draft, the cattle were able to select a diet containing a high proportion of forbs, diet CP averaged over 5.5% and the DMD/CP ratio was generally 9-11. Thus the cattle were able to select a diet of sufficient quality to maintain a moderate LW gain, and a diet containing sufficient rumen degradable nitrogen. These observations are similar to those observed for Drafts 2 and 4 in the trial at Toorak Research Station in the current project and reported above. The results are also consistent with the dietary measurements at Morungle, Richmond, on Mitchell grass downs pasture where the cattle were also able to select a diet high in non-grass and maintain diet quality through the dry season.

4.10 Swans Lagoon breeder experiment

A report of this experiment has already been published as a peer-reviewed paper in the *Recent Advances in Animal Nutrition Conference* in Armidale in July 2007. This paper is attached as Appendix 3.

The rainfall during the trial was as reported for the Swans Lagoon heifer herds (Table 4.2.1 above). Pastures were comparable with those described for the B..TT paddock used for the heifer herd grazing poor native pasture at a moderate stocking rate. The intention was to provide supplements to the breeder herd only if essential to alleviate liveweight loss and risk of mortality during the late dry season. Because most of the breeders were lactating through the wet season and through to May, or for some cows in some years through to July, and because of the dry seasonal conditions, it was necessary to feed molasses-urea supplements late in the dry season to 3 of the 4 drafts of cattle, and also to adjust the stocking rate in some years. Draft 2 was fed molasses-urea from mid-November to mid-December 2001. Draft 3 was fed molasses-urea from October 2002 until mid- February 2003, and also the stocking rate was adjusted so that there were only 26 cows in the paddock from June to September 2003. Draft 4 was fed molasses-urea from late November to mid-December 2003. Since there were no statistically significant differences between the NPNL, early weaned and late-weaned subgroups of cows in the F.NIRS measurements of dietary constituents, the average values for the diet of the various subgroups are presented.

The proportion of non-grass in the diet measured by F.NIRS was generally in the range 7-20% and did not appear to have any consistent cycle with the season. Thus non-grass made only a minor contribution to the diet selected which was consistent with the general absence of native forbs and legumes, or of any introduced legumes in the pasture. The diet selected by these breeders followed the same pattern as that observed for the growing heifer herds at Swans Lagoon (Figure 4.10.1., B..TT paddock) although in this latter herd the proportion of non-grass was even lower and there was evidence that the proportion was higher in the wet than the dry seasons.

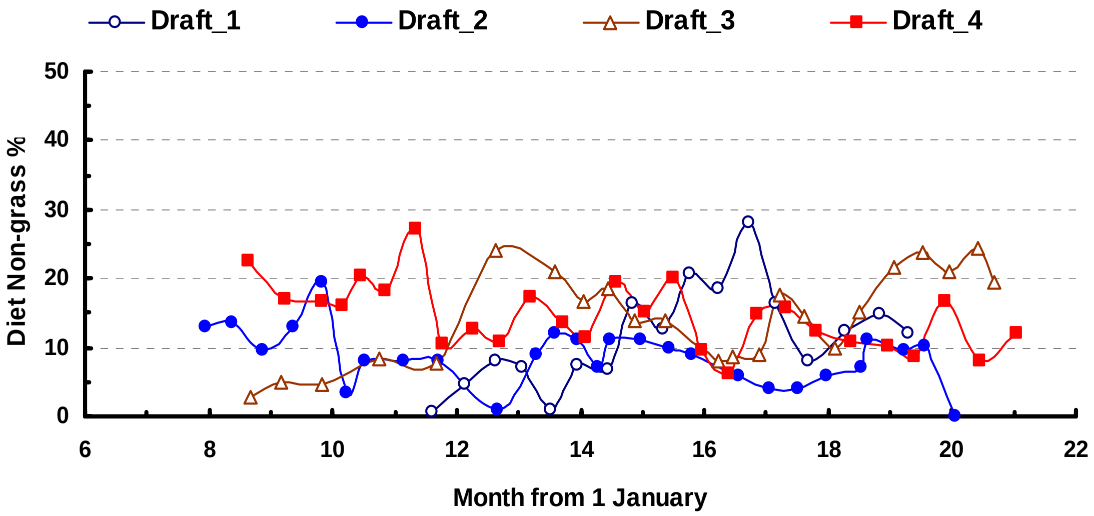


Figure 4.10.1. *F.NIRS measurements of the percent non-grass in the diet selected by each of the 4 drafts of the cows.*

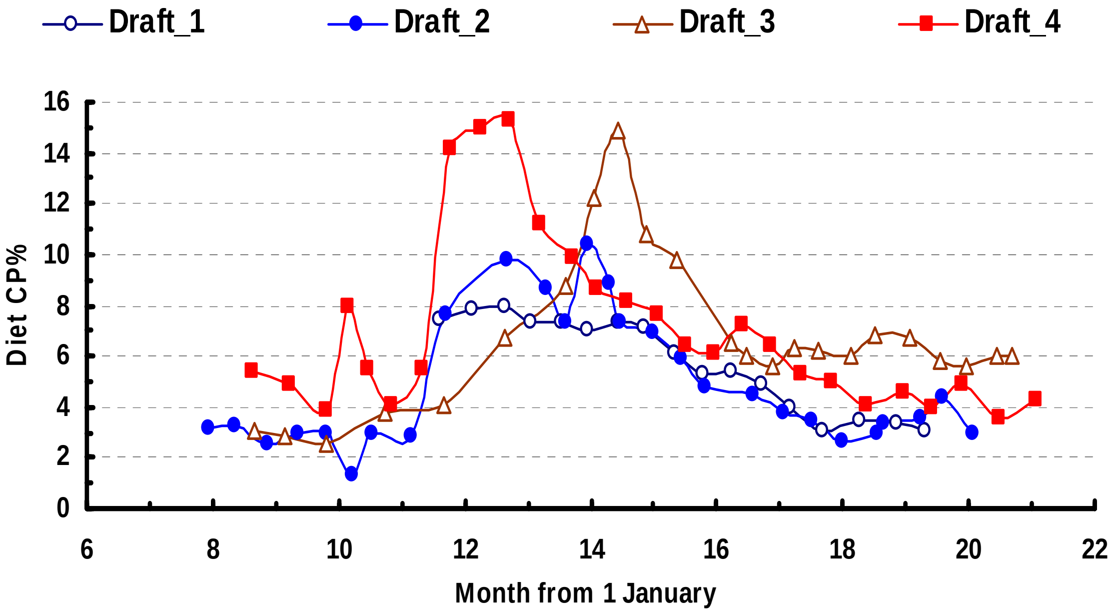


Figure 4.10.2. *F.NIRS measurements of the crude protein content (CP%) of the diet selected by each of the 4 drafts of the cows.*

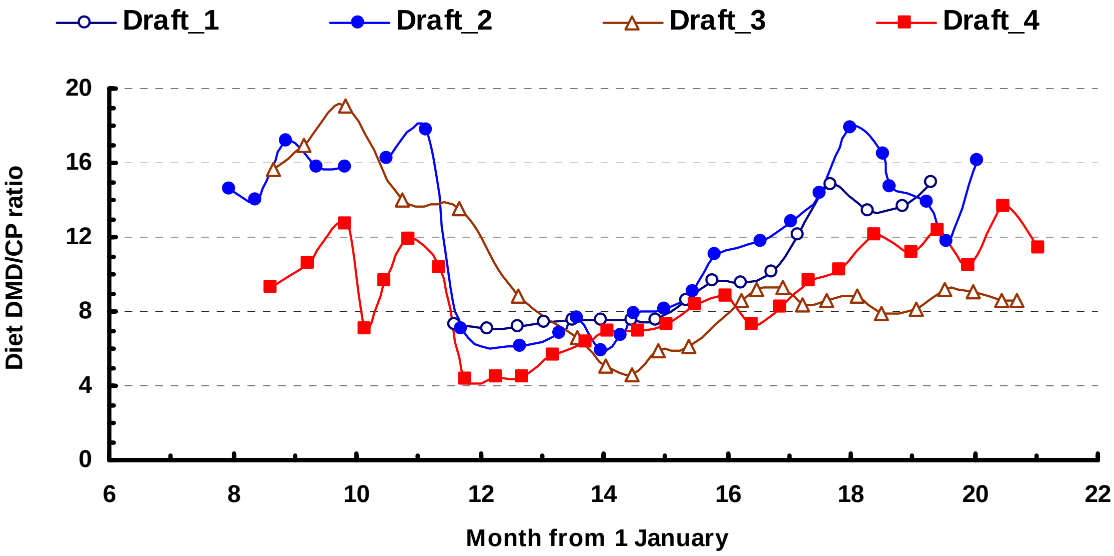


Figure 4.10.3. *F.NIRS measurements of the ratio DM digestibility/crude protein (DMD/CP) of the diet selected each of the 4 drafts of the cows*

During the dry season the diet selected by the cows during the 2001 and 2002 dry seasons (i.e. Drafts 1, Draft 2 and the early months of Draft 3) was consistently only 2-4% crude protein, but the diet selected during the 2003 dry season (the later months of Draft 3 and early months of Draft 4) was consistently higher and usually in the range 5-7% (Figure 4.10.2). The higher dietary crude protein during the 2003 dry season was presumably a consequence of winter rainfall during this latter dry season with 36 mm rain in June and 29 mm rain in October 2003. Dietary CP% increased rapidly following the seasonal break to maximum dietary crude protein concentrations in the range 10-15%. The values for the DMD/CP ratio (Figure 4.10.3) tended, as expected, to be an inverse of the dietary CP%. The DMD/CP was less than 8 during the wet season but increased with the onset of the dry season. The DMD/CP exceeded 8 in April for Drafts 1, 2 and 4, but not until May for Draft 3. Furthermore, although the DMD/CP was usually

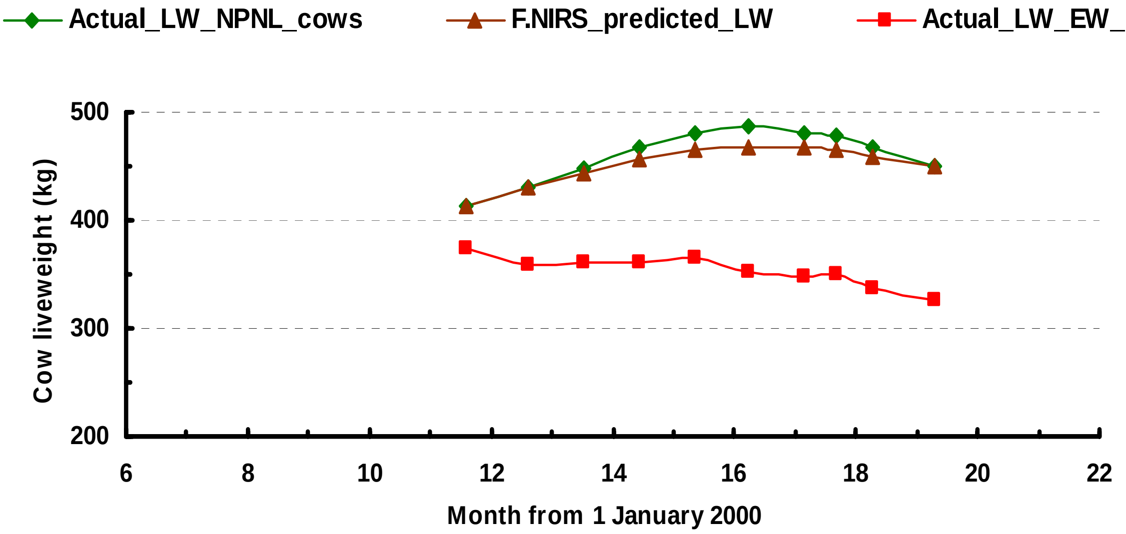


Figure 4.10.4. *The liveweight (LW) measured at monthly intervals in Draft 1 cows which were non-pregnant non-lactating (●) or which lactated from calving in Nov-Jan until weaning in May (■), or the LW pathway predicted from the initial LW and fortnightly F.NIRS measurements of LW change (▲).*

in the range 10-15 through the 2001, 2002 and 2004 mid to late dry seasons, it remained less than 10 until October during the 2003 dry season. This represented the later part of the Draft 3 and the early part of the Draft 4 measurements.

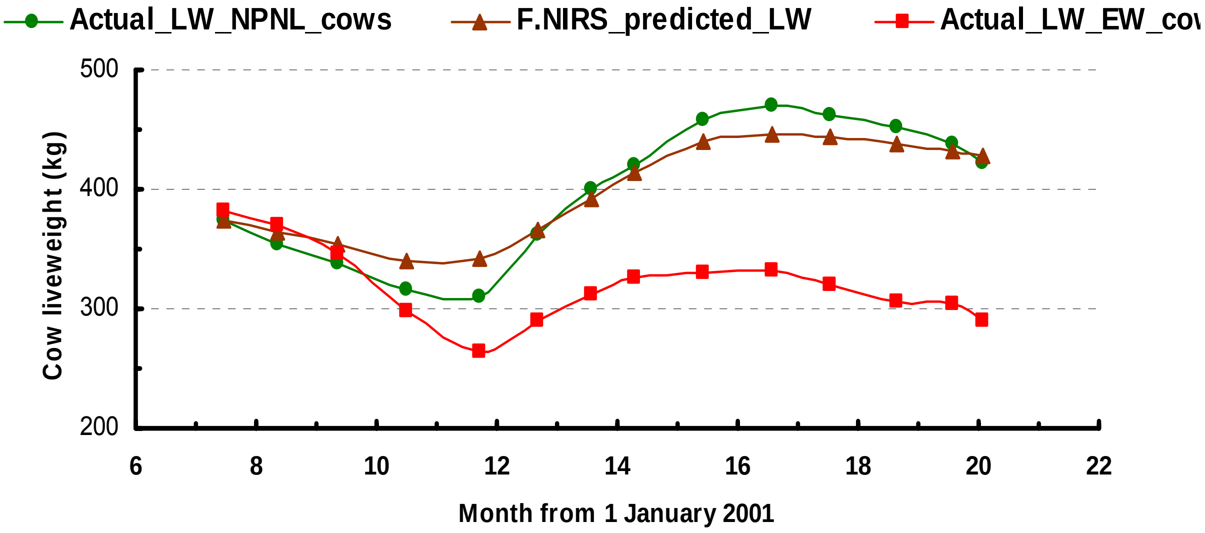


Figure 4.10.5. *The liveweight (LW) measured at monthly intervals in Draft 2 cows which were non-pregnant non-lactating (●) or which lactated from calving in Nov-Jan until weaning in May (■), or the LW pathway predicted from the initial LW and fortnightly F.NIRS measurements of LW change (▲).*

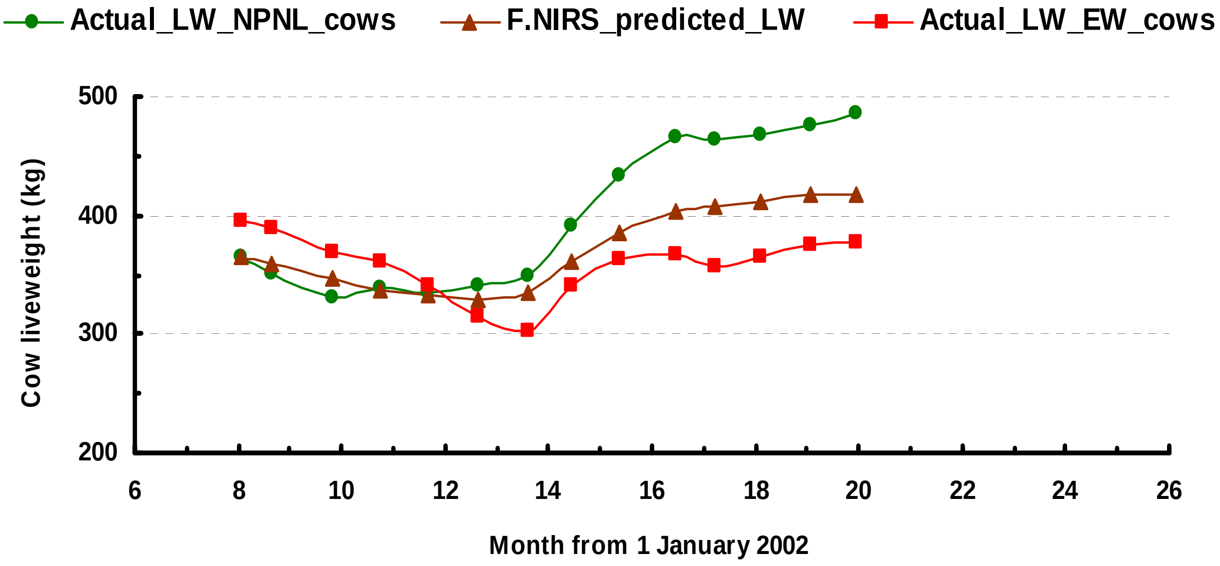


Figure 4.10.6. *The liveweight (LW) measured at monthly intervals in Draft 3 cows which were non-pregnant non-lactating (●) or which lactated from calving in Nov-Jan until weaning in May (■), or the LW pathway predicted from the initial LW and fortnightly F.NIRS measurements of LW change (▲)*

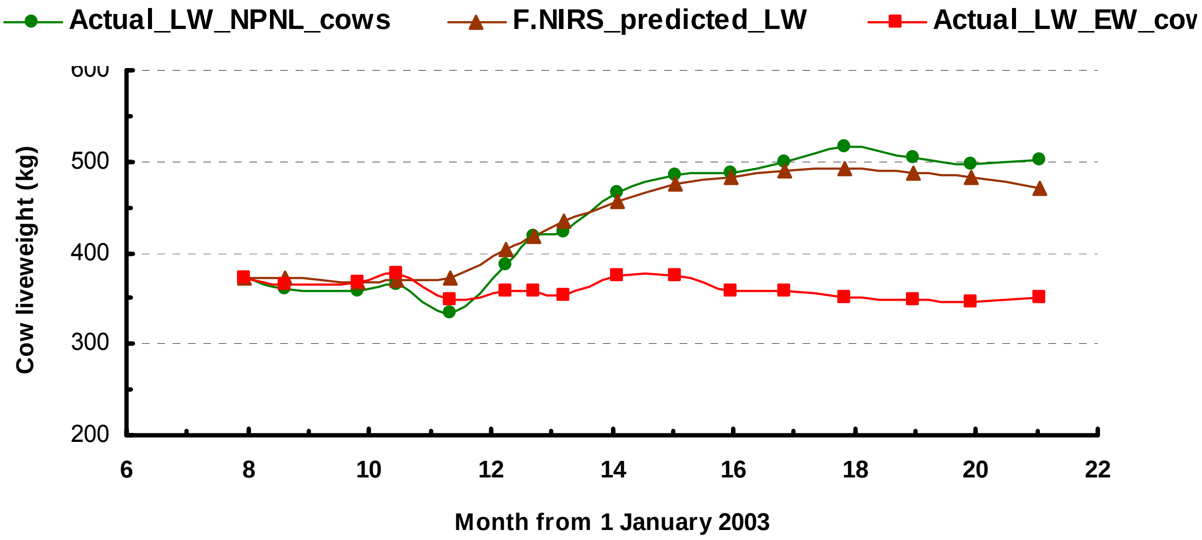


Figure 4.10.7. *The liveweight (LW) measured at monthly intervals in Draft 4 cows which were non-pregnant non-lactating (●) or which lactated from calving in Nov-Jan until weaning in May (■), or the LW pathway predicted from the initial LW and fortnightly F.NIRS measurements of LW change (▲).*

The actual and F.NIRS predicted LW pathways of the cows are shown in Figures 4.10.4 to 4.10.7 for the 4 drafts of cows. As expected the pregnant, later lactating, cows lost more conceptus-free LW during the dry season until calving so that they were in mid-January on average 58 kg lighter than the NPNL cows. The lactating cows gained LW early in 2002 and 2003 with the wet season pastures (Figs 4.10.5 and 4.10.6), but in 2001 and 2004 these cows only maintained LW during the same interval (Figs 4.10.4 and 4.10.7). These lactating cows lost LW (2001, 2002 and 2004) or gained LW only slowly (2003) as the dry season progressed. The NPNL cows, as expected, gained LW rapidly with the high quality pasture of the wet season. Thus, by the early dry season in May at usual first-round weaning time, the NPNL cows were 97-142 (mean 128) kg heavier than the cows which had reared a calf. As the dry season advanced from May the cows, irrespective of whether they had reared a calf, lost LW (2001 and 2002), maintained LW (2004), or continued to slowly gain LW (2003) through to August when the draft was terminated. The weaned cows were still 129 kg lighter in August, indicating that no compensatory LW change occurred between May and August. Most importantly the F.NIRS predicted pathway of LW corresponded closely to the measured LW pathway of the NPNL cows in 3 of the 4 drafts of animals. The exception was for Draft 3 where LW gain of the NPNL cows was much more rapid than that predicted by the F.NIRS. We speculate that this may have been associated with unusually high compensatory growth of this latter draft of cows during the 2002/03 wet season. This may have been a consequence of the difficult late 2002 dry season, the unusually late break of the 2002 dry season (in February 2003) and the prolonged feeding of molasses-urea to this draft of cows.

This trial indicated that F.NIRS measurements can be directly applied to the nutritional management of the breeder herd. First, the predictions of diet quality can be applied directly as these are not influenced by the reproductive cycle. Management manipulations such as urea supplementation, change in stocking rate or change in pasture by movement to another paddock can then be applied if necessary and appropriate. Clearly, management decisions on nutritional manipulation will need to consider the very high nutrient demands of lactation. For example, in circumstances where provision of urea supplements is sufficient to maintain LW in a young animal or a non-lactating breeder, a lactating breeder is likely to continue to lose LW and require a greater nutritional input to maintain LW. Second, the F.NIRS predictions of LW change can be used to predict the LW change of lactating cows as well as NPNL cows if an appropriate correction is applied for the difference in LW change between NPNL and lactating cows. This difference is due to the high nutrient demands for synthesis of milk, with some compensation due to higher voluntary intake of pasture by lactating cows than by NPNL cows. The latter increase in intake varies with stage of lactation and presumably with forage quality, but is likely to be 20-30%. The LW difference due to lactation can be easily measured where NPNL cows and lactating cows are grazing together. A large number of such measurements at Swans Lagoon R.S. in the northern speargrass with the *Bos indicus* cross genotype of the research station herd have indicated that, for cows in mid-lactation, the LW change of lactating cows is consistently 10-15 kg per month lower than that of non-lactating cows and across a range of nutrition (Dixon 1998; Dixon and Hirst 2000). Although this value will be influenced by factors such as cow genotype (being greater for genotypes with higher milk production) and with stage of lactation, reasonable estimates will be possible in most circumstances.

A key aspect of the nutritional management of the breeder herd for high fertility involves achievement of target body status of breeders (as liveweight or body condition score) at critical times of the annual cycle such as the end of the dry season, parturition or the start of mating (Dixon 1998). There is copious evidence that the body status of cows (e.g. as body condition score or liveweight) at parturition and joining (e.g. at ‘start-of-mating’) is a major determinant of the reproductive rates of breeders in environments such as the seasonally dry tropics where lactating cows typically lose a large proportion of their LW and body reserves during the dry season (Meaker 1975; Buck *et al.* 1976; Goddard *et al.* 1980; Anderson 1990; O'Rourke *et al.* 1991*a,b*). This information has been reviewed and discussed in detail by Dixon (1998). Although dynamic effects associated with short-term changes in level of nutrition have been demonstrated experimentally and are possible, the evidence for their role in practice is equivocal and the effect is usually likely to be secondary to static body reserves of the animal. In addition, the nutritional inputs necessary (e.g. 6 weeks of feeding 2 kg/head.day of molasses-urea supplement) to achieve 'spike-feeding' response in breeders in northern Australia, which it has been argued have been due to dynamic effects, do not always occur (DAQ.062 Final Report, 1994) and may often not be economically viable. The benefits of common management options such as urea supplementation, phosphorus supplementation, weaning and molasses-urea supplements can be estimated with reasonable precision (Dixon 1998).

F.NIRS can be used as a tool for nutritional management of the breeder herd by indicating, in conjunction with estimates of the current body status of the breeder herd, quality and quantity of the pasture, and the outlook for rain to change the quality of the pasture, whether management interventions are needed for the breeder herd to achieve specific targets for satisfactory reproductive performance.

4.11 Transfer of F.NIRS calibration equations to the Rockhampton NIRS instrument

The faecal calibration equations developed from rescanning about 1200 samples from the Davies lab on the Rockhampton instrument had similar error terms to the calibration equations presented by Coates (2004). When a set of selected standards was scanned on both the Rockhampton and the Davies lab NIRS instruments the results were, as expected, not identical. However, differences between the NIR spectra and the equations derived from the 2 instruments were within the range expected. Using the standard procedure in the WinISI software and by considering the Rockhampton instrument as the “slave” instrument and the Davies Laboratory instrument as the “master” instrument, an appropriate standard adjustment equation was calculated and applied to spectral data derived from the Rockhampton instrument. With this correction results from the Rockhampton instrument were very similar to the Davies lab instrument.

4.12 Development of a laboratory-based procedure for expanding F.NIRS calibration equations

4.12.1 Experiment 1

When the NIR spectra of the synthetic fibre bag residues were compared with the NIR specta of the respective faeces there were small but consistent differences. As expected from previously published work and from the nature of digestive processes in ruminants, the spectra from the synthetic fibre bags was much more similar to that of respective faeces than that of the respective feed. Also the largest differences were in the visible region of the spectra, and the differences were small in the NIR region. Nevertheless the differences were large enough to cause unacceptable data fits, as indicated by GH values, if the synthetic fibre bag residue spectra were predicted directly from a faecal calibration equation. A mathematical approach was successfully used to relate the faecal and synthetic fibre bag residue spectra. When this was done calibration equations with excellent error statistics were found for the 3 forages used in the experiment.

4.12.2 Experiment 2

This experiment examined a wide range of forages and established that use of synthetic fibre bag residues in lieu of faeces was more generally valid.

A short paper reporting the results of the 2 experiments (4.12.1 and 4.12.2) and outlining procedure by which digested forage residues were used as a proxy for faeces in faecal NIRS calibration equations was presented to the 12th Australian Near Infrared Spectroscopy Conference and is given in Appendix 9.

These experiments have established the 'proof of concept' that it is possible to use digested forage residues as a proxy for faecal samples as reference data values for F.NIRS calibration equations to measure attributes of diet quality such as crude protein and digestibility. The paper was well received at a specialist NIR conference well attended by current Australian and some overseas NIR experts; if there were any fundamental flaws in the concept then this audience would likely have identified them.

The importance of this experimentation is that F.NIRS calibration equations for diet CP and DMD can be expanded into new pasture systems, or be improved for pasture systems already examined, with a much lower cost of experimentation. The established approaches require animals to be fed in pens on harvested forages for sufficient time to obtain diet-faecal pairs, or the use of oesophageally-fistulated animals (Coates and Dixon 2007). Providing further experimentation supports the results of the 2 experiments reported herein, this as an important development for F.NIRS technology as it will make possible improvement and/or development of F.NIRS calibrations encompassing the diversity of pasture systems.

4.13 Using NIRS to measure morphological components of the ingested pasture diet

4.13.1 Experiment 1

The results for this experiment are given in Appendix 10 and formed a paper presented at the NIR2005 12th International Conference on Near-InfraRed Spectroscopy held in Auckland, New Zealand, in April 2005. In the experiment 346 samples of Rhodes, Green Panic and Buffel grasses were sampled, the leaf blade proportion measured by manual separation and NIR measurements made to develop and validate NIRS calibration equations. The leaf blade content of these tropical grasses could be measured with a SEP (standard error of prediction) of 6.2%, equivalent to a 95% confidence interval of 12.4%. This experiment demonstrated that, in a closed population, NIRS could be used to measure the proportion of leaf blade in harvested samples of tropical grasses with an error comparable with that of manual sorting and an error which would be acceptable for many experimental purposes.

4.13.2 Experiment 2

The results for this experiment are given in Appendix 11 and formed the project report of the student, Ms M. Vivant, for her home university (ISARA, Lyon, France). This experiment showed that in cut pasture samples containing a mixture of the leaf and stem of buffel grass, black speargrass and seca stylo, NIRS could be used to measure the proportions of each of the 3 plant species, of legume leaf, or of total grass leaf blade in mixed pasture material. The proportion of seca in seca-grass mixtures was measured with and SECV of 1.4%, the proportion of leaf with and SECV of 3.8%, and the proportion of a grass species in a mixture of the 2 species examined with an SECV of 4.7%. Although the proportion of total leaf blade in mixed pasture could be predicted satisfactorily, large error was associated with the prediction of the leaf blade content of the individual grasses.

4.13.3 Experiment 3

The results for this experiment are given in Appendix 12 and formed a short paper presented at the Northern Beef Research Update Conference in 2007. Satisfactory calibration equations could be developed for the 2 major grass species present, *Heteropogon contortus and Bothriochloa bladia,* with SEP values of 93 and 105 g/kg, respectively. This indicated that there was appreciable error associated with measurement of grass species proportion by NIRS, and likely only grass species comprising at least substantial proportions of extrusa could be measured. Grass leaf blade could be measured with comparable error. The proportions of stylo and of other dicot forbs could be measured with lower error than for grasses, with SEP of 44 and 38 g/kg, respectively. The experiment established that NIRS can be used to measure the plant species and morphological components present in oesophageal extrusa samples with error acceptable for many experimental purposes, and thus offers the opportunity to greatly reduce the tedious and skilled labour required for manual sorting of extrusa samples.

4.13.4 Experiment 4

The results for this experiment are given in Appendix 13 and formed a short paper presented at the Recent Advances in Animal Nutrition 2007 conference in The University of New England. This experiment involved the incubation of samples of the leaf or stem, or known proportions of leaf and stem, in synthetic fibre bags in the rumen. A calibration equation was developed to measure the leaf content of forages from NIRS analysis of the forages following rumen digestion, and thus in faeces. Results also indicated that the proportions of tropical grass species in the diet can be measured from NIRS measurements of faeces. These results, together with experiment 2 in section 4.13.2 establishing that synthetic bag residues could be used in lieu of faeces to predict diet attributes, indicates that the F.NIRS calibration equations can be developed to measure from faeces the proportions of the morphological components and classes of species of plants of the diet selected. With this approach of generating calibration samples as proxy faecal samples derived from digested forage residues it would be feasible to develop general F.NIRS calibration equations to measure the proportions of plant species, ands of morphological components such as leaf blade, in the diet selected by grazing animals.

4.14 Development of a decision support procedure for timing and quantity of urea supplements using F.NIRS outputs

Two major papers were developed to review the published literature on the responses of cattle in the northern Australian rangelands to supplementation with rumen degradable nitrogen. Urea is almost always the preferred source of rumen degradable nitrogen in such supplements. These papers are included as Appendices 1 and 2. It should be noted that the recently completed project NBP.331 (Dr Stuart McLennan, DPI&F, Animal Research Institute, Yeerongpilly)

'Improved prediction of the performance of cattle in the tropics' examined in detail the appropriateness and application of the decision support systems Grazfeed and CNCPS (Cornell Net Carbohydrate and Protein Systems) for tropical pastures in northern Australia. F.NIRS is the only technology currently available, or being developed, available to measure essential input variables for these and similar Decision Support Systems (DSS) for cattle grazing tropical pastures.

Appendix 1. A review paper 'The use of faecal NIRS to improve nutritional management of cattle in northern Australia' by RM Dixon and DB Coates was presented at the conference Recent Advances in Animal Nutrition in Australia held 11-13 July 2005 in the University of New England, Armidale. This is arguably the premier Animal Nutrition conference series in Australia, and is an excellent venue to present development in R&D in ruminant nutrition to an audience of scientists and technical representatives of the stockfeed industry. The paper provided:

- a review of F.NIRS technology with focus on how it has been developed in NIRS_Task_1 and the NIRS_Task_2 projects, building on the assumption that the reader can access the Coates (2004) Final Report of NIRS_Task_1 project for more detailed information of the F.NIRS calibration equations,
- a review of the effects of physiological state of the animal and supplementation on the predictions derived from current F.NIRS calibration equations,
- various procedures to use F.NIRS measurements to predict N deficiency in the animal,
- the physiological basis for using the ratio DM digestibility / crude protein content of the diet, as measured by F.NIRS, as an index of when cattle are likely to respond to urea supplements,
- the evidence, especially from NIRS_Task_2 experimentation, of the appropriate values for the DMD/CP index to indicate an animal response to urea supplements,
- use of the DMD/CP index as a measure of the amount of supplementary urea required in specific circumstances.

Appendix 2. This is a document which was prepared as a working paper to propose the DMD/CP ratio as an index of the responses of cattle to urea supplements. It was circulated among the staff working on the 3 NIRS projects for comment and feedback from the team members with a variety of backgrounds and roles both in the NIRS projects and in the northern cattle industry. This document developed the argument and the calculations for the DMD/CP ratio in considerable detail to allow the non-specialist in ruminant nutrition to understand the reasons behind and the use of the index.

4.15 Trials to generate diet-faecal pairs for faecal calibration equations

The generation of the diet-faecal pair samples for the 33 forage diets and 10 forage-concentrate diets measured made a substantial contribution to the array of forages used to develop the F.NIRS calibration equations. These comprised 20% of the 160 diet-faecal forage diet pairs generated for NIRS_Task_1. Furthermore they represented diets of native pastures from the northern speargrass pasture system and from the Mitchell grass Downs, diets containing mulga, and improved grasses at the peak of their summer nutritive value.

4.16 Reporting of research outcomes

- As discussed above the NIRS Task 2 project was conducted in conjunction with NIRS Tasks 1 and 3. Communication and reporting has usually been jointly with or through these other projects.

- Scientific audience:
    - Nutrition workshops amongst nutritionists working in the north (Appendix 3 is included in these).

  - Major paper presented at the Recent Advances in Animal Nutrition conference, Armidale, July 2005 (Appendix 2).
  - Paper presented at the NIR2005 conference in Auckland, NZ, April 2005. (Given in Appendix 10).
  - Paper presented to the 12th Australian Near Infrared Spectroscopy Conference, May 2006. (Given in Appendix 9).
  - 2 papers presented to the Australian Society of Animal Production meeting, CQ Sub-branch on 5th and 6th July 2005. (Given in Appendices 5 and 6).
  - Presentation on faecal NIRS technology to the Foss Pacific Directions 2006 Conference.
  - Short paper presented at the Australian Rangelands conference in Renmark, 3-7 September 2006. Coates, D.B., Dixon, R.M. and Sullivan, M. Using faecal NIRS to measure the proportion of grass in the diet selected by cattle grazing tropical pastures. In: *Aus`tralian Rangeland Society 14th Biennial Conference.* (Ed. Paul Erkelenz). pp. 110-113. (Appendix 14).
  - Presentation by David Coates at a Symposium in Nevada, USA. Coates, D. B. and Dixon, R. M. (2007). Faecal NIRS calibration for diet predictions. In: *Proceedings of a Symposium on the application of F.NIRS to the nutrition and physiology of rangeland herbivores, 60th Annual Meeting of the Society for Range Management*, 10-16th Feb 2007, Reno, Nevada, USA.
  - 3 short papers presented at the Northern Beef Research Update Conference, Townsville, March 2007 (Appendices 7, 8 and 12).
  - Major paper presented at the Recent Advances in Animal Nutrition conference, Armidale, July 2007 (Appendix 4).
  - Short paper presented at the Recent Advances in Animal Nutrition conference, Armidale, July 2007 (Appendix 13).
  - Scientific journal paper: Coates, D. B. and Dixon, R. M. (2007a). Faecal near infrared reflectance spectroscopy (F.NIRS) measurements of non-grass proportions in the diet of cattle grazing tropical rangelands. *The Rangeland Journal* 29, 51-63.

- Northern cattle industry. There has been extensive publicity, often by presentations by David Coates, during the last 7 years. In addition:
  - Major display at Beef 2003 in Rockhampton.
  - Major display at the Meat Profit Day in Longreach, August 2004.
  - Field Day at Brian Pastures Research Station, April 2004.
  - Field Days at Jericho, March 2005.
  - Meeting of the Duringa Landcare group, November 2004.
  - Presentations to the CQ Beef Research Committee.
  - Presentations to the Leucaena Network Committee.
  - Presentation to Longreach Pastoral College students in beef production.
  - Producer group visits to Swans Lagoon.
  - Number of media articles e.g. Qld Country Life.
  - ABC Radio interview.

5 Success in Achieving Objectives

5.1 F.NIRS measurement of diet quality and LW change of young cattle and breeder herds

5.1.1 Using F.NIRS to measure diet quality

Trials in which young cattle without supplements grazed a variety of pastures, LW was measured and diet quality predicted with F.NIRS, were made for a total of 39 herd-years during the 4 years of experimentation. These herds were in the northern speargrass (20 herd-years at Swans Lagoon (Ayr), 2 at Mingela (Charters Towers), 2 at Fletcherview (Charters Towers), Mitchell grass Downs (4 herd-years at Toorak (Julia Creek), 2 at Longreach Pastoral College, 1 at Richmond), southern speargrass (4 herd-years at Brian Pastures (Gayndah)), arid zone mulga association (Croxdale, Charleville) and Leucaena-grass pasture (3 drafts at Brian Pastures, Gayndah). Difficulties arising from low-rainfall years and drought were accommodated and results obtained for a greater number of herd-years than was scheduled in the original project workplan. In general the F.NIRS measurements of diet quality as crude protein content, digestibility and non-grass proportion, were consistent with established knowledge of the diet selected by cattle in such environments, the pattern and sequence of rainfall events, and the performance of the cattle. The results provide a unique description of the seasonal changes in the diet selected by cattle grazing a range of pastures in northern Australia. An unexpected observation was the importance of the dicotyledonous forbs in native pasture to maintain diet quality, particularly diet protein concentration, through the dry season even when the pastures were completely senesced. This was particularly important for Mitchell grass pastures in years when forbs often constituted an appreciable proportion of the diet through the dry season. These results provide strong evidence that F.NIRS technology does provide reliable and acceptably accurate information of the quality of the diet selected by cattle in most northern grazing systems.

There were two pasture situations in the present experiments where F.NIRS appeared to be less reliable to predict diet quality. The first such situation was where cattle were grazing Leucaena-grass pastures at the Brian Pastures site and up to 35% of the faecal samples were identified as spectrally dissimilar to the faecal samples in the Coates (2004) calibration data sets for diet CP and DMD. This particularly seemed to occur when the proportion of Leucaena was high. The Coates (2004) data sets contained only 5 diets containing Leucaena. Examination of the internal prediction of these Leucaena diets within this calibration data set indicated that the measurement of diet CP and DMD was acceptable. As discussed previously (section 4.3 above) the spectral dissimilarities are likely associated with the limited number of diets containing Leucaena included in the data set used to calculate the calibration equations. The second situation where F.NIRS predictions of diet CP and DMD may have been less reliable was where the cattle were grazing arid zone Mulga shrublands. At the Croxdale site a substantial (12-27%) part of the diet selected consisted of non-grass, and from observation, knowledge of Mulga grazing systems and the faecal N concentrations, this non-grass component appeared to consist principally of mulga browse. Such browse contains high concentrations of condensed tannins which would severely reduce the availability of the protein in the diet. As with the Leucaena diets, these circumstances were acknowledged when the present project was being planned, but addressing them was considered beyond the scope of the present project. A calculation procedure was developed to correct for the low availability of dietary protein in browse diets (Appendix 2).

5.1.2 Using F.NIRS to measure liveweight change

Prediction of animal growth rate is obviously a highly desirable and much sought objective of livestock scientists, animal nutritionists and livestock managers. It is a particularly difficult objective in ruminants grazing in extensive systems such as the seasonally dry tropics where nutrient intake is usually not known, environmental factors may have major impacts, and change in liveweight sometimes deviates markedly from change in body energy reserves of the animal.

Even if F.NIRS technology could measure protein and ME intake of the grazing animal with only small errors, there would be potentially substantial errors from other sources. A further consideration is that since F.NIRS involves analysis of the undigested residues of the diet along with undigested micro-organisms and some endogenous inputs in faeces, it seems likely that the F.NIRS measurements are primarily representative of the diet and that there is limited opportunity to incorporate the effects of animal or environmental factors which influence intake. Principles of NIRS, and also some experimental evidence, suggest that the characteristics of faeces being measured in F.NIRS relate primarily to the undigested plant material in the diet. This is not absolutely true, since it has been demonstrated that F.NIRS can be used to determine gender and animal species in deer (Tolleson *et al.* 2005), and pregnancy status and parasite burden.

Numerous studies have demonstrated that NIRS analysis of faeces (i.e. F.NIRS), as well as NIRS analysis of forages, can measure the DM digestibility of forage diets in ruminants. A premise underlying the development of such F.NIRS calibrations is that the fractions of dietary forage which can be digested in the gastrointestinal tract of ruminants are closely associated with the NIR spectral characteristics of the undigested fraction. However, it is important that NIRS calibration equations are simply empirical partial least squares relationships (or multiple regressions or other comparable mathematical approaches) between the spectra of faeces and the measured reference values, such as in this case DM digestibility. It follows that similar empirical relationships are likely between the NIRS spectra of faeces and any characteristic correlated with DM digestibility. Therefore, since voluntary DM intake of forage diets is generally correlated with DM digestibility, it is not unexpected that it may be possible to develop F.NIRS calibrations for DM intake. Further, since ME intake is a function of DM intake and DM digestibility, and animal liveweight change is broadly a function of ME intake for a given type of animal, it is not unexpected that that it may be possible to develop F.NIRS calibrations for ME intake and LW change, at least for a given type of animal consuming forage diets. A similar sequence of correlation relationships likely explains the observation of Gibbs *et al.* (2004) that F.NIRS calibrations could be developed to measure urinary purine derivative excretion; this latter variable will be correlated with ME intake.

Fundamentals of ruminant nutrition indicate that the correlations between DM digestibility, DM intake, ME intake and LW change are primarily applicable to animals in a specific physiological state and set of circumstances. This led Coates (2004) to limit the F.NIRS calibration data set for LW change to an animal model consisting of a young growing *Bos indicus* type animal consuming tropical forage, and as far as possible in the absence of factors which would constrain animal growth other than diet DM digestibility and diet crude protein content (see Section 4.1.10). Such factors which would be expected to affect animal growth include disease, parasites, nutritional deficiencies such as phosphorus, supplements, compensatory growth, pregnancy and lactation and pasture DM on offer. Also, as discussed in Section 4.1.10 the Coates (2004) calibration equations cannot be expected to correctly predict LW change in animals of greater maturity, in late pregnancy and lactation, or being fed supplements. This hypothesis was substantiated in the present Task_2 studies. A further consideration is that if, as discussed, the F.NIRS calibrations for LW change are defacto calibrations for ME intake, any factors which cause a disassociation between ME intake and LW change will be expected to cause error in the F.NIRS prediction of LW change. As discussed extensively in Appendix 3, during some phases of the annual cycle in the seasonally dry tropics grazing cattle will often undergo large changes in digesta load and large changes in body energy content per unit of body tissue, and short-term increases in voluntary DM intake during the wet season due to compensatory growth. These changes will be expected to cause abberations.

Given the potential sources of error in a F.NIRS calibration for LW change it is perhaps surprising that any calibration relationship exists. It appears that the F.NIRS calibrations for LW change are more specific for the pasture system than are the calibrations for diet quality, and this may be a consequence of the great variety of factors other than diet DM digestibility which potentially affect

LW change. There is an important potential advantage to use of direct F.NIRS calibrations for LW change, rather than prediction of DM digestibility by F.NIRS and then application of SCA (1990) or similar approaches to calculate ME intake and LW change. It is well known that voluntary intake of tropical grasses is strongly influenced by the leaf-stem ratio of the forage independent of DM digestibility, and also by the N content of the forage when N is deficient (Minson 1990). Observations that both leaf-stem ratio and N content of the forage can be measured by F.NIRS established that there are spectral characteristics of faeces which represent these aspects of the forage. F.NIRS calibrations which directly predict DM intake, ME intake, or LW change would encompass these characteristics of the forage diet other than DM digestibility, and therefore should provide more robust measurement of animal performance. However, with the calibration equations presently available, when the two approaches to predict ME intake were compared in the breeder experiment at Swans Lagoon (Dixon et al. 2007, Appendix 3) there did not seem to be any unequivocal advantage of one approach over the other. More experimental information is needed.

Two characteristics of the F.NIRS calibrations for LW change in the present studies are of particular interest. First, inclusion of only a few faecal samples from the specific site and pasture system often improved the calibration substantially. This was most evident for the Leucaena-grass pasture site where the LW change predictions from the general Coates (2004) adg1441 calibration had a large bias error, but the bias was greatly reduced by inclusion of results from any 2 drafts into the calibration to predict the third draft. This phenomena of high specificity of NIRS calibrations to a particular situation, but a requirement for only a small number of local samples to substantially improve an existing calibration, is often observed in NIRS technology (e.g. with fruit and grains). Second, the SEP's of the F.NIRS calibrations for DWG were generally in the range from about 240 g/day for the speargrass pastures such as at Swans Lagoon and Brian Pastures, to about 400 g/day for the Leucaena or Mitchell grass pastures. The 95% confidence interval for prediction can be calculated as about ± 2*SEP. Even with the smaller SEP above, the error of prediction of LW change from the F.NIRS calibration is quite large with a 95% confidence interval of ± 480 g/day. However, when a sequence of F.NIRS measurements are made the error will be expected to decrease by as much as $1/\sqrt{n}$. Since sequential measurements in a mob of cattle will not be strictly independent samples the decrease in the SEP may not be as great as $*1/\sqrt{n}$, but nevertheless this should be indicative of the decrease in error. In the absence of bias the error associated with calculation of cumulative predicted LW from a sequence of F.NIRS measurements will be expected to be lower than the prediction of apparent DWG from a single faecal sample. This explains why for most of the sites of the present studies the cumulative predicted LW was closely correlated with the measured LW, with $R^2 \geq 0.94$ and slopes approaching the ideal 1:1 relationship. The greatest difficulties occurred with the Mitchell grass site at Toorak and the Leucaena-grass pastures at Brian Pastures. Also, as discussed elsewhere above, a substantial part of the error in measurement and prediction of DWG and of cumulative predicted LW was likely also associated with changes in digesta load, body energy content and compensatory growth in the late dry season and the early wet season.

In the northern speargrass the annual liveweight (LW) gain of young animals calculated from the initial LW and frequent F.NIRS measurements of LW change, were generally similar to the measured animal annual LW gain, and the pathways of actual and F.NIRS predicted LW were also generally similar. The greatest deviation between the measured and the predicted LW appeared to occur in the late dry season, and may have been due principally to the well-known effect that, during under-nutrition, the decrease in animal LW often seriously under-estimates the decrease in body energy reserves of the animal. However, at each of the other sites the predicted LW pathway of the animal deviated appreciably from the measured LW during at least some intervals. The differences between sites in the magnitude of the errors likely reflects the origin of the data sets which were used to develop the F.NIRS calibration equations for animal LW change. Most of the 1157 reference value measurements used to construct the Coates (2004) general adg1441 calibration equation for LW change were derived from the northern speargrass region of north Queensland, with a minority drawn from Mitchell grass Downs, buffel grass or other pasture systems. It was therefore not unexpected that the calibration equation should be most reliable in the variety of pastures (including sown grass-legume pastures) growing in the northern speargrass and *Aristida-Bothriochloa* pasture regions, less reliable for other tropical grass pastures, and even less reliable when used to predict in a very different system such as Leucaena-grass pastures. The specificity of NIR calibration equations to the samples similar to the sample sets used for their construction is a well-known phenomena of NIR technology.

There is no evidence that the errors in prediction of LW change were due to any fundamental limitation of F.NIRS technology, and with the development of appropriate data sets the F.NIRS predictions are likely to be reliable for all of these pasture systems.

5.1.3 Application of F.NIRS to breeder herds

The monitor herd of breeders at Swans Lagoon demonstrated the application of the F.NIRS technology to this class of animal. The F.NIRS measurements of diet quality (crude protein content, digestibility, non-grass proportion of the diet) are applicable to the breeder as well as to the growing animal, and can be used in the same manner to indicate whether there are likely to be nutritional deficiencies such as rumen degradable N. The F.NIRS predictions of LW change provide a direct estimate of the LW change of the non-pregnant and non-lactating (NPNL) cow in the northern speargrass environment. The accuracy and reliability of prediction of LW change of NPNL breeders in other environments is likely to be comparable to that for the young growing steer. Clearly the breeder in late pregnancy and in lactation has greatly increased nutritional demands for these reproductive functions, and application of the F.NIRS measurements of LW change to the reproducing cow requires adjustment. As these additional nutrient demands of late pregnancy and lactation can be expressed with acceptable accuracy as an equivalent effect on the LW of the breeder, LW change of the lactating cow can be predicted. As discussed in section 4.1.10 above it would be possible to develop calibration equations to measure LW change of animals in physiological states other than the young growing animal (e.g. such as the lactating breeder), but given the resources which would be required this does not appear practical. Knowledge of the current nutrition of the cow and, from body condition score, the current body energy reserves, allows decisions on whether management interventions are needed for the breeder to achieve target body condition scores at various times in the future and thus achieve productivity appropriate to the region as described by Dixon (1998).

5.2 Accuracy and reliability of F.NIRS to predict cattle responses to N supplements

5.2.1 Using F.NIRS to measure diet quality in cattle fed supplements

It is clear that F.NIRS predictions of diet attributes developed with cattle fed forage-alone diets as described by Coates (2004) cannot always be applied directly to predict mixed forage – concentrate diets. The evidence for this is discussed comprehensively by Dixon and Coates (2005) (Appendix 1). However, when loose mineral mixes containing urea, minerals, and small amounts of protein meal are fed as supplements to forage they have no discernable effect on the F.NIRS measurements of the attributes of the dietary forage. Since the composition and intake of the supplement is usually known, with estimates of forage intake the attributes of the total diet (i.e. forage + supplement) can be calculated.

Molasses-urea supplements can be fed at up to about 2.3 g supplement DM/kg animal LW, or 10% of the diet (equivalent to about 900 g as-fed molasses for a 300 kg animal) before F.NIRS predictions are affected by the molasses component of the diet. Even small amounts of cereal grain and protein meal supplement (1.5 g DM/kg LW) fed daily can affect F.NIRS predictions. However where supplements are given infrequently, faeces sampled at least 48 h after the last meal of supplement provide a reliable F.NIRS measurement of the forage component of the diet. This is presumably because this delay is sufficient for undigested feed residues derived from the supplement to have passed through the gastrointestinal tract. Thus, where supplements are fed infrequently, as is usually the situation in northern grazing systems, F.NIRS measurements of the quality of the diet selected can be readily obtained.

5.2.2 Using F.NIRS measurements to predict animal responses to inorganic nutrients

F.NIRS is particularly appropriate for identification of rumen degradable N (RDN) status of the diet. NIRS is generally not an appropriate technology for measurement of minerals such as P, S or Na, and the measurement of the status of these nutrients must be estimated from other criteria (e.g. soil, plant or animal tissue). F.NIRS does have a role in evaluations of the status of such nutrients since an animal response usually also depends on adequacy of supply of metabolizable energy and protein supply.

A number of options for evaluating when an RDN deficiency is likely are discussed in Appendix 1 and 2. The most practical appears to be the DMD/CP ratio calculated from the F.NIRS measurements of DM digestibility and diet crude protein content.

Nutritional principles dictate that a response to supplementary RDN (e.g. as urea supplement) is a function of the availability in the rumen of RDN relative to the supply of energy for microbial fermentation. Past experimentation suggests that an animal response to RDN is likely when the DMD/CP is about 8, although a range of values from 6 to 12 have been proposed (Appendix 1 and 2). Because the supply of RDN in the rumen will be a function of a number of processes which are difficult to predict quantitatively, adoption of the DMD/CP ratio as a criterion also depends on empirical evidence of when animal responses occur in specific pasture systems.

Since the DMD/CP ratio provides a measure of the magnitude of a deficiency in RDN in the rumen, it also provides an indicator of the amount of urea supplement required in specific situations (Appendix 1).

5.2.3 Evidence for the DMD/CP criterion from the current project

Results from 5 sites of the current project contributed information on the DMD/CP value above which animal responses to urea supplements are likely.

The most comprehensive data is from the replicated trial at Toorak where responses to N supplements were examined in 3 drafts of steers over 3 years (section 4.1). In draft 1 the DMD/CP was >12 from the first measurement in early September until November, although the seasonal break did not occur until mid-December (Figure 4.1.7). A benefit of LMM urea supplements on the animals, as alleviation of LW loss, was observed from October during the late dry season until the seasonal break. In drafts 2 and 4 (supplements could not be fed through draft 3) a LW benefit to feeding LMM supplement was not observed until October even though the DMD/CP was usually in the range 9-11 from April through until the seasonal break. The diets selected by these drafts of steers were high in forbs. Thus, it appears that when forbs, even if senesced, constitute a substantial part of the diet, a higher DMD/CP is required for animal responses to RDN supplements to occur. A similar situation appeared to occur at the Longreach Pastoral College (section 4.9) and Morungle (section 4.5) sites on Mitchell grass where for both drafts measured forbs also comprised a large proportion of the diet; DMD/CP was generally in the range 9-11 on the Longreach Pastoral College site, but there was no effect of the N supplements on LW gain of the cattle.

Three sites in the northern speargrass (Forest Home and Fletcherview, Swans Lagoon; sections 4.2, 4.7 and 4.8) also provided information on the DMD/CP at which animal responses to supplementary RDN are likely.

At the Forest Home site large animal LW responses to urea supplement occurred when the DMD/CP was greater than about 10 (Appendix 1). No supplements were fed during the present trials at the Swans Lagoon site, but previous comprehensive experimentation (Winks *et al*. 1979) has indicated that at this site urea supplementation responses occur when the faecal N concentration declines to < 1.3% N. This appeared to coincide with a DMD/CP of about 8.5 in the present trials. At Fletcherview, near Charters Towers, there was little evidence of a LW benefit due to urea supplement even though the DMD/CP was greater than 9, and often between 10 and 12, for extended intervals during the dry season (Figure 4.8.1). This appears inconsistent with the Forest Home and Swans Lagoon results. Possibly animal responses to supplementary RDN occur at higher DMD/CP on buffel grass pastures than on speargrass or *Bothriochloa pertusa* pastures. We speculate that as a selected and improved grass species limited to relatively high fertility soils, buffel grass when senesced may contain a greater proportion of the N in a rumen degradable form than many other grass species at the same stage of maturity; this would lead to a greater availability of RDN relative to fermentable energy. A further consideration is that *Bos indicus* cattle have a greater ability than *Bos taurus* cattle to conserve endogenous N, and this would presumably lead to a higher threshold value for the DMD/CP ratio at which the former species will respond to RDN supplements. The cattle in the Fletcherview and Forest Home trials were high-grade *Bos indicus*, whereas those in most of the other sites were *Bos indicus* cross.

In conclusion, although more information is needed to determine the DMD/CP value at which animal LW responses to RDN supplements occur in various circumstances, the DMD/CP provides a valuable and objective criterion based on known principles of ruminant nutrition and F.NIRS measurements on when to provide RDN supplements.

5.2.4 Comparison of urea and protein meals as N supplements

In the Toorak trial the effectiveness of a urea-based LMM supplement was compared with a protein meal, CSM, as N supplements. It was expected that the animal response to the LMM supplement would be lower than to the CSM supplement due to a number of nutritional inefficiencies in the utilization of urea N as a source of RDN in the rumen. In Draft 1 the animal LW response was considerably lower for the LMM supplement (20 and 39 kg LW benefit in the younger steers at the time of the seasonal break), but the voluntary intake of N from the LMM supplement was only about half that from the CSM. For Drafts 2 and 4 intakes of supplementary N, and animal responses, were comparable for the LMM and the CSM supplements during the early and mid dry season although the intake of supplementary N from LMM was much greater than from CSM during the late dry season when the animal responses occurred. The animal response to the LMM supplement appeared to be greater than that to the CSM supplement in Draft 4, but the responses were similar in Draft 2.

Thus it appeared that when low amounts of N supplement, which would be expected to increase the crude protein content of the total diet ingested by grazing cattle by 2-4%, it was not important whether the supplementary N was provided as urea or protein meal. The lower-cost LMM supplement was equally effective although there are often management difficulties to achieve appropriate intakes of supplementary urea while avoiding urea toxicity.

5.3 Set up of the NIRS instrument in Rockhampton, expansion of calibration equations and measurement of plant components

5.3.1 An F.NIRS laboratory was set up in Rockhampton and calibration equations transferred.

5.3.2 Development of a laboratory-based procedure to expand F.NIRS calibration equations

A procedure was developed to use synthetic fibre bag residues in lieu of faeces to expand F.NIRS calibration equations. Widespread use of this technique will depend on acceptance by NIR spectroscopists of the validity of the mathematical manipulations required.

It is not envisaged that such a procedure will replace the need for experiments with pen-fed or OF animals to generate diet-faecal pairs, but should allow reduction in the number of diets measured in such trials and reduce the errors associated with F.NIRS measurement.

5.3.3 Using NIRS to measure morphological components of forage and plant species in the diet

It was shown that NIRS can be used to measure the morphological components and species composition of samples of tropical pastures and thus greatly reduce the cost of this key measurement for pasture research. Also 'proof of concept' was obtained that F.NIRS calculations can be developed to measure the leaf-stem content of a forage diet, and the major plant species present in the diet. Progress was made in the development of F.NIRS calibrations to make these measurements.

5.4 Reliability with which F.NIRS can be used to improve decision support systems

Prediction of the animal response to supplements providing metabolizable energy and undegraded dietary protein as well as RDN (e.g. molasses-urea, protein meals, cereal grains) is far more complex than prediction of responses to RDN. Clearly a multiplicity of factors are involved which influence, or potentially influence, intake and digestion of the forage and thus metabolizable energy intake and the efficiency with which nutrients are used for maintenance, LW gain and synthesis of milk or foetal tissues. The principal role of F.NIRS is likely to be to measure the quality attributes, and indirectly or directly the voluntary intake, of the forage component of the diet.

A simple approach to predict animal responses to supplements is to adopt efficiency ratios for the conversion of supplement to LW gain based on experimentation with comparable cattle and forages. In the comprehensive series of experiments of McLennan and colleagues (MLA projects DAQ.100 and NAP3.122) the effects of various amounts of a range of supplements on LW change of young *Bos indicus* cross cattle fed tropical hays has been examined. The conversion ratio of a protein meal supplement such as cottonseed meal to additional LW gain was generally between 3:1 and 6:1. The conversion ratio of cereal grain to additional LW gain seems to be more variable but is likely to be in the range 7:1 to 10:1. Cheffins (1996) has compiled a comparable set of estimates of the LW gain response to supplementation with cereal grain or protein meals. In this context the role of F.NIRS is likely to be to indicate whether an RDN response is likely, and the digestibility and potential voluntary intake in the absence and presence of supplements.

The more comprehensive approach to predicting the animal response to concentrate supplements will be to use Decision Support Systems such as Grazfeed, CNCPS or NUTBAL. The use of such Decision Support Systems for cattle grazing tropical pastures, and the strengths and weaknesses of the various packages, was addressed by the recent MLA project NBP.331 (Improved prediction of the performance of cattle in the tropics, Dr S R McLennan). This project focussed on the Grazfeed and CNCPS packages, and concluded that the underlying equations of both of the Decision Support Systems were sound but there were serious difficulties with prediction of voluntary pasture intake. We have found the same difficulty with application of results from the present project to the NUTBAL package of Stuth and colleagues. It appeared that voluntary intake of pasture predicted by NUTBAL from inputs of the animal description and F.NIRS measures of diet quality was much lower than the actual pasture intake, and these intakes could only be reconciled by arbitrary adjustment of correction factors (such as for intake) within the model. Presumably these difficulties arise with all the Decision Support Systems described above because the digestibility – voluntary intake relationships used to calculate voluntary pasture intake are derived primarily from temperate forages and are less applicable to tropical grass forages.

The poor relationship between digestibility and voluntary intake and the importance of leaf content in determining voluntary intake of tropical grass forages are well known (Minson 1982).

F.NIRS is likely to be able to contribute as an input to the Decision Support Systems in 2 fundamental ways. Firstly F.NIRS provides a means to measure dietary digestibility and crude protein directly rather than having to estimate them from visual evaluation of the pasture. Secondly it is likely that F.NIRS can be used to improve estimation of the voluntary intake, or the potential voluntary intake. Coates (2004) developed calibration equations to predict voluntary forage intake in penned cattle. In addition, prediction of the voluntary intake of pasture is implicit in the existing F.NIRS calibration equations to predict LW change of an animal, as LW change must primarily be a function of metabolizable energy intake, and therefore of digestibility and forage intake. The satisfactory F.NIRS prediction of animal LW change, even at high stocking rate when sometimes little pasture was available at the Swans Lagoon site in the present trials, also supports the hypothesis that voluntary pasture intake can be measured in at least some circumstances even when the amount of pasture on offer is limiting. It is clear from the present experimentation that the leaf content of tropical grasses, both as presented to the animal or after extensive rumen fermentation, can be described by NIRS calibration equations. It is therefore appears likely that the information to measure the leaf content of the tropical grass forage ingested can be determined in faecal NIR spectra, and thus allow F.NIRS to measure the voluntary intake of tropical forages with lower error than is presently possible.

6 Impact on Meat and Livestock Industry – now & in five years time

The principal impact of the NIRS Task 2 project will occur by two pathways.

First, the present project has contributed substantially to the development of F.NIRS as a reliable technology to measure the nutrition of grazing cattle in R&DE conducted primarily for other purposes. Examples of current interest include (i) understanding of the emissions of methane, and manipulation thereof, depends in large part on measurement of the diet selected by grazing cattle, (ii) improved management of both native and sown pastures requires understanding of the diet selected , and (iii) nutrition as a constraint to growth and breeder herd productivity.

The second major pathway of impact of the present project is by examining and demonstrating the strengths and weaknesses of F.NIRS technology in grazing cattle in a diversity of northern grazing systems, it is now much clearer where and how F.NIRS can be used for cattle management on commercial properties. It has provided some of the essential components of the information package needed for F.NIRS technology to be used by the northern cattle industry. As described in Sections 1 and 2 above, the contribution of Task 2 has been in testing, validating and demonstrating the application of F.NIRS technology across a range of environments and doing so under the rigorous conditions which are generally only possible in a research station environment.

F.NIRS is undoubtedly a major technical breakthrough as it provides the technology to measure and understand the nutrition of grazing herbivores. The importance of F.NIRS is not simply the development of a suitable technique to measure the nutritional value and other attributes of the diet selected by the grazing animal. The principal importance of F.NIRS is that it provides an objective, simple and economical measure of the nutrition obtained from pasture by the grazing animal. With this information it becomes possible for the scientist and the cattle manager to apply to grazing cattle, in a manner never previously possible, the vast knowledge of the science of quantitative nutrition which has accumulated over decades. In the past a major problem has always been that the baseline nutrition from pasture has been difficult, expensive and inaccurate to measure under research conditions, and impossible to measure under commercial property conditions. Therefore the calculation of nutrient intake of grazing animals was merely an educated guess, while calculation of the expected response of animals to changes in nutrition inherently contained large errors. These errors and uncertainties would usually far outweigh the errors associated with the estimates, based on knowledge of the nutrition and physiology of cattle, of the requirements and the responses of the animal to nutrients. A comparison is with the cattle feedlot, pig or poultry industries where an exact knowledge of the diet consumed by animals in pens allows precise adjustment of the diet for maximum economic advantage and for manipulation of product characteristics. F.NIRS to understand the pasture diet selected is particularly important to the northern Australian cattle industry, as estimation of the diet selected by grazing animals is more difficult with tropical rather than temperate pastures, with low stocking density, with the heterogeneity of large paddocks of native pastures, and patch grazing effects.

The following research outcomes of the NIRS_Task 2 project are likely to have a major impact during the next 5 years on the use of F.NIRS by northern cattle industry:

(i) Generation of ‘hard’ and reliable information on the ability of F.NIRS to measure the quality of the diet and the liveweight change of cattle in a range of diets across northern Australia. It is clear that F.NIRS estimates are reliable for diet quality across most pasture systems, but is less reliable for an unusual system such as Leucaena-grass pasture. Similarly, predictions of LW change appear reasonably reliable for many northernpasture systems and especially for speargrass, but are not reliable for Mitchellgrass pastures. Calibrations for prediction of cattle grazing Leucaena-grass pastures need to be further developed before they can be applied generally.

(ii) Development and demonstration of how F.NIRS can be used with breeder herds.
(iii) Development of the DMD/CP ratio as a criterion of when animals are likely to respond to urea-based supplements.
(iv) The responses which can be expected on Mitchell grass pastures to urea supplementation, and the relative values of urea and protein meal supplements.

The following research outcomes of the NIRS_Task 2 project are likely to have a major impact during the next 5-10 years on the role of F.NIRS technology for the northern cattle industry, its development for other environments (e.g. temperate pastures) and other animal species (e.g. sheep), and as an important enabling technology for all R&D with grazing animals where nutrition is important to the animal performance:

(i) Development of a F.NIRS laboratory in Rockhampton means that continuation of this technology in Australia is not completely dependent on one laboratory and one key scientist (Mr David Coates).

(ii) The development of a laboratory-based procedure to expand F.NIRS calibration equations (other seasons, other pasture species) provides a method for improvement and progress in F.NIRS at a fraction of the costs for feeding animals in pens or using OF animals.

(iii) The development of NIRS technology to measure leaf content of pastures and of rumen-digested pastures provides a tool to improve measurement of voluntary intake of pasture. These are key parameters of pasture controlling voluntary intake.

(iv) With development of F.NIRS to measure diet quality, the principal constraint to the development of improved decision support systems for cattle grazing tropical pastures is now likely to be the estimation of forage intake. The digestibility – voluntary intake correlations used for temperate pastures appear to be less satisfactory for tropical pastures, perhaps because voluntary intake is more often limited by physical constraints of access and breakdown and RDN deficiency.

7 Conclusions and Recommendations

7.1 Conclusions

The NIRS_Task_2 project achieved all of its major objectives. In a series of trials F.NIRS measurements in herds of growing cattle for up to 4 years and across a range of pasture systems (39 herd-years of data) showed that F.NIRS measurements were generally consistent with previous knowledge of the diet selected by cattle in these pasture systems. Also measurements of LW change in these herds contributed substantially to the F.NIRS calibration equations for growth rate reported for the NIRS_Task_1 project. In the Mitchell grass downs pastures of NW Qld large animal responses were observed to nitrogen supplements when there was abundant senesced *Astrebla spp* grass pasture available. Following low rainfall wet seasons when pasture availability was low and native forbs comprised a substantial proportion of the pasture that was present, F.NIRS measurements indicated that diet quality was maintained through the dry season and animal LW responses to nitrogen supplements were smaller or absent. F.NIRS predicted these responses. The DMD/CP ratio, calculated from the F.NIRS measurements, was developed as a criterion of the likely response of cattle to rumen degradable nitrogen supplements. A method to apply F.NIRS to breeder herds was tested and demonstrated with a small herd in the northern speargrass. An NIRS instrument was set up for F.NIRS analysis in Rockhampton and faecal calibrations, with appropriate corrections, transferred to this instrument from the instrument in Davies Laboratories, Townsville. NIRS was developed to predict, from samples of pasture and from faeces derived from that pasture, the leaf component and to a limited extent the plant species components, of tropical pastures. 'Proof-of-concept' was established that it is possible to use a laboratory-based method (i.e. forage residues following rumen digestion) as proxy faecal samples to expand F.NIRS calibration equations cost-effectively and to include forages which it is not practical to feed to cattle (e.g. forbs which are a minority component of pastures). The project also provided major support for the NIRS_Task_1 project by conducting trials to provide diet-faecal pairs for faecal calibration equations to predict diet characteristics, and for the faecal calibration equations for animal LW change.

F.NIRS is a major technological advance for understanding and manipulating the nutrition of cattle grazing in extensive rangelands such as those of northern Australia. However, as the Conclusions & Recommendations of the Final Report of project NIRS_Task_1 (Coates 2004) also emphasise, F.NIRS provides only one aspect of the information (i.e. knowledge of the quality of the diet selected by the grazing animal) needed to understand, manipulate and improve the nutritional management and productivity of cattle grazing the rangelands of northern Australia. Other essential information which is needed includes: (i) the nutritional requirements of the animal in the range of specific circumstances which will be encountered, and (ii) the responses of the animal to provision of limiting nutrients. Before the advent of F.NIRS technology, the quantity and quality of the diet ingested by cattle grazing in rangelands was at best an ‘educated guess’. Without knowledge of the quantities of various nutrients obtained by the grazing animal from the pasture there was little point in refinement of knowledge of the nutrient requirements of the animal or the responses of the animal to limiting nutrients. The ability of F.NIRS to make reasonably precise and accurate measurements of the quality of the diet ingested by the grazing animal means that it is now important and valuable to know with precision these other aspects of the nutrition of the grazing animal (i.e. nutrient requirements and responses to nutrients). The ability of F.NIRS to measure the quantities of nutrients ingested (i.e. quality of the diet * voluntary DM intake) is more limited and subject to much larger error than application of F.NIRS to measure diet quality. Satisfactory prediction is presently limited to pasture systems in NE Qld from where the majority of the data sets to develop LW change calibrations were developed. There is probably no biological reason why satisfactory calibrations for DM intake, ME intake and LW change could not be developed for other pasture systems and regions.

Irrespective of constraints in use of F.NIRS to directly predict DM intake and ME intake, these intakes can be calculated using well established procedures and the diet DM digestibility measured with F.NIRS. Even without a capacity of F.NIRS to directly measure ME intake, F.NIRS is a major advance in the nutritional management of grazing cattle in the seasonally dry tropics.

It should also be considered that, compared with conventional forage analysis and investigation of cattle nutrition and production, F.NIRS is still a novel and emerging technology. Thus the established knowledge and experience in F.NIRS is miniscule compared with that available for conventional technologies. Knowledge in F.NIRS depends almost entirely on the outputs of two small teams of scientists led by Prof Jerry Stuth and Mr David Coates over only 15 years. Arguably it should be possible to develop F.NIRS technology to obtain as much nutritional information from the faeces of grazing cattle as is presently possible to obtain from analysis of forage by established analytical or animal procedures. This is an ongoing challenge. Meanwhile consideration of F.NIRS should include cognizance that it is a technology in the early stages of its development.

7.2 Recommendations

F.NIRS is still a novel and emerging technology where, compared to investigation in conventional feed analysis or in cattle nutrition, the established knowledge, experience and R&D effort has been miniscule. That F.NIRS has developed only in the last 2 decades is most obviously a consequence of the relatively recent development of NIR instrumentation suitable for routine analysis, the appreciable cost of the instrumentation, and the high level of expertise required to maintain NIR spectrometers and to conduct the associated chemometrics to correctly analyse the spectral data. Future developments in F.NIRS require consideration of the presently small information base in the technology. Research in other animal industries suggests that there are many potential applications for beef cattle production which have not as yet been explored.

It is recommended that further R&D be undertaken to take full advantage of the existing F.NIRS technology and to develop it further. In particular it is recommended that R&D resources be invested in the following activities:

(i) Support for the maintenance and ongoing validation of F.NIRS calibration equations, and the necessary skill base. Calibration maintenance is a necessary aspect of NIRS. This will require access to samples from appropriate cattle experiments conducted for other reasons, resources for NIRS analysis, and for the conduct of animal experiments to generate diet-faecal pairs and for growth performance.
(ii) Further develop F.NIRS calibration equations for pasture systems not adequately represented in current equations. There is limited data for many pasture systems, including Mitchell, buffel, Leucaena, arid zone and improved pastures. Browse diets, and the effects of the condensed tannins present in many browses, need to be addressed.
(iii) Experimentation to more closely determine the diet DMD/CP ratio at which cattle response to urea supplements under various circumstances and pasture systems.
(iv) Further develop F.NIRS calibration equations and their application to predict animal responses where molasses, protein meal and cereal grain supplements are fed.
(v) Develop F.NIRS technology to measure the plant species and plant components which grazing cattle select from the pasture to improve understanding of the impacts of grazing cattle on rangeland vegetation.
(vi) Develop F.NIRS to measure metabolizable energy intake of grazing cattle.

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9 Appendices

9.1 Appendix 1. List of abbreviations

B..TT	Paddock B of the Tick Trial paddock series at Swans Lagoon Research Station. Low fertility soil with native pasture grazed at moderate stocking rate.
C..TT	Paddock C of the Tick Trial paddock series at Swans Lagoon Research Station. Low fertility soil with native pasture grazed at high stocking rate.
CP	crude protein
CQU	Central Queensland University
CS	Body condition score (of cattle)
CSM	cottonseed meal supplement
Delta (δ) C	Ratio of $^{13}C/^{12}C$ stable isotopes in plant material
DM	dry matter
DMD	dry matter digestibility
DMD/CP	ratio of diet *in vivo* DM digestibility to diet CP content
DNR	Department of Natural Resources (Queensland)
DPI&F	Department of Primary Industries and Fisheries (Queensland)
E..LH	Paddock E of the Leichhardt paddock series at Swans Lagoon Research Station. Moderate fertility soil with native pasture grazed at moderate stocking rate.
F..LH	Paddock F of the Leichhardt paddock series at Swans Lagoon Research Station. Moderate fertility soil with native pasture grazed at high stocking rate.
F.NIRS	Faecal near infrared reflectance spectroscopy
GH	Global H value
LH	Leichhardt Trial paddock series at Swans Lagoon Research Station
LMM	loose mineral mix supplement
LW	liveweight of animals
LW∆	liveweight change of animals
MCP	microbial crude protein
M8U	molasses-urea supplement containing 72 g urea/kg
N	nitrogen
NIRS	Near infrared reflectance spectroscopy
NIRS_Task_1	Project NIRS NAP3.121, Improving faecal NIRS calibration equations.
NIRS_Task_2	Present project NBP.302. Utilising faecal NIRS measurements to improve prediction of grower and breeder cattle performance and supplement management.
NIRS_Task_3	Project NBP.303, Delivery of faecal NIRS and associated DSS as a management tool for the northern cattle industry.
Non-grass	The proportion of the diet consisting of plant species other than grass, determined from F.NIRS calibration equations
NPNL	non-pregnant non-lactating cows
#0, #1, etc.	Age group of cattle born in the 1999/2000, 2000/2001 etc financial year.
OF	oesophageally fistulated steer
Poddy	Poddy paddock near the Leichhardt Trial paddock series at Swans Lagoon Research Station. Native pasture with a para grass swamp area grazed at a moderate stocking rate.
R^2	coefficient of determination
RDN	rumen degradable nitrogen (in the diet)
RS	Research Station
SEC	standard error of calibration (in NIRS data analysis)
SECV	standard error of cross-calibration (in NIRS data analysis)
SEP	standard error of prediction (in NIRS data analysis)
TT	Tick Trial paddock series at Swans Lagoon Research Station

WinISI	The software program used for analysis of the data obtained from the NIRS instrument to calculate calibration equations and predictions of unknown samples
Y.O.	Years old (of cattle)

9.2 Appendix 2. Published paper, Dixon and Coates (2005), RAAN

Appendix 2. Paper **The use of faecal NIRS to improve the nutritional management of cattle in northern Australia (2005).** R M Dixon and D B Coates, presented at the conference. *Recent Advances in Animal Nutrition in Australia* (Editors P B Cronje and N Richards). pp. 65-75. **Refereed.** The University of New England, Armidale.

This document is included as an attached pdf file “NBP.302_Appendix_2”.

9.3 Appendix 3. Working paper 'Use of faecal NIRS estimates of dietary CP and DMD to predict the response to urea supplements' by R M Dixon

Appendix 3. Working paper **'Use of faecal NIRS estimates of dietary CP and DMD to predict the response to urea supplements'**.

This document was prepared as a working paper to propose the DMD/CP ratio as an index of the responses of cattle to urea supplements. It was circulated among the staff working on the 3 NIRS projects for comment and feedback from the team members with a variety of backgrounds and roles both in the NIRS projects and in the northern cattle industry. This document developed the argument and the calculations for the DMD/CP ratio in considerable detail to allow the non-specialist in ruminant nutrition to understand the reasons behind and the use of the index.

This document follows.

DISCUSSION PAPER – Use of Faecal NIRS estimates of dietary CP and DMD to predict the response to urea supplements

Rob Dixon, 7 November 2003

1. Introduction

Clearly one of the principal uses of faecal NIRS is to provide estimates of diet quality which can be used to better predict the responses of the animal to various types and amounts of supplements providing nitrogen and/or metabolisable energy.

This document sets out to make some best estimates of when, in Bos indicus cross cattle grazing northern native pastures, a responses is likely to supplementary urea. Also, how much supplementary urea is likely to be required and how do the calculations need to be modified when diets contain browse species such as mulga.

2. Use of a DMD/CP ratio

A simple approach to deciding whether the rumen fermentation is likely to be deficient in Effective Rumen Degradable Dietary Protein (ERDP) for microbial activity is to use the dry matter digestibility (DMD) and the crude protein (CP) of the diet as predicted with faecal NIRS and to calculate the ratio (i.e. the DMD/CP)(Table 1). A threshold value for this ratio needs to be identified above which the rumen fermentation is likely to be deficient in ERDP and thus when an animal is expected to increase intake of low quality pasture and increase rumen microbial protein synthesis in response to provision of ERDP.

This approach has been used by Hogan (1982) except that the calculations were based on DOM/CP (digestible organic matter per unit crude protein; strictly in the SCA(1990) nomenclature digestible organic matter in the dry matter per unit dry matter i.e. DOMD/CP) rather than DDM/CP (digestible dry matter per unit crude protein). These units differ by a factor of about 0.93 for a 50% digestible forage (DMD/CP = OMD*1.08/CP; SCA 1990). Experiments of Hogan and Weston where 23 temperate forage diets comprising a wide range of quality and of 7 pasture species fed to sheep showed that there was a curvelinear relationship between DOM/CP ratio and the rumen ammonia concentration (Hogan 1982; Figure 1); when DOM/CP = 10 (i.e. DMD/CP = 10.8) the rumen ammonia concentration was about 20 mg/litre and thus deficient for microbial digestion and synthesis. Thus at a DOM/CP > 10 (i.e. DMD/CP > 10.8) a response would be expected to soluble N supplements such as urea.

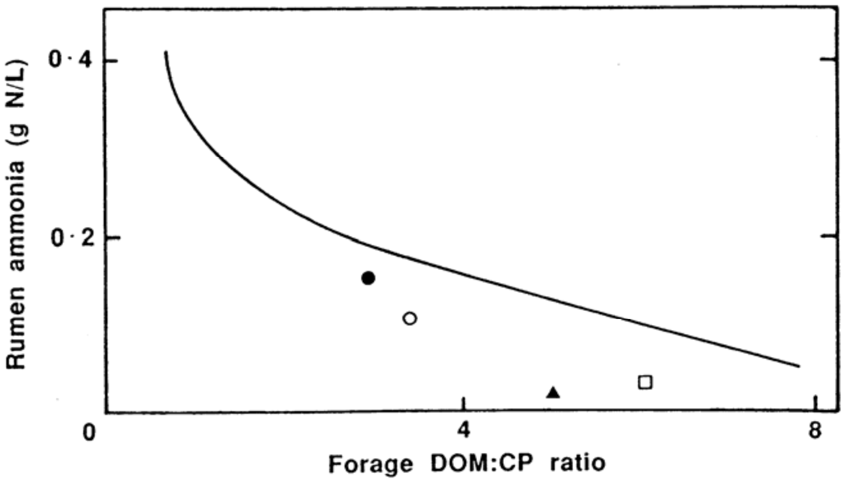

Figure 1. *The effect of changes in the ratio of digestible organic matter to crude protein (DOM:CP) in forages on levels of rumen ammonia. The line shows data derived from temperate forages described by Hogan (1982), while the symbols are data for 2 tropical grasses (Digitaria*

decumbens (□), Setaria sphacelata (▲), one temperate grass (Lolium perenne , (○) and one temperate legume (Trifolium resupinatum, (●)) (Hogan et al 1986).

Unfortunately these OMD/CP values cannot be directly applied to tropical forages. Hogan and colleagues showed that with tropical grass forages there was a different relationship between DOM/CP and the rumen ammonia concentration; rumen ammonia was likely to be deficient for microbial protein synthesis when the DOM/CP was as low as 5.5 (i.e. DMD/CP=6)(Hogan et al. 1989) (Figure 1). Insufficient information is available from cattle fed tropical grass diets to satisfactorily estimate the relationship between OMD/CP and rumen ammonia concentration. However, Hogan (1996) summarized the available experimentation and suggested that in temperate grasses a DOM/CP ratio of >7 (i.e. DMD/CP>7.6) “indicates a potential deficiency in (rumen) ammonia.”, while with tropical grasses where the availability of the protein in the forage for the rumen microbes is expected to be lower “….deficiencies of rumen (ammonia) could occur with DOM/CP ratio of greater than 5” (i.e. DMD/CP>5.4).

Table 1. *The DMD/CP ratios for ranges of dietary CP and dietary DMD*

CP% predicted from faecal NIRS	**DMD% predicted from faecal NIRS**								
	40.0	**42.5**	**45.0**	**47.5**	**50.0**	**52.5**	**55.0**	**57.5**	**60.0**
4.0	10.0	10.6	11.3	11.9	12.5	13.1	13.8	14.4	15.0
4.5	8.9	9.4	10.0	10.6	11.1	11.7	12.2	12.8	13.3
5.0	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
5.5	7.3	7.7	8.2	8.6	9.1	9.5	10.0	10.5	10.9
6.0	6.7	7.1	7.5	7.9	8.3	8.8	9.2	9.6	10.0
6.5	6.2	6.5	6.9	7.3	7.7	8.1	8.5	8.8	9.2
7.0	5.7	6.1	6.4	6.8	7.1	7.5	7.9	8.2	8.6
7.5	5.3	5.7	6.0	6.3	6.7	7.0	7.3	7.7	8.0
8.0	5.0	5.3	5.6	5.9	6.3	6.6	6.9	7.2	7.5
8.5	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1
9.0	4.4	4.7	5.0	5.3	5.6	5.8	6.1	6.4	6.7

The Texas A&M group (Stuth et al 1999) who pioneered faecal NIRS technology in north America have used a similar approach for the NUTBAL model to make predictions from faecal NIRS results. They suggest when the DOM/CP ratio (digestible organic matter per unit crude protein) is greater than 7 (i.e. DMD/CP > 7.6) the animal is likely to be deficient in nitrogen substrate for microbial fermentation, but the data on which this threshold is based is not clear.

An alternative way to show the information in Table 1 is to plot the lines for DMD/CP ratio = 7, 8, 9 and 10 against the values for predicted dietary CP% and DMD%. This is shown in Figure 2.

3. Calculations from SCA (1990) based on the amount of rumen degradable protein (RDP) required for rumen microbial protein synthesis

3.1. The amount of microbial crude protein (MCP) synthesised per kg digestible organic matter intake (DOMI) ranges from about 80 to 230 g MCP/kg DOMI. The values at the lowest end of this range have been obtained with low quality tropical roughages (e.g. Friere *et al* 1980; McMeniman et al 1986; Dixon et al 1998; current research programs of McLennan and Poppi) whereas the highest values have been associated with high quality temperate pastures.

There appears to be a difference between low quality temperate roughages and low quality tropical roughages in this efficiency of microbial protein synthesis as typical values for cereal crop straws and senesced temperate grasses appear to be about 120 g microbial crude protein (MCP) synthesised per kg digestible organic matter intake (DOMI) (Doyle and colleagues).

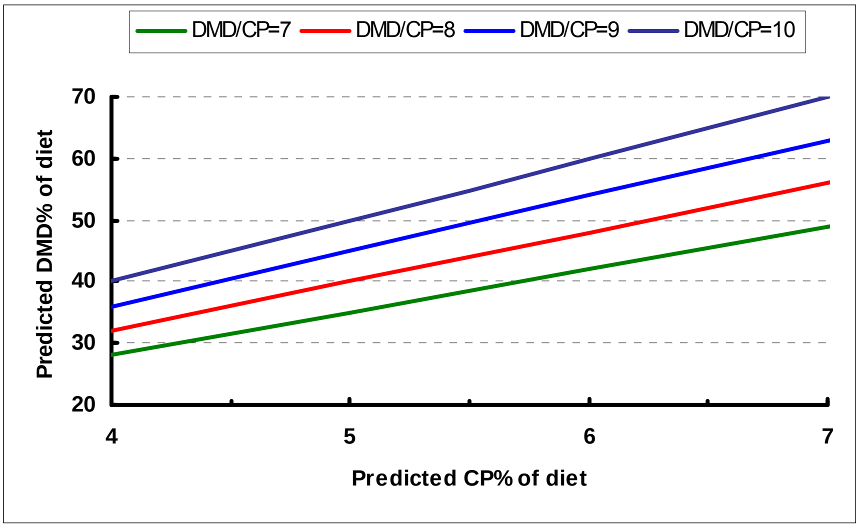

Figure 2. *Comparison of the threshold values for adequacy of nitrogenous substrate for microbial protein synthesis calculated on a requirement for urea supplement when the DMD/CP ratio exceeds 7, 8, 9 or 10.*

For NIRS predictions of cattle grazing tropical pastures it is therefore proposed that, as a minimum, sufficient effective rumen degradable protein (ERDP) is needed to synthesis 90 g MCP/kg DOMI (SCA 1990; AFRC 1993). However, in the following discussion the ERDP required to synthesise 120 g MCP/kg DOMI has also been calculated as this may be a more appropriate value, at least in some circumstances such as with cattle in moderate growth. Additional supply of MCP is important for the animal in growth and is likely associated with increased efficiency of utilization of ME for liveweight gain.

3.2. Numerous studies have shown that there is some transfer (recycling) of endogenous blood urea and of non-urea endogenous nitrogen into the rumen, and some of this N is available as RDP substrate for rumen microbes. The ARC (1980), SCA (1990), AFRC (1993) and NRC (1996) feeding standards all acknowledge and discuss the issue but ignore this recycled nitrogen as a contribution to RDP. The justification for ignoring this recycled nitrogen to RDP intake has been (i) that there is considerable ammonia absorption from the rumen to the blood even on a very low protein (e.g. 4% CP) roughage diets, (ii) that the extent of both recycling and absorption is difficult to predict quantitatively and (iii) that the recycling and absorption process will tend to cancel each other.

3.3. In ruminants fed low digestibility, low protein diets, there is extensive evidence that recycling of N is usually substantially greater than ammonia absorption from the rumen. Therefore recycling of N may make an important net contribution to RDP. The most direct evidence is from measures of non-ammonia nitrogen (NAN) flow from the rumen to the small intestine. In sheep fed temperate forage diets the flow of NAN from the rumen is up to 1.5 times the N intake (Hogan 1982), indicating that net recycling of endogenous N to the rumen can be up to 50% of total N intake. It should be noted however that such high gains of NAN across the rumen have usually been measured only with low CP forages being consumed at low intake.

3.4. Amounts of N recycled to the rumen of cattle

In six reports of cattle fed low quality roughage diets (CP 4.2 – 8.7%, digestibility 50-55%, intake 13-18 g DM/kg LW) the blood urea transfer to the rumen measured with tracers has ranged from 3.7–18.1 g N /day but with no obvious reasons for the variation between experiments. The mean input for the 4 diets containing less than 6% CP was 28 mg urea N/kg LW. This urea will be readily degraded in the rumen. Therefore a best estimate for this input is (0.18 * LW(kg)) g RDP.

Endogenous recycling to the rumen other than urea (e.g. salivary proteins, sloughed rumen epithelised cells) (Kennedy & Milligan 1980; Hart *et al* 1982) is likely to be correlated with DM intake and best estimates of 0.5 g salivary protein N and 1.5 g epithelial sloughing N per kg DM intake (i.e. 3.1 and 9.4 g CP/kg DM intake) appears appropriate (Norton 1984). No experimental results appear to be available to indicate the extent to which this non-urea endogenous N is degraded by rumen fermentation to form RDP and thus be available for microbial protein synthesis. However, salivary proteins may be moderately susceptible to degradation in the rumen and sloughed epithelial cells are likely to be resistant to degradation. Thus degradabilities in the rumen of 0.50 and 0.10 have been assumed for these respective inputs of N into the rumen. Summation of the amounts of N available from these two sources described above suggests an input of 2.5 g RDP per kg DM intake but this estimate is subject to appreciable error.

However, not all of the RDP recycled to the rumen is available for microbial protein synthesis. Even on low quality roughage diets deficient in RDP there is appreciable absorption of ammonia through the rumen wall. For example, even when rumen ammonia concentrations are < 50 mg N/litre in sheep fed low quality roughage, 25 - 50% of the rumen ammonia is absorbed through the rumen wall and is thus not available as RDP (Nolan & Stachiw 1979; Hettiarchchi *et al.* 1999). A best estimate is that 25% of the ammonia is absorbed and is lost for microbial protein synthesis i.e. that ERDP = 0.75 RDP.

It should be noted that the best estimates cited above are conservative and, at least under some circumstances, may seriously underestimate the amount of ERDP made available for rumen fermentation from recycling of N to the rumen. For example, under extremely low rumen ammonia concentrations (e.g. <10 mg/litre such as observed by Hennessy and Nolan 1988 and in field observations at Swans Lagoon) much less than 25% of ammonia is likely absorbed from the rumen and thus not available as ERDP. There is evidence for much greater endogenous urea transfer to the rumen under some circumstances than discussed above. Also some estimates of non-urea endogenous N transfer to the rumen (e.g. Leng and Nolan 1984) are much greater than the estimate discussed above.

3.5. Calculation of the MCP/DOM ratio for a range of dietary CP% and DMD% value

Assumptions:

- For lower quality mature tropical grasses D_g of the total N = 0.6.
- Recycling of degradable endogenous N to the rumen as urea and non-urea N is as described g RDP/day
- DOMD = 0.93 DMD (this is an approximation for a 50% DM digestibility diet; the SCA calculation (p. 7 of the book) is [DOMD% = 0.95 DMD% - 0.9],
- and where VI is pasture intake in g DM/kg LW, LW is liveweight in kg

MCP/kg DOM = 0.75 [(CP%/100) * VI*LW * 0.6) + 0.18 * LW + 2.5 * (VI*LW/1000)] / ((VI*LW/1000) * 0.93 * DMD%/100)

As an example consider a 300 kg steer consuming 15 g DM/kg LW (i.e. 4500 g DM/day).

MCP/kg DOM = 0.75 [(CP%/100) 15*300/1000 * 0.6 + 0.18 * LW + 2.5*(15*300/1000)] /(15*300/1000) * 0.93 * DMD%/100

Table 2. *Expected microbial protein synthesis MCP/kg DOMI for 300 kg steer consuming 1.5% LW of pasture (i.e. 4.5 kg DM/day) and where the dietary CP and DMD have been measured by faecal NIRS. The "steps" of heavy lines indicate the combinations of CP and DMD where MCP/kg DOMI is < 90 and thus when ERDP is likely to be deficient.*

CP % predicted from NIRS	ERDP available (g)	DMD % predicted from NIRS				
		40	45	50	55	60
4	130	78	69	62	56	52
5	150	90	80	72	65	60
6	170	102	91	81	74	68
7	191	114	101	91	83	76
8	211	126	112	101	92	84
9	231	138	123	110	100	92

If the supply of ERDP is less than the amount needed for microbial crude protein synthesis then digestion of fibre, microbial activity, microbial protein synthesis and voluntary intake will all be reduced, and probably reduced severely. Tables A1, 2 and A2 give the calculated MCP/DOMI values for pasture intakes of 2.0%, 1.5% and 1.0% LW, respectively, and in each of the tables the "steps" of heavy lines are used to indicate the combinations of CP and DMD where the g MCP/DOMI is greater or less than 90. For combinations in the top right-hand side of each table the MCP/DOMI is <90 and therefore supply of ERDP is likely to be deficient and a response to urea supplementation expected. Note that whether a combination of CP and DMD is expected to be deficient in ERDP depends partly on the level of forage intake. Figure 3 shows the same information as Table 3 but in a different format; a CP and DMD combination above the line indicates a situation where there is likely to be an ERDP deficiency and the distance from the line the severity of the deficiency. It also shows when ERDP is likely to be insufficient for microbial activity if the amount of ERDP required is to supply 120 g MCP/kg DOMI.

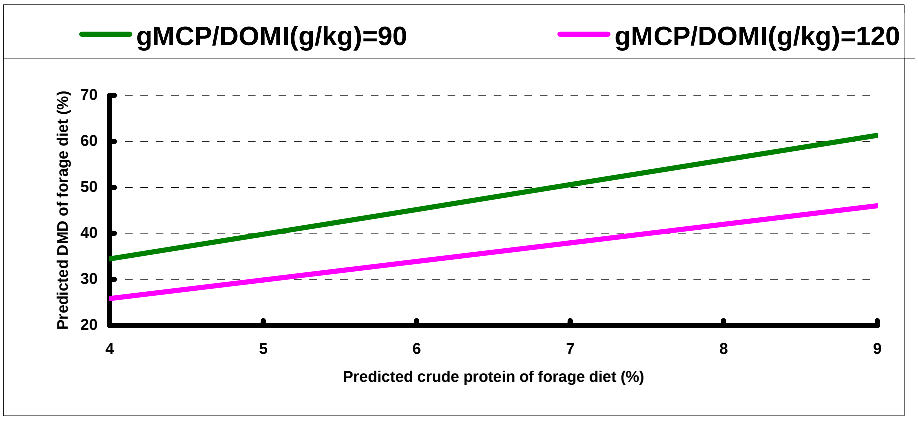

Figure 3. *Lines where the ratio g MCP/kg DMD equals 90 (green line) or 120 (purple line) g/kg. Calculations are for a for 300 kg steer consuming 1.5% LW of pasture (i.e. 4.5 kg DM/day) and where the dietary CP and DMD have been measured by faecal NIRS*

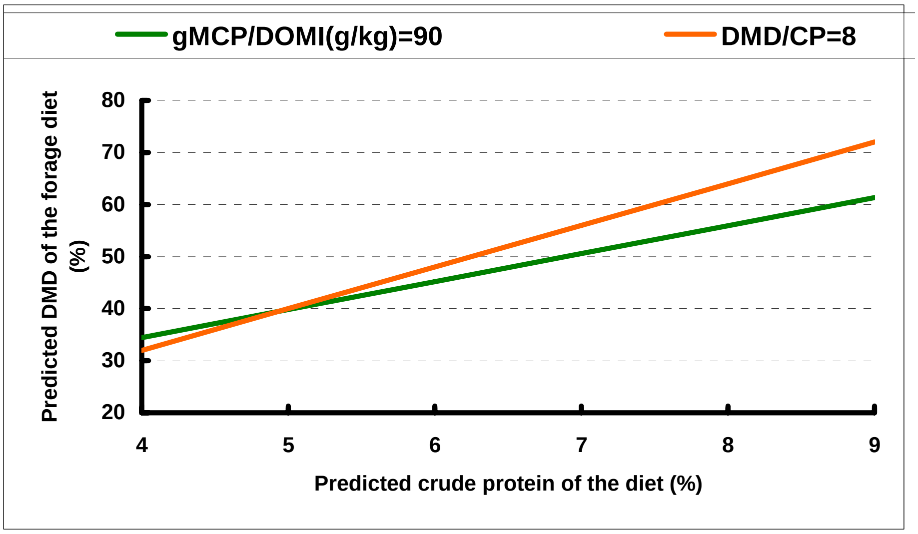

Figure 4. *Comparison of the criteria of 90 g MCP/kg DOMI or a DMD/CP ratio = 8 as indicators of when ERDP is likely deficient and a response is likely to supplementary urea.*

4. Which criteria ? The ratio of DMD/CP or MCP/DOMI

Figure 4 compares the 2 methods of calculation when the DMD/CP ratio = 8, and when the MCP/DOMI = 90. Clearly the slopes differ, the reason being that the MCP/DOMI calculations include the input of endogenous nitrogen recycled to the rumen independently of the CP or DMD contents of the diet.

Calculation of the requirement for supplementary urea from the DOM/CP ratio has the advantage of simplicity whereas the calculation of the MCP/DOMI has the advantage of accommodating the recycling of endogenous N to the rumen in amounts independent of the DM intake. In forage diets of 4-6% CP, which are of greatest interest in the present context, the recycling of urea has been shown to be equivalent to 20-60% of total dietary protein intake. However, endogenous N recycling is likely to be of lesser importance as the CP content of the diet increases.

The DMD/CP ratio in relation to the commencement of a LW response to urea supplementation at Toorak in the 2001 and 2002 dry seasons is shown in Figure 5. At Toorak in 2001 there was definitely a response to urea when DMD/CP was >10. At Toorak in 2002 the DMD/CP was generally 8-9 through the dry season; there was no response to the urea supplement until September and there was a large response through October to December without much of an associated change in the DMD/CP ratio.

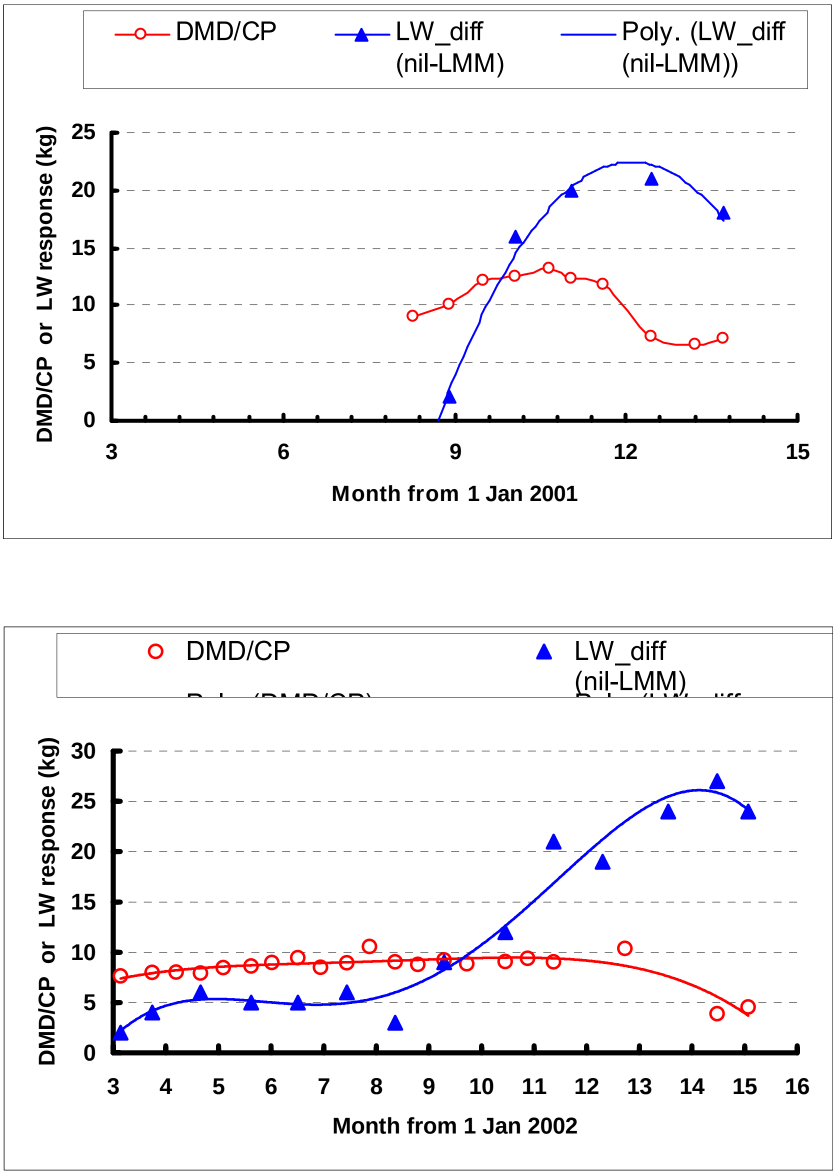

Figure 5. *Results from **Toorak NIRS trial** for #0 and #1 steers through the 2001 and 2002 dry seasons, respectively. The ratio of DMD/CP at various sampling dates is shown in red symbols. The cumulative liveweight benefit (kg of increased LW gain) of feeding a urea-based loose mineral mix is shown in blue symbols. The urea-supplemented steers were 22 kg heavier at the end of the 2001 dry season and 27 kg heavier at the end of the 2002 dry season.*

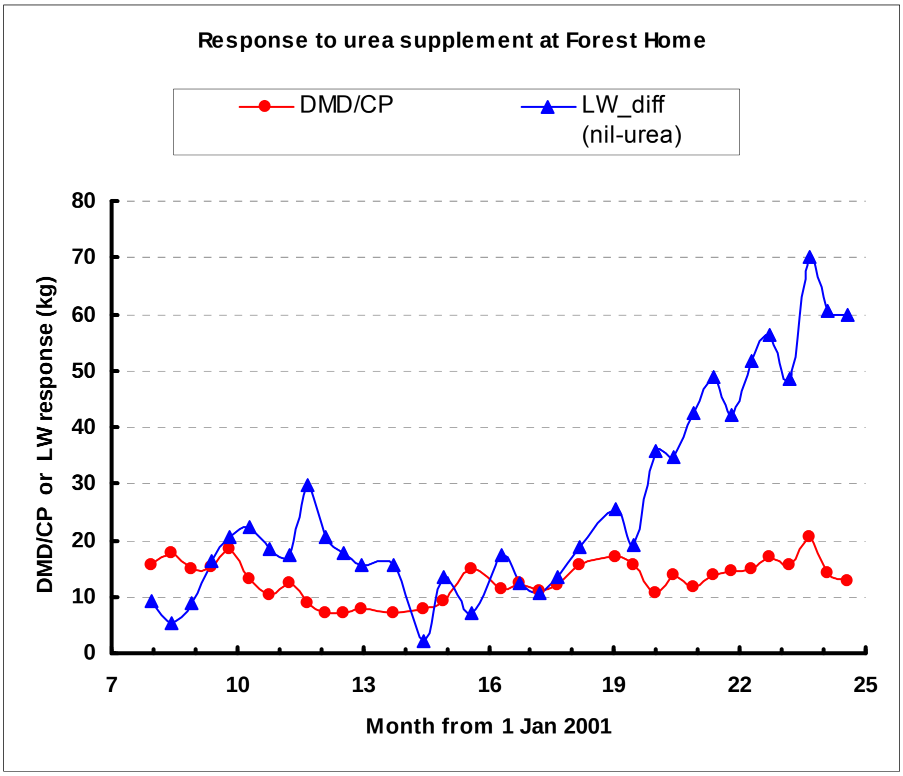

Figure 6. *Results for #0 steers at from* ***Forest Home trial site*** *(David Coates data) from August 2001 through to January 2003 and thus during the later part of the 2001dry season and the 2002 dry seasons. The ratio of DMD/CP at various sampling dates is shown in red symbols. The cumulative liveweight benefit (kg of reduced LW loss or increased LW gain) of feeding urea in the water is shown in blue symbols. Thus urea-supplemented steers were 30 kg heavier at the end of the 2001 dry season and 60 kg heavier at the end of the 2002 dry season, and the LW benefit appeared to occur when the DMD/CP was > about 9.*

The DMD/CP ratio in relation to urea supplementation at Forest Home, Mingela, during the late 2001 and 2002 dry seasons is shown in Figure 6. A large response occurred to urea supplement through both dry seasons and both wet seasons were below average. At the commencement of the 2002 dry season the response to urea supplement appeared to commence when the DMD/CP was between 8 and 9.

The results from the current NIRS monitor herds at Swans Lagoon also indicate when a urea supplementation response is likely, although no urea supplements are being fed in this trial. The experiments of Winks and colleagues at Swans Lagoon in the 1970's indicated that in this environment a urea supplementation response can be expected when faecal N concentration is less than about 1.3% N (i.e. <8.1% CP). Figure 7 shows the changes in DMD/CP ratio and the faecal CP% in one of the monitor herd paddocks. Figures A1 – A4 in the appendix show these changes for 4 other monitor herds. In all of the paddocks the faecal CP% was decreasing to < 8.1% when the DMD/CP ratio was between 8 and 9. Thus a urea supplementation response would be expected when DMD/CP > about 9.

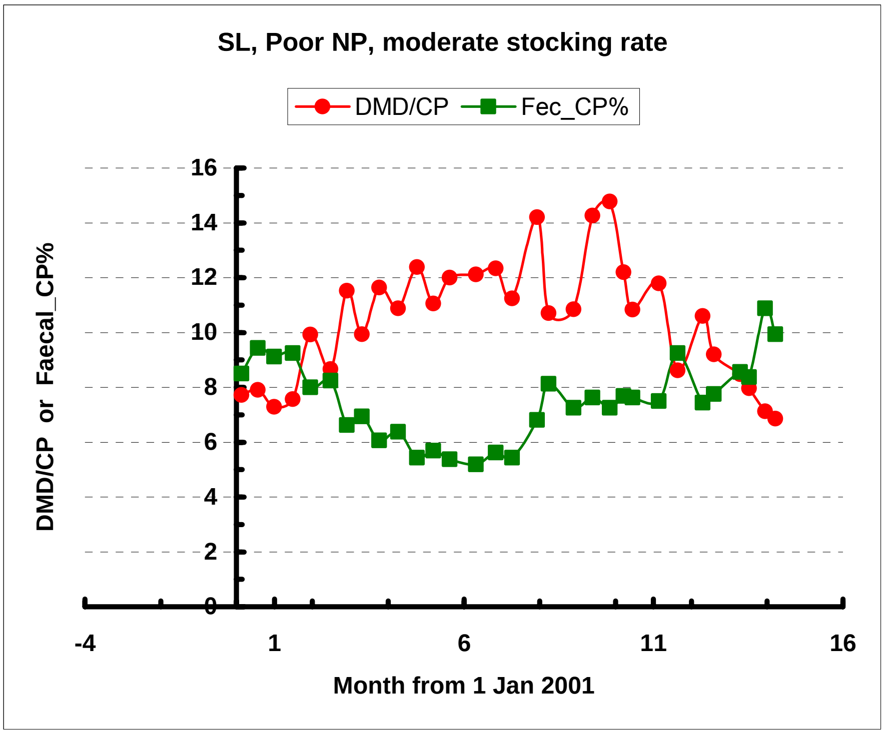

Figure 7. *Results for #0 heifers at Swans Lagoon from January 2001 through to March 2002. The ratio of DMD/CP at various sampling dates is shown in red symbols. The Faecal CP% is shown in green symbols. The experiments of Winks and colleagues at Swans Lagoon have indicated that a urea supplementation response can be expected in this environment when faecal N concentration is < 1.3% N (i.e. <8.1% CP). Thus a urea supplementation response would be expected when DMD/CP > about 9.*

5. Decision on the value of DMD/CP to use as an indicator of ERDP deficiency

There is considerable uncertainty about the most appropriate value for the DMD/CP ratio, and indeed whether different values should be used depending on the circumstances. Furthermore, because recycling of endogenous N is likely to be more important with the lower CP diets, arguably the threshold value should be modified depending on the CP or DMD of the diet. However, given:
(i) the similarity of the lines in Figure 4 for CP and DMD combinations when DMD/CP=8 and when g MCP/CP = 90,
(ii) the physiological and nutritional basis for the calculation of the latter criteria, and
(iii) the conclusions of Hogan and Stuth discussed above on the critical DMD/CP ratio,
(iv) the results from Toorak, Forest Home and Swans Lagoon discussed:
then if the value of DMD/CP is > 10 a urea response appears very likely. Also, at least for the coastal speargrass country, if the DMD/CP ratio is greater than 8-9 a response to urea supplements is likely.

6. Error and uncertainty from other sources in the calculation of MCP/DOMI or DMD/CP

6.1. The measurement of in vitro DMD is known to have difficulties as a measure of the ME content of low quality tropical grass forages. The most common concern is that the ME content is underestimated by the IVDMD measurement. The errors associated with the prediction of availability of digestible energy from the forage may well be more important for the interpretation of faecal NIRS results than the procedure used to calculate protein/energy availability and response to urea.

6.2. It is well known that one of the prerequisites for a response of the grazing animal to urea supplementation is an ability to increase pasture intake. Thus one of the established provisos for recommending urea supplementation is that there should be “adequate” standing pasture and where voluntary intake of pasture is not constrained by its availability to the animal. However, what is “adequate”? Given the importance of pasture evaluation as part of using NIRS outputs it seems opportune to try to define what is an “adequate” amount of pasture in kg DM/ha as well as other pasture quality attributes as required.

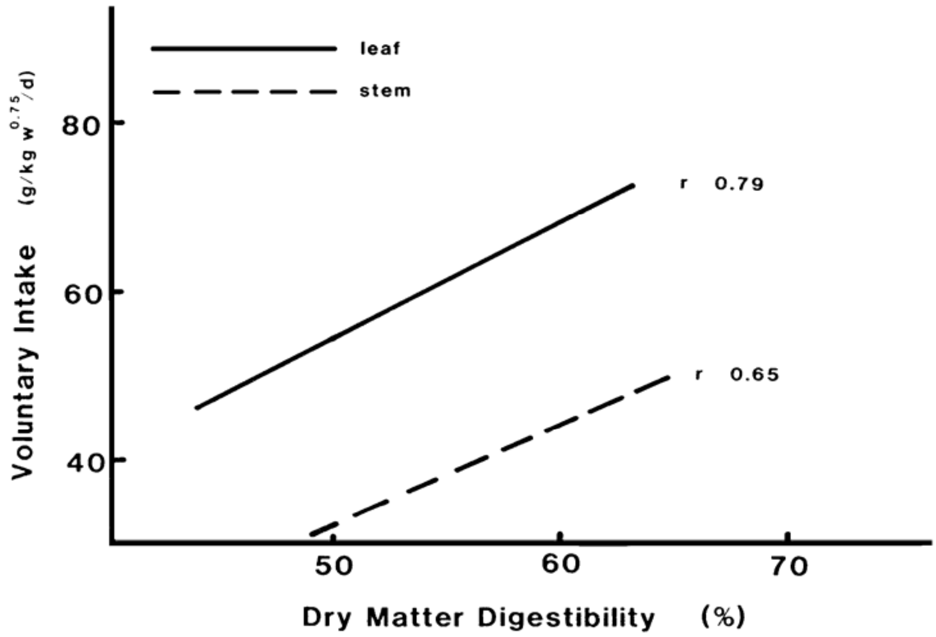

Figure 5. *The relationship between intake and digestibility of leaf and stem fractions of tropical grasses (Minson 1982).*

Table 5. Comparison of the responses of sheep to urea supplement when fed a basal diet of forage which consisted of leaf or stem of barley straw (Rafiq et al 2002).

Measurement	High-leaf forage		High-stem forage	
	No supplement	Urea/S supplement	No supplement	Urea/S supplement
Forage DM intake (g/kg LW)	493	643	423	420
OM digestibility (%)	51	56	49	53
ME intake (kj ME per kg metabolic W)	224	343	191	232
LW change (g/day)	-98	-31	-105	-80

6.3 It has been shown in pen experiments that voluntary intakes of ruminants consuming leaf of tropical grasses is much higher than if the animals are consuming stem (Minson 1982). Decision Support Systems such as GRAZFEED and NUTBAL use digestibility as a predictor of voluntary forage intake and do not include leaf/stem ratio of the diet as a factor.

However, for tropical grass diets the difference between a diet of leaf and a diet of stem can be equivalent to about 20 percentage units in digestibility (Figure 5). Similarly urea responses are much greater with high-leaf diets than high-stem diets of cereal straw (Table 5; Rafiq et al 2002). Thus the results from pen experiments agree with the field observations that one aspect of "adequate" pasture quality to obtain a urea response is leafiness. Again how do we state criteria for degree of leaf availability in the pasture?

7. Amounts of urea required

The general QDPI recommendation for the amount of supplementary urea required has been based on the work at Swans Lagoon summarized in Figure 6. The recommendation is 30 g urea per day for a large weaner/yearling, and a proportionally larger amount for heavier animals (50-60 g urea per day for a breeder) on the assumption of similar pasture intake per unit LW.

The recommendation of 30 g urea per day for a yearling was arrived at as the amount of urea which would give most of the animal LW change response in most years. It is clear from Figure 6 that less than 30 g urea would be necessary in some years to obtain most of the animal response. Also in some years LW responses were obtained to 60 or 90 g urea per day e.g. in 1972. The faecal NIRS technology should allow identification of the situations where responses are likely to greater or lesser amounts of supplementary urea. One approach is to speculate that the 1972 response in Figure 6 occurred in a situation where pasture DMD was high and CP low e.g. 60% DMD and 4% CP to give a DMD/CP ratio = 15. It might therefore be sensible to recommend for yearling animals (200-250 kg) that amounts of urea supplement such as those shown in Table 6 should be used. If the same proportions of LW are required for breeders then up to about 180 g urea per day should be fed.

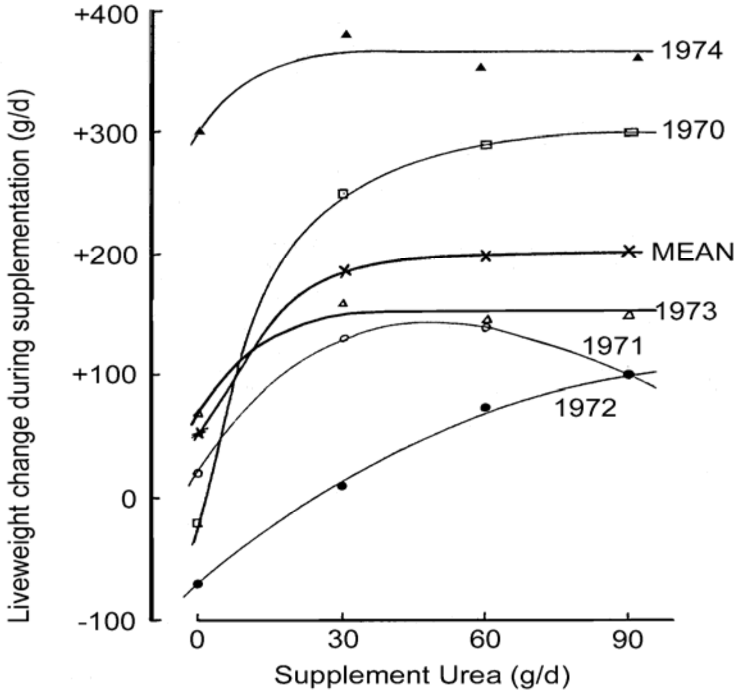

Figure 6 *Summary of liveweight responses of young Bos indicus cross cattle to various levels of urea fed through the dry season (Winks et al 1972; 1979).*

Table 6. *Possible amounts of urea supplement to be recommended for yearling steers with increasing DMD/CP ratio predicted from faecal NIRS.*

DMD/CP ratio	Amount of urea supplement per head per day
8 to 9	15-20
9 to 10	30
10 - 13	60
>13	90

8. Modifications required for diets containing browse, in particular mulga

Although often high in CP content many browses also contain high concentrations of condensed tannins which make the browse unpalatable and can severely reduce the availability of the browse protein. The native browse species in Australia for which most information is available is mulga. Although mulga leaf contains 10-15% CP it also contains about 5-15% condensed tannins. Apparent protein digestibility when sheep are fed mulga leaf is usually in the range 35-40%, although there is one report of 52% (Norton et al 1972; Norton et al 1996).

The low availability of mulga protein will mean that the DMD/CP ratio at which ERDP is likely to become limiting rumen microbial fermentation will also differ to that for tropical grass forages as discussed above. However, if the D_g of the browse protein can be estimated, then it should be possible to calculate a modified DMD/CP ratio above which animals are likely to respond to urea supplement.

An estimate of the value of mulga protein can be calculated from the historical and now superseded approach to defining the availability of protein in feedstuffs and the protein requirements of the animal as “digestible protein.” The ”digestible protein” was measured as the “apparently digestible protein” in a feedstuff measured in a conventional digestibility study. For example NRC (1976) recommends that a 300 kg steer at maintenance requires 4.7 kg of a 8.4 MJ ME/kg diet (39 MJ ME/day) and that the diet contain 8.6% CP or 4.8% digestible CP. The digestible CP content of grasses containing 10-15% CP is about 0.7 of the total protein content. If the apparent CP digestibility in sheep fed mulga leaf diets is 35-40% then it appears that the availability of mulga leaf protein is about half that of the protein of conventional grass forages.

Further information on the nutritional limitations of mulga is available from several decades of R&D work at Charleville and can be obtained from experiments where the responses of sheep fed mulga-based diets have been measured.

(i) With mulga diets the primary nutritional constraints are sulphur, phosphorus and sodium.

(ii) Animal responses have been obtained to cottonseed meal and molasses/urea supplements, but not to urea supplement fed in the absence of molasses (Entwistle and Baird 1976; McMeniman et al 1981; Niven and Entwistle 1983).

(iii) When mulga has been used as a supplement for low quality roughage (sorghum stubble) at levels ranging from nil to 40% of the total DM intake, rumen ammonia concentrations were low for the stubble diet and were not changed by the increasing levels of mulga in the diet (range 12-24 mg N/L)(Goodchild and McMeniman 1994). The absence of an increase in rumen ammonia concentration with increasing levels of mulga suggests that the mulga contributed little ERDP to rumen fermentation in excess of that required to digest the fermentable organic matter in mulga. Conversely the absence of a decrease in rumen ammonia concentrations with increasing levels of mulga in the diet suggested that there was sufficient ERDP in the mulga to digest the fermentable organic matter in the mulga.

Until better information is available it is proposed to calculate an “equivalent protein content” for diets containing browse based on the assumptions that the browse protein is only half as available as grass forage protein to supply ERDP. This correction would only be used where observations in the field indicate that the “Non-grass” predicted by faecal NIRS is likely to be browse.

The calculation “Equivalent protein concentration” is as follows:
Let:

CP of total diet = CP_{DIET}
CP of grass fraction = CP_{G}
CP of non-grass fraction = CP_{NG}
Equivalent CP of total diet = ECP_{DIET}
Proportion of non-grass in diet = NG
Proportion of grass in diet = G

Then:
$CP_{DIET} = CP_{G} * G) + (CP_{NG} * NG)$
and $CP_{NG} = (CP_{DIET} –(CP_{G} * G))/ NG$
Equivalent $CP_{NG} = 0.5 * [(CP_{DIET} –(CP_{G} * G))/ NG]$

$ECP_{DIET} = (CP_{G} * G) +(0.5 * [(CP_{DIET} –(CP_{G} * G))/ NG] * NG)$
$ECP_{DIET} = (CP_{G} * G) + \frac{1}{2} (CP_{DIET} –(CP_{G} * G))$

Table 6. *Calculation of the “Equivalent crude protein” to correct the NIRS predictions of dietary crude protein of diets consisting of low quality grasses and a browse such as Mulga*

Diet CP% measured with NIRS	Diet Non-grass proportion measured with NIRS	Assumed CP% of the grass in the diet			
		3	4	5	6
6	0.2	4.2	4.6	5.0	5.4
6	0.4	3.9	4.2	4.5	4.8
6	0.6	3.6	3.8	4.0	4.2
6	0.8	3.3	3.4	3.5	6.3
8	0.2	5.2	5.6	6.0	6.4
8	0.4	4.9	5.2	5.5	5.8
8	0.6	4.6	4.8	5.0	5.2
8	0.8	4.3	4.4	4.5	4.6
10	0.2	6.2	6.6	7.0	7.4
10	0.4	5.9	6.2	6.5	6.8
10	0.6	5.6	5.8	6.0	6.2
10	0.8	5.3	5.4	5.5	5.6
12	0.2	7.2	7.6	8.0	8.4
12	0.4	6.9	7.2	7.5	7.8
12	0.6	6.6	6.8	7.0	7.2
12	0.8	6.3	6.4	6.5	6.6
14	0.2	8.2	8.6	9.0	9.4
14	0.4	7.9	8.2	8.5	8.8
14	0.6	7.6	7.8	8.0	8.2
14	0.8	7.3	7.4	7.5	7.6

Using the DMD predicted for the diet, the DMD/CP ratio is then calculated using the “equivalent crude protein” value rather than the NIRS measurement of diet CP%, and the ratio interpreted as for forages.

The consequences of use of this correction factor on the calculated DMD/CP ratio for a situation where NIRS predictions indicated that the cattle were consuming an appreciable amount of non-grass, and observation of the site indicated that the non-grass in the diet would have been at least primarily Mulga, are shown in Figure 7.

Presumably interpretation of the NIRS results in field situations where cattle are consuming large amounts of browse will need to continue to be extremely cautious. However, if field experience and further experimentation indicate that the proposed calculation (or a modification of this calculation) gives “sensible” results in the field it will be one way to use the faecal NIRS predictions with mulga diets.

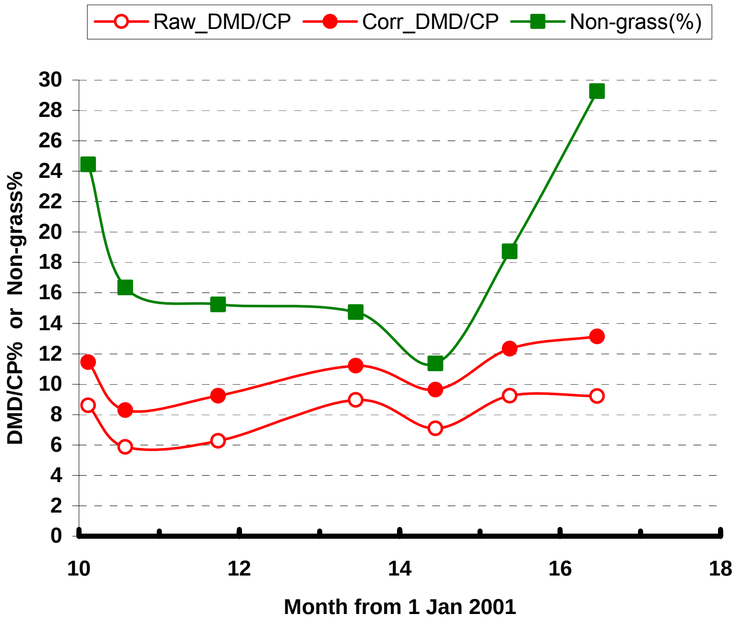

Figure 7. Results from Croxdale of the DMD/CP ratio calculated from the DMD and CP as measured from faecal NIRS and the same ratio following correction of the CP content as described above. It was assumed that all of the non-grass in the diet predicted by NIRS was Mulga and that the grass component of the diet was 5% crude protein. Clearly the correction has a major impact on the time for which the DMD/CP ratio was greater than 9.

Appendix.

Table A1. *Expected microbial protein synthesis MCP/kg DOMI for 300 kg steer consuming 2% LW of pasture (i.e. 6 kg DM/day) and where the dietary CP and DMD have been measured by faecal NIRS. The "steps" of heavy lines indicate the combinations of CP and DMD where MCP/kg DOMI is < 90 and thus when ERDP is likely to be deficient.*

CP % predicted from NIRS	ERDP available (g)	DMD % predicted from NIRS				
		40	45	50	55	60
4	160	72	64	57	52	48
5	187	84	74	67	61	56
6	214	96	85	77	70	64
7	241	108	96	86	78	72
8	268	120	107	96	87	80
9	295	132	117	106	96	88

Table A2. *Expected microbial protein synthesis MCP/kg DOMI for 300 kg steer consuming 1% LW of pasture (i.e. 3 kg DM/day) and where the dietary CP and DMD have been measured by faecal NIRS. The "steps" of heavy lines indicate the combinations of CP and DMD where MCP/kg DOMI is < 90 and thus when ERDP is likely to be deficient.*

CP % predicted from NIRS	ERDP available (g)	DMD % predicted from NIRS				
		40	45	50	55	60
4	100	90	80	72	65	60
5	114	102	91	81	74	68
6	127	114	101	91	83	76
7	141	126	112	101	92	84
8	154	138	123	110	100	92
9	168	150	134	120	109	100

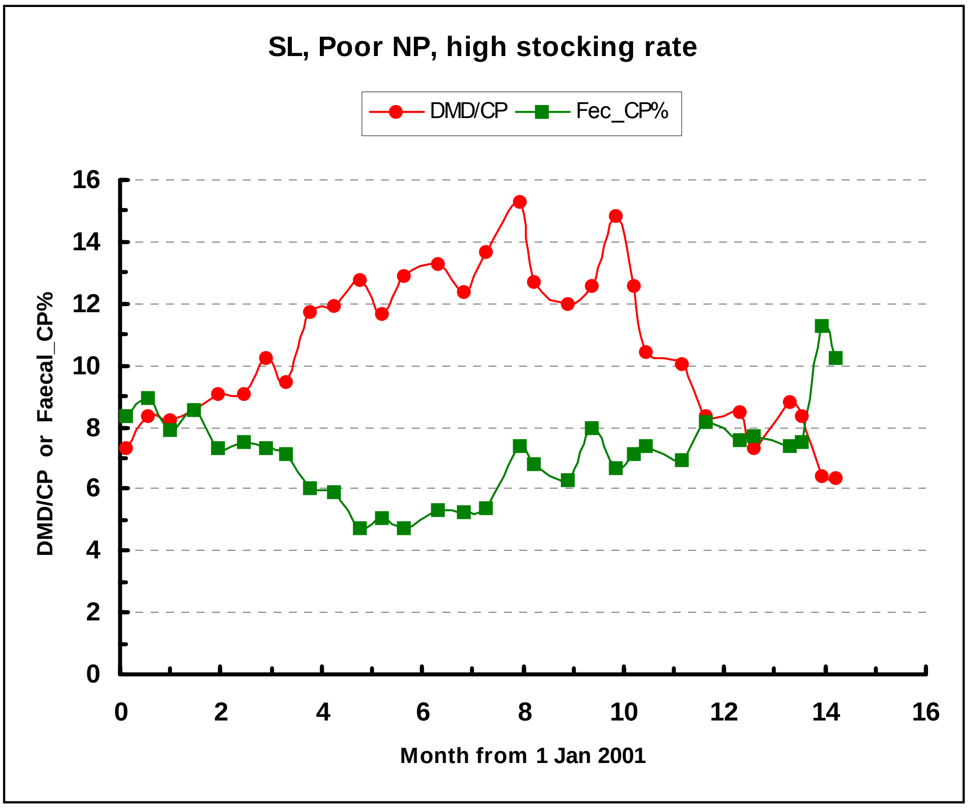

Figure A1. *Results for #0 heifers at Swans Lagoon from January 2001 through to March 2002.*

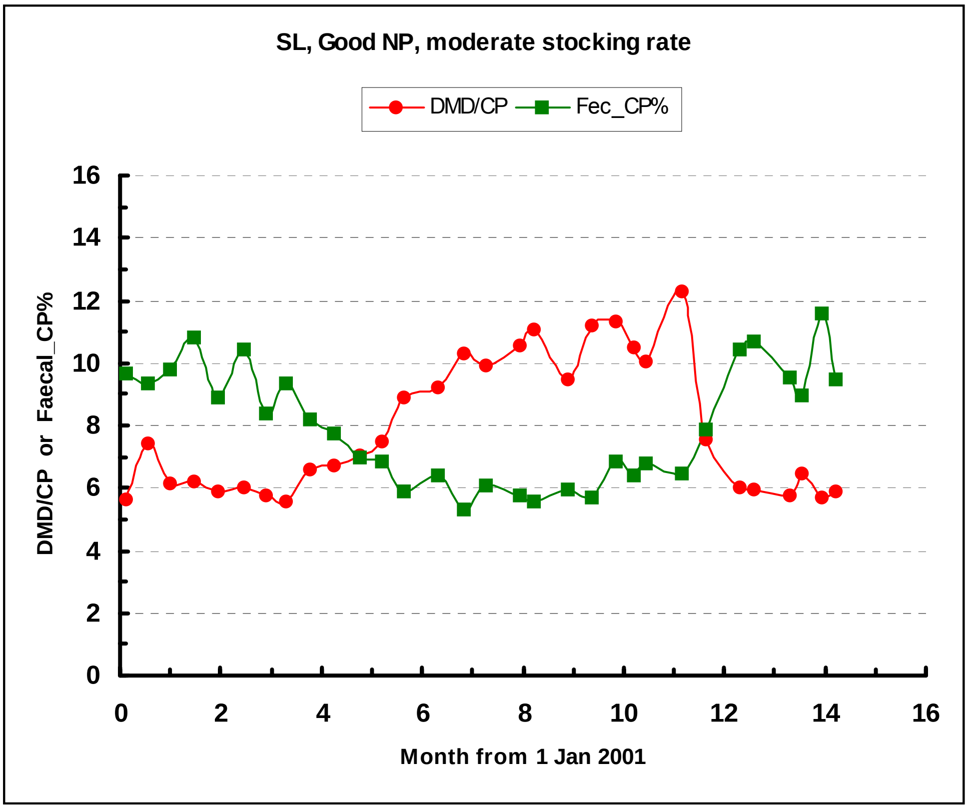

Figure A2*. Results for #0 heifers at Swans Lagoon from January 2001 through to March 2002.*

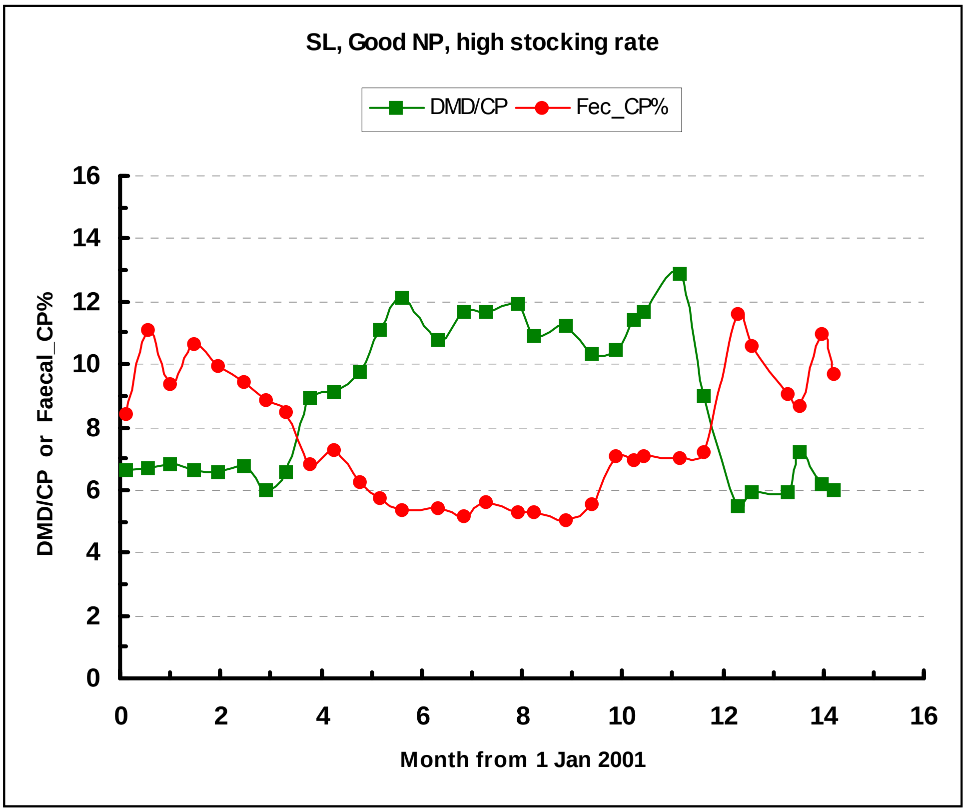

***Figure A3**. Results for #0 heifers at Swans Lagoon from January 2001 through to March 2002.*

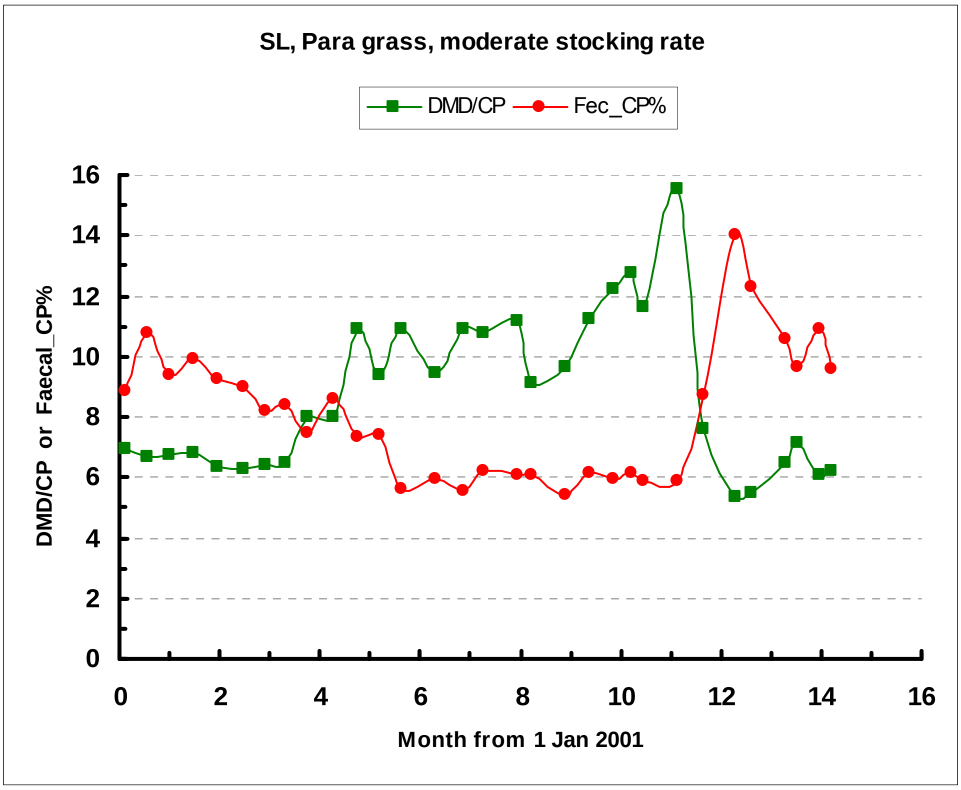

***Figure A4.** Results for #0 heifers at Swans Lagoon from January 2001 through to March 2002.*

9.4 Appendix 4. Published paper, Dixon et al. (2007), RAAN

Appendix 4. Paper **Using faecal near-infrared reflectance spectroscopy to improve nutritional management of breeders in the seasonally dry tropics (2007).** R M Dixon, D R Smith and D B Coates. *Recent Advances in Animal Nutrition in Australia.* (Editors P B Cronje and N Richards). pp. 123-133. **Refereed.** The University of New England, Armidale.

This document is included as an attached pdf file “NBP.302_Appendix_4”.

9.5 Appendix 5. ASAP short paper

Paper presented at the meeting of the Australian Society of Animal Production, CQ Sub-branch, July 2005.

Faecal NIRS measurement of the diet selected by heifers grazing northern speargrass pastures

Dixon[1], R. M., Smith[2], D. & Coates[3] D.B.
[1,2,3]DPI&F, Rockhampton and Charters Towers, respectively.
[4]CSIRO Davies Laboratories, Aitkenvale, Townsville.

NIRS analyses of faeces (F.NIRS) can be used to measure the quality of the diet selected by grazing cattle (Coates 2004). F.NIRS was used to measure the diet selected by small herds of cattle grazing several speargrass- based pastures.

Five paddocks (24-40 ha) of speargrass-based pasture, or this pasture with some stylo or a para grass swamp, at Swans Lagoon near Townsville were used. The paddocks were grazed at moderate or high stocking rates, or for the para grass paddock only at a moderate stocking rate. Yearling *Bos indicus* cross heifers (10 or 20 per paddock for moderate and high stocking rates, respectively) were introduced in Jan to March, and replaced with a new draft annually. Except in the para grass paddock, molasses-urea supplements were fed in the late dry season, and it was necessary to destock most paddocks at intervals when pasture availability was low. Heifers were weighed monthly. Faecal samples were obtained fortnightly and analysed by NIRS. CP content and DM digestibility (DMD) of the diet, DMD/CP ratio, proportion of non-grass in the diet and LW change were predicted using established F.NIRS calibration equations (Coates 2004).

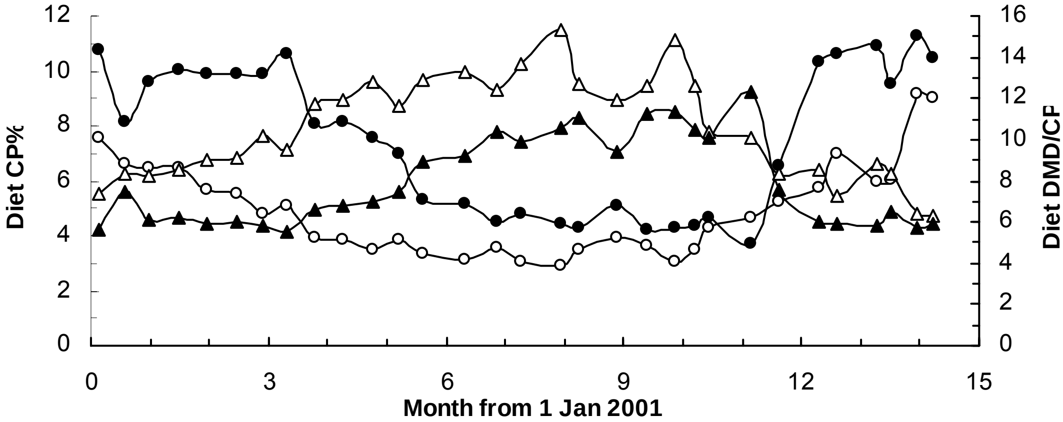

Figure 1. Diet CP (○,●) and DMD/CP (Δ,▲) in 2 paddock groups (speargrass pasture at high stocking rate and speargrass & stylo pasture at moderate stocking rate, respectively.

Changes in diet CP content and the DMD/CP ratio of 2 herds through one annual cycle are shown in Figure 1. Other paddock groups and other years followed similar patterns. During the wet season diet CP and DMD were high and DMD/CP was low. There was a progressive decline in diet CP and DMD, and increase in DMD/CP, with the onset and advancement of the dry season. Cattle are likely to respond to RDN supplements when the DMD/CP > 8. The DMD/CP exceeded this value early in the season in the high stocking rate speargrass paddock, but later in the season when stylo or para grass was available, and with the moderate stocking rate. F.NIRS predictions of LW change were correlated with the measured LW change across all paddocks, indicating that these predictions are valid even when pasture availability is low. In conclusion, these observations support the hypothesis that F.NIRS can be used reliably to measure the nutrition of grazing cattle.

Coates, D.B. (2004). Faecal NIRS – Technology for improving nutritional management of grazing cattle. Final Report, NAP3.121, Meat and Livestock Australia, Sydney.

9.6 Appendix 6. ASAP short paper

Paper presented at the meeting of the Australian Society of Animal Production, CQ Sub-branch, July 2005.

Responses of steers grazing Mitchell grass pastures to nitrogen supplements

Sullivan[1], M.T., Dixon[2], R. M., O'Connor[3], S.N. & Coates[4] D.B.
[1,2,3]DPI&F, Mt Isa, Rockhampton and Toorak R.S., respectively.
[4]CSIRO Davies Laboratories, Aitkenvale, Townsville.

Rumen degradable nitrogen (RDN) is often the first-limiting nutrient of cattle grazing dry season pastures. Although urea supplements are widely used in the northern cattle industry, there are few experimental measurements of the responses (Winks 1984; Dixon 1998).

A 3-year experiment at a site near Julia Creek examined the LW responses of steers grazing Mitchell grass pastures to supplements providing principally RDN (a loose mineral mix containing 30% urea) or cottonseed meal (400 g/head.day). In August 2001, and in March 2002 and 2004, drafts of *Bos indicus* cross steers were allocated to six 130 ha paddocks. Draft 1 consisted of both yearling and 2.5 Y.O steers, and Drafts 2 and 3 of yearlings. Faecal NIRS was used to measure the crude protein (CP) content, digestibility (DMD) and proportion of non-grass of the diet selected.

Table 1. Liveweights of the 3 drafts of steers, initially yearlings or 2.5 y.o., at the commencement of measurements in August (Draft 1) or March (Drafts 2 & 3), the maximum and minimum LW during the dry season, and the final LW in March the following year. The seasonal break was the first rainfall event of at least 50 mm over 3 days.

Measurements	Treat	Draft 1		Draft 2	Draft 3
		Yearling	2.5 yo	Yearling	Yearling
Initial LW (kg)	-	229	405	239	229
Maximum LW in the mid-late dry (kg)	Nil	-	-	352	322
	LMM	-	-	371	333
	CSM	-	-	365	324
Minimum LW in the late dry (kg)	Nil	214	375	324	273
	LMM	230	393	351	302
	CSM	247	408	351	281
Date of the seasonal break	-	24/10/01	24/10/01	23/02/03	4/01/05
Final LW in March/April (kg)	Nil	333	464	359	400
	LMM	347	478	383	414
	CSM	362	484	381	390

Faecal NIRS indicated that the diet CP, digestibility and non-grass proportion (i.e. forbs) were high during the wet season and declined progressively during the dry season. For Draft 1 diet CP and DMD/CP were 5.3% and 10 respectively in Sept. Subsequently CP declined to less than 5% and DMD/CP increased to 12-13. A large response was observed to the N supplement. Steers in Drafts 2 and 3 gained LW through the dry season until Jan or Nov, respectively, and then lost LW until wet season pasture was available. Supplements improved LW of Draft 2, but not of Draft 3, steers. Faecal NIRS measures for these drafts of steers indicated that diet CP was maintained at >5% despite very dry conditions, and DMD/CP was 9-10. It appears that the high diet quality through the dry season for Drafts 2 and 3 was associated with availability of forbs and for this reason limited or no response occurred due to the N supplements. In conclusion, supplements improved steer LW in 2 of the 3 years.

Dixon, R.M. (1998). Improving cost-effectiveness of supplementation systems for breeder herds in northern Australia. Final Report, Project DAQ.098, Meat Research Corporation, Sydney.

Winks, L. (1984). Cattle growth in the dry tropics of Australia. Review number 45, Australian Meat Research Committee, Sydney.

9.7 Appendix 7. NBRUC short paper

Proceedings, Northern Beef Research Update Conference, 2007.
(Poster in file: NBP.302_Appendices_7+8+12.pdf)

Faecal NIRS measurements of diet quality and growth of cattle grazing Mitchell grass - forest country pastures near Richmond, N Qld.

R. M. Dixon[A], F. Hamlyn-Hill[A], R. Cribb[B], A. McClymont[C] and D. B. Coates[D]

[A], Queensland DPI&F, Rockhampton or Charters Towers; [B], Middle Park Station, Richmond, Qld; [C], Burleigh Station, Richmond, Qld; [D], CSIRO Davies Laboratory, Townsville.

Faecal near infrared spectroscopy (F.NIRS) can measure many of the components of the diet selected, intake, and liveweight (LW) change of grazing cattle (Coates 2004, Dixon and Coates 2005). F.NIRS measurements were made in a herd to determine diet characteristics and to predict LW.

From Sept 2001 until Feb 2003 cattle grazed a 280 ha paddock, half black soil Mitchell grass downs and half red soil open woodland on Morungle Station. The herd comprised 2 age groups of Brahman and Brahman cross steers (350 kg, n 17; 178 kg, n 24). In April 2002 the heavier subgroup was replaced with young steers (156 kg, n 21). Steers were weighed and sampled regularly and F.NIRS predictions made using Coates (2004) calibration equations.

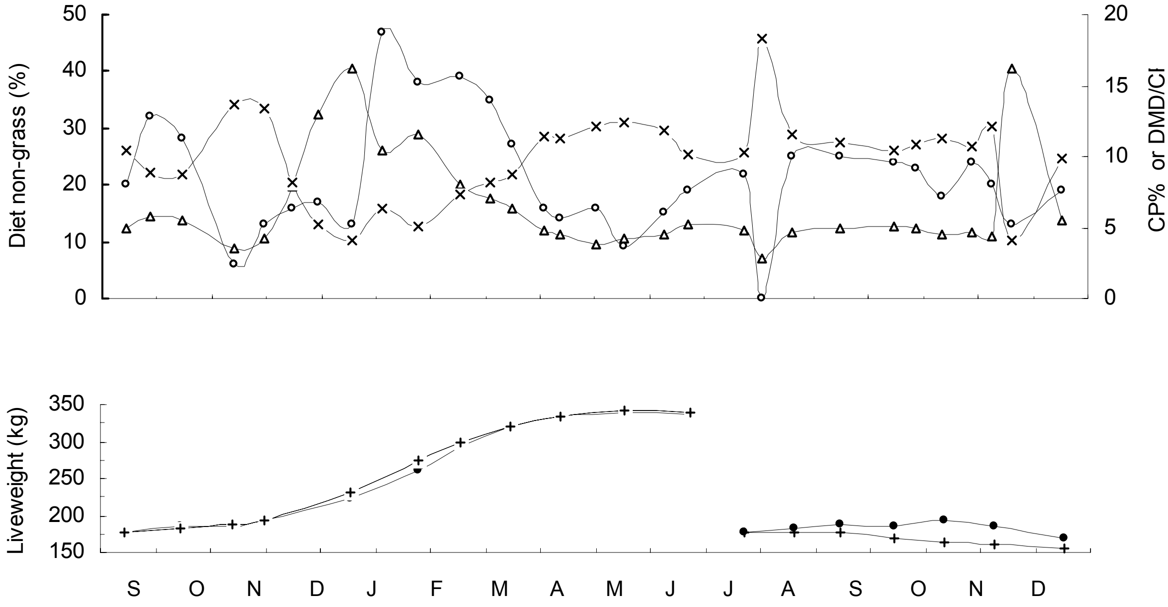

Fig. 1. The non-grass (○), crude protein (Δ) and DMD/CP ratio (x) of the diet selected by grazing steers, and the actual (●) and F.NIRS predicted (+) liveweight of steers in successive drafts.

There was 975 mm rain from Nov 2001 to Feb 2002, but thereafter only 25 mm until Feb 2003. Pasture availability was about 4000 kg pasture/ha in Sept 2001, about 3000 kg/ha in May 2002, and then declined progressively. Non-grass (i.e. forbs) often comprised a substantial part of the diet and the animals apparently selected for this pasture component. Forbs apparently made an important contribution to diet protein. Diet CP did not decrease to the very low concentrations, or the DMD/CP (ratio dry matter digestibility to crude protein) increase to the high values often observed in cattle grazing tropical native pastures. F.NIRS satisfactorily predicted steer LW change. Diet quality was generally in accord with expectations from the rainfall, and steer LW changes in accord with the quality and quantity of pasture available at various times.

Coates DB (2004) Faecal NIRS - Technology for improving nutritional management of grazing cattle. MLA Project NAP3.121 Final Report.

Dixon RM, Coates DB (2005) The use of faecal NIRS to improve nutritional management of cattle in northern Australia. *Recent Advance in Animal Nutrition in Australia,* 15, 65-75.

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9.8 Appendix 8. NBRUC short paper

Proceedings, Northern Beef Research Update Conference, 2007.
(Poster in file: NBP.302_Appendices_7+8+12.pdf)

F.NIRS measurements of diet quality and growth of cattle grazing arid grassland-browse associations near Charleville, SW Qld.

R. M. Dixon[A]*, M. R. Jeffery*[AB] *and D. B. Coates*[C]
[A], Queensland DPI&F, Rockhampton or Charleville; [C], CSIRO Davies Laboratory, Townsville.

Faecal near infrared spectroscopy (F.NIRS) can measure many of the components of the diet selected, intake, and liveweight (LW) change of grazing cattle (Coates 2004; Dixon and Coates 2005). F.NIRS measurements were made in a herd to determine diet characteristics and to predict LW.

From Nov 2001 until Apr 2003 cattle grazed one of 2 paddocks (300 or 430 ha) on Croxdale Research Station comprising Coolibah flats of black/grey clays and loams, and red sands with Mulga/turkey bush vegetation. The herd initially comprised Brahman cross steers (251 kg, n 19). In June 2002 the heavier steers were replaced with heifers (177 kg, n 21). Steers were weighed and sampled regularly, and F.NIRS predictions made using Coates (2004) calibration equations.

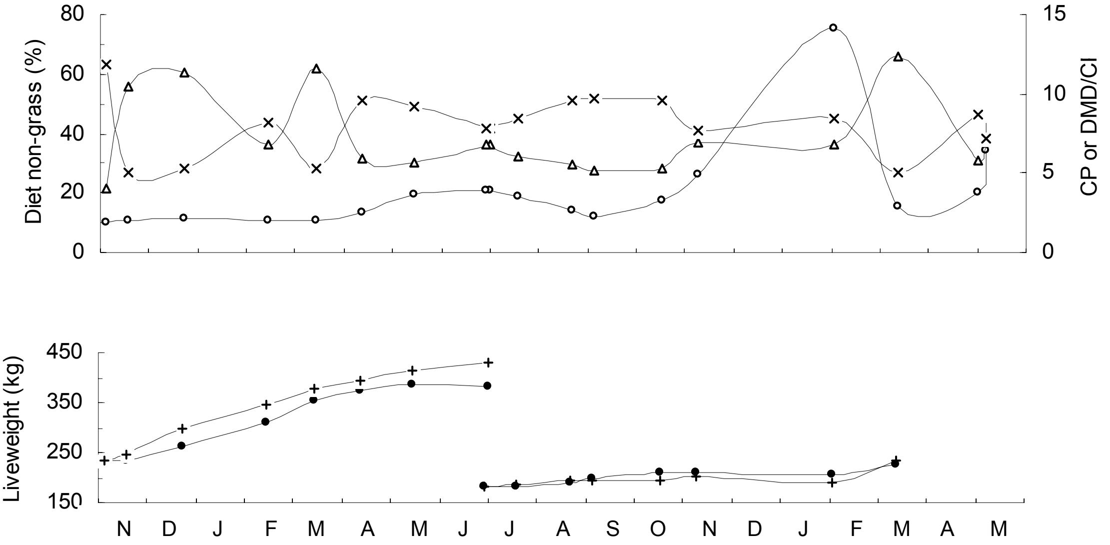

Fig. 1. The non-grass (○), crude protein (Δ) and DMD/CP ratio (x) of the diet selected by grazing steers, and the actual (●) and F.NIRS predicted (+) liveweight of steers in successive drafts.

There was 365 mm rain from Nov 2001 to Feb 2002, then 90 mm through until Jan 2003, 82 mm in Feb 2003 and 18 mm in Mar and Apr 2003. Pasture availability was about 1000 kg pasture/ha from Nov 2001 through to July 2002, and then declined progressively to about 400 kg DM/ha by Apr 2003. Non-grass comprised 10-21% of the diet from Nov 2001 until Oct 2002, but then increased in Nov 2002 and Jan 2003 indicating increased ingestion of browse following extended dry season conditions. Non-grass declined following the rain in Feb 2003 before increasing again in Apr-May 2003. Diet CP was initially low (4%) but increased with the rain and new pasture growth in Nov 2001 to Mar 2002. Diet CP then declined and was 5-7% until the rain in Feb 2003. F.NIRS tended to over-estimate steer LW change during Nov and Dec 2001. Diet quality and steer LW changes were generally in accord with expectations from rainfall and observations of pasture. Browse made a major contribution to the diet when little pasture was available.

Coates DB (2004) Faecal NIRS - Technology for improving nutritional management of grazing cattle. MLA Project NAP3.121 Final Report.

Dixon RM, Coates DB (2005) The use of faecal NIRS to improve nutritional management of cattle in northern Australia. *Recent Advance in Animal Nutrition in Australia,* 15, 65-75.

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9.9 Appendix 9. Short conference paper

Paper presented at the 12th Australian Near Infrared Spectroscopy Conference, 9th and 10th May 2006, Rockhampton, Queensland, Australia.

Expanding faecal NIRS calibrations to measure dietary characteristics using digested residues of forages as a proxy for faeces

R. M. Dixon and D. B. Coates.

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Characteristics of the diet of cattle can be determined from NIRS measurements of faeces, but the reference values for the calibration equations depend on diet-faecal sample pairs (Coates 2004; Dixon and Coates 2005). Such samples require animals fed in pens or prepared with oesophageal fistula, but these procedures are costly and sometimes inappropriate. The components of the NIRS spectra of faeces which relate to diet are most likely the undigested plant components in faeces. Two experiments examined whether the forage residues remaining after ruminal digestion processes could be used as a proxy for faeces spectra in calibration equations to predict diet characteristics from measurements of faeces.

In Experiment 1 three steers with rumen cannulae were fed each of 3 forages (*Panicum maximum*, panic, 0.8% N; *Chloris gayana*, Rhodes, 3.0% N; and *Medicago sativa,* lucerne, 3.3% N). Each forage was incubated in synthetic fibre bags in the rumen for 2, 3 or 4 days before bags were removed, washed and dried. Faeces were sampled. Dried and ground faeces and forage residues were scanned (400-2500 nm; Foss 6500). Using established calibrations (Coates 2004) diet N was predicted satisfactorily from faecal spectra. However, predictions of diet N from the spectra of digested forage residues were 21-53% of the actual diet N and thus were not acceptable.

In Experiment two 47 forages (22 grasses, 16 legumes and 9 non-leguminous forbs) were incubated for 4 days in the rumen of 3 steers fed Rhodes grass hay. Faecal samples were available for 20 of the grasses from previous pen experiments. The spectra of the digested forage residues were modified using the SNV and Detrend transformed difference spectra between faeces and digested forage residues measured in Experiment 1. The difference spectrum for the panic forage (low N content) appeared to differ from those for the Rhodes and lucerne forages (high N content). Therefore the former difference spectrum was used to modify forages < 1.9%N, and the mean of the latter difference spectrum used to modify forages ≥ 1.9%N. Established calibration equations were used to predict the N content of the 47 incubated forages from the modified spectra, and also from faeces for the 20 grasses where these were available. One forage species (*Crinum flaccidium*) was a spectral outlier (GH ~100). The SEP of prediction of N content of the 20 grasses from faecal spectra was 0.23. The SEP of predictions from the corrected spectra of the digested forage residues were 0.43, 0.61 and 0.31 for the grasses, legumes and non-leguminous forbs, respectively. It appears possible to use the spectra of residues of forages following rumen digestion in synthetic fibre bags as a proxy for faeces to expand faecal NIRS calibration equations to measure diet characteristics.

References
Coates, D. B. *Final Report Project NAP.121,* Meat and Livestock Australia (2004).
Dixon, R.M. and Coates, D.B. *Recent Adv. Anim. Nut. Aust.* 15: 65-75 (2005).

9.10 Appendix 10. Conference paper

Paper **Use of NIRS to measure the proportion of leaf in tropical grass forages** by Rob Dixon and Grant Zhu. 2007. In NIR2005. Proceedings of the 12th International Conference on Near-InfraRed Spectroscopy (Editors G R Burling-Claridge, S E Holroyd and R M W Sumner). pp. 397-400. **Refereed.** New Zealand Near Infrared Spectroscopy Soc. Ltd, AgResearch, New Zealand.

This published version of the document is included as an attached pdf file "NBP.302_Appendix_10A", and the Poster in attached pdf file "NBP.302_Appendix_10B"

9.11 Appendix 11. Draft short conference paper

DRAFT. Using NIRS to Measure the Botanical and Morphological Composition of Pastures

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Although the proportions of the various plant species and their morphological components are important determinants of the nutritional value of a pasture for grazing animals, their measurement generally depends on laborious manual sorting of pasture samples. Near infrared reflectance spectroscopy (NIRS) has been used to measure botanical and morphological composition of pastures (Coleman et al. 1990; Dixon and Zhu 2007). The present study examined NIRS to measure the proportions of 3 pasture species (2 grasses and one legume) and the proportions of leaf of each of these species in harvested samples of a tropical pasture.

Samples were harvested on 3 dates (2 March, 4 April and 26 May 2005) from pasture consisting predominantly of buffel grass *(Cenchrus ciliaris),* black speargrass *(Heteropogon contortus)* and seca stylo *(Stylosanthes scabra)* at a site 20 km N of Rockhampton, Qld. An area was divided into five 25 x 25 m blocks. Triplicate samples of each of the 3 species of plants were harvested from random sites within each block, the plant of the designated species closest to the sampling point being harvested. Samples were manually separated into leaf blade and stem and dried (60°C) to determine these proportions. Samples of separated leaf or stem, leaf and stem mixed in the ratios 200/800 and 400/600, the 2 grass species mixed in the ratio 500/500, and these latter mixed grass samples further mixed with seca 500/500 were scanned to provide in total 360 calibration samples. In addition, validation samples (n 45) were obtained in triplicate from each block at each sampling time by harvesting 0.25 m^2 quadrats, manual separation to determine the proportions of leaf and stem of each of the 3 species, and then scanning the remixed sample. Samples were ground (1 mm screen, Model 1093 Cyclotec mill, Foss Tecator AB, Hoganas, Sweden). NIRS spectra (400-2500 nm) were measured using a scanning monochrometer (Foss 6500, NIRSystems, Inc., Silver Spring, Md., USA) fitted with a spinning cup. Chemometric analysis used ISI software (Infrasoft International, Port Matilda, Penn., USA) and involved transformations of the absorbance data (standard normal variate and detrend, first (1,4,4,1) and second derivatives (2,4,4,1) of the spectra) and modified partial least squares (MPLS) models in selected wavelength ranges (700-2500 and 1100-2500 nm) to develop and validate calibration equations.

Table 1. Calibration and validation statistics (g/kg dry matter) for first derivative calibration equations

Measurement	Calibration (n 360)		Validation (n 45)						
	R^2_{cal}	SECV	Mean	Std Dev	Min.	Max.	R^2_{val}	Bias	SEP(C)
Total *C. ciliaris*	0.99	49	228	267	0	861	0.96	15	59
Total *H. contortus*	0.99	47	374	256	0	783	0.95	-10	61
Total *S. scabra*	1.00	14	397	154	0	698	0.99	-5	18
C. ciliaris leaf	0.92	34	58	71	0	263	0.68	5	43
H. contortus leaf	0.98	32	128	98	0	292	0.84	0	45
Grass leaf	0.98	35	187	66	55	348	0.66	-17	46
S. scabra leaf	0.99	21	84	40	0	168	0.79	-3	23
Total leaf	0.98	40	271	65	158	416	0.73	-11	47

SECV, standard error of cross validation; SEP(C), standard error of prediction following correction for bias.

The calibration models calculated following first derivative transformation and the 1100-2500 nm range (Table 1) were generally the most satisfactory although there were only small differences between models. The ratios of the validation population SD to the SEP(C) indicated that the proportion of total DM of each species was measured with an error acceptable for many experimental purposes.

Measurement of total leaf, or leaf of individual plant species (as a proportion of total DM) was less satisfactory but may have been associated primarily with the low proportions of leaf in the pasture. To satisfactorily predict at other sites, and with other pasture species, the NIRS calibration equations will need to be expanded with additional data.

Coleman, S.W., Christiansen, S. and Shenk, J.S. (1990). *Crop Sci.* **30:** 202-207.

Dixon, R.M. and Zhu, G. (2007). In: *Proceedings of the 12th International Conference.* pp. 397-400. (Eds G. R. Burling-Claridge, S. E. Holroyd and R. M. W. Sumner). NZ Near Infrared Spectroscopy Society.

9.12 Appendix 12. NBRUC short paper

Proceedings, Northern Beef Research Update Conference, 2007.
(Poster in file: NBP.302_Appendices_7+8+12.pdf)

Using NIRS to measure the composition of extrusa from oesophageally fistulated cattle

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[B]CSIRO Davies Laboratory, Townsville

The diet selected by grazing cattle has usually been measured from the constituents of extrusa collected from oesophageally fistulated animals. Botanical and morphological composition of the extrusa is normally determined by extremely laborious manual sorting or microscopic examination of the extrusa. The proportions of grass, forbs and the principal grass species in extrusa have been measured using NIRS (Volesky and Coleman 1996). The present study examined NIRS as a technology to measure the composition of extrusa from cattle grazing tropical grass pastures.

Extrusa samples (n 87) were collected in March 1993-1996 and 1998 from oesophageally fistulated steers grazing 18 paddocks (2 replicates each of 9 grazing treatments) of speargrass-based pasture at Galloway Plains, Calliope, CQ (Orr 2005). Each paddock was sampled by 6-8 steers. Proportions of green leaf, dead leaf, green stem and dead stem of each plant species present in extrusa, and N content, were measured. Samples from each paddock in each year were dried, ground and bulked. NIRS spectra (400-2500 nm) were measured using a Foss 6500 scanning monochrometer fitted with a spinning cup. Chemometric analysis used ISI software and involved transformations of the absorbance data (SNV+D, 1,4,4,1 and 2,4,4,1) and MPLS to develop and test calibration equations.

Table 1. The population (n 87), calibration (n 63) and validation (n 24) statistics (g/kg dry matter) for the first derivative (1,4,4,1) calibration equations

Measurement	Mean	s.d.	Min.	Max.	Calibration		Validation	
					R^2_{cal}	SECV	Bias	SEP(C)
N content	11.6	3.1	6.7	19.7	0.92	0.97	-0.11	0.83
Heteropogon contortus	284	202	6	794	0.85	98	-41	93
Bothriochloa bladia	200	147	13	590	0.70	109	45	105
Grass leaf blade	671	237	118	968	0.93	77	-15	77
Total grass	760	231	205	987	0.94	68	16	51
Stylo	158	248	0	763	0.96	68	4	44
Forbs (other dicots)	59	69	0	294	0.74	58	-20	38

s.d., standard deviation; Min, minimum; Max, maximum; SECV, standard error of calibration; SEP(C), standard error of prediction following correction for bias.

The calibration equations indicated that N content and the proportions of total grass leaf blade, total grass and total stylo could be measured with an accuracy suitable for many experimental purposes. Measurements of the proportions of green and dead components of grass, of the forbs and sedge plant groups, or of the specific grass species, was generally less satisfactory. It may be possible to use NIRS to measure satisfactorily some of these latter constituents when they comprise higher proportions of the extrusa (Volesky and Coleman 1996).

In conclusion, NIRS can be used satisfactorily in a closed population to measure the proportions of leaf blade, total grass and stylo in extrusa obtained from oesophageally fistulated cattle grazing speargrass pastures at a specific site over a number of years. Additional reference values are likely to be required to expand the NIRS calibration equations to measure constituents in extrusa obtained from cattle grazing other pasture systems.

Orr DM (2005) Effects of stocking rate, legume augmentation, supplements and fire on animal production and stability of native pastures. MLA Project NAP3.207 Final Report.

Volesky JD, Coleman SW (1996) Estimation of botanical composition of oesophageal extrusa samples using near infrared reflectance spectroscopy. *Journal of Range Management* **49,**163-166.

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9.13 Appendix 13. Short conference paper, RAAN

Appendix 13. Paper **Using faecal NIRS to measure the species and leaf contents of tropical grass diets of ruminants (2007).** R M Dixon and G Zhu. *Recent Advances in Animal Nutrition in Australia* (Editors P B Cronje and N Richards). pp. 251. **Refereed.** The University of New England, Armidale.

This document is included as an attached pdf file “NBP.302_Appendix_13”.

9.14 Appendix 14. Short conference paper

Appendix 14. Paper **Using faecal near infrared reflectance spectroscopy (F.NIRS) to measure the proportion of grass in the diet selected by cattle grazing tropical pastures (2006).** D B Coates, R M Dixon and M Sullivan. (Editor P. Erkelenz). pp. 251. **Refereed.** Australian Rangeland Society 14th Biennial Conference, 3-7 September 2006.

Mug-shot

USING FAECAL NIRS TO MEASURE THE PROPORTION OF GRASS IN THE DIET SELECTED BY CATTLE GRAZING TROPICAL PASTURES

D. B. Coates, R. M. Dixon and M. Sullivan

CSIRO & DPI&F Logos

Background

- **Native pastures across northern Australia are predominantly tropical grasses but also usually contain dicot forbs. Shrubs and trees provide browses.**
- **How much do these forbs and browses contribute to the**
- **diet of cattle ?**

Methods

- **Faecal NIRS can be used to measure the ratio of C4 tropical grasses to C3 plants (dC) and crude protein (CP) in the diet of grazing cattle.**
- **'Non-grass' was defined as the C3 dicot plants in the diet (i.e. native legumes, other forbs, browse).**
- **F.NIRS was used to measure protein and non-grass in the diet selected by cattle grazing 3 pasture systems:**
  (i) Northern speargrass - Swans Lagoon (Townsville),
  (ii) Mitchell - Toorak near Julia Greek,
  (iii) Monsoonal tallgrass (Newcastle Waters and Carlton Hill Station).

Results

Swans Lagoon.

- **Diet non-grass and CP were higher for cattle grazing native pasture (NP) oversown with stylo than those grazing NP without stylo.**
- **Cattle on NP actively selected for non-grass (native legumes and forbs) during March-April but diet non-grass and CP fell to very low levels during May-June. The increase in diet non-grass and CP in July-August was probably browse.**

Toorak.

- **In May 2002 pasture contained <2% non-grass but cattle selected substantial amounts of non-grass through the dry season (April-Dec).**
- **In May 2004 pasture contained 19% non-grass and cattle selected about 36% non-grass in the diet through the dry season.**
- **Dry season diet CP averaged 5.5 - 5.8% in the 2 dry seasons.**

Newcastle Waters and Carlton Hill.

- **The beneficial effect of diet non-grass on diet CP was demonstrated.**
- **Diet CP was linearly related to diet non-grass. The non-grass selected was 9-10% higher in CP than the grass during the late wet and the dry season.**

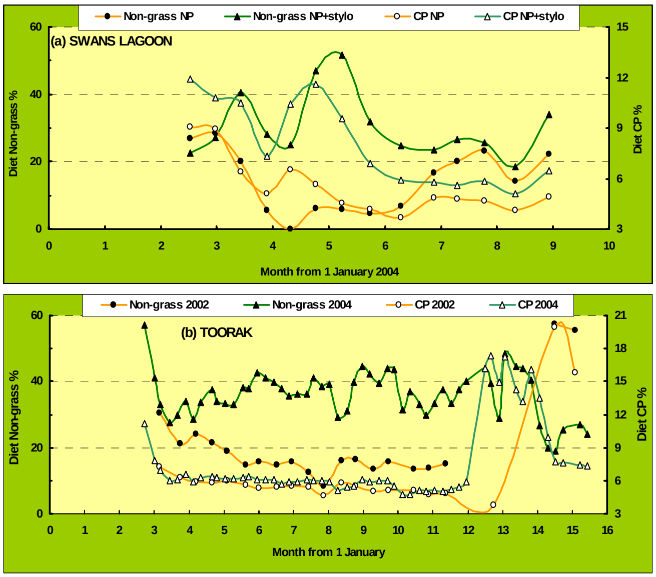

Figure 1. Faecal NIRS predictions of diet non-grass and crude protein concentration at (a) Swans Lagoon and (b) Toorak Research Station

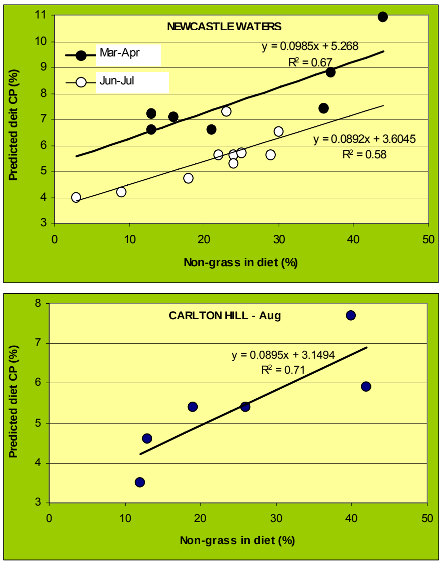

Figure 2. Relationship between predicted diet CP% and diet non-grass% for samples collected from Newcastle Waters and Carlton Hill.

Findings:

- **These and other trials demonstrate that in the northern rangelands grazing cattle rarely select diets composed entirely of grass.**
- **Non-grass usually contains more protein than grass. Thus selection of non-grass by cattle increases diet CP and ameliorates the usual dry season protein deficiency.**
- **Non-grass in the diet of cattle during the mid- to late dry season is often the result of browsing. Because browses often contain high concentrations of condensed tannins the available CP in the diet may be much lower than the total CP.**
- **The importance of non-grass in the diet of cattle grazing rangelands in northern Australia has not been generally appreciated.**
- **Faecal NIRS provides a reliable and economical procedure to measure the non-grass in the diet selected by grazing herbivores.**

MLA logo and acknowledgement

USING FAECAL NEAR INFRARED REFLECTANCE SPECTROSCOPY (F.NIRS) TO MEASURE THE PROPORTION OF GRASS IN THE DIET SELECTED BY CATTLE GRAZING TROPICAL PASTURES

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ABSTRACT

A F.NIRS calibration equation was developed for predicting the δ13C ratio in faeces, and therefore the proportions of C_4 tropical grasses to C_3 non-grass plants (primarily forbs, legumes and browses) selected by grazing cattle. This calibration equation was used to measure seasonal profiles of dietary non-grass for a NE Qld speargrass site with and without introduced pasture legume, and for a NW Qld Mitchell grass site. In addition, results are presented for cattle grazing savannahs in the monsoonal tropics of central, northern Australia. Non-grass can form a substantial component of the diet even where there is ample grass on offer and may contribute substantially to diet protein content during the dry season.

INTRODUCTION

In the tropics and subtropics of northern Australia the native and introduced pasture grasses are predominantly C_4 species. Conversely, most of the non-grass vegetation comprises C_3 species. Diet C_4 and C_3 proportions can be determined from faecal $^{13}C/^{12}C$ ratios ($\delta^{13}C$, Jones 1981). The $\delta^{13}C$ is usually measured by mass spectroscopy, but Near Infrared Reflectance Spectroscopy (NIRS) provides a rapid and inexpensive alternative (Clark *et al.* 1995, Coates 2004). This paper reports the development and application of F.NIRS for the measurement of $\delta^{13}C$ of faeces for cattle grazing tropical pastures in northern Australia.

METHODS

NIRS measurements

A calibration equation to measure the $\delta^{13}C$ was developed from faeces of cattle grazing a wide range of pastures comprised of C_4 grasses and C_3 non-grasses. Faecal $\delta^{13}C$ was measured by mass spectroscopy, while reflectance (700-2500 nm) of dried and ground faeces was measured using a Foss 6500 scanning monochromator. Calibration and validation statistics for $\delta^{13}C$ calculated in a MPLS model with first derivative of log 1/R spectra and SNV-detrend transformed data were excellent (n 1501; range -12.27 to -27.65‰; SEC 0.78; SECV 0.78; R^2_{cal} 0.94; SEP 0.83). Diet proportions of non-grass were calculated as: % non-grass = (faecal $\delta^{13}C$ - 13.5) * 7. This assumes that the average faecal $\delta^{13}C$ for C_4 grass and C_3 non-grass diets are -13.5‰ and -27.5‰, respectively.

Sampling procedure

F.NIRS measurements examined the seasonal profiles of diet non-grass and crude protein (CP) at two sites grazed by young *Bos indicus* cross cattle. At Swans Lagoon near Townsville in the northern speargrass pasture region, heifers grazed a paddock of unimproved native pasture (NP) or NP oversown with seca and verano stylos (NP+stylo). At Toorak near Julia Creek, measurements were made with two drafts of steers grazing Mitchell grass downs pasture in 2002 and 2004. Pasture composition was assessed at the end of the wet season at both sites. In addition F.NIRS measurements were made on two properties in the monsoonal tropics. Samples representing cattle located at various watering points were collected on two occasions (March-April and June-July) at Newcastle Waters (south of Daly Waters) and one occasion in August at

Carlton Hill (near Kununurra). Samples were stored frozen, dried (65ºC), ground, and then scanned.

RESULTS

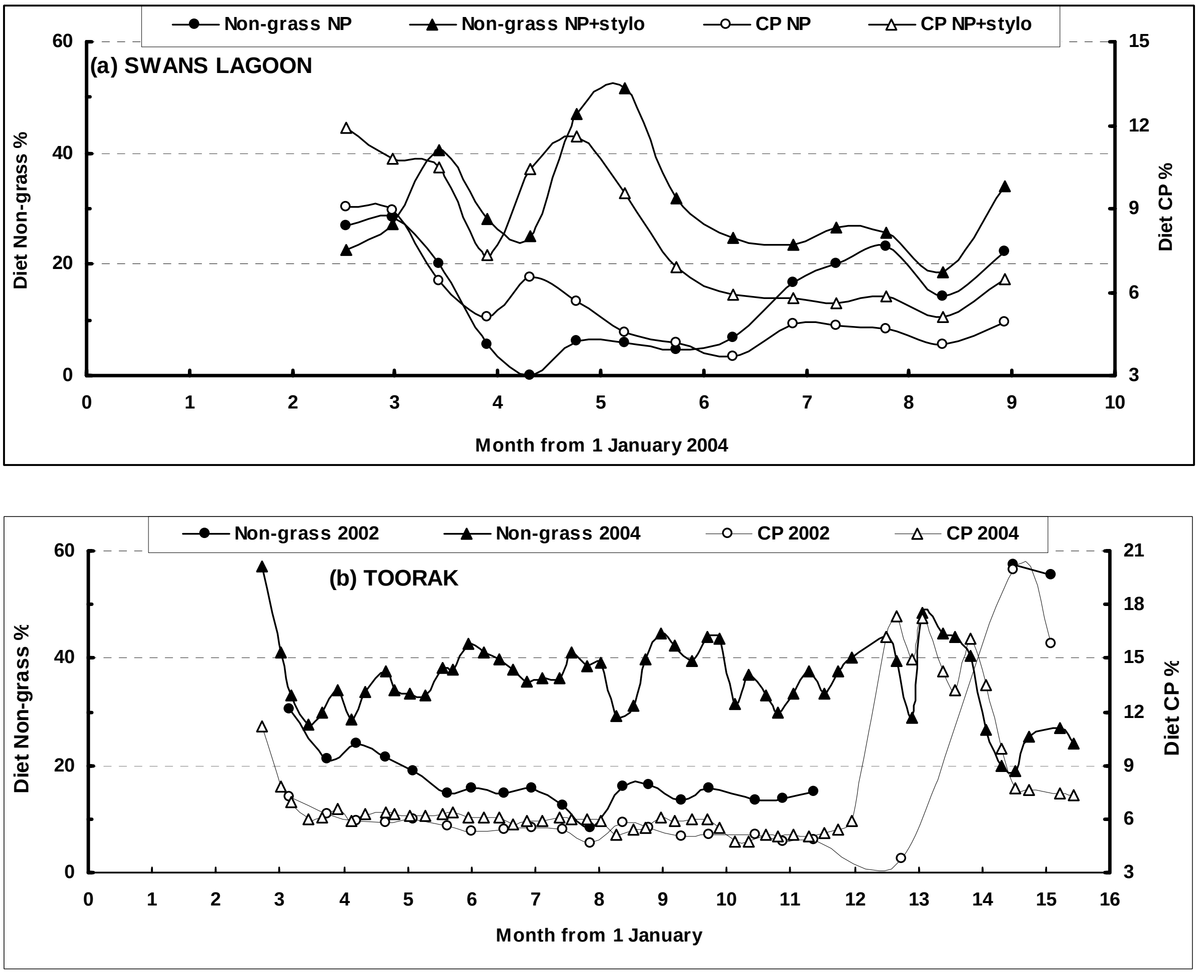

Figure 1: Faecal NIRS predictions of diet non-grass proportions and crude protein concentration at (a) Swans Lagoon and (b) Toorak Research Station

At Swans Lagoon, in heifers grazing NP, the diet non-grass was 20-27% from March to mid-April, declined to 0-7% in the mid dry season, but increased again in the late dry season (Fig.1a). Diet CP declined from about 9% in March to 3-5% from June to September. In April, native legumes and forbs comprised 8% of the 3.1 t/ha of total pasture DM on offer. Presence of stylos in the pasture (NP+stylo) resulted in much more non-grass in the diet selected through the dry season, and this was >50% in early June. Diet CP was correspondingly higher (mean of 6.4% June-September). In April the stylo, native legume and forbs comprised 32% of the total 3.1 t/ha pasture DM on offer.

At Toorak, rainfall in the wet seasons preceding F.NIRS measurements was only 54% (236 mm) and 70% (308 mm) of the long-term average for the 2002 and 2004 drafts respectively. Pasture on offer in May was 1.11 and 1.43 t/ha, respectively. Non-grass, which consisted of native legumes and forbs, comprised <2% of pasture DM in May 2002 but almost 19% in May 2004. In 2002 the non-grass was 30-20% of the diet in April and May, declining to 8-19% (mean 14%) from mid-June to December (Fig.1b). Diet CP of 7.2-5.8% in April and May declined progressively and was <5% by the late dry season.

In 2004 non-grass in the diet was much higher and averaged about 36% through the dry season, April-December. Diet CP in 2004 was only slightly higher than in 2002 (means of 5.8 and 5.5% respectively for the period April-December). In both drafts of steers diet non-grass and CP concentration increased sharply following the break in the dry season.

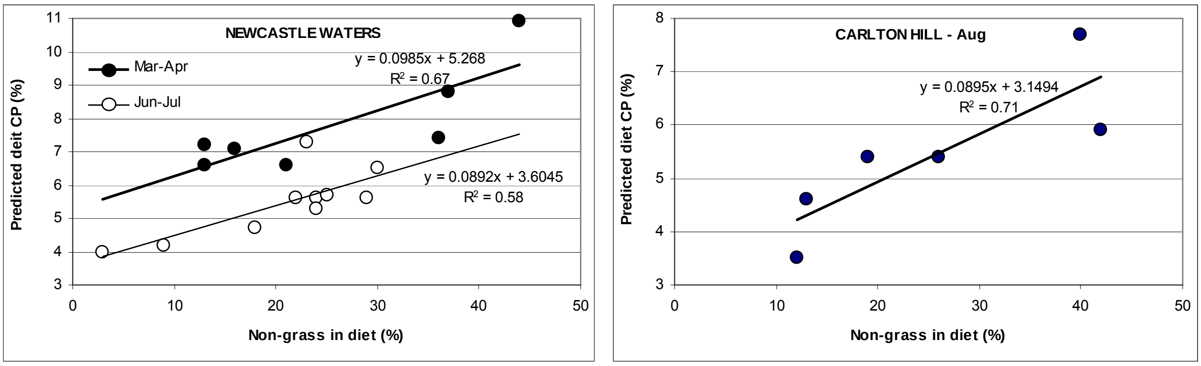

Figure 2: Relationship between predicted diet CP% and diet non-grass% for samples collected from different cattle watering points at Newcastle Waters and Carlton Hill.

The linear relationships ($P < 0.05$) between diet CP and non-grass at both sites in the monsoonal tropics (Fig.2) indicated that the protein content of the non-grass was higher than that of the grass. The intercepts of the regressions provide a measure of the protein content of the grass selected (3.1-5.3%), while the slopes indicate that the protein content of the selected non-grass ranged from 8.9-9.9%. For every 11% increase in diet non-grass, CP of the entire diet increased by >1%. The regressions for the two sampling at Newcastle Waters suggested that the grass selected decreased from 5.3 to 3.6% CP, while the non-grass selected decreased from 9.9 to 8.9% CP, during the interval between samplings.

DISCUSSION

Errors in the F.NIRS measurement of the non-grass % were potentially associated with both the use of faecal δ^{13}C for this purpose, and the F.NIRS prediction of faecal δ^{13}C. First, calculation of dietary non-grass from faecal δ^{13}C did not allow for any differences in the digestibility of the grass and non-grass fractions of the diet (see Jones 1981). Higher digestibility of the non-grass fraction, as often occurs, leads to slight under-estimation in diet non-grass proportions. If the non-grass is lower in digestibility than the grass, as may occur when browse is ingested, diet non-grass may be over-estimated. Second, the presence of C_4 forbs in the diet may also lead to errors. Third, there will be variable analytical errors bearing in mind that the standard error of prediction (SEP) of 0.83 is equivalent to 6% non-grass.

The F.NIRS measurements presented demonstrate a number of characteristics of the diets selected by cattle through the seasonal cycle in northern Australia. First, diets devoid of non-grass would appear to be uncommon and only rarely occur where grass is either completely or extremely dominant, or at certain times of the year. Secondly, the non-grass species can often comprise a substantial, and sometimes the dominant, component of the diet. The proportion of diet non-grass appears to be associated with the amounts and types of species present, and also with seasonal effects. A high degree of selection for non-grass during the dry season was clearly demonstrated on the NP+stylo pasture at Swans Lagoon, and on the Mitchell grass downs at Toorak. At the latter site, although the proportion of non-grass in the pasture in May 2002 was <2%, diet non-grass averaged almost 15% through the dry season May-December (Fig.1b). Comparable amounts in 2004 were <20% in the pasture in May but 36% in the diet through the dry season, May-December. Extreme examples of selection for non-grass commonly occur when little grass is available such as during drought.

The results presented, together with numerous comparable F.NIRS measurements of the diet selected by grazing cattle across northern Australia (D.B. Coates, unpublished data), indicate that non-grass often comprises a substantial proportion of the diet selected and that protein in the non-grass components of the diet is often much higher than in the grass fraction. The selection of non-grass material would therefore delay the onset and reduce the severity of the dry season protein deficiency often observed in northern Australia. At Toorak, the similar diet protein concentrations during the two dry seasons, despite the substantial difference in diet non-grass proportions, appeared to contradict this hypothesis. However, it seems likely that this was an unusual situation due to the protein in the grass being lower in 2004 than in 2002. DM digestibility of the diet was lower in 2004 than in 2002 (data not shown) and this would be consistent with a lower leaf-stem ratio and lower grass CP. The late dry season increase in diet non-grass of cattle grazing NP at Swans Lagoon probably reflected an increase in browsing behaviour stimulated by very low grass protein levels and the lack of herbaceous non-grass components in speargrass pastures at that time of year. In contrast, cattle grazing the NP+stylo pasture had access to the perennial seca stylo.

CONCLUSIONS

The contribution of non-grass to the diets of cattle grazing the rangelands of northern Australia can be easily and reliably estimated using faecal NIRS**.** The non-grass fraction can make a substantial contribution to the diet in terms of proportional DM and protein status. Since the protein level of grass during the dry season is generally well below maintenance requirements for cattle, the edible non-grass components of the vegetation form an important part of the fodder resource, even where grasses dominate.

ACKNOWLEDGEMENTS

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9.15 Appendix 15. Scientific journal paper

The conference paper described in Appendix 15 was developed into a full journal paper as follows:

Coates, D. B. and Dixon, R. M. (2007). Faecal near infrared reflectance spectroscopy (F.NIRS) measurements of non-grass proportions in the diet of cattle grazing tropical rangelands. *The Rangeland Journal* 29, 51-63.

Abstract. Frequent F.NIRS analyses of faeces from cattle grazing a range of tropical pastures were used to measure the non-grass component, and other aspects, of their diets. Seasonal profiles of non-grass and crude protein in the diet are presented for 9 sites from the speargrass, *Aristida-Bothriochloa*, and Mitchell grass pasture regions, and for three shrubland sites where browse was plentiful. In grass-dominated native pastures of the speargrass and *Aristida-Bothriochloa* pasture regions of Queensland where little browse was available, non-grass was usually only 5-15% of the diet. Diet non-grass was even lower for a buffel grass pasture. In uncleared eucalypt woodland in the speargrass region, browse may have contributed up to 20% of the diet in the late dry season when grasses were senesced. In regions with abundant browse (e.g. mulga lands and desert upland systems) cattle preferentially selected actively growing grasses and/or forbs when they were available. With diminishing availability and/or declining quality of the forbs and grass due to grazing selection and dry conditions, browse contributed increasingly to intake. In Mitchell grass pastures forbs often comprised more than 50% of the diet, and there appeared to be strong selection for forbs during the dry season. Where browse was available in association with Mitchell grass pastures, it appeared to contribute to intake only in the late dry season. Dry season sampling in monsoonal tallgrass and Mitchell grass pastures indicated dietary crude protein to be linearly correlated with diet non-grass, demonstrating the importance of non-grass in the prevention or alleviation of dry season protein deficiency in cattle. Changes in diet selected by cattle in relation to season and rainfall were generally in accord with the previous limited information, largely with sheep, in comparable vegetation systems. The results demonstrate the value of F.NIRS technology to assist understanding of diet selection by grazing cattle in northern Australia.

9.16 Appendix 16. Water quality measurements made at various experimental sites at intervals during 2002-2004

Measurement	Swans Lagoon site				Toorak site				BP	Mor	Conservative Limit
	mean	sd	Min.	Max.	mean	sd	Min.	Max.			
pH	8.0	0.4	7.4	8.8	8.4	0.2	8.2	8.6	8.3	7.6	
Conductivity (µS/cm)	287	286	110	980	457	93	335	560	630	290	
Total dissolved ions (mg/L)	222	219	81	757	390	94	259	470	433	240	3500
Hardness as CaCO3 (mg/L)	77	78	19	272	48	25	29	83	191	68	
Alkalinity as CaCO3 (mg/L)	108	101	39	360	197	54	120	240	140	110	
Sodium adsorption ratio (mg/L)	1	1	1	3	7	3	2	9	2	1	
Residual alkali (mg/L)	1	1	0	2	3	2	0	4	0	1	
Ca (mg/L)	16	14	5	52	12	2	10	15	35	11	
Mg (mg/L)	9	10	2	34	11	0	11	11	25	10	250
Na (mg/L)	31	35	11	120	87	37	36	120	66	26	
K (mg/L)	4	2	0	8	9	2	8	12	7	9	
CO3 (mg/L)	0	0	0	0	1	0	0	3	0	0	
HCO3 (mg/L)	132	123	48	439	235	63	146	280	170	130	
SO4 (mg/L)	3	4	0	14	5	4	1	10	13	14	1000
Cl (mg/L)	27	37	8	120	33	4	28	38	120	38	7000
F (mg/L)	0.3	0.5	0	1.6	0.3	0.03	0.3	0.4	0.16	0.2	2
Nitrate as N (mg/L)	0	0	0	0.2	0.2	0.1	0	0.3	0	0	100
Suspended solids (mg/L)	13	12	0	40	1	1	0	2	0	5	-

BP, Brian Pastures site; Mor, Morungle site; The indicative ‘Conservative limits’ are the maximum concentrations of the respective constituents for drinking water for livestock as recommended by Church (1971) and SCA (1990).