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Prepared by: D.B Coates, J.H Ternouth

CSIRO, University of QLD

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Effect of P-status on phosphorus absorption and excretion rates and reproductive function in pregnant and lactating beef heifers

CSIRO

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

PART 1

ABSTRACT

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ABSTRACT

Widespread dietary phosphorus deficiency is a major limitation to beef cattle productivity in northern Australia. Breeding cows are particularly susceptible because of the high demand for phosphorus during late pregnancy and lactation.

A knowledge of the efficiency of utilization of dietary phosphorus and a realistic appreciation of the phosphorus requirements of breeders in the tropics may be considered as a necessary foundation on which to develop effective and economic solutions to the problem of widespread phosphorus deficiency in breeders in northern Australia. An experiment studying the phosphorus kinetics of first calf cows grazing pastures of different P status was conducted to provide such basic information.

Phosphorus intakes, phosphorus absorption coefficients, excretion rates of endogenous faecal phosphorus, phosphorus status and productivity of pregnant and lactating cows were measured. High phosphorus absorption coefficients were measured in 3-year-old pregnant or lactating cows, comparable with those measured in weaner and yearling cattle. Phosphorus absorption coefficients were high in all groups and ranged between 0.67 and 0.86 g/g. Excretion rates of endogenous faecal phosphorus were lower for cows grazing low phosphorus pasture compared with those grazing pasture of higher P status. Cows on low phosphorus pasture utilized phosphorus very efficiently, surviving and rearing calves on very low phosphorus intakes. Phosphorus deficiency had adverse effects on cow liveweight, milk production and calf growth rates but there was no direct effect of phosphorus deficiency on post-partum reproductive function.

Because of abnormal seasonal conditions and the deterioration of the pasture P status of annually fertilized pasture which led to signs of P deficiency in HP cows, it was not possible to determine the extent to which P intakes may have either met or fallen short of requirements during lactation. However, all the evidence from the experiment suggested that current recommended requirements are substantially overestimated. The experiment provided estimates of absorptive efficiency and endogenous faecal P excretion rates from which requirements can be reassessed.

PART 2

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

Background and industry context

Phosphorus (P) and nitrogen deficiencies are known to be the major nutrients limiting beef production in northern Australia. The animals most likely to suffer from these deficiencies are growing cattle and breeders. The former have been the subject of substantial MRC funded research, in particular completed projects CS PO.19 and UQ AP.3. The results of these projects have underlined the separate primary and secondary effects of P on the growth of cattle. A primary deficiency will respond to a P supplement whilst a secondary deficiency is when the liveweight gain is only improved by the application of phosphorus fertilizer. These projects established both in the animal house and in the field the basic data necessary to re-assess the P requirements of growing cattle. Computation of the requirements of cattle from this data has shown that earlier observations (Little 1981) were correct and that overseas recommendations were excessive.

The successful outcomes to these earlier projects lead to the financial request that a pilot study on breeder cattle be undertaken using existing cattle at Lansdown.

Objectives

The broad objective of the project was to improve our knowledge and understanding of the P requirement of breeding cows grazing tropical pastures by carrying out P kinetic studies on pastures of different P status. The following specific objectives were designed to meet the broad objective.

(i) To measure the P intakes, P absorption coefficients and excretion rates of endogenous faecal P of pregnant and lactating beef cattle.

(ii) To determine the effect of different degrees of P deficiency/adequacy on the P economy of pregnant and lactating beef cattle.

(iii) To determine whether absorption coefficients and excretion rates of P in female cattle are affected by age and physiological status.

(iv) To determine the influence of P status on the weight change, mothering ability and post-partum reproductive function of first calf heifers.

(v) To assess the P requirements of pregnant and lactating first calf cows.

Methodology

The study was performed at Lansdown Pasture Research Station (Townsville) using 21 maiden Droughtmaster heifers. The heifers grazed three pasture types, selected to represent an improved high soil P pasture (Sabi grass + stylo), an improved low soil P pasture and an unfertilized native grass/stylo pasture.

P kinetic studies were undertaken in June, October and December of 1990 and in May 1991 to correspond with early to mid-pregnancy, pre-calving, post-calving and late lactational physiological stages.

Additional measurements of dietary P concentration, digestibility of forage, plasma inorganic phosphate and faecal P concentration, were made between the P kinetic studies, particularly during lactation when the demand for P was highest.

Post-partum reproductive function was monitored by regular plasma progesterone assay.

Rib bone biopsy and tail bone densitometry were used to determine the treatment effects on animal P status.

Main results and conclusions

The weather detracted from the success of this project as there were late rains in May-June 1990 which extended the growing season through much of the normal dry season and pregnancy period of the cows. Then shortly after calving very heavy rain, causing extensive flooding and waterlogging of the pastures, was followed by no significant further rain after February 1991.

The result of these abnormal weather conditions was better than normal pastures, in terms of yield, % green matter and nutrient composition during much of pregnancy (1990) but poorer pastures during lactation in 1991.

There were substantial differences between treatments in the liveweights of the animals, the cows on the fertilized improved pasture lost less liveweight than those grazing the other pastures whilst the calves gained most weight. The differences between treatments in calf growth were associated with differences in milk production. The cows grazing the fertilized improved pasture had significantly higher intakes of dry matter and P during both pregnancy and lactation.

Detailed measurements of the endogenous faecal P losses of the cows showed these values were low, much lower than those to be found in the literature and somewhat lower than those found previously in growing cattle on the same site in previous years. The coefficient of P absorption was high, higher than those reported elsewhere but similar to those recorded in growing cattle in previous years.

The treatments had no effect on reproductive parameters with cattle on all treatments returning to oestrous progressively between January and July.

The P status of the cows as measured by plasma inorganic P was higher on the fertilized improved pasture than the unfertilized pastures but declined markedly during lactation. In June 1991, there was no difference between treatments, they were all below 20 mg/l. At the start of lactation, densitometer measurements of the ninth coccygeal vertebra showed that the cattle grazing the fertilized improved pasture had better bone mineralisation, but this advantage had disappeared by the end of the lactation. An alternative measurement using the rib biopsy technique also showed no differences between treatments at the end of lactation. Rib cortical bone thickness was marginal in all treatments.

It was concluded that there are substantial production advantages in terms of liveweight gain and calf growth in grazing breeders on improved fertilized pastures. While there was no difference in post-partum reproductive performance in this study, it could be reasonably expected that the improved, fertilized pastures would confer an advantage in this trait under more normal seasonal conditions.

It is also concluded that P utilization in breeding cows is very efficient as a result of high absorption coefficients of dietary P and low excretion rates of endogenous P. Current published recommended P requirements for breeding cows are much too high. The data from this study will allow provisional estimates of the desirable P intakes of breeding cattle in the same way as has been determined for growing cattle.

Recommendations

CS.148 has provided new and vital information on the phosphorus nutrition and phosphorus kinetics of breeding cows under grazing conditions, information which seriously questions the values for phosphorus absorption coefficients and faecal excretion of endogenous phosphorus used by various international councils for the factorial calculation of phosphorus requirements in cattle. Notably, the experimental results indicate that current published requirements are far too high and that there is an urgent need to make a reassessment of phosphorus requirements. CS.148 was not able to resolve all the issues needed to undertake a comprehensive and reliable reassessment of such requirements. Because of the importance of phosphorus deficiency in the beef industry of northern Australia, it is strongly recommended that further studies be undertaken to:

(i) quantify the intake and excretion of nutrients, especially energy, N and P by breeder cattle grazing native and improved pastures in 'normal' seasons in different northern Australian environments;

(ii) determine the effects of these nutrients and their interactions on the reproductive performance of cows;

(iii) extend the data already gathered to reliably predict the P requirements of breeder cattle;

(iv) determine the value of providing supplementary P to breeder cattle under different conditions, with particular consideration to both the use or absence of legumes and the use of supplementary protein.

PART 3

FINAL REPORT

CS.148 Effect of P-status on phosphorus absorption and excretion rates and reproductive function in pregnant and lactating beef heifers.

CONTENTS

BACKGROUND

In northern Australia, widespread dietary deficiencies of nitrogen (N) and phosphorus (P) are major limitations to beef cattle productivity, especially in cattle grazing native pastures. An extensive program of research conducted through the 80's was directed at developing economically sound technologies to improve cattle productivity by way of increasing the dietary availability of both N and P. In essence, the work focused on the management of P inputs as either fertilizer or supplement for increased productivity of cattle grazing legume based pastures. Grazing trials were located at Manbulloo near Katherine in the Northern Territory, Springmount near Mareeba and Lansdown near Townsville in north Queensland, and Narayen near Mundubbera in south-east Queensland.

Funding assistance for some aspects of the work being done at Springmount, Lansdown and Narayen was provided by the AMLRDC under Project CS.PO19, ***Mineral nutrition of legume-based cattle production systems in northern Australia***, from 1986. In June 1988, the AMLRDC funded a workshop in Townsville, ***Phosphorus and beef production in northern Australia***, at which results from the four sites were combined and presented as a series of papers. These were subsequently published in the *Tropical Grasslands* journal, September issue, Volume 24, 1990. The workshop highlighted a lack of knowledge of some fundamental aspects of the P nutrition of cattle in the tropics and sub-tropics, *viz.* reliable information on P absorption coefficients and excretion rates of endogenous faecal P, applicable to cattle grazing P adequate and P deficient tropical pastures.

Such information was deemed necessary for both an improved understanding of, and a reassessment of, the P requirements of cattle in the tropics and sub-tropics. It was believed such knowledge was basic to an enlightened understanding of the extent and severity of P deficiency under grazing and to the development of sound and reliable strategies designed to overcome or ameliorate problems associated with P deficiency in cattle. Consequently, a project was developed in which P kinetic studies were carried out at the three sites incorporated within Project CS.PO19. This work was again funded by the AMLRDC and was successfully undertaken during 1989 and 1990.

The results of the P kinetic studies were enlightening and collectively represented a significant advance in our knowledge of P absorption and excretion in grazing cattle and of their ability to cope with low P intakes. The work provided clear evidence that published recommended requirements of P for growth in cattle are substantially over-estimated and that the over-estimation probably results largely from the use of low absorption coefficients in the calculation of requirements.

The successful outcome of the P kinetic studies on growing cattle suggested that the work could be usefully extended to cover breeding females. Because of the high demands for dietary P in breeders for foetal growth during late pregnancy, and for milk production during lactation, breeders form the largest class of cattle suffering from P deficiency in northern Australia. Production losses due to P deficiency in breeders are of great economic importance and include poor calving rates, poor growth rates in suckling calves, high cow mortality rates, low cow weight and condition and an increased incidence of botulism due to bone chewing. Any advances in our understanding of the P requirements of this most important class of cattle, and of those factors determining such requirements, must be of ultimate benefit in the process of developing strategies to overcome the adverse effects of P deficiency in breeders.

The use of yearling heifers in the initial P kinetic studies at the Lansdown site provided an ideal opportunity to continue the work on these heifers as they entered their reproductive stage. A proposal for the extended work received favourable consideration by the Corporation and funding was provided under contract covering one year's field work.

The project was undertaken by Mr David Coates of CSIRO, Division of Tropical Crops and Pastures, and Dr John Ternouth of the Queensland University Department of Agriculture. Professor Keith Entwistle of Tropical Veterinary Science, James Cook University, provided assistance with reproductive aspects of the project including the progesterone assays. Technical assistance was provided by Mr Michael Breen of the Division of Tropical Crops and Pastures.

OBJECTIVES

The broad objective of the project was to improve our knowledge and understanding of the P requirement of breeding cows grazing tropical pastures by carrying out P kinetic studies on pastures of different P status. The following specific objectives were designed to meet the broad objective.

(i) To measure the P intakes, P absorption coefficients and excretion rates of endogenous faecal P of pregnant and lactating beef cattle.

(ii) To determine the effect of different degrees of P deficiency/adequacy on the P economy of pregnant and lactating beef cattle.

(iii) To determine whether absorption coefficients and excretion rates of P in female cattle are affected by age and physiological status.

(iv) To determine the influence of P status on the weight change, mothering ability and post-partum reproductive function of first calf heifers.

(v) To reassess, using the acquired information on P absorption coefficients and faecal endogenous P excretion rates, the P requirements of pregnant and lactating first calf cows.

METHODOLOGY

The research was carried out at Lansdown Pasture Research Station near Townsville during 1990 and 1991. Thirty 2-year-old Droughtmaster heifers were joined with Droughtmaster bulls in February 1990 after injections with prostoglandins to sychronise oestrus. The heifers were pregnancy tested on May 15 and eight heifers diagnosed pregnant were allocated to each of three pasture treatments where they grazed for the next 14 months. The treatments were:

1. Grass-legume pasture of Urochloa (Sabi grass), Verano and Seca fertilized annually with 10 kg P/ha - treatment HP.

2. Unfertilized grass-legume pasture as above - treatment LP1.

3. Unfertilized native grass-stylo pasture - treatment LP2.

Of the 24 heifers, three were diagnosed as only possibly pregnant and were later confirmed as being empty. Group numbers then became 8, 6 and 7 for treatments HP, LP1 and LP2 respectively.

P kinetic studies were undertaken in June, October and December of 1990 and in May 1991 to correspond with early to mid-pregnancy, pre-calving, post-calving and late lactational physiological stages. The methodology used in the P kinetic studies has been described in detail by Ternouth *et al.* (1990)*. The dietary P concentration and the digestibility of the diet were estimated using oesophageal-fistulated steers. Faecal output of the experimental heifers was determined by means of intraruminal chromic oxide capsules and analysis of faecal samples collected over a 10 day period. The proportion of endogenous P in the faeces was determined by infusing the experimental heifers with 32P and relating the specific activity of P in the faeces to the specific activity of inorganic P in the plasma. Measures of forage intake, P intake, P absorption coefficients and excretion rates of endogenous faecal P were derived from the above determinations. Milk production was measured at the December and May studies by weighing calves before and after suckling.

Additional measurements of dietary P concentration, digestibility of forage, plasma inorganic phosphate and faecal P concentration, were made between the P kinetic studies, particularly during lactation when the demand for P was highest. Grass and legume proportions in the diets were estimated from the carbon isotope ratios in the faeces.

Post-partum reproductive function was monitored by regular plasma progesterone assay.

Rib bone biopsy and tail bone densitometry were used to determine the treatment effects on animal P status.

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* Ternouth, J.H., McLean, R.W., MacDonald, R.N. and Adamu, A. (1990). Field estimates of the phosphorus kinetics in grazing cattle. *Animal Production in Australia* **18**, 396-399.

RESULTS

Seasonal conditions

The experimental period from May 1990 to July 1991 was most atypical in terms of the amount and distribution of rainfall. High rainfall registrations in March and April and useful late season rainfall in May and June of 1990, resulted in an extended green season in 1990. Cattle, especially those grazing legume-based pasture, gained weight well into the 1990 dry season. By way of contrast, the 1990-91 wet was abnormally short, lasting barely two months from mid-December to mid-February. However, the rainfall recorded during this period (> 1250 mm) was over 150% of the average annual rainfall. The short wet season was followed by a long dry season. The effect of the amount and distribution of rainfall on soil moisture, pasture growth index and the duration of dry periods is illustrated in Fig. 1.

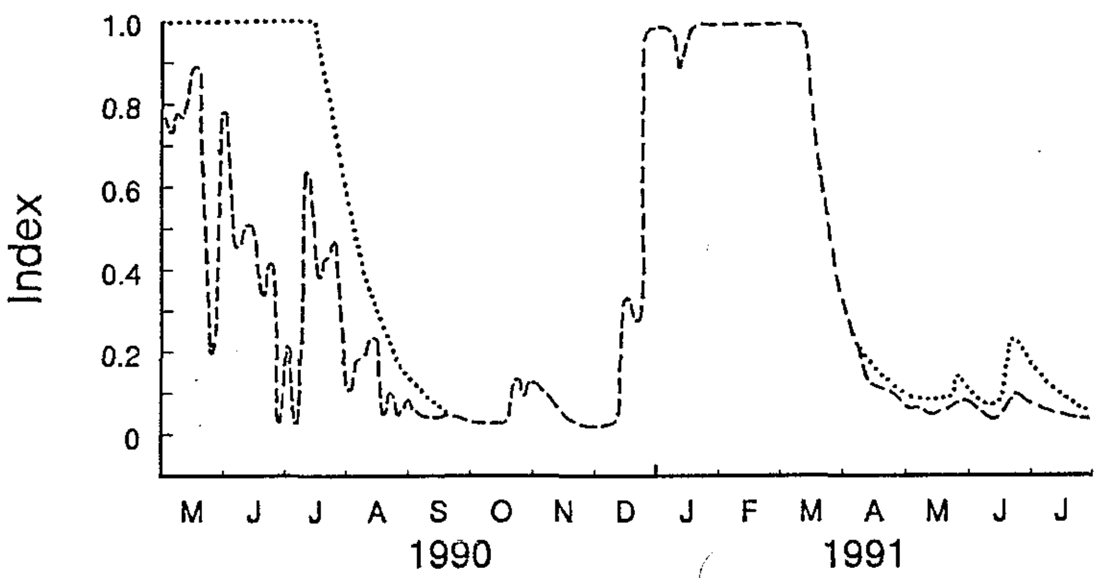

Fig. 1. Seasonal conditions during the experimental period, May 1990 to July 1991, as represented by *soil moisture index* (-----) and *pasture growth index* (— — —). For definition of these parameters see: Jones, R.J., Coates, D.B. and McCaskill, M.R. (1990). *Animal Production in Australia.* **18**, 260-263.

The topography of the experimental area was generally flat with a very gentle slope. As a result, paddock conditions, especially in treatments HP and LP1, were abominable during the short, intense wet season. Shallow surface water covered a high proportion of the paddocks for weeks on end; cattle mobility was restricted due to the waterlogging and softness of the surface soil; stress on animals must have sometimes been severe due to the continual rain and the high mosquito population that developed. Under these conditions, pasture plants, especially the grasses, were poorly anchored and were often uprooted during grazing. This must have adversely affected grazing behaviour and forage intake. As a consequence, the environmental conditions probably had an important and overriding influence on cow and calf performance for the duration of the intense wet. In addition, waterlogging had harmful effects on the nutrient status of pasture plants. This was especially so for Sabi grass where root damage appeared to be severe resulting in lowered P and N concentrations and high manganese and aluminium concentrations. There was widespread mortality of Sabi grass plants due to the prolonged waterlogging, especially at low fertility (treatment LP1). Phosphorus concentrations were low even for annually fertilized pasture (treatment HP). The interpretation of results was complicated by all these effects.

The pasture resource

At the stocking rates imposed, pasture dry matter on offer was never limiting. Presentation yields were in excess of 5 t/ha in May 1990 and at least 4 t/ha at the end of May 1991. There were differences in the botanical composition of pastures between treatments due to differences in soil fertility (through application of superphosphate) and establishment factors. There was no sown grass (Sabi grass) in treatment LP2 where stylo became established in native grass pasture through natural spread. Stylo content was lowest in the annually fertilized pasture as a result of superphosphate favouring the sown grass. Sedges formed a significant component of the pastures following the intense wet in 1990-91 but they were more prominent in the low fertility treatments. A reduction in the Sabi grass content of treatment LP1 reflected the adverse effect of severe waterlogging at low soil P status. Treatment differences in botanical composition and the changes in composition from May 1990 to May 1991 are shown in Table 1.

Table 1. Botanical composition (% component) of experimental pastures according to treatment at the beginning and the end of the experimental period.

Treatment	Stylo	Sabi grass	Other grasses	Sedges	Weeds
		May 1990			
HP	20	73	6	0	1
LP1	41	54	4	0	1
LP2	*	*	*	*	*
		May 1991			
HP	13	69	8	8	2
LP1	50	29	5	15	1
LP2	25	0	55	19	1

* Data not available

Treatment differences in the P concentration of plucked pasture samples and of the diet selected by oesophageal-fistulated steers are depicted in Figs. 2 and 3. The P content of both pasture and diets was substantially higher in treatment HP than in the low fertility treatments up to the end of March, 1991, but differences were minimal during April and May. Overall, the P content of pasture and diet was marginally higher in treatment LP1 than in treatment LP2. The lack of any advantage in the diet P of treatment HP over the LP treatments in April and May was atypical compared with data from previous years. It probably resulted from the effect of impaired root function on plant P concentration following prolonged waterlogging.

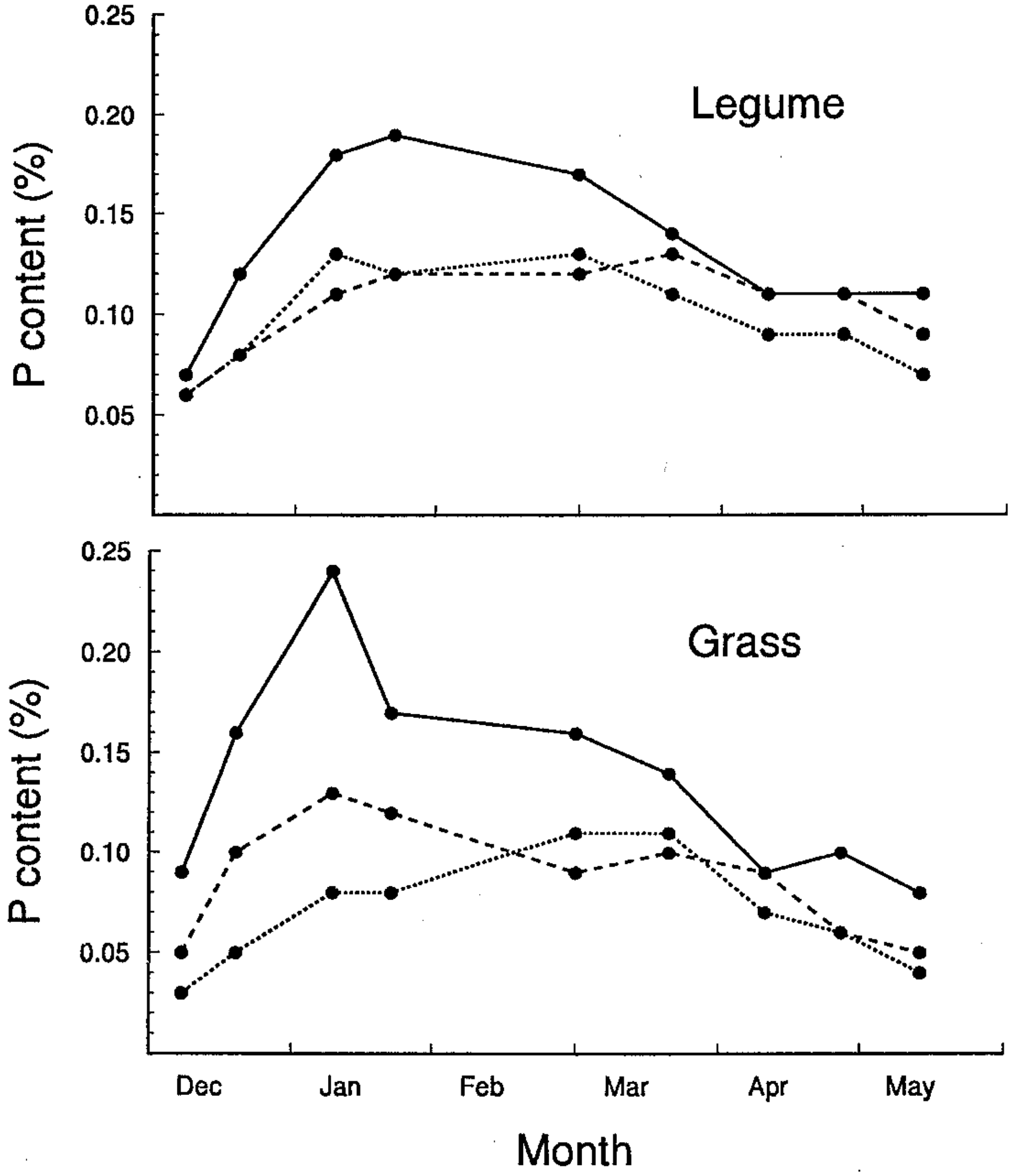

Fig. 2. Treatment effect on phosphorus concentration of plucked grass and stylo samples. •——• Treatment HP (annually fertilized); •– – –• Treatment LP1 (unfertilized); •--------• Treatment LP2 (unfertilized).

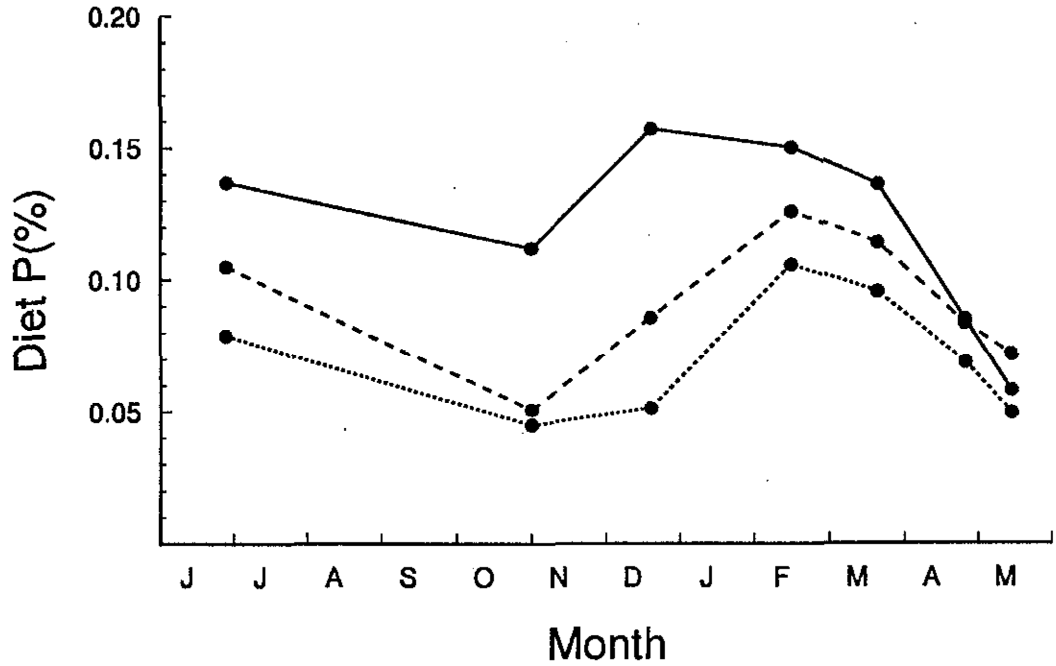

Fig. 3. Treatment effect on phosphorus concentration of the diet selected by OF steers. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

The N content (Fig. 4) of plucked legume samples was similar across treatments but the N content of native grass samples in LP2 was slightly lower than that of plucked Sabi grass in treatments HP and LP1. There was a big difference between the N concentration of grass and legume samples, with grass averaging about half that

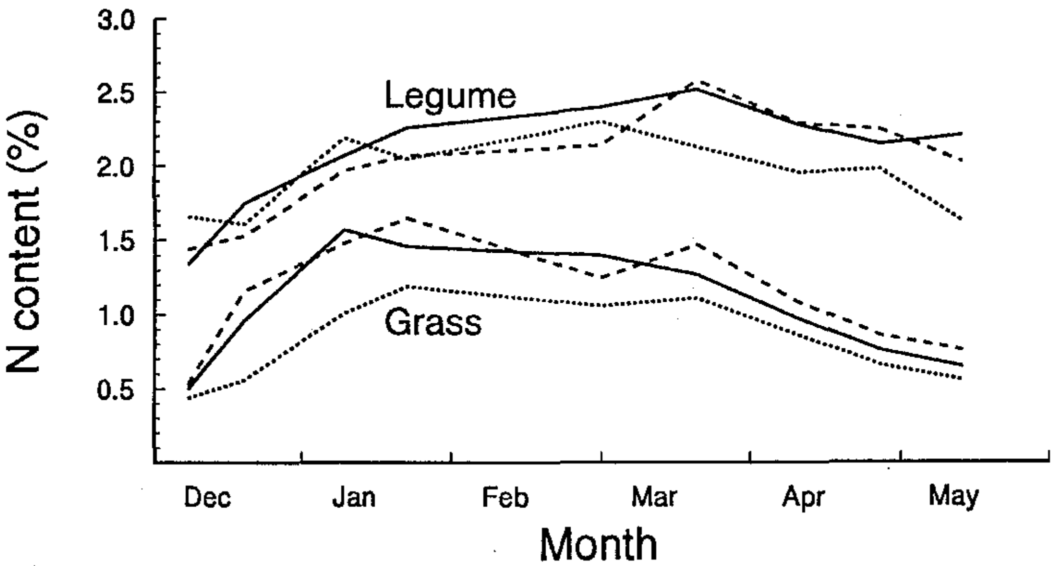

Fig. 4. Treatment effect on the nitrogen concentration of plucked grass and legume samples. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

Table 2. The proportion of legume and the estimated N content in diets of cows grazing stylo-grass pastures during the period December 1990 to May 1991.

Date	% legume in diet			% N in diet		
	HP	LP1	LP2	HP	LP1	LP2
07.12.90	7	15	30	0.56	0.64	0.79
19.12.90	7	15	28	1.05	1.16	0.88
09.01.91	0	5	10	1.50	1.50	1.12
22.01.91	5	5	10	1.54	1.53	1.28
28.02.91	10	30	30	1.50	1.52	1.43
20.03.91	15	38	40	1.46	1.82	1.52
10.04.91	20	43	50	1.26	1.60	1.41
26.04.91	18	35	55	1.01	1.32	1.40
13.05.91	20	50	65	0.94	1.40	1.26

of legume (1% and 2% respectively). Treatment differences in diet N concentration were therefore largely determined by differences in the legume content of the diet which was lowest in the HP treatment (see Table 2). Diet N levels calculated from the N content of plucked pasture samples and the dietary grass: legume proportions, indicated that HP cows may have suffered from insufficient dietary N during late lactation.

Dietary concentrations of P and N were reflected in faecal P and N concentrations (Figs. 5 and 6). Faecal P concentrations confirmed the higher dietary P levels of HP cows throughout most of the experimental period but also the absence of

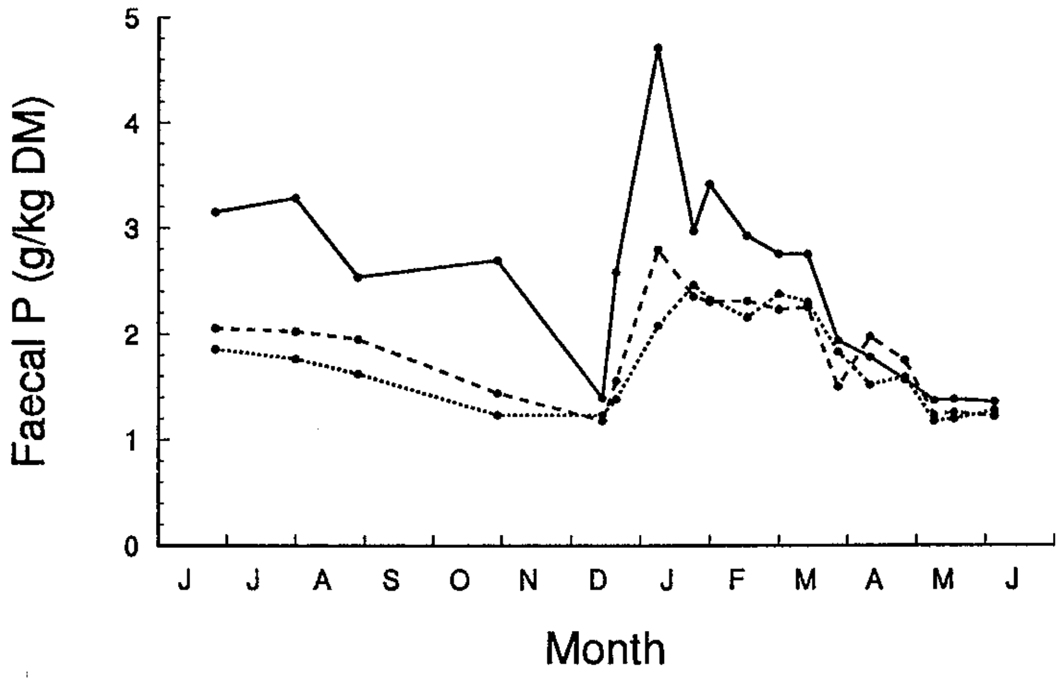

Fig. 5. Treatment effect on faecal phosphours concentrations. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

treatment differences from about mid-March, 1991. Faecal N concentrations tended to be slightly lower in HP cows throughout the experimental period but the difference became pronounced towards the end of the experiment (Fig. 7) when the dietary legume content of HP cows was much lower than that of the LP cows. The levels of dietary legume at this time were associated with differences in legume availability between treatments (Table 1). Faecal N levels of HP cows after mid-April 1991 indicated a deficiency of dietary N.

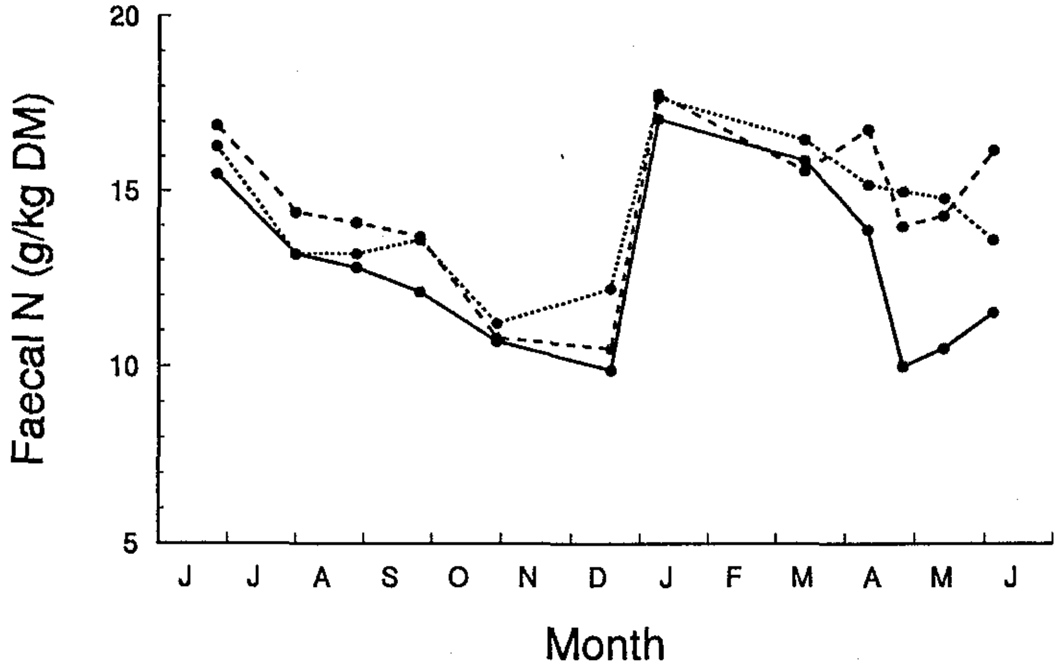

Fig. 6. Treatment effect on faecal nitrogen concentration. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

The *in vitro* analysis of samples of extrusa indicated a substantially higher digestibility of forage selected from the Sabi grass/stylo pastures of treatments HP and LP1 compared with the native grass/stylo pasture of treatment LP2, except during the last few months of the experiment when there was little difference between treatments (Fig. 7). The mean difference for the four determinations June 1990 to February 1991 was over 7 units.

Animal performance

Figure 8 shows the cumulative liveweight changes of the cows according to treatment for the duration of the experiment. In the pre-calving period, May to October, HP cows had higher gains than LP cows right from the outset. Cows in treatment LP1

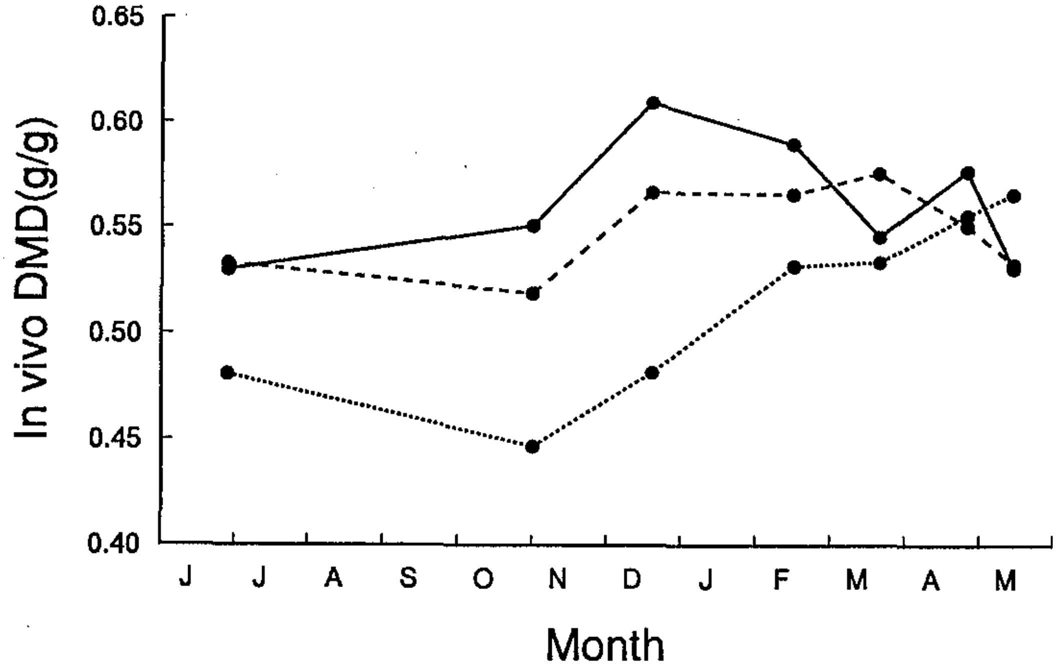

Fig. 7. Treatment effect on the dry matter digestibility of the diet selected by OF steers. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

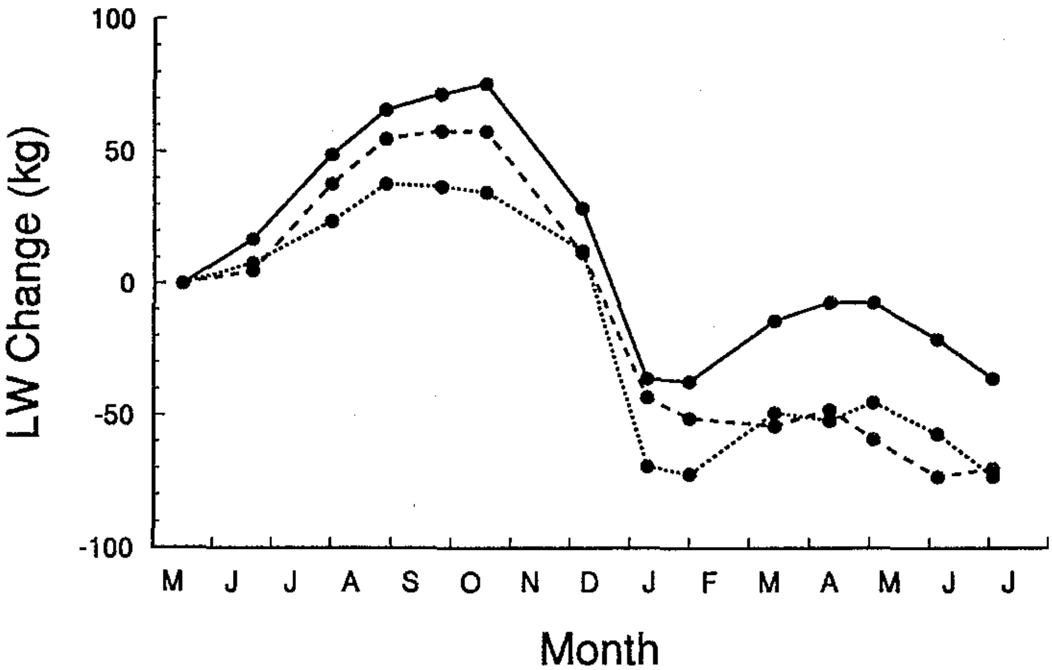

Fig. 8. Treatment effect on the cumulative liveweight change of cows during pregnancy and lactation. •——• HP (annually fertilized Sabi grass/stylo pasture); •– – –• LP1 (unfertilized Sabi grass/stylo pasture); •--------• LP2 (unfertilized native grass/stylo pasture).

made higher gains than those in treatment LP2. Treatment differences during this period were probably related to both phosphorus status and digestibility of forage. In the post-calving to pre-weaning period, January to June, cows in treatments HP and LP2 made slight weight gains (15 and 12 kg respectively) but those in treatment LP1 lost weight (30 kg loss). HP cows performed no better than LP2 cows in the post-calving period. This was thought to be the result of HP cows being more affected by the extreme wet conditions of January and February and the development of P deficiency in HP cows during the latter half of the post-calving period. Cumulative weight changes for the duration of the experiment, 15.5.90 to 4.6.91, were -21, -73 and -57 kg/hd for treatments HP, LP1 and LP2 respectively.

Calf growth rates were measured over the period December 6 to June 4 when calves were weaned. Treatment differences were confounded by the intense wet period. Overall, there was no difference between treatments HP and LP2 where average daily gains were 0.768 and 0.747 kg/hd respectively, but calves in treatment LP1 had lower growth rates of 0.652 kg/hd. When the period was divided into three shorter periods of December 6 to January 9 (representing the pre-wet period), January 9 to March 13 (wet) and March 13 to June 4 (post-wet) a different picture emerged (Table 3). Growth rates were highest for HP calves and lowest for LP2 calves in the pre-wet and post-wet periods but the ranking was reversed in the wet period. Calf gains for treatment LP1 were intermediate in the pre- and post-wet periods and lowest in the wet period. The changes in treatment ranking order that occurred between periods and the low growth rates of calves in treatments HP and LP1 in the wet period, point clearly to the adverse effects of the intense wet period on animal performance in the Sabi grass/stylo paddocks.

Table 3. Treatment and seasonal effects on calf growth rates.

Period		Growth rate (kg/hd.d)		
		HP	LP1	LP2
Pre-wet	(06.12.90 to 09.01.91)	0.884	0.712	0.661
Wet	(09.01.91 to 13.03.91)	0.692	0.497	0.825
Post-wet	(13.03.91 to 04.06.91)	0.798	0.753	0.707

Estimates of milk production (Table 4) made at the beginning and end of the lactation period were reasonably consistent with the pattern of liveweight change in both cows and calves. HP cows had the highest milk yields on both occasions. There were small differences in milk yield between LP treatments. These differences were consistent with differences in calf growth rates in the December sampling but not at the May sampling. There was no significant effect of treatment on the P concentration of milk.

Table 4. Milk yield and phosphorus concentration of milk from cows grazing stylo-grass pastures at the beginning and end of lactation.

	HP	LP1	LP2
	Milk production (l/d)		
22 December 1990	5.32	4.36	3.98
17 May 1991	4.04	2.08	2.56
	Phosphorus concentration (g/l)		
22 December 1990	1.20	1.27	1.15
17 May 1991	1.14	1.09	1.01

Treatment effects on post-partum reproductive function is illustrated in Fig. 9. Cow numbers were too small to make an unequivocal assessment of the effect of treatment on the post-partum resumption of oestrus cycling but the indications were that there was little or no effect of treatment. There was no indication that P-deficiency *per se* directly influenced reproductive function.

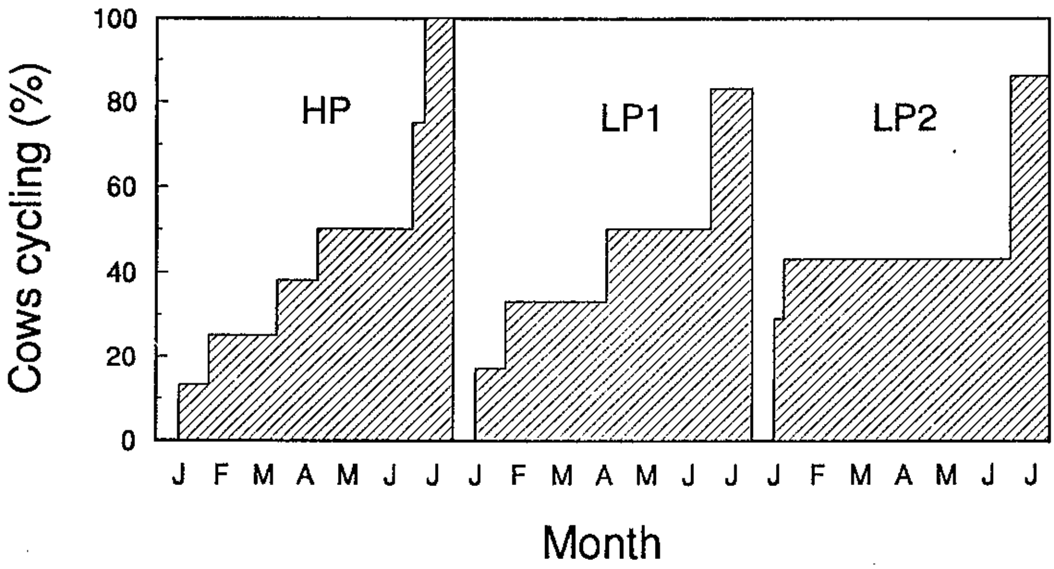

Fig. 9. Treatment effect on the number of cows cycling for the period post calving to 6 weeks after calves were weaned.

The high proportion of cows in all groups that demonstrated oestrus cycling one month after calves were weaned was surprising considering the low liveweight and condition of cows and the poor quality of pastures at that time. Mean liveweights were 370, 339 and 354 kg for treatments HP, LP1 and LP2 respectively; all cows had been losing weight from the end of April, and weight loss continued even after calves were weaned. These results suggest that post-partum reproductive function is determined by a complex interaction between energy intake, post-absorptive partitioning of nutrients between milk and body tissues, lactation effects and genotype. Any effect of P-deficiency would likely be an indirect effect operating via appetite (energy intake) and the partitioning of nutrients.

Intake of dry matter and phosphorus

Gross dry matter intakes (DMI in kg/hd.d) and relative DMI's are shown in Table 5. Cows in treatment HP always had higher gross DMI and relative DMI than cows in treatment LP1. Intakes were also higher for HP cows than LP2 cows in the June and December samplings but there was no difference in relative intake between these two treatments in the October and May samplings. Cows in LP2 had higher intakes than LP1 cows except at the June sampling. The depressed intake of LP1 cows relative to HP cows was probably due to a simple deficiency of forage P but the intake of LP2 cows relative to the other treatments was also affected by treatment differences in forage digestibility. The higher intake of LP2 cows compared with LP1 cows in October and December is difficult to reconcile with forage digestibility being lower in treatment LP2 on both occasions as well as diet P concentration being lower in December.

There were substantial increases in both gross and relative forage intakes after cows had calved. This was apparent even in treatment LP2 where forage digestibility was only marginally higher in December compared with the pre-calving diet in October.

There were large differences in P intake between HP and LP cows at the first three samplings (Table 5). The lowest intakes were measured in treatment LP2 where they were well under half those of treatment HP. Intakes of P were low in all treatments from June to the break of the wet season. Although P intakes were not measured between December and May, it can be inferred from pasture and diet P measurements that P intakes were highest during the three months January to March 1991, probably peaking in January for treatments HP and LP1 and in February for treatment LP2 (see Figs. 2, 3 and 4). Assuming a DMI of around 8 kg/hd.d, maximum P intakes of cows in treatments LP1 and LP2 were estimated at little more than 10 and 8 g/hd.d respectively. By May, P intakes in all treatments had declined to very low levels.

Table 5. Effect of treatment and season on dry matter intake and phosphorus intake of cows grazing stylo-grass pastures.

	Treatment		
	HP	LP1	LP2
	Dry matter intake (kg/hd.d)		
June	6.73	4.86	4.50
October	7.39	5.93	6.86
December	10.73	7.71	8.56
May	8.61	6.01	8.47
	Relative dry matter intake (g/kg LW.d)		
June	16.1	11.6	10.6
October	15.4	12.6	15.1
December	25.5	20.0	22.3
May	22.4	17.4	22.4
	Phosphorus intake (g/hd.d)		
June	9.2	5.1	3.6
October	8.3	3.0	3.1
December	16.9	6.6	4.4
May	5.0	4.3	4.2

Phosphorus kinetics

The quantity of dietary P absorbed (mg/kg LW.d) was related to P intake and was highest in treatment HP except in May when the P absorbed was low in all treatments (Table 6). Dietary P absorbed by LP cows was extremely low in October due to low P intakes and, for treatment LP1, the lower efficiency of P absorption measured at that time. Treatment means for P absorption coefficients (g/g) varied between 0.67 and 0.86 with differences due to treatment and season. LP cows had higher P absorption coefficients than HP cows at the June sampling, treatment LP2 had the highest absorptive efficiency in October, but there were no significant treatment differences at December and May. Post-calving P absorption coefficients were high in all treatments particularly late in lactation (May). The lowest P absorption coefficients were measured at the October sampling but even these were approaching or exceeding 0.7.

The P absorption coefficients measured in this experiment were much higher than those used in calculating the P requirements of pregnant and lactating cattle in the literature, eg. a value of 0.58 was adopted by the ARC (1980) and 0.55 by INRA (1989). However, Ternouth (1989, 1990) has reported values of 0.7-0.8 for mature sheep and cattle. These results clearly demonstrate the high efficiency with which breeding cows can absorb P from low-P diets. The absorption coefficients of HP cows also suggest that the value of 0.7 adopted by the SCA (1990) for calculating the P requirements of cows is more realistic than the low values used by ARC (1980) and INRA (1989).

Faecal excretion of total and endogenous P (mg/kg LW.d) was positively related to P intake and was much lower in LP cows than HP cows (Table 6). Very low levels of endogenous P were measured in LP cows, especially those in treatment LP1 indicating a well developed ability to conserve P on low-P diets.

Table 6. Effect of treatment and season on the daily phosphorus kinetics of cows grazing stylo-grass pastures.

	Treatment		
	HP	LP1	LP2
	Phosphorus intake (mg/kg LW)		
June	22.0	12.2	8.4
October	17.3	6.4	6.8
December	40.2	17.2	11.5
May	13.0	12.5	11.1
	Dietary phosphorus absorption (mg/kg LW)		
June	15.0	9.8	7.2
October	11.8	4.3	5.6
December	30.7	12.4	8.3
May	10.9	10.4	9.5
	Dietary phosphorus absorption coefficient (g/g)		
June	.69	.80	.86
October	.68	.67	.82
December	.76	.72	.73
May	.83	.83	.86
	Total faecal phosphorus excretion (mg/kg LW)		
June	23.8	11.2	10.3
October	18.5	8.8	10.4
December	25.5	13.5	14.4
May	14.0	9.8	11.9
	Endogenous faecal phosphorus excretion (mg/kg LW)		
June	16.9	8.8	9.2
October	13.0	6.7	9.1
December	16.0	8.7	11.3
May	11.9	7.6	10.4

Phosphorus status

Measurements of tail-bone density in December and June, rib cortical bone thickness in June, and plasma inorganic phosphate (Pi) levels made at regular intervals, were used to monitor the P status of the cows. Differences between treatment means for tail-bone density in December were consistent with treatment differences in diet P and liveweight change from May to December. HP cows had the highest tail-bone density, LP2 cows the lowest (Table 7). Tail-bone density in treatments HP and LP2 declined from December to June and this too was consistent with the demand for P during lactation and the mobilization of P reserves from skeletal stores due to low levels of dietary P. The apparent rise in tail bone density of LP1 cows from December to June was inconsistent with all other supporting data but the June treatment mean was influenced to a great extent by one very high estimate of tail-bone density. When the relevant cow was excluded from the LP1 treatment means, there was no apparent change in density between the December and June estimates.

There was no difference between treatments in rib cortical bone thickness of biopsy samples taken after the calves were weaned even though P intakes of HP cows were substantially higher than those of the LP cows for most of the experimental period (Table 7.)

Table 7. Effect of treatment on tail-bone density and rib cortical bone thickness of cows grazing stylo-grass pastures.

	Treatment		
	HP	LP1	LP2
		Tail-bone density	
December 1990	1.442	1.402 (1.393)	1.362
June 1991	1.386	1.434 (1.396)	1.290
		Rib cortical bone thickness	
June 1991	2.55	2.71	2.79

Values in parenthesis are means when one cow with abnormally high tail-bone density is excluded.

Plasma Pi levels (Fig. 10) provided a useful indication over time of the adequacy or otherwise of dietary P within treatments as well as reflecting differences between treatments.

Cows in treatment LP1 had the lowest plasma Pi levels for the duration of the experiment. Levels were fairly low but stable in this treatment from June to October but they declined rapidly after calving and during the intense wet. Following the wet, there was a trend for a continuing but slower decline in plasma Pi until calves were weaned early in June. Cows in treatment LP2 had plasma Pi values similar to those of LP1 cows up to calving, but with the onset of the wet season there was a temporary rise in plasma Pi levels. However, from mid-February onwards, levels were similar to or little better than those of LP1 cows. HP cows had satisfactory plasma Pi levels (> 60 mg/l) through to calving. Despite a significant rise in dietary P levels in the wet season there was a gradual decline in plasma Pi through January to mid-March followed by a sharp fall to low levels in April. These changes reflected the interaction of dietary P levels, environmental influences on animal behaviour and forage intake and animal demand for P. They are consistent with the pattern of liveweight changes already described for cows and calves. There was a sharp rise in plasma Pi in all cows after calves were weaned due to a cessation of the lactation demand for P.

Plasma Pi levels in calves were determined once at weaning time. There were treatment differences with HP calves (79 mg/l) > LP2 calves (68 mg/l) > LP1 calves (60 mg/l). These differences were consistent with treatment differences in the volume of milk produced by the cows (see Table 4).

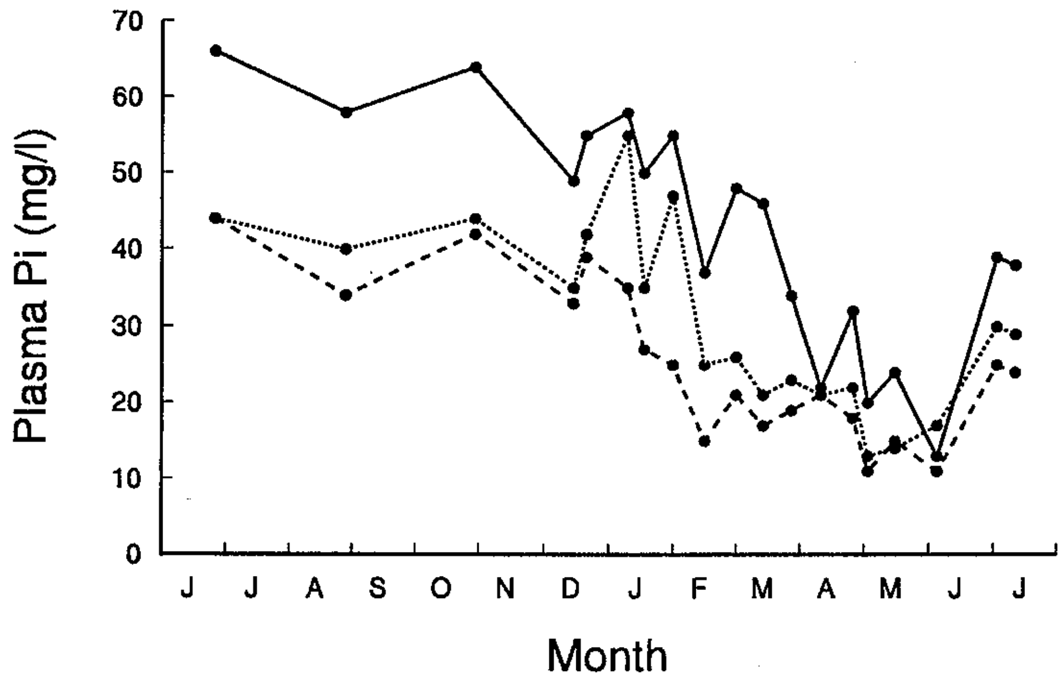

Fig. 10. Treatment effect on plasma inorganic phosphate concentrations. ●——● HP (annually fertilized Sabi grass/stylo pasture); O–––O LP1 (unfertilized Sabi grass/stylo pasture); □--------□ LP2 (unfertilized native grass/stylo pasture).

Conclusions

The experiment provided for the first time a comprehensive data set on the P kinetics of pregnant and lactating beef cows. The results clearly demonstrated that such animals have the ability to utilize P most efficiently. Such efficiency was effected by high dietary P-absorption coefficients and low excretion rates of endogenous faecal P. Even cows grazing pasture annually fertilized with superphosphate had high dietary P absorption coefficients, but cows grazing low-P pasture had lower endogenous faecal P excretion rates than cows grazing fertilized pasture. The P-absorption coefficients in first calf cows at 3.5 years were as high as those previously measured in yearling heifers on similar pastures. This is contrary to the commonly accepted notion (ARC 1980; INRA 1989) that P-absorption coefficients are lower in adult than in younger cattle.

The performance of cows on low-P pasture was adversely affected from the very beginning of the experiment when liveweight gains were depressed during mid- and late-gestation. Reduced levels of performance after calving were reflected in depressed milk production and lower liveweight gains in their calves. The depressed performance of P-deficient cows was due to reduced voluntary intake of pasture.

Phosphorus deficiency *per se* had no effect on post-partum reproductive function which was impaired in cows grazing fertilized pasture as well as those on low-P pasture. The influence of lactation on post-partum reproductive function was demonstrated by only two of the 21 cows in the experiment failing to demonstrate oestrus cycling immediately their calves were weaned compared with less than 50% prior to weaning.

The abnormal set of seasonal conditions experienced during the experiment and the effect of these conditions on the pastures and cattle, made it difficult to draw reliable conclusions regarding the P requirements of pregnant and lactating cows. Nevertheless, the low P intakes and the P kinetics results suggest that published P requirements, like those for growing cattle, are overestimated. The over-estimation appears to be due primarily to the adoption of low P-absorption coefficients in the calculation of requirements using the factorial technique. Our results suggest a P-absorption coefficient of 0.7 g/g would be conservative for both breeding and growing beef cattle on low to moderate P intakes.

Additional but similar research work needs to be conducted under more suitable seasonal conditions to add confidence to the findings of this experiment and to provide further information for the assessment of the P requirements of breeding cows on pasture.

SUCCESS IN ACHIEVING OBJECTIVES

The project was successfully conducted and completed according to the pre-arranged schedule. Within the limitations imposed by a single experiment of one year's duration, the broad objective of the project was successfully met.

The success in meeting the stated specific objectives is detailed below.

(i) *To measure the P intakes, P absorption coefficients and excretion rates of endogenous faecal P of pregnant and lactating beef cattle.*

This objective was fully achieved.

(ii) *To determine the effect of different degrees of P deficiency/adequacy on the P economy of pregnant and lactating beef cattle.*
This objective was successfully achieved within the constraints of the experiment but limited to a large extent by the abnormal seasonal conditions which resulted in a significant reduction in the P-status of annually fertilized pasture while the cows were lactating. As such, the contrast between treatments was much narrower than would normally be expected during this period.

(iii) *To determine whether absorption coefficients and excretion rates of P in female cattle are affected by age and physiological status.*
This objective was successfully achieved to the extent that the project provided clear evidence that there is no age related obligatory reduction in P absorptive efficiency in cattle. P absorptive efficiency and excretion rates of endogenous faecal P would appear to be governed by P demand relative to P intake rather than any effect of age.

(iv) *To determine the influence of P status on the weight change, mothering ability and post-partum reproductive function of first calf cows.*
This objective was achieved within the limitations imposed by the size and scope of the experiment but restricted by the number and contrast of treatments, and the limitations resulting from the abnormal seasonal conditions. The reduced P status of annually fertilized pasture following the intense wet period meant that cows in none of the treatments could be regarded as having adequate P intakes during the latter half of lactation. Moreover, the intense wet period introduced constraints to production not normally encountered thus confounding treatment effects on weight change, mothering ability and post-partum reproductive function.

(v) *To assess the P requirements of pregnant and lactating first calf cows.*
This objective was only partially achieved because of seasonal conditions and restrictions due to number, contrast and duration of treatments. Nevertheless, the measurements of P-absorption coefficients and endogenous faecal P excretion rates have provided important information for the future assessment of the P requirements of breeding cattle and can be used to provide factorial estimates of requirements.

TECHNOLOGY TRANSFER

The results of this project are of direct importance to the scientific community. They are of importance to the beef industry of north Australia only in so far as they provide an improved knowledge base on which to build further research and development aimed at providing realistic, well founded and economic solutions to the problems of P-deficiency in cattle, and in particular, in breeding cattle. The requirement for technology transfer is therefore one aimed at the scientific community. It will be achieved through the normal channel of publishing the results in an appropriate scientific journal.

IMPACT

Because of the nature of the project, it is impossible to assess the likely impact of this work on the meat and livestock industries. Suffice it to say that appropriate solutions to major problems are more likely to be developed from reliable and accurate knowledge bases than from poor or inaccurate ones. The problem of P-deficiency in breeders in north Australia is widespread and of major economic significance and it is a problem that will remain as long as the northern beef industry continues. Well conducted research aimed at improving our knowledge of the basic issues governing the P requirements of breeders can be viewed as a worthwhile long term investment.

FUNDING

Work on the project commenced at the beginning of 1990. All the experimental work was undertaken within the 1990-91 year. Sample preparation and analysis, and the collation, analysis and interpretation of data continued through to the end of 1991. It is estimated that CSIRO, UQ and JCU contributed approximately $60,000 to the project in staff salaries and overheads while the MRC allocated $31,383 to the work.

CONCLUSIONS AND RECOMMENDATIONS

The project has provided new and important information on the absorption and excretion of P in pregnant and lactating beef cattle. In particular it was shown that breeding females maintained high P-absorption coefficients and that P absorptive efficiency does not decline with age.

Low P intakes of cows grazing low-P pastures were insufficient to meet the unavoidable losses of endogenous P in the faeces and the demand for P for foetal growth and milk production, regardless of the absorptive efficiency of dietary P.

Phosphorus deficiency resulted in reduced voluntary intake of pasture, depressed liveweight gain or increased liveweight loss, lowered milk production and calf growth rate, and low plasma Pi levels in cows.

There were insufficient data to fully determine the P requirements of pregnant and lactating cows but there was sufficient evidence to suggest that current recommended P requirements are overestimated and need refining. However, the data obtained may be used factorially to estimate P requirements.

The methodology adopted was effective in meeting most of the objectives of the project but the lack of sufficient treatment contrasts in pasture P status and the abnormal seasonal conditions experienced limited the extent to which data could be interpreted and conclusions could be drawn.

Further research work of this kind using similar methodology but incorporating a wider range of pasture P status, together with some other refinements regarding the timing of measurements, would be beneficial in furthering our understanding of the P requirements of breeders. We believe there is an urgent need to satisfactorily resolve the controversy over the P requirements of both growing and breeding cattle. In particular we are concerned at a recent revision of the ARC (1980) recommended requirements by TCORN (*Nutrition Abstract and Reviews*, 1990) in which recommended allowances were increased without reasonable supporting evidence. The British, American and French recommended requirements all appear to be unrealistic. There is a real need to set requirements which are realistic in the Australian context.

Summarising, this trial has shown that the productivity of breeder cattle is affected by their P nutrition. It is recommended that further studies be undertaken to:

(i) quantify the intake and excretion of nutrients, especially energy, N and P by breeder cattle grazing native and improved pastures in 'normal' seasons in different northern Australian environments;

(ii) determine the effects of these nutrients and their interactions on the reproductive performance of cows;

(iii) extend the data already gathered to reliably predict the P requirements of breeder cattle;

(iv) determine the value of providing supplementary P to breeder cattle under different conditions, with particular consideration to both the use or absence of legumes and the use of supplementary protein.