Wet season phosphorus supplementation increases grazing pressure

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Abstract

Recent MLA funded pen studies in both steers and breeding females on diets replicating wet season pastures, demonstrated that dry matter intakes can be halved with acute phosphorus (P) deficiency. These pen trials were performed on diets that represented a typical wet season tropical pasture of 100 to 110 grams of crude protein per kilogram of dry matter (CP/kg DM) and 60 to 65% dry matter digestibility (DMD). The outcomes of these pen studies together with a grazing trial at Kidman Springs in young breeders demonstrated the clinical signs associated with P deficiency and decreased feed intake are reduced fertility, growth rates, milk production and survival. In other words, all these clinical signs are secondary outcomes from an energy depleted diet. This recent research validated findings of previous grazing trials in South Africa (Read *et al*. 1986) using chromium markers to monitor intakes. Read *et al*. (1986) demonstrated all the clinical signs above but most importantly showed that the dry matter intakes of grazing cattle can be reduced by half on P deficient pastures. The latest pen trials in young breeders also revealed, when the dietary intake of P is insufficient to supply the animal's requirements for lactation, pregnancy and growth, skeletal reserves of P are mobilised. This mobilised P does not impact dry matter intakes but manifests itself in bone demineralisation which, if not corrected, will ultimately lead to clinical signs of lameness (peg leg) in prolonged dietary P deficiencies. Peg leg together with increased breeder mortality was evidenced in the grazing trial at Kidman Springs (unpublished) which consequently had to be terminated. The key message for producers and extension officers is that to gain full responses from supplementation, P must be provided to all animals on a positive plane of nutrition. The increased grazing pressure with wet season supplementation must be recognised in pasture management where P supplementation is undertaken. This presents special challenges for beef producers in P deficient regions when setting stocking rates and implementing wet season spelling. The plasma inorganic P test is the most accurate test to determine the level of dietary P.

Keywords: decreased feed intake, P, grazing pressure, Plasma Inorganic P

Introduction

The north Australian pastoral industry operates on large areas of soil types which are deficient in P. Despite research extending over one hundred years, the physiology and role of P in beef cattle nutrition on pastures remained indistinct. The primary focus of early research in the Charters Towers and Cloncurry regions was to address clinical osteomalacia (peg leg). Turner (1935) found that peg leg commonly observed in young lactating breeder cows could be prevented by administering phosphate supplements. He also demonstrated significant weight gains in treated animals. Hart *et al* (1965) established improved liveweight performance and improved fertility in lactating cows on the Barkly Tableland. Initially there were two schools of thought as to the real action of P - one suggesting that a P deficiency may not affect reproduction per se but simply be due to decreased energy intake while the other suggesting that reproductive failure may be one aspect only of a general cellular deprivation of P. Later in South Africa, Read *et al* (1986) produced a comprehensive set of clinical signs associated with breeder cattle grazing P deficient pastures including severely impaired reproductive performance, lower body mass of breeders (by 121 kg), lower weaner weights and a doubling of mortality rates. By using chromium markers, he was able to demonstrate that these clinical outcomes were due to decreased pasture consumption and concluded by saying "possibly the most serious effect of the deficiency is the depression of feed intake, especially during lactation and early pregnancy."

The feeding of non-protein nitrogen (NPN) supplements over the dry season when pasture quality is reduced, has enabled beef producers to maintain the body weight of their stock and reduce mortalities. As dry season supplementation can increase dry matter intakes by up to 30%, monitoring pasture utilisation and adjusting stocking rates over the dry becomes paramount in sustaining long-term carrying capacities. Similarly, P supplementation has consequences for pasture intake over the wet season and this needs to be recognised when establishing stocking rates and managing wet season spelling. However, the role of P in ruminant nutrition is further complicated by mobilisation of P from body reserves (muscles and bones) to support basic biological functions of lactation and pregnancy when dietary P is insufficient. If the deficiency is prolonged, exhaustive mobilisation of P from bones leads to skeletal disorders and lameness commonly known as 'peg leg'.

Most commercially available dry season supplements contain around 2-4% P. Consequently, the most obvious (and terminal if not treated) clinical sign of a P deficiency i.e., 'peg leg' is rarely seen in northern Australia. Unfortunately treating the clinical manifestation of peg leg in the dry season does not address the real benefits and productivity gains on offer by providing P to cattle over the wet season.

Subsequently the message to provide supplementary P over the growing season to improve feed intake was not widely accepted. Sampling for a mineral deficiency over the dry season when the real benefits are realised over the wet season has further confused an already complex understanding of the pathways involved in P metabolism. In addition, there was a hypothesis that feeding P over the dry season would build up body reserves and counteract or partially negate the need to provide P over the entire growing season.

Approach

Some results of recent pen trials and field research are evaluated to explore the following aspects of P nutrition:

1. The impact of dietary P on feed intake when energy and protein is adequate
2. How P impacts fertility, weight gains and mortality rates.
3. The hypothesis of building reserves of P in the body and the role of mobilised P to increase feed intake.
4. The best diagnostic tests to establish levels of dietary P.

Results

Aspects of special interest were evaluated in three recent projects over the past 10 years.

Project 1. "Validation and demonstration of a diagnostic tool for P status of beef cattle". MLA funded project B.NBP.0537. Quigley et al (2015).

Along with other objectives, this project examined the following issues:

(a) the Faecal P:ME diagnostic test,

(b) response of steers to various levels of P in a moderate energy protein diet.

A replicated pen study involved feeding steers a ration of approximately 9 MJ ME/kg and 11% crude protein i.e. mimicking a wet season pasture diet at 5 levels of P ranging from expected acutely deficiency to above adequate. Key findings were that feed intake and live weight gain are closely correlated with the level of P in the diet and plasma inorganic P (PiP) test is the best test for this (Table 1).

Table 1. Response of feed intake, liveweight gain, faecal P, faecal P:metabolisable energy (ME), faecal P:crude protein (CP) and plasma inorganic P (PiP) to dietary P intake (g/kg DM) (Quigley *et al*. 2015).

Variable	R^2	Root MSE
Feed intake (kg/day)	80%	0.74
Live weight gain_(kg/day)	89%	0.09**
Faecal P (mg/kg DM)	68%	272.5
Faecal P:ME (mg P/MJ ME)	73%	37.2
Faecal P:CP (mg P/g CP)	69%	2.84
PiP (mmol/L)	87%	0.19**

The dry matter intakes of the animals fed the high P diet (2.4 g P/kg DM) were almost double those fed the low P diet (0.9 g P/ kg DM). This produced a difference in live-weight of >100 kg after 6 months (Fig. 1).

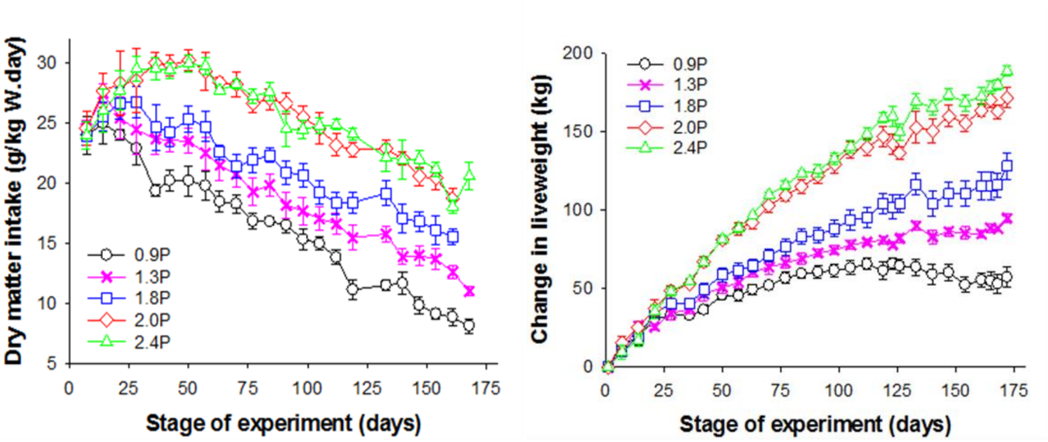

Fig. 1. Dry matter intake (g/kg LW.day) changes in liveweight (kg) of steers offered diets with increasing P (P) (0.9, 1.3, 1.8, 2.0 and 2.4 g P/kg DM) content over 172 days (Quigley *et al*. 2015).

A field study project utilised walk over weighing and auto-drafting to evaluate the effectiveness of P supplementation in a large breeder herd on the Barkly Tableland. No differences in fertility were observed in the supplemented and unsupplemented breeders. Also, there was no difference in the liveweight performance of supplemented and unsupplemented marker steers running with the breeders over two very different wet seasons – one above average rainfall and one just below. The PiP levels of both groups exceeded 1.5 mmol/L during the trial. This indicated that the diet selected by the cattle contained sufficient P. The paddock contained areas of both low and high P soils and in both years, cattle were able to select pasture containing sufficient diet P over the growing period.

Project 2. "Improved management of cattle P status through applied physiology" MLA funded project B.NBP.0689. Dixon et al (2020)

Among other objectives, this project examined the mobilisation of P from bones as an alternative to feeding P over the wet. Five pen trials were conducted using both pregnant heifers and mature cows. Live weight gains, feed intakes, milk production and calf liveweight gain were recorded. The diet was similar to the rations utilised in the steer research with both low and levels of diet P (Table 2).

Table 2. The response of 1st lactation heifers and their calves to diets low (L) or high (H) in P. Animals were fed low or high P diets in pregnancy and/or early lactation (R. Dixon (2020).

Treatment	Cow liveweight (kg)		Cow dry matter intake (kg DM/d)		Milk yield (kg/d)	Calf gain (kg LW/d)
	Calving	Weaning	Pregnancy	Lactation		
H-Preg_H-Lact	416	441	6.9	10.9	8.7	0.93
H-Preg_L-Lact	407	342	7.1	6.3	6.5	0.69
L-Preg_H-Lact	357	406	5.2	9.4	7.8	0.83
L-Preg_L-Lact	373	300	5.5	4.9	4.9	0.57

This pen trial with heifers reflected not only the feed intake and subsequent body weight differences observed in the steer trial of Quigley *et al.* (2015), but also reported the consequent effects on milk production and calf growth rate. It was apparent that heifers fed high levels of P during pregnancy (HL), were unable to sustain adequate feed intakes when fed a low P diet during lactation. The HL group were 34 kg heavier than the LL at calving and this liveweight difference resulted in higher dry matter intakes in the HL group (NRDR 2007) but both groups lost approximately 70 kg of liveweight during lactation.

The PiP changed radically within two weeks of the change in diet. There were rapid responses to both increased and decreased dietary P when diets were changed around calving.

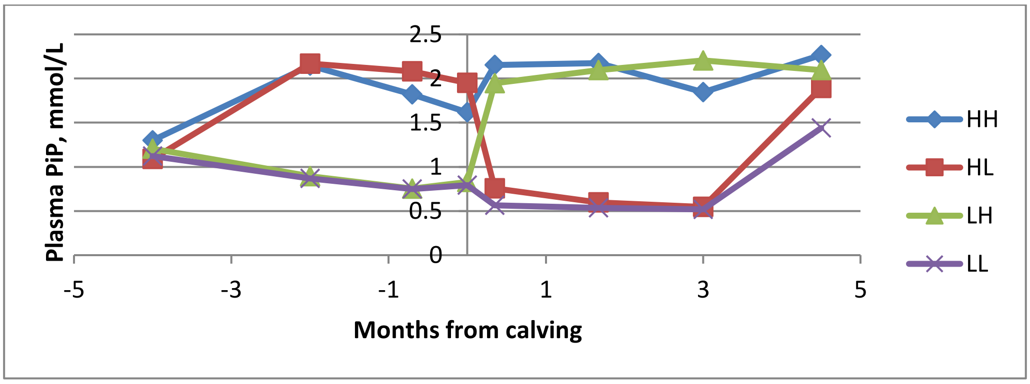

Fig. 2. Plasma inorganic P responses in young cows due to the addition of P to the diet throughout late pregnancy and early lactation (HH), pregnancy only (HL), lactation only (LH) or no added P (LL), followed by recovery of liveweight when all were fed a P adequate diet for 1.5 months after weaning (Dixon *et al.* 2019).

It should be noted the low P diet was extremely P deficient and probably represented regions which are classified as 'acutely' P deficient in northern Australia. In a later experiment with mature cows there was a much greater benefit of P mobilisation during early lactation to maintain calf growth as these animals had already achieved mature body weight. The adult cows on the low P diet during lactation lost over 30 kg of weight while those on the high P diet gained around 20 kg.

Project 3: "Findings of the Kidman Springs (VRRS) P supplementation trial" DPIRD, NT project (Schatz et al 2019).

This project evaluated the impact of year-round P supplementation on young breeder cow performance under field conditions. Although feed intake was not assessed, all the clinical signs of P deficiency were observed: - a difference in lactating cow body weight of 69 – 120 kg, a difference in wet cow pregnancy rates of 25 – 60%, a difference in weaner weights of 13 – 45 kg and a difference in mortality rates of 7 – 11% per annum. The trial was terminated due to very poor body condition of many cows and a high prevalence of 'peg leg' in the control group which received no P in their supplement.

Discussion

While pen trials are expensive to conduct, they are invaluable because all research inputs and outputs can be measured accurately. The unequivocable demonstration that dietary P is driving feed intake which in turn determines the liveweight gain, conception rates, milk production and mortality rates is critical to understanding the role of P in cattle nutrition. The primary clinical signs of P deficiency appear not to be due to a generalised cellular deprivation of P but due to a lack of energy per se. Some previous pen experiments (Gartner et al 1981) have shown that steers fed P deficient diets maintain their feed intake at very low liveweight gain for many weeks (e.g. 4-20 weeks) but this trial was performed on a diet of only 54% Dry Matter Digestibility. As the average daily gains are only slight, the demand for P becomes much less. The responses to P supplementation become most evident when both energy and protein are readily available as P becomes the limiting nutrient. Other mineral deficiencies such as cobalt, copper, zinc, iodine and selenium also only become evident on a positive plane of nutrition.

In two pen studies using mature lactating cows, it was found that they were able to mobilise sufficient body reserves of fat and P to largely maintain milk production and calf growth. Nevertheless, these mature cows could only maintain milk output with large losses in liveweight. Mobilisation of P is essential to maintain the vital biological processes of lactation and pregnancy. However, there are limits to mobilisation as the pen trial with heifers showed that the mobilisation of P is not sufficient for this class of animal to maintain milk output when fed an extremely P deficient diet.

Prolonged reduction of skeletal P reserves as observed at Kidman Springs can lead to 'peg leg' if replenishment does not occur. The message for all producers in P-deficient country is that significant productivity gains are possible through P supplementation over the wet season. Feeding P to lactating and pregnant breeders over the dry season addresses the clinical signs of 'peg leg' in the herd. However, in very acutely P deficient pastures P should be fed to all stock for as much of the wet season as is practical to achieve the major benefits of improved weight gains, conception rates and decreased mortality rates. The increase in feed intake by all classes of P deficient cattle when fed P supplements will impact grazing pressure significantly. This will require beef producers to adjust stock numbers and grazing pressure. It is important to note that P deficiency in pastures is a continuum and that the same responses to supplementation will not occur in marginally deficient country as occurs in acutely' P deficient land types. Extension officers and advisors need to use the results of the PIP test judiciously depending on the level of m/mol of P in the resultant blood test, the digestibility of the diet and the class of animal being supplemented prior to providing recommendations on the amount to supplement that is required.

Conclusion

The dietary P status of cattle operates at two levels. If dietary P is low when pastures are adequate in energy and protein, then feed intake is reduced and productivity is severely compromised. Prolonged dietary P deficiency leads to mobilisation of skeletal P that allows maintenance of basic biological functions including pregnancy and lactation, but bone fragility can result. Producers providing wet season P supplements need to be aware of the increased grazing pressure over the 'wet' due to higher pasture intakes.

Conflicts of Interest

The authors declare no conflicts of interest.

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