Phosphorus management of beef cattle in northern Australia

Second edition

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Reviewed edition (2023) coordinated and edited by:

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Published by

Meat & Livestock Australia Limited
ABN: 39 081 678 364

ISBN: 978-1-74191-956-1

MLA acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Preface

This updated edition of *Phosphorus management of beef cattle in northern Australia* provides a technical resource for producers and extension staff on the need to feed phosphorus (P), how a producer might determine a P deficiency and how to manage supplementary feeding of the mineral.

Property case studies provide insights into the practical considerations and real-life benefits of an effective supplementation strategy. As the need for supplement will vary between properties and districts, producers are encouraged to monitor their costs and production benefits to ensure their supplementation program is effective.

Acknowledgments

The authors acknowledge the early publication *Phosphorus nutrition of beef cattle in northern Australia* by Terry McCosker and Lyle Winks (1994), the 2012 publication *Phosphorus management of beef cattle in northern Australia*, and the subsequent research led by Simon Quigley, Tim Schatz and Rob Dixon that has improved our knowledge of P in beef cattle in the last decade. Geoff Niethe's contributions to the editing process are acknowledged.

More information on the recent research on phoshorus can be found on the MLA website at:

The authors also wish to acknowledge the many past and present researchers, beef advisors and producers who have contributed to our current understanding of P nutrition and supplementation in northern Australia.

We acknowledge the permission of Bernie English, Tim Schatz, Simon Quigley, Désirée Jackson and Sally Leigo to use their photographs.

Contents

Key messages

In many of regions of northern Australia, phosphorus (P) is a serious nutritional limitation to cattle production, reducing herd efficiency and profitability.

- Phosphorus (P) is an essential nutritional requirement in cattle.
- Many soils across northern Australia are deficient in P, thus pastures growing on these soils do not contain enough P for cattle nutritional requirements.
- Signs of acute phosphorus deficiency include bone chewing, broken bones, peg-leg, poor body condition of breeders and botulism.
- Deficient animals respond best to P when pastures contain adequate energy and protein for cattle growth and reproduction.
- Soil analysis of P analysed using the Colwell P test (bicarbonate extracted phosphorus) can determine P status of the soil (where different soil types are present in a paddock, all should be tested).
- Deficiency is related to soil P status. As a general rule, where soil Colwell P levels:
  - » are deficient (5mg/kg or less), all classes of stock are likely to respond to feeding P
  - » are marginal (6–8mg/kg), young cattle are likely to respond to feeding P
  - » exceed 8mg/kg, the economic benefit from feeding P diminishes.
- Responses to P supplement may be lower if animals running on P-deficient country have access to adjacent areas of high-P soils, such as frontage country.
- There are no simple diagnostic tests for the P status of cattle. Soil, blood and faecal P are useful indicators.
- A blood test for plasma inorganic phosphorus (PIP) should ideally be combined with diet quality measured by Faecal Near Infrared Reflectance Spectroscopy (F.NIRS) analysis of dung samples.
- Cattle grazing P-deficient pastures require a P supplement to meet their nutritional requirements, relying on bone mobilisation of P will erode herd productivity.
- Cattle grazing deficient pastures and fed an effective P supplement will eat 10–30% more pasture (deficient cattle have a depressed intake).
- If P is fed over the wet season on deficient country:
  - » young growing stock can increase their growth by up to 90kg above base growth
  - » breeders can increase weaning rates by 10–30% and mature breeders can maintain an additional 100kg over the wet season.
- Stocking rates must be matched to carrying capacity to ensure cattle have enough pasture for requirements.
- Supplement blocks and loose licks each have merits – to attain production goals, cattle must eat it. Monitor intakes and adjust recipe when required to avoid wasting money on supplement that sits in the paddock.
- On deficient pastures, wet season supplement intakes should aim to provide at least 6g P/head/day to young growing cattle and 10g P/head/day to breeders.
- Dry season supplement mixes should contain a source of protein (e.g. urea) with sufficient P content to provide 2–5g P per day per animal.
- The economic benefits from feeding P are maximised when done in conjunction with other aspects of good herd management.
- Order P supplement early and make realistic calculations for how much P you need to last the entire wet season.

1 Why feed phosphorus

Phosphorus (P) is an essential nutrient for cattle but is deficient in many pastures across northern Australia. Even when energy and protein are adequate in the diet, P-deficient pastures put a handbrake on feed intake for cattle, meaning nutritional requirements are not being met. If feed intake is limited, so too are liveweight gain (LWG) and body condition. Phosphorus deficiency in cattle causes significant production and economic losses in beef enterprises across northern Australia. This manual aims to support beef producers to identify where a deficiency is a problem and how to remedy the issue through implementation of an effective P supplementation program.

Symptoms of P deficiency

Phosphorus is needed for maintenance, growth and production including:

- skeletal growth and muscle
- metabolising fat, carbohydrates and protein
- producing milk.

Cattle mobilise key minerals (P and Calcium) from the skeleton to support lactation, pregnancy and liveweight gain. Mobilisation of minerals leads to weak bones, bone breakages and deformities. Cattle chew bones in their craving for P and there can be an increased risk of death from botulism toxicity if the vaccination program is not rigorous. Vaccination for botulism is not a preventative solution to address a P deficiency. Supplementation with P will reduce bone chewing (and so reduce botulism risk) but will not eliminate it.

Marginal P deficiency

A marginal P deficiency is common and difficult to diagnose. Overall herd productivity, including growth rates, breeder condition, weaning rates and weights will be lower than expected. Shortage of feed due to heavy stocking rates or dry years, low energy and protein in the pasture and diet, weaning management, disease or another nutrient deficiency, can also be factors that contribute to poor productivity. Herd management issues need to be addressed to achieve the best results from P supplementation. Be realistic about land condition and the number of animals the property can support. No supplementation program can replace good pasture and herd management.

Severe P deficiency

If an acute deficiency is observed, breeders show lameness and tenderness walking to the yards. Depraved appetite leading to pica (eating things of no nutritional value) such as bones, stones, polythene pipe or horns is also an indicator of P deficiency. A protein deficiency in the diet can also induce pica. Clinical signs of P deficiency include peg-leg (arched body, staggering gait and brittle bones), especially in drier years. Broken bones can occur when working the cattle in yards. These clinical signs are the last signs of P deficiency to appear. If these signs are evident in a herd, then there will be significant losses in productivity occurring prior to reaching this stage. It is rare to observe these severe problems in modern times as awareness of P deficiency has increased across northern Australia and small amounts of P are often included in dry season licks. A P-supplementation program is critical to address a P deficiency in a herd.

Bone chewing (top) indicates P deficiency but may also be caused by severe protein deficiency. Bones accumulate in the rumen (bottom).
Source: Désirée Jackson

Phosphorus in tropical pastures

In tropical pastures, the largest responses to P supplementation are observed on P-deficient country in growing cattle grazing green grass during the wet season. In the dry season, energy and protein both decline as the pasture senesces (hays off). Many producers routinely feed urea-based supplements during this time because the loss of body condition from protein deficiency becomes obvious. Dry season supplements often contain a small quantity of P.

The amount of P that cattle need depends on the class of stock (e.g. requirements for growth, lactation and gestation). Cattle are generally not growing over the dry season, so their requirement for P to support bone and muscle development is decreased. A growing animal will need two to three times as much P as it does to maintain weight during the dry season (see Table A.2.4 in Appendix 2). Breeding cows have a high requirement for P to develop a foetus, produce milk and attain sufficient body condition to cycle. Cattle with the highest P requirements are first-calf cows that can be gestating and then lactating while still growing. Young suckling calves also

Table 1.1: Indicative liveweight and weaning rate responses[1] of feeding Phosphorus to cattle grazing native pasture and stylo-based pastures, growing on Phosphorus-deficient soils in northern Australia

	Acutely deficient	Deficient	Marginal
Typical soil P (P mg/kg)[2]	<4	4–5	6–8
Likely weight response to P supplement by growing cattle (kg/year)[1]			
Native pasture	30–40	20–40	0–20
Stylo pasture[3]	45–70	40–60	0–40
Extended growing season grazing good quality pasture[4]	45–90	40–70	
Likely response to P supplement by breeder cattle grazing native pastures			
Increased weaning rate (%)	10–40	10–20	0–10
Increase in calf weight at weaning (kg)	10–40	5–15	0–10

[1] Best estimate of what the average commercial property would be expected to achieve. Approx 25% of commercial properties will achieve less than 30kg benefit and 25% will achieve more than 40kg increase in growth rate (see page 15 for recent research). Monitor herd response and cost of supplementation to assess benefit for your individual circumstances.
[2] P mg/kg= bicarbonate extractable phosphorus (Colwell P).
[3] Verano and seca stylo grow well on P-deficient soils (unusual for legumes) and provide additional protein to support growth.
[4] If rainfall is sufficient over the growing season to allow for an extended period of good quality (crude protein >8% and metabolisable energy >10 MJ) legume-pasture, greater gains are achievable.

need a large amount of P in the milk (0.9–1.4 g/L milk produced) for rapid growth. If diet P from pasture is insufficient, cows can use bone P reserves to prioritise P concentration in the milk. However, the quantity of milk produced is less. Bone mobilisation is not a long-term replacement for dietary P and cows will lose body condition and are less likely to go back in calf again. All cattle grazing P-deficient pastures during the wet season will respond to an effective P supplementation program.

Benefits of P supplementation

- increased growth rate of young cattle (see Table 1.1)
- empty cows up to 100kg/year heavier
- cattle reach sale weight sooner at heavier weights
- replacement heifers reach critical mating weight sooner
- increased pasture intake (10–30%) improves body condition with benefits to milk production, weaner weights and pregnancy rates.

The values in Table 1.1 give approximate responses for growth and reproduction when implementing an effective P supplementation program. Producers are encouraged to use available tools to estimate P deficiency and monitor supplementation strategies and commercial benefits for their individual property or region.

Acutely P-deficient land systems frequently include infertile soils with low water-holding capacity. These land types support native grasses characterised by rapid growth to maturity and early senescence (haying off). Infertile P-deficient soils have lower potential productivity for both pastures and cattle compared with P-adequate land systems. Acutely P-deficient land systems will therefore never achieve the productivity of more fertile land types. However, an effective supplementation strategy will ensure optimal animal production is achieved where P-deficient soils are present.

Reduced mortality rates

Mortality rates decrease following P supplementation due to improved pasture intake and thus improved body condition score, particularly during lactation and leading into the dry season. With better body condition, cattle are better equipped to handle the dry season.

Stock appropriately if feeding P

Phosphorus deficiency restricts normal feed intake in cattle. Supplemented P-deficient cattle increase pasture intake up to 30% per animal equivalent (AE) on an annual basis. Short-term increases in pasture intake may be as high as 50–80% (although the P-deficient animal is usually lower in body weight compared with a P-adequate animal). Ensure forage budgets are adequate to meet feed intake requirements. Total stock numbers may need to decrease when initiating a supplementation strategy. However, research has demonstrated the benefits of P supplementation through improved productivity (kg/beef) and profitability.

Adjust stocking rates to avoid deterioration of the pasture base and loss of land condition when supplementing with P.

Summary

- Phosphorus deficiency in cattle is a major nutritional and economic issue.
- Key benefits of a successful P supplementation program are:
  - » increased feed intake and improved body condition score
  - » increased weaning and growth rates
  - » heavier cattle
  - » reduced mortalities.
- The response to supplementation depends on the level of deficiency (marginal, acute, severely acute).
- Ensure adequate pasture is available.

2. How to identify a phosphorus deficiency

Although most soils in northern Australia are classed as phosphorus deficient, the whole of a property or paddock may not be deficient. Work through the following questions to determine whether a paddock or property has a P deficiency.

1. Do your cattle chew old bones, show peg leg, sometimes break bones during handling, or die from botulism toxicity?

These signs of severe P deficiency are a clear indicator that P supplementation is required. Any P deficiency, even severe, can be remedied and Chapter 5 outlines how to implement an effective P supplementation program.

> Where acute deficiency exists, a significant improvement in productivity and profitability is expected from an effective P supplementation strategy in conjunction with appropriate stocking rates and grazing land management.

2. Are your cattle performing to expectations?

Are growth rates, breeder condition and weaning rates appropriate for the district and land types? If adequate quantity of pasture is available, then low growth rates, low reproductive rates, poor dry season body condition and high mortality can indicate marginal P deficiency.

Proportion of female cattle sold is a useful indicator of mortality. Elevated breeder mortalities result in fewer cull breeders and a need to retain more heifers. Some heifers are usually retained as replacements breeders. However where significant extra heifers are not being retained due to herd expansion, a rule of thumb for a functional herd is; female sales as a percentage of total sales should be similar to the number of male cattle sold. If female cattle sales as a percentage of total sales are 40–45%, this may be an indication of a subclinical P deficiency. More severe P deficiency may be indicated where the female sales percentage falls below 40%.

> Reduced productivity from acute P deficiency is a serious economic loss and an animal welfare concern.

3. Is the district generally known to be P-deficient?

Neighbours, agents and local beef advisors would have some knowledge of the level of deficiency in a district. Are the vegetation and land types on the property known to be deficient? Vegetation can be a useful indicator of the P content in soils and of potential P deficiency in pasture and cattle. Appendix 1 lists land types, the main vegetation/soil associations and their estimated P status. This is a good first step to assessing a property for P deficiency. If land types are mixed across paddocks, are some land types P-deficient and others P-adequate?

Methods to identify a P deficiency

Methods to confirm a suspected P deficiency on your property have varying degrees of difficulty and reliability and are described below.

Soil P maps

Over the years and continuing to the present day, thousands of soils have been sampled and analysed, and P status categorised. At a broad scale, soil or vegetation maps show that much of the soils of northern Australia are deficient in P (Figure 2.1).

However at this scale, maps cannot define small pockets of soil with adequate or even high content of P such as riparian zones (creek frontage) or different soil types. It is recognised that updated P maps are required. A newer P map (2024) for Queensland has been developed by Queensland Department of Environmental Science and MLA using 6796 unique site location samples. These samples came from extracting all available soil P data across Queensland, supplemented by additional soil sampling in under-represented areas.

> **This 2024 map shows the bicarbonate extractable P for Queensland with a clear variation in soil types.**

Some soils can be classified generally, for example:

- In north Queensland, deep sands are acutely P-deficient while most other land types are deficient to marginal.
- Goldfields, riparian zones (frontage), Mitchell grass downs and basalt soils are likely to be adequate or marginal.
- The Barkly Tablelands are largely deficient but may contain isolated pockets of adequate soils.
- In Western Australia, the Pindan region of the Kimberley region is generally considered acutely P-deficient, while some areas of the Pilbara contain many land types and careful consideration of P strategies is required.

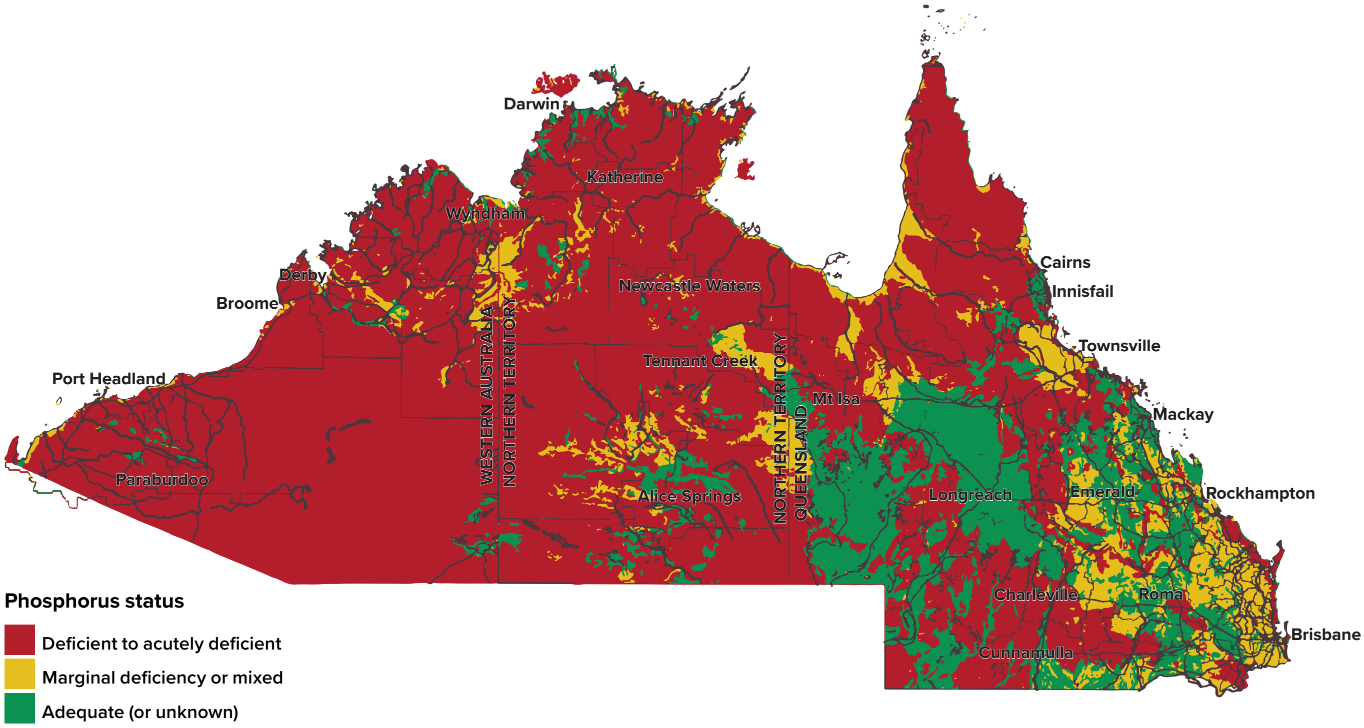
Soil testing

Taking soil samples for analysis will provide further evidence to support decisions about the need for, or profitability of P supplementation.

Soil sampling is relatively easy but should be done according to recommended protocols, or results will be difficult to interpret. Your local beef advisor, consultant or departmental extension officer should be able to provide a sampling protocol.

Avoid sampling near water points, on past supplementation sites or dung pats. If there are different land types across a paddock (for example open Mitchell Grass downs in the main part of the paddock and open red country with buffel grass around creek frontages), sample each land type independently and send to the laboratory as separate samples.

Figure 2.1: Map showing general extent of P deficiency across northern Australia



Source: Adapted from McCosker and Winks 1994

The cost of soil samples can be a barrier if many samples are required to get a good overview of the paddocks, but a few extra samples to provide a good indication of P status across the paddock will pay off in the long run.

Soil P content is expressed as milligrams per kilogram (mg/kg). This is the same as parts per million (ppm) of P.

Careful soil sampling that captures different land types across large paddocks aids in understanding P status. The test for soil P relevant to rangeland beef cattle production refers to bicarbonate extractable P (Colwell P) in mg/kg. Soil laboratory reports should be read carefully. Acid-extractable P overestimates the P available to cattle and can be misleading in considering a P supplementation program for a herd. The Colwell P method is recommended for beef producers to measure P in northern Australia.

The P status (acute to adequate) of beef cattle and the corresponding Colwell P value is shown in Table 2.1.

Table 2.1: P status of beef cattle and indicative soil P levels

P status	Acute	Deficient	Marginal	Adequate
Colwell P levels PB (mg/kg)	<4	4–6	6–8	>8

Note: Always read a laboratory report carefully. In general, the reports you receive will be focused on crop nutrient requirements in the soil, not livestock. For grazing cattle, focus on Colwell P in the report. This test for soil P levels refers to bicarbonate extractable P. Some soil labs report the acid-extractable P, and this is higher than the bicarbonate extractable (Colwell) P.

Soil tests are a useful tool to understand the P content of the soil, especially where paddocks are uniform in land type. Where a paddock contains many mixed land types and soil results are inconclusive or marginal (Colwell P of 6–8mg/kg), the P-Screen Test and/or trial feeding will help support decision making. Refer back to Table 1.1 for estimated production responses for various levels of soil Colwell P. If soil Colwell P levels are greater than 8mg/kg, the pastures will contain sufficient P and feeding a P supplement is unlikely to be economical.

Paddocks with a mix of soil types

All classes of cattle grazing continuously on land with uniform soils (such as parts of the Mitchell Grass downs) with less than 6mg P/kg are at risk of P deficiency and will respond to P supplement during the wet season. However, there is often variation of soil types within a paddock, and riparian zones can be over 15mg P/kg. A range of soil types within a paddock is particularly evident in parts of the Pilbara. Cattle find the best areas of pasture which usually contain adequate P. Some producers grow out heifers on P-adequate country to ensure sufficient liveweight gain and body condition for joining.

As an example, a trial paddock in the Barkly Tableland comprised open black soil plains with 2mg/kg soil P (acute) but also comprised some red ridges with 9mg/kg soil P (adequate). The red soil responded more quickly after rainfall and stock also preferred this less boggy part of the paddock during the wet season. Cattle preferentially grazed the red ridge country with high P pastures during the wet season and so did not respond to P supplementation.

A mixture of land types within a single paddock may reduce or eliminate the need for P supplementation if a land type has adequate P content soil.

All classes of cattle grazing continuously on land with uniform soils having less than 6mg/kg P are expected to respond to P supplementation.

A good manager uses knowledge of paddocks and grazing patterns to target P supplementation appropriately across an entire property.

Nearly all soils with termite mounds are P-deficient but not all P-deficient soils have termite mounds. Source: Sally Leigo

The P-Screen Test

The P-Screen Test includes sampling blood to measure plasma inorganic P (PIP) and dung samples for faecal NIRS (F.NIRS) to estimate diet quality. The P-Screen Test provides the most accurate diagnostic test available to determine the likelihood of a response to P supplementation. See Appendix 5 for relevant laboratory details.

The most appropriate animals to sample are young growing steers, growing heifers or mated maiden heifers less than six months pregnant. Avoid sampling suckling calves or weaners after weaning. Milk is rich in P and the PIP concentration in these animals will be adequate even when their mothers are P-deficient. Although lactating cows are most at risk of P deficiency, they are not a good class of animal to test for phosphorus status. Blood P concentration is essentially influenced by mobilisation of P from their tissues and bones. Where possible, animals not supplemented with P should be tested. The amount of time spent ingesting P supplement by individuals within the herd are unknown factors that affect the P-Screen Test. If withdrawal of supplement is not possible or is not advised due to potential severe deficiency, then withdraw supplement for a minimum of two weeks prior to sampling.

Test animals from the same group and paddock in similar status (e.g. growing steers) and condition. Blood samples should be taken in the mid to late wet season, generally March to May. At this time of year pasture quality is sufficient to support growth in non-lactating cattle. Blood sampling from June onwards will generally be too late (unless a late break of season) as growth rate of the cattle will have slowed because of declining protein and digestibility of the pasture.

It is recommended to take 20 blood samples minimum, with an additional 4–5 samples to allow for possible sampling, storage and transportation problems. Each blood sample is analysed individually for plasma inorganic phosphorous (PIP). Dung from the blood sampled animals needs to be collected, mixed together and a subsample dried and sent for F.NIRS analysis to measure the protein and digestibility of the diet (see Appendix 5 for relevant sample analysis laboratories).

Estimated P status is best based on combined blood PIP and diet digestibility from the F.NIRS results (see Table 2.2). If PIP is greater than 2.0 mmol/L, cattle are expected to have adequate P intake and are unlikely to respond to a P supplement.

Table 2.2 shows the best estimates of P status in growing and breeder cattle for a range of blood plasma inorganic P concentrations and diet dry matter digestibility (DMD). If DMD is less than 50%, no growth response is expected. If DMD is in the range of 50–54% then young cattle and non-lactating breeders will be gaining liveweight only slowly and the potential response to P supplements will be low. If the diet DMD is less than 50% then cattle are likely to be losing liveweight.

Table 2.2: Phosphorus status in cattle for a range of plasma inorganic P levels and diet DM digestibility in tropical pastures

Category	**Dry matter digestibility (DMD)**		
PIP (mmol/L)	>60% (Good pastures)	55–60% (Moderate pastures)	<54% (Poor quality pasture providing maintenance requirements or less)
Growing cattle and breeders not-lactating and up to the last two months of pregnancy			
<1.0	Acutely deficient	Acutely deficient	Deficient
1.0–1.5	Acutely deficient	Deficient	Marginal
1.5–2.0	Deficient	Marginal	Adequate
Breeders in the last two months of pregnancy and early to mid-lactation			
<1.0	Acutely deficient	Acutely deficient	Deficient
1.0–1.3	Acutely deficient	Deficient	Deficient
1.3–1.5	Deficient	Marginal	Marginal

Dung samples

Dung samples taken from animals unsupplemented with P during the wet season and submitted for P testing will help build a picture of their dietary P status.

However, dung samples on their own are not a reliable indicator of more marginal deficiencies.

Sampling dung should occur after the seasonal break, from unsupplemented animals and when animals have acclimatised to the pasture, usually between March and May. Wet chemistry P analysis of the dung is a useful tool for capturing extremes of P concentrations but there is a great variation between individual animals, and it should be used in conjunction with other methods to determine a supplementation strategy.

Collecting samples of fresh dung for concentrations of P in faeces and F.NIRS. Source: Désirée Jackson

Pasture

The analysis of pasture alone as an indicator of P status is inaccurate because there is a large variation in soil types, pasture species and maturity, and between different parts of the same plant.

Trial feeding

Trial feeding is a method that can be used to determine the effectiveness of P supplementation. Trial feeding involves dividing cattle of similar physiological status such as age, weight, sex, pregnancy and lactation into two small groups. The groups are then allocated either a suitable amount of P supplement or not. Records of growth, weaning rates (if breeders), mortalities and the cost of supplement are collated. The data collected will help give an estimate of the effectiveness of the supplementation program.

Trial feeding is a practical tool to see if feeding P will provide production and economic benefits. Knowing what the difference is in herd productivity or growth for that particular property is a good way to calculate how much a production or reproductive gain is costing and whether the economics of feeding P are viable for your business.

One limitation is that to accurately measure results, a before and after record of herd productivity is needed. Initially, supplement dry stock (steers or heifers) as weight gain improvement is easy to observe over one wet season. If the supplementation program significantly increases growth in this class of stock, it is likely that the paddock is P-deficient and breeders will benefit from supplementation. The benefits are substantial if in a P-deficient area and for a relatively small cost per head (see P cost calculator in Chapter 5; p17).

An auto-drafter is an ideal (but expensive) piece of equipment to determine liveweight gain responses to P supplementation as it allows comparison of unsupplemented versus supplemented cattle in the same paddock.

The exercise is still valuable without an auto drafter by keeping good records of:

- the weight of cattle going into the paddock
- the time they are in there
- how much P is consumed (see lick intake calculator in Appendix 3)
- their weight when they come out of the paddock.

Good records should be kept for the first couple of years to see the response in a given paddock, but once confident in the benefit of feeding, this would not need to be done every year.

Summary

- Know the signs of P deficiency in your livestock and land types.
- Vegetation maps and local knowledge indicate areas of likely P-deficiency.
- Soil, blood and dung samples help confirm a P-deficiency in livestock.
- A significant production and economic response to P supplementation can be expected where soil is acutely deficient (less than 4mg/kg Colwell P) and deficient (5mg/kg Colwell P).
- In regions where soil P is marginal (6–8mg/kg Colwell P), trial feeding can help identify economic and production benefits for a particular property.
- Blood testing for plasma inorganic phosphorus (PiP) should be done in conjunction with dung samples for predicting diet quality (F.NIRS).

3. How much phosphorus to supplement

How much phosphorus (P) cattle require depends on the class of stock (reproductive status, growth and lactation).

Tables in Appendix 2 show the total P requirement for various classes of growing and breeding stock. This is the **total requirement** and cattle can obtain it from:

- pasture
- bone mobilisation
- supplementation.

There is a common misconception that supplemental P needs to equal the total amount of P the animal requires (see Tables in Appendix 2). Grazing cattle will get some P from pastures, and supplemental P is additional, so the total diet meets the requirements.

Phosphorus from pasture

Cattle can digest, absorb and use 70–75% of the P in pasture. In uniform land systems rich in P concentration such as most basalt or brigalow land types, or uniformly poor P land types, the decision whether to supplement or not can be made with confidence. Where a paddock has a mix of land types with varying levels of soil P, then cattle will selectively graze parts of a paddock or plant species and plant parts containing greater P concentrations. Small areas in the paddock, such as the lighter red soils in amongst the black soils of the Barkly Tableland or alluvial riparian zones, can provide a significant amount of the P required in the diet of cattle.

Careful management of stocking rates and an effective P supplementation program will ensure good weight gain in steers.
Source: Bernie English

Phosphorus from bone reserves

Phosphorus is the second most common mineral in the body after calcium and is stored in the bones (80%) and muscles (20%). When dietary P from severely P-deficient pastures is not enough to meet the physiological demands of growth, gestation or lactation, a mature beef cow in good P status can mobilise 30–40% of the P in her bone reserves (page 12).

Beef cows grazing P-deficient pastures use bone P and body condition reserves to sustain limited reproductive function without P supplementation over the wet season. This physiological mechanism enables cows to support lactation and pregnancy (at less productive levels) but is not a long-term replacement for diet P and has a negative effect on herd productivity. During P mobilisation cows lose liveweight rapidly (-0.5kg/d) because mobilised P in the blood provides P for milk but does not support the increase in feed intake over the wet season that is observed with P supplementation.

Research has shown that where breeders are grazing acutely P-deficient pastures and are never fed P supplements, their bone P reserves and their productivity such as conception rates, weaning rates, cow liveweight and cow survival, declines year-by-year as an accumulation of the adverse effects of the P deficiency. Future productivity is therefore reduced in every season that the breeder mobilises bone P if this bone P is not replaced. Early weaning can help stop the lactation drain on the cow's body reserves of fat and of P.

Cows grazing P-deficient pastures and producing a calf will have difficulty replacing bone reserves and will lose condition, become unproductive and have greater mortality. The breeder that calves every 18–24 months, as often occurs in northern Australia, will have a greater opportunity to replenish some body P reserves but there is a cost to overall herd productivity and profitability.

After periods of P mobilisation from the bone, P must be replaced to set the breeder up for the next annual cycle of pregnancy and lactation. Breeders on P-deficient pastures can benefit from dry season P supplement, but this is not a replacement for a wet season supplement on P-deficient pasture. The rate of bone P replenishment is greater with protein and energy rich pasture diets that support liveweight gain. On good wet season pasture, non-lactating breeders may be replenishing 6–10g P per day, but on dry season pasture only 1–2g P per day.

Ensuring target P amounts are eaten during the wet season is the most effective way to ensure breeders can remain productive and get enough P when grazing P-deficient pastures.

In P-deficient country, feed P supplements for the entire wet season.

Lesser amounts of P supplement for breeders during the wet-dry-transition season and during the dry season will help rebuild bone reserves and support animal welfare.

The effect of P deficiency on breeding cattle (Queensland)

Mature breeders

The benefit of supplementing P in breeders was measured in research trials at Brian Pastures Research Station, Queensland. Mature breeder cows were fed an acutely P-deficient diet or with additional added P (as can be provided by P supplements) for the first three months of lactation. The results of consecutive experiments were similar (Table 3.1). Acutely P-deficient cows had 20% lower feed intakes than the cows with adequate P in their diets (after adjustment for the liveweights of the cows). These cows were losing rather than gaining liveweight – the difference after three months was about 50kg. However, milk production and calf growth in the P-deficient cows was nearly equal (90% of that in the P-adequate cows).

These experiments demonstrate that cows in good P-status at calving and then P-deficient during lactation were producing enough milk to provide for a healthy weaner, but there was a 'cost' in that the P-deficient breeder had low feed intakes, lost liveweight and lost P in the bone reserves which would impact her future productivity.

Table 3.1: Mature cows fed acutely P-deficient or P-adequate diets during early lactation (Dixon *et al.* 2020)

Measurement	Experiment 1		Experiment 2	
	P-deficient	P-adequate	P-deficient	P-adequate
LW, calving (kg)	465	433	468	453
LW, after 14 weeks (kg)	444	477	437	468
LW change during lactation (kg)	-21	+44	-31	+19
Voluntary intake (kg DM/day)	8.2	10.2	7.9	9.8
Calf LW gain (kg/day)	0.64	0.69	0.80	0.92

First-calf cows

The capacity of deficient first-calf cows to use P from skeletal bone reserves (in the absence of sufficient diet P) during early lactation is similar to the mature breeder but she has increased demand through skeletal growth. In a further experiment at Brian Pastures, heifers were fed an acutely P-deficient diet or a P-adequate diet during the last four months of pregnancy. Once they calved, the heifers in the P-adequate group were allocated to either a P-deficient or a P-adequate diet during early lactation. The heifers in the P-deficient group were also allocated to either a P-deficient or a P-adequate diet during early lactation. P-deficient heifers during late pregnancy were 47kg lighter at calving. After calving, regardless of whether these females had been in the P-deficient or P-adequate group during pregnancy, there were severe adverse effects of P deficiency during early lactation. During three months of lactation the P-deficient first-calf cows lost 65kg liveweight while the P-adequate cows gained 36kg (i.e. a difference of 100kg). This was associated with a severe decrease in voluntary intake by 40–46%, milk yield was 60–70%, and calf growth in P-deficient first-calf cows was only about 70% of that in the P-adequate heifers. Using P from bone reserves cannot replace a supplement P from diet.

Table 3.2: Measurements in first-calf cows during early lactation that had been fed combinations of acutely P-deficient or P-adequate diets during late pregnancy and lactation (Dixon *et al.* 2020)

Measurement	**Diet in pregnancy** P-deficient		**Diet in pregnancy** P-adequate	
	Subsequent diet in lactation		**Subsequent diet in lactation**	
	P-deficient	P-adequate	P-deficient	P-adequate
LW, calving (kg)	362	362	407	411
LW, weaning (kg)	297	400	342	445
LW change during lactation (kg)	-65	+38	-65	+34
Intake, lactation (kg DM/day)	5.0	9.2	6.3	10.5
Milk yield (kg/day)	4.9	7.9	6.5	8.7
Calf LW gain (kg/day)	0.54	0.81	0.72	0.96
Rib bone (% change)	-36	-20	-30	-14

Further information on this research can be found at: ***Improved management of cattle phosphorus status through applied physiology***

These results in the Brian Pastures experiments represent an extreme situation. Heifers fed high levels of P during pregnancy were unable to sustain adequate feed intakes when fed a P-deficient diet during lactation, highlighting the importance of dietary P during lactation.

An effective wet season P supplementation program ensuring adequate feed availability, results in healthy, productive breeders and heavier weaners. Source: Bernie English

Phosphorus from supplement

Phosphorus supplementation is a key strategy to increase dietary intake of P to meet total P requirements. Table 3.3 shows how much total supplement containing different P% cattle need to consume to achieve target intakes of P(g/d). Appendix 2 provides tables with specific estimates for individual classes of stock.

However, in extensive production systems on deficient land types, a general rule of thumb is:

- 6g P/day for growing cattle
- 10g P/day for breeding animals (see Table 3.3).

Calculate the quantity of P in the supplement to work out how much of the total supplement needs to be consumed each day. Can cattle eat sufficient lick to get enough P? e.g. lactating breeders grazing wet season pastures.

The amount of P supplement needed is the difference between the total requirement and the amount the animal obtains from the pasture.

Table 3.3: The quantity (g) of total supplement required at different phosphorus concentrations to achieve target intakes

Target intakes of P (g P/head/day)	%P in lick	Required intake of lick (g/head/day)
Growing cattle		
6	2	300
	5	120
	10	60
	15	40
Lactating cows		
10	5	200
	10	100
	15	67

Putting it into practice

If cattle on acutely deficient country are consuming a 50% monocalcium phosphate (MCP)/50% salt mixture, and there is approximately 21% P in MCP, they would eat 10.5g of P with every 100g of supplement eaten. Beef cows would need to eat 100g per day of this mix, while growing animals would need between 60–80g per day.

Tip: If animals are eating only a small quantity of supplement, it needs a higher P content. If they are eating plenty of supplement, the P concentration can be decreased. Higher P concentration will reduce the costs of transport and handling but may reduce intake through poor palatability.

Remember that when P supplements are fed as loose mineral mixes or blocks there is usually large variation among individual animals in their daily intake of the supplement. There is not much that can be done about this variation and the best we can do is aim to achieve an average supplement intake that is close to the target for the herd.

Summary

- Cattle access phosphorus from pasture, bone mobilisation and supplementary phosphorus.
- When their diet is deficient in P, lactating cows will mobilise skeletal P reserves to provide P for the calf in milk.
- Mobilised bone P is not a long-term replacement for dietary P and both cow and calf will have reduced production.
- Long-term bone mobilisation will result in lameness, injuries in the yards and, in severe cases, peg leg.
- It is critical to provide a P supplement to lactating cows when pastures are deficient or acutely P-deficient.
- Aim for target intakes of 6g/d P for growing cattle and 10g/d P for breeding cattle.

4. When to feed phosphorus

Phosphorous should be fed to all livestock grazing P-deficient land types. Feeding P in the wet season gives the greatest economic benefit on P-deficient country. Protein content and pasture digestibility decrease in the dry season, and cattle growth rates decline. Cattle are not likely to show a weight gain response to supplementary P from the middle of the dry season until the next seasonal break.

Typically supplements should include enough P to provide 6–10g P/day in the wet season and 2–5g P/day in the dry season.

Feed P when the grass is green

Feeding P in the wet season (growing season) gives the greatest economic benefit on P-deficient country.

To achieve maximum benefit from wet season P supplementation, a consistent supply must be maintained while grass is green.

Getting out to paddocks is a challenge in wet weather and P supplements should preferably be kept dry. Some producers have devised ways of distributing supplement regularly under challenging conditions (see Watson River case study on page 29). Putting out regular amounts of P is preferred as this allows producers to monitor cattle and ensure consumption of target amounts (see Chapter 5). If it is impractical to achieve this, then a bulk amount of P can be put out at the end of the dry season for the upcoming wet season. Ensure that there is enough per head per day for the length of the estimated wet season, topping up if necessary during occasional dry spells as the season progresses.

Wet season P supplement should contain enough P% to achieve 6–10g P intake per head per day. Typically a minimum 8% mix is required.

P supplements boost calf numbers and weight.

Dry season urea-based supplements that contain some P will benefit heavily pregnant and lactating cows that have a high demand for P to grow the foetus and produce milk. These supplements will also benefit cows in poor body condition that have recently had weaners removed and need to replenish bone P and regain condition.

In the dry season, supplementing nitrogen (e.g. urea) is of greatest importance because of protein deficiency in senescent tropical grasses. However, some P (2–4%) is recommended in dry season supplements for breeding cows. On P-deficient pastures, P supplement will always be needed by late pregnant and lactating cows due to the increased demands of lactation.

If dietary P is deficient, cattle mobilise P reserves from muscle and skeletal tissue because of the high demand of pregnancy and milk production. An animal consuming sufficient dietary P will not mobilise much P from the bone. Providing a P supplement can reduce or eliminate the mobilisation of P reserves and maintain them for times when demand for P increases (e.g. lactation). Whenever breeders use P reserves for pregnancy and lactation, those reserves will need to be replaced by feeding a diet supplement before the next reproductive cycle.

Cattle should consume 2–5g P per head per day supplement during the dry season on deficient country.

Stylo pastures

Stylo or legume pastures maintain a greater nutritional value for a longer period than tropical native grass pastures. On these pastures protein and energy content of the diet may be maintained well into the mid or even late dry season. Cattle grazing native grasses with stylo pasture on low-P soils are expected to respond to P supplements into the mid dry season—while the nutritional quality of the pasture is maintained by the stylo and there is adequate pasture available. In north Queensland, improving native pastures with stylos and P supplement can increase liveweight gain by up to 60% (see Table 4.1 on page 16).

Effect of P on intake and growth

The importance of feeding P when energy and protein are sufficient to support growth was demonstrated in 2015 research in Queensland. The below diagrams show feed intake in growing steers is depressed by low dietary P levels when energy and crude protein are adequate. In this experiment the diet contained 9.2 MJ/ME (63% DM digestibility) energy and 10.5% crude protein (CP) (similar to a good quality wet season pasture diet). The figure below shows the positive effect on intake and liveweight gain of increasing the P content of the diet from 0.9g to 2.4g P/kg dry matter intake (DMI) in growing steers (energy and protein were the same at each level of P). In northern beef production systems the best results are observed in the wet season when energy and protein are able to support liveweight gain (LWG).

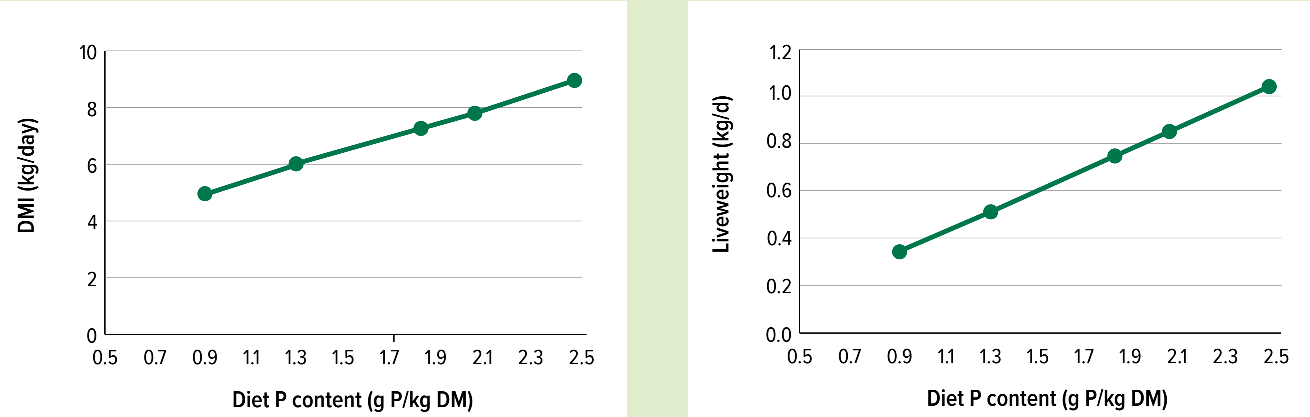


Figure 4.1: Relationship between DMI (Left) - and LWG (Right) and the P content of the diet at 0.9, 1.3, 1.8, 2.0 and 2.4g P/kg DM

Note: Diets contained adequate energy (>8.5 MJ) and crude protein (>10%). Relationships are based on repeatedly measured data over the entire experimental period (175 days).

Source: Quigley (2015)

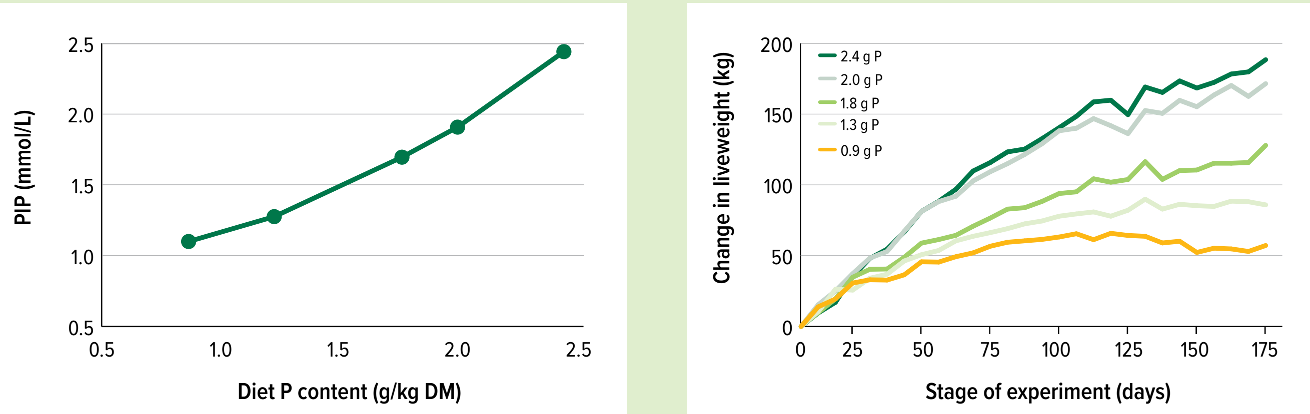


Figure 4.2: The relationship between blood plasma inorganic phosphorus (PIP) and dietary P (left) and cumulative change in liveweight of steers with increasing P content (0.9, 1.3, 1.8, 2.0 and 2.4g P/kg DM) over 172 days (right)

Source: Quigley (2015)

Steers from a pen trial fed either 2.4g P\kg DM (left steer) or 0.9g P/kg DM (right steer) for 172 days. Source: L/Jarvis and S. Quigley

The experiment demonstrated that adequate P drives:

- increased intake
- improved liveweight gain
- skeletal development.

Read the final report *Validation and demonstration of a diagnostic tool for phosphorus status of beef cattle.*

Table 4.1: Data showing the positive effect on liveweight gain by improving native pasture with stylo and/or P supplement at Springmount in far north Queensland

Soil P (ppm)	t/DM ha stylo	P supplement	LWG (kg) dry season	LWG (kg) wet season	Annual LWG (kg)
2	0.2	**No**	-26	74	48
	0	Yes	-34	114	80
3	1.5	Yes	-4	122	118
4	1.2	**No**	-1	97	96
	1.5	Yes	16	142	158
6	0.9	Yes	4	130	134
10	2.5	**No**	38	129	167
	1.6	Yes	42	142	184

Source: Adapted from Coates *et al.* (1990)

Phosphorus in herd management

Ensuring there is sufficient pasture available so that breeders can maintain good body condition is critical for herd fertility and growth rates. Supplements should be considered 'supplementary'. To be most effective, P supplementation needs good herd and pasture management.

For most of northern Australia, important aspects of management to be considered are:

- matching stocking rate to carrying capacity
- botulism vaccination
- matching time of calving to peak pasture nutritional quality
- culling unproductive breeders
- maintaining pasture condition through appropriate stocking rate and pasture management
- earlier weaning (where necessary) to minimise loss of breeder body condition during lactation so that cows regain condition quicker for rebreeding
- matching type of country to the class of stock (weaners, growing replacement heifers and first-calf cows need the better pastures).

There will often be a trade-off between breeder herd and steer grow-out production. For best outcomes in P-deficient rangelands, P supplementation needs to be combined with well-managed pastures and herds.

Steers grazing native stylo pasture may respond to a P supplement during the early to mid-dry season if there is sufficient grass.
Source: Bernie English

5. Starting a supplementation program

Getting started feeding P

Once a P deficiency has been identified, getting started on a supplementation program on part or all of a property is an important decision. Supplement feeding can be a significant cost for any business. One option is to start with one paddock to get the right loose mix recipes for your land types and class of cattle. Although feeding mature breeders will ultimately have the biggest flow-on effect by increasing calving percentages, weaner body weights and conception rates — first-calf cows or growing steers will show a quicker growth response compared to mature cows. First-calf cows have a higher requirement for P due to the fact they are still growing and as such are a priority for P supplementation.

Key considerations:

- is the deficiency acute or marginal and in which paddocks?
- how to get targeted supplement intakes for the class of cattle
- the best method to put out P during the wet season for individual circumstances
- the cost-benefit.

There is varying advice about the best way to supplement P. Case studies in this manual offer practical insights into P feeding strategies and on-farm benefits from beef producers who have tackled these issues first-hand.

Ensuring cattle eat enough P to support growth, gestation and lactation during the wet season is critical. There is no benefit to a supplement that sits in the paddock and is not eaten. Producers should record intakes based on the:

- amount fed
- amount disappearing from consumption
- the number of cattle (see 'lick intake calculator' in Appendix 3).

Getting intakes right

Phosphorus for livestock is usually supplied in the form of inorganic P as part of the calcium phosphates; mono calcium phosphate (MCP), mono dicalcium phosphate (MDCP) or hydrous dicalcium phosphate (DCP). These products are usually mixed with other feed ingredients and fed as a loose lick or solid block. Feeding inorganic P on its own might seem the cheapest option but a bitter taste means that cattle will not eat enough for requirements. Intakes can be increased or decreased by adding salt, protein meals or molasses or sometimes by changing the source of P. Test various ratios of protein meal to P source to find a mixture that achieves the target intake of supplementary P. As protein meals can spoil or go mouldy when wet, a lick shed, or cover will be required for protection during the wet season.

Different types of loose licks or blocks designed for wet season P supplementation can be trialled to see which forms are acceptable to cattle, and whether intakes are close to the targets for that class of stock.

Loose licks, whether packaged products or home mixed, provide for greater flexibility as the proportions of salt and/or protein meal can be adjusted to achieve the desired P intake. Salt can be an attractant or a deterrent depending on the land type and water source. Some bore waters are high in salts and can affect intake. Bore water rich in calcium increases the need to supplement with P in deficient country. Loose mixes, unlike blocks, offer the flexibility to alter formulations by adding ingredients such as salt or protein meals on-farm.

Wet season blocks do not require troughs and shelters and large quantities can be distributed quickly. However, they are usually more expensive per gram of P than loose mixes. Blocks are popular due to ease of handling, particularly in regions with inexperienced labour. When selecting blocks, it will be a matter of trying available products in your region. Hard blocks may reduce intakes, staying intact through most of the wet season. If block intakes are small, the type of block may have to be changed or loose licks considered.

There are no universal formulations that suit all regions, land types or properties. Monitor loose mix intakes and be prepared to adjust supplement composition if the target P intakes are not being achieved. Sometimes the P source has to be changed to achieve the desired intakes.

Different formulations may be required between paddocks and herds to achieve effective supplementary P intake, and it may take several wet seasons to get an effective P supplementation strategy. However, the financial and production benefits of getting supplement delivery and intake right make it worthwhile.

Proprietary P supplements

Read the labels carefully because P will be listed as one of the nutrients, but cattle may not eat enough to meet their needs of supplementary P if the concentration (%) in the lick is small (refer to Table 3.3).

Calculating cost of P in a supplement

Supplement prices should always be compared on the cost of the nutrient to be fed, in this case phosphorus, not on the cost of the mix. The cost of phosphorus can be calculated as in the example below.

Cost of supplement
= $1,330/tonne (= $1.33/kg)

Phosphorus content of supplement
= 12%

Weight of phosphorus per tonne of supplement
= 120kg

Thus the cost of the phosphorus (120kg) in this mix is
$1,330 ÷ 120kg = $11.08/kg P

or 1.1 cents/g P or 11 cents per day per cow during the wet season for a 10g intake of supplement (approx $3.32 per month)

Phosphorus supplements may include:

- **Phosphorus:** Commonly as a calcium phosphate with 18–23% P.
- **Salt:** A lesser inclusion of salt in the supplement is often an attractant to get animals to eat the supplement, while a greater inclusion of salt in the supplement often restricts intake.
- **Sulphate of ammonia:** Sulphate of ammonia (such as GranAm®) reduces palatability but is often included as a source of sulphur when feeding urea-based loose mixes.

DIY loose lick recipes

Three typical wet season mixes are:

- 70% calcium phosphate, 25% salt and 5% lime (typical northern tropics recipe)
- 50% salt and 50% calcium phosphate (recommended as MCP, MDCP or hydrous DCP)
- 50% salt, 40% calcium phosphate and 10% sulphate of ammonia.

However, many properties get customised wet season P formulations made for them. The important factor is that cattle consume enough to meet requirements.

Be cautious of using hard blocks that remain intact throughout the wet season, as they can ultimately reduce P intake if they last 'too well'.

Half-tonne bags require equipment for lifting.

How to feed P

The most common ways to feed P supplements to cattle during the wet season are:

- loose mix in the open
- loose mix under shelters
- loose mix in bulk bags
- blocks
- medicated water.

Small bags can be left in the paddock.

What to consider when deciding how to feed P

Supplement choice is a balance of cost and practicality and differs between properties and regions.

Some producers find blocks are the easiest form of P supplement to handle in the wet and most proprietary blocks are weather-proof. However, blocks are also the most expensive option per kg of P and should be monitored to make sure cattle are eating enough phosphorus.

Proprietary mixes are usually available in tonne and half-tonne bulk bags or in more easily handled bags of 25 or 50kg.

Loose mixes fed in the open will benefit from approximately 5% lime in the mix as it forms a crust on the lick in wet weather, protecting against spoilage. Too much lime, however, can produce a very hard supplement that will restrict intake and leave wastage.

While some properties successfully feed wet season mixes without shelter, rain damage may greatly reduce palatability and, in higher rainfall regions, lead to P wastage if the supplement dissolves.

Water medication is less effective in the wet season as cattle have access to surface water. Although cattle have been seen to walk through standing water to get to their regular trough, most are likely to miss out on the P supplement when they need it most.

Feed troughs

Troughs are made from a wide variety of materials and products:

- plastic troughs do not corrode but may be expensive
- hollowed tree trunks are cheap and durable
- old metal drums
- tractor tyres cut in half
- steel wheel rims from large mine machinery.

Shelters

Homemade supplement shelters can be cost-effective but need to be sturdy or they could be damaged by cattle or heavy gusts of wind. The salt in the supplement mixes can rust out flimsy steel shelters within a few years. Permanent shelters are prone to bogging over the wet and need to be maintained by applying gravel around the trough and shelter.

Various troughs and shelters. Shelters reduce the leaching of soluble P under heavy rainfall.

Table 5.1: Advantages and disadvantages in methods for feeding out P supplements

	Loose lick	Blocks	Loose lick in bulk bags
Infrastructure required	Need lick sheds/covered troughs	Weather resistant in most cases	Reasonably weather resistant with 5% lime
Cost	Lower cost/kg of P	Higher cost/kg P	Lower cost/kg of P
Recipe	Recipe can be changed to achieve target intakes (weather permitting)	Set recipe	Recipe cannot be changed quickly to achieve target intakes
Distribution	Difficult to put out requirements for the full wet season	Can be distributed in paddocks before onset of wet; flexible distribution	Can be distributed in paddocks before onset of wet
Labour	More labour intensive	Less labour intensive	Needs suitable lifting gear
Weather	Can be spoilt by storm rain	Rain resistant	Can be spoilt by prolonged rain
Freight	Can increase P% to reduce freight cost/tonne of P	More expensive to freight as P% is usually lower	Can increase P% to reduce freight cost/tonne of P

Choosing feeding sites

Managers need to plan the physical and logistical aspects of both wet and dry season feeding, including:

- the location of feeding sites
- access to the site during the wet season
- the method of delivery
- suitable troughs and shelters.

Feeding sites should be selected on:

- **Soil type:** can it take heavy trampling around the trough and what is the P status of surrounding country?
- **Access:** for efficient distribution and for checking consumption during the wet season.
- **Flexibility:** movable feeders can be shifted to encourage animals to use various parts of a paddock and so relieve the pressure on conventional feeding areas.
- **Location of watering points:** placing supplements away from watering points can encourage more even grazing patterns.
- **Location of supplement:** once cattle are eating the supplement, it can be put in places to encourage grazing at that location.

As P supplements must be available throughout the wet season, supplies must be replaced regularly as they are eaten, or an adequate supply (to last up to 12 weeks) put out before the wet and protected from the weather.

Inorganic P sources

Calcium phosphates

Calcium phosphates are the most common source of inorganic P fed to cattle in northern Australia and are sold under a range of brand and trade names. They have different physical characteristics, including colouration (typically white to grey) and form (typically granules or powders). Particle size may depend upon whether the P source is added into a loose lick or block; in loose mixes, finely powdered calcium phosphates can be wasted in windy conditions. Some common feed-grade P sources and their P and calcium content are shown in Table 5.2.

Alternative phosphate sources

There are other quality phosphate sources suitable for feeding to cattle but, because of their expense, they are used in specialised applications.

Monosodium phosphate (MSP 23–25% P), technical grade mono-ammonium phosphate (MAP) and technical grade di-ammonium phosphate (DAP) are soluble and suitable for water medication systems. The pH of the water influences the most suitable source of P. For water with neutral pH, technical grade MAP is cheapest. Both MAP and DAP contain nitrogen compounds and alkaline technical grade DAP may increase urea breakdown. Urea phosphate may also be used in alkaline water. Food grade phosphoric acid can also be used as a P source for beef cattle in molasses mixes.

The citric acid solubility test

In cattle, inorganic P is absorbed in the small intestine (after the rumen) and so must be made soluble within the digestive tract before reaching the small intestine for it to be available to the animal. Before reaching the small intestine, digesta is retained in the acid abomasum (pH of 2–3) for 20–120 minutes.

Laboratory methods assess availability of P in various inorganic P sources from their solubility in water, ammonium citrate (an alkaline solution) or citric acid (an acid solution).

The citric acid method mimics the acidic environment of the digestive tract and is considered the most reliable indicator of the availability of P to cattle. Both monocalcium phosphate (MCP) and mono-dicalcium phosphate (MDCP) sources of inorganic P have high P availability in citric acid.

There is no evidence to suggest there are practical differences in availability between these sources. Dicalcium phosphate (DCP) in its hydrous form also has a wide range of availability, probably due to the variety of manufacturing methods. The anhydrous forms of DCP have poor solubility and is not recommended.

Inorganic P in the form of tricalcium phosphate (TCP) has the poorest availability of feed grade calcium phosphates. Rock phosphate is the parent material from which calcium phosphates are manufactured. It has poor availability for cattle in its unrefined form and often contains fluorine as a contaminant. It is not suitable for feeding to livestock.

Table 5.2: Calcium phosphate classification and P content

Name	Main ingredient	Typical P%	P range (%)	Ca range (%)
MCP	Mono-calcium phosphate	23	21–23	15–18
MDCP	Mono-di-calcium phosphate	21	21	16–20
DCP*	Di-calcium phosphate	18	16–18	21–29
TCP**	Tri-calcium phosphate	16	16–18	30–34
Technical Grade MAP	Mono-ammonium phosphate	26.6	26.6	0
Technical Grade Phosphoric Acid	Phosphoric acid	26	26	0

Note: *DCP may be anhydrous or hydrous. Anhydrous DCP should be avoided as the P has a lower availability. **TCP is not recommended for on-farm use.

For more information on suitable forms of P for water medication, read MLA's *Supplementation of beef cattle using water medication*

Associated minerals and elements

Calcium

The calcium in calcium phosphate supplements brings the calcium:P balance in the supplement close to the 2:1 ratio found in bones. The calcium:P ratio in the total diet (including pasture) of beef cattle is more important than the ratio in the supplement alone and should not exceed 7:1.

Most grass pastures in northern Australia are rich in calcium concentration. The P concentration in most tropical grasses decrease as they mature. This does not occur with calcium. In the context of P supplementation of grazing cattle, a high calcium to P ratio in the total diet can decrease the mobilisation of bone minerals including P.

In general, calcium deficiency in beef cattle is rare in northern Australia, although it has been occasionally observed on yearling mated beef heifers grazing lush, high oxalate pastures such as setaria or kikuyu around calving, as well as in high-producing dairy cows. Excessive calcium makes P deficiency harder to resolve and careful consideration is recommended before adding calcium into P supplements.

Calcium as finely ground limestone is often included into loose licks as a binder to reduce weather damage when these supplements are fed in the open during the wet season (5% is ideal but above this will make the lick hard and unpalatable). The addition of limestone is not recommended unless it is necessary for weather protection such as when feeding loose mix type supplement in bulk bags (half tonne or one tonne). Many bore waters are rich in calcium, and this may provide additional calcium in the diet.

Limestone is sometimes added as a hardening agent in half tonne bags that are put out for the entire wet season.

Heavy metal contamination

Inorganic P sources can contain trace heavy metals such as arsenic, cadmium, lead and mercury. Feeding calcium phosphates containing high concentrations of heavy metals can lead to accumulation in animal tissue, particularly in the liver and kidney, and this can affect both animal health and productivity. Animal feed grade phosphates produced by reputable manufacturers are safe for animal consumption. Phosphorus fertilisers such as superphosphate and rock phosphate can contain concentrations of heavy metals and are not suitable for feeding to livestock.

Regulatory requirements limit the concentrations of heavy metals permitted in cattle supplements. Reputable suppliers of feed grade inorganic P supplements can supply independently validated analysis demonstrating acceptable heavy metal concentration and compliance with regulatory requirements. It is recommended that P supplements should be purchased only from suppliers who can assure heavy metal content of the raw material and product.

Cement powder has been used as a hardening agent to make home made blocks but this should not be done. Cement powder may contain unacceptable levels of heavy metals and is not registered for livestock feeding.

A related problem is excessive intake of fluorine as this is toxic to cattle and can cause bone abnormalities. Fluorine is present in high concentrations in most rock phosphates and removed by reputable companies during manufacture of feed grade calcium phosphates, but it can be present in high concentration in some bores in northern Australia. In dry times, evaporation concentrates fluorine in stock water. Water analysis can rule out problems that may reduce the effectiveness of feeding P.

Rock phosphates are not suitable for feeding to livestock because of poor availability of the P and the presence of heavy metals and fluorine as contaminants.

Summary

- Choose a supplement that ensures adequate consumption of P irrespective of whether it is the source fed alone or mixed into a supplement during the wet season.
- Compare P supplement options that will be consumed during the wet season on a cost per unit of P basis.
- Use only high quality P sources to ensure that P is readily available and scant in both heavy metals and fluorine.

6. Fertilising pastures with phosphorus

Phosphorus fertiliser has been applied to grass-legume pastures in many regions of Australia. Phosphorus fertiliser raises the concentration of P in the herbage and can double or triple total pasture yield. The phosphorus increases fixation of nitrogen in the root nodules of the legumes, and this is passed on to the grass for higher plant protein and production. The extra grass and legume growth allows for increased stocking rates and greater animal production per hectare.

While much superphosphate, as single super (9% P and 11% sulphur) or as triple super (20% P), has been applied to southern and some tropical pastures over the past century, it is expensive and becomes economic only where higher rainfall allows for greater pasture production and intensive stocking rates.

For most extensively stocked regions of Australia, it is more practical and profitable to supply P directly to the animal as a supplement when compared with the application of P fertiliser to the soil.

Phosphorus fertiliser

Current phosphorus fertiliser options include:

- single superphosphate (8.5% P and 11% sulphur)
- Di-ammonium phosphate (DAP, 20.2% P, 0% sulphur)
- Di-ammonium phosphate + sulphur (16.2% P, 6% sulphur).

Legume response

The main areas (90%) of sown pastures in northern Australia are found in Queensland. The largest area (70%) is of buffel grass in the central region of the Brigalow belt where, despite soils having reasonable fertility, some phosphorus deficiency in cattle has been reported.

Economic analysis has indicated potential returns of 9–15% from the application of P fertiliser when establishing legumes into grass pastures on poor P soils characterised by inadequate P available for the requirement of the legume grown. Economic returns of 12–24% may be possible when adding P fertiliser to already established grass/legume pastures on these soils.

Phosphorus and sulphur in superphosphate encourages the Rhizobium bacteria in the legume's root nodules to fix more nitrogen from the atmosphere. This nitrogen allows the legume to grow more vigorously while raising the protein content in the leaf.

This protein is ingested by the animal and improves its growth rate. Nitrogen returned to the soil through dung, urine, and leaf fall boosts the growth of grass. Superphosphate boosts total pasture growth and total animal growth.

Sown grass-legume pastures

A grass legume pasture on the Atherton Tablelands, Queensland.
Source: Bernie English

On the Atherton Tablelands, soil levels of 30mg P/kg are recommended for productive pastures. Soil nutrient analysis should be undertaken before seeking advice on suitable P fertiliser application.

The tropical legume species suitable for grazing may have different P requirements. Forage legumes such as trailing butterfly pea and centro need moderate concentration of soil P (8–10mg P/kg) to grow well and persist. These legumes require adequate P in the soil for successful establishment and need sulphur for establishment on basalt country. Grazing must be carefully managed as these palatable species are easily overgrazed.

Amarillo forage peanut is well suited to the wet coastal areas and is grazing tolerant; it can persist under poorer levels of soil P but still responds vigorously to superphosphate.

Leucaena requires P concentration greater than 15mg P/kg and may need additional sulphur on basalt soils. Leucaena demands careful establishment but is a perennial species and can be productive for many years under suitable management.

Establishment requires:

- careful seed bed preparation
- suitable planting equipment
- appropriate herbicides
- pest control.

Although P fertiliser is generally applied to pastures sown with improved species of grass and legumes it is also applied to pure grass pastures that are heavily fertilised with nitrogen.

Steers grazing grass/legume pasture fertilised with superphosphate (applied only to pastures in high-rainfall areas) are capable of heavy stocking rates. Source: Bernie English

Legumes in native pastures

Native pastures are often oversown with hardy legumes such as stylos. Seca and Verano stylo are versatile legumes that can grow in soils with marginal to low soil P (4–6mg/kg) but will respond to P fertiliser with improved growth and a greater concentration of nitrogen and P in the leaf. They will benefit from some fertiliser every three to five years. Typically, country is burnt before aerially sowing stylo to allow the legume to establish without competition from grasses.

Economic modelling in the northern Gulf region of Queensland estimates that applying P fertiliser on existing stylo:

- increases net present value (NPV)
- has a relatively short payback period (5–6 years)
- generates an internal rate of return of between 22–25% depending on utilisation rate of the pasture and timing of selling animals.

The stylos may be ignored by cattle when there is ample green grass leaf available but are preferentially grazed at the end of the wet season and into the dry season when they provide protein in the diet as grass quality declines.

Seca stylo in a native grass pasture.

Loss of grasses

Oversowing stylos into native pastures may allow cattle to remain in good condition at considerably higher stocking rates compared with those on native grass-only pastures. However higher stocking rates, aided by P supplement, can result in the loss of the preferred grasses in a native pasture, resulting in an unstable stylo-dominant pasture with little or no grass. This may be reversed by reducing the stocking rate, burning at the end of the dry season and wet season spelling or by applying a P fertiliser to boost grass growth.

Legume and P supplement can allow overgrazing, loss of productive grasses and legume dominance if not managed correctly. Source: Bernie English

Summary

- Fertiliser can be used in areas of high rainfall and productive soils.
- Native pastures oversown with stylos will boost productivity but periodic wet season spelling is necessary to maintain the native grasses in the mixture.

7. Profitability of phosphorus supplementation

Does it pay to feed phosphorus?

The financial cost of feeding P supplements is often discussed by producers as a barrier to feeding P for the first time because there is uncertainty around the benefit of spending money on a supplement when there is green grass available.

Effective P supplementation of cattle grazing P-deficient or acutely P-deficient land systems substantially increases the profitability of beef enterprises in northern Australia. The payback period on the investment can be within one to four years depending on the class of stock supplemented and the level of P deficiency.

An effective P program improves beef enterprise profitability through:

- increased weaning percentages
- reduced breeder mortality rates
- increased kg/AE turned off
- greater growth rates
- heavier sale cattle including cull cows.

An effective wet season P supplementation strategy is substantially more profitable than only feeding P during the dry season with urea supplementation. The sale of extra heavy cows helps pay for the initial costs of feeding the supplement, including investment in infrastructure such as troughs, storage, and possibly wet weather access roads in the first year, as well as recurring costs of supplement and freight.

Table 7.1: Profitability and financial risk of implementing P supplementation strategies for 1) an acutely P-deficient cattle herd in the Katherine region supplemented in the dry season or year-round and 2) breeder herds in the Fitzroy NRM region which were either marginally deficient or acutely deficient in P, and supplemented in the wet and/or dry seasons

Strategy	NPV of change[A]	Annualised NPV[B]	Peak deficit (with interest)[C]	Years to peak deficit	Payback period (years)[D]	IRR (%)[E]
Katherine region, NT						
Acute P herd, dry season N+P	$3,015,469	$196,161	-$363,738	3	3	60
Acute P herd, dry season N+P, wet season P	$7,691,352	$500,334	-$359,780	3	3	172
Fitzroy NRM region, central Qld						
Marginal P breeders, wet season P	$86,137	$5,603	-$7,187	3	3	114
Marginal P breeders, dry season N+P	-$3,576	-$233	-$34,107	n/c	n/c	3
Marginal P breeders, dry season N+P, wet season P	-$18,434	-$1,199	-$61,210	n/c	n/c	-4
Deficient P breeders, wet season P	$96,874	$6,302	-$26,907	3	3	52
Deficient P breeders, dry season N+P	$56,247	$3,659	-$37,094	3	4	25
Deficient P breeders, dry season N+P, wet season P	$36,655	$2,384	-$57,965	3	14	14
Acute P breeders, wet season P	$695,035	$45,213	-$38,877	3	3	81
Acute P breeders, dry season N+P	$435,778	$28,348	-$56,453	3	4	49
Acute P breeders, dry season N+P, wet season P	$630,094	$40,989	-$87,535	3	4	47

[A]NPV is the net present value of an investment, referring to the net returns (income minus costs) over the 30-year life of the investment and represents the extra return added by the management strategy, i.e. it is the difference between the base, case study property with no P supplementation and the same property after the P supplementation strategy is implemented.

[B]The annualised NPV represents the average annual change in NPV over 30 years, resulting from the P supplementation strategy and can be considered as an approximation of the change in profit per year.

[C]Peak deficit is the maximum difference in cash flow between the P supplementation strategy and the base scenario over the 30-year period of the analysis. It is a measure of riskiness.

[D]Payback period is the number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment.

[E]IRR is the internal rate of return, i.e. the rate of return on the additional capital invested. It is a discounted measure of project worth.

Source: Bowen *et al*. 2020

The profitability and financial risk of implementing a phosphorus supplement has been calculated for acutely and marginally deficient phosphorus country in Table 7.1. The analysis focuses on representative properties in the Katherine region of the NT, and the Fitzroy region of Central Queensland. Where acute deficiency exists, feeding N+P over the dry season followed by an effective wet season P supplementation program realised the greatest profits (NPV) and had the shortest payback periods. In marginal areas, an effective wet season supplementation program alone was the best option.

Further information on this analysis can be found at: *Improving profitability and resilience of grazing businesses in Queensland – Preparing for, responding to, and recovering from drought*

It is sometimes difficult to isolate the benefits of P supplementation on its own as it is often introduced at the same time as other improvements in herd or station management. The case studies from Amber Station, Watson River and Myroodah included in this document reflect a practical approach to property-wide herd and infrastructure improvements including P supplementation. On the other hand, the Kidman Springs P supplementation research case study captures the benefits of implementing a P strategy while all other herd management strategies and infrastructure improvements remain the same.

If P prices go up, is it still worthwhile?

Industry data, compiled in May 2022, indicates that P supplement prices have ranged between approximately $750 and $1,800 per tonne (and in 2023 have exceeded $2,000) of mixed product over the past decade. When P prices rise, many producers stop providing P supplement to some or all their herd due to financial constraints in the business. In P-deficient areas, this strategy will result in loss of performance, profitability and potentially a severe animal welfare issue.

How expensive can P get before it is not economical to feed it? The answer to this question will be different for each beef business depending on:

- deficiency level of soils
- number of head to feed
- land condition and management
- the sale price of cattle
- the price of supplement.

However, we can use the Kidman Springs P trial data (described in the following case study) to explore the impact of supplement cost on the profitability of P supplementation for a breeder herd when all other management costs are held the same.

Over the five year Kidman P trial, the supplemented breeders (the +P group) consumed a total of 16,848kg of wet and dry season supplement with a cost of $15,872 (average supplement cost $0.94/kg fed). For the purposes of this scenario, we included increased production across the herd, including sale cattle and the increased liveweight (LW) of breeders remaining on site. The average price per kilogram of beef produced was $2.30/kg LW (2016 prices).

If we use the earnings before interest and tax (EBIT/AE) data for the +P breeders in the Kidman Springs trial we can consider the effect of cost of P supplement (while holding all production costs steady). For this specific scenario Bush AgriBusiness estimated the effect that increasing the cost of a P supplement has on profitability (EBIT/AE). In this case, at 2016 prices and management costs, as the cost of supplement increased, the benefit to the profitability became neutral ($0 EBIT/AE) when P supplement costs approximately $4/kg ($4,000/ tonne). This value will not be the same for other situations due to differences in business structures and herd management. However, the main message here is applicable to all businesses in P-deficient country. Phosphorus supplementation should not be the first cost cutting measure when times are tough. All businesses operating in P-deficient country should carefully consider the negative effect that ceasing P supplementation has on overall business profitability, due to the major positive flow through effects on breeder productivity. The take home message is that on P-deficient country a P supplementation strategy should not be cut as a short-term cost saving measure.

Summary

- Supplementing breeding and growing herds with P provides a good return on investment in deficient areas.
- Failure to supplement P on acutely P-deficient country is likely to make an enterprise uneconomic.
- Do the figures on your own unique property to accurately evaluate the benefit of a P supplementation program.

Case study 1: 'Kidman Springs Station', Victoria River District, Northern Territory

The Northern Territory Department of Industry Tourism and Trade (NT DITT) conducted a phosphorus (P) supplementation trial at Victoria River Research Station (known locally as 'Kidman Springs') from 2014 to 2019. The trial was designed to provide objective measurements for beef producers on the benefits of P supplementation of breeders grazing native pastures typical of the Victoria River District (VRD).

Kidman Springs covers approximately 31,400ha in the VRD about 220km south-west of Katherine, NT. The VRD contains three main soil types which include cracking clays, calcareous red earths and sandy red earths. The soils are neutral to slightly alkaline and are mostly phosphorus-deficient (<5mg/kg Colwell phosphorus). Like many parts of northern Australia, the district has a distinct monsoonal wet season (November to March) followed by a dry season (April to October). Kidman Springs receives an average rainfall of 760mm with most falling between December and March.

In recent years, phosphorus supplementation has been a major aspect of research at Kidman Springs. Depending on the season, Kidman Springs runs approximately 880 Brahman breeders managed extensively, comparable with most commercial properties in the region. The supplementation program has involved supplying urea/salt dry mixes during the dry season and phosphorus/salt dry mixes during the wet season.

Routine management of the breeder herd has involved:

- two mustering rounds for weaning
- husbandry practices including vaccination against botulism and vibriosis
- data collection including pregnancy testing and measurements of weight, height, body condition and lactation status
- blood sampling as required.

Typically, the first weaning round is completed in May with a second-round muster in September prior to the start of calving. Following weaning, heifers are kept separate from older breeders until they have weaned their first calf at approximately three-and-a-half years old. They are mated for the first time at two years of age to young bulls, from mid-December to the end of March. Pasture assessments are conducted each year by rangeland scientists and this information is used to set the stocking rate for each paddock.

In May 2014, 179 Brahman weaner heifers were assigned randomly to two supplementation strategies:

1. No P supplementation (-P) and
2. with P supplementation (+P).

Loose lick supplements provided by Ridley AgriProducts were fed to both groups; the dry season supplement fed to the +P group contained P (25% MCP, 25% urea, 10% GranAm®, 40% salt, 1% trace minerals) whereas the lick fed to the -P group did not contain P (25% urea, 10% GranAm®, 64% salt, 1% trace minerals).

The +P wet season lick contained 42.5% MCP, 7.5% GranAm®, 50% salt. The -P wet season lick did not contain any P (73.5% salt, 7.5% GranAm®, 19% limestone). The two groups grazed adjoining paddocks and the herds switched paddocks annually to minimise any paddock effects.

The two groups were managed the same way except for their supplement so that differences were a result of the P supplement. No animals were culled during the study and any losses were replaced to maintain constant stocking rates. However, the replacement cattle were not included in the measured performance of the two herds.

Trial results

The average liveweights (LW) of the heifers in the two treatments at the start of the study were very similar (~174kg). There was no difference in growth rate during the first post-weaning dry season (May to October 2014) but +P animals gained 33kg more over the 2014–15 wet season. The average liveweight of the +P supplemented animals were heavier at every muster from this time onwards (Figure CS1.1). For example, lactating cows in the +P supplemented group were >100kg heavier compared to the non-P supplemented group at weaning musters.

The pregnancy rates of each treatment at each muster are shown in Table CS1.1. The data is shown for all animals (All) as well as for each lactational status (wet and dry). The group fed the P supplement had greater pregnancy rates than the group without P supplement.

The mortality rate in each year (Table CS1.2) was greater in the non-P supplemented cows and by May 2019 14.8% of the animals originally allocated to the -P treatment had died/gone missing compared with 2.3% from the +P treatment.

The mortality rate in the -P cows would have been greater but lactating cows with a body condition score of less than two were removed from the trial for welfare reasons in 2017 and 2019. These animals were supplementary fed until they improved. In May 2019, the trial was concluded a year earlier than planned because several of the lactating cows from the -P treatment were showing symptoms of peg leg and were in poor body condition.

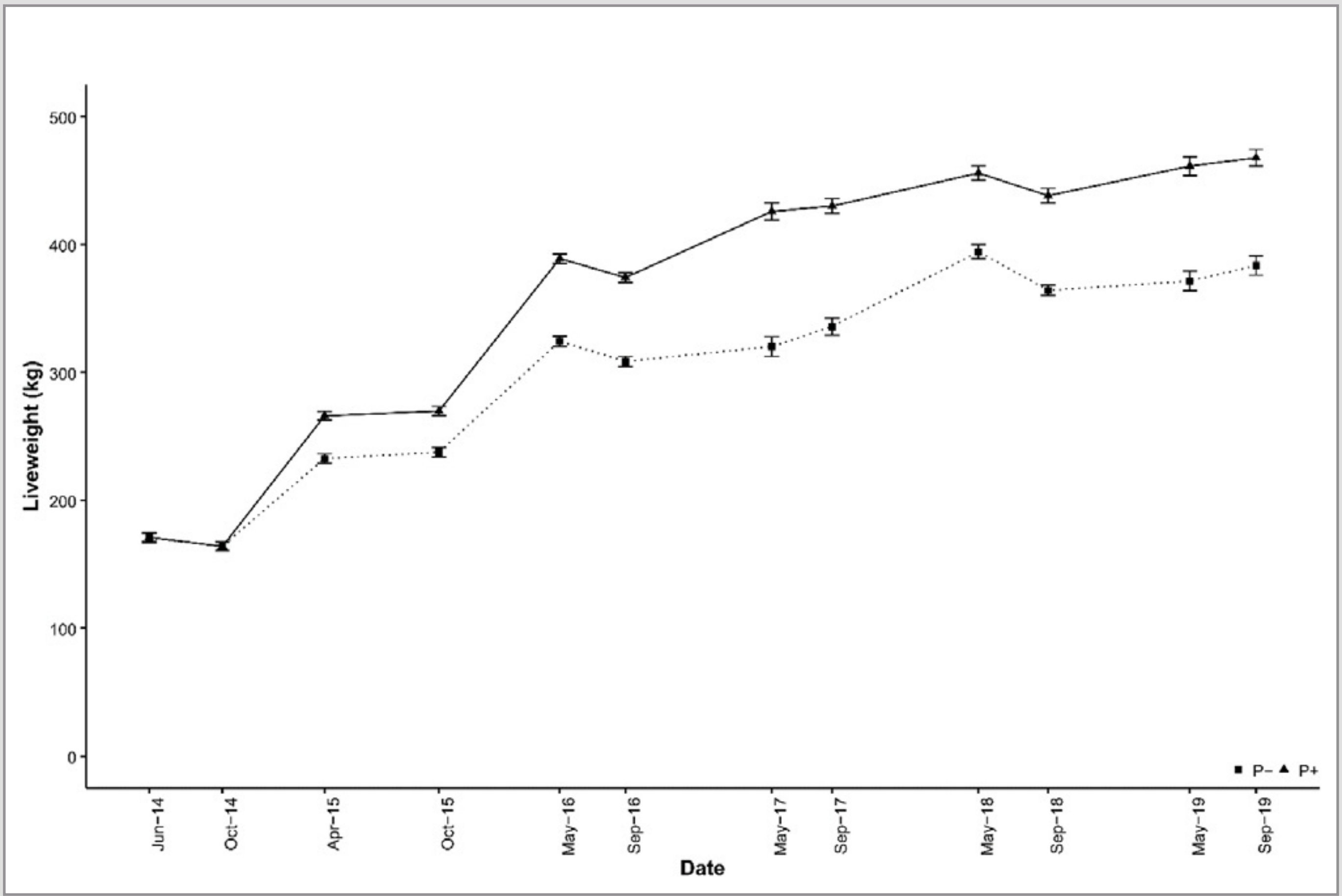


Figure CS1.1: Growth path data for all cows (lactating and non-lactating) in the -P and +P treatments (points represent times where cattle were weighed)

Table CS1.1: The pregnancy percentages of each treatment at the first-round weaning musters in each year

Lactation	Dry		Wet		All	
Treatment	-P	+P	-P	+P	-P	+P
2016	60.2%	70.0%				
2017	88.2%	90.0%	5.1%	30.0%	46.9%	56.7%
2018	96.0%	95.8%	20.0%	59.6%	67.5%	78.9%
2019	84.8%	92.9%	9.3%	75.4%	42.1%	80.9%

Table CS1.2: The mortality rates (percentage of animals that died/went missing) in each treatment throughout the study

Year	Cumulative mortality rate	
	P-	P+
2014/15	2.3%	1.1%
2015/16	5.7%	1.1%
2016/17	8.0%	1.1%
2017/18	9.1%	1.1%
2018/19	14.8%	2.2%

The productivity in terms of kilograms of beef produced from each treatment was substantially higher for the +P herd. Over the five years of the trial, 60,146kg of liveweight was produced from the +P group compared to 34,099kg from the -P group (Table CS1.3). An extra $7,899 was spent on supplement for the +P group and $62,235 more value of weight was produced if both treatments had started with 100 heifers.

Data from the first four years of this study was used to model the effect of P supplementation on an average herd in the Katherine (NT) region (see Table 7.1 in Chapter 7). Researchers found that it resulted in a large increase in annual business profit (>AU$500,000) and had an internal rate of return of 172%. The result confirms that P supplementation was very profitable in this case study.

Conclusion

The performance of breeder cows fed P supplementation in the Kidman experiment was a significant improvement compared with breeders not fed P under the same paddock conditions. The economic analysis (refer Chapter 7) showed that it was profitable and had clear benefits in terms of animal health and welfare. The responses generated in animal performance compared to the relatively low cost of P supplementation provide a case for beef producers on P-deficient soils in northern Australia to feed P.

Table CS1.3: Summary of the production and costs of each treatment (calculated for both treatments starting with 100 heifers)

	-P	+P	Difference (+P less -P)
Total weight of calves produced (kg)	17,464	29,520	12,056
Total increase in weight of females (kg)	13,134	25,551	12,417
Total weight of beef produced (kg)	30,598	55,071	24,472
Value of beef produced (@ cows = $1.5/kg, weaners = $3/kg)	$72,094	$126,886	$54,792
Total value of supplement consumed	$8,783	$15,872	$7,089

Case study 2: 'Watson River Station', Cape York, Queensland

Background

'Watson River Station', located south of Weipa on Cape York Peninsula, has an annual rainfall of 1,500mm. Like many areas across north Queensland, the soils are acutely deficient in P and property access during the wet season is a challenge. On a mix of sandy and clay soils on forest country, Watson River runs 1,300–1,500 Brahman breeders. Weaning rates, including joiner heifers, average 57% and breeder losses range from 2–3%. Weaner steers are transported to a second family property on the Atherton Tablelands to be grown out to around 320kg prior to sale to local bullock producers.

It is about a decade since the first P case study was completed on Watson River Station. At that time, Cameron and Doreen Quartermaine had developed the 89,000ha property to the point where half was fenced, and the balance was bush country. During the intervening period, intergenerational transfer has occurred with Luke and Ally Quartermaine now managing Watson River. Their goal is to continue developing the bush country and equip a third generation with the necessary skills to take over the Watson River beef operation.

Feeding P

Aside from property development and herd improvement, the most significant management strategy applied over several decades by the Quartermaine family has been the feeding of P supplements to all cattle for the entire wet season.

"On Watson River we do our P lick order for our cattle before we do our food order for the station," Cameron said.

The Watson River wet season P recipe (Table CS2.1) includes a mix of monodicalcium phosphate (MDCP: 21% P), GranAm®, lime, sulphur, salt and trace minerals, as well as 2% molasses to settle dust during supplement production in the factory. A similar recipe has been used for decades on the Watson River.

Feeding in lick sheds eliminates rain spoilage and maintains lick palatability. Over the wet season, mature breeders require at least 10g P/head/day with less for weaners or replacement heifers. The Quartermaines aim for breeders to consume around 80g/head/day of lick which, at 12% P (as fed), delivers the required 10g of P/breeder/day. However, it is not unusual to see daily lick intakes fluctuate during the wet season. GranAm®, a source of non-protein nitrogen, is used to help fill the protein gap as pasture quality declines later in the wet season.

Although used successfully on Watson River, GranAm® is sour and can sometimes reduce supplement intake. Many northern producers are reluctant to use GranAm® in their wet season supplements as target wet season P intakes are often difficult to achieve. The inclusion of lime (7%) in exposed wet season P loose licks (as in bulk bags) helps form a surface crust and weatherproof the recipe. In the case of Watson River, all supplement is fed and protected in substantial lick sheds so the inclusion of lime in their recipe may be revisited next year. High humidity during the 2019 to 2020 wet season caused some crusting of covered supplement and may have restricted intakes.

Table CS2.1: The wet season lick recipe is 12% P as fed and is readily consumed by all classes of cattle on Watson River

Ingredients	Inclusion rate
GranAm®	10%
Monodicalcium phosphate (MDCP)	57%
Lime	7%
Sulphur	3%
Salt	20%
Molasses	2%
Trace minerals	1%

P supplementation on Watson River greatly improves pasture intake over the wet season and is critical in maximising herd productivity, from liveweight gain through to pregnancy and lactation rates. The herd and economic benefits of wet season P are further highlighted by the Watson River herd analysis conducted by the Queensland Department of Agriculture and Fisheries team in March 2020. When compared to not feeding P supplements, P supplementation on Watson River increased weaning rates from 46% to 57% and reduced breeder mortalities from 6% to 3%. Feeding P also increased female and steer sale weights by 7% and 9% respectively. Even though the number of weaners produced by the wet season P supplemented herd only increased by 29 (776 to 805), the overall lift in herd efficiency due to the wet season P feeding program improved overall property profitability by about 60% (Table CS2.2).

Table CS2.2: The herd performance, turn-off age, turn-off value and gross margins at Watson River with, and without, wet season P supplementation

	No wet season P supplementation	With wet season P supplementation
Total adult equivalents (AE)	2,100	2,100
Total cattle carried	2,467	2,341
Total breeders mated and kept	1,558	1,347
Total calves weaned	776	805
Weaners/total cows mated	46%	57%
Overall breeders deaths	6%	3%
Female sales/total sales	39%	46%
Total cows and heifers sold	244	336
Total steers sold	388	401
Average female price	$687	$784
Average steer price	$382	$514
Direct costs excluding bulls	$50,005	$70,917
Bull replacement	$32,245	$26,737
GM per adult equivalent	$111	$177

Wet season access

The difficulty of delivering wet season lick during the northern monsoon season should not be underestimated. However, due to the considerable production gains from P feeding, the Quartermaine family have infrastructure and management systems in place so P can be fed to all cattle while there is green grass.

Cameron and Luke have installed four large shipping containers at points around the property for bulk dry mix storage. These containers can hold up to 14 tonnes of dry mix and are filled before the wet season in November each year. A quad bike and side-by-side bridges allow access over flooded creeks to deliver supplement to 31 covered troughs throughout nine paddocks (see photo above). The lick troughs on Watson River are well sheltered from monsoonal rains by wide corrugated iron lick sheds. Each trough holds roughly 240kg of supplement (12 x 20kg bags), and lick shed materials range from steel to strong and termite-resistant bush timber such as Cooktown ironwood.

All lick sheds include back rubbers carefully positioned to control buffalo fly on breeders, weaners and calves (see photo above). The buffalo fly insecticide and oil is stored in bulk in the shipping containers along with the P supplement. The side-by-side buggy and quad bikes are the main means of travel during the wet season to check cattle, fill supplement troughs and change back rubbers on a weekly basis.

Herd and land management

Luke and Ally have used the opportunity provided by recent cattle prices to sell down a portion of the herd and effectively halve the stocking rate on the fenced portion of Watson River. This is aimed at improving land condition through wet season spelling and reducing end of dry season mortalities.

The heavier culling of breeders and replacement heifers has produced a breeding herd with an even temperament and better overall reproductive performance. The feeding of wet season P supplements and the focus on temperament allows for an efficient first-round muster even with extensive surface water across all paddocks. The Watson River first-round muster is a couple of months earlier than on comparable properties that do not have the same herd supplementation and management strategies in place. This enables more timely weaning and helps maintain breeder body condition.

Watson River currently has approximately 325ha of improved grasses and legumes on cleared country as well as a hay paddock. The fertilised hay paddock produces sufficient hay to meet the Watson River requirements, as well as a surplus supply for sale or use at local events like the annual show and rodeo.

Future development plans include the:

- subdivision of existing breeder paddocks for pasture spelling and improved herd management
- installation of additional water and cattle handling facilities on the remaining bush country to expand the breeder herd over time.

Breeders and heifers are vaccinated for botulism, weaners are vaccinated with 7-in-1 and all cattle are treated to control ticks. Luke has kept a few of the better Watson River male calves as herd bulls.

As the next generation of managers on Watson River Station, Luke and Ally share a passion for, and a commitment to, the northern beef industry. Their clear focus on feeding wet season P, herd management, moderate stocking rates and wet season spelling are the key strategies for a successful beef operation on Watson River for years to come.

Case study 3: 'Mystery Park', St Lawrence, Queensland

Strategic phosphorus (P) supplementation has allowed Queensland beef producers Rob and Ainsley McArthur to boost the productivity and profitability of their entire business.

Rob and Ainsley McArthur from 'Mystery Park', St Lawrence, Central Queensland operate a cattle breeding, backgrounding and agistment enterprise, running 5,000 tropically adapted composite cattle.

About 14 years ago, the couple recorded conception rates of below 60% in their breeder herd, as well as low growth rates across their commercial herd. Bulls are evaluated for breeding soundness each year and are joined with cows at 2.5% from 1 January for 63 days.

They decided to dig deeper to identify the cause and found an unexpected problem. Their region isn't typically associated with deficient soil phosphorus concentration, but given their herd's performance, the McArthurs decided not to rule out P deficiency.

"It wasn't until we got our specific property lot numbers assessed with the Queensland Department of Agriculture and Fisheries for land and soil types and completed faecal sampling for an indication of diet quality (faecal NIRS [near infrared reflectance spectroscopy]) and P status through wet chemistry analysis, that we learned that some areas of our property were P deficient," Rob said.

"Despite paddocks on creek flats showing adequate P concentrations, these paddocks weren't enough to offset P deficiencies on the balance of our land types".

"Learning about the different land types of our property enabled us to take a targeted approach with P supplementation."

Supplementation strategy

To ensure P supplementation was cost-effective, Rob and Ainsley set specific production goals. Initially, these were:

- target weights for yearling heifers and steers
- conception rate targets within the breeding herd.

The McArthurs begin supplementing P in the late dry season (September and October), just before late pregnancy.

"That's generally still the dry season for us, and cattle most often have access to a urea-based, dry season supplement. We begin adding P to this urea-based lick so that the cows can build their P reserves prior to first calves born in mid October," Ainsley said.

When the season breaks and the animals' nutritional needs such as energy and protein are already met by the grass, then P is the next biggest issue in the diet.

"We then ramp up the P supplementation in the growing season, making it ad lib (free choice) until the pasture's growth slows and starts to hay off," Rob said.

However, helping the cattle to meet their P requirements through consuming enough of the P supplementation was a challenging task.

"We persisted, and it really came down to trial and error," Ainsley said.

The supplement needed to be palatable, easy to deliver during the wet season and cost-effective."

Eventually, the McArthurs settled on a winning combination which they've been using for more than five years now.

"We mix monodicalcium phosphate (MDCP) with a protein meal, which acts as an attractant to get the cattle to eat it," Rob said.

"We are targeting lactating breeders to consume approx 10g P of MDCP per day and dry cattle about half of this per day.

"It's important to remember that around 20% of the MDCP is phosphorous. To begin with we mix the protein meal and MDCP at a ratio of 1:1 and as cattle acquire a taste it moves back to a ratio of 1:2. This is then fed out in open troughs."

Growing season results

As a result of implementing a P supplementation program, Rob and Ainsley have:

- improved body condition across their herd
- 18% increase in conception rates in their breeder herd (from 60% to 78%)
- increased heifer growth rates
- increased the percentage of heifers reaching target joining weights.

"The 18% lift in our pregnancy rate on the cows was achieved in a very tight joining window of 63 days which means our cows are having a calf every 12 months – this is a huge benefit to our business," Ainsley said.

"We were able to put more pressure on the cows to go into calf earlier and as a result we have a more consistent line of weaners.

"The fact that we've got more kilograms on the herd means we're producing more kilograms of beef per hectare – this has improved our gross margin and we've been able to be market ready, earlier.

"P supplementation has helped us maintain body condition score on the cows as well, which contributes to them being able to get back in calf earlier. Retaining cows at body condition score of three or more has a huge impact on their ability to reconceive."

"As soon as we got the P intake correct, we saw the results within the growing season," Rob said.

"P supplementation for us was a low hanging fruit in our business. It's not a magic bullet but it's a one percenter that if you add all those up together, it helps with production," Ainsley said.

Measurement is key

According to Rob and Ainsley, measuring everything is key to seeing results.

"We know how much the protein meal and MDCP is per tonne, we know how many kilograms are delivered to each paddock and how many grams per head the cattle are eating," Ainsley said.

The McArthurs test faecal samples to monitor phosphorus levels in the cattle's diet as well as other key nutrients such as dietary crude protein, dry matter digestibility, faecal nitrogen and the non-grass proportion of their diet.

"Regular testing allows us to ensure our P supplementation strategy is meeting the requirements of the cattle year-to-year," Rob said.

Case study 4: 'Myroodah Station', West Kimberley, Western Australia

Shane and Abbie Dunn manage 'Myroodah Station' which is owned by Kimberley Agriculture and Pastoral Company (KAPCO) in West Kimberley, WA.

Operating across 404,000ha, the pastures on Myroodah Station range from ribbon grass, soft, curly spinifexes, wire grass and buffel, to kangaroo grass. Soils are cracking clays on river frontage, Pindan, and stony plains through to deeper desert sands.

The extensive beef cattle enterprise is primarily a breeding operation with 12,000 Brahman and Brahman-cross breeders. The primary market are bulls which are exported to Vietnam from Broome.

Heifers are mated at two years old and cows can stay in the herd until about 13 years old. Good quality bulls are purchased from Queensland with estimated breeding values (EBVs) where possible and run at a proportion of 4% of the breeding herd.

At Myroodah Station, phosphorus (P) is a key piece of the productivity puzzle. Shane and Abbie took over management of the property four years ago and it was clear there were herd management issues.

"We had healthy cattle with minimal stress on them, knuckling over and our weaner performance was not consistent, so we knew there was an issue," Shane said.

Shane got involved in both the 2019 and 2020 MLA P Challenges to determine if:

- P deficiency was an issue on Myroodah Station
- his P supplementation program was adequate.

The P Challenge involved collecting a blood sample from around 20 animals within a mob (herd) to test for plasma inorganic P (PIP). When combined with soil and diet quality assessments, based on faecal NIRS results from samples collected at the same time as the blood test, the P status and diet quality of the mob was determined.

Identifying the problem

The Challenges revealed Myroodah Station was located in one of the most P-deficient areas in northern Australia with blood PIP concentration in cattle around 1.0 mmol/L.

"I was surprised by the results as we were providing P in a traditional sense (wet season supplementation) and understood the area was P deficient, but the results showed we were still deficient and needed to look at our supplementation strategy," Shane said.

"To make our business work we were looking at three key drivers – reducing herd mortality, increasing weaning rates and selling heavier cattle. So we were looking at all the options and P supplementation was an important tool to improve productivity overall."

The new P approach

Traditionally, Shane would put a 30% urea-based product out in June before the cattle needed it and then supply a P-based supplement prior to the start of the wet season in November/December.

However, now the P Challenge is done and dusted, Shane is taking a different approach to P supplementation.

"We're increasing the P percentage in our lick blocks from 12% to 15% and supplying the blocks on a year-round, 24/7 basis," Shane said.

Shane uses a Mack six-wheeled ex-army truck with a Hiab crane to distribute approximately eight tonnes of lick blocks at a time.

"We put a pallet of blocks at the lick station which include six urea blocks, four phosphorus (15%) blocks, and a sulphur and mineral block in the dry season," Shane said.

"I use P in lick block format because it's convenient for my staff to distribute over a larger area, rather than concentrated in certain points – and we can leave more blocks out in the wet season without having to worry about conditions.

"I find the free choice approach in the dry season works well with cattle in different areas looking for different supplement. You can easily drive out and observe the use across the property."

Results

Since using the blood tests to improve his supplementation strategy, Shane has improved liveweight gain, reduced herd mortality and increased weaning rates (see table below).

"No cattle are knuckling over now and we're picking up a stronger, more even line of weaners. Plus, our sales weights are also increasing by 10–15kg per head," Shane said.

"With changes to our management approach including the P supplementation, KAPCO weaning rates have increased from 58% to 76% and we're getting more commercial buyer interest in our cattle. We have also received feedback that they are performing better in the export feedlot system."

Table CS4.1: A modelled (Breedcow Dynama) comparison of the herd performance, turn-off age, turn-off value and gross margins with, and without, wet season P supplementation on Myroodah station in the West Kimberley

	Myroodah without P	Myroodah with P
Total adult equivalents	20,027	20,027
Total cattle carried	28,798	27,496
Total breeders mated and kept	12,095	10,032
Total calves weaned	8,569	8,938
Weaners/total cows mated	58.8%	74.29%
Overall breeders deaths	6%	3%
Female sales/total sales	44.16%	48.03%
Total cows and heifers sold	3,060	3,861
Total steers sold	3,869	4,178
Average female price	$782	$964
Average steer price	$1,145	$1,214
Direct costs excluding bulls	$714,084	$1,046,037
Bull replacement	$497,749	$406,207
GM per adult equivalent	$280	$367

Raising the productivity bar

P supplementation is just one piece of the puzzle boosting productivity at Myroodah Station, where manager Shane Dunn has a suite of tools to increase the return on investment for station owner, KAPCO.

Here's how Shane is improving productivity on-farm by focusing on four key areas.

1. Decreasing herd mortality

Shane manages calf mortalities by:

- focusing on a mustering and weaning program
- providing a thorough supplementation program
- having a good supply of feed available by monitoring stocking rates and paddock spelling
- implementing a feral animal control program for wild dogs and pigs.

2. Reducing stress

Breeder mobs are drafted and processed in a day and back on hay with calves that night. With the right infrastructure and station hands, approximately 1,000 breeders plus progeny can be processed comfortably in a day. Shane also tries to leave cow groups together and just takes out the non-performers.

Weaners are on pellets and hay and put through the yards twice a day for six days – this is done once with horses and then on foot.

Having completed this weaner management program for three years, the benefits are now coming through the herd – the heifers are relaxed in mustering and through the yards which reduces costs and is hopefully reflected in the future calving percentage. Sale cattle are also handling the mustering and yards easily with turn-off weights increasing each year.

3. Boosting fertility

To boost fertility across the herd, Shane takes a holistic approach including:

- implementing a thorough vaccine program from weaning onward, including vibrio for bulls and heifers, and 7-in-1 vaccination
- buying good quality bulls
- control mating maiden heifers
- taking out non-productive cattle from the herd post pregnancy testing
- supplementing with P year-round
- reducing the stress on the herd through management, staff training and infrastructure.

4. Building seasonal resilience

Good water infrastructure is one of the tools Shane uses to build seasonal resilience. Over the past three years, KAPCO has made significant investments in water infrastructure by:

- replacing diesel motors in their water pumps with solar (they are nearly 90% solar)
- increasing the volume-holding capacity of all bores to avoid a shortage of supply
- improving access to water with more bores and trough upgrades.

Land use is also being managed by:

- rotating and spelling some areas
- identifying where cattle can do better as a breeder
- putting dry (sale) cattle in areas that are better for non-lactating animals
- managing a fire program and adapting to seasonal conditions.

Case study 5: 'Amber Station', Mount Surprise, Queensland

Background and property description

Phosphorus supplementation can greatly improve herd performance of northern breeding operations and is a fundamental feature of a resilient livestock business. However, innovative supplement delivery technologies and persistence are necessary to overcome wet season property access challenges and to achieve sufficient P intakes across the herd.

'Amber Station' is a partly developed 104,000ha breeding property located 55km north of Mount Surprise, Queensland. It was purchased by Werrington Cattle Company with the new managers, Georgia and Dan Slaney, taking up residence in late 2019.

Historically, Amber Station operated as a low-cost breeding operation producing weaners for transfer to other family properties.

At the time of purchase, about half the property was fenced into five large paddocks; the other half was open but linked to laneways and holding squares around strategic dams and water points. Steep gullies and rocky outcrops often acted as a natural boundary, and the number of neighbouring cattle running on Amber suggested minimal stock control.

An assessment of the breeding herd and calves purchased with the property indicated a P deficiency.

Werrington Cattle Co has a long history of successful wet season P and dry season supplementation of breeder herds, so the first management decision on Amber Station was to feed bulka bags of both wet and dry season supplement side-by-side. Two thousand cows purchased with the station consumed 22 tonnes of P supplement in just three weeks. Dan explained he had never seen such high intakes of P supplements.

Within weeks, they noticed a dramatic turnaround in the cattle condition which coincided with a significant reduction in supplement intakes.

Amber Station receives reliable wet season rainfall (~ 800mm) and is fortunate to have several creeks branching off the Lynd River which runs through Amber all year round. Along with a variety of native pastures and shrubs, Seca stylo and other introduced stylos are widespread. Ranges and rocky outcrops intersect the property and key soil types include decomposed granites, sandy country, watercourse frontages and some basalt soils. In addition to the river and natural springs, Amber has a house bore and 28 dams. The current property management plan focuses on implementing a P (wet and dry season) supplementation program and investing in yards, fences and water to improve the carrying capacity and running efficiency of Amber. Only breeders with better reproductive performance will be retained and herd bulls will be selected on objective criteria that focus on improving herd fertility, temperament and survivability.

An effective wet season P supplementation program provides intakes of 10g/day for each cow-calf unit during the wet season and targeted dry season supplementation (with P) for weaners and replacement heifers. Bulka bags are preferred because of the lack of lick sheds and poor wet season access — this delivery system has been successful for nearly two decades.

Using 250kg or 400kg bags allows a wider distribution of lick across each paddock when cattle are typically scattered due to surface water. Smaller 25kg bags are transported by helicopter to replenish existing lick sites when wet season vehicle access is limited.

Amber cows and calves consuming dry season supplement with P.

The Amber wet season P supplement recipe includes a mix of Kynofos 21™ (21% P), GranAm®, lime, Rumigro™ and salt. The aim is for breeders to consume around 100g/head/day of lick which, at 10% P (as fed), delivers the required 10g P/breeder/day. However, daily lick intakes can fluctuate during the wet season. GranAm®, a source of non-protein nitrogen, is used to help fill the protein gap as pasture quality declines later in the wet season. While used successfully in wet season P supplements on Werrington and Amber, GranAm® is sour and can reduce supplement intake in some situations. Many northern producers are reluctant to use GranAm® in their wet season supplements as target wet season P intakes are often difficult to achieve. In wet weather, inclusion of 5% lime helps form a surface crust and weatherproof the recipe.

The aim is for the Amber dry season urea-based supplements to include approximately 10–15% Kynofos 21™ which will supply around 3g and 5g P/head/day to heifers and breeders respectively during the dry season. Georgia and Dan observe cattle are less likely to gorge wet season P supplements when fed dry season licks with P in the months before the wet season, and that this results in steadier, but adequate, supplement intake over the growing season.

Georgia and Dan also believe the nitrogen component (urea equivalent) of GranAm® may be exacerbating the hard crusting of their wet season bulka bag licks and will trial a new recipe by removing GranAm® and adjusting the Kynofos 21™ and lime components. The Werrington Cattle Co team are very proactive in trialling new ideas to work out what best suits each enterprise and paddock situation.

Amber lick truck replenishing supplement supplies at lick sites.

Table CS5.1: The Amber wet season lick recipe is 10% P as fed and includes lime to waterproof the exposed bulka bags

Ingredient	Inclusion rate
GranAm®	12%
Kynofos 21	48%
Lime	5%
Rumigro	0.5%
Salt	34.5%

The Amber breeder management strategy requires regular pregnancy testing of all breeders. This, combined with a successful P supplementation program, better cattle control, and selection for fertility will allow the mating period to be progressively shortened. These strategies aim to achieve a female mortality rate of 2% in the long term, as well as produce a more consistent line of heavier weaner steers available for transfer to other properties within the family business.

The plan includes investments in additional fencing and property infrastructure to allow pasture spelling, less grazing pressure on parts of the property and an expansion of the herd over the next decade. Rebuilding the existing yards and cattle handling infrastructure will improve the safety of staff and ease of livestock handling. Upgrading and adding to existing station roads will improve access throughout the property for more of the year.

An economic analysis completed in 2020 as part of this case study indicates the expected return to the total funds invested in the property purchase, livestock, plant and equipment and property development, over the first decade could average 4–5%/year using long-term cattle prices and costs. This estimate did not include any allowance for a potential change in the value of the land component of the investment.

An estimated comparison between Amber with little to no P feeding and Amber at the end of the five-year development plan with full P supplementation of the Amber herd was undertaken.

The benefits of feeding P include:

- an increase in weaning rates from 47% to 66% – in 2022, rates rose to 83%
- a reduction in breeder deaths from 8% to 2%
- improved female and steer cattle weights and a subsequent increase in the value of these cattle
- higher weaner rates.

The overall contribution of P supplementation to the predicted increase in gross margin/adult equivalent on Amber is significant. Since this analysis was done in 2020, Dan is pleased to report that he has seen ongoing improvements.

Table CS5.2: A modelled comparison of the herd performance, turn-off age, turn-off value and gross margins with, and without, wet season P supplementation between a typical northern Gulf property and after the implementation of the Amber five-year property development plan

	Amber without P	Amber with P and development (2020)
Total adult equivalents	5,200	8,742
Total cattle carried	6,196	8,259
Total breeders mated and kept	4,158	4,860
Total calves weaned	2,012	3,945
Weaners/total cows mated	47%	66%
Overall breeders deaths	8%	2%
Female sales/total sales	34%	48%
Total cows and heifers sold	519	1,810
Total steers sold	1,006	1,972
Average female price	$696	$774
Average steer price	$366	$428
Direct costs excluding bulls	$104,307	$475,747
Bull replacement	$78,359	$96,842
GM per adult equivalent	$105	$191

Appendix 1 – Regional vegetation types

Table A.1: The phosphorus (P) status of soils based on vegetation types

Soil–vegetation	Distinguishing features	P status
Southern Queensland		
Wallum	Coastal lowlands; sandy loams with clay subsoil; open forest of bloodwood to tea-tree and Banksia; also deficient in other essential minerals	Deficient
Darling Downs	Highly fertile brown, red and black cracking clays	Adequate
Traprock	Uplands around Stanthorpe, eucalypt woodland on shallow dense loams	Marginal to deficient
Aristida–Bothriochloa	Sandy surfaced duplex soils supporting eucalypt–acacia woodland	Marginal to deficient
Brigalow Belt	Deep grey, brown and red cracking and non-cracking clays	Adequate
Mitchell grass	Rolling downs, floodplains and channels	Variable
Poplar box woodlands	Red and brown soils with distinct B horizons; poplar box, silverleaf ironbark	Marginal to adequate
Poplar box–mulga	Sandy to loamy red earths supporting mulga with some poplar box	Deficient
Cypress pine–bull oak, ironbark	Sandy loams, deep sands and shallow hard-setting clay loams	Deficient
Black speargrass		
(a) Spotted gum ridges	Spotted gum, wattle, narrowleaf ironbark	Deficient
(b) Steep ironbark slopes	Narrowleaf ironbark on podzolic soils derived from granite	Marginal to adequate
(c) Lower ironbark slopes	Silverleaf ironbark	Adequate
(d) Blue gum flats	Alluvial and basaltic flats	Adequate
(e) Basaltic soils	Grey, brown and black cracking clays	Adequate
Western Queensland		
Mitchell grass downs and flooded alluvials	Open grasslands; grey and brown cracking clays	Variable
Mulga	Mulga with poplar box, gidyea, sandalwood	Deficient
Gidyea	Scrub often sown to buffel grass	Adequate
Spinifex	Spinifex and wire grass; shallow, gravelly sands to loams and earths	Deficient
Channel country	Intermittently flooded channels and floodplains	Adequate
Central Queensland		
Flood plains	Coolibah, poplar box and bluegum over speargrass	Adequate
Queensland bluegrass	Open grasslands on cracking and non-cracking clays	Adequate
Brigalow–softwood scrub	Duplex to cracking clays	Adequate
Black speargrass; *Aristida-Bothriochloa*		
(a) On red-brown soils developed on granite	Silver and narrowleaf ironbark on duplex soils and structured earths with red-brown clay subsoils; rolling country	Adequate
(b) Shallow soils on volcanic rocks and granites	Rolling to steep mountains carrying narrowleaf ironbark, lemon- scented gum and brush box on shallow skeletal soils and shallow duplexes	Adequate
(c) Duplex soils on sedimentary and metamorphic rock	Undulating eucalypt woodlands with narrow and silverleaf ironbark, poplar box and gum-topped box; duplex soils with heavy clay subsoils	Marginal to deficient
(d) Yellow duplexes on granite	Sandy-surfaced soils with yellow clay subsoil; silverleaf ironbark, gum-topped box, poplar box, sandalwood	Deficient
(e) Red and yellow massive earths	Level to undulating plateaus and plains; narrow and silverleaf ironbark woodlands with wattles, quinine and ash; desert and pitted bluegrass, wiregrass with spinifex in the north-west	Deficient
(f) Shallow soils on hills and mountains	Rolling to steep mountains; ironbark, lancewood, bendee, rosewood and wattles	Deficient

Soil–vegetation	Distinguishing features	P status
Saltwater couch pastures	Along coastline; saline non-cracking soils	Adequate
Blady grass pastures	Bloodwood, stringy bark, poplar gum and teatree; variable soils	Variable, marginal to deficient
Northern Queensland		
Red, grey and yellow earths	Sandy to hard-setting; termite mounds common; eucalypts, teatree, wattles; much of Peninsula, west and south of Charters Towers	Deficient
Sandy soils	On coast; teatree, stunted eucalypts; Croydon sandy forest, cypress pine	Deficient
Bluegrass–browntop plains	South of Gulf of Carpentaria, open grasslands with eucalypts in water courses; grey to brown self-mulching soils	Marginal
Red and yellow duplexes	West and south of Charters Towers, coastal strip south of Townsville; ironbark, poplar gum, bloodwood	Marginal
Georgetown granites	Around Georgetown; grey box, lancewood, bloodwood, ironbark	Marginal to adequate
Frontage country	Alluvial soils along main streams	Adequate
Basalt country	North-west of Charters Towers; ironbark; deficient in salt and sulphur	Adequate
Northern Territory (south)		
Spinifex	Sand plains and sandy rises; sparse shrubs of blue mallee	Deficient
Mulga	Dense forests to open woodland on red earth plains and alluvial plains	Deficient
Bluebush/saltbush	Southern bluebush and bladder saltbush with mulga, Georgina gidyea and myall	Adequate
Gidyea	Georgina gidyea on sandy plains and shallow gravelly loams	Adequate
Mitchell grass	Cracking clay soils with Mitchell grass along the bases of the ranges and with open woodland of Georgina gidyea	Variable
Flooded country	Channels and floodplains; coolibah, river red gum	Adequate
Northern Territory (north)		
Tallgrass pastures	Eucalypt woodland, sorghums, giant speargrass, ribbon grass; sandy to stony skeletal soils and red and yellow earths	Deficient
Midgrass pastures	Low eucalypt woodland, *Aristida* and ribbon grass on yellow earths; north of Mitchell grass plains	Deficient
Shortgrass pastures	In Victoria River basin, calcareous loams; bloodwood, southern box woodland with *Enneapogon, Aristida*	Marginal
Spinifex	Curly spinifex in Arnhem Land, Gulf, VRD and Barkly Tableland	Deficient
Mitchell grass	Barkly Tableland and VRD; black soil plains grading into coolibah woodlands; deficient in sodium and sulphur	Deficient; variable towards Qld border
Saltwater couch pastures	Coastal saline flats of loams or grey clays merging into fringing saltpans	Adequate; adjacent country deficient
Western Australia (Kimberley)		
Pindan	Curly spinifex and ribbon grass; red and yellow sands with low scrubby woodland	Deficient
Spinifex	Curly and soft spinifex with eucalypt open forest	Deficient
Tallgrass pastures	Ribbon grass, kangaroo grass, cane grass and black speargrass under eucalypt woodland	Deficient
Midgrass pastures	Ribbon grass, bluegrass, brown top, kerosene grass, wire grass under low eucalypt woodland	Deficient
Shortgrass pastures	Ribbon grass, *Enneapogon*, curly spinifex under open eucalypt woodland of bloodwood and southern box	Marginal
Mitchell grass	Black soil plains in eastern Fitzroy basin, extending north-west into the Meda and May River basins; deficient in sodium	Marginal
Frontage	On levees of major rivers – Fitzroy and Ord and tributaries; ribbon grass, bluegrass, sorghum under open eucalypt woodland	Adequate

Soil–vegetation	Distinguishing features	P status
Western Australia (Pilbara)		
Spinifex	Hard and soft spinifex on rocky outcrops and sand plains with scattered *Acacia* shrubs	Deficient
Mulga	Shrubland of mulga, sandalwood and cassia with *Aristida* and sparse annual grasses	Deficient
Bluebush/saltbush	On hard-setting loams over red clays in low shrubland; sparse seasonal grasses	Marginal
Coastal plains	Tussock grasslands; Roebourne plains and buffel grasses	Marginal
Mitchell grass	Fortesque flood-out country and on basaltic soils in Chichester and Hammersley Ranges	Adequate
Frontage	On levees of rivers and streams	Adequate

Appendix 2 – Supplementary phosphorus (P) requirements for various classes of stock

These tables have been reviewed and updated by Rob Dixon (QAAFI) to estimate supplementary P requirement of various classes of cattle (e.g. growing cattle, breeding cows etc.).

Supplementary P requirements depend on the base soil P status and pasture content. The following tables use the soil categories of Adequate, Marginal, Deficient and Acutely deficient. Colwell P mg/kg equates to 8+ (Adequate), 6 to 7 (Marginal), 4 to 5 (Deficient), and less than 4 (Acutely deficient). Estimated pasture P content in the notes for each table.

The category 'Adequate' is for rangeland pastures. Pastures growing on high P soils (e.g. good Brigalow scrub soils) should not require any P supplements. However, if high growth rates are desired, cattle grazing good quality improved pastures may require some additional P supplement. This should be calculated from the 'Total P required per kg DM' column and estimates of the P concentration of the pasture.

These are estimated requirements based on available data and should be used as a guide. Adjust your program based on individual property observations and record keeping. Achieving good target intakes and ensuring supplement is available during times of high requirements is a priority.

Table A2.1: Estimated supplementary P required by mature breeder cows[A] during the wet season

Liveweight (kg)	Live weight change (kg/day)	Total P required (g P/day)	Total P required (g P/kg DM)	Amounts of P supplement required Category of rangeland pasture[B]			
				Adequate	Marginal	Deficient	Acutely deficient
400	-0.50	14.5	1.1	0	0	0	5
	-0.25	16.6	1.3	0	0	3	6
	0.00	18.6	1.5	0	2	5	8
	+0.25	21.4	1.6	0	3	6	10
	+0.50	23.7	1.7	1	5	8	12
	+0.75	25.7	1.8	3	8	10	N/A[C]
500	-0.50	16.0	1.1	0	0	1	5
	-0.25	18.1	1.3	0	0	3	7
	0.00	20.2	1.4	0	2	5	9
	+0.25	23.0	1.5	0	3	6	11
	+0.50	25.1	1.6	0	5	8	13
	+0.75	27.1	1.7	2	7	10	N/A

[A] Assumptions; cows are producing 6kg milk/day, 4 weeks pregnant, and are not using bone P reserves.

[B] Pasture is expected to contain 1.6, 1.3, 1.1 and 0.8g P/kg DM, in Adequate, Marginal, Deficient and Acutely Deficient categories respectively.

[C] If cows are severely P-deficient at calving the amount of P supplement should be increased. It is seldom possible to obtain very high growth rates of cattle grazing 'acutely deficient' rangeland pastures even with high levels of P supplementation.

Table A2.2: Estimated supplementary P requirements of mature breeder cows[A] during the transition (wet to dry) season, weaned and 5 months pregnant.

Liveweight (kg)	Live weight change (kg/day)	Total P required (g P/day)	Total P required (g P/kg DM)	Amounts of P supplement required Category of rangeland pasture[B]			
				Adequate	Marginal	Deficient	Acutely deficient
400	-0.50	7	1.0	0	0	0	2
	-0.25	10	1.3	0	0	2	4
	0.00	12	1.5	0	2	3	6
	+0.25	15	1.6	0	3	5	8
	+0.50	18	1.7	2	5	7	10
	+0.75	20	1.9	4	7	9	N/A[C]
500	-0.50	8	1.1	0	0	0	2
	-0.25	11	1.2	0	0	2	4
	0.00	14	1.4	0	2	3	6
	+0.25	17	1.5	0	3	5	8
	+0.50	19	1.6	1	4	6	10
	+0.75	21	1.7	3	6	8	N/A

[A] Cows are 20 weeks pregnant, not producing milk, and replenishing 3g P/day into body reserves.

[B] Pasture is expected to contain 1.6, 1.3, 1.1 and 0.8g P/kg DM, in Adequate, Marginal, Deficient and Acutely Deficient categories respectively.

[C] It is seldom possible to obtain very high growth rates of cattle grazing 'acutely deficient' rangeland pastures even with high levels of P supplementation.

Table A2.3: The amounts of P supplement required by mature breeder dry cows[A] in the late dry season

Cow liveweight (kg)	Cow total liveweight change (kg/day)	Cow liveweight change (kg/day)[B]	Total P require (g P/day)	Total P required (g P/kg diet DM)	Amounts of P supplement required Category of rangeland pasture[C]			
					Adequate	Marginal	Deficient	Acutely deficient
400	-0.50	-1.00	11	1.0	0	0	2	4
	-0.25	-0.75	13	1.3	0	2	4	6
	0.00	-0.50	16	1.6	2	4	6	8
	+0.25	-0.25	19	1.7	3	6	8	11
	+0.50	0.00	21	1.9	5	8	10	13
	+0.75	+0.25	23	2.1	7	10	12	N/A[D]
500	-0.50	-1.00	12	1.1	0	1	3	5
	-0.25	-0.75	15	1.3	0	2	5	7
	0.00	-0.50	17	1.5	2	4	7	9
	+0.25	-0.25	20	1.6	3	6	8	11
	+0.50	0.00	22	1.8	4	7	10	13
	+0.75	+0.25	25	1.9	6	9	12	N/A

[A] Cows are not producing milk, are in late pregnancy.

[B] Liveweight of the cow minus the estimated weight of the foetus, placenta and surrounding fluids (55–60kg at birth).

[C] Pasture contained 1.3, 1.0, 0.7 and 0.4g P/kg DM in the Adequate, Marginal, Deficient and Acutely-deficient categories, respectively (tropical grasses decrease in P concentration with senescence (haying off). The estimates of diet P from the pasture are lower than during the growing season).

[D] Not Applicable. If cattle are losing liveweight during the dry season they will not respond with increased growth to supplementary P. However cattle may benefit by replenishing bone P reserves. It is seldom possible to obtain very high growth rates of cattle grazing 'acutely deficient' rangeland pastures even with high levels of P supplementation.

Note: These amounts of P do not include any mobilisation or replenishment of bone P. Without P supplements cows in these circumstances are usually mobilising body P reserves. Cows that have been P-deficient should be replenishing body P reserves to prepare for the high demands of P during lactation. P replenishment of 5g P/day will require an extra 7g P/day of P supplement in addition to the recommendations below.

Table A2.4: Estimated supplementary P requirement for growing[A] steers and heifers during the wet season on pastures ranging from adequate to acutely deficient in P

Liveweight (kg)	Live weight change (kg/day)	Total P required (g P/day)	Total P required (g P/kg DM)	Amounts of P supplement required Category of rangeland pasture[C]			
				Adequate[A]	Marginal	Deficient	Acutely deficient
150[B]	0	3	0.9	0	0	0	1
	0.25	7	1.4	0	0	1	3
	0.50	9	1.8	0	3	4	5
	0.75	12	2.2	1	5	6	8
	1.00	15	2.7	3	8	9	N/A[D]
200	0	4	0.9	0	0	0	0
	0.25	7	1.3	0	0	1	3
	0.50	10	1.6	0	2	3	5
	0.75	13	1.9	2	4	6	7
	1.00	15	2.3	5	7	8	N/A
300	0	6	0.9	0	0	0	0
	0.25	9	1.1	0	0	0	3
	0.50	12	1.4	0	1	2	5
	0.75	14	1.6	0	3	5	7
	1.00	16	1.9	3	5	7	N/A
	1.25	18	2.2	5	8	9	N/A
400	0	8	0.9	0	0	0	1
	0.25	11	1.1	0	0	0	3
	0.50	13	1.3	0	0	2	5
	0.75	16	1.5	0	2	4	7
	1.00	18	1.7	1	4	6	N/A
	1.25	20	1.9	3	6	8	N/A
500	0	10	0.9	0	0	0	1
	0.25	13	1.1	0	0	0	3
	0.50	15	1.2	0	0	2	5
	0.75	17	1.4	0	1	4	7
	1.00	19	1.6	0	3	6	N/A
	1.25	21	1.8	2	6	8	N/A

[A] Sufficient energy and protein are required to achieve target growth rates.

[B] Calves less than 130kg liveweight need to be fed concentrates designed for this purpose.

[C] Pasture is expected to contain 1.6, 1.3, 1.1 and 0.8g P/kg DM, in Adequate, Marginal, Deficient and Acutely Deficient categories respectively.

[D] It is seldom possible to obtain very high growth rates of cattle grazing 'acutely deficient' rangeland pastures even with high levels of P supplementation.

Appendix 3 – Calculating supplement intakes and costs

Use the tables below to calculate costs and intakes. Work through the following steps:

1. Work out the target intakes for what your class of stock require (Table A3.1).
2. Calculate the P% in the mix using Table A3.2 (this example is MDCP 50%/salt 50% – the P content of MDCP is ~21% and therefore in the total mix is ~10%).
3. Calculate intakes of target group using Table A3.3.

Note: This is a wet season example and protein columns in the tables should be included for dry season supplementation programs and are available at the link on this page.

You can photocopy the table on the next page or access the excel version here: *Lick-intake-calculator_ME-CP-P_with-calculations.xlsx (live.com)*

Table A3.1: Target P intakes

Paddock: ____________________

Class of cattle: ____________________

Target intakes

Class	P (g/hd/day) Wet season	P (g/hd/day) Dry season
Breeders	*10*	*5*
Yearlings	*6*	*3*
Weaners	*6*	*3*

Table A3.2: Supplement details

Supplement	$/t	Crude protein (%)	Urea (%)	Protein meal (%)	P (%)	Salt (%)
50% MDCP & 50% salt	*1,391*	*0*	*0*	*0*	*10%*	*50%*

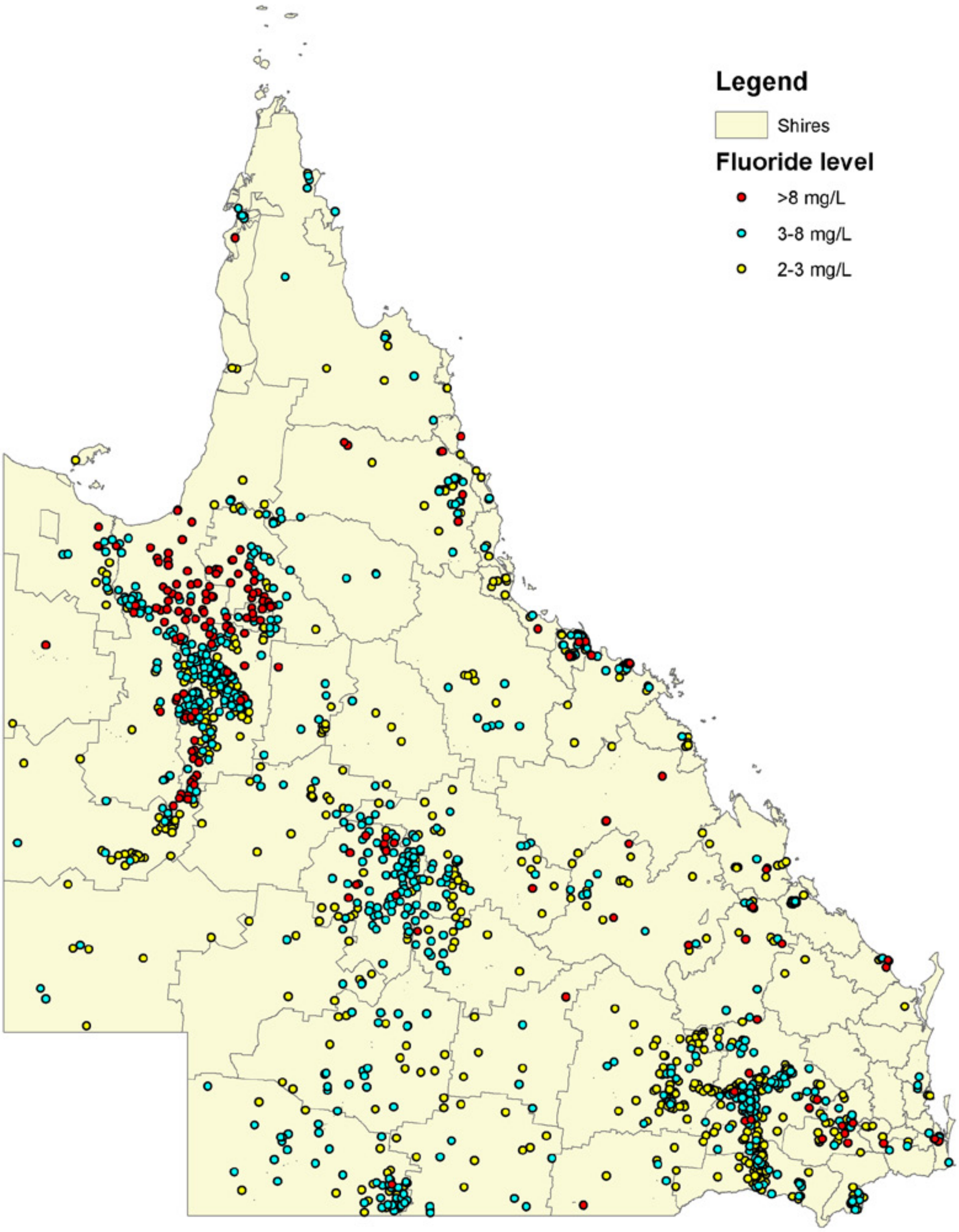
Table A3.3: What the herd intake is in the paddock over the course of the wet season

Intakes and costs

A	B	C	D	E	F	G	H	I	J	K	L
Date	Days	No. head	Residue left (kg)	Lick put out (kg)	Total on offer (kg)	Herd lick intake (kg)	Per head lick intake (g/hd/day)	CP intake (g/hd/day)	P intake (g/hd/day)	Salt intake (g/hd/day)	Cost ($/hd/ period)
	= A - A from previous line				= D + E	= F from previous line - D	= G ÷ C ÷ B x 1000	= H x CP% of lick ÷ 100	= H x P% of lick ÷ 100	= H x Salt% of lick ÷ 100	= H x B ÷ 1,000 x price $ per tonne ÷ 1,000
11/2/22				*150*	*150*						
21/2/22	*10*	*100*	*50*	*75*	*125*	*100*	*100*	*0*	*10*	*50*	*1.39*

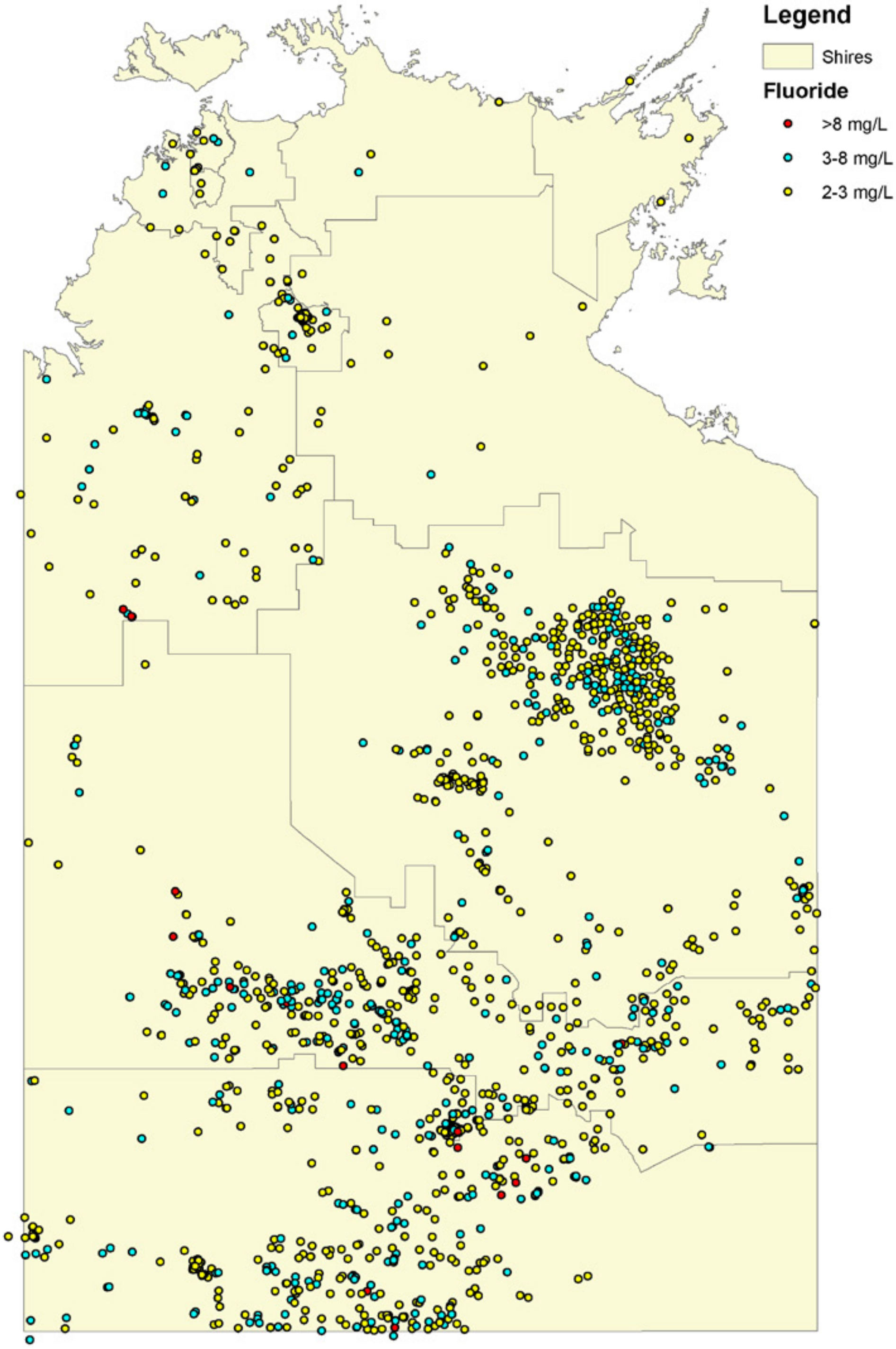
Appendix 4 – Fluoride levels

Figure A.4.1: Fluoride concentration of registered bores in Queensland. The bore water fluoride database points were provided by the Queensland Department of Natural Resources and Mines (2012).



Note: Bore with less than 2mg/L not included.

Figure A.4.2: Fluoride concentration of registered bores in the Northern Territory



Note: The mapping is for point source data only and it should not be used to extrapolate potential fluoride readings over a wider area. Data supplied by Department of Natural Resources, Environment, The Arts and Sport (2012). © Northern Territory of Australia.

Appendix 5 – Analysis laboratories

Analysis for blood phosphorus levels

Queensland

School of Veterinary Science
Building 8114, Level
The University of Queensland
Gatton QLD 4343

Phone: (07) 5460 1843
Fax: (07) 5460 1540
Email: vls@uq.edu.au

Northern Territory

Berrimah Veterinary Laboratories
Berrimah Farm, Department of Resources Makagon Road
Berrimah NT 0828

GPO Box 3000
Darwin NT 0801

Phone: (08) 8999 2249
Fax: (08) 8999 202
Email: bvl@nt.gov.au

Western Australia

DDLS Animal Pathology
Duty Pathologist Specimen Reception C Block
Department of Primary Industries and Regional Development
3 Baron-hay Court
South Perth WA 6151

Phone: (08) 9368 3351
Fax: (08) 9474 1881
Email: DDLS@agric.wa.gov.au

Victoria

Regional Laboratory Services
PO Box 805
Benalla VIC 3672

Phone: (03) 5762 7502
Fax: (03) 5762 728
Email: info@regionallabservices.com.au

Analysis for fluoride levels in water

GOVERNMENT LABORATORIES

Northern Territory

Department of Resources – Primary Industry, BAL Building
Berrimah Farm, Makagon Road
Berrimah NT 0828

Phone: (08) 8999 2196
Fax: (08) 8999 2191
Email: waterlabsdarwin.dpir@nt.gov.au

Western Australia

Chemcentre Laboratory
Cnr Townsing Drive and Manning Road
Bentley WA 6102

PO Box 1250
Bentley Delivery Centre WA 6983

Phone: (08) 9422 9800
Fax: (08) 9422 9801
Email: enquiriesr@chemcentre.wa.gov.au

Analysis for Faecal NIRS

Queensland, NT and Western Australia

Symbio Alliance
52 Brandl Street
Eight Mile Plains QLD 4113

PO Box 4312
Eight Mile Plains QLD 4113

Phone: (07) 3340 5700
Fax: (07) 3219 033
Email: admin@symbioalliance.com.au

Western Australia

Gcology
PO Box 1187
Osborne Park DC
WA 6916

Phone: (08) 9429 4912

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Glossary

AE	Adult equivalents (AE) is a standardised animal unit. An AE is a non-pregnant, non-lactating animal weighing 450kg live weight that is maintaining condition.
Breeder	Industry term for a mature cow producing calves.
Bulka bag	A bag used to feed supplement.
DM	Dry matter (DM) is moisture free feed.
DMI	Dry matter intake (DMI) is the amount of moisture free feed an animal consumes.
Dry cow	A non-lactating cow.
Dry season	In northern Australia the 'dry' season is generally the winter period between May and November, exact timing is dependent on regional location and inter-seasonal variability.
First-calf cow	A cow on her first lactation, sometimes colloquially referred to in industry as first calf heifers.
LW	Liveweight.
LWG	Liveweight gain. In this manual it is reported as kg/head/day.
PIP	Plasma inorganic phosphorus.
F.NIRS	Faecal near infra-red spectroscopy.
Wet cow	A lactating cow.
Wet season	The wet season in northern Australia refers to the monsoonal summer season where higher rainfall is expected and is generally between November and April, the timing of the seasonal break depends on regional location and inter-seasonal variability.

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