Better management of phosphorus nutrition of grazing cattle – an update & recent developments

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(On behalf of a large team from UQ and QDAF)

Why Phosphorous?

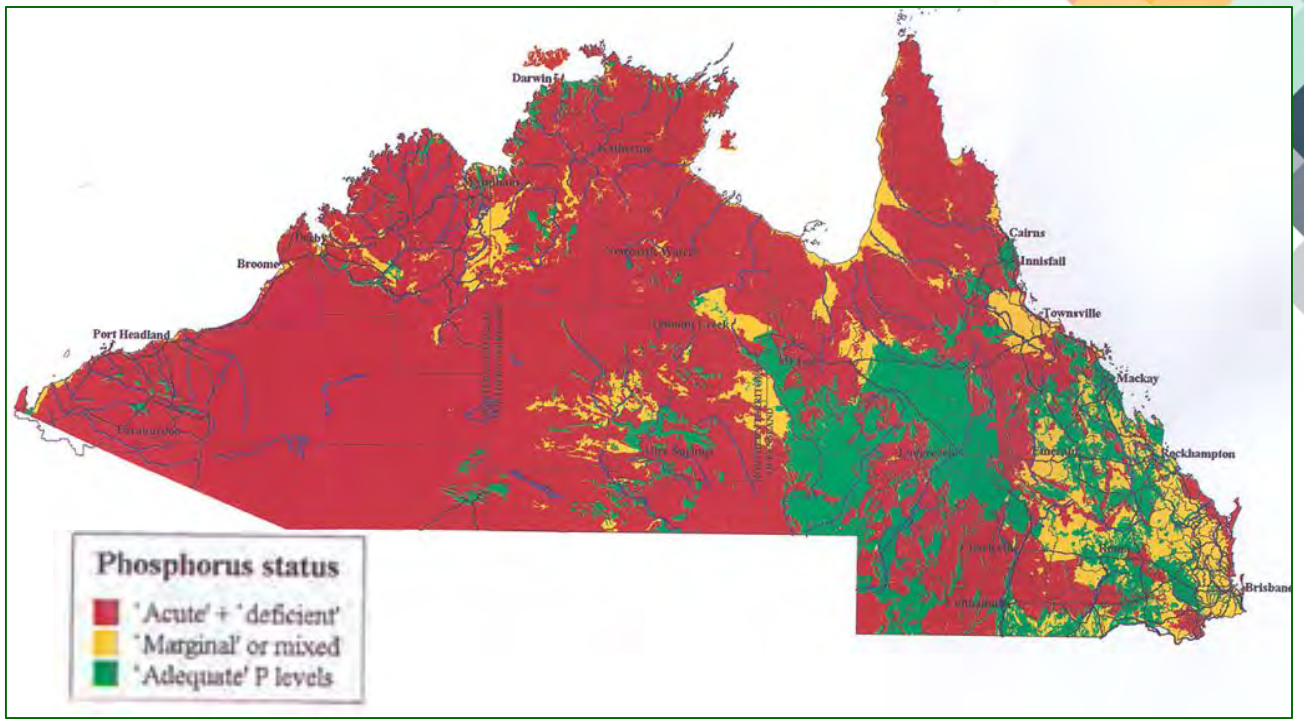
Cattle need phosphorus (P) for vital body functions:

- The essential chemistry of cell metabolism in all animals
- Using the energy and protein in the diet
- Building bones and producing milk
- Achieving high feed intake and efficient feed utilisation

Severe and prolonged diet P deficiency causes:

- Reduced feed intake
- Poor growth
- Reduced breeder herd productivity

P deficiency is often the most important nutritional constraint which cattle managers can address – for pastures based on tropical C_4 native grasses with low digestibility and deficient in protein during the dry season.



Classes of P deficiency - and consequences on growing cattle generally expected in the northern Australian rangelands

Soil P, indicator values and expected decreases in liveweight gain of young cattle

Variable	Category of P status for grazing cattle			
	Acutely deficient	Deficient	Marginal	Adequate
Soil P ($P_{B\ ppm}$)	< 4	4 - 6	7 - 8	> 8
Diet P (g P/kg DM)	< 0.5	0.5 – 1.0	1.0 – 1.5	> 1.5
Blood P (mmol/L)	< 0.8	0.8 – 1.1	1.1 – 1.6	> 1.6
Likely liveweight gain response of growing cattle to P supplements (kg/year)				
Native pasture	40 - 60	20 - 40	0 - 20	Nil
Stylo-grass pasture	70 - 100	40 - 70	0 - 40	Nil

Soil P ($P_{B\ ppm}$) = Colwell (1963) bicarbonate –soluble P in the top 100 mm soil.
Stylosanthes spp may be an exception compared with other tropical grass-legume pastures.

How much diet P is required by grazing cattle ?

Growing steer (400 kg)

LW gain (kg/day)	Diet P (g/day)	Diet P g/kg diet)
-0.3	4	0.6
0.0	7	1.0
0.6	14	1.4
1.2	21	1.6

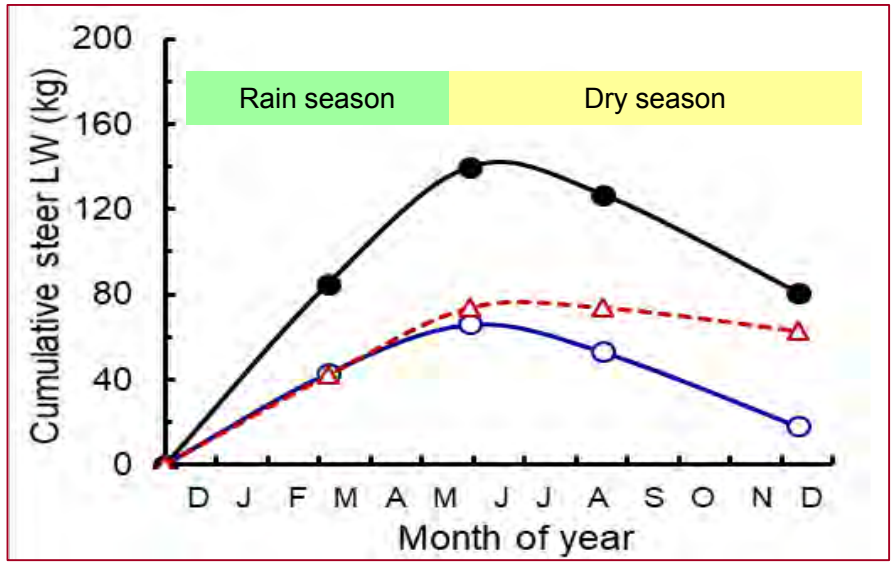
Breeder In early-mid lactation
(producing 5 kg milk/day)

LW gain (kg/day)	Diet P (g/day)	Diet P (g/kg diet)
-0.3	13	1.6
0.0	17	1.7
0.6	23	1.9

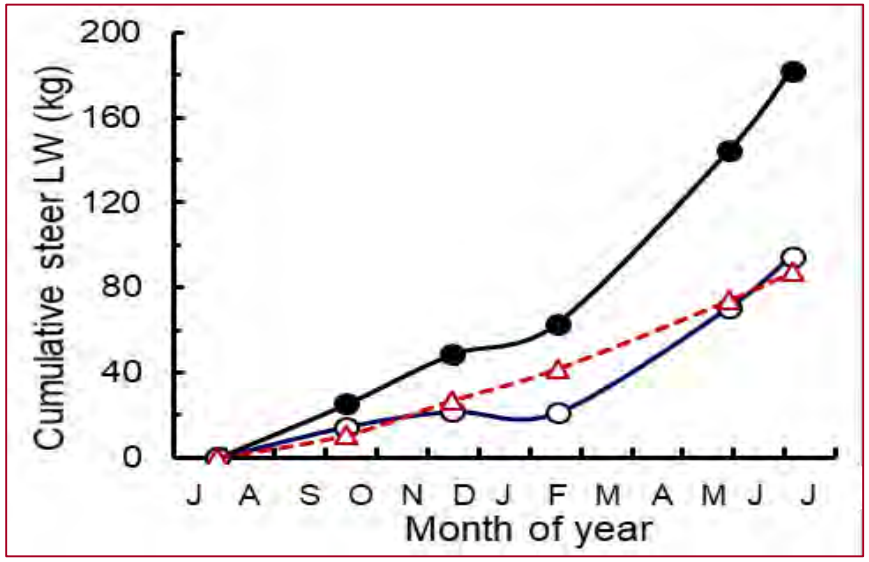
The amount of P required is very dependent on the level of production as growth rate or milk production

Liveweight gain responses of young cattle to P supplements through seasonal cycles

Steers at Katherine, Northern Territory, grazing native pasture + stylo. The wet season ended in March and cattle growth ended in June (Winter et al. 1990).



Steers at Lansdown, N Qld, grazing Urochloa-stylo pastures. Unusual seasonal seasons. Cattle growth continued from July through the following 12 months (Coates et al. 2018)



Grazing steers either not supplemented (○) or fed P supplements (●).

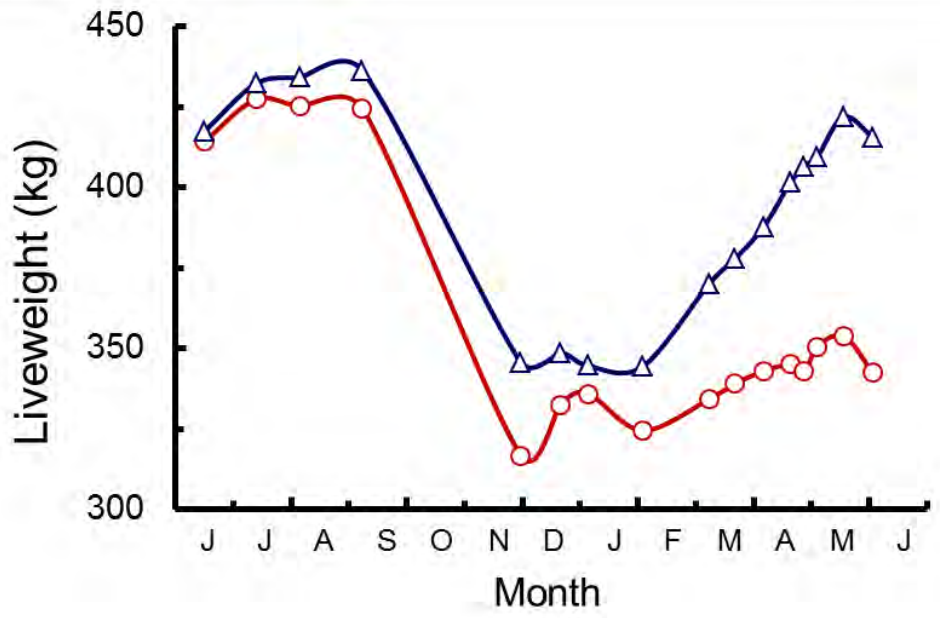
Cumulative increase in LW due to P supplement (Δ, - - -).

Liveweight (LW) gain responses by cattle to P supplement only occur when the pasture digestibility (energy) and protein are sufficient for growth.
Usually, but not always, this is during the wet season in the north.

The liveweight responses of breeder cows to P supplements

Breeder cows grazing P deficient pastures at Mareeba, N Qld.
Cow liveweight through the annual cycle

P-adequate (——), P-deficient (——).



Effects of P supplement on the breeder:

- Cows lost extensive liveweight during the dry season (July) through to the seasonal break (January). Partly due calving.
- Dry season: P supplement had only a small effect on liveweight loss.
- Lactation and the wet season:
  P supplement had a large effect on cow liveweight gain.

Dixon et al. 2016.

Expected responses to P deficiency of breeder cattle grazing in the northern Australian rangelands

Estimates of the production of commercial breeder herds and their responses to P supplements for various classes of P deficiency under commercial conditions

Variable	Effect of P supplement	Acutely deficient	Deficient	Marginal	Adequate
Soil P ($P_{B\ ppm}$)	--	< 4	4 - 6	7-8	> 8
Weaning rate (%)	No P supp	57	67	72	77
	Change	+15	+6	+5	nil
Weaner LW (kg)	No P supp	180	190	200	200
	Change	+15	+15	+10	Nil
Mortality (%)	No P supp	12	8	4	2
	Change	-5	-3	-2	nil

But the most serious effects of the P deficiency are likely to be after the first year of deficiency. Breeders can use body reserves to maintain milk output in Year 1.

But breeder herd responses may be much larger in very P-deficient pastures

Results at the end of the rainy season for first-calf cows at weaning

Known very P-deficient region, Northern Territory (Schatz and McCosker, 2018 PASAP).

These are abnormally large responses compared to most of northern Australia

Measurement at weaning of the first-calf cows	With P supp	No P supp	Difference
Cow liveweight at end of rainy season (kg)	382	262	120
P8 fat depth (mm)	3.9	0.1	3.8
Re-conception rate (%)	30	5	25
Weaner liveweight (kg)	173	139	34
Mortality to 3.5 y.o. (including cows removed for welfare reasons) (%)	1	28	27

P nutrition in northern breeder herds

- Expected responses to P supplementation where very deficient pastures:
  - increase weaning rates by 10-30%
  - reduce mortality by 5-15%
  - increase sale liveweight of culls by 100-150 kg.
- The improved breeder production seems to be mostly due to better liveweight & body condition
- Reduced fertility seems to happen most often with:
  - very P deficient situations
  - younger cows
  - cows lactating in the dry season
- BUT - The responses to P supplements may vary substantially between years and with seasonal conditions

Recommendations on P nutrition in grazing cattle

The long-standing ‘simple’ management advice on P deficiency:

- “Feed P supplements in the wet season and N supplements in the dry season”

  Also that lactating cows need some extra P in the dry season on senesced pasture.

- Why feed P supplements in the wet season?
  - Energy and protein in pasture is much higher
  - Breeder need more P (e.g. 4 *versus* 24 g P/day) -- the P supplement response is greater.

- This advice was based on the research before 1990 and mostly with growing cattle.

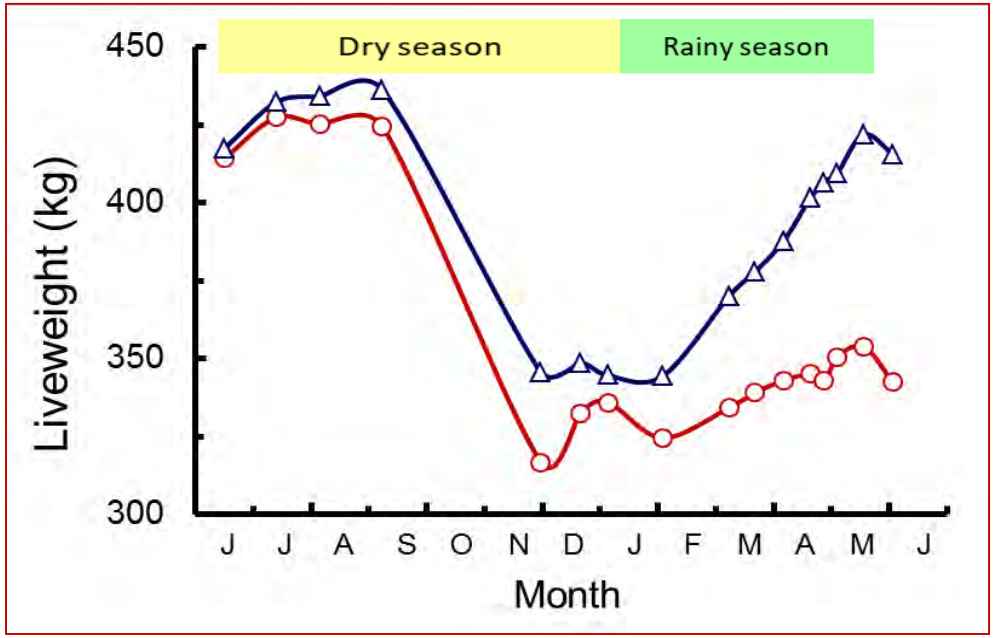
  It was assumed that P nutrition in the breeder cow was essentially the same as the steer.

- BUT – research since 1990 has shown that during lactation cows can use (mobilise) body P reserves (bone) when diet P is deficient + producer experience of benefits to dry season P supplementation

Field evidence that P-deficient breeder cows mobilize bone P

Breeder cows grazing P deficient pastures at Mareeba, N Qld.
Cow liveweight through the annual cycle

P-adequate (——), P-deficient (——).



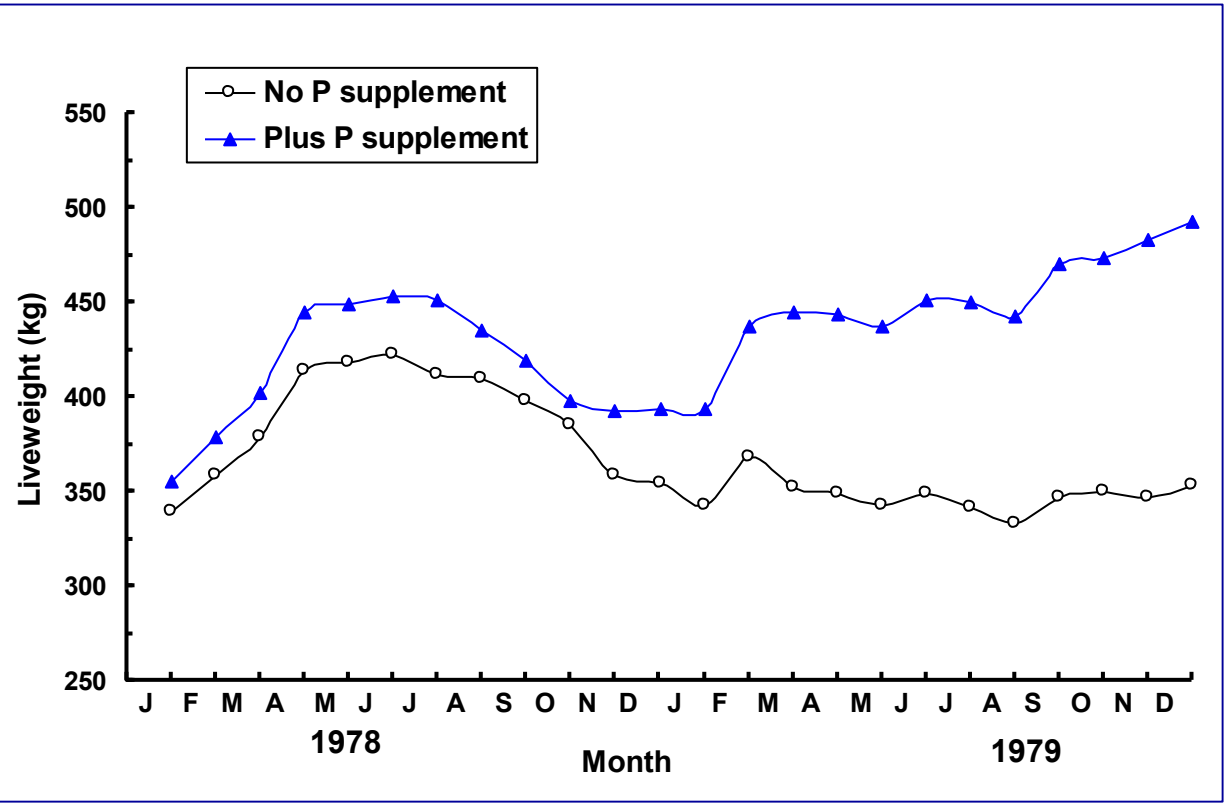
Effects of P supplement on the breeder:

In this (and other similar) experiments the cows not fed P supplements mobilized (lost) about 30% of their bone P during the 12-month cycle.

(We know this because the amount of P in bone was measured).

More field evidence that breeders can mobilize bone P

Breeders grazing very P-deficient native pasture with/without P supplements for 5 years.
At the beginning of Year 1 the breeders were pregnant heifers with 'full' body P reserves.
Research from South Africa.



The conclusion:

Breeders were able to mobilise body P in Year 1 to maintain LW – but could not continue to do so in subsequent years.

In Years 3, 4 and 5 there were large effects of P supplement on weaning weight, pregnancy rate, blood P and bone P.

More field evidence that breeders do mobilize bone P

Herds of breeders grazed severely P deficient pasture +/- P supplementation for 5 consecutive years. Commenced with P-replete pregnant heifers.

Year	Rainy season Average LW (kg)			Rainy season PIP (mmol/L)		Late dry season Rib-bone P (mg/cc)		
	-P	+P	Difference	-P	+P	-P	+P	Difference
1	359	415	+56	1.1	1.2	183	172	-9
2	367	502	+135	0.6	1.6	134	136	+2
3	369	482	+113	0.6	2.2	108	147	+39
4	366	485	+119	0.5	1.2	121	142	+21
5	362	526	+164	0.4	1.4	101	133	+32

Treatment differences increased from Year 2 for cow liveweight and blood P (PIP), and from Year 3 for rib-bone P concentration (Read *et al.* 1986 SAJAS 16, 7-17).

More field evidence that breeders do mobilize bone P

Herds of breeders grazing severely P deficient pasture ± P supplementation for 5 consecutive years. Commenced with P-replete pregnant heifers.

Year	Calving rate (%)			Weaning weight (kg)		
	-P	+P	Difference	-P	+P	Difference
1	83	83	0	168	192	+24
2	29	71	42	205	242	+37
3	55	91	36	186	245	+59
4	26	79	53	168	243	+75
5	63	72	9	182	237	+55

In Years 3, 4 and 5 there were large effects of P supplement on blood P, bone P, liveweight of calves at weaning and pregnancy rate (Read *et al.* 1986).

Is there mobilisation of body P in the northern breeder cow?

The evidence:

Sheep, goats, dairy cows and humans can mobilise bone P during pregnancy and lactation

Is P mobilization important?

- 450 kg breeder cow: about 2500 g P in the skeleton + 625 g P soft tissues
- Cattle can mobilise 30% of bone minerals during prolonged P deficiency
- Example: 25% loss of bone P + 30 kg LW loss = 665 g P mobilised over 4 months

  This is equivalent to about 7 g diet P per day

  A 450 kg breeder in early lactation requires about 24 g P/day

  So body P mobilization can provide up to about one-third of the P requirement

Recent project on P nutrition in breeders

A major project by UQ, QDAF and MLA has investigated in *Bos indicus* breeders the extent and importance of mobilisation of body P reserves when diets are P deficient

Question 1: How much can body P reserves be mobilised in the late dry / wet season to provide for pregnancy and lactation when the diet is P deficient ?

Question 2: If body P reserves are mobilised for lactation can these P reserves be replenished later in the annual cycle (dry season) ?

Question 3: What blood measurements (markers) can be used to estimate P mobilisation / replenishment ?

- The project has involved a series of major intensive experiments at the AgForce / QDAF Brian Pastures Research Facility, Gayndah.
- Measurement of the nutrition and physiology of mature breeders and first-calf cows during late pregnancy and early lactation.

Example: Effects of diet P during early lactation in mature breeders

Breeders calved in 'good' P status.
From calving the cows were fed diets adequate in P or severely deficient in P for 3 months (i.e. early lactation)

Measurement	**Experiment 1**			**Experiment 2**	
	P-deficient diet	P-adequate diet		P-deficient diet	P-adequate diet
P intake (% of P required)	28%	120%		17%	92%
DM intake (g/kg LW.day)	17	21		17	22
Calf LW at 100 days (kg)	112	129		96	96
Cow LW change (kg/100 days)					
P balance (g P/d)					
1-2 months lactation					

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Cow LW change (kg/100 days)	-33	+21		-19	+45
P balance (g P/d)					
1-2 months lactation	-6	+6		-6	+4

Outcomes for understanding P nutrition

Best estimates of the amount of body P reserves which can be mobilised:

- Mature breeders in early lactation:
  - Could mobilise about 6 g P/day ≡ ⅓ of their P requirements
  - Cows were largely able to maintain milk output and calf growth
  - BUT at the cost of severe liveweight loss
- First-calf cows in early lactation:
  - Less able to mobilise body P reserves
    (probably because they are still growing)
- Voluntary intake of feed is reduced by 20-40% when blood P is less than 1 mmol/L

The answer to Question 1: Substantial bone P can be mobilized by breeders compared to the amount of P needed per day.

Next question in understanding P nutrition

Question 2:

How much body P can be stored if extra P is fed in the dry season ? (replenishment)

Experiment A: Mature breeders post-weaning:

- When feeding a diet with sufficient energy and protein for about maintenance - bone P could be replenished slowly.
- When feeding a diet with sufficient energy and protein sufficient for rapid LW gain (1 kg/day) - bone P could be replenished rapidly.

Experiment: Pregnant first-calf heifers in the late dry season and losing liveweight rapidly:

- Heifers fed to lose nil, 25 or 50 kg maternal LW during the last 3 months pf pregnancy
- Extra diet P intake increased bone P reserves in these heifers regardless of LW (store 7 g P/day)

The answer: Substantial amounts of P can be stored even when breeders are losing liveweight (e.g. 7 g P/day)

Next question in understanding P nutrition

Question 3: What blood measurements (markers) can be used to estimate P mobilisation / replenishment ?

Developing better markers has been a major aspect of the major phosphorus project.

1) Blood phosphorus concentration (PIP) (well known and established measurement)
2) Blood calcium concentration -- and the ratio blood Ca:PIP
3) Measurements of bone mobilisation (CTX-1)
4) Measurements of the rate of bone growth.

The answer:

Markers in blood and urine – and also bone biopsies - are valuable as research tools.

There are challenges to develop, test and apply these to commercial herds for better diagnoses

Implications of the availability of P in body reserves of the animal (mobilization) for breeder herd management

- Managers can expect to be able to use cow body P reserves during late pregnancy / early lactation when it is not possible / inconvenient to provide P supplements,
- If P is mobilized during late pregnancy and lactation to meet high P demands – then this P must to be replaced (replenishment) later in lactation or post-lactation.
  (Using cow P reserves is like taking out an overdraft from the bank – it needs to be repaid)
- Mobilization of bone P – and later replenishment of bone P – is probably less efficient than feeding P supplement through the rainy season (because pasture intake is reduced)

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  (Using cow P reserves is like taking out an overdraft from the bank – it needs to be repaid)
- Mobilization of bone P – and later replenishment of bone P – is likely less efficient than feeding P supplement through the rainy season (because pasture intake is reduced)
- It should be possible to alleviate P deficiency of breeders by rotating them between high-soil-P and low-soil-P land systems (but there is no research information available).

And another idea - remember that earlier weaning is a simple and effective to alleviate P deficiency of breeders. It reduces the demand on the breeder for diet P.

For cattle management – what does it mean?

1) Where it is possible to feed P supplements through the entire wet season -- this is the preferred management.
   Also feed small amounts of (P+N) supplement during the dry season in very P-deficient regions.

2) Where it is not possible to feed P supplements for the entire wet season -- then P supplement for as long as possible (e.g. early in the wet season, starting as soon as possible from the mid-wet season)

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4) (P + N) supplement fed during the dry season and in late pregnancy increases bone P stores

5) Breeders can use body P reserves for pregnancy / lactation but at the cost of reducing liveweight and bone P reserves. First-calf cows have lesser capacity

6) If bone P is mobilised it must be replenished – if a cow is to calve annually

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BUT: these recommendations have not yet been field tested in grazing breeder herds in northern Australia

-- SO CAUTION IS NEEDED IN ADOPTION OF MANAGEMENT CHANGES

Thank you

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