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Soil test and phosphorus rate for high rainfall clover pastures

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Soil test and **phosphorus rate** for **high rainfall clover pastures**

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When new land was first developed, phosphatic fertilisers had to be applied at high rates to overcome Phosphorus (P) deficiency, and to increase P fertility. Once good P fertility has been established after a number of years of applying P, the requirement for applying high rates of P falls.

After that you only need to apply enough fertiliser P to replace that removed in products, fixed by the soil, eroded and leached, that is a maintenance rate of P.

In relation to P fertiliser decisions for pastures you need to ask:

- Do I need P?
- How do I find out?
- If I need P, how much should I apply to achieve my production target?
- Is aiming for my production target the best economic decision?
- How do I know if I applied the right amount?

This Bulletin aims to answer the first 3 of these questions. Agricultural consultants and decision support tools can help to answer the fourth.

It is important to apply only the required P, not only to achieve yield targets but also to reduce the impact on the environment and waterways. Fertiliser manufacture consumes resources and nutrient losses can harm the water quality downstream.

Soil testing

It is possible to predict relative pasture growth from a soil test before the pasture has germinated. It is also possible to use the soil P test to find how much P needs to be applied (if any) to reach a desired production target. The soil test will show how much P is already in the soil and can be used to estimate how much P, if any, needs to be added to achieve the production target. Soils should be tested at least once every three years to assess the changes in the P status either by sampling a third of the paddocks on your farm every year, or each paddock on the farm every three years. Farms with sandy soils or with high P removal in products (dairies) may need to sample more frequently to ensure soil P status can be maintained.

A soil test can also show the status of other major elements required for plant growth, such as potassium and sulphur, which are just as important because serious reductions in productivity and increases in cost can occur if any element besides P is lacking.

Soil sampling and analysis

Test each main soil type (land management unit) in each paddock at three yearly intervals, or more frequently if soils are sandy or there is high P removal in products.

Take a minimum of 30 core samples to 10 cm depth for each paddock / soil type (Figure 1). Correct soil sampling technique is important (Farmnote 69/2009).

Having paddocks fenced according to land management units makes soil testing and fertiliser management easier but is not essential.

Have the soils analysed at an accredited laboratory. Most farmers in Western Australia arrange soil analysis through one of the major fertiliser companies, who provide analysis at their laboratories. Whichever laboratory you use, make sure that it is accredited by the Australasian Soil and Plant Analysis Council (ASPAC) and uses the analytical methods recognised as being most appropriate for Western Australian soils (www.aspac-australasia.com). It may be cost effective to engage an independent or Fertcare accredited soil consultant to interpret the results and recommend fertiliser types and rates.

Tissue testing

Tissue testing is the only reliable way to determine if micro-nutrients such as copper, manganese, zinc, magnesium, iron, and boron are limiting. Tissue testing is of particular importance after liming or where trace elements have not been applied for many years. Unfortunately tissue testing is only possible after the plants have established and, if there is a deficiency of any element, yield loss may have already occurred and will need to be corrected for the following year.

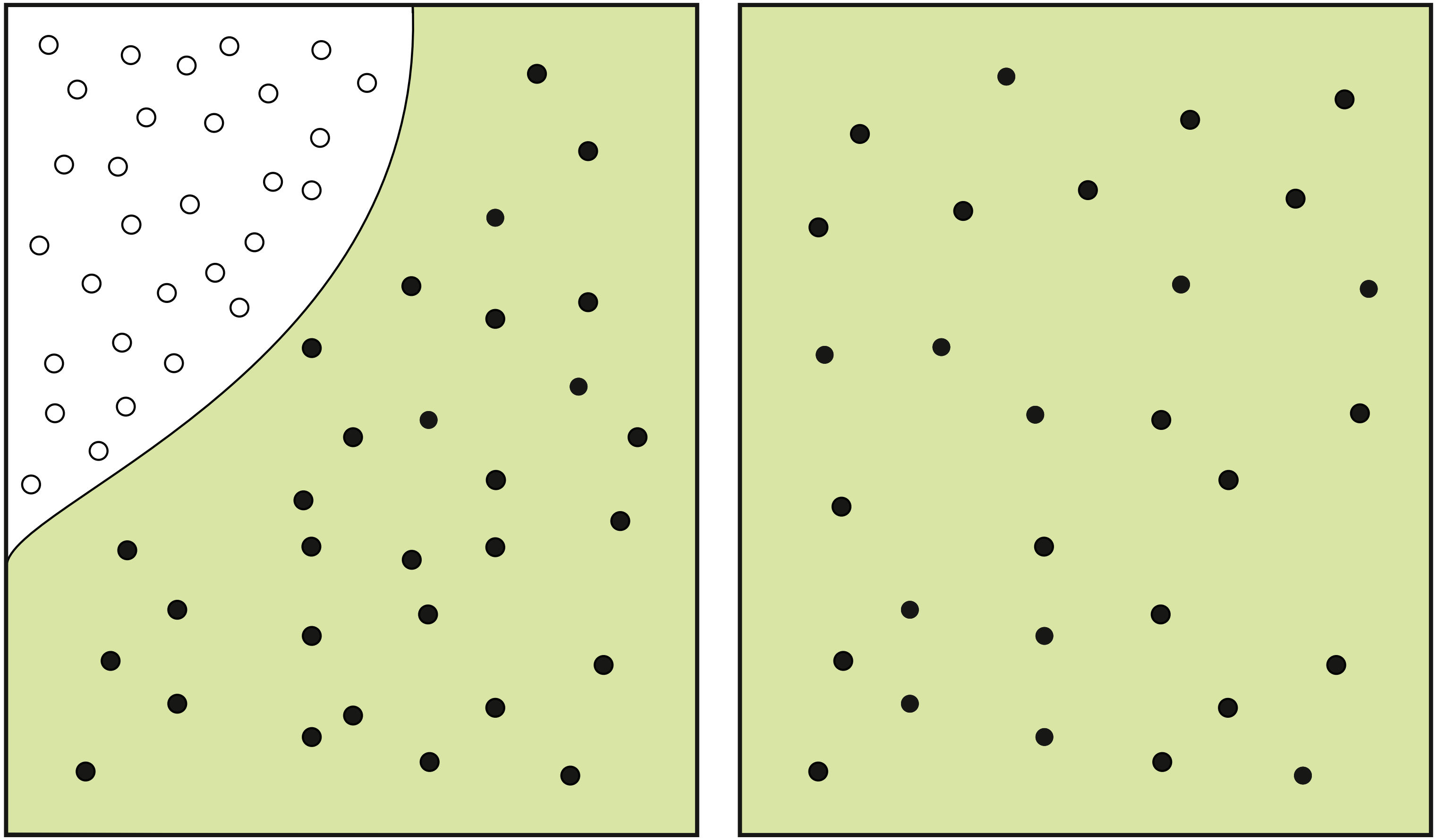

Figure 1 Sampling pattern for a paddock with two distinct soil types (left) or one soil type (right).

Liming

Once you have followed the correct procedures for soil sampling and analysis, and have obtained your results, you should first check the acidity of your soil by looking at the pH measured in calcium chloride ($CaCl_2$). If the pH of the soil is too low (less than 5.5 is acid) then it is likely to be a waste of money applying P before the pH is corrected. This is because the plants cannot grow well enough to use the P and may also be limited in other nutrients. Lime should be applied at 2 tonnes per hectare for sandy soils and 4 tonnes per hectare for loam and clay soils when the soil pH ($CaCl_2$) is less than 5.5 and should be reassessed next soil test. Lime can take several seasons to react with the soil and show a pH change. Limestone is very insoluble and when applied to the surface it can take a long time to move into the soil. Incorporation of lime into the top 10 cm of soil can more rapidly correct soil acidity. Organic matter in the surface of the soil may neutralize the lime leaving the subsoil acidic. The extent of soil disturbance to incorporate lime needs to be weighed up against the impact on existing pasture and available feed.

Time of application

Where possible P should be applied to pasture that has already germinated and is growing well. Alternatively the application should be split between an early winter application and a late spring to early autumn application. More emphasis is now being directed to the second application where trafficability is not a problem.

Deciding on the production level

Even though you may be able to achieve a high production level, you should consider other factors when aiming for a production level or yield target. Profitability and stocking rates will determine the preferred yield level, and to take into account the full range of factors will require a computer model. There is no point in trying to reach a particular production level or target if there is no stock to eat the pasture or if it is unprofitable. Aiming too high will reduce your profitability. Whatever level of production is targeted, it will be difficult to achieve without addressing other nutrient deficiencies, acidity or drainage problems.

From the soil P test (usually Colwell P in WA, this is also know as bicarbonate extractable P, or "bic P") it is possible to determine the proportion of maximum productivity that may be attained in the following growing season (Figure 2) if there are no other limiting factors. It must be emphasized that this is the maximum level of production that can be achieved for clover based pastures in areas where rainfall is greater than 600mm per annum, and where there are no other limiting factors such as acidity, other nutrients or drought. Your ability to turn this pasture into livestock productivity will depend upon such things as grazing strategies and stocking rates.

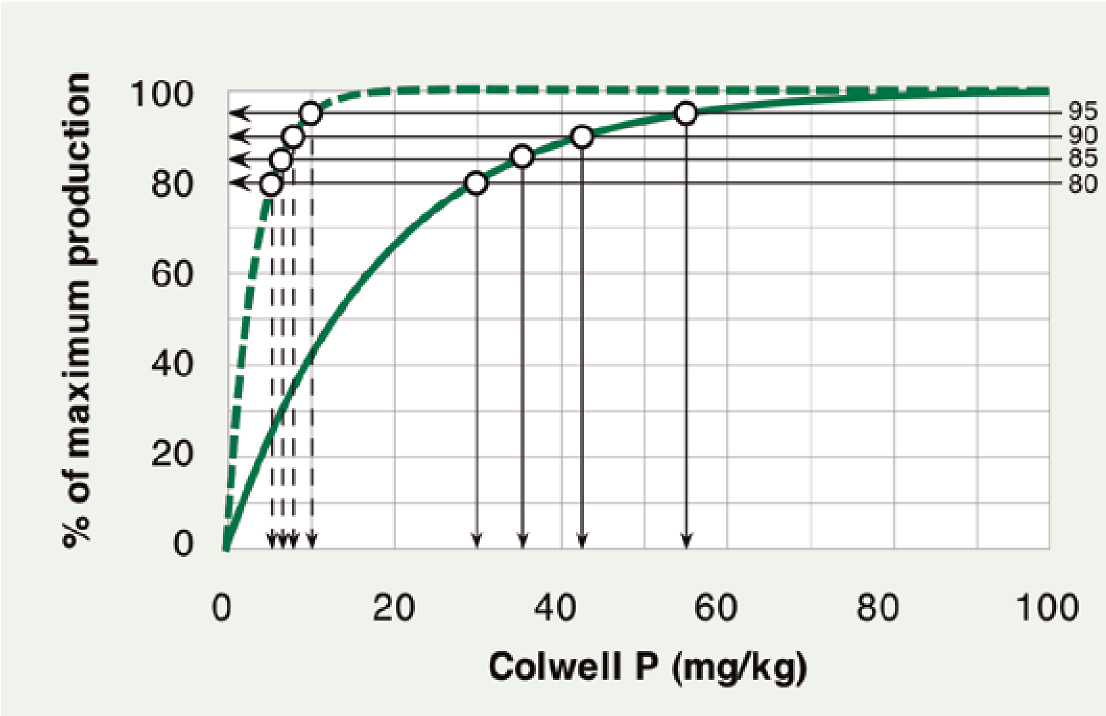

Figure 2 The maximum production that may be achieved based on existing supplies of Colwell P in a low P fixing sandy soil (dashed curve: Phosphorus Retention Index (PRI) below 0.35, Phosphorus Buffering Index (PBI) below 5, Reactive Iron below 100) and a high P fixing clay soil (solid curve: PRI =275-1680, PBI = 280-840, Reactive Iron = 4950-14500) where no other factors are limiting.

Figure 2 shows the relationship between existing supplies of Colwell P in the soil and potential production level. This is expanded on in detail in Table 2 through Table 9.

Phosphorus retention

Different soils will compete with plants for the P that is applied to the soil through a process called adsorption or fixation. Sandy soils have a lower capacity to compete for P (they have low P adsorption or fixation). If you need to apply P, less will be required for a sandy soil than for a clay soil to achieve your desired production target. To measure how strongly they compete, adsorb or fix, a range of methods have been used including **Reactive Iron, PRI & PBI**. The PBI test was recently developed in Eastern Australia and is now the national standard procedure used in all states for agronomic recommendations. The PRI test is still useful and retained for environmental assessment in Western Australia because it is more sensitive for our weathered sandy soils.

Table 1. Conversion of different measures of the P holding capacity (sorption) of soil.

P sorption category	Reactive Iron (mg/kg)	PRI[A] (L/g)	PBI[B]	Refer to
Exceedingly Low	0-100	<0.35	<5	Table 2
Exceptionally Low	100-200	0.35-1	≥5-10	Table 3
Extremely low	200-280	1-2	≥10-15	Table 4
Very, very low	280-650	2-9	≥15-35	Table 5
Very low	650-1250	9-28	≥35-70	Table 6
Low	1250-2500	28-87	≥70-140	Table 7
Moderate	2500-4950	87-275	≥140-280	Table 8
High	4950-14500	275-1680	≥280-840	Table 9

A, ranges estimated from Reactive Iron, PRI and PBI data collected by Summers and Weaver (2006).
B, adapted from Victorian Department of Primary Industries (2007) by D. M. Weaver and R. N. Summers.

You will need to use one of the measures of P sorption (PBI, PRI or Reactive Iron) to determine which of the tables below to use in conjunction with your Colwell P soil test. Table 1 provides approximate ranges of PRI, PBI and Reactive Iron and their respective P sorption categories.

Iron and aluminium exposed at the surfaces of soil constituents (clays, oxides, organic mater, and sandy soils coated with various amounts of iron and aluminium oxides) make soils with different capacities to sorb P and this influences the soil test calibrations shown in the tables below.

Estimating P application

Tables 2 to 9 below will answer the question regarding how much P you should apply to achieve your production target, but not whether this is the best economic decision to make. To calculate the most profitable level and method of applying P fertiliser requires a computer model, which is beyond the scope of this Bulletin. You should discuss economic outcomes with your advisor.

Tables 2 to 9 are constructed from trial data summarized from the 1960's and 1970's on the response of clover pasture and was compiled by Bowden *et al*. (1993). The P requirement of clover is high and grasses generally have a lower requirement. Trials for grasses have not been carried out and the recommendations here are likely to over-estimate the P requirements of most pastures which are grass dominant. To provide this information requires trials on a wide range of soils carried out over several years at a large cost.

Tables 2 through 9 expand on Figure 2, and go on to provide estimates of P fertiliser requirements. The yield with no P applied is the proportion of maximum production that the Colwell P test may achieve. This level of production could also be achieved by applying an equivalent amount of P (kg P/ha) to a soil that contains no Colwell P.

What is already in the soil

In a high production system, like a dairy, the target may be 95% of maximum production, which for an extremely low P fixing soil (sandy soils with PRI<0.35, PBI<5, Reactive Iron<100) will show pasture growth responses up to a target soil P test of 10 mg/kg (Table 2). This is equivalent to applying 23 kg P/ha to a soil in its virgin state (zero P).

For soils in this same P sorption category, a soil P test of 6 mg/kg will enable 84% of maximum yield to be achieved which is more than sufficient for an extensive beef operation. This is equivalent to having applied 14 kg P/ha to a virgin soil in this same P sorption category.

On the other hand, for a high P fixing soil (loams and clays with PRI=275-1680, PBI=280-840, Reactive Iron=4950-14500, Table 9), a soil test P of 60 mg/kg could achieve up to 96% of production which is more than sufficient for a dairy. This is equivalent to applying 126 kg P/ha to a virgin soil in this same P sorption category.

If P is required

To estimate the amount of P required to achieve your production or yield target:

- Refer to your soil test data and choose the appropriate table based on the P sorption category (see Table 1).
- Using the appropriate table, find your soil Colwell P value, follow down the table to your yield target level (%), and read the amount of P that needs to be applied. For example an extremely low PBI soil (PRI<0.35, PBI<5, Reactive Iron<100) (use Table 2) with a soil test P of 8 mg/kg will achieve 91% of maximum yield. To achieve a yield target of 95% of maximum, 5 kg of P will need to be applied.
- A very low PBI soil (PRI=9-28, PBI=35-70, Reactive Iron=650-1250) (use Table 6) with a soil test P of 30 mg/kg will achieve 96% of maximum yield and will not require any P fertiliser in the year following the soil test if the yield target is 95%. The same soil with a soil test P of 20 mg/kg will achieve 87% of maximum production and will not require a P application if the yield target is 80%, but would require 21 kg of P/ha if the target was 95%.
- Calculate how much fertiliser you require. Superphosphate contains 9.1% P, so to apply 5 kg of P/ha would require 55 kg super/ha (5 divided by 0.091). To apply 21 kg of P/ha would require 230 kg super/ha (21 divided by 0.091).

It must be noted that the figures provided assume no other factors are limiting. If pH is low, then availability of P will be reduced, and if other nutrients are deficient then no matter how much P you apply it is unlikely you will not achieve your production target.

Table 2. Units of P (kg/ha) required for an exceedingly low P sorbing soil, PRI <0.35, PBI < 5, Reactive Iron < 100.

Soil test P mg/kg	<2	2	4	6	8	10	12	14	16	18	20
Equivalent P applied to virgin soil (kg/ha)	0	5	9	14	18	23	28	32	37	41	46
Yield with no P applied %	0	46	70	84	91	95	97	99	99	100	100
Yield target %											
60	7	4									
65	7	4									
70	7	4									
75	10	7	3								
80	12	9	5								
85	14	11	7	2							
90	16	13	9	4							
95	21	18	14	9	5						
98	28	25	21	16	12	7					

Table 3. Units of P (kg/ha) required for an exceptionally low P sorbing soil with a PRI 0.35-1, PBI 5-10, Reactive Iron 100-200.

Soil test P mg/kg	<2	2	4	6	8	10	12	14	16	18	20
Equivalent P applied to virgin soil (kg/ha)	0	5	9	14	18	23	28	32	37	41	46
Yield with no P applied %	0	33	55	70	80	87	91	94	96	97	98
Yield target %											
60	10	7	3								
65	12	9	5								
70	12	9	5								
75	14	11	7	2							
80	16	13	9	4							
85	21	18	14	9	5						
90	26	23	19	14	10	5					
95	33	30	26	21	17	12	7	3			
98	44	41	37	32	28	23	18	14	9	5	

Table 4. Units of P (kg/ha) required for an extremely low P sorbing soil with a PRI 1-2, PBI 10-15, Reactive Iron 200-280.

Soil test P mg/kg	<2	2	4	6	8	10	12	15	18	20	25
Equivalent P applied to virgin soil (kg/ha)	0	5	9	14	18	23	28	35	41	46	58
Yield with no P applied %	0	26	46	60	71	78	84	90	94	95	98
Yield target%											
60	12	9	5								
65	14	11	7	2							
70	16	13	9	4							
75	21	18	14	9	5						
80	23	20	16	11	7	2					
85	28	25	21	16	12	7	2				
90	35	32	28	23	19	14	9	2			
95	44	41	37	32	28	23	18	11	5		
98	58	55	51	46	42	37	32	25	19	14	2

Table 5. Units of P (kg/ha) required for a very, very low P sorbing soil with a PRI 2-9, PBI 15-35, Reactive Iron 280-650.

Soil test P mg/kg	<2	4	6	8	10	12	15	20	25	30	35
Equivalent P applied to virgin soil (kg/ha)	0	9	14	18	23	28	35	46	58	69	81
Yield with no P applied %	0	38	51	61	69	76	83	90	95	97	98
Yield target%											
60	16	9	4								
65	19	12	7	3							
70	23	16	11	7	2						
75	26	19	14	10	5						
80	30	23	18	14	9	4					
85	37	30	25	21	16	11	4				
90	44	37	32	28	23	18	11				
95	58	51	46	42	37	32	25	14	2		
98	76	69	64	60	55	50	43	32	20	9	

Table 6. Units of P (kg/ha) required for a very low P sorbing soil with a PRI 9-28, PBI 35-70, Reactive Iron 650-1250.

Soil test P mg/kg	<2	5	10	15	20	25	30	35	40	45	50
Equivalent P applied to virgin soil (kg/ha)	0	12	23	35	46	58	69	81	92	104	115
Yield with no P applied %	0	40	64	79	87	92	96	97	98	99	99
Yield target%											
60	19	9									
65	23	13	2								
70	26	16	5								
75	30	20	9								
80	35	25	14	2							
85	42	32	21	9							
90	51	41	30	18	7						
95	65	55	44	32	21	9					
98	85	75	64	52	41	29	18	6			

Table 7. Units of P (kg/ha) required for a low P sorbing soil with a PRI 28-87, PBI 70-140, Reactive Iron 1250-2500.

Soil test P mg/kg	<2	5	10	15	20	25	30	35	40	45	50
Equivalent P applied to virgin soil (kg/ha)	0	12	23	35	46	58	69	81	92	104	115
Yield with no P applied %	0	37	60	75	84	90	93	96	97	98	99
Yield target%											
60	23	13	2								
65	26	16	5								
70	30	20	9								
75	35	25	14	2							
80	39	29	18	6							
85	46	36	25	13	2						
90	58	48	37	25	14	2					
95	74	64	53	41	30	18	7				
98	97	87	76	64	53	41	30	18	7		

Table 8. Units of P (kg/ha) required for a moderate P sorbing soil with a PRI 87-275, PBI 140-280, Reactive Iron 2500-4950.

Soil test P mg/kg	**<2**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Equivalent P applied to virgin soil (kg/ha)	0	11	22	33	44	55	66	77	88	99	110
Yield with no P applied %	0	32	54	69	79	86	90	93	96	97	98
Yield target%											
60	24	15	4								
65	29	20	9								
70	33	24	13	2							
75	38	29	18	7							
80	44	35	24	13	2						
85	53	44	33	22	11						
90	64	55	44	33	22	11					
95	84	75	64	53	42	31	20	9			
98	110	101	90	79	68	57	46	35	24	13	2

Table 9. Units of P (kg/ha) required for a high P sorbing soil with a PRI 275-1680, PBI 280-840, Reactive Iron 4950-14500.

Soil test P mg/kg	<2	5	10	15	20	25	30	35	40	50	60
Equivalent P applied to virgin soil (kg/ha)	0	11	21	32	42	53	63	74	84	105	126
Yield with no P applied %	0	24	42	56	67	75	81	85	89	93	96
Yield target%											
60	34	25	15	4							
65	40	31	21	10							
70	44	35	25	14	4						
75	53	44	34	23	13	2					
80	61	52	42	31	21	10					
85	72	63	53	42	32	21	11				
90	88	79	69	58	48	37	27	16	6		
95	114	105	95	84	74	63	53	42	32	11	
98	126	117	107	96	86	75	65	54	44	23	2

Type of fertiliser

The above tables were created for very soluble fertilisers such as ordinary single superphosphate or triple superphosphate. The calculations will depend upon the concentration of P in the fertiliser and this can be obtained from the manufacturer. On leaching sands, a large proportion of P from these very soluble fertilisers can wash away before the plants have established if applied too early. Alternative fertilisers are designed for soils which leach and have a PRI < 7 or a PBI < 33. These fertilisers are designed to be more effective at supplying P to sandy soils in high rainfall areas and less will need to be applied. Also these fertilisers are designed to remain in the soil for longer, which will make the soil P test higher in the following year reducing the requirement for more fertiliser to be applied. These alternative fertilisers are not designed for highly P fixing soils, and will likely result in reduced yield if used in these situations.

If P is required on higher PBI soils > 33, then the conventional highly soluble forms of fertiliser such as superphosphate or triple superphosphate are designed for these soils.

If the soil does have a low PRI, low PBI or low Reactive Iron then the application of sulphur must be considered separately. Superphosphate has a similar amount of sulphur as P and can act to provide both elements. However, if P is NOT required then superphosphate is a very expensive form of sulphur and the Farmnote 404/2010 ‘Sulphur for high rainfall pastures’ should be consulted.

Further reading

DAFWA, 1998. "Lime and Nutrient Calculator".

DAFWA Bulletin 4808 October 2010 'Phosphorus for high rainfall pastures'

DAFWA Farmnote No 70/2000 "Looking at liming consider the rate".

DAFWA Farmnote No 418/2010 Soil testing for high rainfall pastures.

DAFWA Farmnote No 69/2002 'Soil Testing – a Guide to Fertiliser Use'

DAFWA Farmnote No 404/2010 'Sulphur for high rainfall pastures'

Bowden, J.W., Shedley, C. and Burgess, S.J. (1993) Soil test and phosphorus rate. Technote 5/93, Western Australian Department of Agriculture

Summers RN and Weaver DM (2006) Current status and 25 year trends for soil acidity, fertility and salinity in the coastal catchments of the Peel-Harvey. Final Report to South West Catchment Council, Project L7-03.

Victorian Department of Primary Industries (2007) Making Better Fertiliser Decisions for Grazed Pastures in Australia. http://www.asris.csiro.au/downloads/BFD/Making%20 Better%20Fertiliser%20Decisions%20for%20 Grazed%20Pastures%20 in%20Australia.pdf

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