Fertiliser application:

Reactive phosphate rock: an effective fertiliser for NSW pastures?

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Reactive phosphate rock (RPR) began to be marketed in southern Australia in 1990 as an alternative, cheaper P fertiliser for permanent pasture. Guidelines for the use of this fertiliser were based on New Zealand results which were limited to a small number of high rainfall sites. It was suggested that RPRs would be effective in pasture environments where the annual rainfall exceeded 800 mm, and the soil pH (water) was less than 6. However, concern was expressed about the reliance on the New Zealand results, given the large areas of quite acidic soils and the presence of subterranean clover in many pastures in the high rainfall zone of Australia (>550 mm annual rainfall). There was therefore an urgent need to identify those pasture environments in Australia where RPR would be effective, given that RPRs were 25-30% cheaper per unit of applied P than single superphosphate.

A large, national research project was established in 1991 to undertake a systematic investigation of the agronomic effectiveness of a series of phosphate rock products across a wide range of permanent pasture environments in temperate and tropical Australia. Collaborating scientists from Departments of Agriculture (or Primary Industries) in every State, from La Trobe University and the Universities of New England and Western Australia, all joined the project team. Funds were obtained from the International Wool Secretariat, the Meat Research Corporation, and the Dairy Research and Development Corporation, with analytical and financeial support being provided by the fertiliser industry. There was a genuine consensus by all participants of the need to determine where RPRs might be used so that potential cost savings might be possible, and importantly, where RPRs should not be used to avoid production losses.

This paper reports on some of the major findings from National RPR Project. A complete report on the results from the project will be published in a special issue of the Australian Journal of Experimental Agriculture in the latter half of 1997.

Methods

A large network of 30 field sites were set up, extending from the Atherton Tablelands in North Queensland to the south west of Western Australia. Two large experiments were established at each site, where pasture dry matter responses to different fertiliser treatments applied to small 2 x 3 m plots were measured on a regular basis during the growing season. The project continued for four growing seasons to enable sufficient time for the RPRs to become effective, given the experience in New Zealand where a lag phase was required for RPR to become equivalent to water soluble P fertiliser.

One experiment involved controls (nil P) plus six levels of P, applied as triple superphosphate, the highly reactive North Carolina phosphate rock (hereafter described as RPR), and RPR that had been 50% acidulated with sulfuric acid (partially acidulated phosphate rock). Additional treatments included large, single applications of these three fertilisers, applied in the first year only. The other experiment involved controls plus three levels of P, applied as five different phosphate rocks that varied in reactivity, and single superphosphate. This experiment set out to determine what the required level of reactivity (degree of carbonate substitution within the phosphate rock molecule) should be for the different pasture environments. Additional plots received RPR or water soluble P without basal sulfur (S) to determine the importance of adding S with the P forms.

The effectiveness of RPR was determined by calculating its substitution value, which is the ratio of the total P required as superphosphate (single or triple) to the P required from RPR to produce 50% of the maximum yield response from the superphosphate. The required P rates were determined from curves that were fitted to the yield response data for the RPR and superphosphate fertilisers. The substitution value was first determined for the annual dry matter production (total of all harvests), and then on an individual harvest basis. Pasture environments suitable for RPR use were identified by relating the substitution values to the average annual rainfall over the four years of the project, and to a full range of chemical and physical measurements, made on the soil at each site. Pasture nutrient analysis was also undertaken for selected plots over time and the botanical composition was also measured during each growing season.

Results and discussion

Where are highly reactive PRs effective or ineffective?

Overall, RPR was equivalent in effectiveness to triple superphosphate by the 4th year at a third of the sites in this project (nine out of 26 effective sites) with the substitution value in the 4th year being equal to or greater than 0.9. At four of these nine sites, RPR was effective in the first year, and in each following year. RPR was only moderately effective at another third of sites with the year-4 substitution value lying between 0.6 and 0.8, while RPR was ineffective (year-4 substitution value less than 0.5) at the eight remaining sites.

The key features of the pasture environment That influence RPR effectiveness were:

- average annual rainfall,
- soil pH,
- the P sorption capacity of the surface soil,
- the texture of the surface soil,
- the botanical composition of the pasture, and
- the likelihood of P leaching occurring (especially with very sandy soils and high rainfall).

These properties are presented in Table 1 for a number of sites, that are grouped on the basis of RPR effectiveness.

Our conclusions are that RPR will become effective and equivalent to triple or single superphosphate in the medium term (around four years) if the pasture soil is acidic (pH in $CaCl_2$ less than 5.0) and the soil surface remains moist for extended periods to enable RPR dissolution to proceed. Annual rainfall needs to be above 700 mm in Southern Australia, and 800 mm in the New England Tablelands where summer rainfall is less effective. The leaching of water soluble fertiliser P from the soil will improve RPR performance in the short term. This can occur either vertically (at T16 and W30 which are deep acidic sands, Table 1) or laterally (by drainage waters from surface-flooded soils); the leaching reduces the effectiveness of the superphosphate enabling RPR to become effective in the the first year. On the other hand, there are two soil conditions that will reduce RPR effectiveness: a sandy surface soil will enable the surface soil to dry out relatively quickly in moderate rainfall areas mid restrict RPR dissolution (sites N6, S24 and N4), while a very high P sorption ("fixing") capacity in the soil pH reduce the availability of the dissolved P from the RPR particles (sites T19 and V 11). Clover is less able to take up sorbed P than grasses and we observed that RPR performance was limited for clover dominant pastures on high P sorbing soils (sites V12 and S25).

The two sites at Yass and Braidwood in the Southern Tablelands of NSW (N7 and N8 respectively) were suitable for RPR use by the 4th year of annual applications (Table 1). However the two sites in the New England Tablelands (N6 and N4) received less rain over the four years of the project and had higher sand contents in their soil surface layer. RPRs were only moderately effective at these

Table 1. Average annual rainfall, soil pH, the P sorption class, sand percentage in the surface soil, and pasure species at selected sites which are grouped on the basis of RPR performance.

Site	Average rainfall (mm/year)	Soil pH $CaCl_2$ (0-10 cm)	P soption class	Sand in surface soil (%)	Pasture species
RPR effective from the 1st year onwards					
T16	1078	4.1	very low	97	Temperate grass, white clover
W30	895	4.4	very low	89	Subclover
RPR effective by the 4th year					
V13	802	4.2	medium	66	Temperate grass, white & subclover
N7	706	4.0	medium	63	Subclover
NS	700	4.0	medium	54	Subclover
RPR moderately effective by the 4th year					
N6	678	4.8	low	74	Temperate grass, white & subclover
T17	448	4.6	medium	57	Temperate grass, subclover
S24	729	4.3	very low	77	Temperate grass, subclover
V12	976	4.0	high	54	Subclover
T19	1226	4.7	very high	18	Temperate grass, white clover
N4	672	4.6	low	75	Temperate grass, white & subclover
RPR ineffective in the 4th year					
V11	1143	4.5	very high	15	Temperate grass, white clover
S25	744	5.0	high	62	Subclover
S22	580	4.2	very low	94	Subclover
V14	475	4.5	medium	94	Temperate grass, subclover
T20	581	4.4	low	90	Temperate grass, sub clover
S21	485	4.7	very low	94	Subclover

sites by the 4th year with substitution values of 0.8 and 0.5 respectively.

An expert system has been developed and will be made available to industry to provide advice on the suitability of particular pasture environments for RPRs. This computer model makes use of a number of variables and predicts whether annual applications of RPR will be effective in the first year or by the 4th year, or be marginally effective or ineffective by the 4th year. Information required from the farmer includes annual rainfall, soil pH (0-10 cm), the likelihood for P leaching, soil surface texture and colour, pasture composition, location, and the reactivity of the phosphate rock being used. The expert system criteria were used with Geographic Information Systems mapping technology to construct a map of permanent pasture environments in NSW where RPR would be expected to become effective by the 4th year of annual applications (Figure 1). There is a surprisingly large area of the high rainfall pastoral zone in NSW where pasture environments are suitable for RPR use in the medium term. Phosphate rocks that are less reactive would require more rainfall for dissolution, and therefore would be more restricted in their use.

Capital versus annual P applications

An important finding was that at the majority of sites there was no production penalty, over a four year period, in applying large capital applications in the first year of the project compared with the same amount of total P applied as annual applications. Indeed, for the Q3 site at Mackay in central Queensland where the soil had a very low P status (Colwell P of 3 μg/g), large year-1 applications resulted in significant production gains. However there were important exceptions where capital applications are not recommended. For example capital applications of superphosphate or partially acidulated phosphate rock (containing water soluble P fertiliser) should not be used on P-leaching sandy soils, RPR fertilisers would be the recommended form of P fertiliser for such environments, Also capital applications of superphosphate should not be recommended on very high P-sorbing soils: smaller annual applications are the more productive strategy for these soils.

Use of RPR and winter feed production

A problem with RPR use is that seasonal 'lags' in pasture production occurred in the early part of the growing season (during the autumn/winter period for pastures in southern Australia, and for the early growth of legume pastures on low P soils in the tropics). These seasonal declines in RPR performance were frequently observed at many southern sites. This was also the case for a number of the

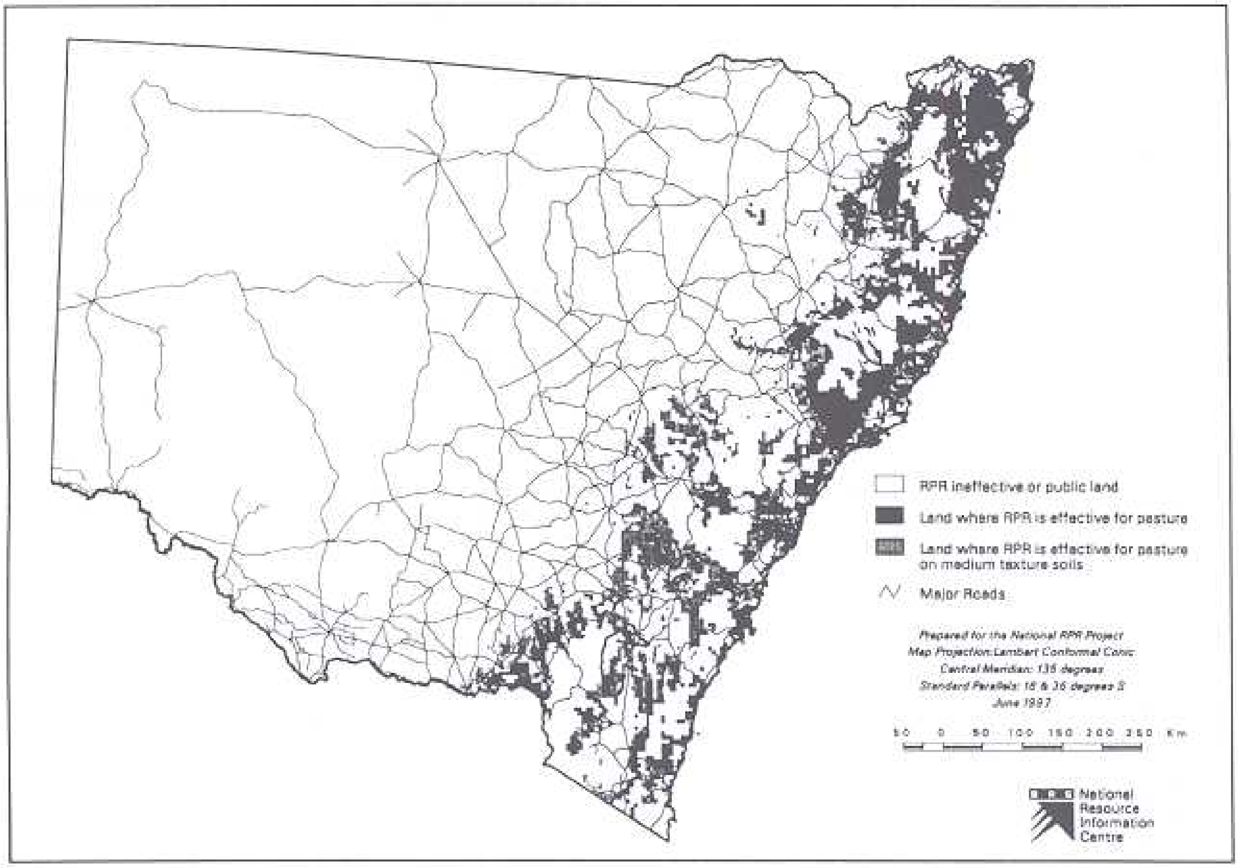

Figure 1. A map of NSW showing land where the rainfall and soil properties are likely to result in RPR being an effective P fertiliser for permanent pastures in the medium term (after 3-5 years).

sites where the annual substitution value in the 4th year with annual applications was equal to or greater than 0.9, and where RPR was deemed to be an effective fertiliser for that site. It would appear that the slower rate of release of P from the dissolving RPR particles was less able to meet the high demand for fertiliser P in the cool months at the beginning of the growing season, than the superphosphate fertilisers. However, the use of the partially acidulated phosphate rock or the use of RPR as large single ("capital") applications in the first year minimised this seasonal feed problem.

The need for sulfur

Sulfur deficiency, resulting in a significant reduction in annual pasture production on minus S plots, occurred at two thirds of sites during the course of the four year project. These results indicate that S deficiency is an important issue with RPR use, given that improved pastures with a history of superphosphate applications were selected for the sites, as RPRs contain minimal amounts of S. It is likely that S deficiency will be a problem in the short to medium term for many of the improved pasture soils in the high rainfall zone, if P fertilisers that do not contain S are used repeatedly.

The effect of soil P status

The use of annual applications of RPR fertiliser on pasture soils that are low in available P, and therefore very responsive to P, is not recommended. The delay in the build-up of plant-available P from dissolving RPR in these soils means that there will be significant production penalties associated with RPR use, even if equivalent pasture yields (to those produced by superphosphate) are obtained in the medium term of (say) four years plus. Our findings indicate that it would be better to build up the soil P status with water soluble P fertiliser or a partially acidulated phosphate rock, before using RPR on such soil.

The effect of RPR on soil pH

There was considerable between-year and within-site variation in soil pH at our experimental sites. There were only a few sites where an increase in soil pH could be attributed to the use of RPR, which consumes soil acidity as it dissolves. RPRs can therefore not be considered to be an alternative to lime or dolomite applications in alleviating acid soil conditions.

Conclusions

There are large areas of the high rainfall pastoral zone in NSW where RPRs will become equivalent in agronomic effectiveness to single or triple superphosphate, after a lag period of around 3-5 years. The attractiveness of RPR for pastoral farmers in these regions will depend on the extent of any cost savings over superphosphate fertilisers. However, there are also some shortcomings associated with RPR use. These include the need to add S with RPR (which will reduce the extent of any cost savings), the likelihood of reduced pasture responses to RPR during the winter months, and pasture production penalties with low P soils during the lag phase following a switch to RPR fertiliser.

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