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Modifying
FERTILISER PRACTICES

By J. S. Yeates, D. M. Deeley and M. F. Clarke, Division of Plant Research, Department of Agriculture, and D. Allen, Government Chemical Laboratories

If modified fertiliser practices are adopted, phosphorus losses from the Peel-Harvey catchment can be reduced. Farmers can save money on fertiliser applications and the need for more expensive catchment management measures to reduce algal pollution of the estuary will be avoided.

Research data available so far indicate that, with farmer co-operation and the use of the new slow release fertiliser New Coastal Superphosphate, long-term phosphorus application rates can be reduced by 30 to 40 per cent—and possibly even halved—without lowering agricultural production. This will also reduce phosphorus loss to drainage water.

Although much of the research since 1982 has concentrated on the Peel-Harvey catchment, many of the results apply to all of the high rainfall coastal belt between Perth and Albany. Already farmers throughout this area have benefited from the research.

Background

Most of the phosphorus-leaching soils in the Peel-Harvey catchment are used for beef, sheep and dairy production on subterranean clover based annual pastures.

The major soil types include the deep grey Bassendean sands—the wet phase Joel series and dry Gavin ridges—and the sandy clay duplex Coolup sands. These sands require phosphorus and trace elements before productive pasture can be established, and continuing applications of phosphorus, sulphur and potassium to maintain fertility. Once pasture is established the Joel and Coolup sands become highly productive soils. In the estuary catchment most have now been cleared and support profitable farming.

A considerable amount was known about the nutrition of the sandy soils of the high rainfall areas of Western Australia when the

Pasture growth responses to applied sulphur.
Pasture growth in response to difference sources of phosphorus trials on new land.

Peel-Harvey study began in 1976. A research programme on phosphorus and sulphur nutrition was also in progress on the sands of the western south coast during the early years of the study.

When phosphorus leaching was recognised as the major cause of the algal problems in the estuary, three potential ways of reducing losses were apparent. These were:

1. ensuring that pastures on the sandy soils were not over-fertilised with phosphorus.
2. correct timing of fertiliser applications to maximise phosphorus use by pastures and to minimise leaching losses.
3. the use of a fertiliser in which phosphorus release patterns were better matched to the needs of pasture on the deep sands than those of conventional superphosphate.

Two other options were also highlighted. They were planting deep-rooted species, including millable trees, which make better use of soluble nutrients in leaching soils, or modifying the sandy soils of the catchment with clay materials to reduce phosphorus leaching losses. These aspects are discussed later in the Journal.

Phosphorus needs of plants

Despite high and rapid leaching losses of applied superphosphate on the sandy soils, some phosphorus is retained in the soil. This can be in an insoluble form (from fertiliser residues), adsorbed (attached to soil particles) or as organic phosphorus in plant and animal residues. This phosphorus builds up over time with annual superphosphate applications. If enough superphosphate has been applied over time, soil phosphorus levels will be adequate for optimum pasture growth in the next season. No more phosphorus will be needed for at least one year, and possibly longer.

This soil phosphorus store, or 'super bank', can be measured by a soil test taken in late summer. From this soil test the rate of fertiliser phosphorus needed for optimum economic production in the following season can be predicted.

The shape of the response curve in Figure 1 shows it is rarely economic to fertilise for maximum plant growth as a lot of fertiliser must be applied to get the last small increase in growth. In Figure 1 it can be seen that the first 5.5 kilograms of phosphorus applied gives 50 per cent of the total response to phosphorus; almost 30 kg is needed to get the last 25 per cent of the response. On the Peel-Harvey sands, it is usually uneconomic to fertilise for more than 80 to 90 per cent of maximum plant growth.

As a result of recent research less phosphorus is now recommended on the sands than was previously used for two reasons:

1. On the sands, residual phosphorus is fairly readily available to plants. A lower level of soil test phosphorus is required for optimum plant growth than was previously believed necessary. This level is lower than that required on gravel and clay soils which tightly bind phosphorus.
2. Many of the sandy soils of the Peel-Harvey catchment, particularly the duplex Coolup sands, currently have soil phosphorus levels greatly in excess of that now known to be needed for optimum pasture growth. Soil levels exceeding 50 parts per million (ppm) bicarbonate extractable phosphorus are common on soils where less than 25 ppm are required.

These high soil tests indicate that superphosphate, which has been widely applied each year at rates of 180 kg/ha or more, has often been used in pastures which do not need phosphorus that year and possibly for a number...
of years. This has caused unnecessary direct leaching losses from the fertiliser, and a further build up in the already excessively high 'super banks' from which phosphorus can also leach.

In the 1983-84 soil sampling programme more than 3,500 paddocks on all the 460 farms on the Peel-Harvey coastal plain catchment were tested. About 70 per cent of the paddocks needed no additional phosphorus in 1984. Application rates could have been substantially reduced in many of the remaining paddocks.

In the longer term, after excessive soil phosphorus banks have been allowed to run down, it is believed that only about half the phosphorus application rate applied in the past will be needed to maintain satisfactory soil test levels for pasture growth. Leaching losses should be reduced by a similar proportion.

Soil testing and the accurate prediction of phosphorus fertiliser needs are therefore crucial to the reduction of phosphorus losses from the sandy soils.

The sulphur problem

Although phosphorus rates can be considerably reduced without losing production on many sandy soils, 'cutting back the super' is not as simple as it sounds.

Superphosphate also contains sulphur which, unlike phosphorus, does not build up a significant bank over time. A severe sulphur deficiency can develop within one or two years of not using a sulphur containing fertiliser. Many farmers have been unknowingly applying superphosphate primarily to supply sulphur, often mistakenly believing that growth reductions caused by leaving superphosphate off have been due to phosphorus deficiency.

One of the major problems confronting farmers wishing to follow phosphorus soil testing advice has been how to apply sulphur in a form other than superphosphate.

Fine gypsum, which is cheap and readily available, is difficult to spread with existing equipment. Because it leaches rapidly it should be applied in late winter—early spring just before sulphur deficiencies first appear in legume pastures. By this time paddocks are often waterlogged and boggy.

Because of these problems farmers have preferred autumn spreading of superphosphate to supply sulphur, despite its costing more than gypsum. These problems have been overcome with the development by the Department of Agriculture and CSBP and Farmers of New Coastal Superphosphate, a slow release, high sulphur phosphatic fertiliser.

The planned introduction in 1985 of granulated gypsum, which can be easily spread in autumn, will also help avoid the problems of fine gypsum. Granulated gypsum is being field tested in 1984.

Fertiliser application time

Delayed application can improve plant use, and therefore reduce required rates of applied fertiliser on light soils of the higher rainfall areas of Western Australia. Nitrogen, potassium and sulphur applied four to eight weeks after the break of the season may be more than twice as effective as applications at or before the break. Rapid leaching from early applications may remove nutrients from the topsoil before plants have established effective root systems.

Although soluble phosphorus (superphosphate) applied after the break can be more efficient than earlier applications, this effect is often only small and may even be reversed under the wet and cold winter conditions experienced on coastal soils. In a trial at Scott River, only 21 per cent of phosphorus applied in 200 kg/ha superphosphate in June 1981 was recovered from the soil by plants in the following two years, compared with 34 per cent when superphosphate was applied in April 1981. Superphosphate spread in September 1981 gave a 30 per cent recovery.

The effects of changing the application time of soluble fertilisers will vary with different seasonal patterns of leaching rains and plant growth. Though there may be some benefit, on average leaching losses will still be large.

Farmers are usually unwilling to apply fertilisers during winter because of difficulties in topdressing wet, boggy paddocks. Also, if phosphorus fertiliser is needed for plant growth, early application is necessary for optimum yield (as distinct from maximum plant uptake of phosphorus). Delayed fertiliser application is not considered a practical method for reducing phosphorus losses from the Peel-Harvey catchment sands.
Table 1. Analysis of phosphorus containing fertilisers tested on sandy soils of the high rainfall areas.

<table>
<thead>
<tr>
<th>Phosphorus source</th>
<th>% of total phosphorus</th>
<th>Total phosphorus (%)</th>
<th>Total sulphur (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water soluble</td>
<td>Citrate soluble</td>
<td>Acid soluble</td>
</tr>
<tr>
<td>Superphosphate</td>
<td>84</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Triple superphosphate</td>
<td>less than 1</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>Island 'A' grade rock phosphate</td>
<td>less than 1</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>Queensland rock phosphate</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Christmas Island 'C' grade rock phosphate</td>
<td>less than 1</td>
<td>66</td>
<td>33</td>
</tr>
<tr>
<td>Calcined (heat treated) Christmas Island 'C' rock phosphate</td>
<td>less than 1</td>
<td>not analysed</td>
<td></td>
</tr>
<tr>
<td>North Carolina 'reactive' rock phosphate</td>
<td></td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>Lime reverted superphosphate 1</td>
<td>9</td>
<td>50</td>
<td>41</td>
</tr>
<tr>
<td>Lime reverted superphosphate 2</td>
<td>32</td>
<td>55</td>
<td>12</td>
</tr>
<tr>
<td>Lime reverted superphosphate 3 (1983 Coastal Superphosphate)</td>
<td>17</td>
<td>71</td>
<td>12</td>
</tr>
<tr>
<td>Island 'A' rock phosphate—superphosphate—elemental sulphur 1</td>
<td>less than 1</td>
<td>66</td>
<td>33</td>
</tr>
<tr>
<td>Island 'A' rock phosphate—superphosphate—elemental sulphur 2</td>
<td>less than 1</td>
<td>not analysed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>17</td>
<td>56</td>
</tr>
</tbody>
</table>

Note: All rock phosphates were ground to particle sizes less than 0.15 mm diameter.

Types of phosphorus fertilisers

Phosphorus can be rapidly lost from superphosphate applied to pasture on sandy soils of the high rainfall areas. At sites near Albany and at Keysbrook about 80 per cent of the soluble phosphorus was leached from the top 10 cm of soil after only 150 mm of rain fell in six weeks after the break of season, and when the pasture was still at a very early growth stage.

Even if plants can get enough phosphorus for adequate growth from this year's superphosphate application, much of that applied will be leached beyond the root zone. Only a relatively small amount of phosphorus (from the insoluble or adsorbed portion of the fertiliser and from organic matter) remains to build up the soil bank.

The use of 'slow release' fertilisers can reduce these losses. These fertilisers have low or reduced water solubility. They are not new and have been tested for many years.

Table 1 shows the phosphatic fertilisers tested during the Peel-Harvey research programme. Their phosphorus content is split into three categories.

Water soluble phosphorus dissolves quickly in the soil and is readily used by plants. It can leach rapidly on the sands.

Citrate soluble phosphorus dissolves more slowly, and is less available to plants. Most of this phosphorus will dissolve within a year of application on the high rainfall sandy soils.

Acid soluble phosphorus dissolves very slowly on most soils and is not readily available to plants. Solubility is enhanced by fine grinding, acid soils, and leaching conditions, but some forms, for example Christmas Island 'C' grade rock phosphate, still dissolve extremely slowly.

Slow release phosphorus sources include a range of rock phosphates, lime reverted superphosphates and some other compounds which contain phosphorus in citrate or acid soluble forms. On heavy soils they are greatly inferior to water soluble phosphorus (ordinary superphosphates) because leaching is not important and water soluble phosphorus is more quickly available to plants. On very sandy soils such as the Bussendene and Coolup sands however, some slow release sources can be more effective than superphosphate because of their reduced leaching losses.

The major problem on the leaching sands was to identify sources which release phosphorus rapidly enough to match plant requirements over the growing season, but slowly enough to reduce losses. These sources must be cheap enough to replace conventional superphosphate, be at least as convenient to use, and contain adequate sulphur.

Figure 2. Phosphorus losses measured from laboratory leaching columns under simulated continuous rainfall.
Two new fertilisers

Two potentially useful slow release fertilisers were identified from field trials on sandy soils.

Coastal Superphosphate

Coastal Superphosphate was a lime-reverted superphosphate with 71 per cent citrate soluble phosphorus. It was sold in 1983 by CSBP and Farmers. Although leaching losses from Coastal Superphosphate were lower than from ordinary superphosphate, it was difficult to granulate and handle and contained insufficient sulphur for many situations. Overall leaching losses were still too high.

New Coastal Superphosphate

The 1983 Coastal Superphosphate was replaced in 1984 by New Coastal Superphosphate which is a granulated mixture of superphosphate, rock phosphate and elemental sulphur. When applied at the recommended rates, this fertiliser supplies enough phosphorus and sulphur to maintain pasture production on previously well fertilised land without building up soil phosphorus banks to unnecessarily high levels.

As a source of phosphorus, New Coastal Superphosphate has many advantages over ordinary superphosphate and 1983 Coastal Superphosphate on leaching sands of the high rainfall area. It granulates well and is easy to topdress on to pastures. Leaching losses are low (Figure 2).

Field trials started in 1981 show that New Coastal Superphosphate is similar to or only slightly less effective than ordinary superphosphate in the year of application, but has a much higher residual value (Figure 3). Compared with superphosphate, less phosphorus as New Coastal Superphosphate is required to maintain the phosphorus soil bank at satisfactory levels. Exactly how much less needs to be applied is still not clear. It is being studied in long term experiments which started in the Harvey and Denmark districts in 1984.

A major advantage of New Coastal Superphosphate over the other superphosphates is its high level of slow release (elemental) sulphur. New Coastal Superphosphate is particularly suited to those sands with high phosphorus soil test levels which require only small applications of phosphorus, but need relatively large amounts of sulphur in a form not severely leached.

New Coastal Superphosphate is more expensive per tonne than ordinary superphosphate, but cheaper per hectare at the rates required for maintenance applications to old land pasture. This factor, and the anticipated benefits of reducing algal pollution in the Peel-Harvey estuarine system, has led to a high level of farmer interest and acceptance in 1984.

Future research

A computer recommendation system has been recently developed to help define the optimum combination of phosphorus, sulphur and potassium fertilisers for pastures. This system, known as the PHOSUL K model, was used to process the 1983-84 results of the soil sampling work conducted in the Peel-Harvey coastal catchment. It will be refined in future years using the results of further research. The model can be used in other high rainfall areas.

Long term experimental work has started to better predict the rate of run-down of high phosphorus soil banks, and the rates of fertilisers required to maintain optimum soil test levels. The research will involve field, laboratory and computer modelling studies. The results will be important in predicting the long term effects of modified fertiliser practices on phosphorus drainage losses in the catchment.

The soil test work has highlighted the need for an effective, low cost, sulphur-only fertiliser for use in years when high soil phosphorus banks are run-down to the point where it again becomes profitable to apply phosphorus. Granulated gypsum should fill this need from 1985.

The potassium requirement of pastures on the Peel-Harvey sandy soils is also important. Soil samples show that, in contrast to superphosphate use, potassium fertiliser application rates have often been too low to maintain optimum pasture growth. Potash should have been partly substituted for the high rate of superphosphate used in the past.

Fertilisers with a wider range of phosphorus, sulphur and potassium ratios than are currently available are probably necessary. This will ensure optimum applications of each to pastures and make modified fertiliser recommendations more acceptable to farmers.

Figure 3. Residual value of ordinary superphosphate, 1983 Coastal Superphosphate and New Coastal Superphosphate, all applied in 1981, in the year of application and the following two years on deep grey sands.

Acknowledgement

Much of the research data collected between 1981 and 1983 were from a project funded by the Rural Credits Development Fund of the Reserve Bank.