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Potassium for crops and pastures in medium and low rainfall areas

By W.J. Cox*

The occurrence of potassium deficiency, its diagnosis in crops and pastures and its treatment.

Although superphosphate is the most commonly applied fertiliser in Western Australia, substantial quantities of nitrogen and potassium fertiliser are used. Potassium usage has mainly been associated with intensively farmed crops such as vegetable and orchard crops, and in the dairy industry. Only in more recent times has potassium use been extended to pastures and crops on the sandplain soils of the western margin of the wheatbelt.

Large areas of sandplain occur along the west and south coasts with smaller areas scattered throughout the wheatbelt (Figure 1). These soils contain low quantities of total and exchangeable potassium, and in the early 1960s it was already evident that potassium deficiency affected pasture establishment and production. Since then observations of potassium deficiency have increased and responses have now been obtained in lupins and cereals.

Potassium (chemical symbol K) is one of the essential elements needed for growth by plants and animals. Its main role in plant growth is in the functioning of leaf pores (stomata); it is also involved in enzyme activity and the transport of sugars. In animals, potassium is apparently associated with heart function and appetite but deficiencies never occur in the field.

OCCURRENCE

The likelihood of potassium deficiency occurring in crops and pastures is mainly determined by soil type, rainfall and management practices.

Soil type

Potassium is present in soil in a number of forms; water soluble, exchangeable, slowly available and unavailable. Water soluble and exchangeable potassium are the most available for plants and are the forms usually extracted when soil testing for potassium.

Plant-available potassium is usually associated with soil organic matter and clay; the coarser sand fraction contains negligible extractable potassium.

As exchangeable potassium is taken up by plants it is replenished from non-exchangeable potassium held in clay particles. The size of this reserve determines whether the soil can supply potassium to crops and pastures for many years without potassium fertilisers being needed.

Potassium deficiency is therefore most common on soils low in extractable potassium. In the virgin state many sandy-surfaced soils are low in extractable potassium and this may be further accentuated by subsequent management practices. Soils containing clay at the surface or within the root zone have higher amounts of extractable potassium (Table 1).

Historical note — potassium deficiency in cereals

In 1926, at the time of development of light land in the wheatbelt, it was predicted by the then Director of Agriculture G.L. Sutton that: "The addition of potash manures has not been found necessary but I am anticipating that as cropping of our lighter land continues we will require to include potash as part of our regular wheat fertiliser on these lands."

Evidence to support this prediction was slow to accumulate as early experiments with potash on wheat at the Light Lands Farm at Wongan Hills indicated that potash usage was not warranted. Further experiments were begun in the early thirties by Dr L.J.H. Teakle on a range of predominantly heavy soil types on the experimental farms at Nabawa, Dampawah, Wongan Hills, Yilgarn, Merredin and Salmon Gums. These failed to show any benefit from potassium application. Indications of potassium deficiency and responses in cereals were not obtained until 1959 with the development of light land on the Western sandplain.
The red clays associated with the Salmon Gum — Gimlet vegetation in the eastern wheatbelt contain more than 750 ppm extractable potassium — a level normally adequate for many generations of farming.

For virgin soils, the gradation in potassium content from low to high is: white sands, grey sands, pale yellow sands, yellow sands, loam, clay.

In most sandy soils the potassium concentration is highest in the surface layer where potassium is associated with soil organic matter. The potassium level then decreases down the profile except where clay or gravel occurs (Fig. 2).

Clay and gravelly clay contain much more potassium than sand, and where grey sand overlies yellow sand or these Table 1. Extractable potassium levels (ppm K) on a number of soils

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
<th>Depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eneabba</td>
<td>15 cm grey sand over white sand</td>
<td>20 15 10 10</td>
</tr>
<tr>
<td>Badgingarra</td>
<td>deep grey sand</td>
<td>7 3 2 1</td>
</tr>
<tr>
<td>Eneabba</td>
<td>15 cm grey sand over yellow sand and clay at 80 cm</td>
<td>20 10 20 30</td>
</tr>
<tr>
<td>Gibson</td>
<td>grey sand over yellow brown clay</td>
<td>120 120 600 -</td>
</tr>
<tr>
<td>Merredin</td>
<td>red-brown clay</td>
<td>1050 860 - -</td>
</tr>
<tr>
<td>Badgingarra</td>
<td>15 cm grey sand over gravel</td>
<td>150 90 - -</td>
</tr>
<tr>
<td>Lancelin</td>
<td>10 cm grey sand over yellow sand</td>
<td>40 16 12 6</td>
</tr>
</tbody>
</table>

sands overlie gravel or clay, the depth to the clay or gravel determines whether plants become deficient and respond to applied potassium; deep rooted crops are less susceptible to a deficiency than shallow rooted pastures on these duplex soils.

Rainfall

Potassium is retained in the soil attached to clay and organic matter. As a consequence potassium is readily leached beyond the root zone in sandy soils which contain little clay and organic matter whereas on clays and loams leaching losses are minimal.

Leaching losses are greatest in high rainfall areas and minimal in low rainfall areas. Losses of native potassium of 4-8 kg/ha have been found in a sandy soil at Muresk; elsewhere losses up to 65 kg/ha have been recorded when 330 kg/ha KCl was applied.

Intensity of land use

Land use influences the amount of potassium removed or lost through leaching.

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Table 1. Extractable potassium levels (ppm K) on a number of soils

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About 80 per cent of the potassium eaten by animals is returned to the soil through urine and dung. It is, however, returned unevenly and clover dominant patches are very noticeable on potassium deficient pastures grazed by cattle. Shifts of potassium to areas where the stock camp can also occur. Sales of wool, meat or live sheep result in some losses.

**Fodder conservation**

Most fodder conservation practices remove substantial quantities of potassium and may precipitate a deficiency on a naturally marginal soil. It can also result in potassium deficiency on soils originally adequate in potassium.

The drain on soil potassium reserves can be appreciated when it is realised that cereal hay cut at the soft dough stage contains an average of 1.12 per cent potassium. A 3 tonne crop would remove 34 kg of potassium equivalent to 70 kg muriate of potash per hectare.

Pasture hay has a similar potassium content although the yields are less than for cereal hay, resulting in a lower total loss. Much of the potassium removed is returned in dung and urine where the hay is fed but not necessarily on the same paddocks from which the hay was cut. Potassium deficiency may therefore develop where the same area is cut for hay repeatedly.

Cropping removes only small quantities of potassium compared with fodder conservation. A 2 tonne/ha cereal crop containing 0.4 per cent potassium removes only 8 kg of potassium equivalent to 16 kg of muriate of potash. A lupin crop yielding 1 tonne would remove a similar amount as lupin grain contains 0.8 per cent potassium.

**Fertilisers**

Heavy use of fertilisers increases the demand for potassium through increased yield, crop removal and increased leaching losses. Superphosphate contains substantial quantities of calcium which increases the potential for potassium leaching. Calcium also reduces potassium uptake by plants as a result of competition at the root surface (Table 2).

**Table 2. Effect of superphosphate on clover yield and potassium uptake**

<table>
<thead>
<tr>
<th>Superphosphate</th>
<th>Yield kg/ha</th>
<th>% K</th>
<th>% Ca</th>
<th>K uptake kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>3525</td>
<td>1.76</td>
<td>1.33</td>
<td>62</td>
</tr>
<tr>
<td>265</td>
<td>4130</td>
<td>0.88</td>
<td>1.78</td>
<td>36</td>
</tr>
</tbody>
</table>

The combined effect of crop removal and leaching losses is that the soil potassium status declines with time. The rate at which any deficiencies appear would depend on the original potassium status as well as the magnitude of losses. Increased production is therefore likely to increase pressures on soil potassium reserves and increase the need for additional fertiliser potassium.

**DIAGNOSIS**

Although large areas of soils are deficient in potassium it is important to be able to predict the particular areas where a deficiency of potassium is likely. Prediction methods range from simple observation to the more complicated process of soil testing.

**Pasture and crop appearance**

Severely potassium deficient pastures are usually characterised by their low productivity and declining content of clovers and other legumes (Plate 1). The legume component is replaced by grasses which are more efficient in securing their potassium because of their deeper root system and an inherent ability to extract more potassium from the soil.

In mildly deficient pastures some clover is still present but it is generally patchy with some areas growing normally while others grow slowly if at all. This uneven appearance is mainly caused by potassium in urine and dung patches although sulphur could also be involved on sulphur deficient soils.

In instances of more severe deficiency the clover plants may be only sparsely scattered throughout the pasture. In such cases the only healthy clover is associated with dung and urine patches from which the plant derives enough potassium for normal growth.

In cases of severe potassium deficiency grass production is also markedly
Plate 3.
Response to potassium in cereals. Left super only, right super and potash

Plate 4.
Potassium deficient sub. clover
decreased because of the reduced availability of soil nitrogen previously supplied by the legumes. With extreme deficiency, grass production is further reduced because of a shortage of potassium for the growth of grasses. The result is an extremely poor pasture with a very low carrying capacity. Crops grown on such soils are short, pale and in the case of cereals, have few tillers (Plates 2 and 3).

Deterioration in pasture composition and productivity is not only caused by potassium deficiency. Sulphur or molybdenum deficiency, and poor grazing management, may cause the same general symptoms. Seasonal conditions including a number of false breaks may also result in 'deteriorated' pastures.

Therefore, because symptoms are not specific for potassium deficiency, more reliable indicators should be used.

Specific plant symptoms
Although the symptoms of potassium deficiency vary with species and variety, all plants show the symptoms on the older leaves while the younger leaves appear quite healthy. The symptoms may appear at anytime but are most evident in late spring during the period of potential maximum growth. The symptoms for the major species are:

- Sub clover. Leaf margins become scorched with some fine spotting on the leaf surface. Leaf size is reduced and the colour changes from dark green to dull yellow in severely deficient plants. Finally the older leaves scorch completely and die rapidly (Plate 4). Where drought is an associated problem the leaves may also develop red margins in addition to very pronounced spotting. Deficient plants generally set a reduced amount of seed or in more severe cases fail to set seed.

- Serradella. Deep rooted species such as serradella and lupins are not as sensitive to potassium deficiency on duplex soils (eg sand over clay). However on deep sands these species are also affected. The oldest leaves turn yellow with the leaflets closest to the tip affected first (Plate 5). The leaflets then shed.

- Lupins. In Unicrop, Marri and Illyarrie, the oldest leaflet develops mild yellowing at the tip followed almost immediately by leaf loss. The result is a stunted plant with all the leaves at the top. Sandplain lupins do not shed leaves to the same extent as the narrow-leaved varieties; the older leaves develop a distinct scorching of the leaf tips.

- Cereals. The oldest leaves rapidly develop chlorotic tips, followed by necrosis. The area extends down the
margin to give an 'arrow' of normal tissue (Plates 6 and 7). In severe cases, the whole leaf dies. These symptoms are comparable to symptoms of nitrogen deficiency, except that yellowing is less even, and the yellow patches die more quickly. Symptoms vary slightly within cereals, with both barley and cereal rye having a distinct red flame-like appearance at the tips and margins.

In all plants, symptoms of potassium deficiency are often not clearly defined or are complicated by insect or disease damage, other nutrient deficiencies or drought which often make it necessary to follow up with plant analysis to determine the cause of specific symptoms. Plant analysis is also useful where there are no gross symptoms but where the addition of potash will increase yield.

**PLANT ANALYSIS**

A more objective way of identifying deficient crops and pastures is by plant analysis or “tissue testing” which measures the concentration of an element in part of all of the plant. This is matched with levels of potassium which are known to cause deficiency, as established by calibration trials and experience. Deficient clover plants up to eight weeks old generally contain less than 1.5 per cent potassium, and less than 1 per cent potassium when older than 10 to 12 weeks. Comparable standards are available for cereals and lupins.

Plant analysis is the main way to verify deficiency symptoms but it has the drawback of being expensive. An additional problem is that the confirmation is generally received too late to correct the deficiency in the same growing season.

**SOIL TESTING**

Analysis of representative soil samples taken from suspect paddocks is the most convenient way of predicting probable potassium deficiency. The analysis gives the quantity of extractable potassium and to attach meaning to this, information from trials is used, relating soil potassium levels with responses to potash. Soil testing for potassium for crops is at present only of diagnostic value in indentifying deficient areas. Although soil tests can be used to predict the amount of potassium required by clover and lupins no calibration data is available for wheat. Potassium responses obtained are too few on which to base a soil test.

Traditionally soil testing is based on a sample taken from the top 10 cm of soil, and although this may be valid for most soils, it can be misleading for example where there is a clay subsoil. The subsoil can contain substantial quantities of potassium for plants even though the surface sandy soil contains low amounts. In such cases a representative surface 10 cm soil sample should be accompanied by a subsoil sample and a description of the profile, for example “sand over brown clay at 20 cm”.

**RATES OF APPLICATION**

Once deficient soils, crops and pastures have been identified, it is necessary to know how much potash to apply to overcome this deficiency and increase production. The optimal fertiliser dressing depends on the soil type, and other influences on yield as well as economic considerations. Trials have indicated that substantial responses to applied potassium are possible on the wetter margins of the wheatbelt. Soil testing can be used to indicate requirement.

**Pastures**

Potassium deficiency in pastures is generally associated with soil test levels (taken from the surface 10 cm) less than 60 ppm. Where the deficiency has been diagnosed in low rainfall areas (less than 300 mm) it is suggested that 75 kg/ha of potash, be applied at the break of the season in test strips. If substantial responses are observed it is possible to topdress affected areas in subsequent years.

In medium rainfall (300 to 600 mm) areas it is suggested that 30 kg of muriate of potash be applied four weeks after germination, with a further 60 kg in August.
Table 3. Optimum rate of muriate of potash application (kg/ha) for lupins

<table>
<thead>
<tr>
<th>Soil Test (0 to 10 cm)</th>
<th>$100</th>
<th>$125</th>
<th>$150</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10 ppm</td>
<td>145</td>
<td>165</td>
<td>180</td>
</tr>
<tr>
<td>11 to 20</td>
<td>120</td>
<td>155</td>
<td>165</td>
</tr>
<tr>
<td>21 to 30</td>
<td>18</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>31 to 40</td>
<td>0</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>above 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

In cases of severe potassium deficiency where there is no clover in the sward, the addition of potash alone will not solve the problem. In such cases it is essential to reseed the pasture with clover or serradella. On the deeper sands serradella is better adapted because of its deeper rooting habit.

Cereals
A number of responses in wheat grain yields to potassium applications were reported in 1976. These responses ranged from 20 to 230 kg/ha with a median of 88 kg/ha. Only one rate of muriate of potash was used in these trials (135 kg/ha) and at the current prices of wheat (12c/kg) and muriate of potash (14c/kg) only one response was economic although several others may have been economic if the residual value of potassium and possible effects in the pasture phase of the rotation had been considered.

Generally responses are only obtained if the soil test (to 10 cm depth) is less than 20 ppm. Although no general recommendation is possible it is suggested that test strips at 50 and 100 kg/ha be applied topdressed at seeding (in the low rainfall areas) or four weeks after seeding (medium rainfall areas). Harvesting of these strips compared with untreated areas will indicate if economic responses can be obtained. Departmental trials have generally not given economic responses above 50 kg/ha muriate of potash.

Lupins
Substantially more information is available for grain lupins based on a series of trials done between 1974 and 1979. These results gave the basis for recommendations, which are summarised in Table 3.

Where the soil potassium level is less than 20 ppm, the amount of potassium fertiliser required is considerably greater than at a higher level of soil potassium. At soil levels about 40 ppm, it has so far been uneconomical to apply potash. These recommendations are for application four to six weeks after seeding and higher rates are required if applied at seeding.

RESIDUAL VALUE OF POTASSIUM
The value of a fertiliser depends on both the immediate and future effects.
Rainfall, soil type and farming system will affect the future effect (residual value) of potassium applied in fertilisers. In leaching situations the residual effect is very low (Fig. 3). Another benefit of potassium is to improve the legume component of pasture, and therefore also the nitrogen supply. Although this effect has not been measured generally, up to 200 kg/ha increase in wheat yield has been recorded.

METHOD OF APPLICATION
Like some of the nitrogen fertilisers, potassium can drastically reduce germination when applied in contact with seed. These harmful effects are greatest if the fertiliser is drilled with the seed into moist soil followed by a dry period.
Potash and super-potash mixes should therefore be applied separately from the seed. Also high rates applied on pastures may cause slight leaf burning.
The optimum time of application depends of rainfall, soil type and seasonal crop and pasture requirement,

as potassium is readily leached on most soils. In the drier parts of the wheatbelt, potassium can safely be applied close to the break of the season. However, where average rainfall is more than 350 mm a year, application for lupins and pastures should be delayed for four to eight weeks after seeding or germination.
In very sandy high rainfall areas, applications should be split, with one-third applied four weeks after germination and the rest in early to mid August. The same probably applies to cereals.
If the deficiency is identified late in the season an application may still be worthwhile provided that at least six weeks of growing season remain. In pastures, growth responses do generally not occur after flowering although seed set may increase.

POTASSIUM SOURCES
Australia imports all its potassium requirements – mainly from Canada. Muriate of potash (KCl) contains 50 per cent potassium and is the most commonly used source of potassium although sulphate of potash is preferred for some orchard and horticultural crops. On a unit cost basis, only muriate of potash can be
Table 4. Sources of potassium

<table>
<thead>
<tr>
<th>Source of potassium</th>
<th>Per cent potassium</th>
<th>Net price Kwinana per 100 kg potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muriate of potash (KCl)</td>
<td>50</td>
<td>$28.54</td>
</tr>
<tr>
<td>Sulphate of potash (K₂SO₄)</td>
<td>41</td>
<td>$72.35</td>
</tr>
</tbody>
</table>

recommended for crops and pastures (Table 4).

Muriate of potash is a coarse, crystalline, pink-coloured product which runs freely through a combine or spreader. However, spreading equipment must be hosed with water after use as muriate of potash is particularly corrosive.

In addition, muriate of potash is available in superphosphate mixes containing 5 parts superphosphate and 1 part muriate of potash (5:1) and 3 parts superphosphate to 2 parts muriate of potash (3:2). These mixes were designed primarily for the high rainfall dairy pastures although they can be used elsewhere. The 3:2 mix is for situations with a higher potash requirement.

World reserves of potassium have been estimated to be adequate for another 200 to 300 years at the current rate of usage, but prices could be expected to increase in line with inflation.

CONCLUSIONS

Although potassium deficiency in pastures is widespread on sandplain soils, the cereal grain responses recorded to date are considered to be an indication of a deficiency that could develop on a wide variety of soils in the Western Australian wheatbelt. Deficiencies could become worse by the removal of potassium in crop products as well as enhanced leaching resulting from the continued use of superphosphate and nitrogen fertilisers.

Techniques for identifying deficient soils and affected crops and pastures are available and the technology exists for treatment of the problem.

Large scale usage of potassium will however depend on cost/benefits which is closely related to product prices.

Further information

Advisers at each of the District and Regional offices of the Department of Agriculture can help identify potassium deficiencies and recommend treatment.

Further reading

(1) Anon (1977) – Potassium deficiency of sub clover. Farmnote 79/77.