The Potash Development Association

4. POTASH MANURING FOR ARABLE CROPS

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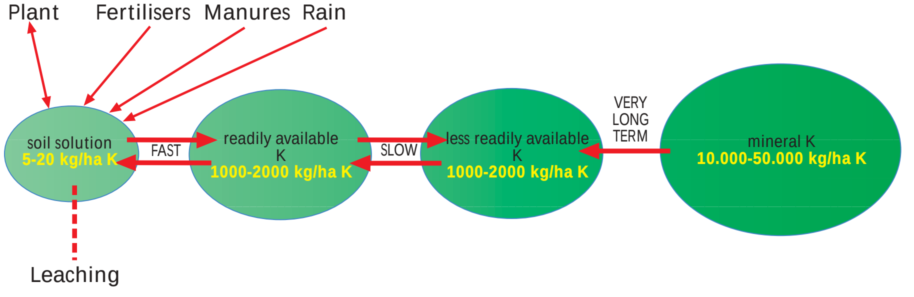
Background

It is important that potash (K) manuring is optimised so that yield and crop quality are not jeopardised. Easily recognised K deficiency symptoms in growing crops are usually seen only when there is an acute shortage of K. In cereals, pale yellow leaves can be due to mild K deficiency but are often considered to be nitrogen (N) deficiency. Applying N would be highly inappropriate.

This note summarises present knowledge regarding the relationship between soil and crop K and crop requirements for K and suggests a strategy for potash manuring for arable crops.

Soil - crop relationships

Fig 1 **Simplified K cycle for crops & soils indicating content of K in different forms**



Plant roots take up K, like other nutrients, from the soil solution which is in the pores between soil particles. Actively growing crops have a large demand for K, cereals as much as 5 kg/ha each day. However, the roots of annual arable crops do not have time to exploit the whole volume of soil. So it is essential that K in the soil solution is rapidly replenished from the supply within the soil near to where it is being taken up by the roots.

It is helpful to visualise the relationship between crop and soil K as shown in Fig 1. which illustrates soil K in four pools. One is the soil solution, the other three are associated with soil mineral particles and soil organic matter.

Some of the K taken up by the roots is removed in the harvested produce, some is returned to the soil in crop residues. An agronomically insignificant amount of K comes in rainfall, usually not more than 5kg/ha each year. The rest of the K required by the crop comes from the soil K supplies.

Leaching

Only K in the soil solution will be leached from surface soils and even then it may be held lower down the soil profile depending upon the amount of clay present. This subsoil K can be available to deep rooting crops. Losses of K from most soils are small - less than 5 kg/ha per year. Losses from sandy soils containing less than 5% clay can be higher, so large infrequent potash applications should be avoided on these soils.

Potash in the three soil pools can be considered as

- **readily available** (exchangeable K)
  available in days
- **less readily available** (non exchangeable K)
  available over growing season
- **K within soil minerals**
  usually only very slowly available as the minerals disintegrate by weathering. This pool is not considered further because the amounts released by weathering are agronomically insignificant in UK conditions.

K in the soil solution and the readily available pool is measured by the standard methods of soil analysis. According to the amount of K extracted, the soil is characterised into an index or descriptive band. At low K indexes (0 and 1) crops are likely to respond to K whilst at higher indexes (2 and above) there is unlikely to be any response to fresh K fertiliser application. K in the less readily available pool is a reserve of K which has accumulated from past application of fertilisers and organic manures when the amount of K applied exceeded the K offtake in the harvested crop.
It is important to note that the arrows between the first three pools in Fig1 point in both directions. Water soluble K added to soil dissolves in the soil solution and some is taken up by the crop, some remains in solution, some goes to the readily available pool where it is held on soil particles and organic matter, and some is transferred to the less readily available pool where it is held within the soil minerals. But movement of K from left to right in the first three pools in Fig 1 can be reversed when the soil is stressed to supply K to meet the demands of an actively growing crop.

An example of this two way transfer comes from an experiment on a silty clay loam soil (pH 7.0) at Rothamsted. Over a number of years only 40% of the K not taken up by the crop remained in the soil solution and readily available pools. But subsequently for a number of years, no K was applied. In this period only 40% of the K removed in the crop could be accounted for by the decline in the amount of readily available K, the rest had come from the less readily available pool.
The reversible transfer of K between the available and less readily available pools determines the ability of a soil to provide the K required by crops. The amount of K in each pool determines the quantity of K which will be available to the crop. Both the speed of transfer and the quantity varies between soils and depends on a number of factors.

- the amount of clay
- the type of clay
- previous and current cropping
- previous and current manuring
- the growth rate of a crop and its size and hence requirement for K

Because there are so many factors controlling plant available K, the amount can vary between soil types and frequently within fields. Many of the sites which hold K in the readily available and less readily available pools are on clay particles and soil organic matter. In general therefore, heavier textured soils (clay loams and clays), will contain larger amounts of readily available K than sandy loams and sandy soils. The latter are also likely to have less organic matter to hold K in either pool. However, the heavier textured soils need greater care with cultivations to maintain a good soil structure so that the roots can explore the largest possible volume of soil to obtain the K demanded by the crop.
There is evidence that there is a close relationship between the amount of K in the readily and less readily available pools. On one soil the relationship was 1:2, whether this same relationship holds for other soils is not known. But the advantage of maintaining an adequate amount of K in both pools is illustrated in the next section.

The value of soil K reserves and the response to potash

K reserves can be accumulated to the benefit of crops in a way that may not be matched by fresh K fertiliser.

Fig 2 **The benefits of adequate K reserves in soil when fresh K fertiliser is applied**

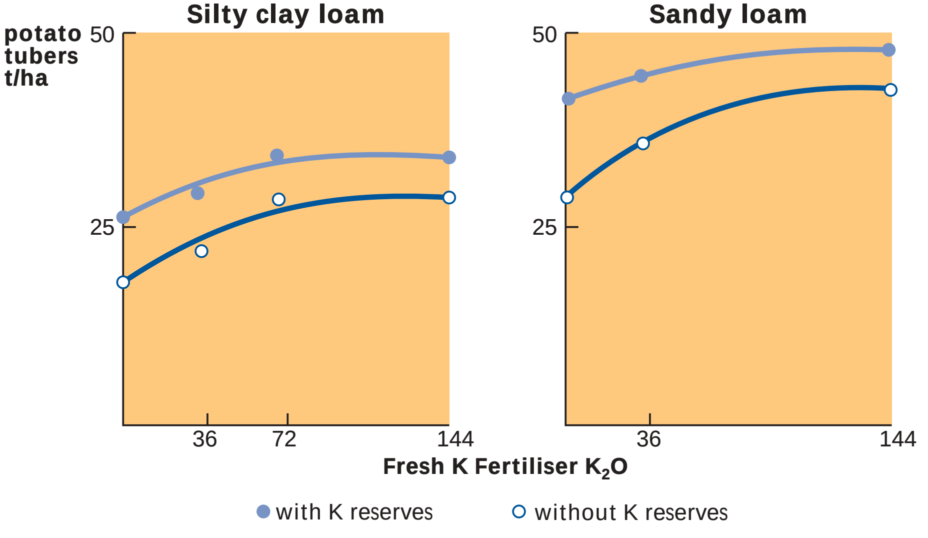


Fig 2 shows that potato yields were increased by fresh potash applied to the crop but yields were always larger on soil with adequate K reserves . Field beans responded similarly but less K demanding crops may not always respond, depending on the K release characteristics of the soil as in the following example.

Table 1

Effect of K on Cereals, Field Beans and Potatoes

Sandy clay loam, Saxmundham 1977 - 80

CROP yield t/ha	No K in previous 77 years Fertiliser K during trial*		K added annually in previous 77 years Fertiliser K during trial*	
	NO	YES	NO	YES
Winter wheat	8.49	8.54	8.50	8.60
Winter barley	7.58	7.74	7.69	7.71
Spring barley	5.68	5.68	5.71	5.86
Beans	2.52	3.60	4.42	4.38
Potatoes	28.8	39.6	43.1	44.0

***NO** = none applied

***YES** = 62 kg/ha K_2O for cereals & beans
250 kg/ha K_2O for potatoes

An experiment on sandy clay loam (Table1) shows how crops respond to K. This trial compared plots which had received annual dressings of potash over the period 1899-1977 with those receiving none over the 77 year period.
The cereals did not respond to fresh fertiliser K even where no K had been applied previously whereas the beans and potatoes both showed responses but gave even larger yields on the plots that had previously received K.

Nitrogen and potash relationship

Adequate K reserves are essential to achieve the best possible response to N and thus reduce unit costs of production.

Fig 3 **N&K interaction on yields**

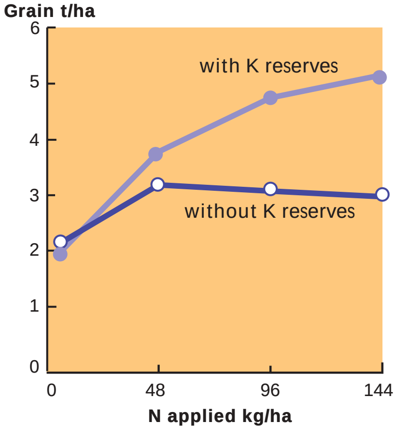


Fig 3 shows how the yields of spring barley grown on a silty clay loam did not respond to nitrogen above 48 kg/ha where K reserves had been depleted by not applying K in the past. In such cases applying the larger amounts of N was both uneconomic and would have left a large residue of nitrate at risk to loss by leaching. The largest rate of N tested was economically justified in the presence of K.

Crop Demand

Some K is required for essential metabolic processes in plant cytoplasm but the majority of K is in the cell vacuole where it is involved with turgor and water control in the plant. Photosynthesis in the green leaves to produce sugars is most efficient in turgid leaves - hence the need for adequate K.

a. Percentage K in the plant

When the K concentration in barley plants is measured as a % of dry matter, it is difficult to distinguish between sufficiency and deficiency. However expressed on a tissue water basis, the K status of the crop does not change during active growth, and is affected only by the quantity of available K in the soil. Thus there is a way of analysing the crop to determine whether the soil K supply is sufficient. Crops with less than the optimum K in tissue water yielded less grain; similar optimum levels appear to hold for other cereals and for grass.

b. Quantity of K in the plant

The amount of K in the crop at harvest depends upon crop yield and this is often controlled by nitrogen levels (Table 2). Table 2 also shows that cereal straw contains more potash than does grain and tops of sugar beet more than the roots. Fig 1 shows that returning these residues to the soil returns the K they contain. Therefore K manuring can aim to just replace the offtake in the grain and roots.

Table 2

Effect of Nitrogen on Potash Offtake kg K_2O/ha

Barnfield, Rothamsted 1969 - 73

Crop	Nitrogen applied kg/ha		
	48	96	144
Spring barley - grain	21	28	31
straw	31	58	80

Crop	Nitrogen applied kg/ha		
	72	144	216
Sugar beet - roots	59	87	110
tops	78	131	158
Potatoes - tubers	125	190	247

K Manuring

On soils with small reserves of K, potash fertilisers are applied in the expectation of getting an increase in yield. On soils which will hold appreciable reserves of K, such reserves have been accumulated from past application of fertilisers and manure. In consequence, potash fertilisers are now applied not in the expectation of getting a yield response but to replace the K removed in the crop taken from the field. Such replacement dressings should maintain the quantity of K in the readily available pool and the relation between this quantity and that in the less readily available pool.

Based on this approach replacement is only necessary on soils at index 2. On soils at index 3 and above replacement is not necessary until soil analysis shows that the soil K index has fallen to 2.

On soils at index 0 and 1 it is advisable to apply more K than that removed in the crop to increase soil K reserves. The benefits for this are shown in Fig 2 and Table 1. For economic reasons this is probably best done a little at a time.

These, however, are general guidelines, some specific points need to be borne in mind.

- Light-textured soils have little clay and organic matter and therefore a very limited capacity to hold readily - and less readily - available K. On such soils K fertiliser must be applied each year and the quantity applied should at least meet the maximum offtake by the crop. On such soils it could be preferable to apply N and K at the same time.

- An exception to the above is sugar beet grown on light textured soils. Recent experiments show no response to K even on low index soils and applying K can increase root % K which is not desirable for processing purposes. K offtake in the roots can be replaced at other times in the rotation.

- Crops which are responsive to K (potatoes and some vegetables), may be given more K than is removed. This results in a positive balance which can be allowed for by applying less K to other crops in the rotation

Other PDA leaflets

1 Role of Potash (out of print)
2 Potash - Maintaining the Balance (out of print)
3 Potash for Quality (out of print)
4 Potash manuring for Arable Crops
5a Results from Cereal Demonstration Plots
5b Results from Grass Demonstration Plots
6 Potash, Magnesium & Sodium Fertilisers for Grass
7 P & K Balance for Cereals
8 Principles of Potash Use
9 Potash for Silage
10 Potash & Cereal Straw
11 Cereals and Potash
12 Potash for Sugar Beet
13 Oilseed Rape and Potash
14 Potash for Grassland
15 Potash for Potatoes
16 Fodder Beet -Fertiliser Requirements
17 Forage Maize - Fertiliser Requirements
18 Grain Legumes need Potash
19 Potash for Heavy Soils
20 Potash & Biosolids
21 Cutting Fertiliser Costs (out of print)
22 N & K top dressing for arable crops
23 Potash for Organic Growers
24 Effective use of Soil Analysis
25 What you should know about fertilisers
26 Nutrient requirements of forage crops
27 Fodder Beet - P & K offtake
28 Why Maintain Soil Potash Reserves?

Grassland Kalculator
Arable Kalculator
P&K Offtake Standards
Nutrient Content of Manures

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The Potash Development Association is an independent technical organisation formed to support the efficient use of potash fertiliser in the UK

Leaflet 4 3/2000

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