leaflet 11

The Potash Development Association

Potash for Cereals

Introduction

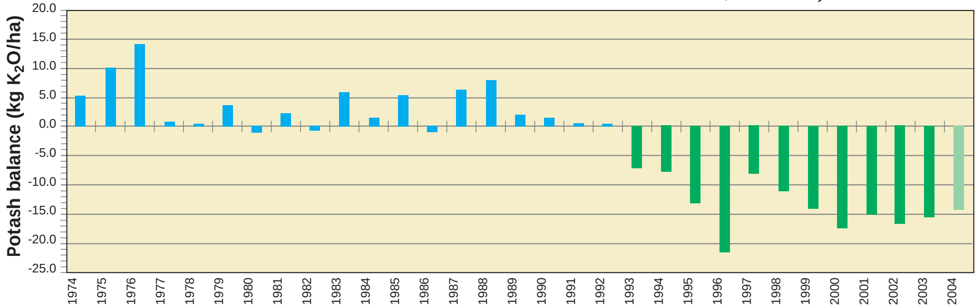
There is tremendous pressure on cereal farmers to reduce costs. Expenditure on fertilisers ranges between £60-100 per hectare and this represents around a third of total cereal variable costs making this an important area for potential cost cutting. Basal P and K are particular targets because reductions in use may have little or no visible effect in the short term. This leaflet provides a comprehensive review of phosphate and potash nutrition for cereals and gives detailed recommendations for optimum economic fertiliser usage.

National balance sheet for basal nutrients

Since around 1997, average potash usage in England and Wales has been less than potash removed by grain and straw resulting in an inevitable reduction of soil potash reserves. A similar imbalance has also developed for some other main arable crops and this also applies to phosphate. These trends have continued and will lead to serious consequences for yield and quality. The length of time before financial penalties occur will depend upon soil type and the P and K reserves of individual fields.

Overall annual potash balance in England & Wales for cereals, oilseed rape, potatoes and sugarbeet (axcluding manure inputs).

Sources: Defra, British Survey of Fertiliser Practice



The area of cereals receiving no P or K at all has also increased significantly in recent years - in 2002/03, 40% of the winter wheat area sown received no P or K. As only around 25% of the soils growing cereals are at an index where potash can safely be omitted, this is further evidence of imprudent cost cutting.

It must not be assumed that because cereals are known to be efficient scavengers of P and K and because no visual symptoms are seen, that such cost cutting is without penalty. Serious economic consequences can occur with out any visible symptoms of deficiency. Soil P and K values may decline only slowly but as they fall below accepted threshold levels, the risk of yield and quality losses increases. Such risks are not worth taking because of the essential requirement of these nutrients for the maintenance of yield and quality.

Why potash is important

Potash affects both yield and quality of grain as well as the general health and vigour of the plant. Cereal crops need at least as much, if not more, potash than any other nutrient including nitrogen. Potash is needed in such large amounts because it is the major regulator of solution concentrations throughout the plant. It controls cell sap content to maintain the turgor of the plant and supports the movement of all materials within the plant. Potash supply is thus essential for all nutrient uptake by the roots and movement to the leaves for photosynthesis, and for the distribution of sugars and proteins made by the green tissue for plant growth and grain fill.

The practical implications of shortage of potash are summarised in the following table :

Deficient K	Satisfactory K
Low yield	No yield restriction
Inefficient N response	Full N response
Increased risk of N loss	Minimum N loss
Reduced 1000 grain and specific weights	Full 1000 grain and specific weights
Reduced grain ripening period	Maximum grain ripening period
Fewer grains per ear	Full grain number per ear
Poorer grain sample	Normal grain sample
Weaker straw	Normal straw strength for variety
Increased risk of lodging	Lodging risk normal for variety
Increased susceptibility to drought	Normal drought resistance
Increased disease susceptibility	Normal disease susceptibility

Effect on cereal yield components

Adequate available potash is essential for the production of high-quality marketable grain with good specific weight and well filled grains. A shortage will result in premature ripening with significantly lower individual grain size and weight, and will also prevent some potential grain sites from developing, thus reducing the number of grains per ear.

	Level of potash		
	Deficient	Intermediate	Sufficient
Days from flowering to ripening	46	68	75
Grain number per ear	36	38	43
1000 grain weight (g)	17	33	34

Effect on straw strength

Potash enhances the development of strong cell walls and therefore stiffer straw. Lodging is affected by obvious factors such as variety, N rate and weather, but low potash levels also increase the risk of lodged crops with the associated loss of yield and quality. The effect can be as dramatic as a lack of growth regulator in some circumstances as illustrated in the photograph below.

Effect on plant vigour and health

In the absence of satisfactory potash supply, plants will be poor and stunted, especially in dry seasons. Physiological stress will be more damaging if potash nutrition is limiting - frost damage will be more severe, waterlogged areas will take longer to recover and plants will wilt earlier and remain flaccid for longer under drought conditions.

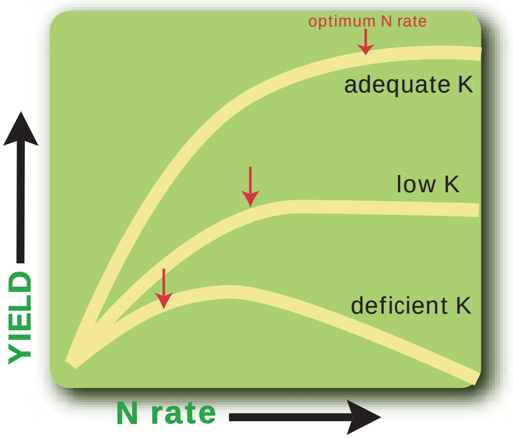
Crops will be more susceptible to disease and pests especially where nitrogen and potash availability are imbalanced. This will result in weaker, sappier growth which will contain a higher concentration of soluble N compounds and simple carbohydrates providing a readily available food source and attractive focus for pathogens. Thinner cell walls with less mechanical resistance to predators may also result from potassium shortage. A review of over 1000 cereal trials found that where potash levels were low and out of balance with N supply, application of potash reduced disease and bacterial infections in over 70% of cases.

N:K partnership

Cereals require a balance of nitrogen and potash to obtain full yield response to applied nitrogen. Careful optimisation of nitrogen is a waste of time if potash supplies are not adequate. As shown in the diagram, both the level of yield and the shape of the N response curve are totally altered by potash limitations.

If potash supply is limiting, the uptake and utilisation of nitrogen will be restricted. If soluble forms of nitrogen remain in the soil and are not taken up there is increased risk of leaching when through-drainage occurs. Ready availability of both nutrients at peak crop demand helps the uptake of the large requirements of N and K. During rapid vegetative growth, the rapid uptake of nitrogen as negatively charged nitrate ions (NO3-) is normally balanced by a similar uptake of positively charged potash ions (K+) which maintains the electrical neutrality of the plant. Adequate potash is clearly important in the production of quality wheat as it assists the conversion of nitrate to protein.

Effect of potash on nitrogen response



Deficiency symptoms

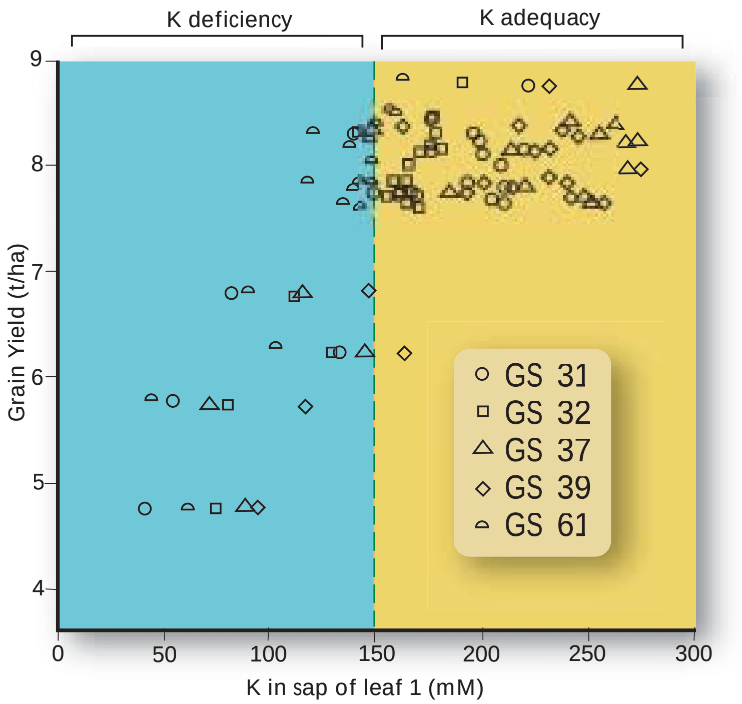
Potassium deficiency causes yellowing and chlorosis to the edge and tip of older leaves, with progressive senescence. Plants may be stunted and exhibit excessive basal tillering. Symptoms are not easily distinguished from those resulting from many other causes especially from physiological stress - drought, water-logging, wind, etc.

By the time such symptoms are seen it is often too late to remedy the situation and avoid crop loss. Potassium deficiency is sometimes referred to as 'hidden hunger' because losses occur despite any recognisable visual symptoms. Visual diagnosis is thus a totally unreliable means of detecting potassium shortage. Soil analysis is the most cost-effective approach providing an indication of adequacy or deficiency for future crops.

Tissue testing

Soil analysis indicates the potential supply of K to a crop. It cannot tell you if sufficient K is actually getting into the crop, only tissue testing can do that. Tissue testing can be used to assess the potassium status of a growing crop but can come too late in the season to remedy a deficiency. Tissue testing can be used as an adjunct to soil analysis or as an extra diagnostic tool in specific circumstances. The maintenance of an adequate level of soil K can be achieved at low cost and will normally ensure that crop needs are being met without the need for tissue sampling and analysis.

Potassium in leaf sap of winter wheat



Source: P Barraclough, IACR Rothamsted

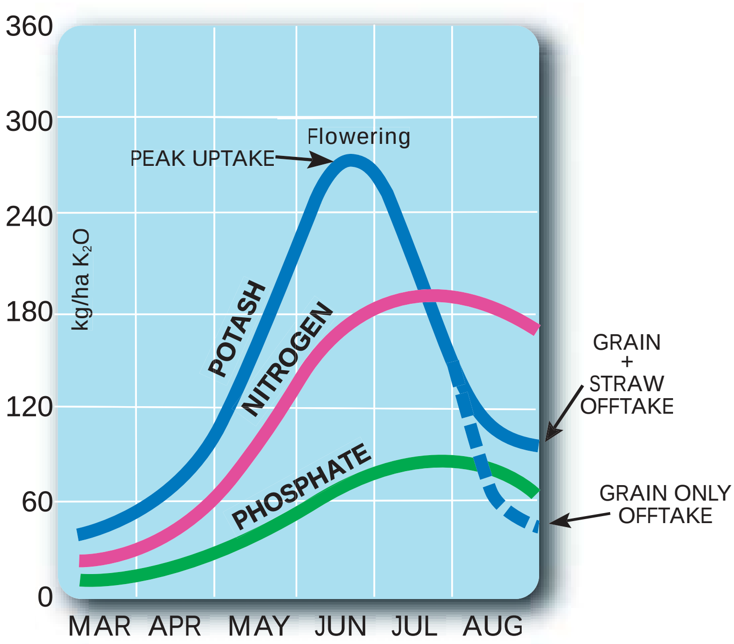
Where tissue testing is used, measurement of tissue water (cell sap) is recommended. This indicates whether K concentrations are at or below optimum levels and is more reliable and meaningful than measurement of K content in the dry matter. %K in dry matter varies widely with season, stage of growth, part of plant, fertiliser (N or K) application and weather or other factors which affect nutrient uptake and rate of growth.

Work at Rothamsted Research funded by the HGCA has indicated that adequacy of potash in winter wheat is represented by tissue water concentration in leaf 1 (the youngest mature leaf blade) between 150 and 200 mM K for growth stages between GS31-61. Plant concentrations below this range may result in yield penalties.

Potash uptake

Potash uptake during establishment is low with winter wheat typically containing around 40-50 kg K2O/ha over winter, more forward winter barley crops may contain up to 80 kg K2O/ha. Whilst these amounts are relatively small, a deficiency of nutrient at this early stage clearly can have critical effects and where soil K levels are low (mid index 1 or below) some potash should be applied to the seedbed - ideally combine drilled if the soil reserves are very low. As the crop reaches tillering and starts to make vigorous vegetative growth, potash and nitrogen uptake increase very rapidly as shown in the diagram. Potash uptake may be as high as 10 kg/ha per day and on light, low K soils this may outpace the soils natural capability to supply. In such circumstances spring NK top dressing makes good sense (see PDA Leaflet 22). This is also good practice on these sandy, low K-retentive soils because split autumn and spring application minimises risk of potash loss under excessive winter rainfall. Peak potash uptake with cereals occurs around late flowering stage when there may be more than 250 kg/ha of potash in a high yielding crop. If this peak requirement is not available, grain number and grain fill will be affected thus prejudicing both yield and quality. This is a key reason for maintaining the adequate soil reserves which can supply these peak amounts more satisfactorily than fresh fertiliser applications. After flowering, potash is redistributed around the plant with a general reduction from leaves to grain and stem bases. Potash is also returned to the soil with the senescence and shedding of older leaves. The rate at which this potash redistribution process occurs varies widely with different seasons and affects potash levels in the straw.

Nutrient uptake of a typical 8t/ha wheat crop

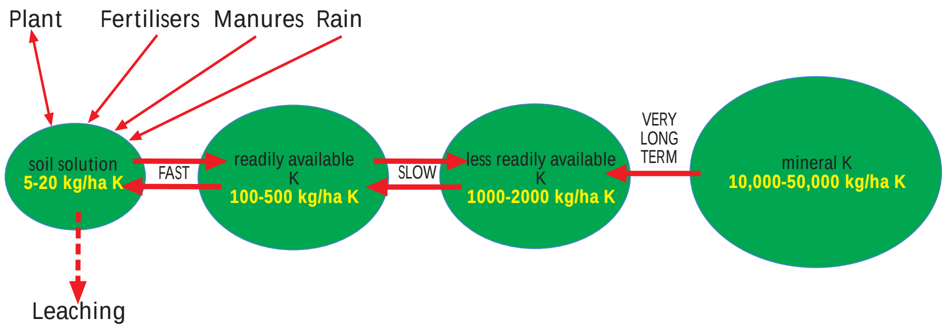


Sources & losses of potash

Virtually all the potash supply to a cereal crop is taken up from the soil. Small quantities of potash (less than 5 kg K2O/ha) are deposited in rainfall, but foliar uptake is not a practical route for the large requirements of this nutrient. Foliar fertiliser applications to cereals are rarely cost-effective. Potash is held in the soil as the positively charged cation, K+, which occurs in small amounts (less than 20 kg/ha) in the soil solution and in much larger amounts in readily or slowly available form attached to the clay minerals. An even larger quantity is also present within the clay minerals but this can be discounted in terms of crop supply as it is only released over long time periods by weathering. The rate and quantity of potash that a soil can supply for crop uptake depends upon soil type, texture, soil condition and previous history of manuring.

Potash in fertilisers and manures is 90-100% available, but if not taken up by crop roots, becomes held by the clay minerals and is therefore not at risk to leaching in the same way as nitrogen. Research studies have shown that for most soils only 1 kg K is lost for every 100 mm of through drainage. Except on light, shallow soils any movement of potash below plough depth is likely to be retrieved by deeper rooting crops such as winter cereals. Applications of potash in excess of crop need will therefore remain as an increase in readily and slowly available soil K reserves for the next crop.

The K cycle



Principles of nutrient management

"Let the soil feed the crop , use fertiliser to feed the soil"

Nutrient reserves in the soil resulting from natural fertility and previous manuring are much more effective in supplying nutrient than newly applied fertiliser. Impoverished soils will often not produce the same yields as fertile soils even if higher fertiliser rates are applied. Thus an adequate supply of potash to the crop should be ensured by maintaining an adequate reserve in the soil. Fertiliser (and manures) should be used simply to maintain this reserve by replacing what is removed in the harvested crop. For impoverished soils extra fertiliser should be used to restore fertility to a satisfactory level. Where nutrient levels are more than adequate, fertiliser usage should be reduced below removal levels, or even omitted.

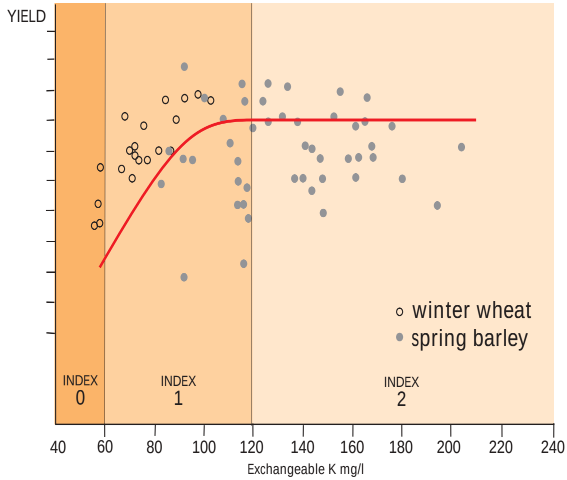
Unlike nitrogen, soil potash reserves are not subject to loss or major change from season to season and thus maintenance of an adequate reserve is a practical strategy on most soils.

Soil analysis

Knowledge of the fertility level in the soil is clearly essential to determine fertiliser policy. It is impossible and irresponsible to guess correct fertiliser use without soil analysis, which should be undertaken every 4-5 years. Soil analysis provides a measure of the nutrient level available to the crop - the total level of potash (and phosphate) in any soil is very much larger but is not relevant to plant use. The physical condition of a soil is also of vital importance, e.g. structure, depth of soil, level of organic matter and stone content. These must be considered first before interpreting soil analysis.

A very large number of cereal trials on different soil types in different regions has been undertaken to establish how cereal performance is related to the available nutrient supply as measured by standard methods of soil analysis.

Response of winter wheat & spring barley to soil K



Yields increase with increasing soil K up to what is described as a critical level, beyond which further improvement in soil K fertility has no effect. Similar data confirm the same principle for soil P. Because soil fertility varies within fields and according to soil conditions and climate, soil analysis is not a precise measurement as these data indicate. The index system has therefore been developed to provide the general pattern of crop response to added nutrient. Soil K index 2 is divided into a lower and an upper half denoted by minus and plus signs.

Soil analysis & crop response

Soil P Index	mg/l	Yield response to added nutrient	Soil K Index	mg/l
0	0-9	Large response likely	0	0-60
1	10-15	Response likely	1	61-120
2	16-25	No response	2-	121-180
		No response	2+	181-240
3	26-45	No response good reserves	3	241-400
4	46-70	Excess nutrient present	4	401-600

Nutrient removal

Potash

Potash removal is the other main factor which needs to be linked to soil analysis to determine correct fertiliser policy.

Potash in grain

Potassium content of grain is typically 0.5-0.6% K in dry matter for all cereals. This equates to around 5.6 kg of potash (K2O) per tonne of grain at 85% dry matter.

Potash in straw

This is of increasing importance as more straw is baled because of the economic pressures caused by lower grain prices. Around 80 – 95% of the barley crop is baled and the reduction in numbers of mixed farms means that a far greater proportion is now sold off farms and not recycled through animals and manure. About half of the wheat crop is also baled and this could rise with developing opportunities for sale into industrial uses.
Potash content in straw is much more variable than in grain and is different for winter and spring wheat and barley, and for oats, and is affected by growing conditions.

Effect of cereal species

Winter cereal straw retains less potassium as there is more time for redistribution of potash out of the upper parts of the plant - typical content is 0.8-1.0% K. Winter barley, being harvested earlier, often retains more K in the straw than wheat. Spring barley and wheat straw typically contain around 1.0-1.25% K. Both spring and winter oats tend to retain much higher levels of K in straw than other cereals - often with values of over 2% K in dry matter.

Effect of growing conditions

With very dry pre-harvest conditions, the rapid desiccation of the crop can result in less movement of potash out of the straw. For a given yield of straw, potash removal with a hot, dry harvest can be double that of a normal season. Greater quantities of potash are also retained in the plant when the straw stays green right up to harvest and this is believed to contribute to the higher potash values found in oat straw. It is possible that treatments such as strobilurin use which retain green-ness later in crop life might also have an effect upon potash retention and thus removal.

Effect of straw yield

Potash removal will obviously increase with straw yield but for practical purposes because straw yields are not normally recorded, typical values for potash removal where both grain and straw are removed are quoted per tonne of grain yield. Straw yield is assumed as a fixed 65% of grain yield.

Phosphate removal

Phosphate content of straw is very much lower than potash. Removal of straw thus has little effect upon phosphate offtake.

Typical removal standards

	METRIC kg/t of grain P_2O_5	K_2O
Cereals - grain only	7.8	5.6
- grain & straw		
Winter wheat/barley	8.6	11.8
Spring wheat/barley	8.8	13.7
Oats	8.8	17.3

Imperial conversion: kg/t x 2 = units/t

On light soils, where it is more difficult to maintain potash at a satisfactory level, it is important for cereal growers to note that baling the straw from a typical 7 t/ha grain crop removes an extra 40-80 kg/ha of potash over and above that in the grain. This is worth around £8-16/ha.

Recommendations

The recommendations below are calculated to achieve full yield and maintain, improve or reduce soil P and K according to the soil index and soil type. The approach firstly identifies the amount of nutrient removed by the cereal crop grown (the maintenance amount or M) and then adjust this according to the current soil index level.

Phosphate

Maintenance requirement M (kg/ha)	
Grain only - All cereals	yield t/ha x 7.8 = M
Grain + Straw	
Winter wheat/barley	yield t/ha x 8.6 = M
Spring wheat/barley	yield t/ha x 8.8 = M
Oats	yield t/ha x 8.8 = M

Soil fertility adjustment (kg/ha)					
Index	**0**	**1**	**2**	**3**	**4**
mg/l	(0-9)	(10-15)	(16-25)	(26-45)	(46-70)
Phosphate requirement	**M+50**	**M+25**	**M**	**M-50**	**nil**

Potash

Maintenance requirement M (kg/ha)	
Grain only - All cereals	yield t/ha x 5.6 = M
Grain + Straw	
Winter wheat/barley	yield t/ha x 11.3 = M
Spring wheat/barley	yield t/ha x 13.7 = M
Oats	yield t/ha x 17.3 = M

Soil fertility adjustment (kg/ha)						
Index	**0**	**1**	**2-**	**2+**	**3**	**4**
mg/l	(0-60)	(61-120)	(121-180)	(181-240)	(241-400)	(401-600)
Potash requirement	**M+50**	**M+25**	**M**	**M-25**	**M-70**	**nil**

Special cases

Sand soils

It is not economic to increase soil K beyond 100 mg/l on these soils because of their very low capacity to hold nutrients. Improvement can be achieved by many years dressing with FYM. Nutrients should be applied 'little and often' on these soils (see PDA Leaflet 22).

Loamy sands

It is not economic to increase soil K beyond 150 mg/l on these soils because of their low capacity to hold nutrients. Improvement can be achieved by many years dressing with FYM (see PDA Leaflet 22).

K releasing clay soils

Some clay soils can release potash over many years. Normal potash rates can be reduced by 50 kg/ha and omitted completely at index 3 (see PDA Leaflet 19).

High pH soils

It is sometimes suggested that calcareous soils may have a different requirement for phosphate and potash. The principles of response and the recommendations given above are applicable to these soils. However for the shallower chalk/limestone soils there can be greater risk of loss of potash, even though they have a higher clay content than sandy soils, because of their depth and a high proportion of stone in the topsoil (both these factors restricting the volume of soil for nutrient provision) Target fertility in these cases must be adjusted as with other low retentive soils. Calcareous soils with pH typically over 7.5 and high organic matter ('puffy chalk soils') may 'lock-up' a higher proportion of applied potash than other soils, so that low index levels may take longer to improve. But this does not alter the amount of nutrient required to achieve full yield.

Manures

Only 15% of winter cereals and 30% of spring barley nationally receive any manure but it is important that nutrient contribution from this source is estimated and fertiliser use adjusted accordingly. Whilst there are often higher priorities for manure use, e.g. for roots, vegetables and conserved forage crops, regular measured applications of manure will benefit cereal crops, especially on the extremes of soil type - very light or very heavy - by improvement of physical characteristics as well as nutrient supply.

Timing

Phosphate

Because phosphate helps root development it is important to ensure adequate supplies of P are available for the developing root system. Unfortunately phosphate is a very immobile nutrient and roots have to grow to where the phosphate is rather than the reverse. Water soluble phosphate in fertilisers may also become less available fairly rapidly in some soils. Hence where soil P is less than adequate, i.e. at less than index 2, phosphate should be applied in the seedbed and at very low soil index is best placed near to the seed. This is of greatest importance on heavy soils and soils with poor structure, as root extension to find the P is even more difficult on such soils. However under good soil and climatic conditions, for soils at the target level of Index 2 maintenance dressings can be applied at any time during the growing season. Rotational manuring may also be considered but policies involving large amounts of phosphate at one time are not desirable if there is any risk of loss of run-off or soil erosion.

Soil P (Olsen test)	Timing guidelines
Under 14mg P/1	All in seedbed
14-18 mg P/1	Annually, in seedbed or in spring
Over 18 mg P/1	At any time (rotational manuring possible)

Potash

Whilst this nutrient is slightly more mobile than phosphate it is still good sense to apply potash in or before the seedbed where soil reserves are low. In these circumstances on heavy soils or where soil structure is poor and nutrient may be accessed by roots less easily, all the requirements are best applied at or before drilling. For light and shallow soils, where fertiliser needs are often high because of a low soil index, it is good practice to split applications for winter cereals, with some in the seedbed and the remainder accompanying nitrogen top dressing in the spring (see PDA Leaflet 22). This ensures a supply at establishment, avoids possible risk of downward movement over winter, provides the beneficial combination of N and K to assist rapid uptake in the spring and permits more flexibility of product choice to provide optimum rates of P and K. For soils with adequate reserves, i.e. at a soil index of 2, potash requirements can be applied at any time as the objective is simply to replenish soil levels for the following crop. Rotational manuring may be attractive but whilst there are no environmental concerns with K, large single dressings are unwise on light or shallow soils because of risk of loss.

Soil K	Timing guidelines	
Less than 100mg k/1	**Winter cereals** -	Light soils : 50% in seedbed, rest in spring
		Other soils : all in the seedbed
	Spring cereals -	Light soils : between January & sowing
		Other soils : between autumn & sowing
100-150mg K/1	**All cereals** -	annually, at any time
Over 150mg K/1	**All cereals** -	at any time (rotational manuring possible)

Economics of potash use

Many factors influence the adequacy of potash supply for optimum growth, but the risk of yield (and quality) penalties increases the lower the soil index. The cost of normal potash recommendations as shown in the table is modest and is covered by only a very small yield difference. 1 kg of potash normally costs only 50-60% as much as 1 kg of phosphate or nitrogen and there is a danger that its agronomic importance is placed on the same level. Making relatively small cost savings on potash which may run the risk of greater losses of crop value is not sound management.

Cost of normal potash recommendations

	Soil K Index 0	 Index 1	 Index 2
8t/ha Winter wheat - straw returned			
Cost of nutrient **£/ha**	**21**	**15**	**10**
Weight of grain with equivalent value **t/ha***	**0. 32**	**0.23**	**0.15**
6t/ha Spring barley - straw removed			
Cost of nutrient **£/ha**	**29**	**23**	**18**
Weight of grain with equivalent value **t/ha***	**0.44**	**0.37**	**0.27**

***Wheat at £65/t Barley at £65/t**

Recent potash response experiments endorse the principles of manuring on which current recommendations are based, e.g. large economic responses are certain at K index 0. Smaller but economic responses are likely at index 1. If replacement dressings are not made at index 2-, soil K will fall to index 1 at a rate depending upon soil type.

General guide to economic return

K index 0 **£10 return for every £1 spent on potash**

K index 1 **Up to £5 return for every £1 spent on potash**

Other PDA leaflets

FOR MORE INFORMATION ON POTASH CONTACT:-

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The Potash Development Association
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