Technical Note TN633

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SAC

Phosphorus, potassium, sulphur and magnesium recommendations for cereals, oilseed rape and potatoes.

SUMMARY

- **Good soil management is required to optimise nutrient use and maximise arable productivity.**
- **Regular soil analysis is essential to manage soil pH and phosphate and potash inputs for optimum yields and profitability.**
- **Emphasis is placed on maintaining soil Moderate PK Status and replacing offtake in combinable crops.**
- **Phosphate recommendations for potatoes take account of results from recent trials.**
- **Appropriate use of bulky organic fertilisers can result in considerable savings on purchased fertilisers.**

1. Introduction

Phosphate, potash, sulphur and magnesium recommendations for cereals, oilseed rape and potatoes have been updated in the light of current advances in understanding of soil nutrient management and results from recent trials. The efficient and profitable use of organic and manufactured fertilisers in arable systems requires good soil conditions and effective soil management. Compaction of the upper soil layers arising from trafficking limits root development, restricts nutrient uptake and reduces growth potential. An SAC field guide to identifying soil compaction is available at http://www.sac.ac.uk/mainrep/pdfs/soilstructure.pdf.

Maintaining the optimum pH in the topsoil in all parts of the field is important to achieve optimum yields and consistent quality. Soil should be sampled and tested every 4–5 years. Over-use of P can lead to phosphorus loss from agricultural land to fresh waters and impair water quality.

This technical note can be used along with PLANET Scotland, a software tool designed for routine use by Scottish farmers and consultants to plan and manage nutrient use on individual fields (http://www.planet4farmers.co.uk).

2. Soil Testing

Soil sampling programme

The optimum availability of most plant nutrients in soil occurs over a small range of soil pH values. Aim for an optimum soil pH of 6.0 to 6.2 in all parts of the field on mineral soils. Aim lower at pH 5.7 to 5.9 on organic soils. Soil pH can vary considerably metre by metre, especially if there is a range in soil textures within fields. GPS sampling for soil pH at 4 samples/ha and variable lime application can be cost-effective in many fields. Identifying major soil types and yield variation in the field is a key step in establishing the need for GPS sampling. Before embarking on GPS sampling within fields for soil pH

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- Compare crop and variety performances between fields
- Monitor crop development including weeds and pest damage
- Identify and cost poor output areas
- Identify and remedy soil structural and wetness problems
- Prioritise fields

Soils should be sampled every 4 to 5 years and analysed for soil pH, extractable P, K and Mg. Fields are best sampled before potatoes which often give a yield response to PK fertiliser in the year of application. Cereals and oilseed rape do not generally respond on moderate PK status soils and sampling time is therefore not so crucial, but the application of fertilisers and manures may influence results for up to 12 weeks after application. Results may be lower than expected if fields are sampled during periods of maximum nutrient uptake, but higher (or more variable) than expected in spring due to decomposition of crop residues. Fields should be sampled between September and February, depending on timing of fertiliser applications. Analyses for P and K can vary considerably, especially at higher P or K values or where different major soil types exist in a field. One average soil test value for a whole field inevitably masks this variation. GPS sampling can help overcome this and identify areas in the field where P and/or K are under- or over-supplied. However, it is not economic to sample soils for P, K and Mg more intensively than 1 sample/ha.

Target soil P and K levels

It is very important to know the method of analysis before interpreting results. The different methods extract different amounts of P, K and Mg and must be interpreted differently. The SAC Modified Morgan's method is recommended for soils in Scotland. Analysis results are classified into soil P, K and Mg Status in Table A. The soil testing method used by Defra (RB209) for England and Wales is compared with the SAC method in Table A, although the comparison is not direct.

Soil analysis does not predict crop uptake of P or K - only whether sufficient is available for crop uptake over a growing season. Actual uptake depends on crop, yield potential, rooting depth and weather. Large responses to P and K in the year of application are only expected where the soil P and K Status is very low, and are infrequent on soils of moderate Status. Potatoes are more responsive to P and K fertiliser than cereals and oilseed rape. For cereal-based arable rotations, the target soil P Status is moderate (M) and K Status is the lower half of moderate (M-). For rotations with potatoes, target P and K levels are upper half of moderate (M+). It is important that the soil P Status is not built up over and above the target level. Besides being wasteful, the loss of soluble P in sediment during bouts of surface run-off can contribute to poor water quality. For soils that are above the target levels for P and K, savings can be made in both P and K applications.

3. Phosphate and potash recommendations

Cereals and oilseed rape

Role in cereal and oilseed rape nutrition

Phosphate helps root development, early growth and the ripening of seeds. With P deficiency leaf colour is generally a dull, bluish green and ripening may be delayed. Potash promotes root development and gives strength and stiffness to the whole plant. Cereals inadequately supplied with K are more prone to lodging at high rates of nitrogen than are those with an adequate supply. Cereals suffering from K deficiency usually have a high proportion of small, shrivelled grains. Deficiency systems appear first in the older parts of the plant. The older leaves may be a lighter green than the young growth and usually show a pronounced marginal and tip scorch. Cereals in the seedling stage may exhibit symptoms identical to frost damage, with the upper portions of the older leaves becoming completely white.

On moderate PK Status soils, apply 'maintenance' PK fertiliser applications to balance the offtake in cereals and oilseed rape. PK offtake can be calculated by multiplying typical or expected yield by PK content as given in Table B. This should maintain soil test P and K levels ready for the next crop or rotation. Soil P levels may decline over the rotation in some soils, due to gradual fixation, when only maintenance applications are made. Regular soil analysis detects this, allowing adjustments to be made. The PK applied in organic fertilisers should be taken into account in assessing the need for manufactured fertiliser (see section 6 below).

Leaf analysis

Leaf analysis identifies what is in the crop; it does not predict how much will be taken up. Its main purpose is to assess if a crop has acquired adequate P and K from soil by a particular growth stage. It can confirm if a fertiliser policy has led to a deficiency or over-supply. Plants are best sampled for P and K during stem extension when plants make maximum demands on the soil.

Soil P and K balance

The balance between PK offtake and PK applied in organic and manufactured fertilisers can be made at the end of the season when actual yield is known. Allowance should be made for any surplus or deficit in PK in planning for the following season's fertiliser. The PLANET Scotland software can be used for field-level nutrient

Table A. Classification of mg/l values into Status for P, K and Mg

SAC Status	P		K		Mg	
	SAC	RB209	SAC	RB209	SAC	RB209
VL	0-1.7	0-9	0-39	0-60	0-19	0-25
L	1.8-4.4	10-15	40-75	61-120	20-60	26-50
M-	4.5-9.4	16-20	76-140	121-180	61-200	51-100
M+	9.5-13.4	21-25	141-200	181-240	61-200	51-100
H	13.5-30.0	26-45	201-400	241-400	201-1000	101-175
VH	>30.0	>45	>400	>400	>1000	>175

planning, record keeping and calculating a *Farmgate Nutrient Balance* of nitrogen, phosphate and potash coming onto the farm (e.g. in feeds, manufactured and organic fertilisers) and those exported off the farm (e.g. in farm produce).

There is information on PK removal in straw separately to that in grain (Table B), which will help in assessing the financial value of straw when the weight is known. However, K content of straw can vary substantially – higher than average rainfall between crop maturity and baling straw will reduce straw K content. As a result less K will be removed from the soil by removal of the straw when the harvest period is wet.

If the soil P or K Status is below target (moderate), apply additional fertiliser to build up to a moderate PK Status. Where soil PK Status is high, rates of PK should be lower than maintenance e.g. 50% of K offtake (Table C).

Table B. Typical yields of cereal and oilseed rape crops (fresh weight)* and standard PK content in grain/seed and straw (fresh weight)

Crop type	Grain/seed or straw	Yield (t/ha)	P content (kg P_2O_5/t)	P offtake (kg P_2O_5/ha)	K content (kg K_2O/t)	K offtake (kg K_2O/ha)
Barley, winter Wheat, winter	Grain only	8.0	7.8	62	5.6	45
Barley, spring Rye, spring Triticale, winter Triticale, spring Wheat, spring Oats, spring Oats, winter	Grain only	6.0	7.8	47	5.6	34
Barley, winter Wheat, winter	Grain + straw**	8.0	8.4	67	10.4	83
Barley, spring Rye, spring Triticale, winter Triticale, spring Wheat, spring	Grain + straw**	6.0	8.6	52	11.8	71
Oats, spring Oats, winter	Grain + straw**	6.0	8.8	53	17.3	104
Oilseed rape, spring	Seed only	2.0	14.0	28	11.0	22
Oilseed rape, spring	Seed + straw**	2.0	15.1	30	17.5	35
Oilseed rape, winter	Seed only	3.5	14.0	49	11.0	38
Oilseed rape, winter	Seed + straw**	3.5	15.1	53	17.5	61
Barley, winter Wheat, winter	Straw only***		1.2		9.5	
Barley, spring Rye, spring Triticale, winter Triticale, spring Wheat, spring Oats, spring Oats, winter	Straw only***		1.5		12.5	
Oilseed rape	Straw only***		2.2		13.0	

*cereals at 15% moisture and oilseed rape at 9% moisture
**Offtake values are per tonne of grain or seed removed but include PK in straw when this is removed without weighing
***These values to be used only when straw weight is known

Table C. Phosphate and potash adjustments for soil PK Status in kg/ha for cereals and oilseed rape

Crops	P_2O_5 Soil P Status				K_2O Soil K Status			
	V. low	Low	Mod.	High	V. low	Low	Mod.	High
Cereals and oilseed rape	+80	+40	0	-20	+60	+20	0	K offtake x 0.5

Potatoes

Role in potato nutrition

With P deficiency leaf colour is generally a dull, bluish green. Phosphate increases the rate of early development of the crop, improving the rate of haulm growth and tuber initiation and early bulking. Except for cases of extreme deficiency, fertiliser P does not increase growth rate or haulm persistence later in the season. A further effect of P is to increase tuber number more than tuber yield, increasing the proportion of seed in the crop. This reinforces the justification for higher rates of fertiliser P on seed crops, but high rates of P should not be regarded as a major means of attaining a high tuber number (Table D). In recent trials inconsistent and marginal increases in tuber number and total yield were recorded where fertiliser P was applied to soils of the Upper Moderate and High P Status. Recommendation rates of P fertiliser have been reduced on these soils, compared to previous SAC recommendations.

Potash is required for the establishment and persistence of vigorous haulm and for improved bulking rate and persistence of late season growth. Fertiliser K increases tuber size and the proportion of ware in the crop. At the levels of K required for optimum yield of ware potatoes, the yield of seed will be reduced. Dry matter content of tubers is reduced by K, particularly if muriate (chloride) is applied rather than sulphate of potash. Recommended rates of K in Table D may have to be reduced to achieve dry matter targets for crisping or processed chips. Alternatively only K fertiliser containing sulphate of potash should be used or, if muriate is used, it should be applied at least 2 months prior to planting to provide time for some chloride to be washed below plough depth. Fertiliser K increases the susceptibility of potatoes to cracking, splitting and scuffing. The recommended rates should only be exceeded if internal bruising is a more persistent problem than external damage. Higher dry matter tubers are more prone to internal bruising. Soft rots are more prevalent in low dry matter and/or damaged tubers. Therefore K rates above those recommended should be avoided.

The available PK applied in organic fertilisers should be taken into account in assessing the need for manufactured fertiliser (see section 6 below). Large dressings of organic fertilisers and irrigation will exacerbate the effects of K on dry matter and associated damage.

Soil P and K balance

The balance between PK offtake and PK applied in organic and manufactured fertilisers can be made at the end of the season when actual yield is known. The PK offtake can be estimated using typical values of 1.0 kg P_2O_5 and 5.8 kg K_2O per tonne fresh tubers. There will often be a surplus of P remaining in the soil after potatoes, which will help to maintain the soil at the target P moderate Status for an arable crop rotation and should be allowed for when assessing fertiliser P for one or more following crops. In many fields there will be a deficit of K remaining in the soil after potatoes, and allowance should be made for any deficit in planning K fertiliser use elsewhere in the rotation.

Timing

All the manufactured P fertiliser should be applied in the spring and either worked into the seedbed or placed at planting. These recommendations should be used for both bed and ridge and furrow systems. All the manufactured K fertiliser should also be applied in spring unless muriate is applied in late winter in an attempt to maintain dry matter content of tubers. Organic fertilisers should be applied in late winter or early spring and must take account of Action Programme Rules in NVZs (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).

The benefit of foliar applied P was evaluated in trials over a decade ago. In these trials, small increases (often non-significant) were recorded in tuber number. Routine use of foliar phosphate is not recommended but there may be circumstances for seed growers where uptake of soil applied P is restricted and foliar applied P may increase tuber numbers.

4. Magnesium recommendations

Potatoes are susceptible to magnesium (Mg) deficiency and may show yield responses to Mg fertiliser on soils where the Mg Status is very low or low. Deficiency symptoms are interveinal chlorosis beginning on older leaves, giving a mottled appearance. Symptoms occur early in the growing season when root growth is restricted, for example by soil compaction or cold weather, but they often disappear as the roots grow and thoroughly explore the soil for nutrients. Magnesium deficiency is most severe in dry summers where irrigation is not applied. When early symptoms of Mg deficiency develop, a foliar application of magnesium sulphate (Epsom salts; 16% MgO) at 15-25 kg/ha may be applied in a single dose but each 5kg should be dissolved in 100 litres water. Other commercial products are available. Label recommendations should not be exceeded.

Table D. Potatoes: phosphate and potash recommendations in kg/ha

Anticipated length of growing season* and intended market	P_2O_5 Soil P Status					K_2O Soil K Status			
	V. low	Low	Moderate		High	V. low	Low	Mod.	High
			Lower (4.5-9.4mg/l)	Upper (9.5-13.4mg/l)					
< 60 days (seed and punnets) and 60-90 days (seed and punnets)	265	225	175	100	50	200	160	110	60
60-90 days (ware) and > 90 days	240	200	150	75	50	240	200	150	100

*The length of growing season is the number of days from 50% emergence to haulm death.

Symptoms in cereals are leaf margin scorch in semi-circles and a mottled appearance in leaves. Oilseed rape symptoms are interveinal yellowing (marbling) of older leaves often associated with a blotchy reddening or purpling usually seen in early spring during stem extension.

Where soil Mg Status is very low or low and soil acidity needs to be corrected, applying magnesian limestone is recommended. An application of 5 t/ha of magnesian limestone will add at least 750 kg MgO/ha, and this Mg will become plant-available over many years. However, if used too frequently, the soil Mg Status can become unnecessarily high. In this situation care should be taken to ensure that there is sufficient available K in soil to ensure that there is no risk of K deficiency in the crop being grown. Where Mg Status is very low or low but additional lime is not required, alternative sources of Mg should be used e.g. calcined magnesite (typically 80% MgO) or kieserite (25% MgO). In such cases between 80 and 120kg/ha MgO should be applied.

5. Sulphur recommendations

As atmospheric deposition of sulphur (S) continues to decline, it is likely that the risk of S deficiency will affect an increasingly wide range of crops grown on many different soil types. Oilseed rape is particularly sensitive to a shortage of sulphur and the application of S as part of the spring top dressing is now common. The best guide for assessing the risk of S deficiency is soil type and field location. Sands, shallow soils or sandy loams with low organic matter levels are most prone to deficiency. Fields that have received regular applications of organic fertilises and organic soils are less likely to show deficiency. Soil analysis can help identify severely deficient soils but in other situations is not as reliable a guide as plant analysis. Sulphur deficiency in cereals causes paling of young leaves and crop stunting that can easily be confused with nitrogen deficiency (which usually affects older leaves first). In oilseed rape, middle and upper leaves (in contrast to Mg) can show interveinal yellowing, and flower petals are unusually pale. Sulphur deficiency symptoms in potatoes are rare but where they occur, younger leaves turn a uniform light green to yellow.

Elemental S, broadcast or applied in furrow, or the application of ammonium sulphate are used by some growers to reduce common scab development of potato tubers. Trials using elemental S have shown highly inconsistent control of common scab. Trials using ammonium sulphate are more limited but results suggest more consistent, but small, reductions in common scab.

If deficiency is expected, the best treatment is to apply S in the spring as water soluble sulphate (SO_4), which is rapidly available for crop uptake e.g. ammonium sulphate (60% SO_3) and kieserite (typically 52% SO_3), as well as a range of compound and blended fertilisers. Recommended rates are given as SO_3-S in Table E (to convert S to SO_3, multiply by 2.5). Elemental sulphur (typically 200-225% SO_3 i.e. 80-90% S) must be oxidised to sulphate before it becomes available for uptake.

Leaf analysis

Leaf analysis is a useful guide to diagnosing S deficiency in cereals and oilseed rape. Although analytical results may be available too late to restore the crop to full yield potential, they can be useful for decisions on S use for future crops.

6. Availability of nutrients in organic fertilisers

Organic fertilisers are valuable sources of P, K, S and Mg, although not all of the total nutrient content will be available for the next crop. Nutrients which are not immediately available will mostly become available over a period of years and will usually be accounted for when soil analysis is carried out. The availability of phosphate to the next crop grown is lower than from water-soluble phosphate fertilisers. As a general rule, around 50% of the phosphate in pig and cattle slurries and other non-agricultural, bulky organic fertilisers will become available to the crop in the year of application. Around 60% of the phosphate in solid animal manures will become available to the crop in the year of application. Most of the potash present in bulky organic fertilisers will become quickly available for crop uptake. Around 90% of the potash in bulky organic fertilisers will become available to the crop in the year of application, although potash availability from green composts may be rather lower in the first year (around 80%) and from dirty water, somewhat higher (estimated to be around 100%). Information on the nutrient contents of organic fertilisers can be found in SAC Technical Note TN622 on "Optimising the application of bulky organic fertilisers".

Where crop responses to phosphate or potash are expected (e.g. where soils have very low or low P or K status for combinable crops) or where responsive crops are grown (e.g. potatoes), the available phosphate and potash content of the organic fertiliser should be used when calculating the nutrient contribution. Where soil status is at the target level (moderate), the total phosphate and potash content of the organic fertiliser should be used in planning the balance that should be applied as manufactured P and K. At high soil P status, take care to ensure that total phosphate inputs do not exceed the amounts removed in crops during the rotation. This will avoid the soil P status reaching an unnecessarily high level and avoid increasing the risk of P loss from agricultural land to fresh waters. It is important to manage manure phosphate and potash supply over the crop rotation. Organic fertilisers also supply useful quantities of sulphur and magnesium, but there is limited data on their availability for the next crop grown. Sulphur and magnesium inputs from manures should largely be regarded as contributing to the maintenance of soil reserves.

Table E. Sulphur recommendations in kg/ha SO_3-S

Crop type	SO_3-S (kg/ha)
Cereals and spring oilseed rape	40
Oilseed rape, winter	75
Potatoes	25

Authors:

Alex Sinclair
SAC
Ferguson Building
Craibstone Estate
Aberdeen AB21 9YA
Tel: 01224 711136

Peter Shipway
SAC
Ferguson Building
Craibstone Estate
Aberdeen AB21 9YA
Tel. 01224 711019

Stuart Wale
SAC
Ferguson Building
Craibstone Estate
Aberdeen AB21 9YA
Tel. 01224 711293

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