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Phosphate and potash recommendations for crops grown in North East Scotland and Tayside

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Summary

- **Regular soil analysis with accompanying field information is essential to manage soil PK inputs for optimum yields, profitability and minimising pollution.**
- **A new soil specific approach to P management is presented that takes into account the relationship between differing soils capacity to regulate P availability for plant uptake.**
- **Soils of NE Scotland and Tayside have been designated and mapped as index 1, 2 and 3 to reflect inherent soil phosphorus sorption capacity (PSC) which impacts how soils must be managed.**
- **For cereal-based arable rotations the target soil P Status has now been lowered to M- on PSC 1 and 2 soils but stays at M+ on PSC 3 soils. The target soil P Status is M+ for rotations including potatoes and responsive vegetable crops.**
- **Adjustments to P and K fertiliser recommendations are made to build up or run down to the new target soil PK Status.**
- **AHDB-funded research on P nutrition has shown that the critical level of grain P in winter wheat is 0.32%. Grain P contents repeatedly below this level indicate crop P uptake was deficient enough to reduce grain yield.**

Introduction

Soils should be sampled every 4 to 5 years and analysed for soil pH, extractable P, K and Mg. The value of accompanying field information such as FID, and previous and next crop increases the value of any subsequent analysis of data including use of PLANET Scotland, a software tool designed for Scottish farmers and consultants to plan and manage nutrient use on individual fields (http://www.planet4farmers.co.uk).

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 soil 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, particularly for K after cuts of silage, 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. Particular care should be taken to avoid building up crop-available phosphate above the target Status. Recent research has shown that phosphate transfer from soil to surface water increases as soil P Status increases. Much of this transfer is due to the loss of crop-available phosphate through land runoff.

Regional differences in soil extractable P concentrations exist primarily in response to variations in land use and particularly the greater role of livestock in the west compared to arable cropping in the east. No obvious or consistent temporal trend in extractable P is apparent, but a very wide range of soil properties and extractable P on concentrations is evident. In this technical note an attempt is made to link advisory P and K data from North East Scotland and Tayside with information from the National Soil Database of Scotland; and to explore the value of introducing 'soil type' into the P fertiliser recommendation system, initially published in TN668 (2015) (www.fas.scot/publications/technical-notes/).

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Trends in soil PK advisory data from 1993-2017

Classification of extractable soil PK into PK Status

SAC Consultancy classifies soil PK test values extracted by the Modified Morgan's method into 6 categories (Table A).

Table A. Classification of extractable soil PK (mg/l) into PK Status

PK Status	Very Low (VL)	Low (L)	Moderate (M-)	Moderate (M+)	High (H)	Very High (VH)
Range (mg P/l)	<1.8	1.8-4.4	4.5-9.4	9.5-13.4	13.5-30	>30
Range (mg K/l)	<40	40-75	76-140	141-200	201-400	>400

Nationally 225,396 samples have been analysed from 1993 to 2017 for the advisory services. PK extractable values are classified into P and K status expressed as % of the total number of samples (Table B). The data show that about 33% of samples required more than maintenance P applications i.e. VL and L samples; compared with 19% required more than maintenance K applications.

Table B. Percentage of national samples in each P and K Status

PK Status	VL	L	M-	M+	H	VH
P	6.5	26.1	40.5	13.7	11.0	2.3
K	2.4	16.8	40.9	22.2	16.2	1.5

Effect of 5-year periods on distribution of P and K Status

North East Scotland and Tayside data from 86,270 samples, divided into 5-year periods, are shown in Table C for P status and Table D for K Status. There has been a large drop in the number of samples from 27,866 (1993-1997) to less than half during the last 10 years.

Changes over time were apparent for extractable soil P. The data showed that between1993-1997 about 25% of samples required more than maintenance P applications i.e. VL and L samples, and 12% of samples require less than maintenance i.e. H and VH samples. In comparison during the last 5 years about 33% of samples require more than maintenance P applications i.e. VL and L samples, and 8% of samples require less than maintenance i.e. H and VH samples.

The distribution of samples across K status remained very similar over the entire time period with about 20% of samples requiring more than maintenance K applications i.e. VL and L samples, and just under 20% requiring less than maintenance i.e. H and VH samples.

Table C. Percentage of samples in each P Status

Years	Total	VL	L	M-	M+	H	VH
1993-1997	27,866	3	22	48	15	11	1
1998-2002	17,864	3	21	48	15	11	1
2003-2007	15,331	4	20	47	16	12	1
2008-2012	13,137	4	25	46	14	10	1
2013-2017	12,072	5	28	45	12	7	1

Table D. Percentage of samples in each K Status

Years	Total	VL	L	M-	M+	H	VH
1993-1997	27,866	2	15	41	24	16	1
1998-2002	17,864	2	16	41	25	15	1
2003-2007	15,331	2	17	39	24	17	1
2008-2012	13,137	3	18	39	23	16	1
2013-2017	12,072	2	16	38	24	18	1

Effect of distribution of P and K status by crop

More than half of samples had additional information recorded such as previous and next crop. This provides a mechanism for assessing the possible influence of different fertiliser strategies for individual crops. Forty-four % of samples were taken in grass and 41% of samples were taken before a spring arable crop. A large proportion of samples from grass continued in grass (71%).

The range in soil P and K status reflects a wide range in intensity of farming. The distribution of soil P and K status is summarised in Tables E and F for different crops grown. These differences are clearly evident with P Status where 43% of samples in grass and 39% in fodder crops with VL or L status compared with only 8% have VL or L status going into vegetables and 28% of samples with H or VH status (Table E). In comparison K Status have 29% of samples in grass and 26% in fodder crops with VL and L status compared with 9% going in to winter arable and 18% in to vegetables in VL and L status. Winter arable has 26% of samples with H or VH status (Table F).

Table E. Percentage of samples of each P Status for next crops

			P	(%)		
	VL	L	M-	M+	H	VH
Grass	8.2	34.8	39.8	10.0	6.5	0.7
Spring arable	1.6	20.8	51.3	15.2	10.1	0.9
Winter arable	0.6	12.2	53.2	19.6	13.5	1.0
Potato	0.5	11.9	51.0	19.9	15.5	1.2
Vegetables	1.4	6.3	38.8	25.6	23.3	4.7
Fodder	6.4	32.9	39.8	13.0	6.3	1.3

Table F. Percentage of samples of each K Status for next crops

			K	(%)		
	VL	L	M-	M+	H	VH
Grass	4.2	24.6	38.6	18.6	12.9	1.1
Spring arable	2.3	15.3	41.6	24.5	15.5	0.8
Winter arable	1.0	8.2	34.1	30.5	25.0	1.2
Potato	1.2	10.8	42.8	26.4	17.7	1.2
Vegetables	1.8	15.9	40.7	22.9	16.3	2.4
Fodder	4.4	21.2	30.6	24.2	17.4	2.2

Estimated yield loss

Large responses to P and K in the year of fertiliser application are only expected where the soil P and K Status is very low, although some vegetable crops respond to fresh additions of P and K at low soil Status. Low PK Status soils do not necessarily have a low yield potential given adequate fertiliser P and K but site/season and other aspects of husbandry are the major determinant of yield potential. Season factors are not predictable so soil PK Status is the main variable determining fertiliser requirements. In NE Scotland and Tayside about 5% of samples had P and K Status of VL or L and pH below pH of 5.5. If soil pH is not corrected by liming in these soils yield potential is expected to be lower by up to 50% in spring barley; 30% in winter wheat; and 20% in grass even with adequate PK fertiliser.

Phosphate helps root development, early growth and the ripening of seeds. Loss of yield is generally more common in the wetter, poorer drained upland areas than in drier, better drained lowland areas, partly because the availability of P is low in acid soils especially with pH values below 5.5. Soil P availability is reduced at low temperatures such as when growth is beginning in spring. Soil P supply to the plant is dependent on soil reserves, which must be converted to a soluble form before being absorbed by plant roots. Early grass growth often occurs before land can be accessed to spread fertiliser so maintaining P status is required for maximum spring yields. Soil P levels may decline over the rotation in some soils, due to gradual sorption, when only maintenance applications are made. A new soil specific approach to P management takes into account the relationship between differing soils capacity to regulate P availability for plant uptake. This soil information has been made available at the farm level jointly by SRUC and The James Hutton Institute as technical note TN668 (2015) Managing soil phosphorus (www.fas.scot/publications/technical-notes/). The current technical note will provide further detail for NE Scotland and Tayside.

Maintaining an adequate level of soil K over the long term is important because, on K deficient soils, it is difficult to distribute fresh K fertiliser sufficiently evenly throughout the rooting zone in the season it is applied, and for the roots to access it so that the crop can respond to all of the applied N fertiliser and produce optimal yields. 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 N than are those with an adequate supply; and have lower resistance to drought.

Application of fertiliser serves 3 purposes:

- To maximise profit;
- To replace PK offtake by the crop over the long term maintaining a balanced soil fertility and helping to optimise nutrient use efficiency; and
- To increase the status of very low and low soils on the assumption that moderate status results in high yield potential.

Effective use of PK fertiliser requires 3 key steps:

1. Based on a recent soil test develop a liming program to bring the soil on pH target. If target pH is not achieved yields will be lower which should be recognised when calculating fertiliser requirements.
2. Calculate the amount of PK that will be removed from the soil based on expected yield.
3. Based on soil test results for PK Status make adjustments if required to reduce or increase rates to bring soils on target.

Adjustments to PK fertiliser recommendations taking account of soil P sorption capacity and soil PK Status

Soil P sorption capacity (PSC)

The PSC of a soil refers to the differing capacity of soils to bind with applied P making it temporality unavailable for plant uptake. Experience has shown that this soil binding effect can be controlled by the slow build-up of P in the soil to a point when soil analysis shows that sufficient P is being released to meet crop demand on an annual basis. The P sorption capacity varies depending on soil chemistry, texture, pH and organic content of your soil. Data from the Soil Survey of Scotland for each soil association have been used to create a map of ranking of PSC for non-calcareous soils from low (PSC 1) to high (PSC 3) in NE Scotland and Tayside (Figure 1). Blank areas cover built-up areas, open water, rock and scree and organic soils. Calcareous soils from the Fraserburgh Association should be tested using the Olsen method (see TN710, 2018) (www.fas.scot/publications/technical-notes/). Soil association groups are listed in Table G for each PSC index in descending order of soil association areas. The percentage areas mapped in PSC 1, 2 and 3 are 41, 38 and 21 % respectively. On organic soils initially applied P is less firmly sorbed than on mineral soils and P uptake by crops may be higher from organic soils than mineral soils. In the absence of further trials on organic soils the advice is to treat organic soils similarly to the PSC 1 mineral soils. Soil association maps and associated PSC indices can be used to aid zone selection as part of GPS soil testing.

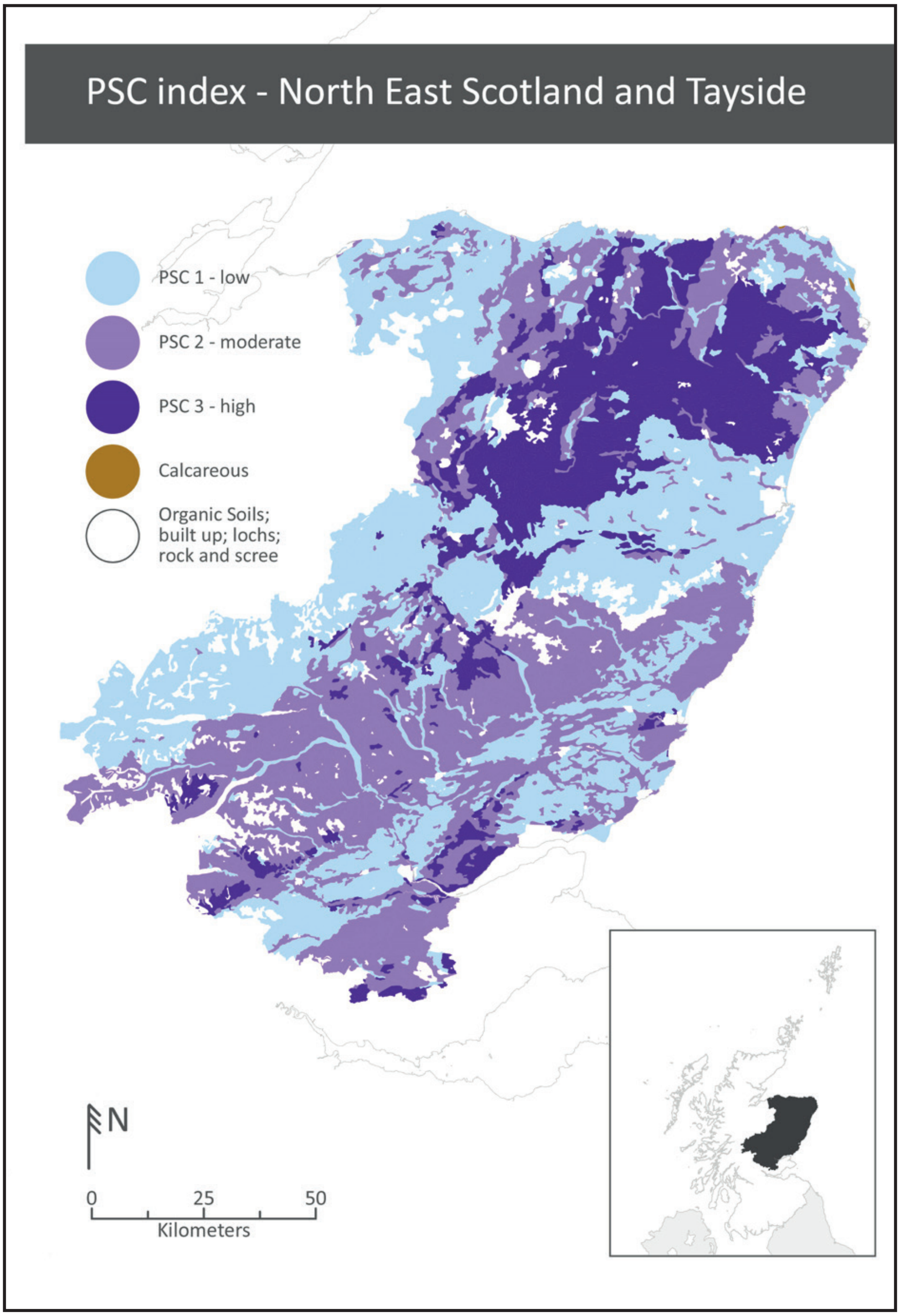

Figure 1. Map of P sorption capacity (PSC) from index 1 to 3 by soil association for non-calcareous mineral soils in NE Scotland and Tayside.

Table G. Soil associations with P sorption capacity (PSC) indices in NE Scotland and Tayside

PSC 1	PSC 2	PSC 3
Countesswells/ Dalbeattie/ Priestlaw	Strichen	Tarves
Corby/ Boyndie/ Dinnet	Alluvial Soils	Foudland
Arkaig	Forfar	Insch
Balrownie	Sourhope	Stiling/ Duffus/ Pow/ Carbrook
Durnhill	Gourdie/ Callander/ Strathfinella	Darleith/ Kirktonmoor
Aberlour	Stonehaven	Rowanhill/ Giffnock/ Winton
Gleneagles/ Auchenblae/ Collieston/ Darnaway	Ordley/ Cuminestown	Leslie
Laurencekirk	Mountboy	Nochty
Links	Peterhead	Corriebreck
Elgin	Hatton/ Tomintoul/ Kessock	
Nigg/ Preston	Carpow/ Panbride	
Deecastle	North Mormond/ Orton	
Kippen/ Largs	Tipperty/ Carden	
Skelmuir	Eckford/ Innerwick	
Cromarty/Kindeace	Tynet	
Doune	Craigellachie/ Polfaden	
Bogtown	Darvel	
Dulsie		
Brightmony		
Ardvanie		

Soil association maps and associated PSC indices can be used to aid zone selection as part of GPS soil testing.

Target soil P and K Status

For established grass/clover swards and cereal and oilseed rape arable rotations, the target soil P Status has been lowered to M- on PSC 1 and 2 soils but stays at M+ on PSC 3 soils. Adjustments to P fertiliser recommendations may be made taking account of PSC indices to build up or run down to the new target soil P tests (Table H). If the PK Status is VL or L, then the adjustment should be to defoliation 1 for grass silage and hay, and defoliation 2 for grazing. The target soil P Status is moderate (M+) for rotations including potatoes and some vegetable crops that respond to fresh additions of P and K at low soil Status. Those soils with a higher PSC that are maintained on target for P represent the greatest erosion risk to water quality as they will contain a higher level of adsorbed P from fertilising. Maintaining soils at target soil P levels is only justified if the land is being actively managed for maximum yields. This requires that other good soil management targets such as pH, nutrient planning as well as adequate drainage status are also considered. Soils of PSC 3 will maintain the lowest P concentrations in soil pore water. This relationship explains the observation that despite equivalent soil P Status, high P sorption soils often require additional fertiliser to maintain target plant available P. Regular soil analysis detects this, allowing adjustments to be made.

Table H. Effect of PSC on annual fertiliser adjustments (kg P_2O_5/ha):

a) Grass, cereals, oilseed rape and fodder crops

P sorption capacity	Soil P status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
PSC 1	+40	+20	0	-10	-20
PSC 2	+60	+30	0	-20	-30
PSC 3	+80	+40	+20	0	-40

b) Vegetable crops that respond to fresh additions of P at low soil Status.

P sorption capacity	Soil P Status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
PSC 1	+60	+30	+15	0	-25
PSC 2	+90	+45	+20	0	-35
PSC 3	+120	+60	+30	0	-50

c) Potatoes

P sorption capacity	Soil P Status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
PSC 1	+80	+60	+40	0	-30
PSC 2	+120	+90	+60	0	-45
PSC 3	+160	+120	+80	0	-60

Effect of K Status on annual fertiliser adjustments (kg K_2O/ha) are shown in Table I.

Table I. Effect of K Status on annual fertiliser adjustments (kg K_2O/ha)

Crop	Soil K Status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
Grass, cereals, oilseed rape & fodder crops	+60	+30	0	0	K offtake x 0.5
Potatoes & responsive vegetable crops	+90	+60	+30	0	-50

Effect of PSC on adjustments to build-up soil P Status more quickly.

The changes are increments of extractable soil P from 1 to 6 mg/l i.e. from VL to lower end of M-; and 6 to 11 mg/l i.e. lower end of M- to M+ (Table J). Change in P on an area basis (kg P_2O_5/ha) are estimates using an estimated amount of soil in 1ha to 20cm depth as 2400 t. The estimated amount to change soil P test will be closer to the total P required when P is applied as inorganic, soluble P at a small surplus to build-up soil P slowly over a number of years, compared with single, large applications of P in organic fertilisers. The table shows that more than twice the amount of P is required moving from 1 to 6 mg/l P i.e. from VL to M- than moving from 6 to 11 mg/l P i.e. from M- to M+ P Status; and about twice the amount of P is required in PSC 3 soils than PSC 1 soils to move to M- and M+ P Status.

Table J. The effect of PSC index on kg P_2O_5/ha required to change soil P test.

PSC index	Change in P on an area basis from 1 to 6 mg/l (kg P_2O_5/ha)*	Change in P on an area basis from 6 to 11 mg/l (kg P_2O_5/ha)*
PSC 1	241	109
PSC 2	346	147
PSC 3	550	222

*using an estimated amount of soil in 1ha to 20cm depth as 2400 t

Effect of K on adjustments to build-up soil K Status more quickly.

Offtakes of K in conserved grass can be considerable from 180 – 330kg K_2O /ha from 2 or 3 cuts totalling 10t DM/ha; and soil K reserves can quickly become depleted especially on light sandy soils decreasing from 75 to 100 mg/l e.g. from M+ to L Status in one season. Heavy clay soils generally have higher K reserves and maintain K Status for longer. If maximum benefits are to be realised from nutrient application to grassland then it is important to balance the use of nitrogenous fertilisers with potash. Typical application rates for 1st cut silage should be in the order of 60-90 kg K_2O /ha and 50-60 kg for 2nd cut. Exact rates will vary with soil K Status, nitrogen application rates and anticipated grass yields but a useful rule of thumb is to apply 2/3rds kg K_2O / ha for every 1 kg of N applied. Where grass offtakes suggest application rates should be in excess of 90 kg K_2O /ha for 1st cut, any surplus over and above 90kg K_2O/ha should be applied later in the season otherwise luxury uptake can occur.

Soil K tests in M+ at sowing or planting can decrease to L at the peak of K offtake and recover to M+ after senescence when K is leaked back in to the soil, or when straw is ploughed back. Data in Table F show that it is possible in arable crops to maintain K soil tests in the M+ even though M- status is adequate for cereal, oilseed rape and grass. The target soil K Status is M+ for rotations including potatoes and vegetable crops that respond to fresh additions of P and K at low soil Status.

An application of 150 - 250 kg/ha K_2O in excess of crop removal should increase soil K concentration by 50 mg/l, the lower rate in light soils and higher rate in heavy soils. Luxury offtake is always a risk particularly in light soils and K should not be applied to young grass in spring for fear of inducing hypomagnesaemia (grass staggers) in freshly turned-out stock. The estimated amount to change soil K test will be closer to the total K required when K is applied at a small surplus to build-up soil K slowly over a number of years, compared with single, large applications of K in inorganic or organic fertilisers.

PK offtake in crops and fertiliser recommendations

Grass

Phosphate and potash recommendations for target M- PK Status for newly sown grass, autumn or spring sown, are 50 kg/ha for both P and K; and add a further 20 kg/ha for grass with high clover/red clover. Where grass is undersown, use appropriate cereal recommendation plus an additional 40kg P_2O_5 and K_2O /ha.

For established grass grown in soils that are on target M- for PK, apply 'maintenance' PK fertiliser applications to balance the offtake in cut or grazed grass but test soil PK status every 4 – 5 years. PK offtake can be calculated by multiplying grass yield by PK content as given in Table K. In order to calculate PK requirements yields in Table K should be replaced by estimated or actual yields where possible. Drought can impair growth and reduce PK offtake and should be taken into account when assessing PK requirement. The balance between PK offtake and PK applied in organic manures and manufactured fertiliser can then be made at the end of the season. Allowance should be made for any surplus or deficit in PK when planning the following season's fertiliser.

Table K. Established grass default yields (fresh weight) and standard PK content (fresh weight)

Utilisation	Defoliation position	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)
Silage*	1st occurrence	23	1.7	39	6.0	138
Silage*	2nd occurrence	12	1.7	20	6.0	72
Silage*	3rd occurrence	9	1.7	15	6.0	54
Hay**	Any defoliation	7	5.9	41	18.0	126
Grazing***	Any defoliation	10	1.4	3***	4.8	2***

*Silage at 25%DM
**Hay at 86%DM
***Under Grazing this calculation assumes approximately 80% of the P_2O_5 and 95% of the K_2O is recycled infield by the animal through its dung and urine.

Cereals, oilseed rape and fodder crops

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 planning, record keeping and calculating a *Farm gate Nutrient Balance* of NPK 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, 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 maturities 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.

On M- PK Status soils and M+ on PSC 3 soils; apply 'maintenance' PK fertiliser applications to balance the offtake in cereals, oilseed rape and fodder crops. PK offtake can be calculated by multiplying typical or expected yield by PK content as given in Table L. This should maintain soil test P and K levels ready for the next crop or rotation. Regular soil analysis detects this, allowing adjustments to be made.

Grain P and K analyses can provide more accurate estimates of crop phosphate and potash offtakes than the typical values in Table L. This information also complements soil analyses for P and K. AHDB-funded research on P nutrition has shown that the critical level of grain P in winter wheat is 0.32%. Grain P contents repeatedly below this level indicate crop P uptake was deficient enough to reduce grain yield. If soil conditions are satisfactory but a field repeatedly shows grain P deficiency, available soil P should be increased for future crops. Grain samples must be representative of fields or areas from where routine soil analyses are taken.

Table L. Typical yields of crops (fresh weight)* and standard PK content in grain/seed, straw and roots (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)
Wheat, winter & spring	Grain only	8.0	6.5	52	5.5	44
Barley, winter & spring	Grain only	6.5	8.0	52	5.5	36
Oats, winter & spring	Grain only	6.0	8.0	48	5.5	33
Wheat, spring	Grain only	6.0	8.0	48	5.5	33
Rye, winter	Grain only	6.0	8.0	48	5.5	33
Triticale, winter	Grain only	8.0	8.0	64	5.5	44
Wheat, winter	Grain+straw**	8.0	7.0	56	10.5	84
Barley, winter	Grain+straw**	6.5	8.5	55	10.5	68
Rye, winter	Grain+straw**	6.0	8.5	51	10.5	63
Triticale, winter	Grain+straw**	6.0	8.5	51	10.5	63
Wheat, spring	Grain+straw**	6.0	8.5	51	12.0	72
Barley, spring	Grain+straw**	6.5	8.5	55	12.0	78
Oats, winter & spring	Grain+straw**	6.0	9.0	54	16.5	99
Oilseed rape, spring	Seed only	2.0	14	28	11.0	22
Oilseed rape, spring	Seed + straw	2.0	15	30	17.5	35
Oilseed rape, winter	Seed only	3.5	14	49	11.0	38
Oilseed rape, winter	Seed + straw	3.5	15	53	17.5	61
Spring cereals	Whole crop	25	1.8	45	5.4	135
Winter cereals	Whole crop	30	1.8	54	5.4	162
Hybrid winter rye	Whole crop	35	1.8	63	5.4	189
Maize	Silage	40	1.4	56	4.4	176
Kale	Cut	40	1.2	50	5.0	200
Potatoes	Roots only	50	1.0	50	5.8	290
Swedes/turnips	Roots only	65	0.7	46	2.4	156
Fodder beet	Roots only	85	0.7	60	4.0	340

*cereals at 15% moisture; oilseed rape at 9% moisture; whole crop 35% DM; maize silage 30% DM; and forage roots lifted

**Offtake values are per tonne of grain or seed removed but include PK in straw when this is removed without weighing. Where the amount of cereal or oilseed rape straw removed is known, offtakes can be calculated using typical values of 1.2 kg P_2O_5/t and 9.5 kg K_2O/t straw for winter wheat/barley; 1.5 kg P_2O_5/t and 12.5 kg K_2O/t for spring wheat/barley; and 2.2 kg P_2O_5/t and 13.0 kg K_2O/t for oilseed rape.

Potatoes

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 M).

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 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.

Table M. Potatoes: phosphate and potash recommendations (kg/ha) at M+ Status

Anticipated length of growing season* and intended market	Soil P Status	Soil K Status
	M+	M+
< 60 days (seed and punnets) and 60-90 days (seed and punnets)	100	110
60-90 days (ware) and > 90 days	75	150

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

Vegetable crops that respond to fresh additions of P and K at low soil Status

The recommendations provided in Table N will ensure sufficient supply of P and K for average yields grown in M+ Status soils.

Table N. P and K recommendations (kg/ha) for responsive vegetables grown in M+ PK Status

Crop	P_2O_5 (kg/ha)	K_2O (kg/ha)
	Soil P Status M+	Soil K Status M+
Brussels sprouts	100	200
Cabbage, all types	100	200
Calabrese (broccoli)	100	75
Cauliflower	100	175
Courgette	75	125
Lettuce	200	175
Leek	150	175
Onions (all types)	150	125
Asparagus[1]	125	200
Beans, broad	150	100
Beans, dwarf/runner	100	75
Carrot	125	125
Parsnip	100	150
Swede, shopping	200	150
Turnips (human consumption)	200	125
Beetroot, all types	100	200
Radish	75	100

[1]Asparagus in its establishment year

Worked examples adjusting PK applications for PK offtake, soil status and PSC index

Grass

The worked examples in Table O show fertiliser recommendations applied to first cut of silage with an expected yield of 20 t/ha (fresh weight) grown in soils from each of the three PSC indices of PSC 1, 2 and 3 (Figure 1). PK offtake values are used from Table K. The soil P Status was low (2 mg/l P) and K Status was at the target of moderate (M-) in each field. The decision of the farmer was to build-up crop available levels of P over a number of years by 4 mg/l P from 2 to 6 mg/l P i.e. up to the lower end of M-; but checking progress by soil analysis after 4 years. Raising P Status over the shorter period of 4 years minimises the period of potential yield loss, but in the short term will increase the annual cost and risk of water pollution. Data from Table H are used for annual P applications for slow change in status and Table J for faster change.

Table O. Adjusting PK applications for PK silage offtake, soil status and PSC index

PSC index	Crop offtake kg P_2O_5/ha	Added kg P_2O_5/ha for slow change in status	Added kg P_2O_5/ha for 3 to 4 years to change status	Crop offtake kg K_2O/ha
1	35	20	50	120
2	35	30	70	120
3	35	40	110	120

Arable rotation including potatoes or vegetables

The worked examples in Table P show fertiliser recommendations applied to spring barley crop with an expected yield of 6 t/ha grown in soils from each of the three PSC indices of PSC 1, 2 and 3 (Figure 1). The soil P was 6 mg/l i.e. lower end of M-, but the decision of the farmer was to build-up crop available levels of P to lower end of M+ to 11 mg/l as the crop rotation includes potatoes and vegetables. The soil K was 70 mg/l i.e. L, and the aim is to build-up the level of K by 50 mg/l to M- in each field. Raising P Status over a shorter period of time minimises the period of potential yield loss, but in the short term will increase the annual cost and risk of water pollution. The straw was removed and PK analytical values used were from Table L. Data from Table H are used for annual P applications for slow change in status and Table J for faster P change over 4 years; Table I for slow change in K level; and checking soil analysis after 4 years.

Table P. Adjusting PK applications for PK barley offtake, soil status and PSC index

PSC index	Crop offtake kg P_2O_5/ha	Added kg P_2O_5/ha for slow change in status	Added kg P_2O_5/ ha for 4 years to change status	Crop offtake kg K_2O/ha	Added kg K_2O/ha for slow change in status
1	60	15	30	83	60
2	60	20	50	83	60
3	60	30	75	83	60

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