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Sulphur Recommendations for Crops

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Summary

- **The risk of sulphur (S) deficiencies in crops is increasing as atmospheric S sources decline.**
- **Soil analysis alone is not sufficiently reliable for diagnosing or predicting S deficiency.**
- **If S deficiency is suspected, plant tissue tests can be used to make a diagnosis.**
- **Good soil management is required to optimise S use.**
- **S crop requirement and S in fertilisers are expressed as kg SO_3 /ha and %SO_3 respectively.**
- **Recommendations take account of S planning in the PLANET Scotland software tool.**
- **Recent research has quantified S supply from livestock manures and biosolids.**

Introduction

Sulphur (S) is an essential crop nutrient that has received less attention in the past as the supply from industrial emissions sources have been sufficient to meet annual requirements for many crop types. As atmospheric deposition of S continues to decline due to reduced emissions from industrial sources, the risk of S deficiency affects an increasingly wide area of farmed land. Sulphur recommendations for cereals, oilseed rape, potatoes and grass 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 limits root development and restricts S uptake. A SRUC 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.

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).

Sulphur deficiency

2.1 Soil type

The best guide for assessing the risk of S deficiency is soil type and winter rainfall (Table A). Sulphur from autumn applications may be lost via overwinter leaching and is likely to be higher on light textured soils with low organic matter in high rainfall areas. Swards that receive high levels of nitrogen (N) fertiliser and are cut regularly for silage are more at risk whereas fields that receive regular applications of bulky organic fertilisers are less likely to show deficiency. Soil analysis can help identify severely deficient soils but in other situations it is not as reliable a guide as herbage analysis. Atmospheric contributions of S depend on the amount

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of rainfall and its distribution, and on proximity to urban and industrial areas. When the prevailing wind comes from the sea, coastal areas are expected to receive additional S deposition.

Table A. Sulphur deficiency risk categories

	Winter rainfall (Oct-Mar)		
Soil type	**Low (<175 mm)**	**Medium (175-375 mm)**	**High (>375 mm)**
Sands and shallow soils	High		
Sandy loams	Low	High	
Other mineral soils	Low		High

2.2 Visual assessment

Sulphur deficiency in grass and cereals causes paling of young leaves initially (Figure 1) and severely deficient crops are stunted and uniformly pale (Figure 2). Sulphur deficiency can easily be confused with N deficiency but N deficiency usually affects older leaves first. In oilseed rape, middle and upper leaves (in contrast to Mg) can show interveinal yellowing (Figure 3). Some leaves of severely deficient oilseed rape plants are cupped upwards, the margins have a purple tinge and flower petals are paler than normal. Sulphur deficiency symptoms in potatoes are rare but where they occur, younger leaves turn light green to yellow. Brassica crops such as swedes, cabbage, forage rape and Brussels sprouts, as well as legumes and clover, may also respond to applied S.

Figure 1. Symptoms of S deficiency in new growth of winter wheat

Figure 2. Symptoms of severe S deficiency in winter barley (left side)

Figure 3. Symptoms of S deficiency in oilseed rape

2.3 Soil extraction

Soil analysis alone is currently **not** sufficiently reliable for diagnosing or predicting S deficiency.The SAC Consultancy interpretative scales for extractable S concentrations (mg/kg) in top soil are shown in Table B. A summary of 9,075 samples of advisory data (1996-2015) for S (% of the total number of samples) is shown in Table C. Changes over time were apparent for extractable soil S and while there was some variability between years a decline of approximately 2 mg/kg in extractable S was apparent over the 20 year period, perhaps reflecting the decline in atmospheric deposition. The change in extractable S is evident from analysis of S status where the relative proportion of soils in the VL and L status increases with time from ~20 % in 1996 to 45 % in 2015 (Figure 4).

Table B. SAC Consultancy interpretative scales for extractable S concentrations (mg/kg)

Element	Very low	Low	Moderate	High	Very high
S	<3.0	3.0 - 6.0	6.1 - 10.0	>10.0	>50

Table C. Summary of advisory data (1996-2015) for S (% of the total number of samples)

Element	Very low	Low	Moderate	High	Very high
S	7.6	33.0	33.0	25.3	0.8

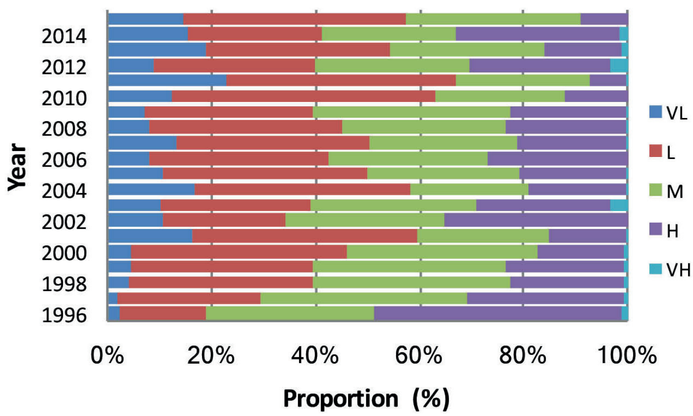

Figure 4. A breakdown of advisory soil data for S by using full data set from 1996-2015. VL = Very Low, L = Low, M = Moderate, H = High, VH = Very High

2.4 Plant tissue tests

The most reliable prediction of the likely response to added S in grass can be obtained by chemical analysis to determine the total N: total S ratio (Table D). Sampling of herbage should be carried out within 10 days of the anticipated silage cut. The critical level of total S in grass is 0.25% S in dry matter.

Total N and S values are also useful guides for interpretation of tissue analysis in cereals and oilseed rape (Table D). 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. For wheat and oilseed rape the Malate Sulphur test (HGCA Topic Sheet No.66, Winter 2002/2003) can detect S deficiency as soon as plants become deficient. A malate:sulphate ratio more than 1.5 means the plant is deficient at the time of sampling; a ratio less than 1.5 means the S supply is sufficient at the time of sampling. Ideally, plants are sampled early in the spring, so that deficiency can be corrected in the current crop. However, there is no point in sampling wheat too early as small, slow-growing plants have a low S requirement, and a "not deficient" test result will be recorded.

Table D. Critical levels of total S and N: S ratio in grass, cereals and oilseed rape and S deficiency

		Total S in dry matter (%)	N:S ratio
Grass	just before cutting	less than 0.25	greater than 13:1
Cereals	at stem extension	less than 0.2	greater than 15:1
Oilseed rape	at early flowering	less than 0.4	greater than 10:1

Sulphur recommendations

Most of the S in crops is in essential amino acids that form protein. Sulphur is a component of some enzymes, vitamins and oils. The amounts needed depend mainly on the type of crop and its yield, while smaller variations may occur between cultivars. The crop requirement for S and S in fertilisers are expressed as kg SO_3/ha and %SO_3 respectively (to convert S to SO_3, multiply by 2.5). The approximate SO_3 removals by a number of crops for the yields indicated are given in Table E.

Table E. Typical crop yields (fresh weight)* and SO_3 removal (fresh weight)

Crop type	Crop removed	Yield (t/ha)	S removal (kg SO_3/ha)
Cabbage	Leaves	50	85-110
Kale	Whole crop	10	85-100
Swedes/turnips	Whole crop	60	75-100
Oilseed rape*, winter	Seed only	3.5	60-75
Oilseed rape*, spring	Seed only	2.0	35-50
Grass, silage	First cut	12	35-60
Grass silage	Second cut	7	25-35
Potatoes	Tubers	50	45-55
Cereals*, winter	Grain only	8.0	40-60
Cereals*, spring	Grain only	6.0	30-45

*cereals at 15% moisture and oilseed rape at 9% moisture

Grass with a high fertiliser N input has a high demand for S and a profitable response to S application can be obtained in second and third cuts of silage, and mid-season grazing. If deficiency is expected, the best treatment is to apply S as water soluble sulphate, which is rapidly available for crop uptake e.g. ammonium sulphate, potassium sulphate and kieserite, as well as a range of compound, blended and liquid fertilisers. Recommended rate is 40kg SO_3/ha applied prior to the start of growth for 2nd and 3rd cuts of silage or mid season under grazing (Table F).

Table F. Sulphur recommendations in kg SO_3/ha

Crop type	kg (SO_3/ha)
Oilseed rape, winter; brassica crops	75
Cereals and spring oilseed rape; prior to the 2nd and 3rd cuts of silage or mid season under grazing.	40
Potatoes; peas	25

Winter oilseed rape is particularly sensitive to a shortage of S and the application of 75kg SO_3/ha as part of the first spring top dressing is recommended. Where deficiency has been recognised or is expected in winter or spring-sown cereals the recommended rate is 40kg SO_3/ha applied as part of the first spring top dressing in winter cereals and first application to spring cereals; but actual rate should be altered depending on expected yield. Sulphur fertilising to correct S deficiency has improved loaf volume of wheat, and malting quality of wheat and barley.

Potato crops are not generally thought to be responsive but where S deficiency is expected apply 25kg SO_3/ha as an S-containing fertiliser in the seedbed. Elemental S, broadcast or applied in furrow, or the application of ammonium sulphate are used by some growers to reduce common scab development of 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.

Many vegetable crops, especially brassicas have a significant requirement for S. In situations where S levels might be low, for example on light soils, following wet winters, where there has been no previous history of manure use or S-containing fertilisers, S should be considered as part of a base dressing to supply both N and S. Apply 25kg SO_3/ha for pea crops in such situations, and up to 75kg SO_3/ha for brassica crops.

Sulphur is present in many commonly used fertilisers and should be accounted as part of a nutrient budget. Sources such as polyhalite or polysulphate are potassium/magnesium/sulphur-containing forms that must dissolve before S becomes available for uptake. Gypsum is slower to dissolve but if finely ground will act quickly in damp conditions. Elemental sulphur must be oxidised to sulphate before it becomes available for uptake predominantly through plant roots. The materials listed in Table G are used individually or as multi-nutrient fertilisers.

Table G. Analysis of some S-containing fertilisers.

S-containing fertiliser	SO_3 content (%)
Ammonium sulphate	60% SO_3, 21% N
Sulphate of potash (SOP)	45% SO_3, 50% K_2O
Kainit	10% SO_3, 11% K_2O, 5% MgO, 26% Na_2O
Kieserite (magnesium sulphate)	50% SO_3, 25% MgO
Epsom salts (magnesium sulphate)	33% SO_3, 16% MgO
Gypsum (calcium sulphate)	40% SO_3
Polyhalite or polysulphate	48% SO_3, 14% K_2O, 6% MgO
Elemental sulphur	typically 200-225% SO_3 (80 - 90% S)

Availability of nutrients in organic fertilisers

Organic fertilisers are valuable sources of N, P, K and S although not all of the total nutrient content will be available for the next crop. Typical dry matter (DM) and nutrient contents of livestock manures and other bulky organic fertilisers are given in Table H. Nutrients which are not immediately available will mostly become available over a period of years.

Recent research published in AHDB (2017) "Nutrient Management Guide (RB209)" has quantified S supply from livestock manures and biosolids applications. For autumn application the % total SO_3 available for the following crop may be 5-10% from livestock manures and 10-20% from biosolids. For spring applications S availability is expected to be higher and as a general rule around 15% of the SO_3 in cattle FYM and 35% of the SO_3 in cattle/pig slurry will be available to the crop in the year of application (Table I). Information on the NPK availability from organic fertilisers can be found in SRUC Technical Note TN650 (2013) on "Optimising the application of bulky organic fertilisers".

Manure type	DM (%)	kg/t (solid manures) or kg/m³ (liquids/slurries)			
		Total N	Total P_2O_5	Total K_2O	Total SO_3
Cattle FYM	25	6.0	3.2	9.4	2.4
Pig FYM	25	7.0	6.0	8.0	3.4
Sheep FYM	25	7.0	3.2	8.0	4.0
Duck FYM	25	6.5	5.5	7.5	2.6
Horse FYM	25	5.0	5.0	6.0	1.6
Goat FYM	40	9.5	4.5	12	2.8
Layer manure	40	19	12	15	5.6
Broiler/Turkey litter	60	28	17	21	8.2
Cattle slurry	6	2.6	1.2	2.5	0.7
Pig slurry	4	3.6	1.5	2.2	0.7
Biosolids, digested cake	25	11	11	0.6	8.2
Biosolids, thermally dried	95	40	55	2.0	23
Biosolids, thermally hydrolysed	30	10	20	0.5	7.5
Biosolids, lime stabilised	25	8.5	7.0	0.8	7.4
Green compost	60	7.5	3.0	6.8	3.4
Green/Food compost	60	11	4.9	8.0	5.1
Food-based digestate, whole	4.1	4.8	1.1	2.4	0.7
Food-based digestate, separated liquor	3.8	4.5	1.0	2.8	1.0
Food-based digestate, separated fibre	2.7	8.9	10.2	3.0	4.1
Farm-based digestate, whole	5.5	3.6	1.7	4.4	0.8
Farm-based digestate, separated liquor	3.0	1.9	0.6	2.5	<0.1
Farm-based digestate, separated fibre	24	5.6	4.7	6.0	2.1
Paper crumble, chemically/ physically treated	40	2.0	0.4	0.2	0.6
Paper crumble, biologically treated	30	7.5	3.8	0.4	2.4
Distillery pot ale	5	2.5	1.8	1.1	0.2
Distillery bioplant sludge	4	2.2	2.1	0.5	0.4
Distillery bioplant effluent	1.5	0.6	0.5	0.2	0.1

Table H. Typical dry matter (DM) and nutrient contents of livestock manures and other bulky organic fertilisers

Organic material	% total SO_3 available
Cattle FYM	15%
Pig FYM	25%
Poultry manure	60%
Cattle/pig slurry	35%
Biosolids	20%

Table I. Sulphur availability from spring-applied organic materials

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