Technical Note TN657

SRUC

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Management of copper in soils for cereals

SUMMARY

- Soils have been designated and mapped “high”, “moderate” or “low” predicted risk of copper (Cu) deficiency in cereals according to their total Cu content in subsoil.
- Soil associations are listed in order of the 10 most spatially extensive association mapping units for each risk level, along with the area that they cover.
- Visual assessment, soil extraction and plant tissue tests for diagnosis of Cu deficiency in cereals are described.
- Historical advisory extractable Cu data measured as potentially deficient (VL or L status) was 26.4% which is in good agreement with the proportion mapped as high risk of Cu deficiency in cereals.
- SAC Consultancy interpretative scales for extractable Cu concentrations in topsoil are tabulated.
- Soil and foliar treatment options are described.
- Copper content of livestock manures and some bulky organic fertilisers are tabulated.

1. Introduction

The soils of Scotland have developed from a range of complex geological parent materials that vary widely in composition. In the relatively young soils over much of the UK, the parent material remains the dominant factor in determining the soil copper status. Copper deficiency in cereals is most likely in coarse textured sandy soils derived from acid schists and granitic rocks, as well as peaty soils. Copper deficiency in cereals can be corrected by soil treatments whereas applying copper amendments to soil is inefficient at increasing copper in grasses and livestock. This technical note will concentrate on management of copper in soils in relation to cereals growth and quality.

Various site related factors will also be expected to influence any relationship that exists between the amount of copper extractable in soil and plant content. Soil drainage modifies the availability of copper by influencing the rate of weathering of soil minerals and controlling the conditions of plant uptake. Poor natural drainage increases the concentration of extractable copper compared to soils of identical parent material developed under conditions of free drainage. Predicting potential bioavailability is made even more complex through interactions that can exist between elements e.g. Cu, molybdenum (Mo) and sulphur (S); but not influenced by soil pH in the optimum range for growing cereals. These complex interactions are more significant in livestock health than in crop growth.

The Soil Survey of Scotland uses parent material and pedological (natural) drainage to group soil (see SRUC technical note TN656 (http://www.sruc.ac.uk/tn656)). In the current technical note soil data are used to develop a risk-based assessment of Cu deficiency in cereals. Soils at risk of copper deficiency can be tested in order to establish the actual status in individual fields. The status in individual fields may have been altered by fertiliser application or amendment by bulky organic fertilisers.

2. Soil type

The James Hutton Institute, who holds the National Soils Database for Scotland, has created the Soil Information for Scottish Soils (SIFSS) website (http://sifss.hutton.ac.uk/SSKIB_Stats.php) which allows you to access information on your soils. SIFSS is also available as a free iPhone app for you to find out what soil type is in your area. The SIFSS system enables the user to select a soil 'map unit' by zooming in on a particular area (i.e. a field). This can be done by specifying a postcode, grid reference, or simply by zooming in using the interactive map. The user can then select a *soil series* from a *soil association* within this map unit. A soil series comprises soils with a similar type and arrangement of horizons which are developed on similar parent material, and a soil association is a collection of one or more soils of the same parent material typically found together in the landscape for an area.

Copper is readily absorbed by the clay and organic fractions in the soil, so only a part of the total Cu present in soils is readily available for plant uptake. Some of the Cu is also immobilised by micro-organisms. Copper does not leach easily through the soil, although mobility is slightly greater in sandy than in peaty or clayey soils, which leads to more severe deficiency in dry seasons. Mobility is increased considerably in poorly drained soils. Most of the applied Cu remains in the cultivated topsoil layer of well drained agricultural soils. Copper concentration in the subsoil (B horizon) is therefore expected to give the best indication of inherent risk of Cu deficiency. The total copper in the B horizon is grouped into soil associations with <5, 5 to 15 and >15 mg/kg and designated "high", "moderate" or "low" risk of Cu deficiency in cereals according to the criteria in Table A.

The distribution of the predicted risk of copper deficiency in cereals from high, moderate and low by soil association in land where cereal production might be possible is mapped in Figure 1. The mapped area of 38,144 km^2 is 48.7% of the total area of Scotland. SAC Consultancy area office boundaries are mapped as an overlay in Figure 1.

Soil associations are listed in Table B in order of the 10 most spatially extensive association mapping units for each risk level, along with the area that they cover (as % of the potential cereal growing area). High risk soils include organic soils, tills derived from granites and granitic rocks (e.g. Countesswells), fluvioglacial and morainic gravels (e.g. Corby and Eckford), alluvial soils and drifts derived from sandstone (e.g. Cromarty).

Table A. Total copper in the B horizon and risk of Cu deficiency in cereals.

Total Cu in B horizon (mg/kg)	Risk level	Interpretation
<5	High	Soil Cu in most soils not adequate for producing optimum cereal yields.
5 - 15	Moderate	Soil Cu in some soils may not be adequate for producing optimum yield of cereals and soil testing for Cu is recommended.
>15	Low	Soil Cu in most soils is adequate for optimum cereal production.

Table B. Soil associations with high, moderate or low risk of Cu deficiency in cereals and association areas as % of the potential cereal growing area of Scotland.

High risk	% mapped area	Moderate risk	% mapped area	Low risk	% mapped area
ORGANIC SOILS	6.17	THURSO	2.67	ETTRICK	14.06
COUNTESSWELLS	3.75	TARVES	2.55	ROWANHILL	6.51
CORBY	3.49	HOBKIRK	1.44	DARLEITH	4.94
ARKAIG	3.17	YARROW	1.19	STRICHEN	3.69
ALLUVIAL SOILS	2.74	RHINS	1.16	BALROWNIE	3.28
LOCHINVER	2.06	SORN	1.16	FOUDLAND	3.27
TORRIDON	0.90	FORFAR	0.98	SOURHOPE	2.29
ECKFORD	0.80	WHITSOME	0.84	INSCH	1.04
CROMARTY	0.60	CANISBAY	0.73	DARVEL	0.96
NORTH MORMOND	0.56	GLENALMOND	0.71	STIRLING	0.92
% of total potential cereal growing area in Scotland	28.6		16.9		50.8

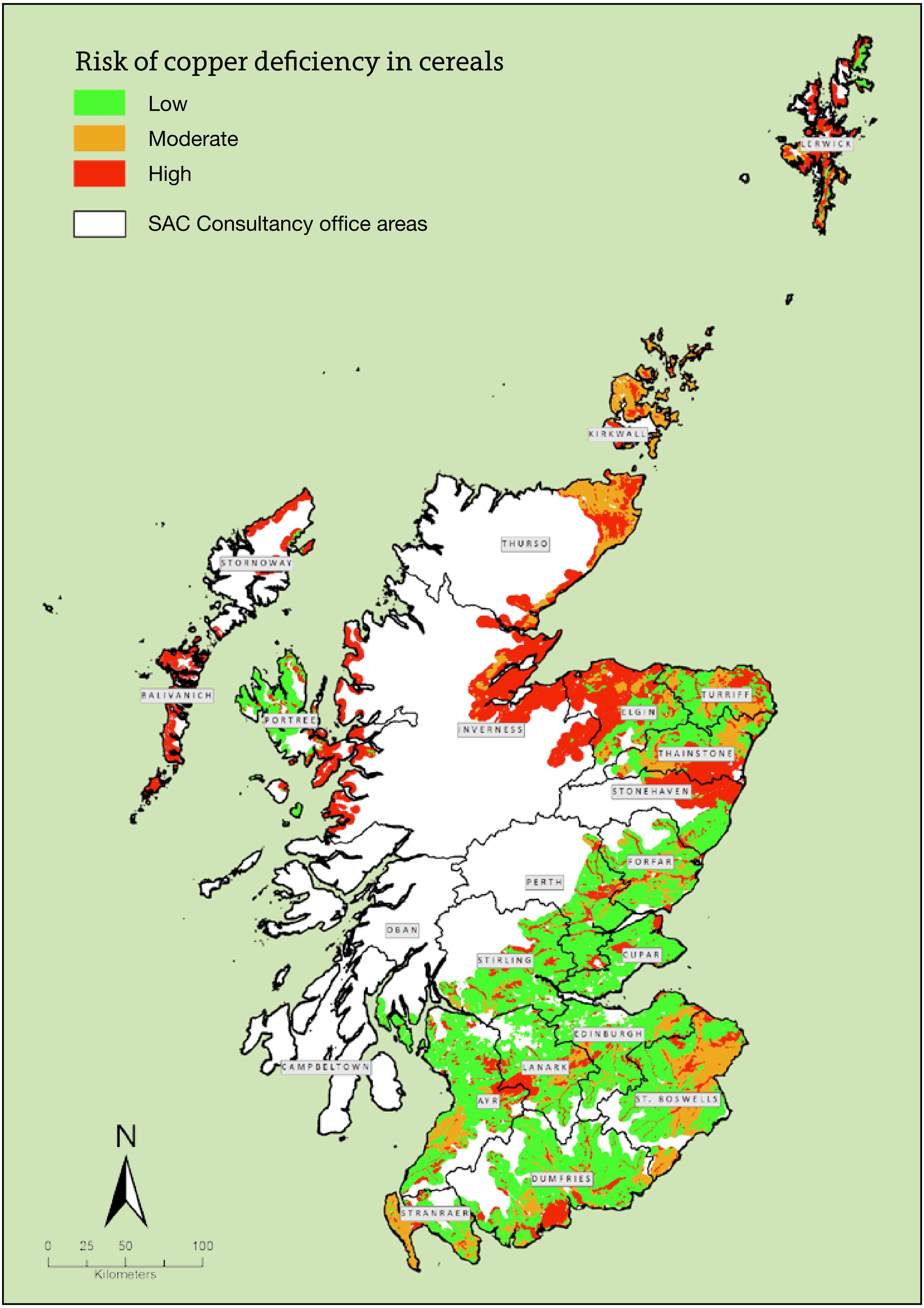

Figure 1. The risk of copper deficiency in cereals (high, moderate and low) by soil association in land with the potential to grow cereals.

3. Diagnostic methods

3.1 Visual assessment.

Symptoms in the growing crop provide a valuable, but not infallible guide to Cu deficiency. Deficiency symptoms are not often seen until the end of tillering, even on very susceptible soil types. Yellowing and withering of the tips of the youngest leaf is often accompanied by spiralling of leaves. Ears have difficulty in emerging from the sheath and those that do emerge usually develop white tips which are devoid of grain. Awns of barley become white and brittle and are easily shed. Many weak tillers develop late in the season causing greater susceptibility to lodging.

In less severe deficiency situations, crops appear quite normal until ear emergence or even until harvest when the ears are not fully developed and are partially blind. Blind ears can also be a symptom of drought on sandy soils and does not necessarily indicate a Cu shortage. **Sub-clinical deficiencies of Cu, where there is no appearance of visual symptoms, can reduce cereal yields.** Fields with a history of poorer than average yields should be tested for extractable Cu, especially if the fields are mapped as high or moderate risk of Cu deficiency (Figure 1).

3.2 Soil extraction.

A range of extractants are used internationally to determine potential plant-available micronutrient levels in the top soil. EDTA-extraction is used for copper in the UK. SAC Consultancy interpretative scales for extractable Cu concentrations in soil are shown in Table C. The benefits of using a soil diagnostic method to determine the presence of deficiency is that it allows for correction to be carried out before the crop is drilled. Soils at risk of copper deficiency can be tested in order to establish the actual status in individual fields. The Cu concentration in individual fields may have been altered by fertiliser application or amendment by bulky organic fertilisers.

It is recommended that very low and low Cu status soils are treated in order to eliminate risk rather than because of visual symptoms of copper deficiency in the crop. A further soil test is recommended after 8 to 10 years.

3.3 Plant tissue tests.

The difference in the Cu concentration of healthy and deficient plants may often be only slight, so that plant analysis for Cu has only limited value compared with soil testing. The interpretation of plant tissue Cu levels is also complicated by variation in the distribution and concentration of Cu in different plant parts due to nutrient mobility and physiological age of the plant part. ADAS work suggests that Cu concentrations <3 mg/kg (dry matter basis) in the leaf or whole ear, and <2 mg/kg in grain, could indicate deficiency, while SAC use <4 mg/kg in the plant prior to GS30 as a threshold guideline for deficiency. Older plant tissue contains more Cu than younger tissues, related to poor Cu mobility within the plant. Sampling method and crop growth stage should therefore be taken account of when interpreting plant analysis results.

Figure 2. Yellowing and withering of tips of youngest leaf and spiralling of leaves of spring barley.

Figure 3. Poorly emerged ears and many weak tillers in winter barley.

Table C. SAC Consultancy interpretative scales for extractable Cu concentrations (mg/kg) in topsoil

	Very low	Low	Moderate	High	Excessive
Element	Deficiency probable	Deficiency possible	No deficiency expected	No risk of deficiency	Crop toxicity may occur
Copper	<1.0	1.0 - 1.6	>1.6 - 8.5	>8.5 - 80	>80

4. Historical advisory extractable Cu levels in topsoil

The Cu concentration in individual fields may have been altered by fertiliser application or amendment by bulky organic fertilisers. A survey of SAC Consultancy advisory soil extractable Cu data will improve our understanding of the extent and distribution of soils currently at risk of copper deficiency in cereals. Advisory data for 10,140 samples from arable and grassland from 1996 to 2008 are summarised in Table D into Cu status. The distribution of Cu status is shown in Figure 4 for the SAC Consultancy office areas with at least 30 soil samples. These offices cover the main cereal growing areas.

The proportion of all samples measured as potentially deficient (VL or L status) was 26.4% where it is recommended that soils are treated with copper in order to eliminate risk rather than because of visual symptoms of copper deficiency in the crop. This proportion of soil samples is in good agreement to the 28.6% of the total area mapped as high risk of Cu deficiency in cereals. A higher proportion of at least 33% of samples in VL or L status were recorded in the Elgin, Inverness, St. Boswells and Dumfries offices.

- Elgin and Inverness offices reflect the proportion of high risk Cu soils of fluvioglacial sands and gravels (e.g. Corby association), alluvial soils and drifts derived from sandstone e.g. Cromarty association.
- Dumfries office reflects the area of tills derived from granites and granitic rocks of Countesswells association.
- St. Boswells office reflect high risk Eckford association fluvioglacial sands and gravels and moderate risk Hobkirk and Whitsome association drifts derived from sandstones.

Countesswells association (high risk) in the Thainstone and Stonehaven areas is more livestock based with more grass and less arable land.

The Cu concentration in individual topsoils may have been altered by fertiliser application or amendment by bulky organic fertilisers. In the Inverness and Elgin office areas there is evidence of the application of distillery effluents which are often a useful source of copper (see Table F).

Table D. Summary of advisory data for Cu (% of the total number of samples).

	Very low (VL)	Low (L)	Moderate (M)	High (H)
Element	Deficiency probable	Deficiency possible	No deficiency expected	No risk of deficiency
Copper	6.7	19.7	71.1	2.5

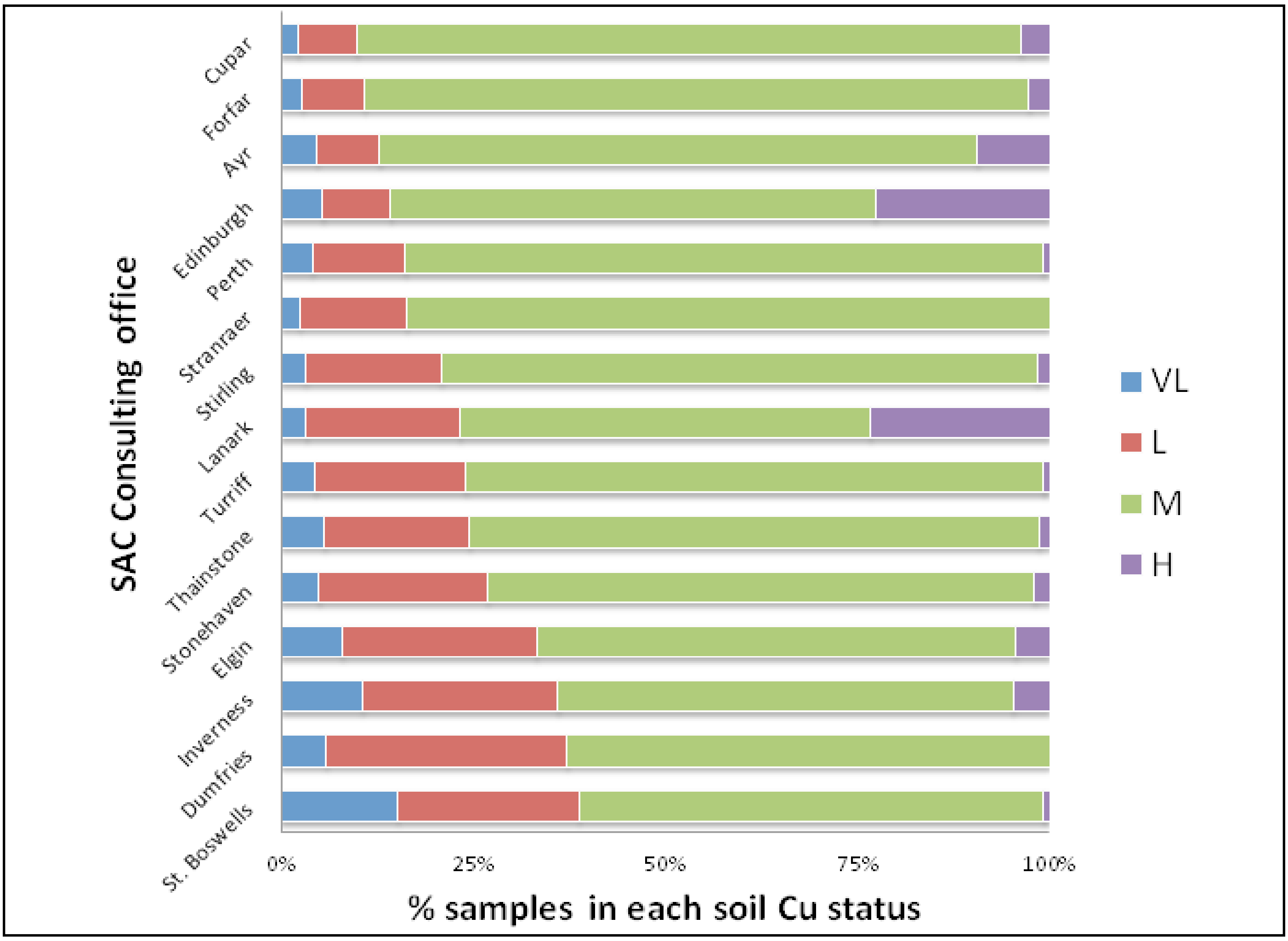

Figure 4. The distribution of Cu status for SAC Consultancy offices.

5. Treatments

The four main types of copper treatments are: simple inorganic solids; inorganic flowable suspensions; chelated products; and "cocktails". There is a wide range of products on the market. Current treatment recommendations are:

Soil application:

- A dressing of 5-10 kg/ha copper oxychloride (52% Cu), or 10-20 kg/ha copper sulphate (25%), depending on the extractable Cu status of the soil, applied on stubble or ploughing. The correcting effect could last up to ten years, although soil applied Cu is not always effective at correcting deficiency in the first season after application, possibly because of insufficient mixing and distribution of Cu in the topsoil, which justifies an additional foliar spray in the first year;
- Cu oxysulphate (a mixture of CuO and $CuSO_4$, typically 20% Cu in powder form) and fritted Cu are also available.

Foliar application:

- Copper oxychloride at 0.5-1.0 kg/ha, depending on severity of deficiency, plus wetter in at least 150 litres water once there is sufficient leaf canopy;
- Chelated Cu products most commonly based on EDTA (typically around 9% Cu w/v) applied at about 70 g Cu per ha, although phenolic acid and lignosulphonate chelates are also available.
- Or proprietary Cu products and "Cocktail" foliar feeds as an alternative.

"Cocktail" foliar feeds containing Cu generally supply much smaller amounts of Cu at recommended product rates than the specific inorganic Cu products. There is no standardisation over the method of expressing the concentration of Cu, but in the vast majority of products, the Cu content is expressed either as Cu % w/w (weight Cu expressed as a percentage of the weight of a product), or Cu % w/v (weight Cu expressed as a percentage of the volume of a product). The use of the w/w notation for liquid products leads to confusion during calculation of application rates of Cu as the specific weight of the liquid needs to be taken account of in order to compare with concentrations expressed as w/v.

The ability of a Cu-containing foliar spray to tank-mix with a pesticide often influences the choice of product. It is difficult to find information on tank mixability of the simple, non-formulated inorganic salts. This is probably partly due to the absence of these salts from the product ranges sold or manufactured by the main agrochemical companies.

Results from Scottish trials are consistent with the idea that high-yielding crops may be more efficient in obtaining Cu from the soil, given similar levels of extractable soil Cu prior to seed sowing, as far greater mobilisation of Cu occurs under a high yielding crop. **It is unnecessary to routinely apply Cu to every potentially high-yielding crop, unless the extractable soil Cu status is VL or L.**

Some livestock manures and other bulky organic manures can supply substantial amounts of Cu and could be of particular benefit on Cu deficient soils (Table F). Organic fertilisers are valuable sources of N, P and K although not all of the total nutrient content will be available for the next crop (see SRUC Technical Note TN650 on "Optimising the application of bulky organic fertilisers"). It is always advisable to have bulky organic fertilisers analysed prior to use, particularly where large volumes are being applied, or where similar materials are used regularly on the farm. The nutrient content of slurry can vary considerably within a store due to settlement and crusting. Similarly, the composition of solid manure in a heap can vary depending on the amount of bedding and losses of nutrients during storage.

Concentrations of Cu in dairy cattle manures are generally higher than in beef cattle manures most likely due to mineral supplements fed to dairy cattle. Concentrations of Cu tend to be higher in dry matter of cattle slurries than in FYM. Higher concentrations of Cu are found in pig manures than in dairy or beef cattle manures which reflect Cu concentrations in the feeds given to rearer pigs. Concentrations of Cu are generally lower in poultry manures than pig manures but higher than cattle manures.

Batches of compost or distillery wastes imported onto the farm may also vary considerably depending on the input materials and on the treatment methods used. Only by knowing the nutrient content of these materials can the amount of nutrients applied be optimised, fertiliser costs reduced and the potential for losses to the environment minimised.

Table F. Typical dry matter (DM) and nutrient contents of livestock manures and other 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 copper
Cattle FYM	25	6.0	3.2	8.0	0.002-0.01
Pig FYM	25	7.0	6.0	8.0	0.03-0.15
Layer manure	35	19	14	9.5	0.01-0.04
Broiler/Turkey litter	60	30	25	18	0.025-0.10
Cattle slurry	6	2.6	1.2	3.2	0.002-0.01
Pig slurry	4	3.6	1.8	2.4	0.01-0.05
Biosolids, liquid digested	4	2.0	3.0	0.1	0.02
Biosolids, digested cake	25	11	18	0.6	0.10
Biosolids, thermally dried	95	40	70	2.0	0.50
Biosolids, thermally hydrolysed	30	10	20	0.5	0.08
Biosolids, lime stabilised	40	8.5	26	0.8	0.20
Green compost	60	7.5	3.0	5.5	0.023
Green/Food compost	60	11	3.8	8.0	0.040
Paper crumble, chemically/ physically treated	40	2.0	0.4	0.2	0.025
Paper crumble, biologically treated	30	7.5	3.8	0.4	0.025
Distillery pot ale	5	2.5	1.8	1.1	0.01-0.02
Distillery bioplant effluent/sludge	2.5	1.5	1.3	0.4	0.02-0.30

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