Factsheet 21/05

Brassicas (cabbage, Brussels sprouts, cauliflower, broccoli, turnip and swede)

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Interpretation of leaf nutrient analysis results

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Brassica crops are noted for their susceptibility to deficiencies of nitrogen, boron and molybdenum and, increasingly, sulphur. Both yield and marketable quality can be affected by these and other nutrient deficiencies. If the nutritional status is below the 'critical level', visual symptoms will be present in the field. In the absence of visual symptoms, 'subclinical' deficiencies or toxicities may be present which will reduce growth and subsequently yield.

This factsheet aims to:

- **Assist with the diagnosis of the most common visual deficiency symptoms**
- **Provide guidance on sampling plants so that meaningful results are obtained**
- **Provide guidance on interpreting leaf tissue analysis results**
- **Provide information on managing nutrient deficiencies**

Visual symptoms

Visual diagnosis of nutrient disorders can be made where specific symptoms of deficiency and toxicity have been accurately described and documented. It is the quickest method for diagnosing the cause of poor crop performance due to nutrient disorders. There are, however, several difficulties in relying solely on visual symptoms:

- Severe deficiencies are rare
- Crop disorders induced by non-nutritional factors such as drought, low temperatures, herbicides, pests and diseases or even air pollutants may result in symptoms that can be mistaken for nutrient disorders
- More than one nutrient may be deficient causing different symptoms from those caused by a single nutrient

Nutrient deficiency symptoms

The diagnosis of a nutrient disorder in the field should follow clearly definable steps:

1 Realisation that something is wrong with the crop
2 Observation of abnormalities, noting if these are worse on older or younger leaves; chlorosis or interveinal yellowing; marginal scorch around leaf edges, necrosis of leaf tissue; pattern of distribution; deformities such as cupping, twisting and thickening
3 Relate a particular disorder to the field circumstances e.g. soil type or pH
4 Knowledge of susceptibility of a brassica crop to that disorder
5 Consider the possibility of symptoms having arisen from other causes such as drought, waterlogging, etc
6 Identification of possible causes by use of photographs illustrating nutrition deficiency
7 If doubt still remains, check diagnosis by means of leaf analysis

Photographs of nutrient deficiencies in brassicas

Note: Not all deficiencies produce clear field symptoms. Photographs are helpful in providing a visual diagnosis, but may be slightly ambiguous. 'A colour illustrated guide to pests, diseases and disorders of vegetables', a CD-ROM that contains further images and information on vegetable nutrient deficiencies is available from HDC. If in doubt, confirm diagnosis with leaf analysis.

Nitrogen (N)

Deficiency symptoms:

Marked reduction in growth with erect and thin stems. Leaves turn pale green, becoming yellow, bronzed, pink or purple as the leaf ages, with leaf abscission in extreme cases. In turnip, cauliflower and young swedes the predominant colour change is to yellow-orange. In cabbage, broccoli, Brussels sprouts and older swedes, this also occurs but is often preceded by a muddy-purple flush on the older leaves. In broccoli, cabbage, Brussels sprouts and cauliflower the new leaves can have a particularly grey, stiff, waxy appearance.

Occurrence:

Very common whenever insufficient N available especially on sandy soils following heavy rainfall, where excessive leaching or waterlogging has occurred.

Similar symptoms:

May also be induced by other factors such as cold weather, drought stress, root damage from nematodes and water logging. Sudden cold and P deficiency can produce purple tints.

Nitrogen – deficient cabbage showing overall pale colour and purple tinge on old leaves*

Nitrogen – Brussels sprout seedling showing grey–green waxy new leaf and bronzed cotyledons*

Nitrogen – turnip showing yellowing of older leaves and pink petioles*

Phosphorus (P)

Deficiency symptoms:

Reduction in growth but with scarcely noticeable foliage symptoms. Possibility of abnormally stiff and erect plants in broccoli and cauliflowers. Older leaves bluish green with dull purple tints, similar to nitrogen deficiency but without yellow-orange colours. Cauliflower may have reddish curds.

Occurrence:

On acid soils, calcareous soils or peats where levels of plant available

Phosphorus – red curd and stiff, pointed, purple edged leaves in cauliflower*

Phosphorus – dull purple flush on swede leaf*

phosphate are low. Temporary deficiencies can occur on cold, wet soil. However occurrence is rare because most vegetable growing soils contain good levels of plant available phosphate.

Similar symptoms:
Low temperatures and drought can cause similar symptoms. N deficiency may also produce purple tinting which may give leaves a very dull appearance.

Potassium (K)
Deficiency symptoms:
Leaves bluish green. Marginal and interveinal scorch and some blotchy chlorosis of older leaves. Tissue collapse can occur, with scorched edges of leaves curling forwards.

Occurrence:
On sandy soils inherently low in K and prone to leaching where insufficient K applied in the base dressing.

Similar symptoms:
Marginal scorch of lower leaves can be confused with chloride toxicity and wind damage.

Potassium – scorched leaves from deficient cabbage*

Potassium – turnip showing tissue collapse and scorch confined to top half of leaf*

Magnesium (Mg)
Deficiency symptoms:
A chlorotic marbling, which may become very striking, occurs on older leaves whilst main veins remain green. The chlorosis may be accompanied by a blotchy purple colour, especially between veins, near margins and on the underside of the leaf. Towards maturity other brilliant orange and red tints may occur particularly in cauliflowers. In turnip the leaf margins may initially remain green whereas some swede varieties show a blotchy reddening moving in from the older leaf margins. Older leaves of plants may wither and die.

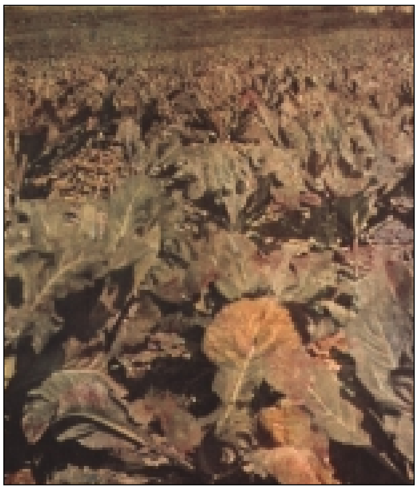
Occurrence:
On acid soils, on soils with very high extractable potassium/magnesium ratios particularly if soil compaction is present, or on very sandy soils subject to leaching after heavy rainfall.

Similar symptoms:
Easily confused with N deficiency and manganese deficiency. Symptoms of Mg deficiency can occur as a result of restricted root growth, commonly due to soil compaction or prolonged wetness. Also frequently associated with low spring temperatures.
Some resemblance to cauliflower mosaic virus symptoms and in turnips beet western yellows virus.

Magnesium – deficiency in swede showing blotchy reddening moving in from leaf edge*

Magnesium – turnip with leaf margin initially remaining green*

Magnesium – deficiency in cauliflower, older leaves chlorotic marbling followed by strong orange, red & purple tints



Magnesium – field view at harvest of deficient crop

Sulphur (S)

Deficiency symptoms:

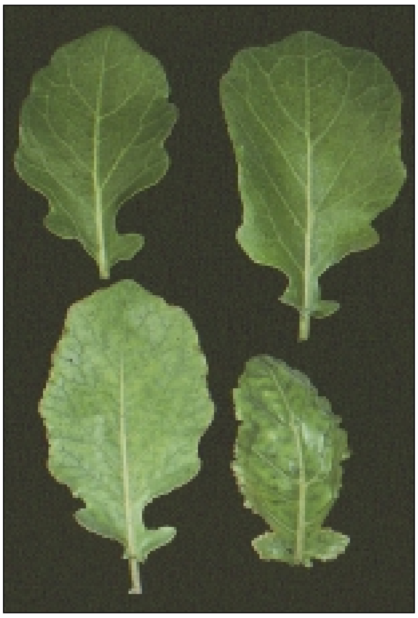
Deficient plants are typically small and spindly characterised by interveinal chlorosis of the young and middle leaves that cup both concavely (mainly while emerging) and convexly, and may become brittle and eventually may fail to grow. The chlorosis is very characteristic in that the veins stand out as a rather blurred, blue-green pattern against a pale green background. On the underside of the leaf these dark areas are purple, and this purple or bronze coloration may later affect whole leaves. Symptoms tend to develop slowly. In Brussels sprouts characteristic symptoms are yellowing tops and restricted rooting.

Occurrence:

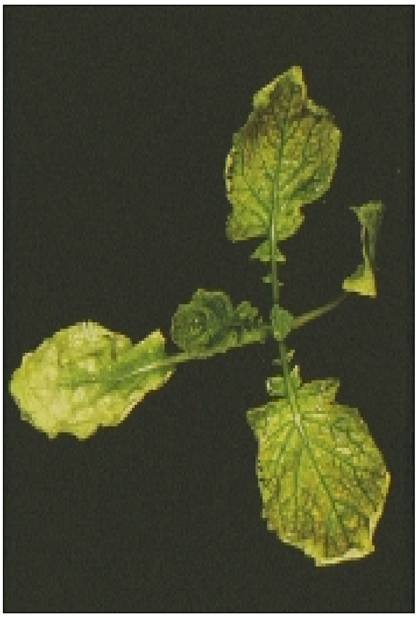
S deficiency can occur on all soil types, but is more likely to be a problem on light textured soils where leaching occurs or on thin soils overlying chalk and low in organic matter. Heavier textured soils such as clays and clay loams are unlikely to suffer from S deficiency, as is any field high in organic matter or receiving frequent applications of animal manures. Areas away from heavy industry or centres of population are likely to be at risk from deficiency and include East Anglia and Lincolnshire, the south-west, Lancashire, the Scottish borders and eastern Scotland.

Similar symptoms:

Distinguished from magnesium deficiency in that chlorosis is on young leaves, and accompanied by cupping and distortion of these leaves. Symptoms can be distinguished from nitrogen deficiency by the fact that they occur on younger leaves.



Sulphur – four week old sprouting broccoli with fourth leaf (bottom right) showing characteristic chlorosis*



Sulphur – turnip showing chlorosis and necrosis moving in from leaf tip*

Sulphur – deficiency in Brussels sprouts showing yellowing of top of plant

Calcium (Ca)

Deficiency symptoms:

Cupping, distortion and tipburn of young leaves, which may lead to death of growing point. Frequently it appears as though a string had been threaded around the leaf edge and drawn tight, causing the leaf to crinkle and cup deeply (as in Brussels sprouts) or buckle upwards, so that the ‘cup’ begins to turn itself inside out. Another common symptom is tissue collapse that occurs in bands across leaves, so that the distal part of the leaf hangs down and eventually shrivels up. The collapsed zone may also occur at the leaf edge. In turnips, the collapse begins with yellowing. In Brussels sprouts, a commercially important physiological disorder known as

Calcium – buckling and cupping of leaves*

‘internal browning’ has been attributed to calcium deficiency and similarly, internal tipburn of stored cabbage.

Occurrence:
Not related to soil type but can be associated with rapid growth in hot, humid weather, excessive soluble salts and soil compaction. This deficiency is rarely due to an absolute lack of calcium, problems occur when calcium movement in the transpiration stream towards susceptible tissue is low.

Similar symptoms:
Frost damage

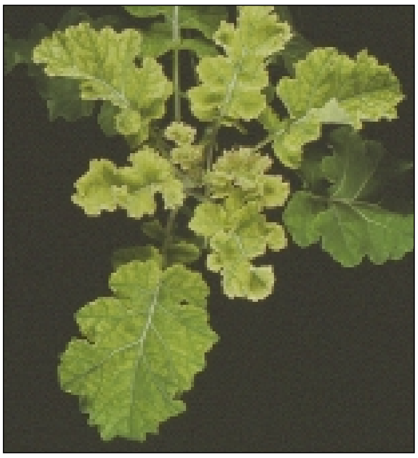
Calcium – tissue collapse in five week old cabbage*

Calcium – ‘internal browning’ in Brussels sprouts*

Manganese (Mn)
Deficiency symptoms:
An interveinal chlorotic yellow or yellow-white marbling (‘freckled’ or ‘speckled’ appearance) of the older leaves is the first symptom to appear. This can be confused with magnesium deficiency but manganese deficiency usually produces a finer more intensely yellow mottle. In severe cases the whole of the leaf may become almost bleached and some necrosis may develop. Severely affected plants are stunted in growth.

Occurrence:
Frequently induced by overliming. Most severe problems occur on organic and peaty soils with a pH above 6.0. Deficiency is generally less severe on sands and loamy sands. Symptoms are often transient and may disappear following rain.

Similar symptoms:
Symptoms may be masked by an additional stress factor such as disease, herbicide damage, and other plant nutrient deficiencies or frost damage. Can be confused with magnesium deficiency. May be confused with cauliflower mosaic virus.



Manganese – sprouting broccoli showing bleaching of young leaves, pink tinges on petioles, veins & leaf edge*

Manganese – severe interveinal chlorotic marbling and necrosis

Boron (B)
Deficiency symptoms:
Brassica crops are sensitive to boron deficiency and exhibit numerous very characteristic symptoms, but not all occur on all species. For all crops the first symptoms may be rolling and curling of the leaves that become brittle and are mottled round the margins. Cracked and corky stems, petioles and midribs can occur on all brassica species.

Cabbage:
Small blister-like swellings appear on the stem and lower surface of the leaf stalks. The stem is frequently hollow and discoloured internally with brown watery areas in the pith. Premature fall of older leaves may occur and heads are often yellow and small when deficiency is severe.

Brussels sprouts:
Interveinal chlorosis, worst on old leaves. Hollows also found in the stems. Brussels sprout plants will produce few sprouts if the deficiency sets in before they are formed: if deficiency occurs later, the sprouts will be small and loose.

Cauliflower:
Cotyledons may grow very large with subsequent very thick, brittle, finger-like new leaves. The stem is frequently hollow and discoloured internally near the curd. If the deficiency appears before curd formation the stem stops growing, causing a flat-topped plant with many side shoots and the curd fails to develop. In contrast if the curd is already present the curd turns brown giving a discoloured product unsuitable for marketing.

Broccoli:
First symptoms similar to those for cabbage but chlorosis is marginal, with brilliant red and yellow colours. Premature fall of older leaves may occur.

Turnip and swede:
If the deficiency occurs at the seedling stage, the new leaves show convex cupping, marginal chlorosis with brilliant red and orange colours. Later

on yellow and purple areas on the leaves of turnips are often associated with the deficiency. The growing point does not normally die in field crops, but some of the consequences of its moribund condition may appear e.g. multiple crowns. Boron deficiency can exist without any external symptoms. It is often only noticed when roots are cut open and brown water-soaked areas are found at irregular intervals, normally in the outer regions of the root. In these circumstances the central tissue may break down and the root becomes increasingly hollow, fibrous, bitter and invaded by rotting organisms. The outside may take on a rough, corky, leathery appearance. This condition is commonly known as 'brown heart' or 'raan'.

Occurrence:
Boron deficiency is more likely to occur on sands, loamy sands and sandy loams that have been limed recently rather than those which are naturally alkaline, and particularly when the soil pH is raised above pH 6.5 and more usually over pH 7.0. Since boron is water soluble and readily leached from sandy soils, deficiency is more common following a wet winter and spring, and particularly in dry summers.

Similar symptoms:
Most incidences of hollow stems in brassicas are associated with irregular water supply resulting in uneven growth. Excessive nitrogen may sometimes be involved in this symptom. Likewise cracking may be physiological in origin and occur in wet seasons or when dry weather is followed by wet weather thus causing a spurge of vegetative growth. Also cracking and corkiness on stems and petioles can result from the action of growth regulator type herbicides. Growing point injury can be due to insect attack e.g. swede midge.

Boron – rosetting of cabbage*

Boron – convex cupping at the seedling stage*

Boron – 14 week old Brussels sprout showing misshapen leaves with several forms of interveinal chlorosis

Boron – left and centre swede roots showing 'brown heart'. Note discoloration and hollow below crown of centre root. Healthy root on right*

Boron – cauliflower longitudinal section showing browning of curd and lesions in pith (not specific for boron; may be due to other causes in the field)

Copper (Cu)

Deficiency symptoms:
Almost unknown though cabbage may show faint diffuse interveinal chlorosis of expanding and mature leaves with withering. In turnips deficiency can cause severe yellowing of the foliage which also develops yellowish-white spots. There is considerable stunting of roots.

Occurrence:
Copper deficiency has only been diagnosed in a few specific soil situations. It could occur on peats and occasionally on loamy peats, mainly in the Fens and also on leached sandy soils, particularly reclaimed heathland and thin organic soils over chalk.

Zinc (Zn)

Deficiency symptoms:
Extremely rare in the UK. Expanding cabbage leaves cupped with out-curved margins and interveinal bronzing of older leaves.

Occurrence:
Associated with coarse sandy soils that are high in pH. Excessive phosphate applications may induce this deficiency.

Iron (Fe)

Deficiency symptoms:
Very rare in brassica crops. Young leaves turn yellow and later virtually white, with some green colour remaining along midrib and main veins. In turnip and swede chlorotic mottling of all foliage. Disorder very unlikely except as a result of heavy metal toxicity.

Occurrence:
Can occur on soils containing free calcium carbonate particularly if poorly drained.

Similar symptoms:
Manganese deficiency may resemble iron deficiency but would be on older leaves.

Iron – deficiency in Savoy cabbage showing severe chlorosis of leaves beginning as a chlorotic mottling

Iron – deficiency in turnips showing chlorotic mottling of leaves

Molybdenum (Mo)

Deficiency symptoms:
Of the brassica crops, cauliflower (both summer and winter) is the most sensitive to molybdenum deficiency. Other brassica species are not normally affected. The characteristic symptoms in cauliflower are known as 'Whiptail'. Growth of the leaf laminar is severely restricted giving narrow strap-like inward cupping of the leaves. The remaining lamina is irregular in outline, puckered, greatly reduced in area and brittle. Growing point becomes blind or stub-like and new shoots may appear from hypocotyl.

Occurrence:
Molybdenum deficiency only occurs on acid soils as this nutrient is more available at higher pHs. If soil pH is 6.5 or higher it will not be a problem.

Similar symptoms:
Blindness of the growing point, with some swelling of the surrounding petiole bases, can also be caused by preceding sub-zero temperatures, or by swede midge attack. In the latter case very small white larvae should be present on the petioles. Both disorders are distinct from whiptail in that leaf shape is unaffected. Cupping of leaves with mottled margins can be confused with manganese toxicity which is the main symptom of soil acidity.

Molybdenum – 'whiptail' in cauliflower*

Molybdenum – plant showing signs of recovery of new growth*

Why analyse leaf samples?

There are two reasons for recommending the use of leaf analysis in brassica crops:

- To confirm a diagnosis based on the appearance of symptoms: in such cases the leaf nutrient concentrations will usually be well below the 'critical level' and there should therefore be little doubt about the diagnosis.
- To test for 'subclinical' deficiencies or toxicities which may be already limiting growth but which are not yet resulting in visible symptoms.

Guidance on methods of crop foliage sampling for nutrient analysis

It is essential to collect leaf samples that accurately reflect the nutritional status of the crop submitted for analysis. Therefore to adequately represent any field or smaller area of crop, the following sampling procedure should be followed:

- sample at the crop stage indicated in table 1 (unless the sample is for the confirmation of a deficiency)
- for each plant take the youngest mature leaf
- if there is a clear differentiation between 'good' and 'poor' crop,

collect a second sample of leaves from the 'good' crop

- sample 20–30 plants to provide a minimum of 250 g of fresh material
- sample the crop following a 'W' pattern, collecting leaves at regular intervals

Do not sample

- diseased or dead plant material
- plant tissue damaged by insects and mechanical equipment
- plant tissue which has been stressed by excesses of cold, heat or moisture
- plant tissue within 10 days of foliar application of nutrients or fungicides

When sending samples to an analytical laboratory:

- ensure there is sufficient plant material, a minimum of 250g of fresh material
- avoid soil contamination
- ensure that the sample is representative of the crop/area
- include all relevant documentation and background information (sowing/planting date, variety, field name, growers details, etc)
- pack the sample, typically in a Jiffy Bag, so it arrives in the best possible condition
- do not post fresh material in an airtight container
- label each sample clearly
- avoid sending samples before weekends and bank holidays
- send by overnight courier or deliver directly to the analytical laboratory

Precise and meaningful analytical results are only possible when carefully selected plant material is submitted for analysis.

Table 1

Crop	Growth Stage
Cabbage	mid growth – as the plant is beginning to heart
Brussels sprouts	mid growth – as the plant initiates the first buttons
Cauliflower	first indication of buttoning
Broccoli	mid growth – when first spears are starting to form
Turnip and swede	first indication of root swelling

Table 2

Element	Unit	Cabbage	B Sprout	Cauliflower	Broccoli	Turnip
Nitrogen	%	3.0–5.0	3.0–5.0	3.0–5.0	3.5–5.5	3.5–5.0
Phosphorus	%	0.3–0.5	0.26–0.6	0.3–0.7	0.3–0.7	0.3–0.7
Potassium	%	3.0–4.5	2.5–4.0	3.0–4.0	2.0–4.0	2.5–5.0
Magnesium	%	0.2–0.7	0.2–0.7	0.2–0.7	0.2–0.7	0.3–0.6
Sulphur	%	0.3–0.8	0.3–0.8	0.3–0.8	0.3–0.8	0.35–0.8
Calcium	%	1.5–3.0	0.5–2.0	1.0–2.0	1.2–2.5	1.8–4.0
Manganese	mg/kg	25–200	25–200	25–200	25–200	30–300
Boron	mg/kg	25–60	25–60	25–60	25–60	30–150
Copper	mg/kg	5–20	5–20	5–20	5–20	5–25
Zinc	mg/kg	20–200	20–200	20–200	20–200	20–100
Iron*	mg/kg	50–200	50–200	50–200	50–200	50–150

*** of limited use as even the smallest amount of soil contamination invalidates the analysis and the deficiency may not be related to actual content.**

Interpretation of leaf tissue analysis results

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. The interpretations given here are based on the best information available.

Soil Nutrition

Though soil nutrition is outside the scope of this factsheet, growers are advised to consult and act upon the nutrition requirements and fertiliser management for brassicas crops in 'Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209)', PLANET Nutrient Management software or the appropriate crop protocols.

All brassicas, and in particular cauliflower, have a high fertility requirement though Brussels sprouts are less likely to develop deficiencies than other brassica crops. Turnips and swedes have a lower fertility requirement than other brassica crops. Brassicas are noted for their deficiencies of nitrogen and boron (or pseudo boron deficiency caused by growing conditions), and the increasing possibility of sulphur deficiency. Cabbages are also fairly susceptible to deficiencies of calcium and magnesium. Turnips and swedes may be prone to deficiencies of phosphorus and potassium because they are often grown on less fertile soils, also to boron as they have in the past been grown on more acid soils.

Strategy and specific action to rectify nutrient deficiencies

As deficiencies normally occur individually, specific treatments should be applied to the soil or crop foliage as appropriate to remedy a problem in a particular field.

All trace elements, except iron which is never a problem, can be applied as simple salts, usually as foliar sprays, though soil treatments are preferable for boron and molybdenum These treatments are cost effective, although more than one spray may be needed for manganese.

Multi-element sprays may not contain enough of a particular element to correct a deficiency, and where no deficiency exists, application can be wasteful. 'Insurance' treatments are not recommended where no deficiency has been identified, but where deficiencies are known to occur prophylactic sprays may be used.

Nitrogen (N)
Leaf analysis is valuable for the confirmation of plant N status. Treatment is usually by addition of N fertiliser at the appropriate rate and time to the soil and plant response to nitrate is very rapid except when the surface soil is very dry. Foliar applications of N are sometimes used as a 'fire brigade' treatment; foliar sprays of ammonium and nitrate salts can cause leaf damage except at very low concentrations. Urea may be used but there is still a risk of scorch.

Phosphorus (P)
Most soils have adequate P supplies and there should never be a need to apply a foliar spray of P if notice is taken of soil analyses results. Foliar feeding is not recommended because there is a high risk of leaf scorch.

Potassium (K)
Soil applications of potassium fertiliser according to crop requirement, based on soil analysis, should mean that K deficiency is not seen in brassica crops. Foliar feeding is not recommended because there is a high risk of leaf scorch.

Magnesium (Mg)
The application of magnesium fertiliser to the soil is a more effective long-term method for controlling the deficiency than the foliar application of a magnesium salt. The latter method however is useful when crops develop symptoms during the growing season, as a spray containing Mg can often greatly improve the appearance and market value of the crop though there may be little affect on yield. Symptoms of Mg deficiency can occur as a result of restricted root growth, commonly due to soil compaction or wetness and frequently associated with low temperatures in the spring. Foliar sprays of 20 kg/ha magnesium sulphate (Epsom salts) plus wetter in 500 l water may accelerate recovery.

Sulphur (S)
All brassica crops are increasingly at risk due to lower S inputs. S deficiency symptoms are more likely to be seen in soils low in organic matter (sulphur is mineralised from organic matter) and light textured soils as sulphur can be leached. Plant analysis is generally considered a more reliable tool for diagnosis of S deficiency than soil testing. Where reserves of sulphur are low and cannot be maintained, fertilisers containing sulphur should be used. Sulphur can be absorbed through leaves so foliar applications may be useful, but cannot be guaranteed to cure a problem. To date, sulphur deficiency has been determined by using tests based on total S, sulphate – S or a N:S ratio. For example, plant material samples with an N:S ratio of >16:1 are deficient and highly likely to respond to a sulphur application. Plant material with an N:S ratio of between16:1–13:1 may benefit from an insurance dressing, and a ratio of <13:1 is satisfactory and unlikely to suffer sulphur deficiency. Recently a new test based on malate:sulphate ratio has been developed and experience in cereals and oil seed rate shows it to be a better indicator of S deficiency. It is recommended that N:S ratios should be monitored as applications of sulphur to growing crops once problems have been seen is not guaranteed to solve the problem.

The sulphur containing compounds 'glucosinolates' are an important component of flavour in brassicas and some have beneficial health effects for humans, these compounds are also part of the plant's own protection system against some pests.

Calcium (Ca)
Ca is a major nutrient and provided soil pH is satisfactory there should be always be a good supply to brassicas. If Ca problems occur it is generally not an absolute deficiency but rather the lack of movement of the element within the plant, due to water stress, so it is the youngest tissues which will suffer. Foliar sprays of Ca have not been found to be useful but irrigation may be helpful.

Boron (B)
Soil analysis should be used to assess the boron need for susceptible crops such as swedes grown on sandy soils. Plant analysis can be used to complement visual diagnosis but often by the time symptoms of deficiency are seen it is too late to apply a remedial treatment. If foliar sprays are required, apply 5–10 kg/ha Solubor in at least 250 l water at an early crop stage, the amount depending on the severity of the deficiency as measured by analysis and the crop requirement.

Copper (Cu)
As there is often only a slight difference in the copper content of healthy and deficient plants, plant analysis has been of much less value in diagnosis than soil analysis. The disorder can be treated by application of Cu compounds to soil using copper sulphate or by foliar sprays of copper oxychloride or cuprous oxide at 2 kg/ha.

Manganese (Mn)
Diagnosis is often possible by visual symptoms and leaf analysis is a useful aid when in doubt. Soil analysis is of no practical use. Response to a foliar spray of manganese sulphate is rapid and reliable and the spray should be applied as soon as symptoms are seen. The normal application rate is 4.5 to 9 kg/ha of manganese sulphate plus wetter in at least 250 l water. The rate of application used should match the severity of deficiency, the risk of leaf scorch which may occur if crops under moisture stress are sprayed in bright sunshine, and field conditions. More than one spray may be necessary. Avoid over liming particularly on organic or peaty soils, for example where lime is applied for clubroot control.

Zinc (Zn)
Leaf analysis is the most useful aid to diagnosis, but commercial incidence in brassica crops is extremely rare.

Iron (Fe)
Very unlikely in brassica crops in the UK. Soil and plant analysis offers little help in diagnosing deficiency, as results are difficult to interpret due to the presence of physiologically inactive forms of iron within the tissue. Also, soil contamination of leaves growing close to the ground may elevate total iron results.

Molybdenum (Mo)
Soil and plant analysis are difficult and not usually necessary, since the deficiency can be identified by plant symptoms. Adequate and even liming to pH 6.5 will generally prevent the deficiency occurring on a field scale. Soil treatment with sodium or ammonium molybdate at 300 g/ha is recommended or a foliar drench at 0.25 g/l if deficiency occurs in the plant raising stage, though all module composts should contain sufficient Mo for good growth.

Always check compatibility if mixing nutrients with agrochemicals

Toxicities

Leaf analysis can be used to confirm toxicities of boron and manganese, but is of less use for heavy metals. Manganese toxicity can occur in acid soils especially those low in organic matter. Symptoms are concave cupping of leaves, particularly middle to old leaves, and a pale ‘rim’ round leaf edges, followed by marginal spotting and scorching.

Boron toxicity is occasionally found as a result of application of too much B. Symptoms are marginal chlorotic band on old leaves.

Copper should not be applied to soils without a demonstrated need by means of soil and plant analysis. Toxic effects from over-application can last many years.

Chloride toxicity causes marginal leaf scorch, abscission and chlorosis and is usually associated with irrigating with saline water.

Analytical laboratories
It is not possible within this factsheet to list all the laboratories that offer a leaf tissue analysis service. Growers should discuss the options with their agronomist or crop protection consultant.

Acknowledgement
Photographs marked * are courtesy of and copyright of Warwick HRI.

Manganese toxicity showing restricted lateral growth of leaf laminae and incurling and brown spotting of margins

Additional information:

August 2005

Design and production: HDR Visual Communication