Nutrient Management Guide (RB209)

Updated January 2021

Section 6 Vegetables and bulbs

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Greenhouse Gas Action Plan:
The industry-wide Greenhouse Gas Action Plan (GHGAP) for agriculture focuses on improving resource use efficiency in order to enhance business performance while reducing GHG emissions from farming.

Using the Nutrient Management Guide (RB209)

The Nutrient Management Guide (RB209) helps you make the most of organic materials and balance the benefits of fertiliser use against the costs – both economic and environmental. The guide outlines the value of nutrients and soil, and explains why good nutrient management is about more than just fertilisers. It can save you money as well as help protect the environment.

AHDB first published the Nutrient Management Guide (RB209) in May 2017. Since its publication, recommendations have been revised, with the latest independent research funded by AHDB and its partners. A list of updates is available at **ahdb.org.uk/rb209**

To improve the accessibility and relevance of the recommendations and information, the Nutrient Management Guide (RB209) is published as seven sections that are updated individually.

Further information

The Nutrient Management Guide (RB209) will be updated regularly. Please email your contact details to **comms@ahdb.org.u**k so that we can send you notifications of when they are published.

RB209: Nutrient Management

Download the app for Apple or Android devices to access the current version of the guide. With quick and easy access to videos, information and recommendations, it is practical for use in the field.

Always consider your local conditions and consult a FACTS Qualified Adviser if necessary.

This section provides guidance for vegetables and bulbs, and should be read in conjunction with Sections 1 and 2. For each crop, recommendations for nitrogen (N), phosphate (P_2O_5) and potash (K_2O) are given in kilograms per hectare (kg/ha). Magnesium (MgO), sulphur (as SO_3) and sodium (Na_2O) recommendations, also in kg/ha, are given where these nutrients are needed.

Recommendations are given for the rate and timing of nutrient application. These are based on the nutrient requirements of the crop being grown, while making allowance for the nutrients supplied by the soil.

Contents

Further information

AHDB publications portal
ahdb.org.uk/knowledge-library

AHDB Crop Walkers' Guide App
Download the app for Apple or Android phones to access all AHDB Crop Walkers' Guides.

Checklist for decision-making

Decisions for fertiliser use must be made separately for each field. Where more than one crop is grown in a field, crops must be considered individually.

1. Confirm the crop to be grown and the intended market. Identify any specific crop quality requirements for this market.
2. Identify the dominant soil type in the cropped area (**Section 1: Principles of nutrient management and fertiliser use**).
3. Assess soil structure and take action to remove soil compaction and improve drainage, if necessary. Poor soil structure can restrict crop growth and results in poor nutrient use efficiency.
4. Carry out soil analysis for pH, P, K and Mg every 3–5 years (**Section 1: Principles of nutrient management and fertiliser use**).

   Target values for vegetable rotations are:

   - Soil pH 6.5 or 7.0 for brassicas if clubroot is a problem (pH 5.8 on peat soils)
   - Soil P Index 3
   - Soil K Index 2+
   - Soil Mg Index 2

Further information

AHDB Field drainage guide
ahdb.org.uk/knowledge-library/field-drainage-guide

Soil management
ahdb.org.uk/greatsoils

Simply Sustainable Soils
www.leafuk.org/leaf/farmers/simplysustainablesoils

Think soils
ahdb.org.uk/knowledge-library/thinksoils

5. Identify the Soil Nitrogen Supply (SNS) Index of the field either by using the Field Assessment Method (page 7) or the Measurement Method (page 14).
6. Calculate the nutrients that will be supplied from organic materials that have been applied since harvest of the previous crop (**Section 2: Organic materials**). Deduct these nutrients from the recommended rates given in the tables. Crop assurance schemes and protocols may restrict application of organic materials.
7. Decide on the strategy for phosphate and potash use. This will be either building up, maintaining or running down the Soil Index levels (**Section 1: Principles of nutrient management and fertiliser use**). Allow for any surplus or deficit of phosphate or potash applied to previous crops in the rotation.
8. Calculate the amount of phosphate and potash removed in the harvested crop (Table 6.8). This is the amount of these nutrients that must be replaced in order to maintain the soil at the target Index.
9. Decide if starter or banded fertiliser would be appropriate.
10. Using the tables, decide on the required rate of each nutrient. Decide on the optimum timings for fertiliser application; then find the best match for these applications using available fertilisers.
11. Check that the fertiliser spreader or sprayer is in good working order and has been recently calibrated (**Section 1: Principles of nutrient management and fertiliser use**).
12. Keep an accurate record of all fertilisers and organic materials applied.

Further information

AHDB UK Fertiliser Price Series
ahdb.org.uk/GB-fertiliser-prices

Crop nitrogen requirement

The nitrogen recommendations for vegetables are based on the following:

1. Size of the crop – the size, frame or weight of the crop needed to produce optimal economic yields.
2. Nitrogen uptake – the optimum nitrogen uptake associated with a crop of that size.
3. Supply of nitrogen – based on the nitrogen supply from the soil within rooting depth, including any nitrogen mineralised from organic matter during the growing season.

Recommendations in the tables in this section are given for typical crops produced in the main part of the growing season. Crops planted earlier may need extra nitrogen because the supply of nitrogen from mineralisation is less than later in the growing season.

Some vegetables, such as beetroot, can have wide-ranging yield potential, depending on the market. The baby beet crop will have a smaller nitrogen demand but is shallow-rooted so will require similar amounts of nitrogen to higher-yielding processing crops.

The recommendations assume effective pest and disease control and that crops are grown on soils in good structural condition. Where crops are grown with minimal control measures or the crop is intended for storage, smaller amounts of nitrogen fertiliser should be considered.

In all cases, too much nitrogen fertiliser can give rise to poor-quality crops, especially when growing conditions are difficult. Where large amounts of nitrogen residues from previous crops are expected, measurement of Soil Mineral Nitrogen (SMN) can be helpful.

Calculating Soil Nitrogen Supply

Fields vary widely in the amount of nitrogen available to a crop before any fertiliser or manure is applied. This variation must be taken into account to avoid inadequate or excessive applications of nitrogen. The Soil Nitrogen Supply (SNS) system assigns an Index of 0 to 6 to indicate the likely extent of this background nitrogen supply. The Index is used in the recommendation tables to indicate the amount of nitrogen, as manufactured fertiliser, manure or a combination of both, that would typically need to be applied to ensure optimum yield.

The SNS Index for each field can be determined either by the Field Assessment Method using records of soil type, previous cropping and excess winter rainfall, or by the Measurement Method using measurements of Soil Mineral Nitrogen (SMN).

Further information

Soil Nitrogen Supply for field vegetables
ahdb.org.uk/knowledge-library/soil-nitrogen-supply-for-field-vegetables

The Field Assessment Method is suited for predicting SNS in the spring after autumn-harvested crops where SMN is expected to be low (<120 kg N/ha) but is less useful in complex horticultural rotations, particularly where there are repeated crops in the same season. Consider sampling SMN in fields with high or uncertain amounts of residues, such as intensively cropped brassica rotations, or in fields where there is a past history of grass or regular inputs of organic manures.

Where there are repeated crops in the same season (i.e. multiple salad crops), the Measurement Method is recommended to determine the SNS Index of the second and third crops. The Measurement Method is also recommended where planting or sowing is late, as Soil Mineral Nitrogen may be higher than expected due to mineralisation.

Field Assessment Method

The Field Assessment Method does not take account of the nitrogen that will become available to a crop from any organic manures applied since harvest of the previous crop.

The available nitrogen from manures applied since harvest of the previous crop, or those that will be applied to the current crop should be calculated separately using the information in **Section 2: Organic materials** and deducted from the fertiliser nitrogen application rates shown in the recommendation tables.

There are five essential steps to follow to identify the appropriate SNS Index:

Step 1. Identify the soil category for the field.
Step 2. Identify the previous crop.
Step 3. Select the rainfall range for the field.
Step 4. Identify the provisional SNS Index using the appropriate table.
Step 5. Make any necessary adjustments to the SNS Index.

In detail, these steps are:

Step 1. Identify the soil category for the field

Careful identification of the soil category in each field is very important. The whole soil profile should be assessed to at least rooting depth. Where the soil varies, and nitrogen is to be applied uniformly, select the soil type that occupies the largest part of the field.

The soil type can be identified using Figure 6.1, which categorises soils on their ability to supply and retain mineral nitrogen. The initial selection can then be checked using Table 6.1. Carefully assess the soil organic matter content when deciding if the soil is organic (10% to 20% organic matter for the purposes of this guide) or peaty (more than 20% organic matter). If necessary, seek professional advice on soil type assessments, remembering this will need to be done only once.

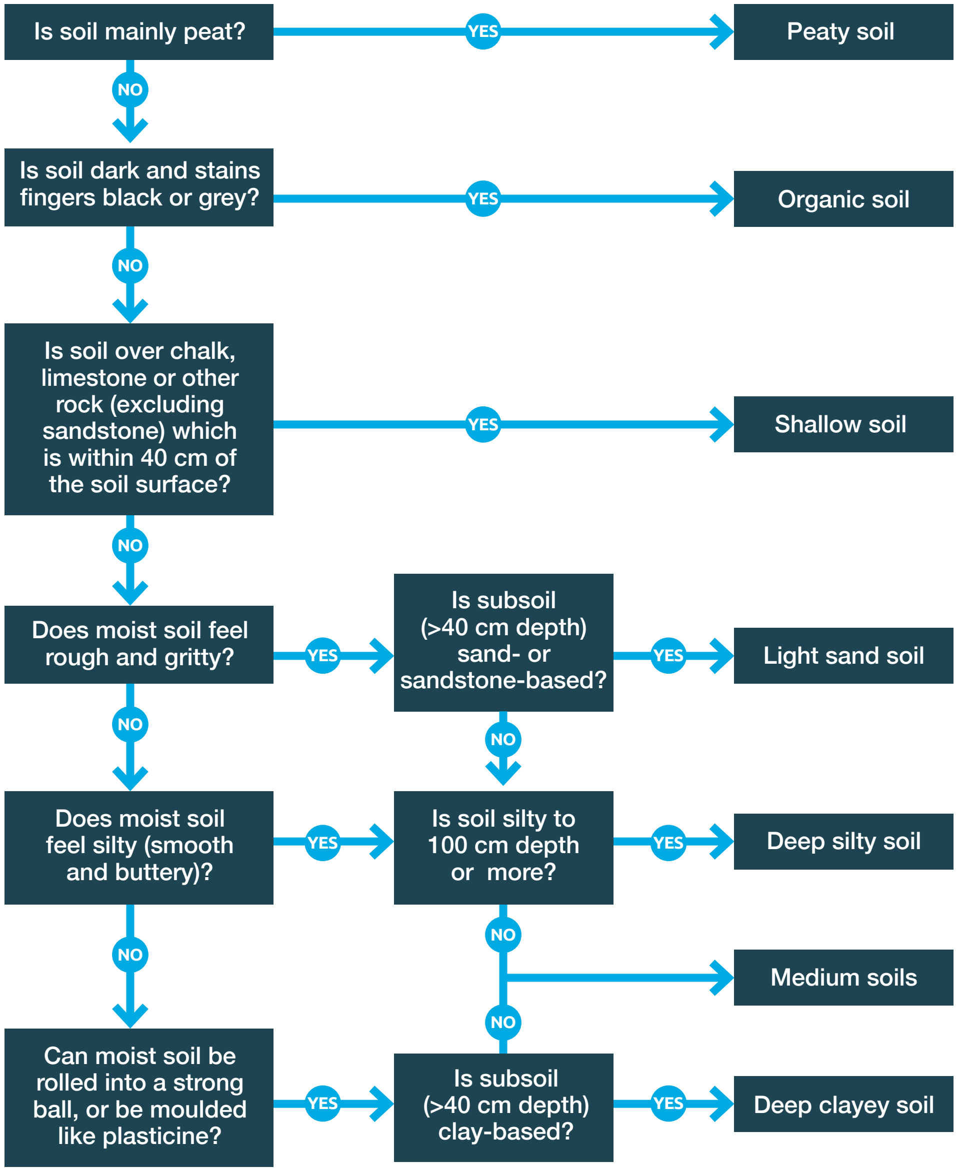

Figure 6.1 Soil category assessment

Table 6.1 Soil category assessment

Soil category	Description of soil types within category	Properties
Light sand soils	Soils that are sand, loamy sand or sandy loam to 40 cm depth and are sand or loamy sand between 40–80 cm, or over sandstone rock.	Soils in this category have poor water-holding capacity and retain little nitrogen.
Shallow soils	Soils over impermeable subsoils and those where the parent rock (chalk, limestone or other rock) is within 40 cm of the soil surface. Sandy soils developed over sandstone rock should be regarded as light sand soils.	Soils in this category are less able to retain or supply nitrogen at depth.
Medium soils	Mostly medium-textured mineral soils that do not fall into any other soil category. These include sandy loams over clay deep loams and silty or clayey topsoils that have sandy or loamy subsoils.	Soils in this category have moderate ability to retain nitrogen and allow average rooting depth.
Deep clayey soils	Soils with predominantly sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay or clay topsoil overlying clay subsoil to more than 40 cm depth. Deep clayey soils normally need artificial field drainage.	Soils in this category are able to retain more nitrogen than lighter soils.
Deep silt soils	Soils of sandy silt loam, silt loam or silt clay loam textures to 100 cm depth or more. Silt soils formed on marine alluvium, warp soils (river alluvium) and brickearth soils are in this category. Silt clays of low fertility should be regarded as other mineral soils.	Soils in this category are able to retain more nitrogen than lighter soils and allow rooting to greater depth.
Organic soils	Soils that are predominantly mineral but with between 10–20% organic matter to depth. These can be distinguished by darker colouring that stains the fingers black or grey.	Soils in this category are able to retain more nitrogen than lighter soils and have higher nitrogen mineralisation potential.
Peat soils	Soils that contain more than 20% organic matter derived from sedge or similar peat material.	Soils in this category have very high nitrogen mineralisation potential.

Step 2. Identify the previous crop

In vegetable rotations, the type and management of crop residues has a large influence on the SNS Index. There are three categories of vegetable crop residues – low, medium and high.

High residual nitrogen vegetables (‘high N vegetables’) are leafy, nitrogen-rich brassica crops such as calabrese, Brussels sprouts and some crops of cauliflower, where significant amounts of crop debris are returned to the soil, especially in rotations where an earlier brassica crop has been grown within the previous 12 months. To be available for crop uptake, this organic nitrogen must have had time to mineralise but the nitrate produced must not have been at risk to loss by leaching.

Medium residual nitrogen vegetables ('medium N vegetables') are crops such as lettuce, leeks and long-season brassicas such as Dutch white cabbage where a moderate amount of crop debris is returned to the soil.

Low residual nitrogen vegetables ('low N vegetables') are crops such as carrots, onions, radish, swedes or turnips where the amount of crop residue is relatively small.

Step 3. Select the rainfall range for the field

The appropriate rainfall category should be identified, based on either annual rainfall or excess winter rainfall. Ideally, an estimate of excess winter rainfall is required because this is closely related to drainage by which nitrate will be lost through leaching. Figure 6.2 shows long-term (1981–2010) average excess winter rainfall, which, in an average year, can be used to select the rainfall category.

There are three SNS Index tables representing 'low rainfall' (annual rainfall less than 600 mm, or less than 150 mm excess winter rainfall), 'moderate rainfall' (between 600–700 mm annual rainfall, or 150–250 mm excess winter rainfall) and 'high rainfall' areas (over 700 mm annual rainfall, over 250 mm excess winter rainfall).

Figure 6.2 Excess winter rainfall (mm)

Step 4. Identify the provisional SNS Index

Tables 6.2 (low rainfall), 6.3 (moderate rainfall) and 6.4 (high rainfall) should be used where the field has not been in grass within the past three years. Take account of the footnotes to the tables.

For organic soils, the SNS is likely to vary widely, typically between Index 3 and 6. Assessments of SNS on these soils should take into account previous experience of crop response to nitrogen. For peats and peaty soils, the SNS is expected to be at Index 5 or 6, irrespective of previous cropping, manuring or excess winter rainfall. However, local experience should be used to judge the nitrogen supply from these soils, particularly when growing shallow-rooted vegetables.

Higher than typical Indices can also occur where there has been a history of grassland or frequent applications of organic materials. Soil analysis for Soil Mineral Nitrogen (SMN) is recommended in these situations.

If grass has been grown in the previous three years, also look at Table 6.5. Select the higher of the Index levels based on the last crop grown (Table 6.2, 6.3, 6.4) and that based on the grass history (Table 6.5).

Table 6.2 Soil Nitrogen Supply (SNS) Indices for low rainfall (500–600 mm annual rainfall, up to 150 mm excess winter rainfall) – based on the last crop grown

Previous crop	Soil category					
	Light sand soils or shallow soils over sandstone	Medium soils or shallow soils not over sandstone	Deep clayey soils	Deep silty soils	Organic soils	Peat soils
Beans	1	2	3	3	All crops in SNS Index 3, 4, 5 or 6. Consult a FACTS Qualified Adviser.	All crops in SNS Index 4, 5 or 6. Consult a FACTS Qualified Adviser.
Cereals	0	1	2	2		
Forage crops (cut)	0	1	2	2		
Oilseed rape	1	2	3	3		
Peas	1	2	3	3		
Potatoes	1	2	3	3		
Sugar beet	1	1	2	2		
Uncropped land	1	2	3	3		
Vegetables (low N)[a]	0	1	2	2		
Vegetables (medium N)[a]	1	3	3[b]	3[b]		
Vegetables (high N)[a]	2	4[b]	4[b]	4[b]		

a. Refer to Step 2.

b. Index may need to be increased by up to 1 where significantly larger amounts of leafy residues are incorporated (see Step 5). Where there is uncertainty, soil sampling for SMN may be appropriate.

Table 6.3 Soil Nitrogen Supply (SNS) Indices for moderate rainfall (600–700 mm annual rainfall, or 150–250 mm excess winter rainfall) – based on the last crop grown

Previous crop	Soil category					
	Light sand soils or shallow soils over sandstone	Medium soils or shallow soils not over sandstone	Deep clayey soils	Deep silty soils	Organic soils	Peat soils
Beans	1	2	2	3	All crops in SNS Index 3, 4, 5 or 6. Consult a FACTS Qualified Adviser.	All crops in SNS Index 4, 5 or 6. Consult a FACTS Qualified Adviser.
Cereals	0	1	1	1		
Forage crops (cut)	0	1	1	1		
Oilseed rape	0	2	2	2		
Peas	1	2	2	3		
Potatoes	0	2	2	2		
Sugar beet	0	1	1	1		
Uncropped land	1	2	2	2		
Vegetables (low N)[a]	0	1	1	1		
Vegetables (medium N)[a]	0	2	3	3		
Vegetables (high N)[a]	1	3	4	4		

a. Refer to Step 2.

Table 6.4 Soil Nitrogen Supply (SNS) Indices for high rainfall (over 700 mm annual rainfall, or over 250 mm excess winter rainfall) – based on the last crop grown

Previous crop	Soil category					
	Light sand soils or shallow soils over sandstone	Medium soils or shallow soils not over sandstone	Deep clayey soils	Deep silty soils	Organic soils	Peat soils
Beans	0	1	2	2	All crops in SNS Index 3, 4, 5 or 6. Consult a FACTS Qualified Adviser.	All crops in SNS Index 4, 5 or 6. Consult a FACTS Qualified Adviser.
Cereals	0	1	1	1		
Forage crops (cut)	0	1	1	1		
Oilseed rape	0	1	1	2		
Peas	0	1	2	2		
Potatoes	0	1	1	2		
Sugar beet	0	1	1	1		
Uncropped land	0	1	1	2		
Vegetables (low N)[a]	0	1	1	1		
Vegetables (medium N)[a]	0	1	1	2		
Vegetables (high N)[a]	1[b]	2	2	3		

a. Refer to Step 2.

b. Index may need to be lowered by 1 where residues are incorporated in the autumn and not followed immediately by an autumn-sown crop.

Table 6.5 Soil Nitrogen Supply (SNS) Indices following ploughing out of grass leys

	SNS Index		
Light sands or shallow soils over sandstone – all rainfall areas	Year 1	Year 2	Year 3
All leys with 2 or more cuts annually receiving little or no manure 1–2 year leys, low N 1–2 year leys, 1 or more cuts 3–5 year leys, low N, 1 or more cuts	0	0	0
1–2 year leys, high N, grazed 3–5 year leys, low N, grazed 3–5 year leys, high N, 1 cut then grazed	1	2	1
3–5 year leys, high N, grazed	3	2	1
Other medium soils and shallow soils – not over sandstone – all rainfall areas			
All leys with 2 or more cuts annually receiving little or no manure 1–2 year leys, low N 1–2 year leys, 1 or more cuts 3–5 year leys, low N, 1 or more cuts	1	1	1
1–2 year leys, high N, grazed 3–5 year leys, low N, grazed 3–5 year leys, high N, 1 cut then grazed	2	2	1
3–5 year leys, high N, grazed	3	3	2
Deep clayey soils and deep silty soils in low rainfall areas (500–600 mm annual rainfall)			
All leys with 2 or more cuts annually receiving little or no manure 1–2 year leys, low N 1–2 year leys, 1 or more cuts 3–5 year leys, low N, 1 or more cuts	2	2	2
1–2 year leys, high N, grazed 3–5 year leys, low N, grazed 3–5 year leys, high N, 1 cut then grazed	3	3	2
3–5 year leys, high N, grazed	5	4	3
Deep clayey soils and deep silty soils in moderate (600–700 mm annual rainfall) or high (over 700 mm annual rainfall) rainfall areas			
All leys with 2 or more cuts annually receiving little or no manure 1–2 year leys, low N 1–2 year leys, 1 or more cuts 3–5 year leys, low N, 1 or more cuts	1	1	1
1–2 year leys, high N, grazed 3–5 year leys, low N, grazed 3–5 year leys, high N, 1 cut then grazed	3	2	1
3–5 year leys, high N, grazed	4	3	2

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The Indices shown in Table 6.5 assume that little or no organic manure has been applied. Where silage fields have received the organic manures produced by livestock that have eaten the silage and the manure has been applied in spring, such fields should be regarded as containing nitrogen residues equivalent to a previous grazing history.

'Low N' grassland means average annual inputs of less than 250 kg N/ha in fertiliser plus crop-available nitrogen in manure used in the last two years, or swards with little clover.

'High N' grassland means average annual applications of more than 250 kg N/ha in fertiliser plus crop-available nitrogen in manure used in the last two years, or clover-rich swards or lucerne.

Step 5. Make any necessary adjustments to the SNS Index

On medium, deep silty or deep clayey soils, nitrogen residues in predominantly vegetable rotations can persist for several years, especially in the drier parts of the country. This is likely to be especially evident following 'high' or 'medium' N vegetables. The SNS tables make some allowance for this long persistency of nitrogen residues, but the Index level may need to be adjusted upwards, particularly where winter rainfall is low, where the history of vegetable cropping is longer than one year, and in circumstances where larger than average amounts of crop residue or unused fertiliser are left behind (see footnote to Table 6.2). In rotations where vegetable crops are grown infrequently in essentially arable rotations, the Index level may need to be adjusted downwards.

Nitrogen-rich leafy residues from many brassica crops are ploughed into the land at various times of the year. The nitrogen in these materials can become available for use by the next crop very rapidly in summer but more slowly in the winter when the soil temperature is lower.

In this situation where double-cropping is practised in the summer season, the SNS Index can be increased by 1 if following 'medium N vegetables' and by up to 2 following 'high N vegetables'. It is important that the growing conditions of the first crop are fully taken into account, especially where nitrogen may be leached from light sand soils in wet seasons or where excess irrigation has been applied. Care needs to be taken where residues are ploughed in after late December; the nitrogen may not become available for uptake by the next crop until after that crop requires the bulk of its nitrogen supply.

Manure history: Where regular applications of organic manures have been made to previous crops in the rotation, increase the Index value by one or two levels depending on manure type, application rate and frequency of application.

Fertiliser residues from previous crop: Nitrogen fertilisation and management of the previous vegetable crop can also have a large impact on SNS. The Index assessments assume that the previous crop grew normally and that it received the recommended rate of nitrogen applied as fertiliser and/or organic manures. Where nitrogen fertiliser recovery of the previous crop is expected to be higher or lower than normal, the SNS Index may need to be adjusted to account for greater or smaller than normal nitrogen residues remaining in the soil.

Where there is uncertainty about the amount of nitrogen in the soil, sampling for Soil Mineral Nitrogen (SMN) may be appropriate.

Measurement Method

Direct measurement of SMN provides a more reliable basis for nitrogen decisions in a number of situations. This method is particularly appropriate where the SNS is likely to be large (>120 kg/ha) or uncertain. This includes fields in intensively cropped brassica rotations or fields receiving regular inputs of organic manures or where there is history of grass (but SMN sampling is not recommended during the first year after ploughing out grass).

Where there are repeated crops in the same season (i.e. multiple salad crops), the Measurement Method is recommended to determine the SNS Index of the second and third crops. The Measurement Method is also recommended where planting or sowing is late as Soil Mineral Nitrogen may be higher than expected due to mineralisation.

For field vegetable crops, it is important to ensure that nitrogen is available to rooting depth, especially with young or shallow-rooted crops, and SMN sampling is also useful to show the availability of SMN within the rooting depth of the crop.

SNS is likely to be low on light sand and shallow soils that have not received regular additions of organic manure or crop residues, particularly in moderate to high rainfall areas; under these circumstances, prediction of SNS using the Field Assessment Method is advised. The Field Assessment Method is also recommended on peaty soils or in the first season after ploughing out long leys or permanent pasture. In these situations, nitrogen released by mineralisation of soil organic matter is a large component of the SNS and the Field Assessment Method or local experience will be a better guide to SNS.

The SNS Index can be identified using the results of direct measurement of SMN (nitrate-N plus ammonium-N) to rooting depth. For field vegetables, SNS is equivalent to measured SMN; as SMN samples are taken before planting, there is no need to make allowances for crop nitrogen content, and there is also no need to add an estimate of nitrogen mineralisation during the growing season as nitrogen from mineralisation is already taken into account in the recommendation tables.

The Measurement Method does not take account of the available nitrogen supplied from organic manures applied after the date of soil sampling for SMN. The available nitrogen from manures applied after sampling should be calculated separately using the information in **Section 2: Organic materials** and deducted from the nitrogen rate shown in the appropriate recommendation table. The nitrogen contribution from manures applied before sampling for SMN will be largely taken account of in the measured value and should not be calculated separately.

When using the Measurement Method, there are two steps to follow:

Step 1. Measure Soil Mineral Nitrogen (SMN).

Step 2. Identify the Soil Nitrogen Supply (SNS) Index.

In detail these two steps are:

Step 1. Measure Soil Mineral Nitrogen (SMN)

Soil sampling must be done well to avoid misleading results and expensive mistakes.

Guidance on how to collect an SMN sample

- SMN samples should be collected as close to planting as possible, and not within two months of applying nitrogen fertiliser or organic materials
- Areas of land known to differ in some important respects (e.g. soil type, previous cropping, application of manures or nitrogen fertiliser) should be sampled separately
- Do not sample unrepresentative areas, such as ex-manure heaps or headlands
- Avoid collecting and sending samples immediately before the weekend or a public holiday
- Samples must be taken to be representative of the area sampled. A minimum of 10–15 soil cores should be taken following a 'W' pattern across each field/area to be sampled
- In larger fields (10–20 ha), increase the number of cores to 15–20, unless the soil type is not uniform, in which case more than one sample should be taken. This can be done by dividing the field into smaller blocks from each of which 10–15 soil cores are taken
- Take samples in 30 cm sections to 90 cm (0–30 cm, 30–60 cm and 60–90 cm) or to rooting depth. Table 6.6 includes typical rooting depths for field vegetable crops; sampling the soil to 90 cm depth is difficult to do manually
- Samples from each depth should be bulked to form a representative sample of that depth. If the bulk sample is too big, take a representative subsample to send to the laboratory; do not stir the sample excessively
- Use appropriate packaging (normally available from the laboratory) and label samples clearly, providing as much information about the field and crop as possible
- Samples should be analysed within three days of sampling. Samples must be kept cool (2–4°C) but not frozen during storage or transport

It is important to avoid cross-contamination of samples from different depths. Using a mechanised one-metre-long gouge auger (2.5 cm diameter) is a satisfactory and efficient method, but care must be taken to avoid excessive soil compaction and contamination between soil layers. If each depth layer is to be sampled individually by hand, a series of screw or gouge augers should be used where the auger diameter becomes progressively narrower as the sampling depth increases.

Analysis in the laboratory

Samples should be analysed for nitrate-N and ammonium-N. Analytical results in mg N/kg should be converted to kg/ha, taking into account the dry bulk density of the soil, then summed to give a value for the whole soil profile. For the majority of mineral soils, a 'standard' bulk density of 1.33 g/ml can be used and the calculation can be simplified to:

SMN (kg N/ha) = mg N/kg x 2 (for each 15 cm layer of soil)

SMN (kg N/ha) = mg N/kg x 4 (for each 30 cm layer of soil)

SMN (kg N/ha) = mg N/kg x 8 (for each 60 cm layer of soil)

Step 2. Identify the SNS Index

Table 6.6 SNS Indices based on sampling (N kg/ha) to 30, 60 and 90 cm depth

	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
SMN kg/ha to 30 cm	<20	20–27	28–33	34–40	41–53	54–80	>80
SMN kg/ha to 60 cm	<40	41–53	54–67	68–80	81–107	108–160	>160
SMN kg/ha to 90 cm	<60	61–80	81–100	101–120	121–160	161–240	>240

Where SMN is measured to a different depth (i.e. 45 cm), the SNS Index should be determined by assuming a uniform concentration of mineral nitrogen in the soil.

Example 6.1

If SMN measured to 45 cm is 54 kg N/ha, then assuming a uniform concentration of nitrogen in the soil, SMN to 60 cm would be 54 kg N/ha x (60 cm/45 cm) = 72 kg N/ha to 60 cm, equivalent to SNS Index 3.

Example 6.2

Brussels sprouts are to be grown on a deep silt soil following winter wheat. Annual rainfall is 650 mm.

Select Table 6.3 (SNS Indices for moderate rainfall areas). On a deep silt soil following cereals, the SNS Index is 1. Refer to the Brussels sprouts recommendation in Table 6.12 which gives a recommendation of 300 kg N/ha.

Example 6.3

Sweetcorn is grown on a light sand soil following courgettes. Annual rainfall is 750 mm; 40 m^3/ha of crop-based digestate was applied in April prior to planting and incorporated into the soil within six hours.

Select Table 6.4 (SNS Indices for high rainfall areas). Courgettes are likely to leave a moderate amount of crop debris and can therefore be categorised as a medium N residue vegetable. On light sand soil after medium N vegetables, the SNS is Index 0. Refer to the sweetcorn recommendation in Table 6.18 which gives a recommendation of 220 kg N/ha.

Since the crop-based digestate was applied after harvest of the last crop, its nitrogen contribution must be calculated separately. This digestate application provides 50 kg N/ha of crop-available nitrogen that is equivalent to inorganic nitrogen fertiliser (**Section 2: Organic materials**).

Crop nitrogen recommendation of 220 kg N/ha minus 50 kg N/ha crop-available nitrogen supply from digestate = 170 kg N/ha as fertiliser should be applied.

Example 6.4

Two crops of baby leaf lettuce are grown on a deep silt soil after cereals. Annual rainfall is 550 mm.

The Field Assessment Method is used to determine SNS for the first crop sown in March. Select Table 6.2 (SNS Indices for low rainfall areas). On deep silt soils after cereals, the SNS Index is 2. Refer to the baby leaf lettuce recommendation in Table 6.19 which gives a recommendation of 40 kg/ha N.

The Measurement Method is used to determine SNS for the second crop. The soil is sampled to rooting depth (0–30 cm) in July, prior to planting the second crop. The analysis report shows that the SMN (0–30 cm) is 62 kg N/ha, which is SNS Index 5. The nitrogen recommendation for baby leaf lettuce at Index 5 is 0. No fertiliser nitrogen should be applied to the second crop.

Phosphate, potash and magnesium recommendations

Many vegetables respond to fresh applications of phosphate and potash fertiliser, especially at low Soil Indices and it is important that these needs are fully met. The target Soil Indices for vegetable rotations are P Index 3 and K Index 2+.

The phosphate and potash recommendations given in the tables are sufficient to replace crop offtake at the target Soil Index and therefore to maintain the target Soil Index. The amount of phosphate and potash needed to supply maintenance needs will depend on crop yields and nutrient offtake. For a more precise calculation of maintenance requirements, use Table 6.8 which contains information on phosphate and potash in crop material. Where the soil is below the target phosphate or potash Index, the recommendations given in the tables are higher to allow the soil to ‘build up’ to the target Index over time.

There are instances where small amounts of nitrogen and phosphate fertiliser placed beneath seedlings or transplants can improve establishment, early growth and subsequent use of nutrients. The use of these techniques is encouraged, but the amount in any starter dose applied should be deducted from the total application required.

Some vegetable crops are susceptible to magnesium deficiency and may show yield responses to magnesium fertiliser on soils at Mg Index 0 and 1. Magnesium recommendations for all field vegetable crops are for 150 kg MgO/ha at Index 0 and 100 kg MgO/ha at Index 1.

Points to consider

- Recommendations assume good soil structure, water supply and pest and disease control
- Recommendations are given as phosphate (P_2O_5), potash (K_2O) and magnesium oxide (MgO). Conversion tables (metric–imperial, oxide–element) are given on page 43
- Don’t forget to make allowance for the phosphate and potash applied in organic materials (**Section 2: Organic materials**)
- All recommendations are given for the midpoint of each Index. For some crops, there are different recommendations depending on whether the soil is in the lower half (2-) or upper half (2+) of K Index 2
- Where a soil analysis value (as given by the laboratory) is close to the range of an adjacent Index, the recommendation may be reduced or increased slightly, taking account of the recommendation given for the adjacent Index. Small adjustments of less than 10 kg/ha are generally not justified
- Where more or less phosphate and potash are applied than suggested in the tables, adjustments can be made later in the rotation

Taking soil samples for pH, phosphorus, potassium, magnesium and sodium

Soil sampling must be done well to avoid misleading results and expensive mistakes.

- The soil in each field should be sampled every 3–5 years
- Take topsoil samples to 15 cm depth using a soil auger
- Collect samples at the same point in the rotation and well before growing a sensitive crop, e.g. sugar beet
- Ideally, sample immediately after the harvest of the previous crop
- Do not sample within six months of a lime or fertiliser application (except nitrogen) and avoid sampling when the soil is very dry
- Do not take samples in headlands, or in the immediate vicinity of hedges, trees or other unusual features
- The soil sample must be representative of the area sampled. Areas of land known to differ in some important respects (e.g. soil type, previous cropping, applications of manure, fertiliser or lime) should be sampled separately. Small areas known to differ from the majority of a field should be excluded from the sample
- Ideally, the sampled area should be no larger than four hectares
- Clean tools before starting and before sampling a new area
- Walk a ‘W’ pattern across the sampling area, stopping at least 25 times
- At each point, collect a subsample (core) to 15 cm depth using a gouge corer or screw auger
- The subsamples should be bulked to form a representative sample and sent to the laboratory for analysis
- Use appropriate packaging (normally available from the laboratory) and label samples clearly, providing as much information about the field and crop as possible

On soils where acidity is known to occur, more frequent testing may be needed than the four-year cycle used for phosphate, potash and magnesium. Since acidity can occur in patches, spot testing with a soil indicator test across the field is often useful. Soil indicator tests can also be useful on soils which contain fragments of free lime, since these can give a misleadingly high pH when analysed following grinding in the laboratory.

PAAG

Professional Agricultural Analysis Group

Most UK laboratories are members of the PAAG that offers farmers and advisers confidence in laboratory analysis:

- Proficiency tests (often called ring tests) carried out by Wageningen University, guaranteeing that analysis from any member can be trusted
  wepal.nl
- List of UK laboratories
  ahdb.org.uk/knowledge-library/soil-testing-companies
- Sampling guidelines
  nutrientmanagement.org/library/sampling

Classification of soil analysis results into Indices

The laboratory soil analysis results for P, K and Mg (in mg/kg dry soil) can be converted into soil Indices using Table 6.7.

Table 6.7 Classification of soil P, K and Mg analysis results into Indices

Index	Phosphorus (P)	Potassium (K)	Magnesium (Mg)
	Olsen P	Ammonium nitrate extract	
	mg/litre		
0	0–9	0–60	0–25
1	10–15	61–120	26–50
2	16–25	121–180 (2-) 181–240 (2+)	51–100
3	26–45	241–400	101–175
4	46–70	401–600	176–250
5	71–100	601–900	251–350
6	101–140	901–1,500	351–600
7	141–200	1,501–2,400	601–1,000
8	201–280	2,401–3,600	1,001–1,500
9	Over 280	Over 3,600	Over 1,500

Phosphate and potash in crop material

Table 6.8 Typical values of phosphate and potash in crop materials

Crop material	Phosphate (P_2O_5)[a]	Potash (K_2O)[a]
	kg/t of fresh material	
Swedes (roots only)	0.7	2.4
Broad beans	1.6	3.6
French beans	1.0	2.4
Beetroot	1.0	4.5
Cabbage	0.9	3.6
Carrots	0.7	3.0
Cauliflowers	1.4	4.8
Onions (bulbs only)	0.7	1.8
Sprouts (buttons)	2.6	6.3
Sprouts (stems)	2.1	7.2
Bulbs	2.4	6.3
Coriander	0.8	5.5
Mint	1.0	3.9

a. The information on the potash and phosphate content of field vegetable crops is limited and the values above should be treated as guides only.

Sulphur recommendations

There is evidence that brassica crops respond to sulphur. Where sulphur deficiency has been recognised or is expected in vegetable brassicas, apply 50–75 kg/ha SO_3.

There are no UK trials on the sulphur response of other vegetable crops. However, atmospheric sulphur emissions have declined significantly and a yield response to sulphur in other crops is possible. Where sulphur deficiency has been recognised or is expected in other vegetable crops, apply 25 kg/ha SO_3. Sulphur should be applied as a sulphate-containing fertiliser at, or soon after, planting. Crops are most at risk of sulphur deficiency where they are grown on light sandy soils, soils with a low organic matter content and in high rainfall areas.

Points to consider

- Recommendations are given as sulphur trioxide (SO_3). Conversion tables (metric–imperial, oxide–element) are given on page 43
- Don't forget to make allowance for the crop-available sulphur applied in organic materials (**Section 2: Organic materials**)
- Further guidance on sulphur can be found in **Section 1: Principles of nutrient management and fertiliser use**

Micronutrient recommendations

Crop requirements for micronutrients are usually met by supply from the soil. However, they are essential to the plant and, if a deficiency is suspected, it is important to diagnose and treat accordingly.

Many soils contain sufficient supplies of micronutrients to achieve potential crop yields. However, the availability of these nutrients for plant uptake can be restricted by other factors, such as:

- pH
- Concentration of other nutrients in the soil
- Poor soil structure, which can impede root growth and nutrient uptake

Visual symptoms of a deficiency of a specific micronutrient are often short-lived and can be confused with those caused by other growth problems, i.e. drought, frost or herbicide damage. Furthermore, by the time symptoms appear, it can be too late to correct a deficiency.

Consequently, decisions about when to apply micronutrients should be informed by crop and soil risk factors before visual symptoms develop. Soil risk factors are described in Table 6.9 and crop-specific guidance is provided from page 24 onwards.

Visual diagnosis of a micronutrient deficiency should be confirmed by leaf and/or soil analysis.

Table 6.9 Micronutrient deficiencies

Micronutrient	Soil risk factors	Soil analysis	Leaf analysis	Treating deficiencies
Boron (B)	Sandy soils, soils high in organic matter or with a pH above 7 are at risk of boron deficiency. Over-liming can also increase the risk.	Hot water extract: deficiency is more likely below 0.8 mg B/l.	Deficiency is more likely below 20 mg B/kg.	If possible, treat deficiencies with a soil-applied fertiliser prior to planting. Deficiencies can also be treated using a foliar spray at an early growth stage.
Copper (Cu)	Soils most at risk of copper deficiency are organic and peat soils in the Fens and leached sandy soils, particularly on reclaimed heathland. Deficiency can occur in shallow soils over chalk with high organic matter, sandy and peat soils.	EDTA extract: deficiency is more likely below 1.0 mg Cu/l, unless soil organic matter is above 6%, when deficiency is more likely below 2.5 mg Cu/l.	Deficiency is more likely below 5 mg Cu/kg Tissue analysis is less reliable than soil analysis for diagnosing deficiencies.	If possible, treat deficiencies with a soil-applied fertiliser prior to planting. Deficiencies can also be treated using a foliar spray of copper oxychloride or cuprous oxide.
Manganese (Mn)	Symptoms are often transient. Deficiency can be triggered by over-liming A high soil pH can increase the likelihood of deficiency and all soils above pH 7.5 are at risk. Sandy soils with a pH above 6.5 and organic, peaty or marshland soils above pH 6 are at a greater risk Under-consolidated seedbeds, low soil temperatures and low rainfall can lead to higher risk of deficiency.	Not reliable.	Deficiency is more likely below 20 mg Mn/kg.	Deficiencies can be treated using a foliar spray of manganese sulphate.
Molybdenum (Mo)	Soils with pH below 6.5 are at greater risk of molybdenum deficiency.	Ammonium oxalate extract: deficiency is more likely below 0.1 mg Mo/l.	Insufficient information to be able to recommend this type of analysis.	Use a liming material to raise the soil pH of acidic soils to 6.5. When soil pH is more than 7 and when treatment is necessary, apply a soil or foliar treatment of sodium molybdate.
Zinc (Zn)	Deficiency is very rare in the UK, however sandy soils with high pH and high phosphate status are more likely to have lower levels of zinc.	EDTA extract: deficiency is more likely below 1.5 mg Zn/l.	Deficiency is more likely below 15–20 mg Zn/kg.	Deficiencies can be treated using soil- or foliar-applied fertilisers.

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Leaf analysis

Suspected nutrient deficiencies based on the appearance of symptoms can be confirmed by leaf nutrient analysis. In such cases, the leaf nutrient concentrations will usually be well below the normal range and there should, therefore, be little doubt about the diagnosis.

Leaf nutrient analysis can also be used to test for subclinical deficiencies or toxicities that may be already limiting growth but which are not yet resulting in visible symptoms.

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. Values presented in this guide are based on the best information available:

- Brussels sprouts and cabbage, page 26
- Cauliflowers and calabrese, page 28
- Bulb onions, salad onions and leeks, page 35
- Carrots and parsnips, page 37

Guidance on how to collect leaf samples

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 correct crop stage as described in Table 6.10 (unless the sample is for the confirmation of a deficiency)
- Samples should not be taken from crops that have recently been sprayed with nutrients or fungicides
- Avoid collecting and sending samples immediately before the weekend or a public holiday
- If areas of fields differ significantly, sample each separately
- Walk a ‘W’ pattern across the sampling area, stopping at least 25 times
- At each point, collect the youngest fully expanded leaf from the plant. Aim to send the laboratory a minimum of 250 g of fresh material in total
- Ensure there is no soil contamination
- Do not sample diseased or dead plants, those damaged by insects and mechanical equipment or stressed by extremes of cold, heat or moisture
- Dry any wet leaves and immediately send to a laboratory between sheets of paper towel
- Use appropriate packaging (normally available from the laboratory) and label samples clearly, providing as much information about the field and crop as possible
- Do not post fresh material in an airtight container
- Send by overnight courier or deliver directly to the laboratory

Table 6.10 Correct growth stage to sample

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
Turnips and swede	First indication of root swelling
Onions and leeks	Four true leaves, taking complete leaves
Carrots and parsnips	Six true leaves or when the roots are 10+ mm in diameter

Selecting the most appropriate fertiliser

For a single nutrient, the recommended amount can be applied using a straight fertiliser. Where more than one nutrient is required, a compound or blended fertiliser can be used. In this case, the compound or blend selected will depend on the ratio of the nutrients in the fertiliser and the amount applied should give as near the recommended amount of each nutrient as possible.

Often, it will not be possible to exactly match the recommendations with available fertilisers. In most cases, the first priority is to get the amount of nitrogen correct because crops respond most to nitrogen.

Slight variation in the rates of phosphate or potash will have less effect on yield, especially on Index 2 soils, and any discrepancy can be corrected in fertiliser applications to future crops.

Example 6.5

Bulb onions grown in an SNS Index 3, P Index 2 and K Index 2+ field require 90 kg N/ha, 50 kg P_2O_5/ha and 35 kg K_2O/ha. A 20:10:10 NPK compound fertiliser is available.

Applied at 450 kg/ha, this fertiliser will supply 90 kg N/ha, 45 kg P_2O_5/ha and 45 kg K_2O/ha. The deficit of 5 kg P_2O_5/ha and surplus of 15 kg K_2O/ha are both small and can be ignored.

Metric to imperial conversion tables are given on page 43. If applying liquid fertilisers, manufacturers can supply tables which convert kg/ha of nutrient to litres/ha of product.

Further information

Approved fertilisers for organic growers
soilassociation.org/farmers-growers/technicalinformation/approved-inputs-for-organic-farms

Techniques for applying fertiliser

Starter fertiliser

The injection of high phosphate liquid fertiliser 2–3 cm below the seed, or around the roots of transplants, can improve the growth and quality of crops, such as bulb and salad onions, lettuce and leeks. Starter fertiliser is particularly useful for crops grown in mixed rotations on soils at P Index 3 or below.

However, responses have been found at P Index 4. No more than 20 kg N/ha and 60 kg P_2O_5/ha should be applied as starter fertiliser, which may be deducted from the recommended total application. In most experiments, comparable yields with starter fertiliser have been obtained with much lower amounts of nitrogen than when fertiliser has been broadcast.

The use of injected liquid starter fertiliser in combination with a supplementary dressing of a conventional fertiliser can increase the overall efficiency of nutrient use and typically reduces the total fertiliser requirement of field vegetables by up to half. Liquid starter fertilisers containing chloride may reduce plant establishment and should be avoided.

Band spreading/placement of fertiliser

For some wide-row crops, there can be benefits from applying early nitrogen in a band or injecting it around the plant, followed by a broadcast top dressing. This may reduce the overall amount of nitrogen required. In experiments using the banding approach, yield and quality of cauliflowers was maintained and post-harvest soil nitrogen residues were less, reducing the risk of nitrate leaching.

Placement of phosphate fertiliser has been shown to increase yields compared with surface broadcast application on low P Index soils. Where fertiliser is placed, a small reduction in the recommended rate of phosphate could be considered.

Fertigation

Fertigation, applying nutrients in irrigation water, has been shown to produce Batavia lettuce with better quality compared with broadcasting fertiliser because nutrients and water can be more effectively targeted to crop need. Field experiments have demonstrated that by using fertigation, savings of up to 33% in nitrogen applications can be made. While the technique has the potential to reduce nitrogen use, some preliminary testing should be carried out to fine-tune the amounts and timing of nutrients, especially on crops other than lettuce.

Vegetables

Asparagus

Table 6.11 Nitrogen, phosphate, potash and magnesium for asparagus

Nutrient	SNS, P, K or Mg Index					
	0	1	2	3	4	5 or higher
	kg/ha					
Establishment year						
Nitrogen (N) – all soil types	150	150	150	90	20	0
Phosphate (P_2O_5)	175	150	125	100	75	0
Potash (K_2O)	250	225	200	150	125	0
Subsequent years						
Nitrogen (N) – year 2, all soil types	See note below[a]					
Nitrogen (N) – other years, all soil types	See note below[b]					
Phosphate (P_2O_5)	75	75	50	50	25	0
Potash (K2O)	100	50	50	50	0	0
Magnesium (MgO)	150	100	0	0	0	0

a. In year 2, apply 120 kg N/ha by end of February – early March.

b. In subsequent years, the amount and timing of nitrogen depends on the previous winter. If the crop is on light soil and over-winter rainfall was high, apply 40–80 kg N/ha by the end of February with an additional 40–80 kg N/ha applied after harvest.

Following moderate or low amounts of winter rainfall apply 40–80 kg N/ha just after the harvest to provide nitrogen for fern growth.

When SMN is measured, top up with fertiliser nitrogen to achieve a target of 120 kg N/ha of mineral nitrogen in the top 30 cm of soil during the cropping period.

Establishment year – nitrogen

Apply one third of the total nitrogen dressing before sowing or planting, one third when the crop is fully established (around mid-June for crowns, mid-July for transplants) and one third at the end of August.

Subsequent years – nitrogen

In year two, apply 120 kg N/ha by end of February/early March.

In subsequent years, the amount and timing of nitrogen depends on the previous winter. If the crop is on light soil and rainfall was high over winter, apply 40–80 kg N/ha by the end of February, with an additional 40–80 kg N/ha applied after harvest.

Following moderate or low amounts of winter rainfall, apply 40–80 kg N/ha just after harvest to provide nitrogen for fern growth.

Where SMN is measured, top up with fertiliser nitrogen to achieve a target of 120 kg N/ha of mineral nitrogen in the top 30 cm of soil during the cropping period.

Sodium

Asparagus can respond to applied sodium. Apply up to 500 kg Na_2O/ha per year at the end of June but not in the establishment year.

Sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting in the establishment year, and in early spring for established crops.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Asparagus nutrient management
ahdb.org.uk/knowledge-library/asparagus-nutrient-management

Asparagus Crop Walkers' Guide
ahdb.org.uk/knowledge-library/asparagus-crop-walkers-guide

Brussels sprouts and cabbage

Table 6.12 Nitrogen, phosphate, potash and magnesium for Brussels sprouts and cabbage

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N)[a] – all soil types							
Brussels sprouts	330	300	270	230	180	80	0[b]
Storage cabbage	340	310	280	240	190	90	0[b]
Head cabbage pre-31 December	325	290	260	220	170	70	0[b]
Head cabbage post-31 December	240	210	180	140	90	0[a]	0[b]
Collards pre-31 December	210	190	180	160	140	90	0[b]
Collards post-31 December	310	290	270	240	210	140	90
Phosphate (P_2O_5)[c]							
All crops	200	150	100	50	0	0	0
Potash (K_2O)[c]							
All crops	300	250	200 (2-) 150 (2+)	60	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

Storage cabbage – nitrogen

For storage cabbage grown on fertile soils, the recommendations for nitrogen may need to be decreased in order to reduce the risks of storage losses.

Post-31 December crops – nitrogen

Apply no more than 100 kg N/ha at sowing or transplanting, less if there is risk of frost damage. The remaining nitrogen should be applied to reflect crop growth. Further top dressings of nitrogen will depend on the harvest date and expected yield; some nitrogen will be required to support growth during the winter, particularly for crops harvested in late winter.

For crops harvested in late spring, more of the top dressing should be left until the beginning of regrowth in spring.

Brussels sprouts and cabbage – sulphur

Where sulphur deficiency has been recognised or is expected, apply 50–75 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Brassica crops – boron

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.

Brussels sprouts – boron

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

a. On light soils where leaching may occur or when crops are established by direct seeding, no more than 100 kg N/ha should be applied prior to seeding or transplanting. On retentive soils in drier parts of the country where leaching risk is low and spring-planted brassicas are established from modules, more nitrogen can be applied prior to planting. The remainder of the nitrogen requirement should be applied after establishment.

b. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil.

c. Phosphate and potash requirements are for average crops and it is important to calculate specific phosphate and potash removals based on yields, especially for the larger-yielding cabbage crops. As a general rule for cabbage crops, increase potash application by 40 kg/ha K_2O for every 10 t/ha fresh weight yield over 40 t/ha.

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Cabbage – boron

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 boron deficiency is severe.

Toxicity

Boron toxicity is occasionally found as a result of over-application. Symptoms are marginal chlorotic bands on old leaves. Leaf analysis can be used to confirm toxicity of boron.

Leaf analysis

Suspected nutrient deficiencies based on the appearance of symptoms can be confirmed by leaf nutrient analysis. 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.

Leaf nutrient analysis can also be used to test for subclinical deficiencies or toxicities that may be already limiting growth but which are not yet resulting in visible symptoms. In this case, sample Brussels sprouts mid-growth as the plant initiates the first buttons and cabbage mid-growth as the plant is beginning to heart.

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. Values in Table 6.13 are based on the best information available.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+ and check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Table 6.13 Interpretation of leaf nutrient analysis (normal range) for Brussels sprouts and cabbage

Nutrient	Brussels spouts	Cabbage
	%	
Nitrogen (N)	3.0–5.0	3.0–5.0
Phosphorus (P)	0.26–0.6	0.3–0.5
Potassium (K)	2.5–4.0	3.0–4.5
Magnesium (Mg)	0.2–0.7	0.2–0.7
Sulphur (S)	0.3–0.8	0.3–0.8
Calcium (Ca)	0.5–2.0	1.5–3.0
Nutrient	mg/kg	
Manganese (Mn)	25–200	25–200
Boron (B)	25–60	25–60
Copper (Cu)	5–20	5–20
Zinc (Zn)	20–200	20–200
Iron (Fe)[a]	50–200	50–200

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

Further information

Nutrient deficiencies of Brassicas poster
ahdb.org.uk/knowledge-library/nutrient-deficiencies-of-brassicas

Interpretation of leaf nutrient analysis results
ahdb.org.uk/knowledge-library/interpretation-of-brassicas-leaf-nutrient-analysis

Cauliflowers and calabrese

Table 6.14 Nitrogen, phosphate, potash and magnesium for cauliflowers and calabrese

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types							
Cauliflower, summer/autumn[a]	290	260	235	210	170	80	0[b]
Cauliflower, winter hardy/Roscoff[a] – seedbed	100	100	100	100	60	0[a]	0[b]
Cauliflower, winter hardy/Roscoff[a] – top dressing	190	160	135	110	100	80	0[b]
Calabrese[a]	235	200	165	135	80	0[b]	0[b]
Phosphate (P_2O_5)							
All crops	200	150	100	50	0	0	0
Potash (K_2O)							
All crops	275	225	175 (2-) 125 (2+)	35	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

a. The recommendations assume overall application. Band spreading of nitrogen may be beneficial (see Techniques for applying fertiliser on page 23).

b. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil.

Cauliflowers and calabrese – nitrogen

Where there is a risk of poor establishment or leaching, apply no more than 100 kg N/ha at sowing or transplanting. The remainder should be applied when the crop is established but before the surface soil dries out.

There is a benefit from banding or placing the nitrogen to be applied at sowing or transplanting. If nitrogen is only applied to half the width of the row, reduce the seedbed application by 33%.

The SNS Index for second crops grown in the same season is likely to be between Index 4 and 6, depending on the growing conditions of the first crop. The Measurement Method can be used to determine the SNS Index (page 14).

Cauliflower, winter hardy/Roscoff – nitrogen

Apply no more than 100 kg N/ha at sowing or transplanting, less if there is risk of frost damage. The amount of nitrogen applied subsequently will depend on crop growth, for example up to 60 kg N/ha per month in the South West and 20 kg N/ha in the North.

Where seedbed SNS exceeds Index 4 and crops are likely to be harvested in April or later, the top dressing should be left until the start of growth in the spring. The SNS may need to be recalculated to take account of any overwinter losses of nitrogen, uptake of nitrogen by the crop, as well as mineral nitrogen to 90 cm.

Cauliflowers and calabrese – sulphur

Where sulphur deficiency has been recognised or is expected, apply 50–75 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Brassica crops – boron

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.

Cauliflower – boron

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 boron 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.

Calabrese – boron

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

Toxicity

Boron toxicity is occasionally found as a result of over-application. Symptoms are marginal chlorotic bands on old leaves. Leaf analysis can be used to confirm toxicity of boron.

Leaf nutrient analysis

Suspected nutrient deficiencies based on the appearance of symptoms can be confirmed by leaf nutrient analysis. 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.

Leaf nutrient analysis can also be used to test for subclinical deficiencies or toxicities that may be already limiting growth but which are not yet resulting in visible symptoms.

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. Values in Table 6.15 are based on the best information available.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Table 6.15 Interpretation of leaf nutrient analysis for cauliflower and calabrese

Nutrient	Cauliflower	Calabrese
	%	
Nitrogen (N)	3.0–5.0	3.5–5.5
Phosphorus (P)	0.3–0.7	0.3–0.7
Potassium (K)	3.0–4.0	2.0–4.0
Magnesium (Mg)	0.2–0.7	0.2–0.7
Sulphur (S)	0.3–0.8	0.3–0.8
Calcium (Ca)	1.0–2.0	1.2–2.5
Nutrient	mg/kg	
Manganese (Mn)	25–200	25–200
Boron (B)	25–60	25–60
Copper (Cu)	5–20	5–20
Zinc (Zn)	20–200	20–200
Iron (Fe)[a]	50–200	50–200

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

Further information

Interpretation of leaf nutrient analysis results (cabbage, Brussels sprouts, cauliflower, broccoli, turnip and swede)
ahdb.org.uk/knowledge-library/interpretation-of-brassicas-leaf-nutrient-analysis

Self-blanching celery

Table 6.16 Nitrogen, phosphate, potash and magnesium for self-blanching celery

	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types							
Seedbed	75	75	75	75	0[a]	0[a]	0[a]
Top dressing	75–150 kg[b]						
Phosphate (P_2O_5)							
	250	200	150	100	50	0	0
Potash (K_2O)							
	450	400	350 (2-) 300 (2+)	210	50	0	0
Magnesium (MgO)							
	150	100	0	0	0	0	0

a. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil.

b. Required 4–6 weeks after planting.

Sodium

Celery is responsive to sodium and it is recommended for celery grown on all soils, except peaty and some Fen silt soils, which generally contain adequate amounts of sodium. Sodium can be applied as agricultural salt at 400 kg/ha (200 kg Na_2O/ha). The application will not have any adverse effect on soil structure, even on soils of low structural stability.

Sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Outdoor Salads: Lettuce & Celery Crop Walkers' Guide
ahdb.org.uk/knowledge-library/outdoor-salads-lettuce-celery-crop-walkers-guide

Peas (market pick) and beans

Table 6.17a Nitrogen, phosphate, potash and magnesium for peas (market pick)

Nutrient	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types	0	0	0	0	0	0	0
Phosphate (P_2O_5)	185	135	85	35	0	0	0
Potash (K_2O)	190	140	90 (2-) 40 (2+)	0	0	0	0
Magnesium (MgO)	100	50	0	0	0	0	0

Table 6.17b Nitrogen, phosphate, potash and magnesium for beans

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types							
Broad beans	0	0	0	0	0	0	0
Dwarf and runner beans – seedbed	180	150	120	80	30	0[a]	0[a]
Runner beans – top dressing	See note below[a]						
Phosphate (P_2O_5)							
All crops	200	150	100	50	0	0	0
Potash (K_2O)							
All crops	200	150	100 (2-) 50 (2+)	0	0	0	0
Magnesium (MgO)							
All crops	100	50	0	0	0	0	0

a. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil.

Dwarf/runner beans – nitrogen

Apply no more than 100 kg N/ha at sowing or planting. The remainder should be applied when the crop is fully established.

Runner beans can require a further top dressing of up to 75 kg N/ha at early picking stage.

Peas and beans – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Pea and Bean Crop Walkers' Guide
ahdb.org.uk/knowledge-library/peas-and-bean-crop-walkers-guide

Agronomy and variety information
www.pgro.org

Radish and sweetcorn

Table 6.18 Nitrogen, phosphate, potash and magnesium for radish and sweetcorn

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types							
Radish	100	90	80	65	50	20	0[a]
Sweetcorn	220	175	125	75	0[a]	0[a]	0[a]
Phosphate (P_2O_5)							
All crops	175	125	75	25	0	0	0
Potash (K_2O)							
All crops	250	200	150 (2-) 100 (2+)	0	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

a. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil (see Techniques for applying fertiliser on page 23).

Radish and sweetcorn – nitrogen

Apply no more than 100 kg N/ha in the seedbed. Apply the remainder as a top dressing when the crop is fully established.

Radish and sweetcorn – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Nitrogen and phosphorus recommendations for optimising yield and quality of sweetcorn
ahdb.org.uk/knowledge-library/nitrogen-and-phosphorus-recommendations-for-optimising-yield-and-quality-of-sweetcorn

Lettuce and leafy salads

Table 6.19 Nitrogen, phosphate, potash and magnesium for lettuce and leafy salads

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types[a]							
Lettuce – whole head	200	180	160	150	125	75	30
Lettuce – baby leaf	60	50	40	30	10	0	0
Wild rocket	125	115	100	90	75	40	0
Phosphate (P_2O_5)[b]							
All crops	250	200	150	100	See notes below[c]		0
Potash (K_2O)							
All crops	250	200	150 (2-) 100 (2+)	0	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

a. Recommendations may need to be reduced if there is a risk of exceeding tissue nitrate concentrations, e.g. for late-season crops grown under dull conditions.

b. The recommendations assume overall application. A starter fertiliser containing nitrogen and phosphate may be beneficial.

c. At P Index 4 and 5, up to 60 kg P_2O_5/ha as starter fertiliser may be beneficial (see Techniques for applying fertiliser on page 23).

Lettuce, whole head – nitrogen

These recommendations are provided for the larger Crisp and Escarole lettuces, while other lower-yielding types such as Lollo Rossa, Little Gem, Cos, Endives and Butterhead may need less nitrogen. Each situation will need to be judged carefully, as rooting depth of the lower-yielding varieties is likely to be 30 cm, compared with 60 cm for the larger crop, so less of the soil nitrogen will be available.

Apply no more than 100 kg N/ha at sowing or planting on light sandy soils. The remainder should be applied when the crop is fully established. When crop covers are used, all the nitrogen will need to be applied as a base dressing, but care should be taken to avoid poor establishment in dry soils.

Lettuce, baby leaf – nitrogen

Early-season crops grown in cold or adverse conditions may require up to an additional 60 kg N/ha to maximise yields. If applying additional nitrogen, tissue nitrate concentration analysis is recommended.

Wild rocket – nitrogen

Early-season crops grown in cold or adverse conditions may require up to an additional 25 kg N/ha to maximise yields. If applying additional nitrogen, tissue nitrate concentration analysis is recommended.

All leafy salads – nitrogen and phosphate

Starter fertilisers containing nitrogen and phosphate can provide equivalent crop yields, with lower amounts of nitrogen than from broadcast fertiliser.

Fertigation can produce better-quality crops as nutrients and water can be more effectively targeted to crop need. Experiments have demonstrated savings of up to 33% in nitrogen applications compared with broadcast fertilisers.

Where more than one crop is grown in the same year, there should be sufficient residues of phosphate, potash and magnesium for a second crop. The SNS Index for second crops grown in the same season will be between Index 3 and 5, depending on the growing conditions of the first crop. Measurement of Soil Mineral Nitrogen is recommended to determine the SNS Index of the second and third crops grown within the same season (page 15).

Minimising nitrate levels

EU legislation stipulates nitrate limits for leafy salads, so growers need to ensure nitrogen applications do not cause crops to exceed these limits. This is particularly important for late-season crops of leafy salad, where even small amounts of fertiliser may lead to high tissue nitrate concentration.

All leafy salads – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+ and check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Nitrogen recommendations for optimising yield and quality of baby leaf lettuce
ahdb.org.uk/knowledge-library/nitrogen-recommendations-for-optimising-yield-and-quality-of-baby-leaf-lettuce

Outdoor Salads: Lettuce and Celery Crop Walkers' Guide
ahdb.org.uk/knowledge-library/outdoor-salads-lettuce-celery-crop-walkers-guide

Red Tractor Assurance Fresh Produce Crop Protocols
assurance.redtractor.org.uk/standards/fresh-produce-crop-protocols

Onions and leeks

Table 6.20 Nitrogen, phosphate, potash and magnesium for onions and leeks

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N) – all soil types[a]							
Bulb onions	160	130	110	90	60	0[b]	0[b]
Salad onions	130	120	110	100	80	50	20
Leeks	200	190	170	160	130	80	40
Phosphate (P_2O_5)							
All crops	200	150	100	50	See notes below[c]		0
Potash (K_2O)							
All crops	275	225	175 (2-) 125 (2+)	35	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

a. The recommendations assume overall application. A starter fertiliser containing nitrogen and phosphate may be beneficial.

b. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30cm of soil.

c. At P Index 4 and 5, up to 60 kg P_2O_5/ha as starter fertiliser may be beneficial.

Bulb onions – nitrogen

At SNS Index 0 on light sands where spring Soil Mineral Nitrogen levels to rooting depth are 30 kg N/ha or less, a further 15 kg N/ha can be supplied. Apply no more than 100 kg N/ha to the seedbed. The remainder should be applied when the crop is fully established for the spring crop and the following spring for the autumn-sown crop.

Salad onions – nitrogen

At SNS Index 0 on light sands where spring Soil Mineral Nitrogen levels to rooting depth are 15 kg N/ha or less, a further 15 kg N/ha can be supplied. Apply no more than 100 kg N/ha to the seedbed of the spring-sown crop. The remainder should be applied when the crop is fully established.

For the autumn-sown crop, care must be taken not to apply too much nitrogen as the crop is prone to disease. Apply no more than 40 kg N/ha. If the crop is planted on organic or peaty soils or where large amounts of crop residue have been incorporated, no seedbed nitrogen is required. The remainder should be applied the following spring.

Leeks – nitrogen

Fertiliser nitrogen should be split to match the growth of the crop. Usually no more than 50 kg N/ha should be applied in the seedbed for drilled crops and no more than 100 kg N/ha for transplants. The remainder should be applied as one or more top dressings when the crop is fully established. An additional top dressing of 50–100 kg N/ha in the autumn may be beneficial where the risk of frost damage is low, on all soils except peat, to support growth and colour. Under NVZ rules, no fertiliser nitrogen should be applied to leeks during the closed period, unless supported by written advice from a FACTS Qualified Adviser. If applying nitrogen in the closed period, then a FACTS Qualified Adviser must provide a written recommendation.

Onions and leeks – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Leaf nutrient analysis

Suspected nutrient deficiencies based on the appearance of symptoms can be confirmed by leaf nutrient analysis. 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.

Leaf nutrient analysis can also be used to test for subclinical deficiencies or toxicities that may be already limiting growth but which are not yet resulting in visible symptoms. In this case, sample at the four true leaf stage, taking complete leaves. Guidance on collecting leaf samples is described on page 22.

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. Values in Table 6.21 are based on the best information available.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Table 6.21 Interpretation of leaf nutrient analysis (normal range) for onions and leeks

Nutrient	Bulb onions	Salad onions	Leeks
	%		
Nitrogen (N)	2.5–4.0	2.0–3.2	2.0–3.8
Phosphorus (P)	0.25–0.4	0.25–0.41	0.27–0.41
Potassium (K)	2.5–5.0	1.9–4.3	1.4–2.3
Magnesium (Mg)	0.3–0.5	0.3–0.5	0.3–0.5
Sulphur (S)	0.5–1.0	0.5–1.0	0.5–1.0
Calcium (Ca)	1.0–2.5	1.0–2.5	1.0–2.5
Nutrient	mg/kg		
Manganese (Mn)	30–300	30–300	30–300
Boron (B)	25–50	25–50	25–50
Copper (Cu)	6–20	6–20	6–20
Zinc (Zn)	25–100	25–100	25–100
Iron (Fe)[a]	60–300	60–300	60–300

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

Further information

Allium Crop Walkers’ Guide
ahdb.org.uk/knowledge-library/alliums-crop-walkers-guide

Nitrogen requirements for leeks
ahdb.org.uk/knowledge-library/nitrogen-requirements-for-leeks

Interpretation of leaf nutrient analysis (bulb onions, salad onions and leeks)
ahdb.org.uk/knowledge-library/interpretation-of-leaf-nutrient-analysis-alliums

Root vegetables

Table 6.22 Nitrogen, phosphate, potash and magnesium for root vegetables

Nutrient	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Beetroot							
Nitrogen (N) – all soil types	290	260	240	220	190	120	60
Phosphate (P_2O_5)	200	150	100	50	0	0	0
Potash (K_2O)	300	250	200 (2-) 150 (2+)	60	0	0	0
Swedes							
Nitrogen (N) – all soil types	135	100	70	30	0[a]	0[a]	0[a]
Phosphate (P_2O_5)	200	150	100	50	0	0	0
Potash (K_2O)	300	250	200 (2-) 150 (2+)	60	0	0	0
Turnips, Parsnips							
Nitrogen (N) – all soil types	170	130	100	70	20	0[a]	0[a]
Phosphate (P_2O_5)	200	150	100	50	0	0	0
Potash (K_2O)	300	250	200 (2-) 150 (2+)	60	0	0	0
Carrots							
Nitrogen (N) – all soil types	100	70	40	0[a]	0[a]	0[a]	0[a]
Phosphate (P_2O_5)	200	150	100	50	0	0	0
Potash (K_2O)	275	225	175 (2-) 125 (2+)	35	0	0	0
All crops							
Magnesium (MgO) – all soil types	150	100	0	0	0	0	0

a. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil.

All root crops – nitrogen

Apply no more than 100 kg N/ha in the seedbed. The remainder should be applied as a top dressing when the crop is fully established.

All root crops – phosphate and potash

High-yielding root crops can take up large amounts of phosphate and potash. The amounts removed can be calculated from the known yield and the amount of phosphate and potash per tonne fresh produce shown in Table 6.8. It is important to do this to maintain the target Index for both phosphate and potash. Where straw is used to protect carrots and is subsequently incorporated into the soil, it contributes approximately 1 kg P_2O_5 and 8 kg K_2O, per tonne of straw. This should be considered when calculating the phosphate and potash requirements of following crops.

All root crops – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Carrots – sodium

On sandy soils, apply 200 kg Na_2O/ha as salt and deeply cultivate the application into the soil before drilling.

Carrots – boron

Boron deficiency can affect carrots on light textured soils with a pH >6.5, particularly in dry seasons. Symptoms include death of the apical growing point and growth of lateral buds. Carrots can show a darkening of the root surface (‘shadow’).

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Leaf nutrient analysis

Suspected nutrient deficiencies based on the appearance of symptoms can be confirmed by leaf nutrient analysis. 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.

Leaf nutrient analysis can also be used to test for 'subclinical' deficiencies or toxicities that may be already limiting growth but which are not yet resulting in visible symptoms. In this case, sample carrots and parsnips at the six true leaf stage or when the roots are 10+ mm in diameter. Guidance on collecting leaf samples is described on page 22.

Interpretation of laboratory results is possible by comparison with normal levels expected for the crop. The interpretations in Table 6.23 are based on the best information available.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Table 6.23 Interpretation of leaf nutrient analysis for carrots and parsnips

Nutrient	Carrots			Parsnips
	Deficient	Normal range	Toxic	Normal range
	%			
Nitrogen (N)	<2.0	2.0–4.5	-	3.0–4.8
Phosphorus (P)	<0.2	0.2–0.5	-	0.3–0.7
Potassium (K)	<2.0	2.5–6.0	-	3.5–6.0
Magnesium (Mg)	<0.15	0.2–0.5	-	0.4–0.8
Sulphur (S)	-	0.2–0.4	-	0.4–0.5
Calcium (Ca)	<1.0	1.0–3.5	-	1.2–2.0
Sodium (Na)	-	0.0–0.2	-	0.0–0.2
Nutrient	mg/kg			
Manganese (Mn)	<20	20–200	-	30–200
Boron (B)	<20	20–60	>150	25–60
Copper (Cu)	<5	5–25	>20	6–30
Zinc (Zn)	<20	20–50	>100	20–40
Iron (Fe)[a]	-	50–100	-	50–500

Further information

Carrot & Parsnip Crop Walkers' Guide (contains photos of nutrient deficiencies)
ahdb.org.uk/knowledge-library/carrot-parsnip-crop-walkers-guide

Interpretation of leaf nutrient analysis results (carrots and parsnips)
ahdb.org.uk/knowledge-library/interpretation-of-leaf-nutrient-analysis-carrots-parsnips

Bulbs and bulb flowers

Table 6.24 Nitrogen, phosphate, potash and magnesium for bulbs and bulb flowers

Nutrient	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N)	125	100	50	0	0	0	0
Phosphate (P_2O_5)	200	150	100	50	0	0	0
Potash (K_2O)	300	250	200 (2-) 150 (2+)	60	0	0	0
Magnesium (MgO)	150	100	0	0	0	0	0

Bulbs – nitrogen

Apply nitrogen as a top dressing just before emergence.

Narcissus – nitrogen

If growth was poor in the previous year, a top dressing of 50 kg N/ha may be required in the second or subsequent year.

Bulbs – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at or soon after planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Further information

Narcissus Manual
ahdb.org.uk/knowledge-library/narcissus-manual

Herbs

Table 6.25 Nitrogen, phosphate, potash and magnesium for herbs

	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Coriander							
Nitrogen (N)	140	125	115	105	90	55	30
Phosphate (P_2O_5)	175	125	75	25	0	0	0
Potash (K_2O)	315	265	215 (2-) 165 (2+)	75	0	0	0
Magnesium (MgO)	150	100	0	0	0	0	0
Mint – establishment year							
Nitrogen (N)	180	170	160	150	130	100	70
Phosphate (P_2O_5)	175	125	75	25	0	0	0
Potash (K_2O)	200	150	100 (2-) 50 (2+)	0	0	0	0
Magnesium (MgO)	150	100	0	0	0	0	0
Mint – subsequent years							
Nitrogen (N)	180	170	160	150	130	100	70
Phosphate (P_2O_5)	175	125	75	25	0	0	0
Potash (K_2O)	280	230	180 (2-) 130 (2+)	40	0	0	0
Magnesium (MgO)	150	100	0	0	0	0	0

Coriander – nitrogen

Apply no more than 100 kg N/ha in the seedbed. The remainder should be applied as a top dressing when the crop is fully established.

The fertiliser recommendations given here should be considered as guideline figures and may need to be adjusted based on local experience, taking into account factors such as planting date, expected yield and end market.

Mint – nitrogen

In the establishment year, apply no more than 100 kg N/ha before planting. The remainder should be applied as a top dressing when the crop is fully established.

For established crops, the nitrogen recommendations are per cut, and should typically be split into two top dressings. Avoid over-fertilising mint, as the shelf life is reduced when Soil Mineral Nitrogen to 30 cm depth is over 200 kg N/ha.

The fertiliser recommendations given here should be considered as guideline figures and may need to be adjusted based on local experience, taking into account factors such as age of crop, expected yield and end market.

Coriander and mint – potash

Coriander and mint take up large amounts of potash, which must be replaced in order to maintain the target Soil Index. The actual amount of potash removed by the crop can be calculated from the known yield and the amount of potash per tonne fresh weight shown in Table 6.8.

Coriander and mint – sulphur

Where sulphur deficiency has been recognised or is expected, apply 25 kg SO_3/ha as a sulphate-containing fertiliser at, or soon after, planting.

Points to consider

- Make allowance for nutrients applied in organic materials (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application at P Index 3 and K Index 2+; check that the soil is maintained at these target Indices by soil sampling every 3–5 years

Courgettes and pumpkins

Table 6.26 Nitrogen, phosphate, potash and magnesium for courgettes

Crop	SNS, P, K or Mg Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen(N) – all soil types							
Courgettes – seedbed	100	100	100	40	0a	0a	0a
Courgettes – top dressing	Up to 75 kg N/ha may be required[a]						
Phosphate (P_2O_5)							
All crops	175	125	75	25	0	0	0
Potash (K_2O)							
All crops	250	200	150 (2-) 100 (2+)	0	0	0	0
Magnesium (MgO)							
All crops	150	100	0	0	0	0	0

a. A small amount of nitrogen may be needed if soil nitrogen levels are low in the top 30 cm of soil (see Techniques for applying fertiliser on page 23).

Courgettes and pumpkin – calcium

While no clear threshold for fruit calcium concentration has been defined, there is a strong body of evidence that the probability of produce developing blossom end rot is linked with the amount of calcium available to the fruit during its development.

Calcium uptake is better when nitrate-based fertilisers are used but is decreased by high soil concentrations of ammonium, potassium, magnesium or aluminium ions. As long as correct soil nutrient Indices and appropriate levels of pH and electrical conductivity are maintained, high growth rates and issues such as blossom end rot should be less likely.

Water supply should match demand and inadequate drainage will exacerbate the problem. Trickle tape application and mulches will also help to provide the crop with a more consistent rate of water and calcium uptake and can be used to match soil moisture levels with growth rates.

Courgettes and pumpkin – boron

There is evidence that suitable boron availability is required for achieving target yield and quality. While boron is a micronutrient, required at much lower concentrations than other minerals, it is essential for a range of biological roles.

Boron has reduced bioavailability at higher pH ranges, therefore soil pH should be maintained around 6.5. Care must be taken to ensure suitable dosage of boron products, as the margin between sufficient and toxic concentrations of boron is poorly defined.

Courgettes and pumpkin – foliar feeds

Combined calcium and boron applications have demonstrated greater benefits than application of calcium alone. Where foliar feeds are to be used, application of dilute solutions are required to avoid tip burn, and application should be made in dull, overcast conditions.

Timing of foliar application is likely to vary between cultivar and growing conditions. Application should begin with first flowering and continue throughout fruit enlargement until maturation begins.

Further information

Outdoor Cucurbits: Nutrient Deficiencies & Physiological Disorders poster
ahdb.org.uk/knowledge-library/outdoor-cucurbits-nutrient-deficiencies-physiological-disorders

Modifying the crop nitrogen requirement

Vegetable crops are planted at many different times of the year and have a range of expected yields. FACTS Qualified Advisers can customise individual field recommendations using Table 6.22 and the following information:

1. Size of the crop – the size, frame or weight of the crop needed to produce optimal economic yields.
2. Nitrogen uptake – the optimum nitrogen uptake associated with a crop of that size.
3. Supply of nitrogen – based on the nitrogen supply from the soil within rooting depth, including any nitrogen mineralised from organic matter during the growing season.

1. Size of the crop (t/ha Dry weight yield)

$$\text{Dry wt yield} = \frac{(\text{Fresh wt yield} \times \text{dm\%}/100)}{\text{DW-HI}}$$

Fresh wt yield (t/ha): The yield of marketable produce removed, or expected to be removed, from the field in commercial practice. Data based on field experiments or expert opinion for well-grown crops.

dm %: The % dry matter of marketable produce for optimally fertilised crops.

DW-HI: The dry weight-harvest Index is the proportion of the whole crop that is taken for market, expressed on a dry-weight basis. For example, in onions, 81% (0.81) of the green crop is bulb but only 26% (0.26) of the sprout crop is produced as sprouts.

2. Nitrogen uptake in an optimally grown crop (kg/ha)

Total N Uptake (kg/ha) = Dry wt yield t/ha x N% x 10

N%: The estimated nitrogen concentration of an optimally fertilised whole plant at harvest. Generally, %N declines as yields increase. For small changes in yield, e.g. if yield increases by 10%, it could be assumed that nitrogen uptake increases by the same amount. For bigger changes, the increase in nitrogen uptake will be less than the increase in yield and the formula below should be used.

$$\%N_{Crit} = a(1+be^{-0.26W})$$

$\%N_{Crit}$: The critical N concentration; a and b are parameters controlling the shape of the curve.

W: Total dry matter yield t/ha.

3. Supply of nitrogen and calculation of Crop Nitrogen Requirement (CNR)

CNR = (NUptake – MineralisedN + SoilMinN) x (FertRec/100)

MineralisedN: The amount of nitrogen released from soil organic matter by mineralisation during the cropping period. This is normally between planting and harvesting dates, but for some crops, such as lettuce and onions where early nitrogen supply is important, a shorter period has been chosen (see Table 6.1).

The calculations are based on mineralisation within the WELL_N model (i.e. 0.7 kg/ha at 15.9°C, scaled for Wellesbourne temperature). When temperature is less than 4°C, mineralisation is assumed to be negligible.

SoilMinN: Soil Mineral Nitrogen to rooting depth.

FertRec: Fertiliser recovery assumed to be 60%.

Table 6.27 Information for modification of vegetable crop nitrogen requirement

Crop	Fresh market yield t/ha	% Dry matter marketable	Dry wt harvest Index	Total dry matter t/ha	Relation N% and dry matter yield		% N	Total N uptake kg/ha	Mineralised kg/ha	Period dates	Root depth cm
					'a'	'b'					
Brussels sprouts	20.3	17.0	0.26	13.3	2.50	3.50	2.8	368	121	20/05–17/12	90
White cabbage storage	110.0	8.6	0.65	14.6	2.55	0.80	2.6	378	122	01/05–12/11	90
Head cabbage – pre-31 December	60.0	8.6	0.48	10.8	2.55	0.80	2.7	270	44	18/05–19/07	90
Head cabbage – post-31 December	53.0	8.6	0.46	10.0	2.55	0.80	2.7	203	74	31/07–15/01	90
Collards – pre-31 December	20.0	8.6	0.34	5.1	3.45	0.60	4.0	260	51	16/07–24/09	45
Collards – pre-31 December	30.0	8.6	0.38	6.8	3.45	0.60	3.8	300	41	15/09–15/01	60
Cauliflower over winter	-	-	-	8.1	3.45	0.60	3.7	300	85	30/07–10/03	75
Calabrese	16.3	10.4	0.17	10.0	1.80	3.50	2.3	226	36	27/04–25/06	90
Cauliflower summer	30.6	8.2	0.37	6.8	3.45	0.60	3.8	259	44	21/05–21/07	75
Lettuce (crisp)	45.5	5.3	0.50	4.8	2.60	1.10	3.4	165	22	15/05–15/06	45
Radish	50.0	-	-	-	-	-	-	100	24	21/05–11/06	30
Bulb onions spring	60.5	12.7	0.81	9.4	1.20	3.50	1.6	147	20	13/03–12/05	60
Bulb onions overwintered	60.5	12.7	0.81	9.4	1.20	3.50	1.6	147	20	as above	60
Salad onions	30.0	12.7	0.81	4.7	1.2	3.50	2.4	114	20	as above	30
Salad onions overwintered	30.0	12.7	0.81	4.7	1.2	3.50	2.4	114	20	as above	30
Leeks	47.0	14.2	0.57	11.8	2.00	4.00	2.4	279	132	21/04–12/12	45
Beetroot	60.0	-	-	-	-	-	-	270*	65	18/05–16/08	60
Parsnips and turnips	48.0	-	-	-	-	-	-	241*	92	30/03–27/08	90
Swede	84.4	11.7	0.62	16.0	1.35	1.87	1.4	222	92	30/03–27/08	90
Carrots	150.0	11.4	0.81	21.2	0.82	7.00	0.8	178	66	02/05–08/08	90
Coriander	48.0	8.0	0.95	4.0	2.38	0.96	4.7	129	29.5	21/05–02/07	30
Mint	25.0	12.3	0.59	5.3	1.57	3.34	3.2	153	27.6	28/05–6/07	30

* N uptake taken from German KNS System 2007.

Insufficient data to include asparagus, celery, peas and beans, sweetcorn, courgettes or bulbs

Conversion tables

Metric to imperial

1 tonne/ha	0.4 tons/acre
100 kg/ha	80 units/acre
1 kg/tonne	2 units/ton
10 cm	4 inches
1 m^3	220 gallons
1 m^3/ha	90 gallons/acre
1 kg/m^3	9 units/1,000 gallons
1 kg	2 units

Note: a ‘unit’ is 1% of 1 hundredweight, or 1.12lbs.

Imperial to metric

1 ton/acre	2.5 tonnes/ha
100 units/acre	125 kg/ha
1 unit/ton	0.5 kg/tonne
1 inch	2.5 cm
1,000 gallons	4.5 m^3
1,000 gallons/acre	11 m^3/ha
1 unit/1,000 gallons	
1 unit	0.5 kg

Element to oxide

P to P_2O_5	Multiply by 2.291
K to K_2O	Multiply by 1.205
Mg to MgO	Multiply by 1.658
S to SO_3	Multiply by 2.5
Na to Na_2O	Multiply by 1.348
Na to salt	Multiply by 2.542

Oxide to element

P_2O_5 to P	Multiply by 0.436
K_2O to K	Multiply by 0.830
MgO to Mg	Multiply by 0.603
SO_3 to S	Multiply by 0.4
Na_2O to Na	Multiply by 0.742
Salt to Na	Multiply by 0.393

Fluid fertiliser

kg/tonne (w/w basis) to kg/m^3	Multiply by specific gravity (w/v basis)

Glossary

Available (nutrient) Form of a nutrient that can be taken up by a crop immediately or within a short period so acting as an effective source of that nutrient for the crop.

Clay Finely divided inorganic crystalline particles in soils, less than 0.002 mm in diameter.

Closed period Period of the year when nitrogen fertilisers or certain manures should not be applied unless specifically permitted. Closed periods apply within NVZs.

Content (nutrient) Commonly used instead of the more accurate 'concentration' to describe nutrients in fertiliser or organic material. For example, 6 kg N/t often is described as the nitrogen content of a manure.

Crop-available nitrogen The total nitrogen content of organic material that is available for crop uptake in the growing season in which it is spread on land.

Crop nitrogen requirement The amount of crop-available nitrogen that must be applied to achieve the economically optimum yield.

Digestate Organic material produced by anaerobic digestion of biodegradable organic materials. May be separated into liquid and fibre fractions after digestion.

Excess winter rainfall Rainfall between the time when the soil profile becomes fully wetted in the autumn (field capacity) and the end of drainage in the spring. There is less evapotranspiration during this period (i.e. water lost through the growing crop).

FACTS UK national certification scheme for advisers on crop nutrition and nutrient management. Membership is renewable annually. A FACTS Qualified Adviser has a certificate and an identity card.

Fertiliser See Manufactured fertiliser.

Grassland Land on which the vegetation consists predominantly of grass species.

Leaching Process by which soluble materials such as nitrate or sulphate are removed from the soil by drainage water passing through it.

Ley Temporary grass, usually ploughed up one to five years (sometimes longer) after sowing.

Lime requirement Amount of standard limestone needed in tonnes/ha to increase soil pH from the measured value to a higher specified value (often 6.5 for arable crops). Can be determined by a laboratory test or inferred from soil pH.

Liquid fertiliser Pumpable fertiliser in which nutrients are dissolved in water (solutions) or held partly as very finely divided particles in suspension (suspensions).

Manufactured fertiliser	Any fertiliser that is manufactured by an industrial process. Includes conventional straight and NPK products (solid or fluid), organo-mineral fertilisers, rock phosphates, slags, ashed poultry manure, liming materials that contain nutrients.
Manure	See Livestock manure.
Micronutrient	Boron, copper, iron, manganese, molybdenum and zinc are needed in very small amounts by crops. Cobalt and selenium are taken up in small amounts by crops and are needed in human and livestock diets.
Mineral nitrogen	Nitrogen in ammonium (NH_4) and nitrate (NO_3) forms.
Mineralisation	Microbial breakdown of organic matter in the soil, releasing nutrients in crop-available, inorganic forms.
Nitrate vulnerable zones (NVZs)	Areas designated by Defra as being at risk from agricultural nitrate pollution.
Offtake	Amount of a nutrient contained in the harvested crop (including straw, tops or haulm) and removed from the field. Usually applied to phosphate and potash.
Olsen P	Concentration of available P in soil, determined by a standard method (developed by Olsen) involving extraction with sodium bicarbonate solution at pH 8.5. The main method used in England, Wales and Northern Ireland and the basis for the soil Index for P.
Organic manure	Any bulky organic nitrogen source of livestock, human or plant origin, including livestock manures.
Organic soil	Soil containing between 10% and 20% organic matter (in this Manual). Elsewhere, it sometimes refers to soils with between 6% and 20% organic matter.
Peaty soil (peat)	Soil containing more than 20% organic matter.
Placement	Application of fertiliser to a zone of the soil usually close to the seed or tuber.
Removal	See Offtake.
Sand	Soil mineral particles larger than 0.05 mm.
Silt	Soil mineral particles in the 0.002–0.05 mm diameter range.
SNS Index	Soil Nitrogen Supply expressed in seven bands or Indices, each associated with a range in kg N/ha.
Soil Index (P, K or Mg)	Concentration of available P, K or Mg, as determined by standard analytical methods, expressed in bands or Indices.
Soil Mineral Nitrogen (SMN)	Ammonium and nitrate nitrogen, measured by the standard analytical method and expressed in kg N/ha.
Soil Nitrogen Supply (SNS)	The amount of nitrogen (kg N/ha) in the soil that becomes available for uptake by the crop in the growing season, taking account of nitrogen losses.

Soil organic matter	Often referred to as humus. Composed of organic compounds ranging from undecomposed plant and animal tissues to fairly stable brown or black material with no trace of the anatomical structure of the material from which it was derived.
Soil texture	Description based on the proportions of sand, silt and clay in the soil.
Soil type	Description based on soil texture, depth, chalk content and organic matter content.
Target Soil Index	Lowest soil P or K Index at which there is a high probability crop yield will not be limited by phosphorus or potassium supply. See Soil Index (P, K or Mg).

Notes

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