AHDB

Nutrient Management Guide (RB209)

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British Beet BBRO Research Organisation

FACTS

PGRO

Section 4 Arable crops

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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.

Section 1 Principles of nutrient management and fertiliser use

Section 2 Organic materials

Section 3 Grass and forage crops

Section 4 Arable crops

Cereals

Oilseeds

Sugar beet

Peas and beans

Biomass crops

Section 5 Potatoes

Section 6 Vegetables and bulbs

Section 7 Fruit, vines and hops

This section provides guidance for arable crops 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 (as MgO), sulphur (as SO_3) and sodium (as 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. The recommendations are based on the nutrient requirements of the crop being grown, while making allowance for the nutrients supplied by the soil.

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Checklist for decision-making

Individual decisions for fertiliser use must be made separately for every field. Where more than one crop is grown in a field, these areas must be considered individually.

1. Confirm the crop to be grown and the intended market. Identify any crop quality requirements for this market. For the purposes of this guide, winter-sown is defined as sown before 1 February and spring-sown as in February or after.

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 if necessary. Poor soil structure can restrict crop growth and results in poor nutrient use efficiency.

Further information

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

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

4. Carry out soil analysis for pH, P, K and Mg every 3–5 years (page 19). Target values to maintain in arable rotations are:
   - Soil pH 6.5 (5.8 on peat soils)
   - Soil P Index 2
   - Soil K lower Index 2 (2-)
   - Soil Mg Index 2

5. Identify the Soil Nitrogen Supply (SNS) Index of the field, either by using the Field Assessment Method (page 6) or the Measurement Method (page 13).

6. Calculate the total and crop-available nutrients from organic materials that have been applied since harvest of the previous crop, or which will be applied to the crop being grown (**Section 2: Organic materials**). Deduct these nutrients from the recommended rates given in the tables.

7. Decide on the strategy for phosphate and potash use. This will be building up, maintaining or running down the Soil Index (**Section 1: Principles for 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 according to targeted crop yield (Table 4.11). This is the amount of these nutrients that must be replaced in order to maintain the soil at the current Index. Remember that some of these nutrients will also be removed in straw.

9. 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.

10. 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**).

11. Keep an accurate record of the fertilisers and organic materials applied.

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 (Table 4.6). The Index is used in the recommendation tables to select the amount of nitrogen, as manufactured fertiliser, manure or a combination of both, that typically would need to be applied to ensure optimum yield.

The SNS Index for each field can be estimated either by the Field Assessment Method using records of soil type, previous cropping and winter rainfall, or by the Measurement Method. This uses measurements of Soil Mineral Nitrogen (SMN) plus estimates of nitrogen already in the crop (at the time of soil sampling) and of available nitrogen from the mineralisation of soil organic matter and crop debris during the period of active crop growth.

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 organic materials 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 one metre depth for arable crops. 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 4.1 which categorises soils on their ability to supply and retain mineral nitrogen. The initial selection can then be checked using Table 4.1. Carefully assess the soil organic matter content when deciding if the soil is organic (10–20% 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.

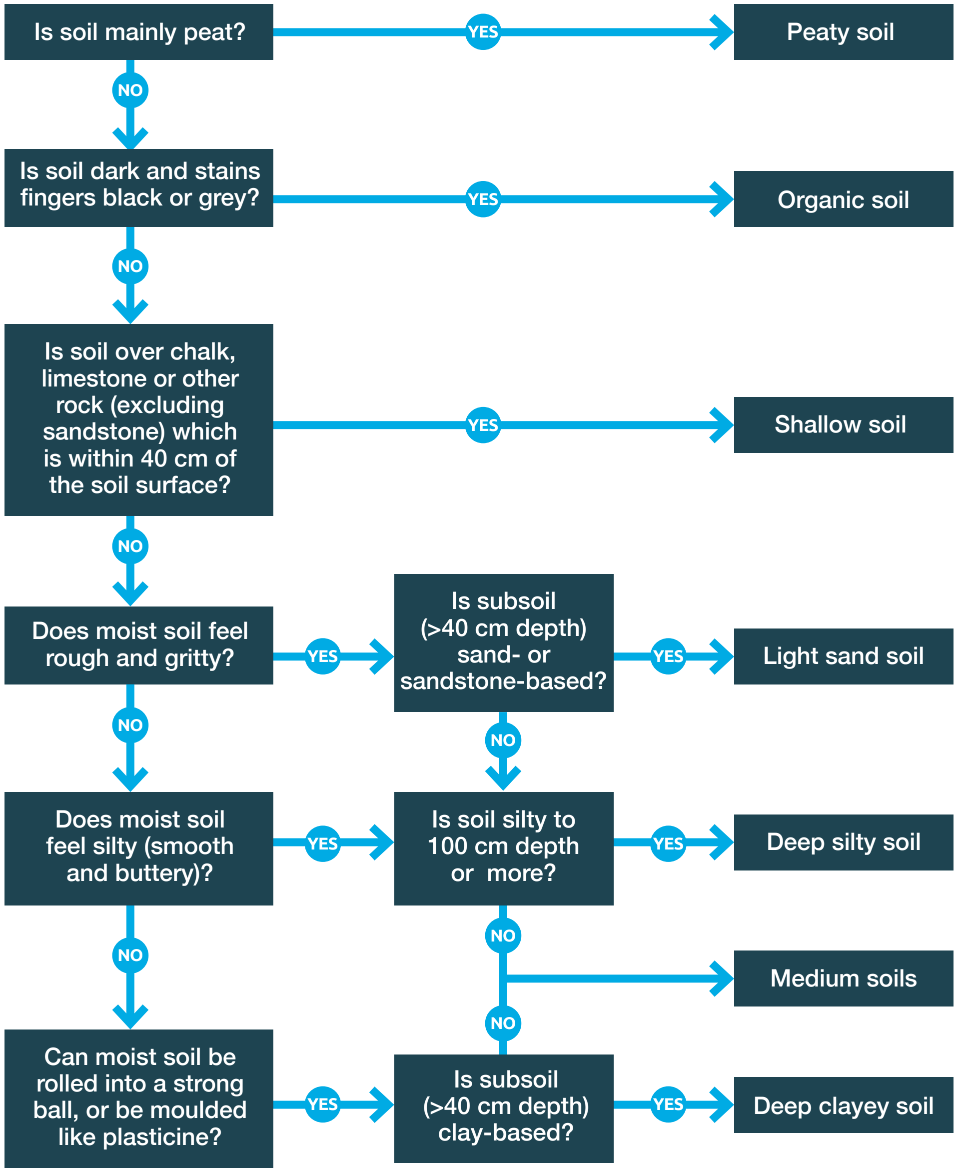

Figure 4.1 Soil category assessment

Table 4.1 Soil category assessment

Soil category	Description of soil types within category	Properties
Light sand soils	Soils which 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 silty soils	Soils of sandy silt loam, silt loam or silty 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. Silty 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

Usually, this is straightforward, but sometimes clarification may be needed:

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 twelve 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, e.g. 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 4.2 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).

> ***Further information***
> AHDB provides Excess Winter Rainfall (EWR) data for the current season
> **ahdb.org.uk/ewr**

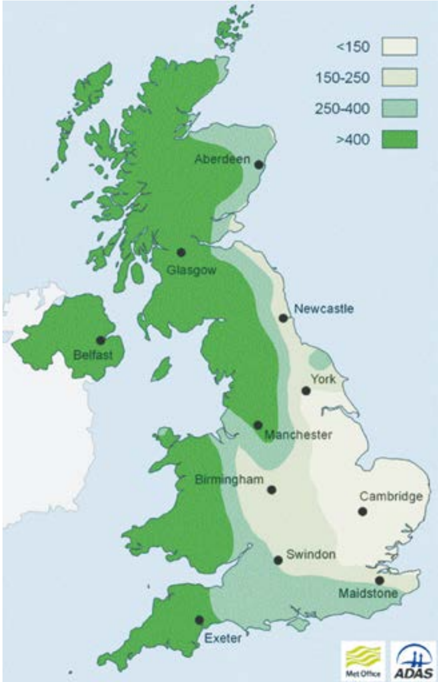

Figure 4.2 Excess winter rainfall (mm)

Step 4. Identify the provisional SNS Index using the appropriate table

Tables 4.2 (low rainfall), 4.3 (moderate rainfall) and 4.4 (high rainfall) should be used where the field has not been in grass within the past three years. Select one of these tables according to rainfall for the field. Take account of the footnotes to the tables.

Higher than typical Indices can occur where there has been a history of grassland or frequent applications of organic manures. The Measurement Method is recommended in these situations (page 13).

If grass has been grown in the previous three years, also look at Table 4.5. Select the higher of the Index levels based on the last crop grown (from Table 4.2, 4.3 or 4.4) and on the grass history (from Table 4.5).

Table 4.2. 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 4.3. 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 4.4. 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 4.5. 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 4.5 assume that little or no organic manure has been applied. Where silage fields have received the organic manure 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

When using the Field Assessment Method, it is not necessary to estimate the amount of nitrogen taken up by the crop over winter. This is already taken into account in the tables.

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.

Point to consider

- The nitrogen contribution from manures applied after harvest of the previous crop should not be considered when deciding the SNS Index; this contribution should be deducted from the recommended nitrogen application rate using the information in **Section 2: Organic Materials**

Field vegetables as previous crop: 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
- In circumstances where larger than average amounts of crop residue or unused fertiliser are left behind (see Footnote to Table 4.2)

In rotations where vegetable crops are grown infrequently and when there is uncertainty, soil sampling for SMN may be appropriate.

Fertiliser residues from previous crop: 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. The Index should be increased if there is reason to believe nitrogen residues are likely to be greater than normal and these residues will not be lost by leaching. This could occur where a cover crop was sown in autumn and grew well over winter. The Index may need to be adjusted downwards if there is reason to believe nitrogen residues are likely to be smaller than usual.

After any adjustment, the SNS Index can be used in the recommendation tables.

Measurement Method

This method is particularly appropriate where the SNS is likely to be large and uncertain. This includes:

- Fields with a history of organic manure application and vegetable rotations where the timing of residue incorporation can strongly affect Soil Mineral Nitrogen (SMN) for the following crop
- Fields where long leys or permanent pasture have been recently ploughed out (but not in the first year after ploughing out)
- Fields where there have been problems such as regular lodging of cereals, very high grain protein or nitrogen contents, or previous crop failure (for example due to drought or disease)
- Fields where there is significant variation in soil texture and/or large amounts of crop residues are incorporated; nitrogen residues also can be large following outdoor pigs

The SNS Index can be identified using the results of direct measurement of SMN to 90 cm depth in spring, 60 cm depth in autumn/early winter, or to maximum rooting depth in shallow soils over rock. The crop nitrogen content (at the time of soil sampling) and an estimate of net mineralisable nitrogen must be added to the SMN result when calculating the SNS.

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. In this scenario, prediction of SNS using the Field Assessment Method is advised.

The Measurement Method is not recommended for peat soils, or in the first season after ploughing out long leys or permanent pasture, where net mineralisation can be very large and uncertain and the measured SMN may be a relatively small component of SNS. For these soils, the Field Assessment Method or local experience will be better guides to SNS.

Points to consider

- Do not confuse Soil Nitrogen Supply (SNS) and Soil Mineral Nitrogen (SMN)
- SMN is the measured amount of mineral nitrogen (nitrate-N plus ammonium-N) in the soil profile
- The Measurement Method is not suitable for organic and peaty soils as SNS (due to mineralisation of soil organic matter) is unpredictable
- SNS = an estimate of crop N (at time of sampling) + a measurement of SMN + an estimate of subsequent N mineralisation

The Measurement Method does not take account of the available nitrogen supplied from organic materials applied after the date of soil sampling for SMN. The available nitrogen from materials 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 materials 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 four steps to follow:

Step 1. Measure Soil Mineral Nitrogen (SMN)
Step 2. Estimate nitrogen already in the crop
Step 3. Make an adjustment for net mineralisable nitrogen
Step 4. Identify Soil Nitrogen Supply (SNS) Index

In detail, these four 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

- In most situations, sampling in late winter or early spring before nitrogen fertiliser is applied gives slightly better predictions of SNS than sampling in the autumn, because overwinter leaching is accounted for, especially in high rainfall areas or on shallow or light sand soils. On soils less prone to leaching, sampling in autumn or early spring is equally effective
- Avoid sampling within two to three months after application of nitrogen fertiliser or organic manures, or within a month after sowing
- Areas of land known to differ in some important respects (e.g. soil type, previous cropping, manure or nitrogen fertiliser application) 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
- Each position should be sampled at three depths in the spring: 0–30 cm, 30–60 cm and 60–90 cm. Sampling to 60 cm is adequate in the autumn
- 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. Estimate nitrogen already in the crop

Where a crop is present when SMN is measured, the amount of nitrogen already taken up must be estimated. For cereals, this is often a small though important component of the SNS, but for oilseed rape it can be large.

The crop nitrogen content in cereals can be estimated according to the number of shoots present (main shoots and tillers), as follows:

Table 4.6 Estimating cereal crop N using shoot number

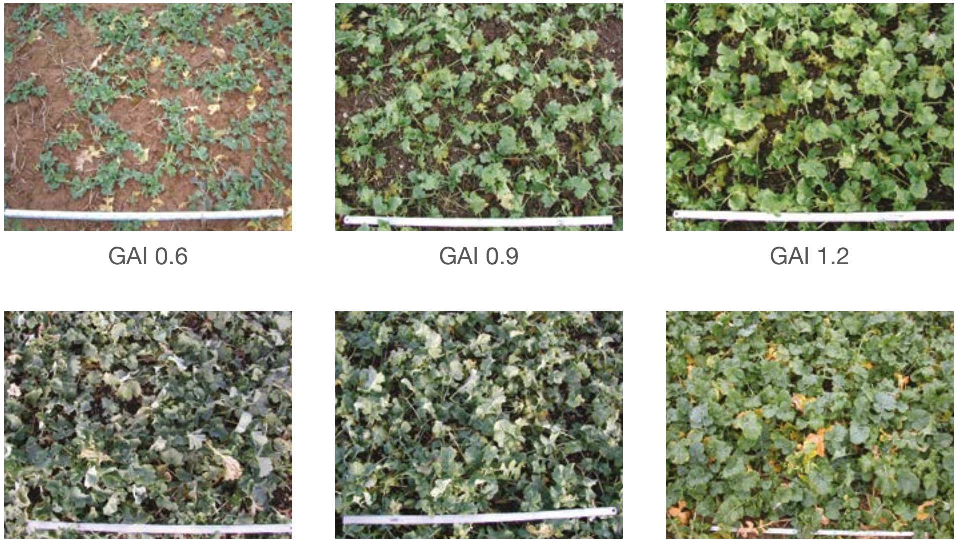
Shoot number/m²	Crop nitrogen content	
	Autumn	Spring
	kg N/ha	
500	5	15
1,000	15	30
1,500	25	50

Large oilseed rape canopies can contain substantial amounts of nitrogen by the spring (in excess of 100 kg N/ha). Research has shown that even for large canopies all of the N in the crop can be treated as contributing to the SNS.

In oilseed rape, the crop contains around 50 kg N/ha for every unit of Green Area Index (GAI, Table 4.7). For larger canopies (GAI of 2 or more), the crop may contain closer to 40 kg N/ha per unit of GAI. Use Figure 4.3 as a guide for estimating GAI.

Table 4.7 Estimating oilseed rape crop N using GAI

Oilseed rape GAI	Crop N
	kg/ha
0.5	25
1.0	50
2.0	80–100



GAI 0.6 GAI 0.9 GAI 1.2

GAI 1.6 GAI 2.2 GAI 2.8

Figure 4.3 Estimating the GAI of an oilseed rape crop

Alternatively, the nitrogen content of an average-density crop can be estimated by measuring the average crop height. This may not be appropriate for semi-dwarf varieties and should not be used on crops that have been flattened by snow.

Table 4.8 Estimating oilseed rape crop N using crop height

Crop height	Crop nitrogen content	
	Autumn	Spring
cm	kg N/ha	
10	35	45
15	55	65
20	75	85

Step 3. Make an allowance for net mineralisable nitrogen

Nitrogen mineralised from soil organic matter and crop debris after soil sampling is a potentially important source of nitrogen for crop uptake. However, in mineral soils of low to average organic matter content (<4% in England and Wales or <10% in Scotland and Northern Ireland), the amount of net mineralisable nitrogen will be relatively small and, for practical purposes, no further adjustment is needed when using the recommendations in this guide. The only exception being after cold winters, when an estimate of around 20 kg N/ha may be appropriate.

An adjustment may be needed where soil organic matter content is above average or where there has been a history of regular manure applications. In these situations, a commercial measurement of Additionally Available N (AAN) gives the most useful prediction of mineralisation.

As a guide, where measurement is not done, for every 1% organic matter above 4%, a topsoil may release an additional 10 kg N/ha. Therefore, a soil that has a topsoil organic matter content of 10% may release around 60 kg/ha more Soil Mineral Nitrogen than an equivalent soil with 4% organic matter content.

However, some soils with an organic matter content above 4% may release little nitrogen and local knowledge must be used when estimating mineralisable nitrogen. Therefore, it is not possible to specify a routine amount by which to adjust SNS based on soil organic matter level.

Add any adjustment for net mineralisable nitrogen to the total of SMN and nitrogen in the crop to give SNS.

Step 4. Identify Soil Nitrogen Supply (SNS) Index

Table 4.9 Soil Nitrogen Supply (SNS) Indices

SNS	SNS Index
Less than 60	0
61–80	1
81–100	2
101–120	3
121–160	4
161–240	5
More than 240	6

Adopting changes to nitrogen use

Large SMN measurements can overestimate SNS and small SMN measurements can underestimate SNS. Uptake of soil N by crops is rarely less than 50 kg N/ha, so SNS estimates less than this should be treated as 50 kg N/ha and no less.

Unless high SNS results (>160 kg N/ha) are confidently expected, they should also be treated with caution. If SNS estimates indicate that large changes (either increases or decreases) in nitrogen fertiliser use are required, crops should be monitored closely through spring for signs of nitrogen deficiency or excess and the planned nitrogen strategy should be adjusted, if necessary. It may be best for changes in nitrogen use to be introduced gradually over a few seasons so that the effect on crop performance can be monitored.

Example 4.1

Spring barley (feed) is to be grown on a light sand soil following sugar beet. Annual rainfall is 650 mm. There have been no organic manures applied or grass grown in the last five years.

Select Table 4.3 (page 10). On a light sand soil following sugar beet, the SNS Index is 0. Refer to the spring barley recommendation (Table 4.19, page 32) which gives a recommendation of 140 kg N/ha.

Example 4.2

Sugar beet is grown on a medium soil after winter wheat; 30 m^3/ha of pig slurry (4% DM) was applied in February and incorporated into the soil within six hours. Although the average annual rainfall is 650 mm, in an unusually dry winter the excess winter rainfall was found to be 100 mm.

Since the winter was dry, select Table 4.2 (SNS Indices for low rainfall areas). On a medium soil after winter wheat, the SNS Index is 1. Refer to the sugar beet recommendation (Table 4.30, page 41) which gives a recommendation of 120 kg N/ha.

Since the pig slurry was applied after harvest of the last crop, its nitrogen contribution must be calculated separately. This manure application provides 65 kg/ha of available nitrogen that is equivalent to manufactured nitrogen fertiliser (**Section 2: Organic materials**).

120 – 65 = 55 kg N/ha as fertiliser should be applied.

Example 4.3

Winter wheat is grown on a medium-textured, low organic matter soil after potatoes, which received some FYM. Annual rainfall is 750 mm. The soil is sampled in early February and analysed for SMN.

The analysis report shows that the SMN (0–90 cm) is 115 kg N/ha and the crop nitrogen content is estimated to be 25 kg N/ha. Because the soil contains little organic matter, no extra allowance is made for net mineralisable nitrogen. The SNS is therefore 140 kg N/ha. Refer to Table 4.9 that shows the SNS Index is 4. Refer to the winter wheat recommendation (Table 4.16, page 28) which gives a recommendation of 120 kg N/ha for a medium soil.

Example 4.4

Winter barley is to be sown following a three-year pure grass ley which has been managed in the last two years using 280 kg/ha/year nitrogen as manufactured fertiliser and crop-available N from manures. An average application of slurry has been applied in early spring each year, before taking one cut of silage followed by grazing.

The soil is a medium soil in a moderate rainfall area.

The previous grass management is classed as ‘high N’. Using Table 4.5 for medium soils, select the category ‘3–5 year leys, high N, grazed’. The SNS Index appropriate for the winter barley crop is Index 3. If regular applications of bulky organic manures had been applied in previous years, the Index value could be increased by one or two levels. In this case, slurry was applied. The SNS Indices for the next two crops following the winter barley are Index 3 and Index 2, respectively.

Example 4.5

Winter wheat is to be sown following spring barley that followed a two-year grazed ley which has been managed using 300 kg/ha/year nitrogen as manufactured fertiliser and crop-available N from manures. The soil is a deep clay in a high rainfall area.

Using Table 4.4, the SNS Index would be 1. Using Table 4.5, the previous grass management is classed as ‘high N, grazed’. The SNS Index from this Table is 2. The higher of these two Indices from Tables 4.4 and 4.5 is 2 and this should be used for the recommendation tables.

Phosphate, potash and magnesium recommendations

Current phosphate, potash and magnesium recommendations are based on achieving and maintaining target Soil Indices for each nutrient in the soil throughout the crop rotation. Soil analysis should be done every 3–5 years. This is now a requirement for England under Defra Farming Rules for Water. The use of regular soil analysis as a basis for making fertiliser decisions and the procedure for taking soil samples is described on page 19.

The phosphate and potash recommendations shown at Index 2 and 2-, respectively, are those required to replace the offtake and maintain target Soil Indices. The larger recommended applications for soils at Index 0 and 1 will bring the soil to Index 2 over a number of years. However, top dressing to the soil surface should be avoided where there is a high risk of run-off into neighbouring watercourses. By not applying fertiliser or manures at Index 3 or above, soil will run down over a number of years to the target Index.

Phosphate and potash recommendations shown in this guide are those required to replace the offtake of the yield shown. The recommendation should be increased or decreased where yields are expected to be substantially more or less than this. The amount to apply can be calculated using records of yield and crop nutrient contents per tonne of yield determined by analysis, or assuming guide values given in Table 4.11.

Recommendations are appropriate where the phosphate or potash balance for preceding crops has been close to neutral. Adjustments can be made where the balance for the preceding crop was significantly positive or negative. This might occur where actual yields were substantially different from those expected, or where there was a change of plan on straw removal. A phosphate or potash 'holiday' can result in a need for greater than normally recommended amounts for following crops.

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 46
- Organic materials supply phosphate and potash which contribute to crop requirements. 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

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, guarantee that analysis from any member can be trusted **wepal.nl**
- List of UK laboratories **nutrientmanagement.org/what-we-do/support-and-advice/find-a-laboratory**
- Sampling guidelines **nutrientmanagement.org/library/sampling**

Taking soil samples for phosphorus, potassium and magnesium

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

- The soil in each field should be sampled every 3–5 years
- 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. However, if the land is min-tilled, phosphate and potash will tend to accumulate near the soil surface and a 15 cm sample will overestimate nutrient concentrations to normal plough depth. In this case, samples are better taken to about 23 cm
- 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 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.

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 4.10.

Table 4.10 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

Table 4.11 Typical values of phosphate and potash in crop materials

Crop material		Phosphate (P_2O_5)	Potash (K_2O)
		kg/t of fresh material	
Winter wheat	Grain only	6.5	5.5
	Grain and straw[a,b]	7.0	10.5
All other cereals	Grain only	8.0	5.5
Winter barley/triticale/rye[a]		8.5	10.5
Spring wheat/barley[a]		8.5	12
Oats[a]		9	16.5
Oilseed rape	Seed only	14	11
	Seed and straw[a]	15	17.5
Peas	Dried	9	10
	Vining	1.5	3
Field beans		11	12
Potatoes	Tubers only	1	5.8
Sugar beet	Roots only	0.8	1.7
	Roots and tops	1.9	7.5

a. Values are per tonne of grain or seed removed but include nutrients in straw when this is also removed without weighing. Note that potash content of straw can vary substantially depending on the amount of water availability during crop maturity and straw baling. It can, therefore, be worthwhile to determine the nutrient content of representative straw samples by laboratory analysis.

b. The straw yield is assumed to be 50% of the grain yield. Where the amount of cereal straw removed is known, offtakes can be calculated using typical values of 1.2 kg P_2O_5/t and 9.5 kg K_2O/t of straw for winter wheat/barley and 1.5 kg P_2O_5/t and 12.5 kg K_2O/t for spring wheat/barley. For oilseed rape, typical offtake values are 2.2 kg P_2O_5/t and 13 kg K_2O/t of straw.

Grain analysis to improve phosphate management

Grain P and K analyses can provide better estimates of crop phosphate and potash offtakes than the typical values in Table 4.11. This information also complements soil analyses for P and K. AHDB-funded research on P nutrition has shown that the critical level of grain P in winter wheat is 0.32% (or 3,200 mg/kg). Grain P contents repeatedly below this level indicate crop P uptake was deficient enough to reduce grain yield.

Crop P deficiencies may arise through low soil P supplies, poor rooting and/or poor growing conditions (e.g. dry topsoil). If soil conditions are satisfactory but a field repeatedly shows grain P deficiency, available soil P should be increased for future crops. For example, by applying organic materials or inorganic phosphate more frequently or at increased rates. Subsequent grain analyses should confirm if this strategy was successful.

Collection of grain samples

- Grain samples must be representative of fields or areas from where routine soil analyses are taken
- Samples should not be taken from stores where grain from different fields has been combined
- Representative samples should be taken from each field, by sampling grain from each trailer load
- Sampled grain should be mixed and approximately 200 g should be put in a clearly labelled plastic bag, with sufficient information to identify the farm and field, and sent to the laboratory

Interpretation of grain analysis results

To calculate grain phosphate and potash offtakes, grain P and K concentrations should be converted to kg P_2O_5 and K_2O per tonne of grain at 15% moisture using the conversion factors on page 46.

Crop phosphate and potash requirements at different Indices

Soil P and K status is best monitored through soil analysis used alongside crop requirements to generate P and K recommendations. Recommendations in Table 4.12 and 4.13 are based around phosphate and potash offtakes in the harvested crop. If the crop yield or nutrient contents are above average, the crop removed more P and K, which must be replaced if the soil is at or below the target index.

If the soil is at target Index (2 for P and 2- for K), only maintenance applications should be made to replace offtakes (Table 4.11 or from grain analysis). If the soil is above the target Index, phosphate or potash applications can be reduced or omitted to allow the Index to decrease over years. However, yield responses are likely where the Soil Index is lower than target. In such cases, phosphate and/or potash should be applied annually and soil P and K Indices should be built up through application of more phosphate or potash than the crop offtake. Further information on building up or running down soil P and K Indices can be found in Section 1: Principles of nutrient management and fertiliser use.

If the soil analysis shows that a particular field is on the borderline between two Indices, P and K rates can be fine-tuned by interpolation, for example by averaging recommendations for Indices 0 and 1.

Example 4.6

Using typical nutrient contents from Table 4.11, estimate P and K offtake in winter wheat. Winter wheat yields 10 t/ha of grain. Straw is baled and removed from the field.

Offtake = yield (t) x grain and straw offtake (kg of nutrient/t)

Phosphate offtake	= 10 x 7.0	= 70 kg P_2O_5/ha
Potash offtake	= 10 x 10.5	= 105 kg K_2O /ha

Example 4.7

Using nutrient contents from laboratory analysis and conversion factors (on page 46), estimate nutrient removal.

Laboratory analysis shows that the grain P content was 0.45% and grain K was 0.40% from a winter wheat crop yielding 10 t/ha, with straw incorporated.

Nutrient removal = yield x grain P/K content x conversion factor

Phosphate	= 10 x 0.45 x 19.5	= 88 kg P_2O_5 /ha
Potash	= 10 x 0.40 x 10.2	= 41 kg K_2O /ha

Sulphur and sodium recommendations

Sulphur and sodium recommendations are given for each crop, where appropriate, because they are not required by all crops or in all parts of England and Wales. Farmers are advised to monitor the sulphur requirements of their crops because the risk of sulphur deficiency is increasing as atmospheric deposition of sulphur declines. Organic manures can supply useful amounts of sulphur (**Section 2: Organic materials**).

All sulphur recommendations are given as SO_3 and sodium recommendations as Na_2O. Conversion tables (metric–imperial, oxide–element) are given on page 46. If applying liquid fertilisers, manufacturers can supply tables which convert kg/ha of nutrient to litres/ha of product.

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.

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.

Guidance on how to collect a leaf tissue sample

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:

- If possible, collect samples early in the season at stem extension rather than after symptoms become visible
- It is recommended to take two tissue samples approximately two weeks apart to help distinguish between permanent and transient sulphur 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 2–3 plants
- 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 analytical laboratory

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. The approximate nutrient content of commonly used fertilisers is described on page 47.

Cereals

All Cereals – phosphate, potash, magnesium and sulphur

Phosphate and potash

The amounts of phosphate and potash needed to replace offtake and maintain the soil at the target Index (P Index 2 and K Index 2-) are shown in Table 4.12 and Table 4.13. Table 4.12 shows the maintenance applications for each crop when straw is incorporated. Table 4.13 shows the maintenance applications when straw is removed (and with straw yield assumed to be 50% of grain yield).

The amounts of phosphate and potash are appropriate to the grain yields shown for each crop in the table. The phosphate and potash recommendations can be adjusted if yields are likely to be larger or smaller than those shown.

To adjust the amounts, multiply the difference in expected grain yield by the phosphate and potash content per tonne of grain yield using the appropriate value for where straw is either incorporated or removed, as given in Table 4.11. Then add this value to (for larger yields), or subtract from (for smaller yields), the amounts in Table 4.12.

For example, at P Index 1, the phosphate recommendation for wheat with an expected yield of 10 t/ha where straw is incorporated is 80 + (2 x 6.5) = 93 kg/ha.

Where the weight of straw to be removed can be estimated separately, use the amounts of phosphate and potash per tonne of straw shown in the footnotes of Table 4.11 to calculate the amounts removed in the straw. Add these to the appropriate amounts for grain yield in order to calculate the overall amounts removed.

Crops grown on soil at Index 0 and 1 would be expected to respond to the higher amounts of phosphate and potash shown in the table. Over a number of years, these extra amounts of fertiliser will help to raise most soils, except light sands, to Index 2. At Index 3 and above, no phosphate and potash need be applied, but analyse soil regularly.

At Index 2, phosphate and potash can be applied when convenient during the year, but at Index 0 and 1, they should be applied annually and worked into the seedbed.

To avoid damage to germinating seedlings, do not combine drill more than 150 kg/ha of nitrogen plus potash on sandy soils.

Table 4.12 Phosphate and potash recommendations for cereals – straw ploughed in/incorporated

Nutrient	Soil P or K index			
	0	1	2	3 and higher
	kg/ha			
Winter wheat (8 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	105	75	45 (2-) 20 (2+)	0
Winter triticale (8 t/ha)				
Phosphate (P_2O_5)	125	95	65	0
Potash (K_2O)	105	75	45 (2-) 20 (2+)	0
Winter barley (6.5 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	95	65	35 (2-) 0 (2+)	0
Spring barley (5.5 t/ha)				
Phosphate (P_2O_5)	105	75	45	0
Potash (K_2O)	90	60	30 (2-) 0 (2+)	0
Spring wheat/spring triticale/rye/oats (6 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	95	65	35 (2-) 0 (2+)	0

Table 4.13 Phosphate and potash recommendations for all cereals – straw removed

Nutrient	Soil P or K index			
	0	1	2	3 and higher
	kg/ha			
Winter wheat (8 t/ha)				
Phosphate (P_2O_5)	115	85	55	0
Potash (K_2O)	145	115	85 (2-) 55 (2+)	0
Winter triticale (8 t/ha)				
Phosphate (P_2O_5)	130	100	70	0
Potash (K_2O)	145	115	85 (2-) 55 (2+)	0
Winter barley (6.5 t/ha)				
Phosphate (P_2O_5)	115	85	55	0
Potash (K_2O)	130	100	70 (2-) 40 (2+)	0
Spring barley (5.5 t/ha)				
Phosphate (P_2O_5)	105	75	45	0
Potash (K_2O)	125	95	65 (2-) 35 (2+)	0
Spring wheat (6 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	130	100	70 (2-) 40 (2+)	0
Spring triticale/rye (6 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	125	95	65 (2-) 35 (2+)	0
Oats (6 t/ha)				
Phosphate (P_2O_5)	115	85	55	0
Potash (K_2O)	160	130	100 (2-) 70 (2+)	0

Magnesium

At Mg Index 0, magnesium fertiliser should be applied every 3–4 years at 50–100 kg MgO/ha.

Sulphur

Not all cereal crops will require sulphur and the responsiveness of a crop to the application of sulphur is dependent on soil texture and winter rainfall.

Figure 4.4 The youngest leaves of sulphur-deficient cereals are often yellow

Use Table 4.14 to assess the risk of deficiency. If deficiency is suspected, tissue and grain analysis can be used to make a diagnosis and, if necessary, the deficiency should be treated.

There are a number of laboratory analyses that can be used to detect sulphur deficiency in leaf tissue, but AHDB trials have shown that the malate:sulphate test is the most reliable.

Where deficiency has been recognised or is expected in winter- or spring-sown cereals, apply 25–50 kg/ha SO_3 as a sulphate-containing fertiliser in early March to early May for wheat and for barley between mid-March and mid-April.

Using sulphur to maximise quality

Further clarity on application rates has been provided by AHDB trials that have shown that acrylamide formation can be minimised by applying 50 kg SO_3/ha to sulphur-deficient wheat grown for flour milling or cereal foods.

Acrylamide is a processing contaminant that has been found in cooked foods. It can form during high-temperature cooking and processing of wheat. Acrylamide formation in wheat-based products is linked to the levels of the amino acid asparagine. AHDB trials have shown that asparagine levels, and hence acrylamide formation, can increase if wheat is sulphur-deficient. Processors have modified their methods to minimise the formation of acrylamide, but growers can also minimise formation by applying sulphur where deficiency is likely.

In addition to reducing acrylamide formation, AHDB trials have shown that loaf volume and malting quality of wheat can be improved by correctly fertilising with sulphur.

Table 4.14 Estimating the risk of sulphur deficiency for cereal crops

Soil texture	Winter rainfall (Nov–Feb)		
	Low (<175 mm)	Medium (175–375 mm)	High (>375 mm)
Sandy	High		
Loamy and coarse silty	Low	High	
Clay, fine silty or peaty	Low		High

All cereals – micronutrients

AHDB research has shown that the most common micronutrient deficiencies limiting productivity of cereals crops are copper (Cu), manganese (Mn) and zinc (Zn), Table 4.15. More information is provided in **Section 1: Principles of nutrient management and fertiliser use**.

Visual symptoms are usually the first sign of a deficiency (Figure 4.5), however, they can be short-lived, easily confused and, by the time symptoms appear, it can be too late to correct the deficiency.

Table 4.15 Nutrient deficiency risk factors and interpretation of soil and leaf analysis

Nutrient	Soil risk factor	Soil analysis	Leaf analysis
Manganese (Mn)	Under-consolidated seedbeds; low soil temperature; low rainfall; over-liming; any soil with pH above 7.5; sandy soils with pH above 6.5; organic, peaty or marshland soil with pH above 6.0	Not reliable	Deficiency is more likely below 20 mg Mn/kg
Copper (Cu)	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	Not reliable
Zinc (Zn)	Sandy soils with high pH and phosphate Index (Index 5 and higher)	EDTA extract: deficiency is more likely below 1.5 mg Zn/l	Deficiency is more likely below 15 mg Zn/kg

Points to consider

- The amounts of phosphate and potash are appropriate to the grain yields shown
- Make allowance for nutrients applied in organic manures (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application on Index 2 soils
- Check that the soil is maintained at Index 2 by soil sampling every 3–5 years
- Drought, frost and herbicide damage can be mistaken for visual symptoms of nutrient deficiencies. It can be difficult to make a definitive diagnosis, but if a deficiency is suspected, it is important to consider:
  - Which nutrient deficiencies can commonly affect the crop species being grown
  - The soil type, condition and pH
  - The results of soil and tissue analysis

Treating micronutrient deficiencies

Options largely depend on when the deficiency is diagnosed. If soil analysis confirms a deficiency early in the season, liming, seed treatments, seedbed fertilisers or autumn applications are possible. If tissue analysis confirms a deficiency later in the season, treatments will be limited to foliar-applied fertilisers.

Copper

Symptoms of copper deficiency include pale, twisted leaves and stunted plants. Ears are sometimes trapped in the leaf sheath and those that emerge have white tips and blind grain sites. Blackening of the ears and straw occurs in copper-deficient wheat on organic chalk soils. This symptom is not seen in wheat grown on sandy or peat soils. Awns of barley become white and brittle and purpling of the stem and nodes is also possible.

If possible, treat deficiencies using soil-applied fertilisers in the autumn. Depending on soil application rate and soil texture, copper treatments may be effective in raising soil copper levels for up to 10 years; regular soil analysis, every 3–5 years, is recommended. Deficiencies can also be treated using foliar-applied fertilisers at late tillering or early stem extension.

Manganese

Symptoms occur in new leaves, which become pale and limp. This is followed by light grey flecking and striping, which occurs at the base of the youngest fully opened leaf. In time, leaves become paler and eventually become necrotic and collapse.

Deficiencies can be treated using seed treatments or foliar-applied fertilisers.

Zinc

Symptoms of zinc deficiency include pale stripes appearing parallel to the midpoint of younger leaves. Affected tissue dies and turns pale brown.

Deficiencies can be treated using seed treatments, or soil- or foliar-applied fertilisers. Foliar nutrients can be applied most cost-efficiently by tank-mixing with other crop inputs, such as fungicides, but check product labels carefully for product compatibility.

Figure 4.5 Micronutrient deficiency symptoms: copper, manganese and zinc (left to right)

Wheat and triticale, sown up to the end of January – nitrogen

Table 4.16 Nitrogen for wheat and triticale (sown up to the end of January)

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Light sand soils	180	150	120	90	60	0–60	0–40
Shallow soils	280[a]	240	210	180	140	80	0–40
Medium soils	250[a]	220	190	160	120	60	0–40
Deep clay soils	250[a]	220	190	160	120	60	0–40
Deep silty soils	240[a]	210	170	130	100	40	0–40
Organic soils	–	–	–	120	80	40–80	0–40
Peat	–	–	–	–	–	0–40	

a. The N recommendation exceeds the N max limit that applies within NVZs. Note the N max limit is calculated for the whole of the area of a crop type grown on farm and not for individual fields. For more details, see **gov.uk/nitrate-vulnerable-zones**

Recent research has shown evidence of a correlation between yield and crop nitrogen demand, supporting the adjustment of nitrogen rates for expected yield when site history indicates consistently below- or above-average yields. If you farm in an NVZ, you will be expected to have written evidence from at least two previous crops. If you don't farm in an NVZ, then a sensible approach would be to take the last five years' field-specific yields, discard the highest and lowest and take an average of the remaining three years.

Where previous experience of growing wheat indicates that yields above 8 t/ha can be realistically expected, increasing the recommended rate by 10 kg N/ha for each 0.5 t/ha additional yield, up to a maximum of 13 t/ha, could be justified. Similarly, for low-yielding crops, the recommended rate could be reduced by 10 kg N/ha for each 0.5 t/ha reduction in expected yield.

However, it is important to consider factors that limit yield, e.g. varietal choice, soil structural condition, seedbed conditions, supply of other nutrients, weed and disease pressure and growing season/climate. If any factor is limiting, a full response to nitrogen will not be obtained. For further guidance, consult a FACTS Qualified Adviser.

Timing of application

There is no requirement for seedbed nitrogen. Depending on the total nitrogen requirement and crop development, it will often be appropriate to apply nitrogen at the following timings.

- Less than 120 kg N/ha:
  Apply all the recommended amount as a single dressing by early stem extension but not before early April
- 120 kg N/ha or more:
  Apply about 40 kg N/ha between mid-February and mid-March, except where:
  - There is a low risk of take-all, and
  - Shoot numbers are very high. Well-tillered crops do not need nitrogen at this stage. Crops with too many tillers will be prone to lodging and higher disease levels. The balance of the application should be applied in one or two dressings during early stem extension. Where more than 120 kg N/ha remains to be applied, half should be applied at the start of stem extension (not before April) and half at least two weeks later (not after early May)

Triticale

The N requirements of triticale are the same as those of wheat in most situations. Hence N recommendations should be calculated as for feed wheat, including the adjustment for yield potential, with the following exceptions:

- If the variety chosen is known to have a high lodging risk, the total N rate should be reduced by 40 kg N/ha
- If the grain price is expected to be significantly below that which would be received for wheat, N rates should be reduced accordingly

Wheat – use of grain nitrogen concentration

Farm nitrogen strategies for wheat can be assessed periodically using information on grain protein concentration. Grain protein at the economic optimum rate of nitrogen is about 11% (1.9% N) for feed wheat and 12% (2.1% N) for bread-making wheat. Where concentrations in yields from a number of adjacent fields are consistently above or below these values during several years, nitrogen fertiliser application rates should be adjusted down or up by 25 kg N/ha per 0.5% difference in grain protein (30 kg N/ha per 0.1% difference in grain %N).

To convert grain %protein to grain %N, divide %protein by 5.7. Both N and protein are reported on a 100% dry matter basis.

The effect of economic changes on nitrogen rates

The recommendations in the tables for wheat and barley are based on a break-even ratio of 5.0 (cost of fertiliser nitrogen as £/kg N divided by value of grain as £/kg). If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the fertiliser nitrogen application.

Wheat grown for bread making

In some circumstances, an application of nitrogen may be economically worthwhile to boost the grain protein concentration. Typically, application of an extra 40 kg N/ha could increase grain protein by up to 1%. Application of soil-applied additional nitrogen during stem extension may give a small yield increase, as well as an increase in grain protein. Application as a foliar urea spray during the milky ripe stage will result in a larger increase in grain protein content but cannot be expected to increase yield.

Point to consider

- Tables contain the total nutrient required – remember to deduct nutrients applied as organic materials (**Section 2: Organic materials**)

Barley, winter-sown – nitrogen

Table 4.17 Nitrogen for winter-sown barley

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Feed barley							
Light sand soils	170	140	110	80	60	0–40	0
Shallow soils	220[a]	190	150	120	60	20–60	0–20
Medium and deep clay soils	190[a]	170	140	110	60	20–60	0–20
Deep fertile silty soils	170	150	120	80	40	0–30	0
Organic soils	–	–	–	110	60	0–40	0
Peaty soils	–	–	–	–	–	0–40	
Malting barley (1.8% grain N)							
Light sand soils	130	90	60	0–40	0	0	0
Other mineral soils	150	120	90	50	0–40	0	0
Organic soils	–	–	–	50	0–40	0	0
Peaty soils	–	–	–	–	–	0	

a. The nitrogen recommendation exceeds the N max limit that applies within NVZs. Note the N max limit is calculated for the whole of the area of a crop type grown on farm and not for individual fields. For more details, see **gov.uk/nitrate-vulnerable-zones**

Recent research has shown evidence of a correlation between yield and crop nitrogen demand, supporting the adjustment of nitrogen rates for expected yield when site history indicates consistently below- or above-average yields. If you farm in an NVZ, you will be expected to have written evidence from at least two previous crops. If you don't farm in an NVZ, then a sensible approach would be to take the last five years' field-specific yields, discard the highest and lowest and take an average of the remaining three years.

Where previous experience of growing winter feed barley indicates that yields above 6.5 t/ha can be realistically expected, increasing the recommended rate by 10 kg N/ha for each 0.5 t/ha additional yield, up to a maximum of 11 t/ha, could be justified. Similarly, for low-yielding crops, the recommended rate could be reduced by 10 kg N/ha for each 0.5 t/ha reduction in expected yield.

However, it is important to consider factors that limit yield, e.g. varietal choice, soil structural condition, seedbed conditions, supply of other nutrients, weed and disease pressure and growing season/climate. If any factor is limiting, a full response to nitrogen will not be obtained. For further guidance, consult a FACTS Qualified Adviser.

Timing of application

There is no requirement for seedbed nitrogen.

Depending on the total nitrogen requirement and crop development, it will often be appropriate to apply nitrogen at the following timings.

- Less than 100 kg N/ha:
  Apply as a single dressing by early stem extension (GS30–31)
- Between 100 and 200 kg N/ha:
  Split the dressing, with half during late tillering in mid-February/early March and half at GS30–31
- 200 kg N/ha or more:
  Apply three splits, with 40% during late tillering in mid-February/early March, 40% at GS30–31 and 20% at GS32

These recommendations assume appropriate measures are taken to control lodging (e.g. choice of variety, use of plant growth regulator). Reduce the recommendation by 25 kg N/ha if the lodging risk is high.

Further information

Wheat growth guide
Barley growth guide
ahdb.org.uk/knowledge-library

Malting barley – nitrogen

Careful judgement of the nitrogen rate is important to ensure that grain N content is neither too high nor too low for the requirement of the target market. Previous experience and consultation will be important in deciding the nitrogen rate to use. Where quality premiums are expected to be low, applying a slightly higher nitrogen rate will maximise the yield potential of the crop.

Where the target grain N content is below 1.8%, the nitrogen rate from the malting section of Table 4.17 should be adjusted as necessary for predicted yield. Then, it should be reduced by approximately 15 kg N/ha to achieve 1.7% grain N, 35 kg N/ha to achieve 1.6% grain N, or 60 kg N/ha to achieve 1.5% grain N. This nitrogen should all be applied by GS30–31.

The effect of economic changes on nitrogen rates

The recommendations in Table 4.17 are based on a break-even ratio of 5.0. If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the nitrogen application.

Point to consider

- Tables contain the total nutrient required – remember to deduct nutrients applied as organic materials (**Section 2: Organic materials**)

Oats and rye, winter-sown – nitrogen

Table 4.18 Nitrogen for winter-sown oats and rye

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Oats							
Light sand soils	150	110	80	20–60	0–40	0	0
All other mineral soils	190	160	130	100	70	0–40	0
Organic soils	–	–	–	100	70	0–40	0
Peaty soils	–	–	–	–	–	0–40	
Rye							
Light sand soils	110	70	20–50	0–20	0	0	0
All other mineral soils	150	120	90	60	30	0-20	0
Organic soils	–	–	–	60	30	0-20	0
Peaty soils	–	–	–	–	–	0–20	

Timing of application

Depending on the total nitrogen requirement and crop development, it will often be appropriate to apply nitrogen at the following timings.

- Less than 100 kg N/ha: Apply as a single dressing by early stem extension, but not before late March
- 100 kg N/ha or more: Split the dressing, with 40 kg N/ha in mid-February/ early march
  - If the remaining N is less than 100 kg N/ha, then apply the rest by early stem extension but not before late March
  - If the remaining N is 100 kg N/ha or more, then apply in two dressings, half at early stem extension (not before late March) and half at least two weeks later

These recommendations assume appropriate measures are taken to control lodging (e.g. choice of variety or use of plant growth regulator). Reduce the recommended rate by 40 kg N/ha for oats or 25 kg N/ha for rye if lodging risk is high.

The effect of economic changes on nitrogen rates

The recommendations in Table 4.18 are based on a break-even ratio of 5.0. If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the nitrogen application.

Point to consider

- Tables contain the total nutrient required – remember to deduct nutrients applied as organic materials **(Section 2: Organic materials)**

Wheat, spring-sown – nitrogen

Table 4.19 Nitrogen for spring-sown wheat

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Light sand soils	160	130	100	70	40	0–40	0
All other mineral soils	210[a]	180	150	120	70	40	0–40
Organic soils	–	–	–	120	70	40	0–40
Peaty soils	–	–	–	–	–	0–40	

a. The N recommendation exceeds the N max limit that applies within NVZs. Note the N max limit is calculated for the whole of the area of a crop type grown on farm and not for individual fields. For more details, see **gov.uk/nitrate-vulnerable-zones**

Timing of application

For crops drilled before March, apply nitrogen at early stem extension but not before early April or after early May. For rates higher than 70 kg N/ha, apply the first 40 kg N/ha of the total in the seedbed, except on light sand soils. On these soils, apply 40 kg N/ha at the three-leaf stage but not before March.

For late-drilled crops, all the nitrogen can be applied in the seedbed, except on light sand soils, where amounts more than 70 kg N/ha should be split, with 40 kg N/ha in the seedbed and the remainder by the three-leaf stage.

Wheat grown for bread making

In some circumstances, an application of nitrogen in addition to that given in Table 4.19 may be economically worthwhile to boost the grain protein concentration. Typically, application of an extra 40 kg N/ha could increase grain protein by up to 1%. Application of this additional nitrogen during stem extension may give a small yield increase, as well as an increase in grain protein. Application as a foliar urea spray during, but not later than, milky ripe stage will result in a larger increase in grain protein content but cannot be expected to increase yield.

The effect of economic changes on nitrogen rates

The recommendations in the table are based on a break-even ratio of 5.0. If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the nitrogen application.

Barley, spring-sown – nitrogen

Table 4.20 Nitrogen for spring-sown barley

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Feed							
Light sand soils	140	110	70	50	0–40	0	0
Other mineral soils	160[a]	140	110	70	30	0–30	0
Organic soils	–	–	–	70	30	0–30	0
Peaty soils	–	–	–	–	–	0–30	
Malting barley (1.8% grain N)							
Light sand soils	110	80	40	0–40	0	0	0
Other mineral soils	130	110	70	40	0–30	0	0
Organic soils	–	–	–	40	0–30	0	0
Peaty soils	–	–	–	–	–	0	

a. The N recommendation exceeds the N max limit that applies within NVZs. Note the N max limit is calculated for the whole of the area of a crop type grown on farm and not for individual fields. For more details, see **gov.uk/nitrate-vulnerable-zones**

Recent research has shown evidence of a correlation between yield and crop nitrogen demand, supporting the adjustment of nitrogen rates for expected yield when site history indicates consistently below- or above-average yields. If you farm in an NVZ, you will be expected to have written evidence from at least two previous crops. If you don't farm in an NVZ, then a sensible approach would be to take the last five years' field-specific yields, discard the highest and lowest and take an average of the remaining three years.

Where previous experience of growing spring feed barley indicates that yields above 5.5 t/ha can be realistically expected, increasing the recommended rate by 10 kg N/ha for each 0.5 t/ha additional yield, up to a maximum of 9 t/ha, could be justified. Similarly, for low-yielding crops, the recommended rate could be reduced by 10 kg N/ha for each 0.5 t/ha reduction in expected yield.

However, it is important to consider factors that limit yield, e.g. varietal choice, soil structural condition, seedbed conditions, supply of other nutrients, weed and disease pressure and growing season/climate. If any factor is limiting, a full response to nitrogen will not be obtained. For further guidance consult a FACTS Qualified Adviser.

Timing of application

For crops drilled before March, apply nitrogen at early stem extension but not before early April or after early May. For amounts greater than 70 kg N/ha, apply the first 40 kg N/ha of the total in the seedbed, except on light sand soils. On these soils, apply 40 kg N/ha at the three-leaf stage but not before March.

For late-drilled crops, all the nitrogen can be applied in the seedbed, except on light sand soils, where amounts greater than 70 kg N/ha should be split, with 40 kg N/ha in the seedbed and the remainder by the three-leaf stage.

Malting barley – nitrogen

Careful judgement of the nitrogen rate is important to ensure that the grain N content is neither too high nor too low for the requirement of the target market. Market requirements vary widely, from less than 1.65% to more than 1.85% grain N. Previous experience and consultation will be important in deciding the nitrogen rate to use. Where quality premiums are expected to be low, use of a slightly higher nitrogen rate will maximise the yield potential of the crop.

Apply all the nitrogen by early stem extension but not after the end of March. Where target grain N is below 1.8%, the nitrogen rate from the malting section of Table 4.20 should be adjusted as necessary for predicted yield, then reduced by approximately 30 kg N/ha to achieve 1.7% grain N, or 60 kg N/ha to achieve 1.6% grain N. Grain N may be diluted in high-yielding crops. This nitrogen should all be applied by mid-March.

Further information

Maltsters' Association of Great Britain (MAGB) barley requirements
ukmalt.com/barley-requirements

The effect of economic changes on nitrogen rates

The recommendations in Table 4.20 are based on a break-even ratio of 5.0. If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the nitrogen application.

Oats, rye and triticale, spring-sown – nitrogen

Table 4.21 Nitrogen for spring-sown oats, rye and triticale

	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Light sand soils	90	60	30	0–30	0	0	0
All other mineral soils	140	110	70	40	0–30	0	0
Organic soils	–	–	–	40	0–30	0	0
Peaty soils	–	–	–	–	–	0	

Point to consider

- Tables contain the total nutrient required – remember to deduct nutrients applied as organic materials (**Section 2: Organic materials**)

Further information

AHDB UK fertiliser price series
ahdb.org.uk/GB-fertiliser-prices

The effect of economic changes on nitrogen rates

The recommendations in Table 4.21 are based on a break-even ratio of 5.0. If the price of nitrogen or the price of grain changes, use Table 4.22 to decide on an amount to add to or subtract from the nitrogen application.

Table 4.22 Effect of economic changes on nitrogen rate – all cereals

Source of N	Fertiliser N content	Fertiliser cost					
	%	£/tonne product					
Ammonium nitrate	34.5	138	207	276	345	414	483
Urea	46.0	184	276	368	460	552	644
Urea-ammonium nitrate liquid	28.0	112	168	224	280	336	392
Cost of fertiliser nitrogen (£/kg N)		0.40	0.60	0.80	1.00	1.20	1.40
		Change to recommended N for all cereals					
£/t		kg N/ha					
50		-30	-60	-80	-100	-110	-130
75		0	-30	-50	-70	-80	-90
100		10	-10	-30	-40	-60	-70
125		20	0	-10	-30	-40	-50
150		30	10	0	-10	-20	-30
175		42	20	0	-10	-20	-30
200		40	30	10	0	-10	-20
225		40	30	20	10	0	-10
250		50	30	20	10	0	-10
275		50	40	30	20	10	0

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Oilseeds

Oilseed rape and linseed – phosphate, potash, magnesium and sulphur

Phosphate and potash

The amounts of phosphate and potash needed to replace offtake for the seed yields shown and maintain the soil at the target Index (P Index 2 and K Index 2-) are shown in Table 4.23. The amounts of phosphate and potash are appropriate for the seed yields shown.

The phosphate and potash recommendations can be adjusted if the yields are likely to be larger or smaller than those shown in Table 4.23.

Example 4.8

At P Index 1, the phosphate recommendation for winter oilseed rape with an expected yield of 4.5 t/ha is 80 + (1 x 14) = 94 kg P_2O_5/ha.

To adjust the amounts, multiply the difference in expected seed yield by the phosphate and potash content per tonne of seed yield using the appropriate value given in Table 4.11 and then add to (for larger yields), or subtract from (for smaller yields), the amounts in Table 4.23.

Crops grown on soil at Index 0 and 1 would be expected to respond to the higher amounts of phosphate and potash shown in Table 4.23. Also, over a number of years, these extra amounts of fertiliser will help raise most soils, except light sands, to Index 2. At Index 3 and above, no phosphate and potash need be applied for a few years, but check soil analyses regularly.

At Index 2, phosphate and potash can be applied when convenient during the year, but at Index 0 and 1 soils, they should be applied and worked into the seedbed.

Table 4.23 Phosphate and potash for oilseed rape and linseed

Nutrient	P or K Index			
	0	1	2	3 and higher
	kg/ha			
Winter oilseed rape (3.5 t/ha)				
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	100	70	40 (2-) 20 (2+)	0
Spring oilseed rape (2 t/ha) or linseed (1.5 t/ha)				
Phosphate (P_2O_5)	90	60	30	0
Potash (K_2O)	80	50	20 (2-) 0 (2+)	0

Alternatively, calculate the required application rates using expected offtake values from Table 4.11 and Soil Index adjustments from **Section 1: Principles of nutrient management and fertiliser use**.

Point to consider

- Ensure the phosphate and potash offtake is balanced by application on Index 2 soils and check that the soil is maintained at Index 2 by soil sampling every 3–5 years

Magnesium

At Mg Index 0 and 1, magnesium at a rate of 50 to 100 kg MgO/ha should be applied every three or four years.

Sulphur

The yield of most winter- and spring-sown oilseed rape grown on mineral soils will increase in response to an application of sulphur, which will also help to minimise green seeds. Apply 50–80 kg SO_3/ha as a sulphate-containing fertiliser to all winter- and spring-sown oilseed rape crops grown on mineral soils, in late February to early March. The green plant pigment, chlorophyll, can remain in the seed at harvest and create problems for rapeseed crushers. A large proportion of immature seed in a sample, or conditions restricting the natural breakdown of chlorophyll during ripening, can lead to high chlorophyll concentrations.

Extracted with the oil, chlorophyll interferes with subsequent processing. Crushers may be unwilling to accept seed lots with more than 4% immature (green) seed.

While a red seed coat can indicate immaturity, seed coat colour is not a reliable indicator of seed quality. The best test is to crush the seed and examine the cotyledons inside, which, in a good sample, should be yellow.

AHDB trials have shown that application of sulphur fertiliser at deficient sites reduced seed chlorophyll content. It is also worth noting that applying high rates of nitrogen fertiliser (above the recommendation) increased chlorophyll content.

Later, severely sulphur-deficient oilseed rape crops will have pale flowers; however, by this time it will be too late to correct the deficiency.

Figure 4.5 The youngest leaves of sulphur-deficient oilseed rape are often yellow

Sunflower – phosphate and potash

Phosphate is required at relatively low levels by the crop. A maintenance application of 40 to 60 kg/ha is usual. Sunflowers require a relatively high level of potassium, but most of this is returned to the soil after harvest. A maintenance application of 40 kg to 60 kg/ha is usual, often as part of a compound fertiliser with phosphate.

Oilseed rape – micronutrients

AHDB research has shown that the most common micronutrient deficiencies limiting productivity of oilseed rape crops are manganese (Mn), boron (B) and molybdenum (Mo) (Table 4.24). More information is provided in **Section 1: Principles of nutrient management and fertiliser use**.

Visual symptoms are usually the first sign of a deficiency, however, they can be short-lived, easily confused and, by the time symptoms appear, it can be too late to correct the deficiency.

Table 4.24 Micronutrient deficiency risk factors

Micronutrient	Soil risk factor	Soil analysis	Leaf analysis
Manganese (Mn)	Under-consolidated seedbeds; low soil temperature; low rainfall; over-liming; any soil with pH above 7.5; sandy soils with pH above 6.5; organic, peaty or marshland soil with pH above 6.0	Not reliable	Deficiency is more likely below 20 mg Mn/kg
Boron (B)	Sandy soils; high organic matter; pH above 7; over-liming	Hot water extract: deficiency is more likely below 0.8 mg B/l	Deficiency is more likely below 20 mg B/kg
Molybdenum (Mo)	Soil with pH below 6.5	Ammonium oxalate extract: deficiency is more likely below 0.1 mg Mo/l	Insufficient information to be able to recommend this type of analysis

Treating micronutrient deficiencies

Options largely depend on when the deficiency is diagnosed. If soil analysis confirms a deficiency early in the season, liming, seed treatments, seedbed or autumn fertiliser applications are possible. If tissue analysis confirms a deficiency later in the season, treatments will be limited to foliar-applied fertilisers.

Boron

Symptoms of boron include smaller and puckered young leaves. Margins turn down and tissue becomes brittle and is easily torn. Stems crack and flowering is poor.

Deficiencies can be treated using soil- or foliar-applied fertilisers.

Manganese

Manganese symptoms include yellowing and mottling between veins, which remain greener. Symptoms appear first on middle leaves and spread to older leaves.

Deficiencies can be treated using seed treatments or foliar-applied fertilisers.

Molybdenum

Molybdenum symptoms include reduced leaf area, pale and limp leaves.

Use a liming material to raise the soil pH of acidic soils to 6.5. When soil pH is more than 7 or when treatment is necessary, a seed treatment, or soil- or foliar-applied fertilisers can be used.

Foliar nutrients can be applied most cost-efficiently by tank-mixing with other crop inputs, such as fungicides, but check product labels carefully for compatibility.

Figure 4.6 Micronutrient deficiency symptoms in oilseed rape: boron, manganese and molybdenum (left to right)

Points to consider

Drought, frost and herbicide damage can also be mistaken for visual symptoms of nutrient deficiencies. It can be difficult to make a definitive diagnosis, but, if a deficiency is suspected, it is important to consider:

- Which nutrient deficiencies can commonly affect the crop species being grown
- The soil type, condition and pH
- The results of soil and tissue analysis

Sunflower – micronutrients

Molybdenum, copper and manganese deficiencies in sunflower can be problems in very acidic soils (<pH 5.0). Sunflowers are also sensitive to boron deficiency, which can be a particular problem on calcareous or sandy soils where boron levels are often naturally low.

Boron is taken up chiefly during the vegetative period prior to heading and signs of deficiency usually become apparent during flowering and seed maturation. A characteristic feature is poor seed-set, with many heads having large areas of hollow seeds. Other symptoms are red-brown necrotic patches and abnormal head and neck development. The timing and rates of boron application are shown in Table 4.25.

Table 4.25 Boron deficiency and its treatment in a sunflower crop

Soil factor	Soil boron level (ppm)	Treatment
Non-calcareous (pH < 7.5)	0.5	1.2 kg/ha incorporated at drilling
Calcareous (pH > 7.5)	0.5	300–500 g/ha as a foliar spray at GS 2.5–3.2
Sandy	0.5	

Oilseed rape, autumn-sown – nitrogen

Table 4.26 Nitrogen for autumn- and winter-sown oilseed rape

Soil category	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Autumn							
All soils	30	30	30	0	0	0	0
Spring							
All other mineral soils	220	190	160	120	80	40–80	0–40
Organic soils	–	–	–	120	80	40–80	0–40
Peaty soils	–	–	–	–	–	40–80	

Timing of application

Autumn nitrogen can be applied to the seedbed or as a top dressing to encourage autumn growth, but research suggests that crops sown after early September are unlikely to respond.

If the green area index (GAI) of the canopy, measured towards the end of winter, is less than 1.5, or less than 2.0 if the SMN in the top 60 cm soil is less than 25 kg N/ha, apply the nitrogen in two equal splits. Apply half at the start of spring growth (end February–early March) and half at green bud (mid-March to early April). Any additional nitrogen for crops yielding above 3.5 t/ha should be applied between yellow bud and early flowering.

Where the GAI of the canopy, measured towards the end of winter, is greater than 2.0, or greater than 1.5 with an SMN in the top 60 cm soil of at least 25 kg N/ha, then the first nitrogen should be reduced to between zero and 40 kg N/ha.

Foliar N applied as a solution of urea (20 kg N per 100 litres) at 40 kg N/ha between mid-flowering and two weeks after the end of flowering will often increase gross output by an average of 0.25 t/ha. This may occur even where the optimum amount of nitrogen has been applied to soil. Temperature at application should be less than 19°C. The economic benefit of this treatment will depend upon the cost of the product and the price of oilseed rape. Note that this foliar-applied nitrogen contributes towards the N max allowance.

Yield variation

The recommendations are for crops yielding 3.5 t/ha. Where previous experience of growing the crop indicates that yields above 3.5 t/ha can be realistically expected, the recommended rate may be increased by up to 30 kg N/ha per 0.5 t/ha of yield, up to an expected yield of 5.0 t/ha. This adjustment should be used with caution because applying too much early nitrogen to crops with large canopies can increase lodging and possibly reduce yield.

Point to consider

- Tables contain the total nutrient required – remember to deduct nutrients applied as organic materials (**Section 2: Organic materials**)

Oilseed rape and linseed, spring-sown – nitrogen

Table 4.27 Nitrogen for spring-sown oilseed rape and linseed

	SNS Index						
	0	1	2	3	4	5	6
	kg N/ha						
Spring oilseed rape							
Light sand soils	120	80	50	0–40	0	0	0
Other mineral soils	150	120	80	50	0–40	0	0
Organic soils	–	–	–	50	0–40	0	0
Peaty soils	–	–	–	–	–	0–40	
Spring linseed							
Light sand soils	80	50	0–40	0	0	0	0
All other mineral soils	100	80	50	0–40	0	0	0
Organic soils	–	–	–	0–40	0	0	0
Peaty soils	–	–	–	–	–	0	

Timing of application

Apply all the nitrogen in the seedbed. On light sand soils where the total rate is more than 80 kg N/ha, the dressing should be split, with 50 kg N/ha in the seedbed and the remainder by early May.

Sunflower – nitrogen

Due to the deep-rooting nature of sunflower, it can remove nutrients from depth in the soil profile. As a result, the crop will yield satisfactorily at quite low levels of soil nitrogen and nitrogen fertiliser applications may be unnecessary.

High levels of nitrogen can lead to excessive vegetative development, encouraging disease, delaying maturity and reducing seed oil content. UK experience indicates that applications of more than 25–50 kg/ha are rarely required.

Point to consider

- Tables contain the total nutrient required, remember to deduct nutrients applied as organic materials (**Section 2: Organic materials**)

The effect of economic changes on nitrogen rates

The recommendations in Table 4.26 and 4.27 are based on a break-even ratio of 2.5. If the price of nitrogen or the value of rapeseed changes, use Table 4.28 to decide on an amount to add or subtract from the nitrogen application.

Table 4.28 Effect of economic changes on nitrogen rate – oilseed rape

Source of N	Fertiliser N content	Fertiliser cost					
	%	£/tonne product					
Ammonium nitrate	34.5	138	207	276	345	414	483
Urea	46.0	184	276	368	460	552	644
Urea-ammonium nitrate liquid	28.0	112	168	224	280	336	392
Cost of fertiliser nitrogen (£/kg N)		0.40	0.60	0.80	1.00	1.20	1.40
		Change to recommended N for oilseed rape					
£/t		kg N/ha					
200		20	-20	-50	-70	-80	-100
225		30	-10	-30	-60	-70	-90
250		40	0	-20	-50	-60	-80
275		50	10	-10	-40	-50	-70
300		60	20	-10	-30	-50	-60
325		70	30	0	-20	-40	-50
350		70	40	10	-10	-30	-50
375		80	40	20	-10	-20	-40
400		90	50	20	0	-20	-30
425		90	50	30	10	-10	-30
425		100	60	30	10	-10	-30

Further information

AHDB UK fertiliser price series
ahdb.org.uk/GB-fertiliser-prices

Peas (dried and vining) and beans

The amounts of phosphate and potash are appropriate to pea yields of 4 t/ha and bean yields of 3.5 t/ha. Where yields are likely to be greater or smaller, phosphate and potash applications should be adjusted accordingly. Table 4.11 gives typical values of the phosphate and potash content in crop material per tonne of yield.

Table 4.29 Nitrogen, phosphate, potash and magnesium for peas and beans

Nutrient	SNS, P or K Index						
	0	1	2	3	4	5	6
	kg/ha						
Nitrogen (N)	0	0	0	0	0	0	0
Phosphate (P_2O_5)	100	70	40	0	0	0	0
Potash (K_2O)	100	70	40 (2-) 20 (2+)	0	0	0	0
Magnesium (MgO)	100	50	0	0	0	0	0

Further information

PGRO grower guides
pgro.org

Phosphate and potash

Seedbed phosphate and potash is only needed at Index 0 and 1.

Sulphur

Peas may suffer from sulphur deficiency on sensitive soil types. Where deficiency is possible, apply 25 kg SO_3/ha.

Sugar beet

Nitrogen

The recommendations do not vary with yield. Nitrogen fertilisers should be applied in spring: 30–40 kg/ha of the total N required immediately after drilling and the remainder when all the beet seedlings have emerged. If in doubt about the appropriate SNS Index, seek advice from a FACTS Qualified Adviser.

Table 4.30 Nitrogen for sugar beet

Soil category	SNS Index				
	0 and 1	2	3	4	5
	kg N/ha				
All mineral soils	120	100	80	0	0
Organic soils				40	0
Peaty soils					0

Phosphate, potash, magnesium and sodium

The amounts of phosphate and potash shown at target Index 2 are needed to replace the offtakes in a 60 t/ha crop (with tops ploughed in) and maintain the soil at the target Index.

The phosphate and potash recommendations at target or lower Indices can be adjusted if yields are likely to be larger or smaller than 60 t/ha by multiplying the difference in expected yield by the phosphate and potash content per tonne of yield given in Table 4.11.

Crops grown on soil at Index 0 and 1 would be expected to respond to the extra amounts of phosphate, potash and magnesium shown in Table 4.31. Also, over a number of years, these extra amounts of fertiliser will help to raise the Index of most soils, except light sands, to Index 2.

Example 4.9

At P Index 1, the recommendation for an expected yield of 70 t/ha where tops are incorporated is 80 + (10 x 0.8) = 88 kg P_2O_5/ha. For potash, growers can access their factory-determined estimates of the amounts of potash removed in their delivered crops from British Sugar Beet Portal as a guide to application rates on Index 2 soils.

Table 4.31 Phosphate, potash, magnesium for sugar beet

	P, K or Mg Index				
	0	1	2	3	4 and higher
	kg N/ha				
Phosphate (P_2O_5)	110	80	50	0	0
Potash (K_2O)	160	130	100	0	0
Magnesium (MgO)	150	75	0	0	0
Na_2O (use K Index)[a]	200	200	100	0	0

a. Sodium can partly replace potash in the nutrition of sugar beet when soils contain too little crop-available potash. An application of 200 kg Na_2O/ha is recommended for beet grown on soils at K Index 0 and 1. On K Index 2 soils, it is only necessary to apply 100 kg Na_2O/ha when the soil contains less than 25 mg Na/L. Fen peats, silts and clays usually contain sufficient sodium and no fertiliser sodium is recommended. Sodium at the recommended rate has no adverse effect on soil structure even on soils of low structural stability.

If inorganic fertilisers containing potash and sodium are applied just before sowing and too close to the seed, plant populations can be reduced in dry conditions, especially on sandy soils. To minimise this risk, all inorganic fertilisers should be applied at least two weeks before sowing and incorporated into the soil. They may be applied in autumn or winter and ploughed in, except on light sand soils where there is a risk of some nutrient loss by leaching. On light sand soils, the fertilisers can be applied in January/February, just before ploughing or cultivating.

Boron

Boron deficiency can adversely affect sugar beet yields. An application of boron may be required where soil analysis indicates that available boron in the soil (hot water extraction) is less than 0.8 mg B/l (ppm B). Deficiency can be corrected by applying 3 kg B/ha. Seek advice from a FACTS Qualified Adviser about form, amount and timing of the application.

Sulphur

The uptake of sulphur by well-grown crops is around 50–70 kg S/ha and those of high-yielding crops closer to 100 kg S/ha. Crops may suffer from sulphur deficiency, especially higher-yielding crops grown on sensitive soils (sands, sandy loams and shallow soils) and where there is no routine use of organic manures in the rotation. However, sulphate-containing fertilisers only need be applied if deficiency symptoms consistently appear in other, more sensitive crops within the rotation, such as oilseed rape and barley. Where deficiency is possible, 25 kg SO_3/ha is effective.

Points to consider

- Make allowance for nutrients applied in organic manures (**Section 2: Organic materials**)
- Ensure the phosphate and potash offtake is balanced by application on Index 2 soils
- Check that soil is maintained at Index 2 by soil sampling every 3–5 years

Further information

Sugar Beet Reference Book
bbro.co.uk/publications/reference-book

British Sugar Beet Portal
bsonline.co.uk

Biomass crops

In the UK, two crops are being grown commercially specifically for biomass for use as a source of energy – willow (*Salix* spp.), grown as short-rotation coppice (SRC), and Miscanthus (elephant grass, normally *Miscanthus x giganteus*). Other possible biomass crops, such as switchgrass and poplar, have only been grown in the UK under experimental conditions.

In addition to these dedicated biomass crops, some normal agricultural crops are also grown for energy purposes. These include wheat grain and sugar beet, both for bioethanol, and oilseed rape for biodiesel. Fertiliser requirements for these crops, if grown for energy use, are covered under the individual crops. Various agricultural by-products may be used for energy generation, such as incineration of cereal straw for electricity generation or anaerobic digestion of animal slurry for biogas generation.

One of the main reasons for growing energy crops is to reduce the use of fossil fuels and decrease greenhouse gas (GHG) emissions. Therefore, it is logical to ensure that GHG emissions associated with growing energy crops, directly or indirectly, are kept to a minimum.

Nitrogen fertilisers lead to large emissions of GHGs, carbon dioxide (CO_2) and nitrous oxide (N_2O), during manufacture, and additional N_2O when applied to soil. N_2O is a particularly powerful GHG, each molecule having the same global-warming potential as about 300 molecules of CO_2. So it is important to consider the environmental effects of nitrogen fertiliser applications when growing crops for energy.

Sources of information

Only a small number of studies on the nutrient requirements of either Miscanthus or short-rotation coppice willow have been conducted, either under UK conditions or worldwide. With such a small knowledge base, it is difficult to be certain of the extent to which the individual results can be generalised, or whether they are site-specific. Consequently, the guidance given here is preliminary and based largely on replacing nutrients removed in the harvested crops, unless otherwise stated.

Miscanthus

Table 4.32 Typical offtake of nutrients in harvested biomass (excluding the first two years after planting when yields are much lower than in later years)

Nutrient	Per tonne dry biomass	In a typical crop yielding 14 tonne dry biomass per ha
	kg/ha	
Nitrogen (N)	6	84
Phosphate (P_2O_5)	1	14
Potash (K_2O)	8.5[a]	120[a]

a. Potash offtake in Miscanthus is very variable as it is affected by weather and time of harvesting. These values refer to crops harvested in January; it is now common for crops to be harvested later (e.g. April–May) and the offtake of potash then is generally less because rainfall leaches out potash from the standing crop and returns it to the soil.

There have been no published studies to test crop responses to different applications of phosphate or potash, and only a few with nitrogen. Nitrogen and phosphate offtakes are small compared with many other crops, because much nitrogen and phosphate is transferred from stems and leaves to the rhizomes before harvest; these nutrients can be reused in future years.

As well as the nutrients removed in the harvested parts of the crop, an additional amount is required for the growth of rhizomes in the first few years after planting. On the basis of (a) a relatively small number of measured nutrient offtakes by Miscanthus, (b) comparisons with offtakes by other crops on soils at different levels of crop-available phosphate or potash, and (c) experience gained by those growing the crop, the following is proposed:

Phosphate

Maintain soil at P Index 1. Check every 3–5 years by soil testing.

Potash

Maintain soil at K Index 1–2. Check every 3–5 years by soil testing.

Nitrogen

In some cases, a biomass yield response to 50–100 kg N/ha has been observed but rarely, if ever, to higher rates and sometimes there is no response for many years (up to 15 years at one UK experiment). For Miscanthus growing on soil previously under arable crops, and with little previous organic manure (i.e. in SNS Index 2 or below), the soil is likely to supply about 40 kg N/ha (depending on soil type and management history). On the basis of current information, annual fertiliser applications in the range of 60–80 kg N/ha (or organic applications estimated to supply this quantity of nitrogen) are likely to provide sufficient nitrogen for maximum production. In soils starting at a higher SNS Index, nitrogen applications are probably not required for some years.

In the first two to three years after planting, some nitrogen is required for the growth of rhizomes in addition to that removed in harvested biomass. However, the quantity of nitrogen removed in these years is less than in subsequent years, so it is likely that no additional nitrogen for rhizome development is required. Thus, in contrast to some earlier suggestions, it is recommended that very little nitrogen (perhaps none) will generally be required in the first two years; nitrogen applications, as inorganic fertiliser or organic manures, only should start for the third year's crop. There is some evidence that nitrogen applications applied in the first year after planting are subject to large losses and also encourage weed growth.

Applying nitrogen in late May, just before rapid growth begins, is common practice and this seems appropriate – though there has been no work to test the best time to apply nitrogen.

Sulphur

There is currently no evidence of sulphur applications being required by Miscanthus in the UK.

Willow

Typical offtakes of nutrients in wood harvested from short-rotation coppice willow after three years' growth following the previous coppicing are shown in Table 4.33.

Table 4.33 Nitrogen, phosphate and potash for willow

	Per tonne dry biomass	In a typical crop yielding 30 tonne dry biomass per ha
	kg N/ha	
Nitrogen (N)	3	90
Phosphate (P_2O_5)	1.8	55
Potash (K_2O)	2.4	72

For short-rotation coppice willow, there is even less experimental data on nutrient requirements than for Miscanthus. Therefore, the recommendations given here are based on a combination of nutrient offtakes measured at a very small number of sites and experience of growers.

No fertilisers are required during the establishment year; so the recommendations below refer to the three-year periods after the initial cutback (in the winter after establishment) and the subsequent three-year periods after each harvest.

With short-rotation coppice, it is almost impossible to enter the plantation to apply fertilisers or manures in the second or third year after cutback or harvesting, unless specialist equipment is available. It is, therefore, necessary to determine nutrient requirements, and make any appropriate applications, in the first year after a cutback, normally during spring in preparation for the period of rapid growth.

In situations where biomass crops are used for bioremediation of biosolids or biofiltration of effluents, levels of nutrient application in excess of those highlighted in Table 4.33 may be justified, recognising the relatively low environmental risks associated with this approach, relative to alternative methods of disposal. In such circumstances, careful monitoring of ground and surface water is required to demonstrate absence of leaching and/or surface run-off of N and P.

Phosphate

Maintain soil at P Index 1. Check every three years (i.e. each harvesting cycle) by soil testing.

Potash

Maintain soil at K Index 1. Check every three years (i.e. each harvesting cycle) by soil testing.

Nitrogen

As with Miscanthus, a combination of nitrogen mineralised from soil organic matter plus that from atmospheric deposition and rain will supply much of the modest nitrogen requirement. The requirement is about 30 kg N/ha per year for a typical UK crop yielding 30 t dry biomass during a three-year cycle, i.e. 90 kg N/ha total offtake. However, larger offtakes have been observed in some situations and, as a grower gains experience of yields in specific soil types and different environments, nitrogen applications can be adjusted using the values in Table 4.33 for nitrogen removed per tonne dry biomass.

Applications of organic materials such as FYM, slurry or sewage sludge are an ideal way of maintaining a suitable supply of nitrogen and other nutrients throughout the three-year growth cycle from a single application made in the first year. The amount applied should be determined on the basis of estimated crop requirement, or within the limits described above for bioremediation or biofiltration systems.

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 1.12lb.

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)

Grain phosphate and potash offtakes

P% to kg P_2O_5	Multiply results by 19.5
K% to kg K_2O	Multiply results by 10.2
P mg/kg (ppm) to kg P_2O_5	Multiply by 0.00195
K mg/kg (ppm) to kg K_2O	Multiply by 0.00102

Analysis of fertilisers and liming materials

The materials listed below are used individually and some are used as components of compound or multi-nutrient fertilisers. The chemical and physical forms of nutrient sources, as well as growing conditions, can influence the effectiveness of fertilisers. A FACTS Qualified Adviser can give advice on appropriate forms for different soil and crop conditions.

The reactivity, or fineness of grinding, of liming materials determines their speed of action. However, the amount of lime needed is determined mainly by its neutralising value.

Nitrogen fertilisers	Typical % nutrient content
Ammonium nitrate	33.5–34.5% N
Liquid nitrogen solutions	18–30% N (w/w)
Calcium ammonium nitrate (CAN)	26–28% N
Ammonium sulphate	21% N, 60% SO_3
Urea	46% N
Calcium nitrate	15.5% N, 26% CaO

Phosphate fertilisers

Single superphosphate (SSP)	18–21% P_2O_5, typically 30% SO_3
Triple superphosphate (TSP)	45–46% P_2O_5
Di-ammonium phosphate (DAP)	18% N, 46% P_2O_5
Mono-ammonium phosphate (MAP)	12% N, 52% P_2O_5
Rock phosphate (e.g. Gafsa)	27–33% P_2O_5

Potash, magnesium and sodium fertilisers

Muriate of potash (MOP)	60% K_2O
Sulphate of potash (SOP)	50% K_2O, 45% SO_3
Potassium nitrate	13% N, 45% K_2O
Kainit	11% K_2O, 5% MgO, 26% Na_2O, 10% SO_3
Sylvinite	Minimum 16% K_2O, typically 32% Na_2O
Kieserite (magnesium sulphate)	25% MgO, 50% SO_3
Calcined magnesite	Typically 80% MgO
Epsom salts (magnesium sulphate)	16% MgO, 33% SO_3
Agricultural salt	50% Na_2O

Sulphur fertilisers

Ammonium sulphate	21% N, 60% SO_3
Epsom salts (magnesium sulphate)	16% MgO, 33% SO_3
Elemental sulphur	Typically 200–225% SO_3 (80–90% S)
Quarried gypsum (calcium sulphate)	40% SO_3
Polyhalite (e.g. Polysulphate)	Minimum 48% SO_3, 14% K_2O, 6% MgO, 17% CaO.

Liming materials	Neutralising Value (NV)
Ground chalk or limestone	50–55
Magnesian limestone	50–55, over 15% MgO
Hydrated lime	c.70
Burnt lime	c.80
Sugar beet lime	22–32 + typically 7–10 kg P_2O_5, 5–7 kg MgO, 3–5kg SO_3/tonne

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Glossary

Additionally available nitrogen (AAN) Nitrogen that will become available to the crop through mineralisation during the growing season.

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.

Biosolids Treated sewage sludge.

Calcareous soil Soil that is alkaline due to the presence of free calcium carbonate or magnesium carbonate or both.

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

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

Cover crop A crop sown primarily for the purpose of taking up nitrogen from the soil and which is not harvested. Also called green manure.

Crop-available nitrogen The total nitrogen content of organic manure 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.

Deposition Transfer of nutrients from the atmosphere to soil or to plant surfaces. The nutrients, mainly nitrogen and sulphur, may be dissolved in rainwater (wet deposition) or transferred in particulate or gaseous forms (dry deposition).

Economic optimum Rate of nitrogen application that achieves the greatest (nitrogen rate) economic return from a crop, taking account of crop value and nitrogen cost.

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, 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.

Farmyard manure (FYM) Livestock excreta that is mixed with straw bedding material that can be stacked in a heap without slumping.

Fertiliser See Manufactured fertiliser.

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

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

Greenhouse gas Gas such as carbon dioxide, methane or nitrous oxide that contributes to global warming by absorbing infrared radiation that otherwise would escape to space.

Green manure See Cover crop.

Incorporation A technique (discing, rotovating, ploughing or other methods of cultivation) that achieves some mixing between an organic manure and the soil. Helps to minimise loss of nitrogen to the air through volatilisation and nutrient run-off to surface waters.

Inorganic fertiliser Manufactured fertiliser that contains only inorganic ingredients or urea.

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.

Liquid fertiliser See Fluid fertiliser.

Livestock manure Dung and urine excreted by livestock or a mixture of litter, dung and urine excreted by livestock, even in processed organic form. Includes FYM, slurry, poultry litter, poultry manure, separated manures, and granular or pelletised manures.

Maintenance application Amount of phosphate or potash that must be applied to replace the amount removed from a field at harvest (including that in any straw, tops or haulm removed).

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 and liming materials that contain nutrients.

Manure See Livestock manure and Organic manure.

Major nutrient Nitrogen, phosphorus and potassium that are needed in relatively large amounts by crops.

Micronutrient Boron, copper, iron, manganese, molybdenum and zinc that are needed in very small amounts by crops (see also Major nutrients). 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.

Mineralisable nitrogen Organic nitrogen that is readily converted to ammonium and nitrate by microbes in the soil, for example during spring.

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.

Nitrous oxide (N_2O) A potent greenhouse gas that is emitted naturally from soils. The amount emitted is related to the supply of mineral nitrogen in the soil. It increases with application of manures and fertilisers, incorporation of crop residues and growth of legumes. It is greater in organic and peaty soils than in other soils.

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. It is 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 material Any bulky organic nitrogen source of livestock, human or plant origin, including livestock manures, biosolids (sewage sludge), compost, digestate and waste-derived materials.

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.

Poultry manure Excreta produced by poultry, including bedding material that is mixed with excreta, but excluding duck manure with a readily available nitrogen content of 30% or less.

Prilled fertiliser Fertiliser in which particles (prills) are formed by allowing molten material to fall as droplets in a tower. Droplets solidify during the fall and tend to be more spherical and somewhat smaller than granules

Removal See Offtake.

Rhizome Horizontal underground plant stem capable of producing the shoot and root systems of a new plant.

Sand Soil mineral particles larger than 0.05 mm.

Silt Soil mineral particles in the 0.002–0.05 mm diameter range.

Slurry Excreta of livestock (other than poultry), including any bedding, rainwater and washings mixed with it, which can be pumped or discharged by gravity. The liquid fraction of separated slurry is also defined as slurry.

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).
Trace element	See Micronutrient.
Volatilisation	Loss of nitrogen as ammonia from the soil to the atmosphere.

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