**Factsheet 09/12** (Project FV 345a)

Field Vegetables

# Soil Nitrogen Supply for field vegetables

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This factsheet reports on the findings of an HGCA project investigating the best practice for predicting Soil Nitrogen Supply (SNS). The project aimed to achieve consensus across the industry on best practice for the estimation of SNS. HDC funded an extension to the project to include an additional 10 sites following Brassica crops. The additional sites provide data on the high but often variable contribution that Brassica residues can make. This collaboration with HGCA allows field vegetable growers to benefit from the best practices for SNS estimation and use of Soil Mineral Nitrogen (SMN) being developed in the arable sector.

## Action points

### Which fields to sample

- The contribution from vegetable crop residues needs to be carefully determined - in some cases the SNS Index can be much lower than expected.
- Consider sampling Soil Mineral Nitrogen (SMN) in fields with high or uncertain amounts of residues such as in intensively cropped Brassica rotations or in fields where there is a past history of grass or regular inputs of organic manures.
- Measurements of SMN on peat and peaty soils can be unreliable.
- Choose the Field Assessment Method described in the Fertiliser Manual (RB 209) for soils where mineral N status is expected to be low (<120kg/ha).

### Time to take samples

For growing field vegetables, previous experience has shown:

- Take samples as close to planting date as possible after N has mineralised from previously incorporated residues. N release from winter incorporated residues (sprouts) can be slow.
- Introduce soil sampling for assessment of soil mineral N over a number of seasons so that experience can be gained in its use.
- Avoid sampling within two months after applications of nitrogen fertiliser or organic manures

### Sampling and handling of samples

- For most crops, sampling soils to three depths 0-30, 30-60 and 60-90cm is appropriate. Sampling can be shallower for shallow rooted crops.
- Care needs to be taken to avoid contamination of samples from lower layers with soil from the surface.
- At least 15 sampling points are needed in a ‘W’ pattern where previous crop management was uniform.
- Avoid excessive mixing when sub-sampling.
- It is important that samples are chilled to between 2-4°C as soon as possible after sampling and are analysed fresh within 72 hours.

### Interpretation of results (assuming good growing conditions)

- For most soils, a conversion factor of 4 can be used to convert mg/kg to kg/ha for each 30cm layer of soil.
- Sampling shallower than 90cm depth. Mineral N has to be scaled to 90cm for assessment of SNS Index.
- Consider using the WELL_N computer decision support system as a tool to interpret the results of the soil analysis when mineral N is not evenly distributed to 90cm.
- If SMN measurements indicate that large changes in N use are required, crops should be monitored for signs of deficiency or excess and the planned N strategy should be adjusted if necessary.

## Background

With the need to maximise the efficiency with which nitrogen fertilisers are used, reduce nitrate losses and minimise the crop's carbon footprint (N fertiliser commonly contributing 50-85% to it), the application of nitrogen has to be managed.

Currently, the SNS Index is an integral part of decision-making for fertiliser applications to all crops (Figure 1). The SNS Index, defined in six categories from low (Index 0) to high (Index 6), is a measure of the quantity of available nitrogen to a growing crop. For mineral soils, the highest indices are after intensive cultivation of Brassicas (Figure 2) on silt soils in the driest parts of the country (See Information box 1) and the lowest are on shallow or light soils following cereals in the wettest parts of the country.

Crops grown on soils with an SNS Index of 6 will generally require little fertiliser (HDC project FV 17). Over-fertilisation could lead to poor storage of produce, or high nitrate levels in salads while under-fertilisation could result in loss of yield.

It is therefore important that the Index is assessed accurately. The tables in the Fertiliser Manual (RB209) are a guide but where large amounts of leafy crop residue or manures have regularly been incorporated, measurement of SMN should be considered.

This factsheet describes:

- Which assessment methods to use
- When to take samples
- Sampling depth
- Sample handling and analysis
- Interpretation of the results.

All are equally relevant in rotations of arable and vegetable crops so the topic was ideally suited as a cross-sector project with HDC and HGCA funding.

### Information box 1

### Measured values of soil mineral N following Brassica crops

Within the HGCA project, HDC-funded soil and crop measurements were made at 10 cereal sites following Brassica vegetables (Table 1). An area of wheat crop was kept unfertilised by nitrogen so that crop nitrogen uptake from the soil could be measured at harvest; this nil-N crop N uptake is taken as the best estimate of SNS.

The values of SNS measured following cauliflower were variable and much lower than expected (SNS Index 2 rather than Index 3/4 by FAM) at three of the sites. This was explained by conservative amounts of N being applied to the previous crops. The levels of soil mineral N were very low after the cabbage crops, suggesting low amounts of soil N and crop residues. Soil mineral N levels were very high after calabrese crops, reflecting the large amounts of residue left behind (average measured SNS = 5).

These tables suggest that the assessments of SNS Index by the FAM can be in error and measurements of soil mineral N would avoid errors in under or over fertilisation of the following crops. Additionally, where shallow rooted crops followed, the measurements would provide information on N in the root zone.

**Table 1. Estimation of SNS Index by Field Assessment Method (FAM) and measurement at HDC-funded sites after vegetables.**

| Year | Previous crop and residue group | Rainfall category | Soil Type | FAM SNS | Spring SMN 0-90 | SNS Index Measured |
|---|---|---|---|---|---|---|
| 2009 | Calabrese High N Veg | Low | Deep silt | 4/5 | 156 | 4 |
| 2009 | | Low | Deep silt | 4/5 | 128 | 4 |
| 2010 | | Low | Deep silt | 4 | 173 | 5 |
| 2010 | | Moderate | Deep silt | 4 | 310 | 6 |
| | | | | **Average** | **192** | **5** |
| 2009 | Cabbage Medium N Veg | Low | Deep silt | 3 | 10 | 0 |
| 2010 | | Low | Deep silt | 3 | 52 | 0 |
| | | | | **Average** | **31** | **0** |
| 2009 | Cauliflower Med/High N Veg | Low | Deep silt | 3/4 | 65 | 1 |
| 2009 | | Low | Deep silt | 3/4 | 71 | 1 |
| 2010 | | Low | Medium | 3/4 | 104 | 3 |
| 2010 | | Low | Deep silt | 3/4 | 150 | 4 |
| | | | | **Average** | **97** | **2** |

1. The SNS Index is an integral part of decision-making for fertiliser applications to all crops

2. Brassica crop residues can contain considerable amounts of N

## Which assessment method to use

Consider sampling Soil Mineral Nitrogen in fields with high or uncertain amounts of residues such as in intensively cropped Brassica rotations or in fields with a past history of grass or regular inputs of organic manures. If measurements confirm high residue levels, savings in fertiliser can be made, avoiding risks of over fertilising. If it is measured as low then it avoids any risk of marketable yield loss.

On retentive silt soils it may be useful to check mineral N levels following wet winters. While SNS is still high, little mineral N might be readily available to young or shallow rooted crops. N rates may need to be adjusted to take account of N moved out of the rooted zone.

On very light soils following very wet winters, it may be useful to check Soil Mineral Nitrogen (SMN). If SMN is very low (<50kg/ha) further N may be justified for shallow rooted crops such as onions.

Where crops are planted in succession in the same year, it may be worthwhile sampling at the planting of second crops.

If the SMN is expected to be less than <120kg/ha, use the Field Assessment Method, unless there is a special reason.

**In Scotland, refer to Technical Note 621 for field vegetables.**

## Assessing SNS Index by the Field Assessment Method (FAM)

The Field Assessment Method is fully described in the Fertiliser Manual (RB209) and is the easiest way of estimating the SNS Index but the method has to be followed carefully to get the best results. This factsheet reproduces text from the Fertiliser Manual (RB209).

Estimates of SNS Index are based on previous cropping, soil type and excess winter rainfall. The SNS Index is suited for predicting SNS in the spring after autumn harvested crops but is less useful in complex horticultural rotations, particularly where there are repeated crops in the same season.

The first step is to determine soil type, which needs to be determined with care, as this influences the amounts of soil nitrogen left behind. Soil type is based on the texture of both surface and subsoil to 1m depth. Appendix 1 in the Fertiliser Manual details how soil type can be determined. Deep silty soils can retain much of the N from previous crop residues, compared with light sandy soils. For the purposes of the Fertiliser Manual, organic soils contain between 10 and 20% organic matter, while peaty soils contain over 20%.

The second step is to identify the previous crop type. In vegetable rotations, type and management of crop residues has a large influence on the SNS Index. There are three categories of vegetable crop residues (Low Medium and High – see Information box 2) but the amounts left can be very different and adjustments to the Index may need to be made in step 5.

The third step is to determine the amount of excess winter rainfall, which, together with soil type, influences the amounts of nitrogen remaining in the soil in the spring. There is a choice of three SNS Index tables, representing Low (A), Medium (B) and High (C) rainfall areas (see pages 91-93 in the Fertiliser Manual). Updated information on these rainfall areas, including maps, is often published in the popular farming press and on information bulletins in the spring for FACTS registered consultants.

The fourth step uses these tables to determine a provisional Soil Nitrogen Supply index. For most soils, this is purely a case of looking up the information from tables A, B and C.

For organic soils, the SNS is likely to vary widely, depending on the amount and age of the soil's organic matter. Here, the SNS Index is likely to be between 3 and 6. The relationship between the actual SNS and the level of soil organic matter is poor. Some soils with more than 10% organic matter can have an SNS similar to that of mineral soils. Assessments of SNS on these soils should take into account previous experience on crop response to N.

For peats and peaty soils, the SNS is expected to be at Index 5 or 6, irrespective of previous cropping, manuring or excess winter rainfall. However, local experience should be used to judge the N supplying performance of these soils, particularly when growing shallow rooted vegetable crops.

The fifth step modifies this assessment. 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 in the Fertiliser Manual 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, the history of vegetable cropping is longer than one year and in circumstances where larger than average amounts of crop residue or unused fertiliser are left behind (see Fertiliser Manual (RB209) Footnote to Table A, p91). In rotations where vegetable crops are grown infrequently in essentially arable rotations, the Index level may need to be adjusted downwards. Where there is uncertainty, soil sampling for SMN may be appropriate

In vegetable rotations where a second crop is grown in the summer season following 'Medium N vegetables', increase the Index for that crop by one level from that arrived at in step four above and by one or two levels if the second crop is following 'High N vegetables'. It is important that the growing conditions including fertiliser applications of the first crop are fully taken into account. For instance, nitrogen may be leached below rooting depth in wet seasons or where excess irrigation has been applied, especially on light sandy soils. Analysis for SMN (0-90cm) before the second crop could be worthwhile.

Once the SNS Index has been determined the Fertiliser Manual tables can be used to provide fertiliser recommendations.

**Information box 2**

### Categories of field vegetable crop residue levels from the Fertiliser Manual RB209

**High N vegetables**

High residual nitrogen 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 of loss by leaching.

**Medium N vegetables**

Medium residual nitrogen vegetables are crops such as lettuce, leeks and long season Brassicas such as Dutch white cabbage where a moderate amount of crop debris is returned to the soil.

**Low N vegetables**

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

## Assessing SNS level by measurement method (Fertiliser Manual RB209)

The measurement method can be used once the need for direct assessment of the SNS Index has been determined. The most effective way of determining it in horticultural rotations is by measuring Soil Mineral Nitrogen (SMN) to 90cm or to rooting depth for shallow rooted crops.

Sampling of SMN is generally carried out before planting so there is no adjustment needed for the crop N content.

Allowances for mineralisation of N from soil organic matter are made in the recommendation tables. For field vegetables, the amount of N measured as soil mineral N to 90cm can be used to determine the SNS Index.

Sampling on peat and peaty soils is not recommended, as mineral N levels can be highly variable and difficult to interpret.

**Table 2. Determining SNS by measuring Soil Mineral Nitrogen**

| SNS Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Mineral N kg/ha 0-90cm | <60 | 61-80 | 81-100 | 101-120 | 121-160 | 161-240 | >240 |

### Sampling time

For growing cereals refer to the HGCA Topic Sheet 115 – taking care to make allowances for the high and variable residues from vegetable crops.

For growing field vegetables, previous experience has shown that it is best to take samples as close to planting date as possible after N has mineralised from previously incorporated residues. (Measurements on sites after Brussels sprouts can have low soil mineral N until April/May because it takes time for N to mineralise from the leafy residues.)

### Taking soil samples

Appropriate sampling equipment must be used (Figure 3). It is important to avoid cross-contamination of samples from different depths. Using a mechanised 1 metre long gouge auger (2.5cm 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. For most crops, sampling soils to three depths, 0-30, 30-60 and 60-90cm, is appropriate. Sampling to rooting depth can be considered for shallow rooted crops.

At least 15 cores will be needed to represent a uniformly managed block of up to 20ha. Five to 10 further sampling points may be necessary where SNS levels are expected to be very high or variable after uneven amounts of leafy residues have been incorporated. It is very important that areas of the field with widely differing texture or cropping history are sampled separately.

**3. A mechanised soil sampler**

Sampling in a 'W' pattern (as opposed to more complex arrangements) is adequate to give representative samples. This design is recommended in the Fertiliser Manual. It requires the sampler to walk in a 'W' pattern across the field and extract soil cores at regular distance. The 'W' should cover as much of the field as is possible. Avoid sampling headlands or other obviously variable patches. Walking in a 'W' shape is adequate in most circumstances but the use of GPS techniques to both measure fields and generate sampling grids can be beneficial in large scale sampling campaigns or for mapping purposes.

## Sample handling and analysis

There are several stages in the sampling, handling and analysis process that have the potential to introduce uncertainties into SMN measurement.

When taking soil core samples, the soil from each sampling point is bulked for each depth. If sub-sampling is required before the sample is sent to the laboratory, it is important that the sub-sample obtained is representative. Take many small representative portions but avoid excessive mixing as this may stimulate mineralisation and lead to over-estimation of the available nitrate-N.

It is vital to keep the interval between sampling and analysis for SMN as short as possible (See Information box 3). Samples should be cooled in the field and transported to the laboratory at 2-4°C, to be analysed within three days of sampling (Figure 4).

For any sets of samples that are to be compared, it is important that the delay from sampling to analysis is standardised. It is suggested that standard delays of ~24, ~48 or ~72 hours could be adopted. Long term (one week or more) storage of soil samples is not appropriate for SMN testing. Freezing is not suitable for commercial SMN testing.

All the samples from the same batch should go to one laboratory, as small differences in handling and analysis may have an effect on the result. (Ring testing is being carried out between laboratories to ensure consistency.)

**4. Make sure soils are analysed within three days of sampling**

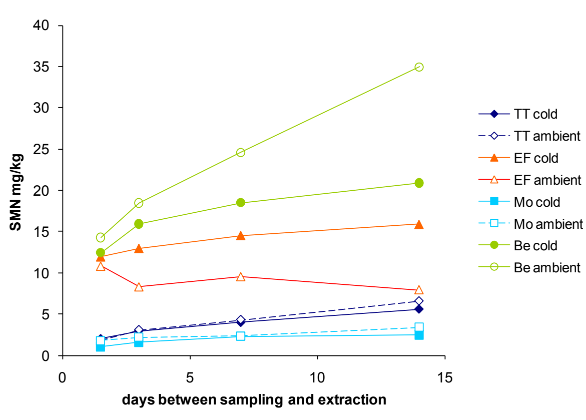
### Information box 3

## Possible effects of sample storage on soil mineral N levels

The effects of sample storage were tested in two seasons. The average increase in topsoil SMN was 0.37mg/kg per day of storage at 2-4°C, compared to 0.49mg/kg per day of storage at ambient temperatures. On average, SMN in a 90cm profile increases by ~5kg/ha per day of delay, even when samples are kept refrigerated (2-4°C).

Figure 5 opposite shows an example of the effect of interval between sampling and extraction on measured SMN for soil samples taken in spring 2009 from four fields stored at two temperatures, Ambient and chilled to between 2 and 4°C. Abbreviations are site codes; TT= Terrington, EF= Lincs site, Mo = Morley, Be = Beccles, BX = Boxworth. This shows that the effects of storage can be variable. On the clayey arable site in Lincolnshire, mineral N actually fell. The difference was attributed to its previous history of grass.

It is concluded that samples should be cooled and stored for less than 3 days before analysis.




**5. An example of the effect of interval between sampling and extraction on measured SMN**

## Interpretation of results

Most results will come back from the laboratory as mg/kg $NO3^-$ and $NH4^+$ on a dry soil basis. These need to be adjusted for the dry bulk density of the soil and converted to kg/ha before they can be interpreted in the SNS tables in the Fertiliser Manual (RB209). Attempts were made to develop a method to assess bulk density in the field while sampling but these failed to provide any advantage over an assumption that the density over the profile is 1.33g/cm$^3$. In the absence of properly conducted assessments of soil bulk density, the mineral N (nitrate and ammonium) figures expressed as mg/kg on a dry basis for a 30cm thick layer can be converted to kg/ha for that depth by multiplying by 4. Adjustments for stoniness made little difference to the estimation of SNS.

At this point, an adjustment could be made to take account of additional release of N from soils with organic matter levels of more than 3% but unless this is backed up by local knowledge of the soils likely performance, it could be risky with high value vegetable crops.

On retentive silt soils, larger levels of soil mineral N in the spring and autumn are closely associated with larger yields and N uptakes of unfertilised cereal crops at harvest (see HDC full report - FV 345a). This confirms that useful levels of mineral N are left behind by Brassica crop residues.

However, there is an additional complication for field vegetable crops which have much shallower rooting than cereals; crops such as salad onions will only be able to take up N from the top 30cm of soil. In such cases SNS to 90cm is irrelevant, though its value has to be estimated to assess the appropriate SNS Index (Information box 4).

**Information box 4**

## Dealing with the interpretation of SMN for shallow rooted crops

The SNS Index is based on measurements of SMN to 90cm so mineral N values to a lesser depth have to be scaled up to what they would be to 90cm (Figure 6), as shown in the Table 3 below. For field vegetables, as samples are taken before planting, there is no need to make allowances for crop N content. For field vegetable crops, mineralisation of N from soil organic matter is taken into account in the recommendation tables.

If the mineral N content to 45cm depth for a crisp lettuce crop is 100kg/ha N. The scaled up value to 90cm would be 200kg/ha equivalent to SNS index 5. This can be used to determine the crop N requirement of the lettuce from tables in the Fertiliser Manual (RB209) or by calculation - see below.

6. Shallow rooted crops have limited access to N

**Table 3. Scaling up the SNS index to take into account shallow rooting depth, see appendix 9. NB – assumes uniform distribution of N**

| Crop | Rooting depth from the Fertiliser Manual | Mineral N to rooting depth | Estimated SMN kg/ha to 90cm | Scaled SNS Index |
|---|---|---|---|---|
| Salad onions | 30cm | 100 | 300 | 6 |
| Crisp lettuce | 45cm | 100 | 200 | 5 |
| Cabbage | 90cm | 100 | 100 | 2 |

## Estimation of fertiliser requirement

Data is taken from Appendix 9 & 10 in the Fertiliser Manual (RB209) to estimate crop nitrogen requirement **(CRN).**

$$CRN = \frac{N\ uptake - (MineralisedN + SoilMinN_{90} \times RootDepth/90)}{Fertiliser\ Recovery}$$

- **N uptake** – is the amount of nitrogen taken up by an optimally fertilised crop.
- **Mineralised N** – is based on estimates of N released from soil organic matter during the growing season.
- **SoilMinN** – based on a measured value to 90cm.
- **RootDepth** – based on rooting depth of crop (cm).
- **Fertiliser Recovery** = 0.6 (Based on a fertiliser recovery of 60%).

**Example for Crisp Lettuce**

Data from Appendix 9 & 10

- **N uptake** – 165kg/ha N.
- **Mineralised N** – 22kg/ha N.
- **SoilMinN** – 100kg/ha sampled to 45cm depth. 200kg/ha to 90cm.
- **RootDepth** – 45cm

$$CRN = \frac{165 - (22 + 200 \times 45/90)}{0.6}$$

- **Crop Nitrogen Requirement = 72kg/ha N.**

The appropriate fertiliser recommendation will be affected by the distribution of N within the profile. For field vegetable crops it is important to ensure that N is available to rooting depth, especially with young or shallow rooted crops. Information box 5 presents two examples with the same SNS but completely different fertiliser recommendations. Consider using the WELL_N computer decision support system as a tool in these situations.

In all situations, good soil conditions are assumed – poor soil structure can restrict root growth and uptake of N.

**Information box 5**

## Example of interpretation of SMN values using the WELL_N Model

Even if the SNS Index is high, if limited N is available in the topsoil, fertiliser may still be required. WELL_N can be used to interpret such results. In this example, the SNS Index is the same for both soils but the distribution of mineral N by depth is completely different, leading to different fertiliser requirements for a Brussels sprout crop following cauliflowers (Table 4).

**Table 4. Interpreting SMN values using the WELL_N Model**

| | Field 1 | Field 2 |
|---|---|---|
| **SNS (Index)** | **6** | **6** |
| | kg/ha N | |
| 0-30cm | 150 | 25 |
| 30-60cm | 100 | 100 |
| 60-90cm | 25 | 150 |
| **0-90cm** | **275** | **275** |
| RB209 (2010) recommendation | 0 | 0 |
| WELL_N recommendation | 25 | 125 |

# Further information

### AHDB publications

**HGCA Topic Sheet 115** Estimating Soil Nitrogen Supply (SNS)

**HGCA Project 3425** Establishing Best Practice for Estimation of Soil Supply

**HGCA Project 3189** Cost-effective sampling strategies for soil management

**HDC Project FV 345a** Establishing Best Practice for determining Soil Nitrogen Supply

**HDC Projects FV 17a and FV 17b** Prediction of Nitrogen requirement for vegetables

**HDC Morph Model** WELL_N Nitrogen Advisory Model (www2.warwick.ac.uk/fac/sci/lifesci/wcc/resources/morph/)

### Other useful publications

**Fertiliser Manual** (RB209 8th Edition) - Defra 2010.

**Fertiliser recommendations for vegetables, minority arable crops and bulbs** (TN621) - SAC 2009 (For Scottish crops).

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