Nitrogen for winter wheat – management guidelines

Autumn 2009

HGCA

Contents

Introduction

Management of nitrogen (N) gets ever harder. Regulations have become more stringent while fertiliser and wheat prices become more volatile. Growers must know how to maximise profit from N, but minimise environmental impact in each field.

While England, Wales, Scotland and Northern Ireland each has its own regulations, they are sufficiently similar for these guidelines to cover the UK.

Errors in N management, unlike those in pest and disease control, remain largely unseen. Over- or under-fertilised crops look similar unless errors are extreme. Errors can often accumulate year-on-year, particularly on heavy soils. Hence good N management requires year round attention.

These guidelines

While other documents deal with all nutrients for all crops, these HGCA guidelines provide more detail on N – the most important nutrient – on the most extensive UK crop, wheat. The aim is to give UK wheat growers comprehensive guidance on using N, whether as fertiliser or organic manure.

After outlining how wheat responds to N and factors affecting N management with the underlying uncertainties, these guidelines follow the annual decision-making cycle for autumn-sown wheat crops. The approach to decision-making follows that used in *The Fertiliser Manual*, due to be published shortly.

Further explanation and guidance is given. In particular, the guidelines explain explicitly how crop demand for N, mineralisation and atmospheric deposition of N affect recommendations. The value of regular checks on the N status of soils, crops and grain is also highlighted.

A worked example calculating Crop N requirement is given in Table 12. A blank template is available on the HGCA website.

Many factors interact to influence crop responses to applied N, especially soil conditions and nutrient availability. These guidelines assume that all manageable constraints on N responsiveness, eg acidity, soil compaction, and low potassium, phosphorus or sulphur, have been identified and remedied.

For further resources on N management, including fertiliser recommendations and Nitrate Vulnerable Zone booklets for each country, see page 17.

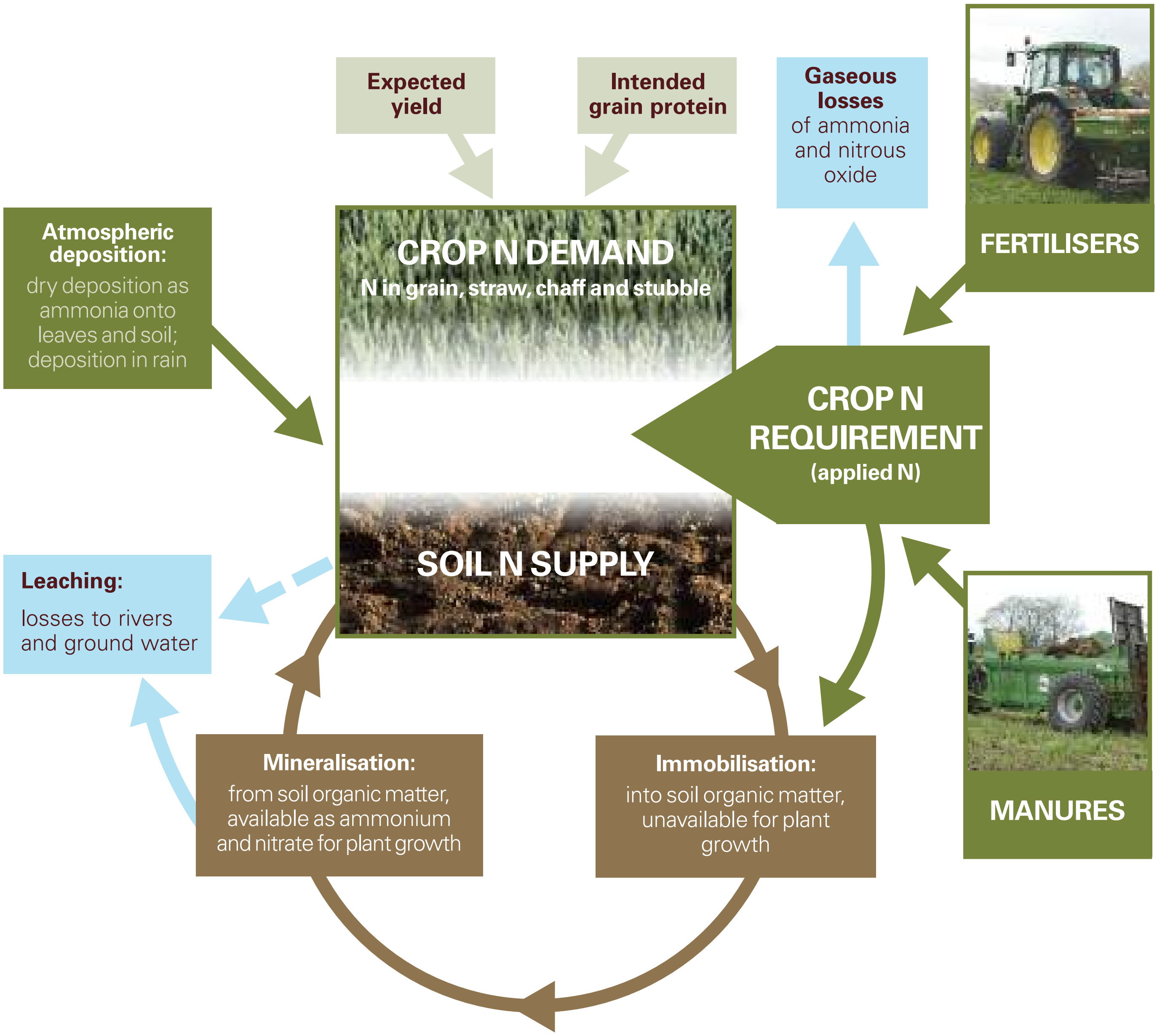
Nitrogen management

Meeting Crop N Requirement
The aim of N management is to respond effectively to the key issues that affect a crop's requirement for applied N – the **Crop N Requirement**.

This is the **Crop N Demand** less the **Soil N Supply**, adjusted for the inefficiencies of applied materials, whether manufactured fertilisers or organic manures.

Thus the crop's requirement for applied N (Crop N Requirement) exceeds the shortfall between Crop N Demand and Soil N Supply.

$$\text{Crop N Requirement} = \frac{\text{Crop N Demand} - \text{Soil N Supply}}{\text{Fertiliser N recovery}}$$



The uncertainty of N management
Research shows that N management of wheat in the UK is both uncertain and often imprecise.

Many factors affect N management, eg soils, varieties, rotations, weather. Often, the processes affected and their interactions cannot be assessed easily or predicted accurately.

There is general consensus that the key determinants of Crop N Requirement in the UK are Soil N Supply and Crop N Demand. This approach is taken in the new *Fertiliser Manual* and in these guidelines. However, other approaches to N management could produce similar results.

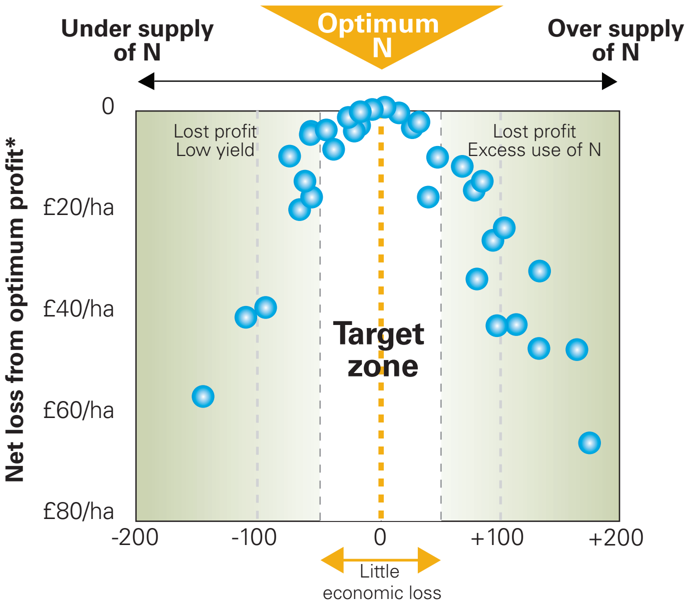
Small, seasonal errors in N use have little effect on profit or pollution, but larger errors – or those repeated each year – can compromise farm performance. Hence, it is important to monitor and correct significant errors.

How wheat responds to nitrogen

N errors
Under-fertilising causes lost profit due to unrealised yield. Over-fertilising causes lost profit due to excess use of N.

Recent trials on 50 fields compared the N requirement pre-sowing, (based on Fertiliser Recommendations, 7th Edition of RB209 and soil analysis) against the 'optimum' N identified post-harvest. This showed that the predicted N requirements were within 50kg/ha of the optimum on just 25 fields.

The main cause was incorrect Soil Nitrogen Supply (SNS) estimation. Economic losses were small where N requirements were within 50kg/ha of the optimum. Larger errors were much more serious. Under-fertilising (or inadequate N supply) and over-fertilising caused similar losses.

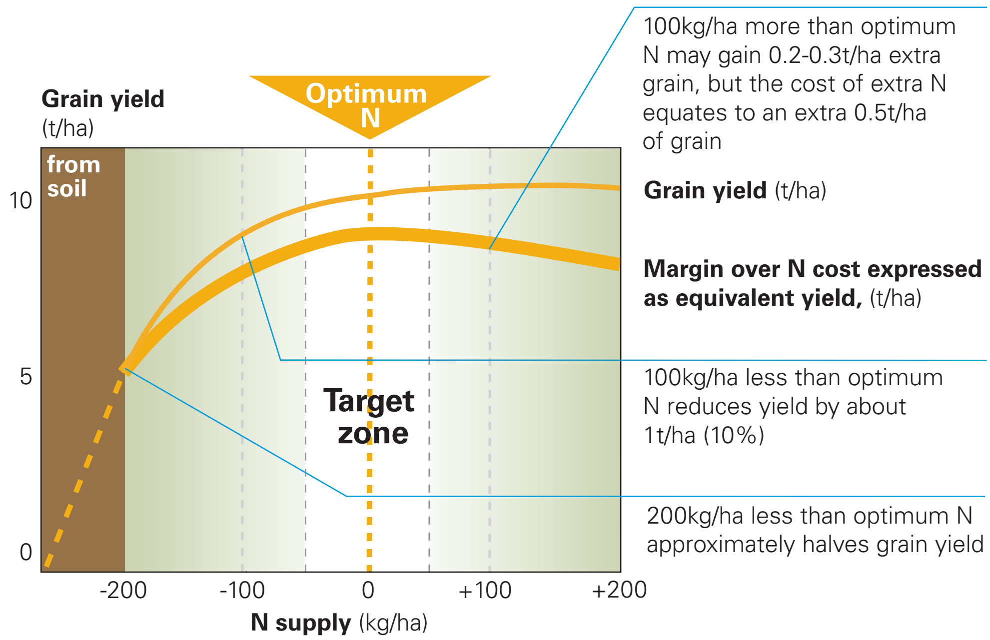


Difference in N supply from optimum (kg/ha)
*based on wheat = £100/t; ammonium nitrate = £173/t

Grain yield
N fertiliser costs more than any other input but, where soil N supplies are small, yield responses are large. Profitable wheat production depends on assessing the optimum N requirement based on likely crop performance and intended market.

Most wheat crops respond similarly to all sources of N (as shown), provided other nutrients are sufficient and lodging, serious weeds and diseases are controlled.

The 'grain yield' graph and those on the opposite page represent generalised responses.

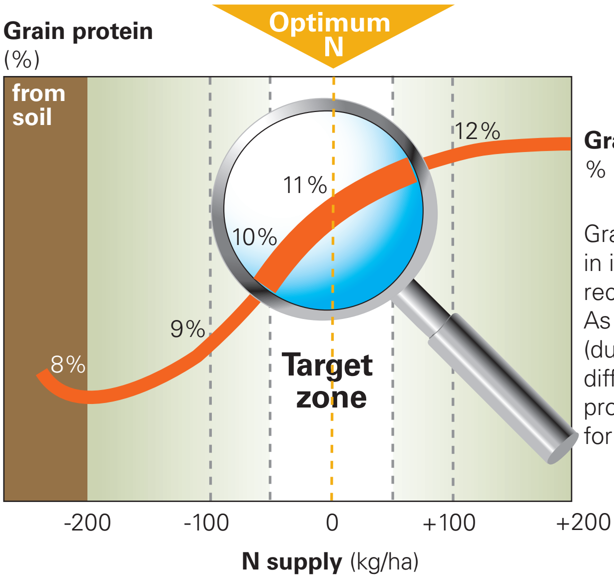


Grain protein
Grain protein with optimum N for yield in feed varieties is consistently about 11% (1.9%N).

Breadmaking varieties optimise for yield at around 12% protein and often need extra N to achieve a market specification of over 13%.

Low grain protein – less than 10% for feed varieties – indicates sub-optimal N use.

Low grain protein indicates high starch content, hence potentially high bioethanol yield per tonne.



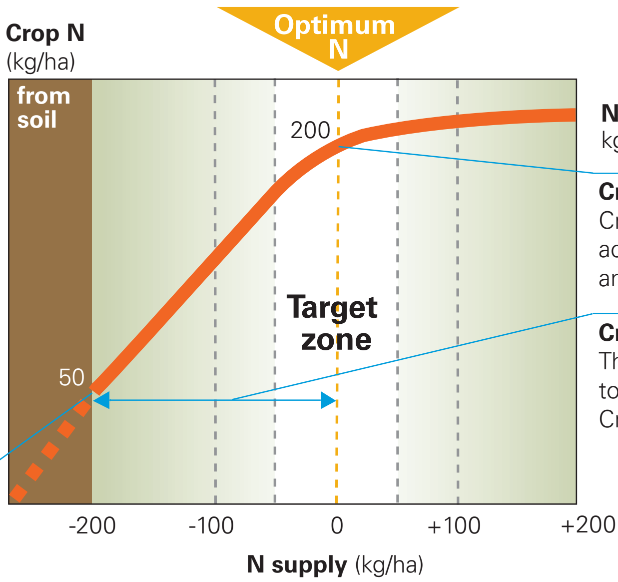
Grain protein is particularly helpful in indicating whether crops are receiving optimal N management. As the optimum N supply changes (due to prices), or as applied N differs from the optimum, grain protein changes – by about 1% for every 50kg/ha N.

Crop N Demand
N demand can be met from soil N, organic manures and manufactured fertilisers.

Optimum N from fertiliser and organic manures depends on:

- Crop N Demand (adjusted for fertiliser and grain prices)
- available soil N
- efficiency of chosen fertilisers and manures.

All of the above amounts can be predicted, but not precisely.



Crop N Demand
Crop N content optimised according to prices of grain and fertliser N.

Crop N Requirement
The amount of applied N needed to meet the shortfall between Crop N Demand and Soil N Supply.

Soil N Supply
The total N amount taken up by an unfertilised crop constitutes its 'Soil N Supply'. This varies with previous cropping and fertiliser use, mineralisation of soil organic matter and atmospheric deposition.

Judge Crop N Demand

Ⓐ Target markets and plan cropping for new season

Intended markets and rotations affect N management. Wheat responds well to N so often performs best after crops that leave high soil N, eg oilseeds and pulses. Wheat grown after cereals tends to have higher protein contents than after break crops; so breadmaking varieties may be best sown after a cereal.

Breadmaking varieties – nabim Groups 1 & 2 normally require additional N above the optimum for yield to achieve the 13% protein normally specified for breadmaking.

Evaluating potential returns

The extra cost of N to achieve a breadmaking specification must be justified according to likely yield as well as grain price (including premium) and fertiliser price (expressed as N:grain ratio) (Tables 1 and 3). These premiums assume a factor of 2 to compensate roughly for normal rejections and deductions.

Table 1. Average premium required to justify growing breadmaking wheat

	N:grain price ratio		
Grain yield (t/ha)	**3**	**5**	**10**
6	£16.80/t	£19.40/t	£31.00/t
8	£12.40/t	£14.40/t	£23.00/t
10	£9.80/t	£11.40/t	£18.20/t
12	£8.20/t	£9.40/t	£15.00/t

Assessing likelihood of rejections and premium deductions

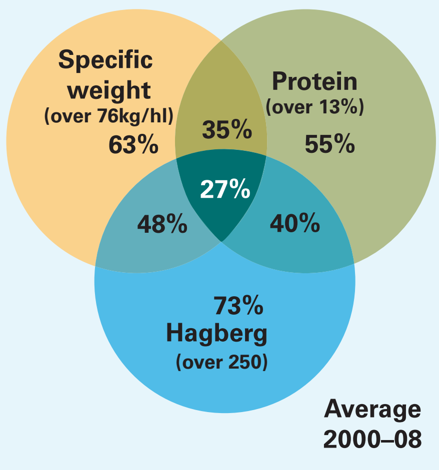
The likelihood of achieving a full premium can be assessed from past farm achievements.

National average success in achieving a given set of quality specifications can be estimated using the HGCA Quality Calculator – http://data.hgca.com/calculator/default.asp

This calculator takes account of year, region, variety group, and market quality parameters and presents results as shown in Figure 1.

The numbers indicate average success in achieving key quality parameters: protein, specific weight and Hagberg; as well as combinations of each for a given situation.

Figure 1. HGCA Quality Calculator results



Each year is different. The overall success rate for all three parameters from 2000-2008 was 27%; in 2003 it was high at 52% but in 2008 just 6%.

Varieties for other markets

Feed markets rarely require a particular grain specification so aim to fertilise feed wheats with amounts of N that optimise grain yield.

Growers targeting distilling markets may need to use sub-optimal N for grain yield, and earlier applications to enhance alcohol yields. Net greenhouse gas (GHG) balance may also be best with sub-optimal N. When biofuel production is linked to GHG savings, using sub-optimal N may become more worthwhile.

Ⓑ Review recent N management

Records from recent crops are essential for planning future N management. Table 16 lists factors to monitor. Note that grain protein content is a better indicator than grain yield of whether N supplies of recent crops matched Crop N Requirements. NB. grain N% = grain protein % ÷ 5.7, both on a dry basis.

Where grain protein from recent crops of feed varieties exceeds 12% or is less than 10%, N supplies were probably excessive or inadequate, respectively. Future N supplies should be adjusted accordingly.

Grain protein of breadmaking varieties is less useful as N is applied late at levels above optimal N. Where grain yield, for a feed variety, is below 10t/ha and grain protein exceeds 11%, another factor may have limited yield.

Consider the effects of other factors, eg low soil P or K Indices on crop performance. Pale stunted growth, over-lush crop canopies, lodging, or high weed populations may indicate N use has been imprecise.

Ⓒ Judge expected Crop N Demand

Crop N Demand relates to expected grain yield and N content, usually expressed as protein%.

Crop N Demand is a ‘strategic judgement’. Adjustments should be made gradually over seasons using evidence from farm experience. Table 2 gives general guidance on yield levels and Crop N Demands, in keeping with *The Fertiliser Manual*.

Field-by-field adjustment of Crop N Demand estimates is not appropriate as grain yields cannot be predicted precisely. Errors in setting Crop N Demand will not restrict individual crop yields. For example, a potential yield of 12t/ha will still be achieved where N use anticipated only 10t/ha; the main effect will be reduced protein%. Hence, grain protein of previous crops is the most useful indicator of whether to modify local judgements of Crop N Demand.

Rotations and varieties

When fertiliser is used at the economic optimum, protein content is relatively consistent within variety types, and rotational positions.

In judging Crop N Demand, grain yield differences after cereals and break crops can be discounted. After break crops lower protein %, with optimum N use, compensates for increased grain yields.

With optimum N use breadmaking varieties have greater protein % than feed varieties. While yields are slightly less, Crop N Demand is 15-20kg/ha greater than for feed varieties (Table 2).

Table 2. Crop N Demand can be estimated according to soil type and variety

Soil type	Guideline yield	Guideline Crop N Demand (grain and straw)	
	t/ha	kg/tonne	kg/ha
nabim group 1 & 2			
Light sandy	7.9	25	200
Other	9.6	25	245
nabim group 3 & 4			
Light sandy	8.1	23	185
Other	9.8	23	225

D Balance grain and fertiliser prices

Optimum crop N contents depend on fertiliser and grain prices (Table 3). The N:grain price ratio (sometimes called the 'break-even ratio') can be calculated using the formula beneath Table 3.

Despite volatile grain and fertiliser prices, adjusting for price ratio changes between 3 and 8 (dark cells in Table 3) has little effect on returns (under £3/ha). Adjust Crop N Demand if price changes are outside this range as indicated in Table 4.

Throughout this publication a N:grain price ratio of 5 is assumed.

Table 3. Look-up for N:grain price ratio or break-even ratio (BER)

Product*	N content w/w	Cost of fertiliser N (£/tonne product)					
Ammonium nitrate (AN)	34.5%	£138	£207	£276	£345	£414	£483
Calcium ammonium nitrate (CAN)	27.0%	£108	£162	£216	£270	£324	£378
Urea	46.0%	£184	£276	£368	£460	£552	£644
Urea ammonium nitrate (UAN) (liquid)	28.0%	£112	£168	£224	£280	£336	£392
Cost of fertiliser N	(£/kg N)	**£0.40**	**£0.60**	**£0.80**	**£1.00**	**£1.20**	**£1.40**
		N:grain price ratio					
Wheat price	**£60/t**	7	10	13	17	20	23
	£120/t	3	5	7	8	10	12
	£180/t	2	3	4	6	7	8
	£240/t	2	3	3	4	5	6

*Fertiliser product comparisons do NOT take account of any differences in fertiliser recovery (see Step Q).

$$\textbf{Break-even ratio (N:grain ratio)} = \frac{\text{Fertiliser product price (£/t)} \div \text{N content (\% x10; or kg/t)}}{\text{Budgeted grain price (£/t)}} \times 1000$$

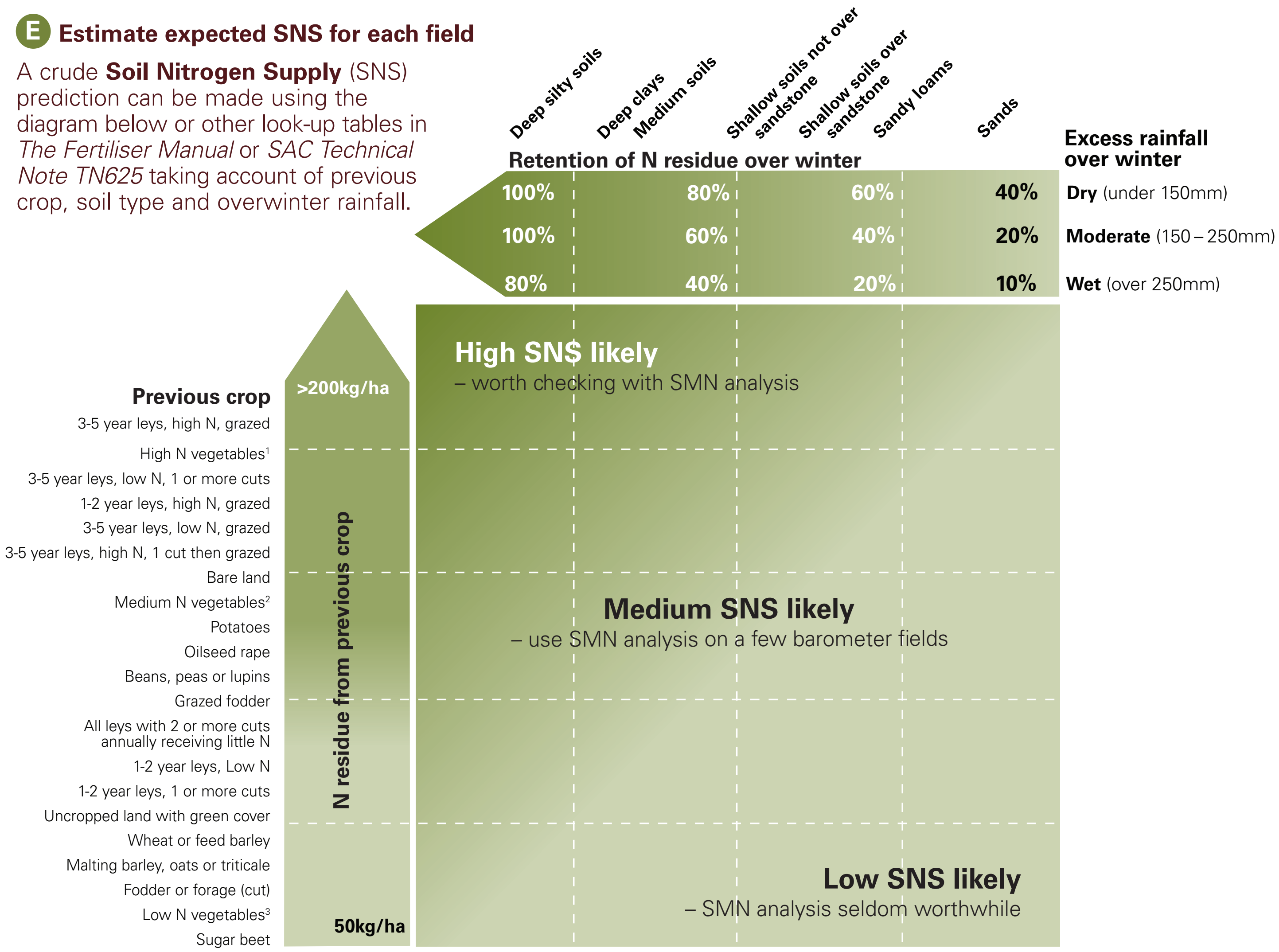
Table 4. How to respond to the N:grain price ratios

N:grain price ratio	1	2	3	4	5	6	7	8	9	10	15	20	25
Adjustment to Crop N Demand (kg/ha)	35	25	15	5	0	-5	-10	-15	-20	-25	-45	-60	-70
Adjustment to fertiliser N (kg/ha)	60	40	25	10	0	-10	-20	-30	-35	-45	-75	-100	-115
			adjustment not worthwhile										

Assess Soil N Supply

E Estimate expected SNS for each field

A crude **Soil Nitrogen Supply** (SNS) prediction can be made using the diagram below or other look-up tables in *The Fertiliser Manual* or *SAC Technical Note TN625* taking account of previous crop, soil type and overwinter rainfall.



[1] **High N vegetables** eg calabrese, Brussels sprouts and some cauliflower crops with lots of crop debris returned to the soil.

[2] **Medium N vegetables** eg lettuce, leeks and long season brassicas such as Dutch white cabbage.

[3] **Low N vegetables** eg carrots, onions, radish, swedes or turnips.

The Fertiliser Manual and *SAC Technical Note TN625* both define a Soil N Supply Index in terms of kg/ha N available to crops from soil (Table 5). This includes an estimate of N released from soil organic matter by mineralisation during summer, but excludes a small amount of N from atmospheric deposition during crop growth – 20-30kg/ha.

Initial crude SNS estimation (as above) indicates whether a field-specific SNS prediction from sampling soil is likely to be worthwhile.

Table 5. SNS prediction from look-up tables

SNS Index	FM	0	1	2	3	4	5	6
	SAC	1	2	3	4	5	6	6
SNS range	(kg/ha N)	under 60	61-80	81-100	101-120	121-160	161-240	over 241
Approx. SNS	(kg/ha N)	50	70	90	110	140	200	260

FM = *The Fertiliser Manual*
SAC = *SAC Technical Note TN625*

F Plan any SMN measurements

Soil N Supply may always be considered low on fields that have grown combinable crops for decades without organic manures. Occasional soil analysis can confirm this. More frequent soil mineral N (SMN) analysis could aid N management on many other farms, especially mixed enterprises. A set of fields should be analysed so that results are:

- representative of the cropped area
- available for any fields with large or uncertain SNS.

Give priority for sampling fields: with known high soil organic matter (but not peats); previously in grass; or receiving significant organic manure. Include fields where effects, eg lodging or unexpectedly high grain protein, have occurred. Consider annual soil sampling of particular 'indicator' fields to assess year-on-year SNS variation.

When to sample

Schedule sampling before any N applications or at least six weeks after applying any organic manure. Allow time for analysis and interpretation before applications. The best time to sample depends on soil type and average excess winter rainfall.

Table 6. Best periods for sampling

Soil type	Average excess overwinter rainfall Low to moderate (<200mm)	 High (>200mm)
Light sandy soils	Jan to Feb	Jan to Feb
Shallow soils	Nov to Feb	Jan to Feb
Medium soils	Nov to Dec	Jan to Feb
Deep clayey and silty soils	Nov to Dec	Dec to Feb
Peat soils[1]	Not worthwhile	Not worthwhile

[1] Large seasonal effects mask variations in spring SMN on peats.

Leaching over winter is usually balanced by mineralisation so SNS changes little between winter and spring. Where samples are taken in autumn on shallow soils and the following winter is wet (over 200mm excess rainfall), results may need adjusting for leaching (see Step I and page 18).

Sample with appropriate equipment or employ a sampling contractor.

Sampling depth varies with season:

- Until January, sample to 60cm
- From February on, sample to 90cm.

Sample in layers, typically 0-30cm, 30-60cm and 60-90cm.
Sample at least 15 points in each field, 20 or more in variable fields.
Bulk soil from each layer but keep layers separate.

Keep samples cool and ensure analysis within 48 hours for nitrate and ammonium N. Arrange topsoil analysis for total N (%) or organic matter (%), if not already known.

G Assess crop condition

For good N management it is important to record sowing dates and monitor crop condition at regular intervals. Note plants/m^2, growth stage and tillering stage. Estimate shoot numbers by multiplying plants/m^2 by the average number of shoots per plant. N estimates may also be adjusted using crop colour.

Table 7. Estimate crop N from shoot numbers and GAI

Shoots/m^2	GAI	Crop N
500	0.5	15kg/ha
1,000	1.0	30kg/ha
1,500	1.5	45kg/ha

H Predict SNS from soil analysis

All soil samples are analysed for soil mineral N (SMN), which is reported as nitrate and ammonium N. Some laboratories also provide direct estimates of mineralisable N – the available N that will be released during summer. Mineralisable N can also be estimated from soil organic N (which changes slowly so only needs to be analysed every 4-5 years).

Calculate expected Soil N Supplies from laboratory N results for soil mineral N, soil organic N and crop N.

Table 8. Calculate SMN – example

Sample depth	Laboratory results		Total SMN	Conversion[1]	SMN
	NO_3-N	NH_4-N			
0-30cm	8.5mg/kg	1.5mg/kg	10.0mg/kg	x 4	40kg/ha
30-60cm	4.0mg/kg	1.0mg/kg	5.0mg/kg	x 4	20kg/ha
60-90cm[2]	2.0[2]mg/kg	0.5[2]mg/kg	2.5mg/kg	x 4	10kg/ha
				TOTAL	70kg/ha

[1] In an average mineral soil, 1mg mineral N/kg dry soil in 30cm depth equates to 4kg/ha available N. Where impermeable rock or stones exceed 5% of soil volume, an adjustment is required.

[2] Where 60-90cm depth has not been analysed, assume half the 30-60cm depth.

Additional N is likely to be released by mineralisation during the season where organic matter content of topsoil exceeds:

– 5% in England and Wales;
– 10% in Scotland and Northern Ireland.

Thus, the organic matter content of all topsoils (even if not formally defined as 'organic', 'humose' or 'peaty') should be known especially where organic manures have been applied.

Increase soil N supplies to allow for mineralisation, according to Table 9.

Table 9. Estimate additional mineralisable N on organic soils

Topsoil organic matter	Topsoil total N	Additional SNS England & Wales	Additional SNS Scotland & N Ireland
<6%	under 0.35%	Insignificant	Insignificant
6-10%	0.35 to 0.6%	+ 40kg/ha N	Insignificant
11-15%	0.6 to 0.9%	+ 100kg/ha N	+ 20kg/ha N
16-20%	1.0 to 1.2%	+ 150kg/ha N	+ 60kg/ha N
>20%	over 1.2%	+>150kg/ha N	+>100kg/ha N

While these estimates of mineralisable N are not quoted in *The Fertiliser Manual* or *SAC Technical Note 625,* they are derived from these N recommendations.

Finally, calculate total SNS.

Table 10. Add crop N, SMN and mineralisable N to give total SNS

N source	(example)	SNS
Crop N (from Table 7)	700 shoots/m²	20kg/ha
SMN (Table 8)		70kg/ha
Mineralisable N (Table 9)	If <5% organic matter	0kg/ha
Total Soil N Supply (SNS)		90kg/ha

I Make final SNS predictions

Gains and losses in available soil N occur over winter due to mineralisation and leaching. Total Soil N Supplies, in autumn and spring on medium or more retentive soils with excess overwinter rainfall below 200mm, are generally similar. Thus, such estimates do not require adjustment for overwinter losses. However, where excess winter rainfall is over 200mm, an adjustment maybe required.

Deep sandy soils should be sampled for SMN analysis from January to February, after most leaching has occurred and before any manure or fertiliser N is applied.

On shallow soils (less than 90cm) halve the SMN in SNS estimates from autumn sampling if subsequent excess rainfall is over 200mm.

Excess rainfall can be estimated from local rainfall data using the method given on page 18, or from national maps published each spring.

Improving SNS estimation

SNS estimation is better than look-up tables, but still lacks precision. Therefore HGCA is funding research – project 3425 (see page 19) – to improve methods for soil sampling, soil analysis and SNS interpretation.

Calculate N requirement

J Estimate fertiliser N recovery

Recovery of fertiliser N is the increase in crop N content (kg/ha) expressed as a percentage of the N applied (kg/ha). Recovery of fertiliser N is very variable and cannot be assessed directly on-farm.

N from all fertilisers and crop-available N from manures are taken to perform similarly to the N from ammonium nitrate fertilisers – see Steps M and Q.

Initially, it is best to use average recoveries, derived from field experiments:

- 60% on most soils
- 70% on sandy and silty soils
- 55% on shallow soils over chalk.

Over several seasons, local N recovery may be deduced indirectly after estimating previous N supplies, grain yields and grain N contents. Note that high-yielding crops often show good N recovery, and *vice versa*.

L Check against average UK recommendations

Note any differences between local field-specific estimates of Crop N Requirements and average UK recommendations (Table 11). The national averages can be explained using the process given in Table 12 so the basis of any local differences should be revealed by this comparison. As experience and field records accumulate, local adjustments may be justified and acted upon with increasing confidence.

Table 11. Crop N Requirements for average UK conditions (kg/ha)

SNS Index (FM)	**0**	**1**	**2**	**3**	**4**	**5**	**6**
SNS Index (SAC)	**1**	**2**	**3**	**4**	**5**	**6**	
Light sandy soils in England	160	130	100	70	40	0-40	0-40
Shallow soils and sands in NW UK	280	240	210	180	140	80	0-40
Medium soils	250	220	190	160	120	60	0-40
Deep clayey soils	250	220	190	160	120	60	0-40
Deep silty soils	220	190	160	130	100	40	0-40
Organic soils				120	80	40-80	0-40
Peat soils						0-6	0-6

Based on: *The Fertiliser Manual* (FM) and *SAC Technical Note TN625* (SAC).

Note: Recommendations for Scotland here differ slightly from those in *SAC Technical Note TN625*.

K Estimate Crop N Requirement

Field-specific Crop N Requirement can now be estimated from:

- Crop N Demand
- Soil N Supply
- fertiliser N recovery

as in the worked example (Table 12).

Good records allow a prediction to be made, recognising the main factors known to govern Crop N Requirement.

If the estimated Crop N Requirement is small, apply a minimum of 40kg/ha N. Only omit applying N altogether if the estimated Crop N Requirement is markedly negative (below -40kg/ha).

A version of Table 12 can be downloaded from the HGCA website www.hgca.com

Table 12. Field-specific worked calculation of Crop N Requirement

Prediction	**Calculation**	**Example**
Guideline crop yield	a	9.8t/ha
Crop N content	b	23kg/t
Price effect on Crop N Demand	c	-10kg/ha
Crop N demand	d = (a x b) + c	215kg/ha
Crop N when soil sampled	e	20kg/ha
SMN	f	70kg/ha
Mineralisable N	g	0kg/ha
Expected Soil N Supply	h = e + f + g	90kg/ha
Crop N shortfall	j = d – h – 20*	105kg/ha
Fertiliser N recovery	k	60%
Crop requirement for applied N	l = j x 100/k	175kg/ha

* increase SNS results by 20kg/ha N to allow for N from atmospheric deposition. Such deposition is factored into *The Fertiliser Manual* and SAC *TN625*.

Assess and apply manure N

M Assess manure N availability and plan manure use

Most manures are from livestock production but the term includes sewage sludge, composts and industrial wastes. They have significant value (Table 13).

In NVZs, limits on organic manure applications are given in terms of total N and crop-available N (see page 17 for list of NVZ booklets).

Where organic manures are available:

- Ensure application equipment is well maintained, calibrated and suitable for applying the manure.
- Calculate the crop-available nutrients (equivalent to fertiliser) and identify fields that will benefit most – taking account of accessibility, likely soil conditions and application equipment.
- Target crops with a high N demand and fields at low soil P or K Indices.
- Plan application rates for each field to ensure compliance with all NVZ regulations. (see NVZ booklets).
- Plan application rates that supply no more than 50-60% of Crop N Requirement. This restricts variations in manure N supply that may reduce crop yields and quality.
- Apply manures in late winter and spring to make best use of N content (after closed spreading periods specified in NVZs). Modern band spreaders can top-dress slurry accurately across full tramline widths, without crop damage.

Table 13. Value of typical manure applications

Manure type (dry matter content)	**Amount applied** (t/ha or m³/ha)	**Total value incl. P&K*** (£/ha)
Pig slurry (4%)	30	£210
Poultry litter (60%)	8	£480
Cattle FYM (25%)	40	£530
Digested liquid sludge (4%)	80	£240
Green compost (60%)	30	£310

*Financial values based on manures applied in spring: 60p/kg N; 60p/kg P_2O_5; 80p/kg K_2O.

Total N in manures has two forms:

- **organic N** breaks down over months or years to become 'crop available'
- **readily available N** (ammonium-N, nitrate-N and uric acid-N) for crop uptake, or for rapid loss through leaching or volatilisation.

For organic manure application crop-available N must be estimated. This comprises 'readily available N' remaining after losses plus mineralised N and is expressed in amounts equivalent to manufactured fertiliser N (ie ammonium nitrate N, kg/ha).

Crop-available N = (readily available N minus losses) + N released from organic N.

Standard manure N contents are shown in Table 14. More reliable results can be obtained by analysis, either on-farm or in a laboratory, but this requires a good sample taken using an appropriate sampling method.

Table 14. Standard N contents of organic manures and crop availability

Manure type	**Dry matter**	**Total N**	**Crop-available N** from spring application	
	(%)	(kg/m³ or /t)	(%)[A]	(kg/m³ or /t)[B]
Cattle farmyard manure (fresh)	25	6.0	10%	0.6
Pig farmyard manure (fresh)	25	7.0	10%	0.7
Cattle slurry	6	2.6	35%[C]	0.9
Layer manure	35	19.0	35%	6.7
Broiler or turkey litter	60	30.0	30%	9.0
Pig slurry	4	3.6	50%[C]	1.8
Liquid digested sewage sludge	4	2.0	40%[C]	0.8
Digested sludge cake	25	11.0	15%	1.6

[A] Surface application in Feb-April is assumed.
[B] Equivalent to fertiliser N (ammonium nitrate N, kg).
[C] Band spreading can increase N availability.

Source: The Fertiliser Manual (Defra)

N Check storage capacity and structures

Ensure storage capacity for organic manures is adequate for closed periods. Also ensure structures are sound to prevent risk of accidental leakage and pollution.

O Apply organic manures – autumn

N applications to wheat in autumn or winter are rarely required. Soil N is almost always sufficient for crop growth.

Only organic manures low in readily available N (eg farmyard manures) should be applied to crops in autumn or early winter. This is a requirement in NVZs (see page 17 for list of NVZ booklets).

Any applications before sowing should be incorporated into the soil within 24 hours (unless slurry is injected or applied by band spreader).

P Apply organic manures – spring

Early spring manure applications are most effective but care is needed:

– **Do not** apply organic manures, if soil is water-logged, flooded, snow-covered or frozen for over 12 of the preceding 24 hours. This is an NVZ requirement.

– **Do not** apply more than 50m^3/ha of slurry or 8t/ha of poultry manure at any one time in January or February and allow at least three weeks between applications.

– **Do not** apply organic manures if there is a high risk of run-off, taking account of slopes, land drains, ground cover, proximity to surface water, weather conditions and soil type. Again, an NVZ requirement and a sensible precaution to prevent nutrient waste.

– **Do not** apply organic manures within 10m of surface water, or within 50m of a borehole, well or spring.

Use manure analysis results, Table 14, or decision support systems (eg MANNER, PLANET) to calculate crop-available N supplied from each application to each field.

Calculate phosphate, potash, sulphur and magnesium applied using tables in *The Fertiliser Manual* or *SAC Technical Note TN622.*

Deduct crop-available N supplied by manures from Crop N Requirement to calculate the balance needed from fertiliser N.

Select and apply fertiliser N

Q Determine preferred fertiliser type(s)

Solid ammonium nitrate granules (about 34% N), or 'AN', is the main form of straight N used on UK wheat. Alternative forms of soil-applied fertiliser N are:

- urea, as granules or prills (46% N)
- 'UAN': a combined solution of ammonium nitrate and urea (usually 37kg N per 100 litres)
- 'CAN': calcium ammonium nitrate (27% N)
- compound (NPK) fertilisers
- ammonium sulphate (21% N; 60% SO_3) provides sulphur as well as N.

Urea can also be used in solution as a foliar spray. It is supplied at 20kg N per 100 litres and may be diluted before application.

Factors governing fertiliser choice relate to price, quality (spreading ease and efficiency), and efficiency of crop recovery. Choice of liquid UAN also has major strategic effects on fertiliser purchase, storage and application equipment.

On average 24% of urea-N can be volatilised as ammonia after application compared to only 5% from ammonium nitrate. Ammonia losses from UAN are intermediate.

Inefficiencies from urea N may be reduced by applying in cool, moist conditions to crops on soil without free lime or chalk and with well-developed canopies.

Where fertiliser is to be applied as urea or liquid UAN, rather than ammonium nitrate, be aware that N recovery is often reduced.

R Schedule fertiliser applications

Adjust Crop N Requirements in spring when estimates of Soil N Supply are revised; or if large changes in fertiliser price or grain futures occur.

N applications are best timed and tailored to match crop demands. Typically, a wheat crop takes up 30% of final N demand by the start of stem extension and 90% by flowering. However, if early uptake is curtailed, compensating uptake can occur after flowering.

Manage N supplies for adequate tillering in early spring and then rapid uptake during stem extension.

Spring-applied N is rarely leached beyond the reach of roots, except after high rainfall on very light soils.

Spring-applied N normally remains in the topsoil throughout summer. Availability of fertiliser N is reduced in dry topsoils, but N uptake resumes after light rain.

S Apply manufactured fertilisers with care

Do not apply manufactured N fertiliser within 2m (1.5m – N. Ireland) of surface water (NVZ requirement) or within 2m of a ditch or the centre of a hedgerow (cross-compliance requirement) in England and Wales.

Do not apply fertiliser N if there is a high risk of run-off, taking account of slopes, land drains, ground cover, proximity to surface water, weather conditions and soil type. Again, an NVZ requirement and a sensible precaution to prevent nutrient waste.

T Make early N fertiliser applications

Crops with total N requirements exceeding 120kg/ha are likely to need 40kg/ha N, or occasionally up to 80kg/ha N, in late February or March. Thus most UK wheat crops will benefit from early N, but particularly those:

- following a cereal crop, where take-all risk is high
- with large Crop N Requirements
- intended to be processed for bioethanol.

Shoot numbers or canopy development should guide the need for early N applications. Both can be assessed visually. Canopy development can also be assessed remotely.

Wheat crops that respond adversely to early N tend to have:

- moderate, or high, lodging risk, eg are early sown, with lush canopies and shoot numbers over 1,200/m^2 by spring
- high Soil N Supplies, eg due to recent organic manure applications.

Sulphur, if needed, should be applied early, possibly as part of the early N dressing, eg as ammonium sulphate. In NVZs, dates and amounts of any N applications should be recorded for each field (or each crop in Northern Ireland).

U Make main N applications

Apply most of the remaining N requirement between early April and early May, ie just before or during early stem extension.

Up to 120kg/ha N can be applied in one application. If remaining N requirements exceed 200kg/ha consider up to three applications: two of 80-100kg/ha N before early May, and a third 40-80kg/ha N later in May to reduce lodging risk.

Overall, aim to apply some fertiliser N to the whole wheat area by:

- mid-April in England and Wales
- end-April in Scotland or N. Ireland.

By early May, most of the remaining N should be applied. Reduce or omit later 'splits' if crop canopy becomes very lush, eg a GAI of four in late April or early May. *The wheat growth guide*, HGCA (2008), gives benchmarks for canopy size at each growth stage (Table 15).

Table 15. Canopy benchmarks

Growth stage		Green Area Index (GAI)
23	3 tillers	0.7
30	ear at 1cm	1.6
31	first node	2.0
39	flag leaf emerged	6.1
59	ears emerged	6.3
61	flowering	6.3
71	watery ripe	5.7
87	hard dough	1.3

In late May, ie until flag leaf emergence (GS39), N applications increase grain protein concentrations as well as grain yield.

V Consider extra late N to boost grain protein for breadmaking

There is usually a 13% grain protein specification for breadmaking – about 1% more than in an optimally fertilised crop. Assess the need for additional N based on past success in achieving a specification and available premiums (Table 3).

Extra N may be applied in two ways, with different effects:

- **At end of May** around flag leaf emergence as fertiliser granules.

  Up to 40kg/ha N will boost grain protein (by 0.5-0.7%) and slightly increase yield (0.1-0.2t/ha).

- **In July** around milky ripe stage (GS75) as a foliar spray of a urea solution.

  Spraying 40kg/ha urea N generally increases protein by 0.75-1.0%.

  Grain protein continues to respond to urea sprays up to 120kg/ha N. However, larger amounts are slightly less effective and may reduce yield. Applying over 60kg/ha N is rarely justified.

  There is a risk that sprays will scorch upper yield-forming leaves. Scorch risk is reduced by spraying in still, cool conditions, such as in the evening. Diluting the concentration of urea does not reduce this risk.

Effects of extra N in May and July are additive; thus applying at both times may achieve a large protein boost. In NVZs, check that extra N does not cause Nmax to be exceeded.

Monitor outcome

W Review the success of N management after harvest

Table 16 provides a checklist to help minimise N management errors by:

- referring to past crop performance and records of yields and proteins
- analysing soil, and organic manures where appropriate
- inspecting crops for signs of poor performance, eg take-all, weed competition or high lodging risk
- correcting decisions and improving strategy as new information becomes available.

However, N decision-making is always imprecise because:

- Crop N Demand depends on yield, and yield predictions are poor.
- Soil N Supply can only be predicted within about 50kg/ha, even using SMN analysis. Predictions based on previous cropping are even more uncertain.
- N requirements depend on predicting crop recovery of fertiliser N, which may vary from 40% to 80%. (Crop N Demand correlates with fertiliser N recovery so uncertainties are not compounded). N requirements may only be estimated within 70kg/ha.
- crop-available N from large organic manure applications can only be estimated within 30kg/ha.

Some discrepancies will cancel out. Nevertheless, applied N will commonly differ from optimum N by more than 50kg/ha (see page 4). Although errors in N use cannot be corrected after harvest, they can be recognised and accounted for next year.

Crop inspection and post-harvest grain analysis can pinpoint large discrepancies. Detecting errors on retentive soils is important, even if only after harvest. Undetected errors will carry over to the next crop making further errors more likely.

Grain protein (or N) content provides the best indicator of optimal N management. *Grain sampling – a farmer's guide,* (HGCA 2003) and *Grain sampling guidelines* (HGCA 2009) show how to sample grain. Optimum grain protein contents are around 11% (1.9% N) for feed wheats and 12% (2.1% N) for breadmaking wheats. Optimum grain N in barley is also 1.9% (see box on page 19). However, grain protein of breadmaking wheats (or grain N in malting barleys) is less helpful because these crops often receive non-optimal (for the yield) N applications.

Grain analysis 'standards' above prove 70-80% successful in identifying crops that had been over- or under-fertilised with N, so grain analysis results should be averaged over several fields or years before conclusions are drawn. Patterns of results that are either low or high compared to optimum levels mean that N levels were low or high respectively. This should be factored into next season's plans (see Step A).

Table 16. Checklist for an example field

Check		**Result**	
Did you use more or less N than intended?	less ✓	same	more
How did N use compare with Table 12?	less	same ✓	more
How do grain prices compare to those budgeted?	more	same	less ✓
How did N prices compare to those budgeted?	less ✓	same	more
Colour of crop in late May?	pale	normal ✓	dark
Estimated weed infestation in May?		little ✓	lots
Crop height and lodging, ignoring overlaps?	short	none ✓	some
Was grain yield more, or less, than expected?+	more ✓	same	less
Was grain protein of feed varieties?	under 10% ✓✓	11%	over 12%
What about other grain analyses?	low ✓	normal	high
Summary position of ticks		✓	
Likely difference from optimum N use	**too little**	**on target**	**too much**

+Give greater emphasis (two ticks) to grain protein.

Resources for N management

NVZ and nitrate regulations

Different rules apply in England and Wales, Scotland, and Northern Ireland to implement the EC Nitrates Directive. On arable farms the main requirements are to:

- **Keep records field-by-field** of advice, pre-sowing estimates of SNS, Crop N Requirements and Nmax amounts, sowing dates, dates and amounts of all N applications (organic manures and fertilisers) and grain yields.

In Scotland, recording advice is not required. In N. Ireland records are required for the total area of each crop.

- **Comply with prescribed limits (Nmax) for manufactured fertilisers and manures.**
- **Only spread N in suitable conditions:** Comply with closed spreading periods for both organic manures and manufactured N fertilisers. Comply with no-spreading areas. Prepare a spreading risk map, if applying organic manures. Do not spread any N on waterlogged, snow-covered or frozen ground.

Good records of N plans and N use, field-by-field and application-by-application, are essential to provide evidence of compliance with regulations, including Nmax limits.

Nitrates and NVZ guidance documents

England
NVZ Guidance Leaflets 1-9
www.defra.gov.uk/environment/quality/water/waterquality/diffuse/nitrate/help-for-farmers.htm

Northern Ireland
www.dardni.gov.uk/publications_environment-nitrates-guidancedoc

Scotland
www.scotland.gov.uk/Publications/2008/12/12134339/1

Wales
Contact the Welsh Assembly Government
http:/wales.gov.uk

Other sources of information/guidance

Available from www.defra.gov.uk

The Fertiliser Manual (RB209),
8th edition of RB209 (TSO 2009), Defra (NB. Publication expected 2010)

Fertiliser Recommendations for Agricultural and Horticultural Crops,
7th edition of RB209, MAFF (2000) (NB. This is the old version)

Managing Livestock Manures – series of four booklets from Defra:

Booklet 1: Making better use of livestock manures on arable land

Booklet 2: Making better use of livestock manures on grassland

Booklet 3: Spreading systems for slurries and solid manures

Booklet 4: Managing manure on organic farms

MANNER-NPK (MANure Nitrogen Evaluation Routine)

Food Security Assessment
(August 2009) Defra

British Survey for Fertiliser Practice
(annual) Defra

Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers
(annual) Defra

Soil Strategy for England
(September 2009) Defra

Low Carbon Transition Plan
(July 2009) Defra

Available from www.sac.ac.uk/publications/technicalnotes

Optimising the application of bulky organic manures and slurries,
SAC Technical Note TN622

Nitrogen recommendations for cereals, oilseed rape and potatoes,
SAC Technical Note TN625

Available from www.ruralni.gov.uk

Rural NI: Farm Nutrient Management Calculators, including: **Crop Nutrient Recommendation Calculator.**

This program will help growers comply with nutrient limit requirements in N. Ireland and draw up a nutrient management plan for their farm.

Available from www.nutrientmanagement.org/

Tried & Tested Nutrient Management Plan (2009),
AIC, CLA, FWAG, LEAF, NFU

Available from www.planet4farmers.co.uk

PLANET
PLANET Version 2 (2008)

The computer-based version of the Fertiliser Manual 'PLANET' enables growers to prepare Nutrient Management Plans according to the recommendations.

PLANET version 3 is currently being developed. This new version will generate nutrient recommendations that mimic the new *Fertiliser Manual*. These recommendations will apply in England, Wales and possibly Northern Ireland (not Scotland).

PLANET version 3 will also produce reports which help show compliance with NVZ rules, including the livestock manure N farm limit, organic manures storage, planning N use, Nmax and record keeping.

PLANET Scotland is also being developed to generate nutrient recommendations and reflect the NVZ rules and compliance requirements that apply.

Calculating excess rainfall

Monitor rainfall
When rainfall (less any capacity for soil water storage) exceeds evapotranspiration (ET), this 'excess rainfall' can lead to N loss through drainage. Small variations in leaching should not affect N decisions, but adjustment for large differences may be worthwhile.

If Soil Moisture Deficit (SMD) exceeds half the soil's Available Water Capacity (AWC), drought is likely to affect crop growth. Estimates of Crop N Demand should be reduced where drought commonly occurs.

To measure seasonal variation in drainage or drought:

- Assume initial SMD at the end of August is about 50mm, unless you have more precise information.
- Use an accurate rain gauge or local rainfall data updated regularly.
- Use average evapotranspiration levels for the UK (Table 7, column a). They do not vary much regionally or between seasons.

Table 17. An example moisture account (millimetres)

	Average ET	Rainfall	Excess rainfall	Cumulative excess rainfall	Cumulative SMD
	a	b	c	d	e
After summer					-50
Autumn (Sept-Nov)	72	166	44	44	0
Winter (Dec-Feb)	41	197	156	200	-2
Spring (Mar-May)	154	`52	0	200	-2
Summer (Jun-Aug)	184	175	0	200	-11

Then regularly calculate the moisture balance:

rainfall in current period b
minus **SMD after last period** e
minus **ET in current period** a

Thus, in autumn, this is calculated as:

166 *minus* **50** *minus* **72 = 44**

- A positive moisture balance indicates drainage and should be added to last period cumulative excess rainfall (d).
- A negative moisture balance indicates a moisture deficit and should be added to last period SMD (e).

To amend planned N use, in light of excess rainfall, see Step I.

Normal excess rainfall amounts

Further information

HGCA publications and details of HGCA funded projects are all available on the HGCA website – www.hgca.com and the *Crop Oracle CD.*

Guides and Topic Sheets

Grain sampling – a farmer's guide, HGCA (2003) G17

Avoiding lodging in winter wheat, HGCA (2005) G25

Grain sampling guidelines, HGCA (2009) GS9 2009

The wheat growth guide, – 2nd edition, HGCA (2008) G40

Topic Sheet 64 (2002), Using manures and biosolids on cereal crops

Project Reports

Project Report 280 (2002). Nitrogen management in second wheats following strobilurin fungicide programmes

Project Report 303 (2003). Integrating manures, slurries and biosolids as nutrient sources in arable crop rotations

Project Report 359 (2005). Managing roots, N and fungicides to improve yield and quality of wheat

Project Report 400 (2006). Managing nitrogen applications to new Group 1 and 2 wheat varieties

Project Report 417 (2007). Optimising nitrogen applications for wheat grown for the biofuels market

Project Report 427 (2007). Detecting soil nitrogen supplies by canopy sensing

Project Report 438 (2008). Optimising fertiliser nitrogen for modern wheat and barley crops

Project Report 458 (2009). Using grain N% as a signature for Good N Use

Ongoing projects

Project RD-2007-3425. Establishing best practice for predicting Soil N Supply

Project RD-2007-3375. Soil and grain nitrogen analysis to provide up-to-date Scottish data to aid revision of N fertiliser guidelines

Project RD-2005-3211. Predicting grain protein in order to assure breadmaking quality and minimise diffuse pollution from wheat production

Project RD-2006-3287. Better estimation of the efficiency of use of soil nitrogen

Project Report 458 (HGCA, 2009) examines the indicative value of grain analysis. Both grain protein in feed wheats and grain N in feed barleys proved useful indicators, however not in oilseed rape, breadmaking wheat or malting barley. Optimum wheat protein is slightly greater than the 11% quoted in *The Fertiliser Manual* and used in these guidelines. Key results are as follows:

	Optimum	Error indicated
Winter feed wheat	11.5% protein (2.0%N)	30kg/ha N per 0.5% protein difference
Winter feed barley	1.9% N	25kg/ha N per 0.1% N difference
Spring feed barley	1.9% N	30kg/ha N per 0.1% N difference

This evidence will be used to improve future fertiliser recommendations. At present the greater value for wheat should not be used to justify Crop N Requirements above those specified in Step C (Table 2), Step W and in *The Fertiliser Manual.*

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