

Crop nutrition for potatoes



Crop nutrition for potatoes

Optimising yield and quality represent the main reasons for sound nutrient application decisions. But financial and environmental considerations, although always present, now play a larger role. The increasing volatility of manufactured fertiliser prices and the increase in the area of land in England and Wales now under Nitrate Vulnerable Zone (NVZ) legislation, have placed additional pressures on those making and justifying nutrient decisions.

This publication expands on Defra's Fertiliser Manual RB209 to give further guidance on how to make best use of the nutrients in organic manures and how to make the right buying decisions for manufactured nitrogen (N), phosphate (P) and potash (K) fertilisers. Restrictions due to the new NVZ rules are identified. Adjustments, based on factors such as levels of pests or senescence at harvest, have been explored.

The method for determining the correct nutrient requirements remains the same as the previous edition of RB209, but the recommended rates have generally been reduced.

This booklet has been divided into three main sections. These cover using organic manures effectively, nitrogen management and management of other nutrients, with tables and worked examples where relevant.



Nitrogen is abbreviated to N throughout this guide.
P refers to phosphate (P_2O_5) and K to potash (K_2O).
Mg refers to magnesium (MgO).
S refers to sulphur.

Although advice is given in this guide concerning the rules that apply in NVZs, it is the responsibility of each grower to ensure that all the mandatory NVZ rules are followed as set out in Defra's NVZ guidance leaflets and the supplementary advice issued by the Environment Agency (EA). If in doubt, advice on the rules such as holdings is available from the FAQ section of the Environment Agency website on www.environment-agency.gov.uk. Alternatively contact the EA at their customer contact centre on 08708 506506.

RB209

In 2009 Defra revised the fertiliser recommendations book Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209) with an 8th edition for England and Wales. Many of the changes for the updated potato section come from Potato Council-funded research.

Any mention of RB209 within this booklet refers to the 8th edition. The information within RB209 does not constitute a blueprint for successful crop production. It must be used in conjunction with a grower's or FACTS qualified advisor's local knowledge so that effective fertiliser policies may be devised to maximise financial returns from current and future crops.

Scottish growers should refer to SAC recommendations (Technical notes TN621 and TN625) at www.sac.ac.uk/publications.

Front cover image supplied by Chafer Machinery Limited

Introduction	2
Section 1	
Using organic manures effectively	4
Worked example.....	11
Section 2	
Nitrogen management.....	12
Identifying the variety determinacy group	15
Worked examples	17 & 18
Section 3	
Management of other nutrients	19
References	22



Image courtesy of Eric Anderson, Scottish Agronomy

1 Using organic manures effectively

Organic manures contain large quantities of valuable nutrients that can significantly reduce the need for expensive manufactured fertilisers with no adverse effects on crop growth and output if applied uniformly. Studies carried out by the British Survey of Fertiliser Practice and Potato Council indicate that although many growers use organic manures, more can be achieved, especially with the added benefits of soil conditioning.

Where organic manures have been used, there has not always been a corresponding reduction in the use of manufactured fertiliser. This may lead to loss of nutrients to the environment, but will mean a potential manufactured fertiliser cost saving is not seen. Although cost benefits have been stated within this publication, the values shown can change rapidly as a result of volatility of manufactured fertiliser prices. However the prices shown illustrate the role that organic manures can play in the drive to reduce the cost of potato crop nutrition. The

value of manure N can be estimated using MANNER software. If organic manures are applied to land within an NVZ, then all of the relevant NVZ rules must be followed. Six key stages are outlined to help farmers make best use of organic manures and the nutrients they contain.

Organic manures must be used and applied carefully to maximise their nutrient value, without risking under-performance of the yield or quality of the potato crop. This will need planning, but the economic benefits make this well worthwhile. For example, the NPK value of 40 t/ha of cattle farmyard manure (FYM) applied in the spring would be worth around £15 /ha of N, £45 /ha of available P and £255 /ha of K – this is a potential saving in purchased manufactured fertiliser of £315 /ha (£125 /acre) before transport and spreading costs. 8 t/ha of broiler litter would be worth around £50 /ha of N, £40 of available P and £60 of K – a total of £150 /ha (£60 /acre).

Summary

- Most potato crops have a high requirement for NPK nutrients, irrespective of their source. The crop-available nutrients in organic manures are equivalent to those in manufactured fertilisers, and can make a cost-effective contribution to partially meet this nutrient requirement: 40 t/ha of cattle farmyard manure (FYM) applied in spring will supply around 25 kg/ha crop-available N, plus 75 kg/ha available P and 320 kg/ha K.
- Organic manures should be applied to land and crops that have a high nutrient requirement. The potato crop provides a good opportunity to use available organic manures, as it has a high nutrient requirement and spreading is possible in late winter/spring on most soils.
- On land in an NVZ, all of the mandatory NVZ rules must be followed. Details are contained in NVZ guidance leaflets.
- The MANNER software will estimate the crop-available N from a manure application. The PLANET software provides a comprehensive field-level nutrient planning and recording tool, including calculation of crop nutrient requirement and manure nutrient supply. It will help assess and show NVZ compliance.
- Use this guide to plan manure use this season.
- Careful use of organic manures will minimise nutrient losses to air and water.



Fertiliser costs are based on ammonium nitrate at £210 /t (60p /kg N); triple superphosphate at £280 /t (60p /kg P); muriate of potash at £480 /t (80p /kg K)

- 1 Understand your purchasers' requirements.
- 2 Select fields that will receive organic manures – choose accessible fields growing crops with a high nutrient requirement and/or that have low soil P or K Indices.
- 3 Know the nutrient content of each organic manure applied – use typical figures or laboratory analysis (see page 6).
- 4 Apply manures evenly, when ground conditions are suitable and at known rates (see page 7).
- 5 Estimate the quantity of nutrients supplied – use look-up tables, MANNER for crop-available nitrogen or PLANET for a complete nutrient plan (see page 8).
- 6 Deduct the organic manure nutrients supplied from the crop nutrient requirement, to give a reduced quantity of manufactured fertiliser that needs to be applied (see page 10).

1 Understand your purchasers' requirements

Make sure that any planned use of organic manure does not conflict with any actual or possible purchaser contracts. When applied unevenly, manures have been associated with variability in potato dry matter concentration, which is one of the reasons some purchasers' contracts (particularly processors) rule out any use of manures.

2 Select the fields for manure application

Fields that have often received FYM because of their convenience and proximity to the farm may be very rich in nutrients. Manures are valuable materials and should be used carefully and applied where they will do the most good. There is little point in applying manures to fields that are already rich in nutrients, or where the crop grown has a low nutrient requirement. To make the best use of the nutrients in organic manure, prioritise applications to fields with low soil P or K Indices or where a crop with a high nutrient requirement is being grown, such as potatoes.

3 Know the nutrient content of manures applied

It is far better to measure or estimate organic manure nutrient contents than rely on experience or guess work. You can:

Use typical values. These are based on the analysis of a large number of samples of different manure types (see Table 1). More detailed information is contained in RB209 and the Managing Livestock Manures booklets.

Sample manure for analysis. This will provide the most reliable information as it is manure-specific. Laboratory analysis should include: dry matter, total N, P, K, and Mg, and ammonium N. Additionally, nitrate N should be measured in composted FYM and poultry manure, and uric-acid N in poultry manures. For slurries, on-farm rapid meters can be used to measure the ammonium-N content.

When sampling manures for analysis, it is important to follow a systematic sampling procedure to ensure that the sample sent for analysis is representative of the manure. **Do not walk across slurry stores. Before walking on a solid manure store, make sure it is safe to do so.**

Solid manure – Time of sampling is not critical. Take a sub-sample from at least 10 locations across the manure heap. At each location, clear away any weathered surface material with a spade or fork, dig a hole approximately 0.5 m deep and take a 1 kg sample. Place the sub-samples on a clean, dry tray or sheet. Break up any lumps and thoroughly mix the whole sample. Then take a representative sub-sample of about 2 kg for analysis.

Slurry – Take at least 5 sub-samples of 2 litres each and pour into a large container. Stir the whole amount thoroughly and immediately pour a 2 litre sub-sample into a clean, smaller container for analysis.

Table 1. Typical TOTAL nutrient content of organic manures (fresh weight basis).

Manure type	Dry matter (%)	Nitrogen (N)	Phosphate (P)	Potash (K)	Sulphur (S)	Magnesium (Mg)
Solid manures:			kg/t			
Cattle FYM ⁽¹⁾	25	6.0	3.2	8.0	2.4	1.8
Pig FYM ⁽¹⁾	25	7.0	6.0	8.0	3.4	1.8
Layer manure	35	19.0	14.0	9.5	4.0	2.6
Broiler/turkey litter	60	30.0	25.0	18.0	8.0	4.4
Slurries:			kg/m³			
Cattle	2	1.6	0.6	2.4	0.3	0.2
	6 ⁽²⁾	2.6	1.2	3.2	0.7	0.6
	10	3.6	1.8	4.0	1.0	0.9
Pig	2	3.0	1.0	2.0	0.7	0.4
	4 ⁽²⁾	3.6	1.8	2.4	1.0	0.7
	6	4.4	2.6	2.8	1.2	1.0
Separated cattle slurries (liquid portion):			kg/m³			
Strainer box	1.5	1.5	0.3	2.2	ND	ND
Weeping wall	3	2.0	0.5	3.0	ND	ND
Mechanical separator	4	3.0	1.2	3.5	ND	ND

⁽¹⁾ Values for N and K will be lower for FYM stored for long periods in the open

⁽²⁾ Typical dry matter and nutrient content of slurry

ND = No data



To convert kg/t to units/ton, multiply by 2.
To convert kg/m³ to units/1000 gallons, multiply by 9.



Ammonium N, nitrate N and uric-acid N are all forms of readily available manure N. This N is equivalent to manufactured fertiliser N provided it is not lost by leaching or in other ways.

4 Apply manures evenly and at known rates

Make sure that organic manure application equipment is well maintained and suitable for applying manure at appropriate agronomic rates. The most common causes of uneven application on farms are incorrect setting of bout (spreading) widths and poor maintenance of spreading equipment. For both slurries and solid manures, the evenness of spreading is usually better with rear

discharge spreaders than side discharge machines. An overlap spread pattern may be needed depending on the type of spreader used (as usually adopted for spreading manufactured fertilisers). It is important to record calibrations.

Application rates can be simply calculated from a knowledge of the capacity or volume of the manure spreader or tanker (e.g. by weighing a full and empty machine on a weighbridge), the number of loads applied to a field and the field area. The application rate is the total quantity applied from all loads divided by the field area.

Table 2. Typical organic manure application rates to supply 250 kg/ha of TOTAL nitrogen (the NVZ organic manure N field limit).

Manure type (% dry matter)	Application rate (t/ha or m ³ /ha fresh weight)
Cattle FYM (25 %)	41
Pig FYM (25 %)	35
Cattle slurry (6 %)	96
Pig slurry (4 %)	69
Layer manure (35 %)	13
Broiler/turkey litter (60 %)	8



For fields that are in an NVZ, all of the mandatory NVZ rules must be followed, including:

- The total application of all organic manures must not exceed 250 kg/ha of total manure N in any 12-month rolling period. Table 2 gives the maximum application rate of some livestock manures to keep within this limit.
- Manures with a high readily-available N content (e.g. slurry, poultry manure) must not be applied during the mandatory closed period for tillage land (1 August to 31 December on sandy or shallow soils; 1 October to 15 January on other soil types). Other manures with a low readily-available N content (e.g. FYM) are not subject to a closed spreading period.
- Where appropriate, manures must be incorporated into bare soil or stubble as soon as possible and within 24 hours of application.
- Manures and manufactured-N fertiliser must not be applied to non-spreading areas or when ground conditions are unsuitable.
- A nitrogen plan must be prepared before any organic manure or manufactured-N fertiliser is applied to the crop.
- No more than 270 kg/ha of N from manufactured fertiliser and crop-available organic manure N may be applied across the whole area of the potato crop. This is the N max limit which is different for other crop types.
- Records must be kept, including details of all N applications. It is advisable to include records of the decision making process. For instance the use of farm records, meteorological office data or the annual rainfall map when calculating the SNS index.
- See Defra's NVZ guidance leaflets for full details of all NVZ rules in England and Wales.
- Although advice is given in this guide concerning the rules that apply in NVZs, it is the responsibility of each grower to ensure that all the mandatory NVZ rules are followed as set out in Defra's NVZ guidance leaflets and the supplementary advice issued by the Environment Agency. If in doubt, advice on the rules such as holdings is available from the FAQ section of the Environment Agency (EA) website on www.environment-agency.gov.uk. Alternatively, contact the EA at their customer contact centre on 08708 506506.

5 Estimate the quantity of nutrients supplied from each manure application

Industry-standard nutrient recommendations for all crops are contained in RB209, based on examination of a wide range of research information and expert knowledge. The recommendations for potatoes are described in detail in this booklet. RB209 also contains full details of how to assess the nutrient value of a wide range of organic manure types.

Nitrogen

The nitrogen recommendations for potatoes are described in section 2. These recommendations are based on many field experiments where the yield response to different N application rates was measured, and from studies to understand how potato growth and yield react to nitrogen application.

The response curves linking yield to supply of N (and other nutrients) are nearly flat around the optimum, making it difficult to identify the optimum N rate with pinpoint accuracy. The first half of the optimal N rate produces more than 80 % of the yield response, with the second half producing the final 10-20 % of yield. The flatness of the response curve and the errors associated with measuring yield and optimal N are of great practical importance when deciding how to integrate the use of organic manure and manufactured-N fertiliser inputs.

Although the crop-available N supply from organic manure applications can be estimated with

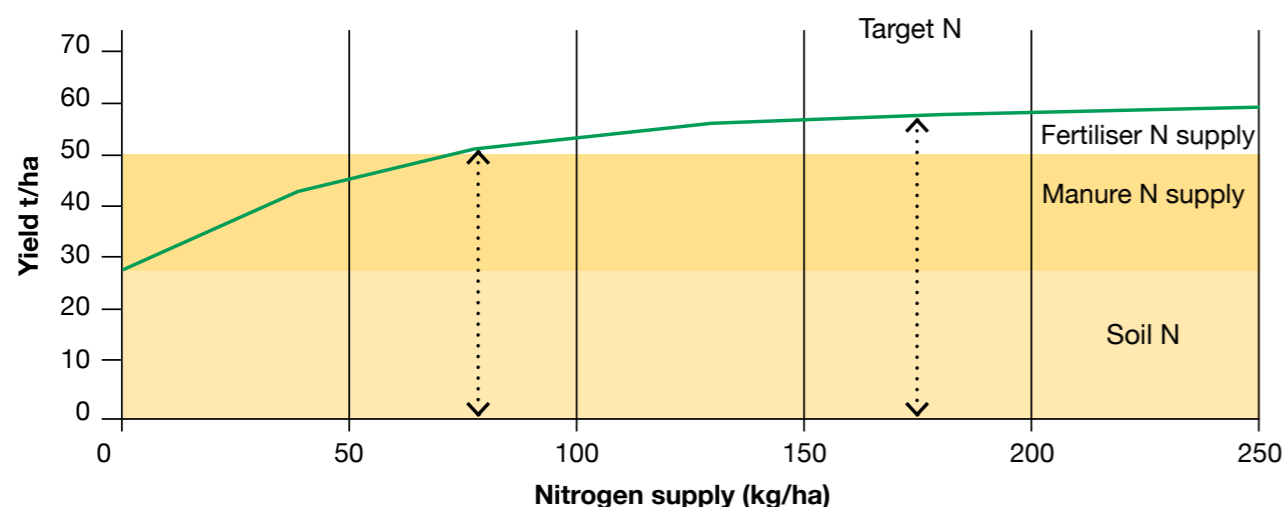
considerable accuracy, the actual N rate available for crop uptake will not be known with the same level of accuracy as for the N from manufactured fertiliser. Thus, the aim should be to supply up to 50-60 % of the planned N rate from applied organic manures, with manufactured-N fertiliser used to top up crop needs (Figure 1).

Whilst moderate over- or under-application of N is unlikely to have a significant effect on yield, use of too much N could have a significant adverse effect on crop quality and will increase N losses to the water or air. Anyone who applies a bit extra to be on the safe side is unlikely to benefit from increased yields but, could risk producing lower dry matter potatoes, delaying skin set and increasing pollution.

To make best use of their N content, manures should be applied in late winter or spring (i.e. after mid January), and should ideally be rapidly incorporated into the soil. Applications during the autumn to early winter period should be avoided where possible, as the larger amount of winter rainfall following application is likely to wash nitrate out of the soil before crops can use it. Rapid soil incorporation will reduce ammonia losses and odour nuisance, retaining N for crop uptake.

The quantity of crop-available N supplied from an organic manure application is influenced by the manure type, its readily available N content, the timing and method of application, soil type and weather patterns. Table 1 gives typical values for the total N content of some organic manure types. The influence of other factors on the availability of this total N for uptake by the next crop grown is summarised in Table 3 for surface-applied manures and Table 4 for manures that are incorporated into the soil within 24 hours after application.

Figure 1. Supplying the potato crop N requirement from organic manure and manufactured-N fertiliser sources.



Where there is uncertainty about the level of residual N present in the soil, for example, where significant quantities of manures have been applied regularly for several years or at unknown application rates, soil sampling to measure soil mineral nitrogen should be considered.

Table 3. Percentage of total nitrogen that is available to the potato crop following SURFACE APPLICATION of organic manures without soil incorporation within 24 hours (% of total N).

Manure type	Dry matter (%)	Time of application and soil type				
		Autumn (Aug-Oct) ¹		Winter (Nov-Jan) ¹		Spring (Feb-Apr)
		Sandy/shallow ⁽²⁾	Medium/heavy ⁽²⁾	Sandy/shallow ⁽²⁾	Medium/heavy ⁽²⁾	All soils
FYM (old and fresh) ³	25	5	10	10	10	10
Layer manure	35	10	25	25	25	35
Broiler/turkey litter	60	10	25	20	25	30
Cattle slurry ⁽⁴⁾	2	5	30	30	30	45
	6	5	25	25	25	35
	10	5	20	20	20	25
Pig slurry ⁽⁴⁾	2	10	35	40	40	55
	4	10	30	35	35	50
	6	10	25	30	30	45

Table 4. Percentage of total nitrogen that is available to the potato crop following SOIL INCORPORATION by ploughing of organic manures (% of total N).

Manure type	Dry matter (%)	Time of application and soil type				
		Autumn (Aug-Oct) ¹		Winter (Nov-Jan) ¹		Spring (Feb-Apr)
		Sandy/shallow ⁽²⁾	Medium/heavy ⁽²⁾	Sandy/shallow ⁽²⁾	Medium/heavy ⁽²⁾	All soils
Old FYM ⁽³⁾	25	5	10	10	10	10
Fresh FYM ⁽³⁾	25	5	10	10	10	15
Layer manure	35	10	35	25	40	50
Broiler/turkey litter	60	10	30	20	30	40
Cattle slurry ⁽⁴⁾	2	5	35	25	35	50
	6	5	30	20	30	40
	10	5	25	15	25	30
Pig slurry ⁽⁴⁾	2	10	45	35	50	65
	4	10	40	30	45	60
	6	10	40	25	40	55

The values in table 3 and 4 should not be used when calculating the contribution of crop available manure N to assess compliance with the NVZ N max limit. See Defra guidance leaflet 7 for further information.



To convert kg/t to units/ton, multiply by 2. To convert kg/m³ to units/1000 gallons, multiply by 9.



- 1) Assuming 450 mm of rainfall (after autumn application) and 250 mm (after winter application) up to the end of soil drainage (usually end March). For spring applications, rainfall is not likely to cause movement of nitrogen to below crop rooting depth.
- 2) Sandy/shallow – means light sand and shallow soils. Medium/heavy – means medium, deep silty and deep clayey soils. Use this category for organic and peat soils.
- 3) Fresh FYM has been spread straight from the building. Old FYM has been stored for 3 months or more.
- 4) For separated cattle and pig slurries, use the 2 % dry matter values.

The MANNER (MANure Nitrogen Evaluation Routine) software provides specific guidance on the crop-available N supplied from a manure application. MANNER is based on a large amount of research and uses the total and readily available (ammonium) N content of an organic manure (either typical values or from analysis of the manure), together with the type and rate of application, to provide a robust estimate of the quantity of crop-available nitrogen.

PLANET (Planning Land Applications of Nutrients for Efficiency and the environment) is a software tool for

the routine field-level planning and recording of fertiliser and manure use based on RB209 recommendations, and to help assess and show compliance with the NVZ regulations.

MANNER and/or PLANET are available free from ADAS by calling 08456 023864.



Phosphate and potash

Manures also contain large quantities of P and K. 40 t/ha of cattle FYM will supply around 130 kg/ha total P and 320 kg/ha total K.

About 50-60 % of the manure's total P is immediately available for crop uptake and the remainder will become available over a period of a few years. For K, about 90 % is in a soluble form and is immediately available to the crop (Table 5). For potatoes, the available P and K content should be used to estimate the quantity of organic manure P and K supplied to the crop. However, the total manure P and K supply will become available to future crops in the rotation.

Sulphur and magnesium

Manures supply useful quantities of S and Mg (Table 1), although there are only limited data on the availability of manure S or Mg to the crop grown following application.

6 Deduct the supply of manure nutrients from the crop nutrient requirement

Once the quantity of nitrogen, P and K available for uptake by the potato crop has been calculated for each manure application, this quantity should be deducted from the recommended rate of each nutrient given in this booklet or in RB209.

Soil conditioning

In addition to the nutrient value of organic manures, research and grower experience has also shown important, but less tangible, benefits from repeated manure applications through improved soil structure, increased soil organic matter, easier cultivations and better water-holding capacity.

Table 5. CROP-AVAILABLE phosphate and potash content in organic manures.

Manure type	Dry matter %	Phosphate (P)		Potash (K)	
		% of total*	kg/tonne or kg/m ³	% of total*	kg/tonne or kg/m ³
Cattle FYM	25	60	1.9	90	7.2
Pig FYM	25	60	3.6	90	7.2
Layer manure	35	60	8.4	90	8.6
Broiler/turkey litter	60	60	15.0	90	16.2
Cattle slurry	2	50	0.3	90	2.2
	6	50	0.6	90	2.9
	10	50	0.9	90	3.6
Pig	2	50	0.5	90	1.8
	4	50	0.9	90	2.2
	6	50	1.3	90	2.5
Separated cattle slurries (liquid portion):					
Strainer box	1.5	50	0.15	90	2.0
Weeping wall	3	50	0.25	90	2.7
Mechanical separator	4	50	0.60	90	3.2

* See Table 1 for the TOTAL phosphate and potash content in livestock manures.

To convert kg/t to units/ton, multiply by 2.
To convert kg/m³ to units/1000 gallons, multiply by 9.
To convert kg/ha to units/acre, multiply by 0.8.



The example shows how to plan your use of N, P and K from the integrated use of organic manures and manufactured fertilisers. For crops grown on land in an NVZ, preparation of a nitrogen plan

allowing for the nitrogen supply from organic manures is a mandatory requirement, before any manure or manufactured-N fertiliser is applied.

Table 6. Example manure application.

Cattle FYM, surface applied in spring at 40 t/ha			
Step	Nitrogen	Phosphate	Potash
Manure TOTAL nutrient content (A) – from Table 1 (kg/t)	6.0	3.2	8.0
Availability (B) – from Tables 3 (or 4) and 5 (%)	10	60	90
Manure CROP-AVAILABLE nutrient content (C) = (A x B/100) (kg/t)	0.6	1.9	7.2
Manure application rate (D) (t/ha)	40	40	40
Crop-available nutrients from FYM (E) = (C x D) (kg/ha)	24	76	288
Example crop. Expected 50 t/ha yield variety group 2, 90-120 days growing season with an SNS Index 0, soil P Index 2 and K index 2. Check compliance to 250 kg/ha total N application of organic manure and this fields contribution to the 270 kg/ha N max limit.			
Crop nutrient requirement from RB209 or Potato Council leaflet (F) (kg/ha)	185	170	300
Manure nutrients (E) (kg/ha)	24	76	288
Manufactured fertiliser requirement (G) = (F-E) (kg/ha)	161	94	12

Scope for improved profits and less pollution

Good practice in combining organic manure nutrients with manufactured fertiliser additions is essential for environmental as well as economic reasons. Generally, N leaching and P losses are the main water pollution concerns, and gaseous ammonia and nitrous oxide emissions to air.

The British Survey of Fertiliser Practice (2008) indicates that around a third of the potato cropping area receives manure additions. However, the reductions in manufactured fertiliser use where organic manures are used are nothing for N, 13 kg/ha for P, and 33 kg/ha for K. This suggests there may be great potential for potato growers to allow for the full nutrient value of applied manures and reduce manufactured fertiliser costs.

Get the basics right first

There is a good level of awareness that high standards of basic husbandry and management must be maintained. In the context of the integrated use of organic manures and manufactured fertilisers, the following ongoing actions will help optimise crop profitability and minimise environmental pollution.

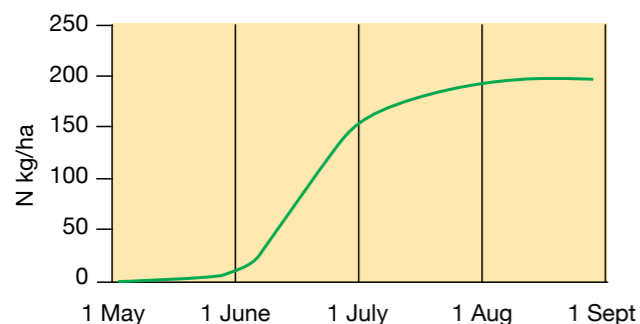
- Make sure each field has a soil analysis for pH, P, K and Mg that is no more than five years old. This will influence the quantity of nutrients needed from the integrated use of organic manures and manufactured fertilisers.
- Calibrate fertiliser and manure spreaders so that nutrient application rates are accurately known.
- Keep the crop healthy so that the crop can make efficient use of the applied nutrients, and achieve high yields and the required quality.
- Make sure that staff are well trained.

2 Nitrogen management

The main differences between this booklet and earlier Potato Council publications are:

- There have been minor modifications to the RB209 Soil Nitrogen Supply (SNS) tables.
- Some varieties have changed varietal groups and new varieties have been added (Table 10).
- Some of the N recommendations have changed (Table 11).
- There is now more information on how to fine-tune N recommendations and use for specific crops.

Figure 2. Pattern of N uptake for a typical crop of Maris Piper emerging in mid May.



The scientific background to the N recommendations

Potato Council-funded work has consistently shown that:

- There is a direct relationship between crop yield potential and total N uptake.
- Most of the N uptake occurs relatively early within the growing season as shown in Figure 2.
- Excess N promotes haulm growth at the expense of tuber bulking. This effect is most noticeable in short-season crops and in Group 3 and 4 varieties such as Maris Piper, Russet Burbank, Markies and Cara.
- N applied much later than tuber initiation (about 20-25 days after emergence) is not used efficiently by the crop. It is best to apply all the N at planting, or apply about 150-180 kg N/ha at planting and the remainder shortly after emergence.

The legislative and regulatory background (England and Wales)

Much potato land is now within NVZs and thus subject to the mandatory NVZ Action Programme rules. Full details of these rules and guidance on holdings, applicable in England and Wales can be found in NVZ guidance leaflets and on www.defra.gov.uk or www.wales.gov.uk. The key requirements for potato growers are summarised below. Please note that there are some differences in the rules for Scotland.

- Growers must adhere to the N max limit. The farm-average application rate of crop-available N from livestock manure plus manufactured-N fertiliser must not exceed 270 kg N/ha for potatoes (an extra 80 kg N/ha is allowed if the current or previous crop received straw for mulching or paper sludge).
- No manufactured-N fertiliser can be applied to potato crops between 1 September and 15 January.
- No organic manures with a high readily available N content (e.g. slurries and poultry manures) can be applied to tillage land between 1 August and 31 December on sandy or shallow soils, or between 1 October and 15 January on all other soil types.
- Fields must be inspected before any application of manufactured-N fertiliser or organic manure. These materials must not be applied if soils are waterlogged, flooded, snow covered or have been frozen for more than 12 hours in any 24-hour period.
- No manufactured-N fertiliser can be applied within 2 m of surface water (10 m for organic manure). Neither material can be applied within 50 m of a spring, well or borehole.
- A risk assessment for run-off should be documented before spreading. No spreading of manufactured-N fertiliser is permitted if there is a significant risk of N getting into surface water due to slope, land drains, ground cover, soil type or weather conditions.
- The required farm and field records must be kept.

Growers should also check that their intended N application rates comply with contracts and with vendor assurance schemes.

The recommendations use the SNS Index to estimate the amount of N likely to be supplied by the soil. Choice of variety and the intended length of the growing season are used to forecast the likely amount of N required by the crop. Therefore, the stages in calculating the recommended N rate are:

- 1 Calculate the SNS index for the field (see page 13)
- 2 Identify the variety group for the crop (see page 15)
- 3 Calculate the intended length of growing season (see page 16)
- 4 Use factors 1, 2 and 3 to find the recommended nitrogen rate (see page 16)
- 5 Fine tune the N recommendations (see page 16)

1 Calculating Soil Nitrogen Supply (SNS) index

Soil Nitrogen Supply is defined as:

The amount of nitrogen (kg N/ha) in the soil that becomes available for uptake by the crop from establishment to the end of the growing season, taking account of nitrogen losses.

The SNS index is mainly influenced by three factors - rainfall, soil type and previous cropping. The SNS index can be calculated in two ways. Of these, the Field Assessment Method using field data is likely to be the most common and this is outlined here. Alternatively, it is possible to calculate the SNS index using soil analysis and this is more fully explained in the RB209 booklet.

Using field data

The steps below will help you determine the SNS for the majority of potato-growing situations. However, this is a summarised version and more detailed information tailored to specific circumstances is given in RB209.

Step one

Work out the average annual rainfall for the field. You can do this by referring to farm records, Meteorological Office data or, if you farm in England or Wales, the map shown in Figure 3. It is advisable to keep records of your decision on the method of calculating annual rainfall. Based on your rainfall, select Table 7, 8 or 9 as appropriate.

Step two

Identify the predominant soil type for the field (again full descriptions are given in RB209) and find the appropriate column in your chosen table.

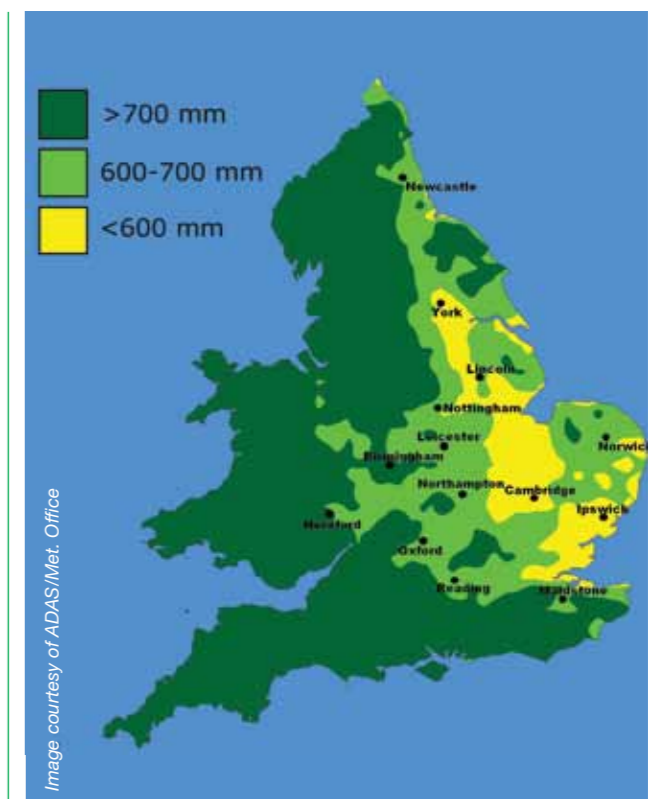


Figure 3. Long-term average annual rainfall in England and Wales (a larger scale version is available at www.potato.org.uk/fertiliser).

Step three

Working down the chosen column, select the row which lists the correct previous crop. The SNS index is shown in the appropriate box (note - if grass has been grown in the last three years you will need to use Table D in RB209 to assess the SNS index). The index may also need adjusting if organic manures have been applied to the land during or before the previous crop (again RB209 contains detailed information on this).

Table 7. Soil Nitrogen Supply Indices for LOW annual rainfall area (average 500 – 600mm per year).

Previous crop	Soil type					
	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 – refer to RB209 for specific guidance	All crops in SNS index 4, 5 or 6
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		
Veg (low N)	0	1	2	2		
Veg (medium N)	1	3	3	3		
Veg (high N)	2	4	4	4		

Table 8. Soil Nitrogen Supply Indices for MODERATE annual rainfall area (average 600 – 700mm per year).

Previous crop	Soil type					
	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 – refer to RB209 for specific guidance	All crops in SNS index 4, 5 or 6
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		
Veg (low N)	0	1	1	1		
Veg (medium N)	0	2	3	3		
Veg (high N)	1	3	4	4		

Table 9. Soil Nitrogen Supply Indices for HIGH annual rainfall area (over 700mm per year).

Previous crop	Soil type					
	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 – refer to RB209 for specific guidance	All crops in SNS index 4, 5 or 6
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		
Veg (low N)	0	1	1	1		
Veg (medium N)	0	1	1	2		
Veg (high N)	1	2	2	3		

2 Identifying the variety determinacy group

The new recommendations split potato varieties into one of four groups according to their degree of determinacy (a measure of the crop's capacity to maintain leaf production after the first appearance of flowers). Ongoing Potato Council research at Cambridge University Farm (CUF) has consistently shown that for a given length of growing season, indeterminate varieties (variety groups 3 and 4) require less nitrogen than determinate varieties

(variety groups 1 and 2). The variety groups shown in Table 10 include the ratings for those varieties included in RB209, and also for other varieties based on NIAB trials and breeder/agent experience of foliage habit (note – determinacy is not the same as the NIAB foliage-maturity score). In addition, factors such as total nutrient balance, water availability and seed management will also influence foliage longevity. The list is provided in good faith as an indication of determinacy groups but you are advised to seek the latest information from your agronomist or seed supplier for any particular variety.

Table 10. Variety Determinacy Ratings.

Variety	Group	Variety	Group	Variety	Group
Accord	1	Innovator	1	Pentland Javelin	2
Agria	3	Juliette	2	Picasso	3
Ambo	3	Kerr's Pink	3	Premiere	1
Amora	3	Kestrel	2	Record	3
Annabelle	1	<i>King Edward</i>	3	Rembrandt	2
Anya	1	Lady Balfour	4	Rocket	1
Asterix	4	Lady Claire	2	Romano	2
Atlantic	2	Lady Christl	3	Rooster	3
Cabaret	3	<i>Lady Rosetta</i>	2	<i>Russet Burbank</i>	3
Caesar	3	<i>Marfona</i>	2	Sante	3
<i>Cara</i>	4	Maris Bard	1	Sassy	3
Carlingford	2	<i>Maris Peer</i>	2	Saturna	3
Charlotte	2	<i>Maris Piper</i>	3	Saxon	2
Colmo	1	Maritiema	2	Shannon	2
Cosmos	3	Markies	4	Shepody	2
Courage	2	Melody	2	Slaney	3
Cultra	3	Minerva	1	Stemster	3
Daisy	3	Morene	3	Vales Emerald	1
Desirée	3	Mozart	2	Vales Everest	4
Dundrod	2	Nadine	2	Vales Sovereign	4
<i>Estima</i>	1	Navan	3	Valor	3
Fambo	3	Nicola	2	Victoria	3
Fianna	3	Orla	2	Vivaldi	2
Harmony	2	Osprey	2	Wilja	2
<i>Hermes</i>	3	<i>Pentland Dell</i>	3	Winston	1

1 = determinate (short haulm longevity) 4 = very indeterminate (very long haulm longevity)

i If growing a variety not listed above, and you have no experience of its determinacy group, or are unable to source the information, assume it is a group 2. This table can be found on the Potato Council website at www.potato.org.uk/fertiliser and will be regularly updated as new data becomes available. Data for varieties in italics are based on many nitrogen response experiments. Data for other varieties are based on comparative observations by researchers and breeders' agents and are provided in good faith. Figures shown may change as more data become available.



3 Identifying growing season length

This is the number of days between 50 % emergence and haulm death from either natural senescence or defoliation. One of the following four options should be selected:

- Less than 60 days
- Between 60 and 90 days
- Between 90 and 120 days
- More than 120 days

4 Calculating the recommended nitrogen rate

Use the information from stages 1, 2 and 3 to find the recommended nitrogen rate in Table 11.

5 Fine tuning the N recommendations

The nitrogen recommendations provide general guidance only and specialist advice may be needed for the specific market outlets. Potato Council-funded work has identified several crop and soil factors that should be considered so that the N recommendations can be fine-tuned for individual crops. However, for crops grown in NVZs care must be taken not to exceed the N max limit for potatoes.

Factors that may influence the nitrogen rate

- If similar crops grown in previous seasons have had problems with excessive canopy production and were defoliated at complete ground cover, consider reducing the N application rate.
- Similarly, if there have been frequent problems

with delayed skin-set; consider reducing the N rate towards the lower end of the recommended range.

- Crops planted into cold soils are slow to emerge and often have restricted canopy development. Additional N may be needed to achieve the intended season length. Also for varieties at the upper end of season length, consider increasing the N rate towards the upper end of the recommended range.
- For crops with an intended season length at the lower end of the given ranges, consider reducing the N rate towards the lower end of the recommended range.
- For crops planted into cloddy or compacted soils, consider increasing the N rate towards the upper end of the recommended range.
- If part of the N application is applied late in the season (more than 35 days after emergence), consider increasing the N rate since the late split will not be used efficiently.
- If there is evidence of pests or disease, consider moving the N rate towards the upper end of the recommended range.

Timing and placement of nitrogen application

For irrigated crops on light sand and shallow soils prone to leaching, apply half to two-thirds of the nitrogen recommendation in the seedbed and the remainder between emergence and tuber initiation. For other crops, apply all of the nitrogen recommendation in the seedbed. The same recommendations should be used for wide bed as well as ridge-and-furrow systems regardless of application method.

Table 11. Recommended N application rate for potatoes (kg/ha)
(Beware of exceeding the N max limit particularly on holdings consisting of few potato fields).

Season length ¹	Variety group	Soil Nitrogen Supply index		
		0 and 1	2, 3 and 4	5 and 6
< 60 days	1	100-140	70-110	40-60
	2	80-120	50-80	0-40
	3	60-100	40-70	0-40
	4	N/A	N/A	N/A
60 – 90 days	1	160-210	130-160	90-120
	2	100-160	60-120	40-80
	3	60-140	40-100	0-60
	4	40-80	20-40	0-40
90 – 120 days	1	220-270	190-220	150-180
	2	150-220	110-160	80-120
	3	110-180	80-100	40-60
	4	80-140	40-60	0-40
> 120 days	1	N/A	N/A	N/A
	2	190-250	150-180	120-150
	3	150-210	120-140	80-100
	4	100-180	60-80	20-40

¹ Season length from 50 % plant emergence to haulm death. N/A. Not applicable
Consideration can be given to group 4 varieties grown for less than 60 days with the addition of 0 to 40 kg/ha for all soil indices.

Table 12. Worked example 1.

Field Location	Cambridge	Soil type	Medium
Variety	Maris Piper	Previous crop	Winter Barley
Intended planting date	15 April	Use of organic manure	No
Intended defoliation date	15 September	Other information	See below

No evidence of PCN or soil compaction; all N to be applied before tuber initiation; no previous problems with either premature canopy senescence or excess canopy production.

Step		Page	Factors	Outcome
1	Calculate Soil Nitrogen Supply	14	Low rainfall area – use Table 7 Medium soil and previous crop is a cereal	SNS index = 1
2	Identify variety group using table 10	15	Maris Piper	Variety group = 3
3	Calculate length of growing season	16	Planted mid April (emerging mid May) and defoliated in mid September = 125 days	Season length > 120 days
4	Use Table 11 to calculate N requirement	16		180 kg N/ha (150-210 kgN/ha)
5	Assess risk factors to fine-tune recommendation	16	Crop should have effective root system and applied N should be efficiently used – but long season	180 kg N/ha
6	Allowance for applied organic manures	10	No manures applied	0 kg N/ha
7	Manufactured-N fertiliser	16		180 kg N/ha



Table 13. Worked example 2

Field Location:	Somerset	Soil type	Medium
Variety	Estima	Previous crop	Oil seed rape
Intended planting date	30 April	Use of Organic Manure	Yes
Intended defoliation date	15 August	Other information	See below

No evidence of PCN but evidence of soil compaction at 25 cm; all N to be applied before tuber initiation. 40 t/ha cattle FYM applied in winter after four months storage, and ploughed in one week later.

Step	Page	Factors	Outcome
1	14	High rainfall area – use Table 9 Medium soil and previous crop OSR	SNS index = 1
2	15	Estima	Variety group = 1
3	16	Planted end April (emerging end May) and defoliated in mid August = 80 days	Season length = 60 to 90 days
4	16		185 kg N/ha (160-210 kgN/ha)
5	16	Crop should have effective root system and applied N should be efficiently used. Adjustment made for soil compaction	200 kg N/ha
6	10	40 t/ha of cattle FYM (Example from Table 6)	24 kg/ha of crop-available N
7	16		176 kg N/ha

3 Management of other nutrients

The fertiliser policy chosen for P, K and Mg depends on many factors that are crop, soil and farm specific. Manufactured fertilisers may be required to achieve some or all of the following if the nutrient supply from the soil and/or applied organic manures is insufficient. Allowing for the full NPK value of any organic manure applications will minimise the amount and cost of fertiliser that needs to be purchased (see section 1):

For yield response: To ensure yield potential is not lost.

For maintaining the soil nutrient Index: To replace the nutrients removed in the harvested crop (where the soil Index is at the target level – P Index 2, K Index 2, Mg Index 2).

For building the soil nutrient Index: To increase the

soil index for subsequent crops (where the soil Index is below the target level)

At Index 3 and above, the probability of a yield increase resulting from fresh P and K additions is small and P and K could be reduced or omitted. Research has also shown that P and K have little effect on tuber quality which is not improved once the optimum rate needed to achieve full yield potential has been applied. Thus, fertiliser applied in excess of that needed for yield is unlikely to improve crop quality but will increase costs. A nutrient replacement strategy (i.e. apply the nutrients that are removed in crop produce) is suitable under certain circumstances. Regular soil analysis is recommended in the autumn prior to the potato crop to monitor soil Index levels.

Table 14. Recommended nutrient rates for a crop yielding 50 t/ha of tubers – nutrients from manufactured fertiliser and organic manures.

	Phosphate, Potash, Magnesium Index				
	0	1	2	3	4 and higher
	kg/ha				
Phosphate (P)	250	210	170	100	0
Potash (K)	360	330	300	150	0
Magnesium (Mg)	120	80	40	0	0

Note: The K recommendations for the lower half (2-) and upper half (2+) of K Index 2 are the same.

Phosphate

Potatoes will often respond to fresh P, but the rate of response is less at high soil P Indices. At Index 3 or 4, yield responses are rare but can be profitable. Within a typical arable rotation, the potato crop is more likely to respond to P than most other crops such as cereals or oilseed rape. Therefore, the potato crop is a good place within the rotation to apply P, provided that any surplus P is allowed for when planning P applications for the crop or crops that follow the potato crop.

The factors distinguishing responsive from unresponsive potato crops are not well understood. If little or no yield response is expected from using P at these Indices, the recommended rate should be reduced or fertiliser not applied. The whole P application should be applied in the seedbed in the spring and worked into the seedbed, or placed at planting.

With recommended rates based on yield response rather than crop uptake, more P is supplied than is removed in the harvested tubers. There is therefore no need to adjust P levels from those recommended if the target yield is higher or lower than 50 t/ha.

A 50 t/ha crop will remove approximately 50 kg P/ha. Applying the recommended rate will therefore apply more P than is removed in the potato tubers. The surplus will add to the soil P reserves and may be available for use by following crops. On Index 2 or 3 soils, allow for this surplus when planning P use for following crops in the rotation. On index 0 or 1 soils, the surplus P will help to build the soil Index level and should not be taken into account when planning P use for following crops.

When the soil Index is 2 or lower, then a large proportion of the applied P should be in a water-soluble form. The fertiliser label will show the total P content of the fertiliser and the amount that is water soluble.



Potash

A 50 t/ha potato crop will remove approximately 300 kg K/ha (5.8 kg K for each tonne of tuber yield), and higher or lower yields will remove more or less K. Since this is always more than the amount needed to maximise yield, a policy based on applying K to replace removal is appropriate. Where the soil K Index is below the target level



(Index 2), slightly more than the replacement amount should be applied, to help build up the soil K Index. Likewise where the soil K Index is above the target level, the applied rate should be below the replacement amount.

As the recommendation for K is yield-based, the amount applied should be based on the expected yield as well as the soil Index. The recommendations in Table 14 and RB209 are based on an expected 50 t/ha. For yields below or above this figure the rate applied should be adjusted. Multiply the expected yield per hectare by 5.8 to give the crop removal figure in kg/ha. For Index 0, add 60 kg/ha, for an Index 1, add 30 kg/ha and for an Index 3 subtract 150 kg/ha. This will adjust the recommended rate to build or run down K towards a target Index 2.

If there is no long-term policy of build up of soil K

at Index 0 or 1, the K recommendations may be reduced by 60 kg/ha at Index 0 and 30 kg/ha at Index 1. On rented land any managed building up or running down of soil K levels should be agreed with the landowner or lessor. At soil K Index 3 or over, application of K could be omitted. This will not influence yield but will result in a more rapid decline in the soil K Index.

The K recommendation can be reduced by 25 kg/ha on genuine sand textured soils (NOT loamy sands or sandy loams) where the soil K is Index 1 or higher.

Where the K requirement is over 300 kg/ha, apply half in autumn/winter and half in the spring. On light sand soils, all of the K requirement should be applied after ploughing and no sooner than late winter. Large applications of K can reduce the dry matter concentration of tubers. Using potassium sulphate rather than potassium chloride (muriate of potash), is likely to avoid suppression of tuber dry matter concentration. It is also important to know and allow for the K content of any organic manures that are applied for the crop (see section 1).

Magnesium

As with K, if there is no long-term policy of building soil Mg the recommendations may be reduced by 80 kg/ha at Index 0 and by 40 kg/ha at Index 1.



P, K and Mg recommendations

The P, K and Mg fertiliser recommendations in RB209 are based on soil Indices which in turn depend on soil analysis. Under most cropping systems, soil nutrient status will change slowly and as such, soil analysis following representative soil sampling should be carried out about every four years.

Different laboratories could use different extraction and analysis procedures but will generally report in mg/l with a corresponding Index. To compare Index to mg/l values for P, K and Mg refer to RB209 appendix 4. In Scotland, soil status is used instead of soil Indices. SAC have recommendations for Scotland, and these can be accessed through Technical notes TN621 and TN625 at: www.sac.ac.uk/publications.

Fertiliser placement and bed systems

The same recommendations should be used for wide bed as well as ridge-and-furrow systems. Where fertiliser is placed, a small reduction in the recommended rate of P and K may be considered.

Organic manures

For all recommendations it is important to consider the quantity of nutrients supplied by organic manures. As mentioned in the organic manure section, of the 30 % of potato fields that have organic manures applied there is only a minimal reduction in the amount of manufactured fertiliser applied. Failure to make realistic reductions will result in excess costs and, in some circumstances, reductions in yield.

Irrigated crops

Irrigated crops, while producing larger yields than

unirrigated crops, do not need more fertiliser since in moist soils nutrients are much more readily available.

Lime, micronutrients (trace elements) and sulphur

Potatoes can tolerate acid soils and are best grown at soil pH levels that are lower than for most other arable crops. Liming immediately before potatoes should be avoided unless the soil pH is very low, as this can increase the risk of common scab and manganese deficiency. Liming after potatoes is often needed if the pH is below the optimum level (6.5 on mineral soils; 5.8 on peat soils).

Trace elements are also essential for plant growth but in most cases, the very small quantity needed can be supplied from soil reserves. However, there are some well-known deficiencies that need routine treatment. The only significant trace element deficiency in potatoes is manganese (Mn) which can occur on peaty, organic or sandy soils at high pH, and on other soil types if over-limed. Manganese deficiency usually occurs in patches during periods of rapid growth and can be treated by one or more foliar sprays of a suitable Mn-containing material.

Although S is an essential plant nutrient, there is no evidence that S fertiliser needs to be applied to the potato crop even on land where other crops (e.g. oilseed rape) are known to need S fertiliser. Although atmospheric deposition of S has declined markedly in recent years due to reduced industrial pollution, the supply of natural sources of S is still regarded as sufficient for the potato crop. However, the possibility of S deficiency in potatoes in future cannot be ruled out. If deficiency does occur, it is most likely to show first in crops grown on deep sand soils with low organic matter, and in areas that are well away from industrial pollution. Organic manures supply some S which will be available for crop uptake.



The following list gives the publications that have either been referenced throughout this booklet, or are suggested reading. These are recommended to gain a deeper insight into both legislative requirements and the benefits of correct decision-making for potato crop nutrition.

The Fertiliser Manual (RB209), 8th edition
www.tsoshop.co.uk

NVZ guidance leaflet

- www.defra.gov.uk/environment/quality/water/waterquality/diffuse/nitrate/library (9 leaflets)
- www.wales.gov.uk/topics/environmentcountryside/epq/waterflooding/nitratezones

ADAS, Managing Livestock Manures booklets
tel. 08456 023864

- Booklet 1. Making better use of livestock manures on arable land
- Booklet 3. Spreading systems for slurries and solid manures

- Booklet 4. Managing manures on organic farms
MANNER software tel. 08456 023864

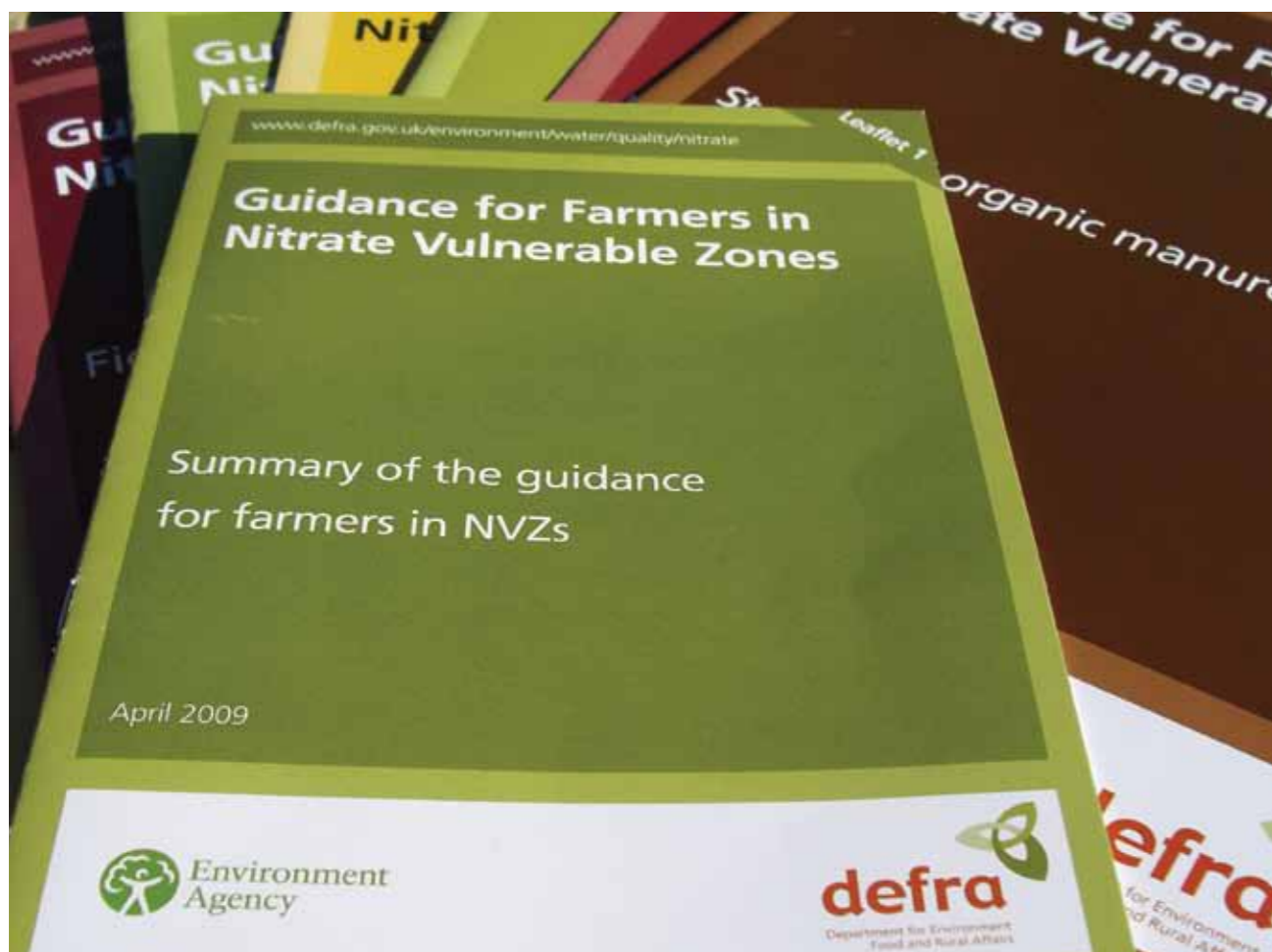
PLANET software tel. 08456 023864 or
www.planet4farmers.co.uk

Tried and Tested team, nutrient management plan
www.nutrientmanagement.org

British Survey of Fertiliser Practice.

Research projects that contributed to the production of this booklet are:

- Efficient use of nutrients and water (807/182).
- Evaluation of the soil nitrogen supply (SNS) system (807/228).
- Improved canopy and N management for the GB potato crop (R405).
- Reference Crops (807/194).
- Grower collaboration (R295).



UNIVERSITY OF
CAMBRIDGE

Potato Council would like to thank Marc Allison at Cambridge University Farm and Brian Chambers at ADAS whose help and guidance in the production of this booklet was invaluable.

Recommendations for RB209 8th edition potato section were developed by an industry group comprising the following people:

Simon Alexander, NNPG (now with SA Consulting)

Marc Allison, CUF

Denis Buckley, TAG (now with Highfield Lodge Agronomy)

Peter Dampney, ADAS

Peter Harkett, McCain Foods (GB) Limited (now with Alpha Agronomy)

Johnny Johnston, Rothamsted Research (now an independent consultant)

David Nelson, Branston Limited

Alex Stephens, AF Stephens, grower

Mike Storey, PCL



Image courtesy of Horstine Farmery



Potato Council
Agriculture and Horticulture Development Board
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL
0247 669 2051

Written by:
Peter Dampney, ADAS and Gary Collins, Potato Council.

While every effort has been made to ensure that the information is accurate, no liability can be accepted for any error or omission in the content of this guide.

© 2009 Agriculture and Horticulture Development Board (AHDB) Potato Council is a division of AHDB.
Printed on 75% Forest Stewardship Council (FSC) certified recycled paper, using vegetable-based inks and chemistry-free plate setting. Printing adopts British Printing Industries Federation environmental policy on conserving energy and natural resources.

