TECHNICAL NOTE TN731 October 2020 • ELEC

Nitrogen recommendations for cereals, oilseed rape and potatoes

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Summary

- **Nitrogen recommendations for cereals and winter oilseed rape include an adjustment for expected yield.**
- **Nitrogen recommendations for potatoes take account of length of growing season, variety group, soil N residues and haulm killing.**
- **New trials suggest that there is no advantage to a split application of nitrogen to potatoes compared with all nitrogen applied at planting.**
- **Take account of fertiliser nitrogen and crop produce prices.**
- **Nitrogen recommendations take account of NVZ Action Programme rules and Nmax.**
- **Careful planning that maximises the efficient use of fertiliser and organic materials can help reduce the amount of N that is lost as nitrous oxide, a greenhouse gas.**

Introduction

Most agricultural soils contain too little, naturally occurring plant-available nitrogen (N) to meet the needs of a crop throughout the growing season. Supplementary N applications have to be made each year. Applying the correct amount of N at the correct time is an essential feature of good crop management.

The "crop N requirement" is the amount of N that should be applied to give the economic optimum yield. Nitrogen recommendations in this technical note are crop N requirements defined in this way. 'Crop N requirement' should not be confused with total N uptake by the crop or with the total supply of N (including that from the soil) that is needed by the crop. The "crop N requirement" can be met by applying manufactured fertilisers, livestock manures or other organic fertilisers individually or in combination.

Provided there are adequate supplies of water and other nutrients, N usually has a large effect on crop growth, yield and quality. Applying N normally gives a large increase in yield but applying too much can reduce yield by aggravating problems such as lodging of cereals and foliar diseases. When too much N is applied, a larger proportion is unused by the crop. This is a financial cost and can also increase the risk of nitrate leaching to water and contribute to other environmental problems.

As N use increases from very small amounts, there is an increase in yield up to the "on-farm economic optimum" N rate. This rate depends on the purchase price of the applied N per kg of N and the sale price per kg of the grain, and defines the point at which further expense on N fertiliser is not worthwhile (i.e. 'breakeven ratio' BER). Cereal recommendations in this note are based on a BER of 3:1 (i.e. 3kg grain needed to pay for each 1 kg of N), and a ratio of 2.5:1 for oilseed rape (i.e. 2.5kg seed needed to pay for each 1 kg of N). When the actual BER on the farm is between 3.5 and 4.5, recommended N rates should be reduced by 11 kg/ha in winter cereals and oilseed rape, and 8 kg/ha in spring cereals and oilseed rape. If on-farm BER is even greater, further reductions in N rates may be considered. Reductions in N use may not be appropriate for milling wheat where achieving a grain protein content of 13% is important.

Nitrogen applied above the economic optimum can result in losses of yield and quality. There may also be an increased need for agro-chemicals such as fungicides and growth regulators, and may preclude flailing as a haulm destruction option in potatoes. At N rates up to and including the economic optimum rate, there is a roughly constant amount of N left in the soil at harvest. At N rates above the economic optimum, there will be a larger surplus of residual N, usually as nitrate, in soil after harvest. This nitrate is at risk of loss in ways that can cause environmental problems

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like leaching to ground and surface water and denitrification to nitrous oxide (a greenhouse gas). At present, agriculture is estimated to contribute around 10% of total UK greenhouse gas emissions. An estimated 70% of the UK's nitrous oxide emissions, around 300 times more potent than carbon dioxide, comes from agriculture. Careful planning that maximises the efficient use of fertiliser and organic materials can help reduce the amount of N that is lost as nitrous oxide.

All recommendations given in this Note are for the economic optimum rate of nitrogen. Substantial changes in the value of the crop produce or the cost of fertiliser are needed to alter the recommendations. Where appropriate, different recommendations are given to achieve crop quality specifications required for different markets.

Where organic materials are applied full account should be taken of the fertiliser nutrients (including N) in order to optimise economic performance and to minimise leaching of excess N as nitrate. The amount of N available to the crop in the years following the application of organic materials depends on the type of material applied, the method and timing of application, and the soil type. In NVZs applications of organic materials, other than compost, to individual fields should not exceed 250 kg/ha of total N from the organic material in any 12 month period. The area of the field used to calculate the 250 kg/ha limit should exclude any areas where organic materials are not spread. Compost shall not be applied to any field where the application would result in the total N contained in organic manure (including compost) applied to any field in any 24 month period exceeding a rate of 500 kg/ha, excluding that deposited by animals whilst grazing. Information on the N contents of organic materials can be found in FAS Technical Notes TN650 and TN699.

N recommendations for different crops

In order to assess the fertiliser N required for each crop in each field, the following factors need to be taken into account:

Soil type	Table 1
Previous crop	Table 2
Previous grass/clover management	Table 3
Crop to be grown and intended market	Tables 4 to 10
Winter rainfall	Tables 4 to 10

N residues from different soil types and assessment of texture

Nitrogen residues from soil reserves have been arranged into six soil types (see Table 1). "Shallow" means any mineral soil with less than 40 cm depth between the soil surface and the underground rock. Types of mineral soils can be identified by hand texturing. Take about a dessertspoonful of soil. If dry, wet up gradually kneading thoroughly between finger and thumb until aggregates are broken down. Enough moisture is needed to hold the soil together and for the soil to exhibit its maximum cohesion. There are 2 questions to be answered:

Question 1	Is it difficult to roll the moist soil into a ball?
Answer	YES, then the soil type is "Sand"; NO, then ask the second question.
Question 2	Does the moist soil feel smooth and silky as well as gritty?
Answer	NO, then the soil type is "Sandy loam"; YES, then the soil type is "Other mineral soil".

"Humose" and "Peaty soils" are identified by percent organic matter, which can be confirmed by laboratory analysis.

Where more than one soil type occurs within a field it may be practical to alter the rate of fertiliser N to suit the different soil types. If this is not practical and the field is to be treated uniformly, select the soil type that covers the largest part of the field. In mineral soils of low organic matter content, the amount of available N residues is relatively small, whereas in humose and peaty sites low N malting barley is not encouraged as N release occurs late in the season and ends up in the grain.

N residues from previous crops

The last crop grown has been allocated into one of five Previous Crop Groups. These Groups are numbered 1 to 5 in ascending order of residual available N in the soil following harvest of the previous crop (see Table 2). A green manure crop in an arable rotation that is maintained in the ground from 3 to 5.5 months until at least 15 August before destroying has been included in Table 2. Residual available N in the soil following harvest will vary depending on the crop grown. When green cover crops are used between the harvest of one crop and establishing the next the N residue group does not change from the original harvested crop. Residues following cereals are generally lower than those following break crops. The management and performance of the previous crop can have a significant effect on the actual level of N residues. Residues are expected to be lower in a high yielding season or where N application has been less than normal, but may be higher than average if the crop has performed badly due to problems such as disease or drought. In tables of N requirements in this Note it is assumed that all previous crops have been managed well and that previous N fertiliser use has been close to the recommended rate, taking account of any use of organic materials. Where there is uncertainty about the amount of residual N in the soil, sampling for Soil Mineral Nitrogen (SMN) may be appropriate e.g. Group 4 and 5. In Group 5, N residues can be very variable. Analysis of the crop debris for total N and C content along with an estimate of the quantity ploughed down is recommended in order to help predict release of available N for the next crop.

N residues from previous grass/clover swards

Nitrogen fertiliser and manure use in the last 2 years of the grassland, and grazing management during the months immediately prior to ploughing out grassland will have a significant effect on the level of N residues. Managements of the previous grass/clover sward have been allocated into one of five Groups. These Groups are numbered 2 to 6 in ascending order of residual available N in the soil following ploughing out of the grassland (see Table 3). Groups 2 to 5 have the same N residues as Groups 2 to 5 in the Previous Crop Groups (Table 2), whereas Group 6 has a higher residue of available N. N residues can be very variable in Groups 5 and 6.

Table 1 Description of soil types

Shallow soils	All mineral soils which are less than 40cm deep.
Sands	Soils which are sand and loamy sand textures to a depth more than 40cm.
Sandy loams	Soils which are sandy loam texture to a depth of more than 40cm.
Other mineral soils	Soils with less than 15 percent organic matter that do not fall into the sandy or shallow soil category i.e. silty and clay soils.
Humose soils	Soils with between 15 and 35 percent organic matter. These soils are darker in colour, stain the fingers black or grey, and have a silky feel.
Peaty soils	Soils that contain more than 35 percent organic matter.

Table 2 Previous Crop Nitrogen Residue Groups in ascending order of residual available N in the soil following harvest

Group	Previous Crop
1	spring barley, spring oats, spring rye, spring wheat, winter barley, winter oats, winter rye, winter wheat, whole crop, triticale, carrots, shopping swedes, turnips (human consumption), linseed, onions, asparagus, radish, narcissus, tulip, swedes/turnips (stock feed), parsnips, ryegrass (seeds).
2	forage maize, forage rape, green manure crop, kale cut, winter oilseed rape, spring oilseed rape, hemp, courgette, beetroot (red baby, other), vining peas, combining peas, potatoes (<60 days, seed and punnets), potatoes (60-90 days, seed and punnets), potatoes (60-90 days, ware), potatoes (90-120 days), potatoes (>120 days), blackberries, loganberries, blackcurrants, redcurrants, blueberries, tayberries, strawberries, raspberries.
3	harvested fodder (root only), beans (broad), beans (dwarf/runner), beans (field vining), lupins, leeks, lettuce, rhubarb, uncropped.
4	grazed fodder, turnips grazed, kale grazed, forage rape grazed, chicory pure stand grazed.
5*	leafy brassica vegetables, leafy non-brassica vegetables, brussels sprouts, cabbage (all types), calabrese (broccoli), cauliflower.
*N residues can be variable in this group. Analysis of the crop debris for total N and C content prior to ploughing down is recommended to help predict release of available N for the next crop.	

Table 3 Previous Grass/Clover Nitrogen Residue Groups in ascending order of residual available N in the soil following ploughing out

Group	Previous Grass/Clover management
2	1-2 year low N* leys and not grazed within 2 months of ploughing
3	1-2 year low N leys and grazed within 2 months of ploughing 1-2 year high N leys* and not grazed within 2 months of ploughing Thin permanent grass, low N, no clover
4	1-2 year high N leys and grazed within 2 months of ploughing 3-5 year low N leys and not grazed within 2 months of ploughing Thick permanent grass, low N
5	3-5 year high N leys and not grazed within 2 months of ploughing 3-5 year low N leys and grazed within 2 months of ploughing Permanent grass, high N, not grazed within 2 months of ploughing
6	3-5 year high N leys and grazed within 2 months of ploughing Permanent grass, high N, grazed within 2 months of ploughing

* Low N: less than 150kg/ha/year fertiliser N used on average in last 2 years.
High N: more than 150kg/ha/year fertiliser N used on average in last 2 years, or high clover.

Winter rainfall

The drier the winter and the greater the soil capacity to hold water, the smaller the proportion of N from crop residues that will be washed out of the soil before crop growth starts in the spring. If winter rainfall between 1 October and 1 March is more than 450mm (18 inches) then standard N recommendations should be adjusted by additional N to crops in N residue Groups 2 to 6 depending on soil type according to the information in the crop Tables 4 to 10.

Winter cereals (Tables 4 and 5)

Autumn nitrogen is NOT generally recommended, as profitable responses are not normally attained and the practice will increase N losses to watercourses. There is a possible N requirement in some winter barley that has been direct drilled, established following minimum cultivation, or established after ploughing down large quantities of straw e.g. after carrots.

Spring N is best applied as a split dressing. In general a 33%/67% (one-two thirds) split between the start of spring growth and growth stage 30-31 is recommended. A 20/80 split will improve bread-making quality and help to prevent lodging, a 50/50 split will help to reduce grain N% for malting or distilling. For wheat grown for bread-making/milling the additional 40 kg/ha, as shown in Table 4, should be applied either as a solid fertiliser as soon as the flag leaf is fully emerged, or as a foliar spray at the milky ripe stage in order to increase grain protein. These adjustments in timing should be used in conjunction with adjustments in the amount of N applied.

Farm N strategies for wheat can be assessed periodically using information on grain protein concentration. Grain protein at the economic optimum rate of N is about 11% (1.9% N) for feed wheat and 12% (2.1% N) for bread-making wheat.

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

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

A whole crop winter rye yield of 30t/ha would be equivalent to the winter barley base yield of 6.5 t/ha which would now be considered a poor crop of winter barley and likewise whole-crop rye. Whole crop rye grown for AD is accurately weighed into AD plants. An additional 2.5 kg N/ha may be justified for every tonne that the expected whole crop rye yield exceeds 30 t/ha (at 35% dry matter), where farm average yield is supported by evidence of yields previously achieved by that crop.

Spring cereals (Tables 6 and 7)

Nitrogen recommendations for spring barley planned for low N malting should be reduced by 20kg N/ha. Nitrogen recommendations should be reduced for crops which are sown ten days or more after the optimum sowing period. Pressure of spring work and adverse weather can often account for delays in excess of ten days. In these circumstances the N recommendation should be reduced for crops which are sown ten days or more after the optimum sowing period by approximately 1.5 kg/ha/day for each day of delay for feed or high N malting and 2.25 kg/ha/day for low N malting.

For crops sown up to the beginning of April apply half fertiliser N to seedbed and half at 2-3 leaf stage for low N malting and start of tillering for feed and High N malting crops. From beginning of April onwards, all may be applied to seedbed. Incorporation in the seed bed, or combine drilling reduces the risk of poor N uptake in dry spring weather.

A new table has been included to highlight the increased importance of growing spring oats. Recent research has shown that the lower N requirement of spring oats compared to barley is associated with a greater uptake of soil N and a smaller residue of nitrate left at harvest.

Combine drilling is recommended for early sown crops and crops grown in high soil pH (>6.4). Combine drilling of urea is NOT recommended as close contact with germinating seed can be damaging. Combine-drilled fertiliser should be limited to 150 kg/ha N + K_2O on sands and sandy loams.

Winter oilseed rape (Table 8)

It is important to sow oilseed rape early in order to achieve sufficient plant size to withstand winter conditions. Sowing date is particularly important in Scotland and the end of August is recognised as the latest advisable sowing date for most areas. Winter barley is generally the most suitable crop for entry of winter oilseed rape in Scotland, although in some areas and in earlier seasons spring barley may be harvested early enough to provide a suitable entry. Autumn sown rape can produce about 20-25 t/ha fresh material by December, and seedbed/autumn application of N is recommended following crops/grass in N residue groups 1, 2 and 3. N top dressing in spring is best split, applying half at the start of spring growth and half prior to stem elongation.

Spring oilseed rape (Table 9)

Spring sown crops generally utilise soil N more efficiently than winter crops. Their requirement for N coincides with the normal period of soil N release in May and June whereas winter crops require N when the soil is still too cold for soil N release in March.

Potatoes (Table 10)

Nitrogen increases haulm growth and persistence. The increase in haulm growth is accompanied by delayed tuber initiation and growth. The main benefit of high N is the greater length of the tuber bulking period, linked to improved haulm persistence. Only moderate amounts of N are required for maximum bulking rates up to the normal 'burning off' dates for specialist seed and punnet production. Nitrogen usually increases tuber yield more than tuber number, hence average tuber size is increased as is the proportion of 'ware' in the crop. For these reasons the amount of N recommended increases as the expected burning off date is delayed.

Whilst flailing is taking over as a rapid way of haulm killing, following the loss of diquat for haulm destruction, there will be occasions when alternative (but much slower) desiccant-only approaches will have to be used. If harvest is to be achieved within acceptable time frames, careful consideration of N use is required. Exceeding the recommended rate should be avoided, especially if wet weather may preclude flailing as a haulm destruction option.

The previous crop/grass N residue group should be used together with the anticipated length of growing season, intended market and variety group to determine the appropriate range of N rates. The length of growing season is the number of days from 50% emergence to haulm death. Recommendations are for optimum growing conditions. Soil compaction, PCNs or free-living nematodes have the potential to reduce root growth. No adjustment is required for irrigated crops. Irrigation should be applied according to a recognised scheduling system, which minimises the risk of returning soils to field capacity and triggering leaching.

In the past, split application of N has been considered of benefit for ware crops grown on sands, sandy loam and shallow soils, or carried out for practical reasons to speed up planting. However, recent trials suggest that there is no advantage to a split application of N to potatoes compared with all N applied at planting. If application is considered post-planting, it should be completed no later than tuber initiation. Typically, one half to two-thirds of the N recommendation would be applied in the seedbed and the remainder no later than tuber initiation. It should be remembered also that in unirrigated crops, during dry weather top-dressings of N will take longer to reach the roots.

Table 4 Winter wheat and triticale: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
Sands and shallow soils	220	210	200	180	150	110
Sandy loams and other mineral soils	200	190	180	160	130	90
Humose soils	140	130	120	100	70	30
Peaty soils	80	70	60	40	10	0
Adjustments:						
Milling varieties	+40	+40	+40	+40	+40	+40
Yield adjustment*						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

* An additional 20kg/ha may be justified for every tonne that the expected yield exceeds 8t/ha, and is permitted in NVZs where farm average yield is supported by evidence of yields previously achieved by that crop.

Table 5 Winter barley, winter oats and winter rye: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
Sands and shallow soils	200	190	180	170	140	100
Sandy loams and other mineral soils	180	170	160	140	110	70
Humose soils	120	110	100	80	50	10
Peaty soils	80	70	60	40	10	0
Adjustments:						
Malt for distilling	-50	-50	-50	-50	-50	-50
Malt for brewing	-30	-30	-30	-30	-30	-30
Yield adjustment*						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

* An additional 15kg/ha may be justified for every tonne that the expected winter barley yield exceeds 6.5t/ha, and is permitted in NVZs where farm average yield is supported by evidence of yields previously achieved by that crop.
An additional 2.5 kg N/ha may be justified for every tonne that the expected whole crop winter rye yield exceeds 30 t/ha (at 35% dry matter).
Insufficient data is available to justify an adjustment for yield potential for winter oats.

Table 6 Spring barley: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
Sands and shallow soils	150	140	130	110	80	40
Sandy loams and other mineral soils	130	120	110	90	60	20
Humose soils	80	70	60	40	10	0
Peaty soils	50	40	30	10	0	0
Adjustments:						
High N grain distilling	+15	+15	+15	+15	+15	+15
Malting (low N)	-20	-20	-20	*	*	*
Undersown crop	-25	-25	-25	-25	-25	-25
Yield adjustment**						
Delayed sowing – Reduce by 1.5 kg/ha/day for each day of delay after 10 days after your optimum sowing period						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

* Avoid growing low N malting barley after crops in groups 4 – 6 and humose/peaty soils that leave high N residues.
** An additional 15kg/ha may be justified for every tonne that the expected spring barley yield exceeds 5.5t/ha, and is permitted in NVZs where farm average yield is supported by evidence of yields previously achieved by that crop.

Table 7 Spring oats: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
Sands and shallow soils	120	110	100	80	50	20
Sandy loams and other mineral soils	100	90	70	50	20	20
Humose soils	50	40	30	20	20	0
Peaty soils	20	20	20	0	0	0
Adjustments:						
Undersown crop	-25	-25	-25	-25	-25	-25
Yield adjustment*						
Delayed sowing – Reduce by 1.5 kg/ha/day for each day of delay after 10 days after your optimum sowing period						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

* An additional 15kg/ha may be justified for every tonne that the expected spring oat yield exceeds 5.5t/ha, and is permitted in NVZs where farm average yield is supported by evidence of yields previously achieved by that crop.

Table 8 Winter oilseed rape: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
Seedbed :						
All soils	30	20	10	0	0	0
Spring:						
All mineral soils	200	190	180	140	110	70
Humose soils	120	110	100	80	50	10
Peaty soils	80	70	60	40	0	0
Adjustments:						
Yield adjustment*						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

* Up to an additional 30kg/ha may be justified in spring if the expected yield is over 4.0t/ha, and is permitted in NVZs where farm average yield is supported by evidence of yields previously achieved by that crop. This adjustment should be used with caution because applying too much early nitrogen to crops with large canopies can increase lodging and may reduce yield.

Table 9 Spring oilseed rape: N recommendations in kg/ha

Previous crop or grass N group (Table 2 or 3)	1	2	3	4	5	6
All mineral soils	100	90	80	60	30	0
Humose soils	50	40	30	10	0	0
Peaty soils	20	10	0	0	0	0
Adjustments:						
Winter rainfall (1 Oct – 1 Mar)						
More than 450mm (18 inches)						
Sands, sandy loams, shallow soils	0	+10	+20	+20	+20	+20
All other soils	0	+10	+10	+10	+10	+10

Table 10 Potatoes: N recommendations in kg/ha

Length of growing season	Variety group[1]	Previous crop or grass N Residue Group					
		1	2	3	4	5	6
< 60 days (seed & punnets)	1	80	70	60	40	0	0
	2	60	50	40	20	0	0
	3	40	30	20	0	0	0
	4	N/A	N/A	N/A	N/A	N/A	N/A
60-90 days (seed & punnets)	1	100	90	80	60	30	0
	2	80	70	60	40	0	0
	3	60	50	40	20	0	0
	4	50	40	30	0	0	0
60-90 days (ware)	1	200	190	180	160	130	90
	2	150	140	130	110	80	40
	3	120	110	100	80	50	0
	4	80	70	60	40	0	0
90-120 days	1	240	230	220	200	170	130
	2	200	190	180	160	130	90
	3	160	150	140	120	90	50
	4	120	110	100	80	50	0
> 120 days	1	N/A	N/A	N/A	N/A	N/A	N/A
	2	220	210	200	185	150	110
	3	180	170	160	160	110	70
	4	140	130	120	110	70	30

[1]Variety group (for other varieties consult RB209, 2020 or PLANET Scotland):

- 1 – short haulm longevity (determinate varieties) – e.g. Accord, Estima, Maris Bard, Rocket, Premiere
- 2 – medium haulm longevity (partially determinate varieties) – e.g. Atlantic, Lady Rosetta, Marfona, Maris Peer, Nadine, Saxon, Shepody, Wilja.
- 3 – long haulm longevity (indeterminate varieties) - e.g. Maincrop varieties such as Desiree, Fianna, Hermes, King Edward, Maris Piper, Rooster, Russet Burbank, Pentland Dell, Pentland Squire, Saturna
- 4 – very long haulm longevity – e.g. Cara, Markies

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Production of this SRUC Technical Note was funded by the Scottish Government as part of its Farm Advisory Service.