TECHNICAL NOTE TN734 February 2024 • ELEC

Fertiliser recommendations for vegetables, minority arable crops and bulbs

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Summary

- Vegetables and some of the minority crops can have a high value.
- Production costs are also often high, with fertilisers accounting for a very small percentage of variable costs.
- Fertilisers should be applied at rates that are likely to result in the maximum yield of crops of acceptable quality, whilst ensuring protection of the surrounding environment.
- Nitrogen (N) recommendations for these crops have been updated in the light of recent trials results and advisory experience.
- Tables that take account of N released from previous crop residues, grass leys and N available from reserves in different soil types have been updated.
- A soil specific approach to P management is presented that considers the relationship between differing soils capacity to regulate P availability for plant uptake.
- N recommendations take account of NVZ Action Programme rules and Nmax and will minimise losses of N to the environment.
- Recommendations are given for nitrogen, phosphorus, potassium, magnesium, sulphur, sodium, boron, copper, manganese, and molybdenum.

A. Nitrogen recommendations

To assess the N fertiliser requirements for each crop, the following factors need to be taken into account:

Stage A1:	Assessment of soil type	Table A1
Stage A2:	Assessment of N residues (taking account of the previous crop or previous grass/ clover management)	Tables A2a, A2b
Stage A3:	Crop to be grown	Tables A3a, A3b, A3c
Stage A4:	Adjustments for individual crop types/markets, expected yields and Spring/ Summer rainfall	
Stage A5:	Adjustments for soil type	Table A4
Stage A6:	Adjustments for Winter rainfall	Table A5
Stage A7:	Adjustments following applications of bulky organic manures	
Stage A8:	Special crop requirements (N fertiliser timing and placement)	

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Stage A1. Assessment of soil type

N residues from soil reserves have been arranged into six soil types (Table A1). "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 dessertspoon of soil. If dry, wet it 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 two 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 soils" 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 impractical, and the field is to be treated uniformly, you should 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.

Table A1. Description of soil types

Shallow soils (SS)	All mineral soils which are less than 40cm deep.
Sands (S)	Soils which are sand and loamy sand textures to a depth of more than 40cm.
Sandy loams (SL)	Soils which are sandy loam texture to a depth of more than 40cm.
Other mineral soils (OMS)	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 (HS)	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 (PS)	Soils that contain more than 35 percent organic matter.

Stage A2. Assessment of N residues

Where crops other than grass have been grown prior to the intended vegetable or minor crop, these have been allocated into one of five Previous Crop Groups. These groups are numbered 1 to 5 in ascending order of residual N in the soil, following harvest of the previous crop (Table A2a). Residual available N in the soil following harvest will vary depending on the crop type grown. Residues following cereals are generally lower than those following leafy crops, potatoes and legumes. The management and performance of the previous crop can have a significant effect on the 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 because of problems such as disease or drought. In the tables of N recommendations 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, considering of any use of organic manures.

Nitrogen fertiliser and manure use in the last 2 years of grassland management, and grazing management during the months immediately prior to ploughing out grassland will have a significant effect on the level of N residues. Management 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 (Table A2b). Groups 2 to 5 have the same N residues as Groups 2 to 5 in the Previous Crop Groups (Table A2a), whereas Group 6 has a higher residue of available N.

Table A2a. Previous crop 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 (stockfeed), parsnips, ryegrass (seeds), willow
2	forage maize, forage rape, green manure crop, kale cut, winter oilseed rape, spring oilseed rape, hemp, courgette, pumpkin, 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, gooseberries
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 A2b. Previous grass/clover 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[1] leys and not grazed within 2 months of ploughing out or during Sept./Oct.
3	1 – 2-year low N leys and grazed within 2 months of ploughing out or during Sept./Oct. 1 – 2-year high N leys and not grazed within 2 months of ploughing out or during Sept./Oct. Thin, permanent grass, low N, no clover
4	1 – 2-year high N leys and grazed within 2 months of ploughing out or during Sept./Oct. 3 – 5-year low N leys and not grazed within 2 months of ploughing out or during Sept./Oct. Thick, permanent grass, low N
5	3 – 5-year high N leys and not grazed within 2 months of ploughing out or during Sept./Oct. 3 – 5-year low N leys and grazed within 2 months of ploughing out or during Sept./Oct. Permanent grass, high N, not grazed within 2 months of ploughing out or during Sept./Oct.
6	3 – 5-year high N leys and grazed within 2 months of ploughing out Permanent grass, high N, grazed within 2 months of ploughing out
[1]Low N means less than 150 kg/ha/yr fertiliser N used on average in last 2 years. High N means more than 150 kg/ha/yr fertiliser N used on average in last 2 years or high clover content.	

Some growers may wish to test their soil for soil mineral nitrogen (SMN). SMN testing can give useful additional information about soil N supply where it is likely to be high or uncertain; where regular inputs of organic manures are used; or where large amounts of leafy crop residues have regularly been incorporated e.g. Group 4 and 5. SMN measurement is not recommended in established grassland, or in the first year after ploughing out grassland.

Care must be taken when interpreting results of SMN testing, since SMN concentrations can vary widely from day to day depending primarily on soil temperature and rainfall. When measuring SMN before a vegetable crop you do not need to add an estimate of N mineralisation during the growing season as this is already considered in the recommendation tables.

Guidance on how to collect an SMN sample can be found in Section 6 "Vegetables and bulbs", Nutrient Management Guide (RB209), 2020). The main considerations for vegetable crops when SMN sampling, which are distinct from other crops are:

- Take SMN samples as close to planting date as possible, but not within 2 months of applying nitrogen fertiliser or organic materials.
- Take samples in 30 cm sections to 90 cm or to rooting depth. Use table A2c to identify the correct N residue group based on sampling depth.

Samples should be analysed for nitrate-N and ammonium-N. Analytical results in mg N/kg should be converted to kg/ha, considering the dry bulk density of the soil, then summed to give a value for the whole soil profile. For most mineral soils, a "standard" bulk density of 1.33 g/ml can be used, and the calculation can be simplified to:

SMN (kg N/ha) = mg N/kg x 2 (for each 15 cm layer of soil)
SMN (kg N/ha) = mg N/kg x 4 (for each 30 cm layer of soil)
SMN (kg N/ha) = mg N/kg x 8 (for each 60 cm layer of soil)

Table A2c. SMN based on sampling (N kg/ha) to 30, 60 and 90 cm depth and ascending order of Nitrogen Residue Groups

	Nitrogen Residue Group					
	1	2	3	4	5	6
	kg N/ha					
SMN kg/ha to 30 cm	<20	20-27	28-33	34-40	41-60	>60
SMN kg/ha to 60 cm	<40	40-53	54-67	68-80	81-120	>120
SMN kg/ha to 90 cm	<60	60-80	81-100	101-120	121-180	>180

Stage A3. Crop to be grown.

The nitrogen (N) recommendations for each of the main vegetable and minor arable crop types grown in Scotland are listed in Tables A3a, A3b and A3c. For forage crops for livestock, see TN733 (2020). The N required will depend on the previous crop or grass/clover management in the field in which the crop is to be grown. Details of how to allocate the correct "Previous crop/grass Nitrogen Residue Group" to the field are given in Tables A2a and A2b. Nitrogen recommendations for herbs (coriander and mint) have been added to Table A3a and should be considered as guideline figures and may need to be adjusted based on local experience, considering factors such as planting date, expected yield and end market.

A surge in popularity of pumpkin crops for celebrating Halloween has highlighted the absence of fertiliser recommendations in previous technical notes. Pumpkin and courgette are part of the cucurbit crop family, are annual fruit crops and are grown in vegetable rotations. Therefore, it seems sensible to group pumpkin and courgette together in this technical note for vegetables and minority arable crops.

The required N can be applied wholly as manufactured fertiliser, although some may be derived from bulky organic manures. Adjustments to the standard values given in Tables A3a, A3b, A3c and A3d should be made by following stages A4 to A8 as described in this Technical Note. Specialist guidance may be needed when making decisions for specific crops. Recommendations for potato crops are provided in the technical note TN731 (February 2020) "Nitrogen recommendations for cereals, oilseed rape and potatoes".

Table A3a. Brassicas, celery, sweetcorn, courgette, pumpkin, lettuces, alliums, asparagus, herbs, and legumes: nitrogen recommendations in kg/ha

Crop	Previous crop/grass Nitrogen Residue Group					
	1	2	3	4	5	6
Brussels sprouts	300	290	280	260	210	170
Cabbage (all types)	340	330	320	300	250	210
Calabrese (broccoli)	270	260	250	230	180	140
Cauliflower	290	280	270	250	210	160
Celery[1] – seedbed[5]	75	75	75	75	0	0
Sweetcorn[5]	220	175	125	75	0	0
Courgette[5]	110	100	90	70	0	0
Pumpkin	110	100	90	70	0	0
Lettuce – whole head	200	190	180	160	110	70
Lettuce – baby leaf	60	50	40	20	10	0
Wild rocket	120	110	100	80	60	40
Leeks[2]	200	190	180	160	130	80
Onions, salad	130	120	110	90	70	50

Onions, bulb[5]	160	130	110	90	60	0
Asparagus – establishment year	150	140	130	110	90	70
Asparagus – year 2	120	120	120	120	120	120
Coriander	140	130	120	100	80	50
Mint[3]	180	170	160	140	110	70
Lupins	0	0	0	0	0	0
Beans, broad	0	0	0	0	0	0
Beans, dwarf/runner[4,5]	180	150	120	80	30	0
Beans, field (vining)	0	0	0	0	0	0
Peas, vining/combining/fresh market	0	0	0	0	0	0

[1]A top dressing of 75-150 kg N/ha will be required 4-6 weeks after planting.

[2]An additional topdressing of 50-100 kg N/ha in the autumn may be beneficial where the risk of frost damage is low to support growth and colour.

[3]N recommendations are the same in the establishment year and for established crops – for established crops, the N recommendations are per cut.

[4]Runner beans only may require an additional top-dressing of up to 75 kg N/ha at early picking stage.

[5]In N Residue Groups 5 and 6 where N recommendations are zero, a small amount of N may be needed if soil N levels are low in the top 30 cm of soil.

Table A3b. Hemp, linseed, chicory pure stand, willow, forage rape, forage maize and kale: nitrogen recommendations in kg/ha

Crop	Previous crop/grass Nitrogen Residue Group					
	1[1]	2	3	4	5	6
Hemp	150	140	130	110	90	70
Chicory pure stand	80	70	60	40	20	0
Willow for biomass[2]	60	50	40	0	0	0
Linseed						
Sands, Shallow	80	70	60	40	20	0
Sandy loam, other mineral	60	50	40	20	0	0
Humose	30	20	20	0	0	0
Peaty	0	0	0	0	0	0
Forage maize, rape						
Sands, Shallow	140	130	120	100	70	30
Sandy loam, other mineral	120	110	100	80	50	10
Humose	70	60	50	30	0	0
Peaty	40	30	20	0	0	0
Kale						
Sands, Shallow	180	170	160	140	110	70
Sandy loam, other mineral	160	150	140	120	90	50
Humose	100	90	80	60	30	0
Peaty	60	50	40	20	0	0

[1]For descriptions of Previous Crop Groups and Previous Grass/Clover Groups, see Tables A2a and A2b

[2]No fertilisers are required during the established year, so the recommendations refer to the three-year periods after the initial cutback (in the winter after establishment) and the subsequent three-year periods after each harvest.

Table A3c. Root crops and bulbs: nitrogen recommendations in kg/ha

Crop	Previous crop/grass Nitrogen Residue Group					
	1	2	3	4	5	6
Carrot	100	70	40	20	0[1]	0[1]
Parsnip	170	140	130	110	80	40
Shopping swedes, turnips (human consumption) and Swedes/turnips (stockfeed)						
Sands, Shallow	120	100	90	70	40	0[1]
Sandy loam, other mineral	120	100	80	50	20	0[1]
Humose	50	40	30	20	0[1]	0[1]
Peaty	20	20	0[1]	0[1]	0[1]	0[1]
Beetroot	290	260	240	220	190	120
Fodder beet (85t/ha roots lifted)	130	120	110	90	60	0[1]
Radish	80	70	60	40	20	0[1]
Narcissus[2]	100	90	80	60	30	0[1]
Tulip	100	90	80	60	30	0[1]

[1]Up to 20 kg/ha of nitrogen may be needed where soil nitrogen supply is expected to be low initially, for example in cold, wet conditions.

[2]Value in table relates to establishment of crops. For established crops, apply 40 kg/ha/annum, if wishing to extend flowering stem length.

Stage A4. Adjustments for soil type

Step A5 should be omitted for linseed, forage maize, rape, and kale; and shopping swedes, turnips (human consumption) and Swedes/turnips (stockfeed), because it has already been completed in Tables A3b and A3c. For other crops, the standard N recommendations in Tables A3a, A3b and A3c are for crops grown in sandy loams and other mineral soils. For these crops grown in sands and shallow soils the N recommendation should be increased by 10% and in humose and peaty soils should be reduced by 10% (Table A4).

Table A4. Adjustment to standard N recommendation for different soil types

Crop	Soil type		
	Sands & shallow soils	Sandy loams & other mineral soils	Humose & peaty soils
Vegetable[1] and minority crops other than linseed, forage maize, forage rape, kale, shopping swedes, turnips (human consumption) and swedes/turnips (stockfeed) for which extra adjustments are detailed in Tables A3b and A3c).	Add 10%	No change	Remove 10%

[1]Vegetables are grown on sands but very rarely grown on shallow soils (less than 40 cm over rock)

Stage A5. Adjustments for rainfall

Where spring rainfall is greater than normal, some N may be lost from the soil profile between first and final Spring N dressings. The amount lost will depend on the amount of rain that falls once the soil is already at water-holding capacity, the crop cover and rooting depth. It may only be necessary to make an adjustment for shallow-rooted crops. When compensating for excessive Spring rainfall, no more than an additional 20 kg N/ha should be applied.

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 450 mm, then the standard N recommendations should be adjusted according to Table A5.

Table A5. Adjustment to standard N recommendation following excessive Winter rainfall.

Crop	Winter rainfall > 450 mm		
	Sands, sandy loams and shallow soils, previous crop group 2	Sands, sandy loams and shallow soils, previous crop groups 3 - 6	All other soils, previous crop groups 2 - 6
All vegetable and minority crops	Add 10 kg/ha	Add 20 kg/ha	Add 10 kg/ha

Stage A6. Adjustments to N recommendations following applications of organic manures and fertilisers

Many growers of vegetables and minor crops choose to apply organic materials (including animal manures, biosolids, composts and anaerobic digestates) as part of their fertiliser strategy and to maintain or enhance soil quality. It is important that full account is taken of the fertiliser nutrients (including N) within them to optimise crop quality, economic performance and to minimise any environmental impact (for example through 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 of application, the soil type, and the month (and year of application). Applications of organic materials to individual fields should not exceed 250 kg /ha of total N from the organic material in any 12-month period (this is mandatory in NVZs). Compost shall not be applied to any field where the application would result in the total nitrogen contained in organic manure (including compost) applied to any field in any 24-month period exceeding a rate of 500 kg per hectare, excluding that deposited by animals whilst grazing (this is mandatory in NVZs). The area of the field used to calculate the 250 kg/ha limit should exclude any areas where manure is not spread. Information on the N contents of organic materials can be found in SAC Consulting Technical Note TN650 on livestock manures and slurries; and TN699 for biosolids, composts, anaerobic digestates and other industrial organic fertilisers.

Stage A7. Adjustments for fertiliser placement, individual crop types and markets, and expected yields.

Adjustments to the N recommendations given in Tables A3a, A3b and A3c may have to be made to optimise crop quality and economic performance. Crops of any given type will require slightly different amounts of N depending on the variety, the intended market and on the expected yield (based on previous yields which will be affected by management practices, soil type, soil nutrient status and topography in particular).

Where yields are likely to be significantly different from those expected, adjust the N recommendation accordingly, although the N rates recommended in Tables A3a, A3b and A3c should not be exceeded other than where the soil is sandy or shallow (Stage A4), or when excessive rainfall has occurred (Stage A5). The adjustment to the N recommendation should depend on the way in which yield affects rooting. If soil is relatively deep, and the increase in yield gives rise to more rooting, then the fertiliser requirement may be no different or even lower, whereas very low yielding crops could have the high N requirements shown in Tables A3 because of very shallow rooting.

Baby vegetables will require less N than fully grown crops. Where lettuce or other crops are grown twice in a season, reduce the N application to the second crop. Each crop will need to be considered with care, since the rooting depth of the lower yielding crops is likely to be less, so less soil N will be available.

Where crops are grown under protection for all or part of the season (e.g. under fleece, cloches or tunnels), it may be possible to reduce the N application, but this may not apply to very early crops established in cold soils.

Starter fertiliser - The injection of starter fertiliser containing both N and phosphate (for P_2O_5 see section B) below the seed or around the roots of transplants can improve the growth and quality of many crops. The amount used should be deducted from the recommended rate when applying the remainder of the N, which should be applied ideally when the soil surface is moist.

Band spreading – For some crops grown in rows or beds, there can be benefits from applying early N in a band, or injecting it around the plant, followed by a broadcast top-dressing (or top-dressings). This may reduce the total amount of N required.

Brussels sprouts and cabbage – On light soils where leaching can occur, or when crops are established by direct seeding, no more than 100 kg/ha N should be applied prior to sowing/transplanting. On retentive soils in drier parts of the country, where leaching risk is low and spring-planted brassicas are established from modules, more N can be applied prior to planting. The remaining N should be applied after establishment.

Cauliflower and calabrese – Apply no more than 100 kg/ha N at sowing/transplanting where there is a risk of poor

establishment or leaching. The remaining N should be applied after establishment. Where band spreading or fertiliser placement is used, reduce the applied N by up to 33%.

Pumpkin – Apply all the N at planting or split between planting and a top dressing before the crop starts vining.

Lettuce, radish, root crops and dwarf/runner beans – Apply no more than 100 kg/ha N at sowing/transplanting. The remaining N should be applied when the crop is fully established.

Onions and leeks – Apply no more than 100 kg/ha N at sowing/transplanting. For Autumn-established crops it may be advisable where soil residues of N are high, to apply as little as 40 kg N/ha at sowing/transplanting since excess N may make the crop more prone to disease. The remaining N should be applied when the crop is fully established for spring crops and the following spring for Autumn-sown crops.

Asparagus – For established crops, apply 40 – 80 kg N/ha by the end of February if the crop is on light soil and Winter rainfall was high with an additional 40 – 80 kg N/ha after harvest. Following moderate or low Winter rainfall, apply 40 – 80 kg N/ha just after harvest to provide N for early growth.

Coriander – Apply no more than 100 kg N/ha in the seedbed. The remainder should be applied as a top dressing when the crop is fully established.
Specialist guidance may be needed when deciding on N fertiliser application rates in relation to any of the factors discussed above.

B. Phosphate (P_2O_5) and Potash (K_2O) recommendations

Many vegetable crops respond to fresh additions of phosphate and potash fertilisers, especially at low soil indices. In order to assess the phosphate and potash fertiliser requirements for each crop, the following factors need to be taken into account:

Stage B1:	Crop to be grown	Tables B1a, B1b, B1c, B1d
Stage B2:	Adjustments based on strategy for P and K use (building or maintaining)	
Stage B3:	Adjustments following applications of organic manures and fertilisers	
Stage B4:	Special crop requirements (fertiliser timing and placement)	

Stage B1. Crop to be grown.

The recommendations provided in Tables B1a, B1b, B1c and B1d will ensure sufficient supply of P and K for average yields of the main vegetable and minority arable crops grown in Scotland. Recommendations for potato crops are provided in the PK technical notes TN715, TN716, TN717 and TN718 which have been updated in 2020.

Table B1a. Brassicas, celery, sweetcorn, courgette, lettuces, alliums, asparagus, and legumes: phosphate and potash recommendations in kg/ha

	P_2O_5 Soil P status			K_2O Soil K status		
Crop	Low	Moderate	High	Low	Moderate	High
Brussels sprouts	150	100	50	250	200	100
Cabbage, all types	150	100	50	250	200	100
Calabrese (broccoli)	125	100	75	100	75	50
Cauliflower	125	100	75	240	175	100
Celery	200	150	100	400	325	210
Sweetcorn	125	75	25	200	125	0
Pumpkin	125	75	25	200	125	75
Courgette	125	75	25	200	125	75
Lettuce	250	200	100	250	175	100
Leek	200	150	100	250	175	100
Onions (all types)	200	150	100	160	125	90

Asparagus – establishment year	150	125	100	225	200	150
Asparagus – year 2	75	50	25	50	50	50
Beans, broad	200	150	100	125	100	75
Beans, dwarf/runner	150	100	50	150	75	0
Beans, field (vining)	60	40	0	60	40	0
Peas, vining/ combining	40	25	0	40	25	0
Lupins	50	20	0	65	30	0

Table B1b. Hemp, linseed, chicory pure stand, willow, forage rape, forage maize and kale: phosphate and potash recommendations in kg/ha

	P_2O_5 Soil P status			K_2O Soil K status		
Crop	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**
Hemp	60	50	40	60	50	40
Chicory pure stand	50	25	0	75	35	0
Willow for biomass[1]	85	55	0	100	70	0
Linseed	75	40	25	120	75	25
Rape (grazed)	50	25	0	75	35	0
Maize (40 t/ha, arable silage)	85	60	20	205	165	110
Kale (grazed)	50	25	0	80	40	0
Kale (40 t/ha, cut)	75	50	0	225	170	130

[1]No fertilisers are required during the established year, so the recommendations refer to the three-year periods after the initial cutback (in the winter after establishment) and the subsequent three-year periods after each harvest.

Table B1c. Root and bulb crops: phosphate and potash recommendations in kg/ha

	P_2O_5 Soil P status			K_2O Soil K status		
Crop	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**
Carrot	160	125	90	160	125	90
Parsnip	150	100	50	200	150	100
Swede, shopping	250	200	150	200	150	100
Turnips (human consumption)	250	200	150	160	125	90
Swedes/turnips (stockfeed) (65t/ha roots lifted)	170	100	50	190	150	110
Beetroot, all types	125	100	75	250	200	150
Fodder beet (85t/ha roots lifted)	80	60	50	390	340	290
Radish	125	75	25	150	100	50
Narcissus	100	75	50	200	150	100
Tulip	100	75	50	200	150	100

Stage B2. Adjustments based on strategy for P and K use (building or maintaining)

It is advisable to maintain soil P and K levels at the target status and for this reason, it may be necessary to apply additional P and/or K to increase the reserves of P and K in the soil.

The amounts needed to supply maintenance needs will depend on expected crop yields and on the treatment of crop residues. Specialist guidance may be needed when deciding on P and K fertiliser application rates in relation to expected yields and offtake for specific crops.

The P sorption capacity (PSC) of a soil refers to the differing capacity of soils to bind with applied P making it temporality unavailable for plant uptake. The PSC varies depending on soil chemistry, texture, pH and organic content of your soil. Data from the Soil Survey of Scotland for each soil association has been used to create a map of ranking of PSC for non- calcareous soils from low (PSC 1) to high (PSC 3) (see FAS/SRUC technical notes TN715, 716, 717 and 718; FAS website downloads).

The target soil P and K Status is moderate (M+) for rotations including most vegetable crops that respond to fresh additions of P and K at low soil Status. Those soils with a higher PSC that are maintained on target for P represent the greatest erosion risk to water quality as they will contain a higher level of adsorbed P from fertilising. Maintaining soils at target soil P levels is only justified if the land is being actively managed for maximum yields. This requires that other good soil management targets such as pH, nutrient planning as well as adequate drainage status are also considered. Soils of PSC 3 will maintain the lowest P concentrations in soil pore water. This relationship explains the observation that despite equivalent soil P Status, high P sorption soils often require additional fertiliser to maintain target plant available P. Regular soil analysis detects this, allowing adjustments to be made.

Table B2. Effects of PSC on annual fertiliser adjustments (kg P_2O_5/ha):

a) Fodder crops.

P sorption capacity	Soil P status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
PSC 1	+40	+20	0	-10	-20
PSC 2	+60	+30	0	-20	-30
PSC 3	+80	+40	+20	0	-40

b) Vegetable crops.

P sorption capacity	Soil P Status				
	Very low (VL)	Low (L)	Mod (M-)	Mod (M+)	High (H)
PSC 1	+60	+30	+15	0	-25
PSC 2	+90	+45	+20	0	-35
PSC 3	+120	+60	+30	0	-50

Stage B3. Adjustments following applications of organic manures and fertilisers

It is important that full account is taken of the N, P and K within organic materials applied immediately prior to cropping and in recent years, to optimise crop quality, economic performance and to minimise any environmental impact (for example through loss of excess P to watercourses). The amount of P and K available to the crop in the years following the application of organic materials depends on the type of material applied. Information on the P and K contents of organic materials can be found in SAC Consulting TN650 (2013) on livestock manures and slurries; and TN699 (2019) for biosolids, composts, anaerobic digestates and other industrial organic fertilisers.

Stage B4. Special crop requirements - P and K fertiliser timing and placement

Starter fertiliser - The injection of starter fertiliser containing high phosphate liquid fertiliser 2 – 3 cm below the seed or around the roots of transplants, can improve the growth and quality of crops such as bulbs and salad onions, lettuce and leeks. Starter fertiliser is particularly useful for crops grown in mixed rotations in soils with Moderate levels of P or less. No more than 60 kg P_2O_5/ha should be applied as a starter fertiliser and the amount used should be deducted from the recommended rate when applying the remainder of the P.

Root crops – High yielding root crops can take up large quantities of P and K and it is particularly important to make allowances for crop offtake when soil P or K levels are moderate (M) or lower. Where straw is used to protect carrots, it contributes approximately 1 kg P_2O_5 and 8 kg K_2O per tonne of straw applied and left in the ground. These quantities should be counted when calculating the P and K requirements of subsequent crops.

C. SECONDARY AND MINOR NUTRIENTS

Magnesium (Mg) – All crops have a requirement for magnesium, which should be applied if soil magnesium levels are low (L) or very low (VL) (see TN714, 2019). For most vegetable and minority crops, apply magnesium (MgO) at 150 kg/ha where the index is VL and 100 kg/ha where the index is L. The exception is peas and beans, where 100 kg/ha MgO should be applied where the soil index is VL and 50 kg/ha where the index is L.

Sulphur (S) - Many vegetable crops, especially brassicas, have a significant requirement for sulphur (see TN685, 2017). In situations where sulphur levels might be low, for example on light soils, following wet winters, where there has been no previous history of manure use or S-containing fertilisers, use of sulphate-containing fertilisers should be considered at, or soon after, planting. Where S deficiency has been recognised or is expected, apply 50-75 kg SO_3/ha for vegetable brassica crops (Brussels sprouts, cabbage, cauliflower and calabrese) and 25 kg SO_3/ha for all other crops.

Sodium (Na) – Several root crops including asparagus and carrots respond to sodium fertilisers, particularly on light soils. For asparagus, apply up to 500 kg/ha Na_2O per year at the end of June, but not in the establishment year. For carrots (and other responsive crops, such as beets) apply 200 kg/ha Na_2O as agricultural salt. Deeply cultivate the application into the soil prior to drilling.

Boron (B) – Some root crops, especially carrots, fodder beet, beetroot, swedes, and turnips are particularly prone to boron deficiency, especially where soil pH values are high, and/or on light sandy soils (see TN671, 2017). Cauliflowers and other brassicas can also be affected, although care must be taken to determine the true cause of symptoms, which can be caused by other factors such as bacterial disease, or uneven water supply. Deficiency is more likely below 20 mg B/kg in leaf analysis. Where soil or leaf analysis indicates a deficiency, or for susceptible crops (those mentioned above), apply boron to the seedbed (2 kg/ha B) or as a foliar spray according to manufacturer's recommendations as soon as leaf cover allows. It is usually enough to apply B once during a rotation, though if root crops, brassicas or carrots are being grown, it is advisable to apply B prior to each of these crops, regardless of whether B has already been applied in the rotation. It is not advisable to over-apply B since B toxicity can cause problems in some crops.

Copper (Cu) – Soils most at risk of copper deficiency leached sandy soils and organic and peat soils (see TN657, 2014). Copper deficiency can occasionally cause problems in some crops including carrots and onions. Problems are unlikely to occur where soil copper concentrations are maintained at values suitable for cereal production. Deficiency is more likely below 5 mg Cu/kg in leaf analysis. Leaf analysis is less reliable than soil analysis for diagnosing deficiencies. If possible, treat deficiencies with a soil-applied fertiliser prior to planting. Deficiencies can also be treated using a foliar spray of copper oxychloride or cuprous oxide.

Manganese (Mn) – Manganese deficiency can occur on many horticultural crops, though it is most seen as "Marsh spot" on peas (symptoms of brown centres in peas and chlorotic leaves). Manganese deficiency symptoms are often transient but usually seen at high soil pH, especially on dry sandy soils, soft seedbeds and/or immediately after liming. Soil analysis to predict deficiency is not reliable. Deficiency is more likely below 20 mg Mn/kg in leaf analysis.
Manganese application as a foliar spray is sometimes beneficial where symptoms occur or are thought likely.

Molybdenum (Mo) – Molybdenum deficiency is very rare, apart from on cauliflower, where it causes "whiptail" (symptoms of narrow, twisted leaves). Maintaining soil pH values greater than 6.5 is the main control, and no molybdenum applications are required.

Worked example.

A farmer intends to grow a crop of carrots in beds for a major retailer on a Sourhope Association field where the soil texture is a loamy sand; P, K and Mg Soil Status are high (H); and P sorption capacity is moderate (PSC 2) (Table C). The previous crop was seed potatoes. The carrots are to be of standard size (i.e. not baby carrots). He has grown carrots before in rotation and knows that he can obtain typical gross yields of around 100 t/ha in this field. Winter rainfall was less than 450 mm and summer rainfall were normal between the first and final spring N dressings. Regular (every 3 or 4 years), moderate applications of high quality, 0 – 10 mm PAS 100 green/food compost (made from garden and food wastes) have been made during the past 10 years. Fifteen tonnes of green/food compost were applied per hectare and worked in prior to drilling the intended carrot crop. This was analysed and was found to contain 11, 3.8 and 8 kg/ fresh tonne of N, P_2O_5 and K_2O respectively. To determine the fertiliser requirement for his crop, he will go through the following stages. Note that decisions made may be different depending on the machinery and equipment available and the experience and preferences of the individual farmer. Final recommendation is 69 kg N, 0 kg P_2O_5, 0 kg K_2O, 200 kg Na_2O and 2 kg B per hectare.

Table C. Worked example.

Stage	Decision	Fertiliser recommendation
A1	The crop to be grown is carrots and the previous crop was seed potatoes. The N recommendation (given that seed potatoes fall within previous crop or grass group 2) is 70 kg N/ha.	70
A2	There is no need to adjust the N recommendation due to low/high expected yield or unusual crop type. Summer rainfall was < 200 mm, therefore there is no need to add additional N for that reason.	-
A3	Increase N recommendation by 10% since the soil is a loamy sand.	+7
A4	Winter rainfall was < 450 mm, therefore there is no need to adjust the N recommendation for that reason.	
A5	The green/food compost contained 11 kg N/ fresh tonne, which means that 165 kg N/ha was applied. Approximately 5% (8.3 kg/ha) of this N will be available to the crop in the year of application, therefore deduct 8 kg/ha from the N recommendation (See SRUC TN699 for further details)..	-8
	Final N recommendation	**N = 69 kg/ha**
A6	Decide to split the N requirement of 69 kg/ha into two (a base dressing and top dressing once the crop canopy is established)	
B1	Soil P and K status is high, therefore crop requirements for P_2O_5 and K_2O are 90 and 90 kg/ha respectively.	90
B2	P sorption capacity is moderate (PSC 2), deduct 35 kg/ha P_2O_5.	35 kg P_2O_5/ha
B3	The green/food compost contained 3.8 and 8 kg of P_2O_5 and K_2O/fresh tonne respectively, which means that 57 and 120 kg of P_2O_5 and K_2O were applied per hectare. Since soil P and K levels are high, all the phosphate and potash should be included in the calculation of amounts applied, therefore deduct 57 kg P_2O_5 and 90 K_2O from the recommendations.	-57 kg P_2O_5/ha -120 kg K_2O/ha
	A Final P_2O_5 and K_2O recommendations	
C	No Mg is required since soil Mg status is high. Since there have been regular moderate applications of green/food compost during the past 10 years, and since carrots have no significant requirement for S, it is decided not to apply S fertiliser. Carrots have a requirement for both Na and B. The Na will be broadcast prior to ploughing and bed formation. Boron will be applied as carrots are a susceptible crop.	**Secondary and minor nutrients** **Na_2O = 200 kg/ha** **B = 2 kg/ha**

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