Knowledge grows

The Nutrition of Arable Crops

Yara's Complete Guide

Crop Knowledge

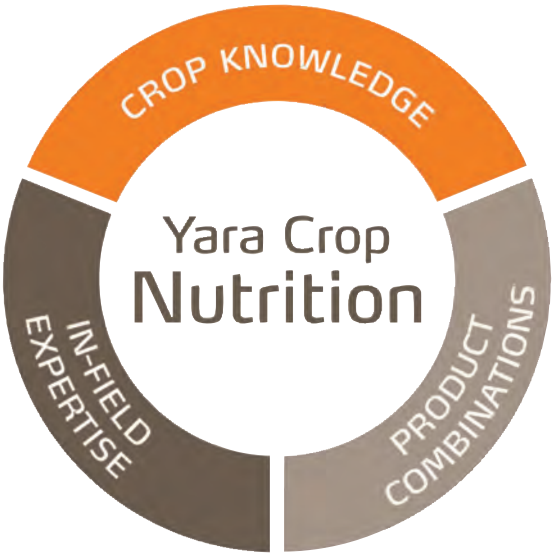
The interpretation and application of long term research trials data into robust and reliable crop nutrition programmes.

Product Combinations

Utilising Yara's range of products to provide a complete programme to meet the plant nutrition demand.

In-field Expertise

Yara has developed a range of decision making tools and analytical services that enable nutrient recommendations to be fine tuned to field specific conditions.



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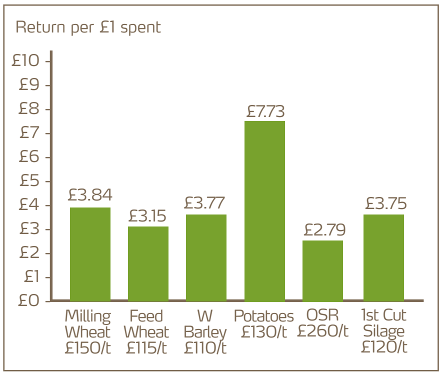
- Liquid fertilizer production and storage facility
- Solid fertilizer facility
- Foliar and micronutrient production and analysis facility
- UK Head Office

The Yara Approach to...

Nitrogen

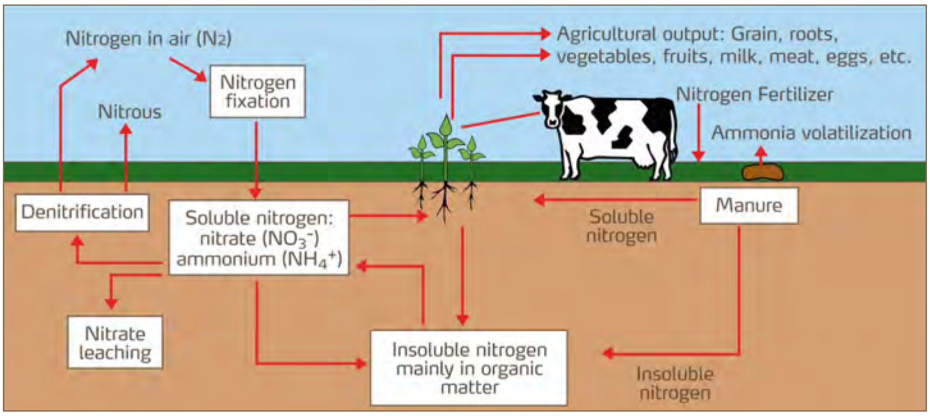
The major nutrient nitrogen is responsible for protein production and producing chlorophyll, the essential ingredient for photosynthesis and is required in the greatest quantity by many of the arable crops. It is also the key to achieving high yields, and this contributes to making it one of the highest returning inputs in arable production systems. Yara trials have shown returns of nearly £4 to over £7, depending on crop, for every £1 spent on nitrogen. Figure A.1 graphically illustrates the typical return by crop.

Figure 1. The value of fertilizer based on 34.5% nitrogen @ 80p/kg N



When nitrogen is in adequate supply, the leaves of plants appear a dark green colour, caused by a high concentration of cholorphyll. Nitrogen deficiency in plants appears as a yellowing (chlorosis) of leaves, starting on the oldest and then developing in the younger leaves if the deficiency becomes severe. Plants may also appear stunted where they are suffering from nitrogen deficiency and will tend to have fewer leaves, reaching maturity earlier than plants with adequate nitrogen.

Figure 2. The Nitrogen Cycle



The key to achieving this return is to apply the correct amount of nitrogen, from the right source at the right time. The nitrogen source is an important consideration in nitrogen efficiency.

Crops take up nitrogen in the form of ammonium and/or nitrate, therefore any other nitrogen form used (e.g. urea) requires chemical reactions in the soil before the crop can utilize it. During these reactions nitrogen can be lost from the soil as ammonia.

Yara has compared the differences between nitrogen sources in trials for more than 50 years. This extensive data set has helped in concluding that nitrate based fertilizers are the most efficient form, helping to reduce risk.

Work carried out in 2009-14, showed large losses in yield from applying urea compared to either ammonium nitrate or UAN (Figure 4). This research showed the risk of using urea where there is little rainfall following application, and how critical this is on the efficiency of nitrogen uptake. Defra studies have also indicated the importance of rainfall in reducing ammonia losses from urea. As it is very difficult to predict the weather, the use of urea introduces uncertainty increasing the risk of a poor return on the investment in nitrogen.

With a very dry spring in 2011 the differences in nitrogen uptake between urea based and nitrate based nitrogen were marked, with 9% less nitrogen in the leaf from urea applications when measured in April. At the same stage in 2010 a 2.5% difference in leaf nitrogen resulted in a 5% yield penalty at harvest.

Figure 3. Effect of nitrogen source on OSR yield (1994-2014)

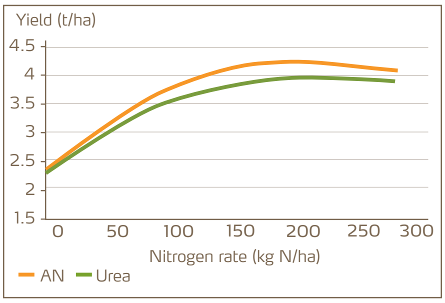
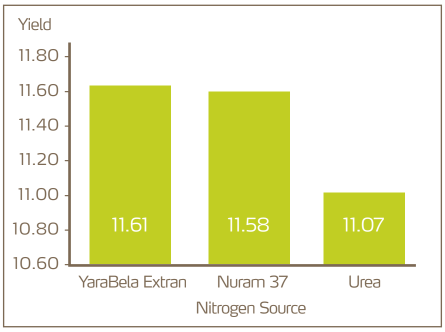


Figure 4. Comparison of different sources of Nitrogen on the yield of Wheat at 225 kgN/ha^{-1} (Yara, 2009-14)



Having chosen the correct source, knowing how much to apply to any given crop and variety is critical for success. Nitrogen is the most important nutrient, with a very complex behaviour in soils. Thus judging the correct rate can be difficult. For this reason Yara developed computer software to help with this decision. Yara's N-Plan nitrogen recommendation programme has been developed from a vast trials dataset to give crop, field, and variety specific recommendations. The system gives the economic optimum rate to apply having considered cropping history, variety, soil type, cultivation method, drilling date, rooting depth, canopy size, fertilizer and grain prices.

Having determined the rate, it is also important to carefully consider the timing of application. Yara, along with independent trials, have shown that, for winter cereals, the critical application timing for yield attainment is between GS30 and GS32 (Figure 5). The Nitrogen can be applied in two or three splits depending on crop canopy size and soil type. Lighter soils are more prone to leaching thus three applications reduce the risk of losses. These same soils tend to be less able to hold nutrient, thus small earlier applications are beneficial (Figure 6) preventing plant loss in the early spring. N-Plan includes application timings in its recommendation. The key is to satisfy the crops requirement as it grows through the spring and early summer (Figure 7).

Figure 5. Critical timing of nitrogen for yield (Levington Agriculture)

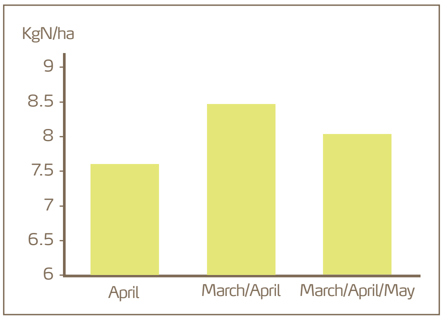
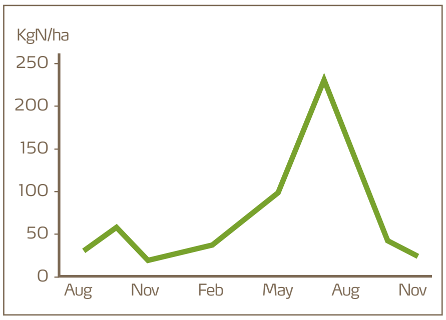


Figure 6. The effect of an early March Nitrogen application to Winter Wheat (Levington Agriculture)

Figure 7. Nitrogen demand of a Winter Wheat crop



The final aspect of Yara's approach to nitrogen is to develop well-researched technology in forms available to the farmer. Yara's R & D programme has developed the N-Sensor, a tractor mounted remote sensing device that scans the crop and adjusts the rate of application according to the crops nitrogen status and the N-Tester chlorophyll meter to help monitor the plants nitrogen status and fine tune recommendations during the growing season.

Sources of Nitrogen Losses

Leaching

Plants take up nitrogen mainly in the nitrate form, which is soluble in water and therefore susceptible to leaching when the field capacity is reached. The risk of nitrate leaching is highest in light, sandy and shallow soils as they are less capable of holding onto nutrients as excess water moves through them, washing nitrate into the groundwater. Once roots start to dry the soil in spring the risk of leaching of fertilizer nitrate is small. The previous crop can have a large impact on the leaching potential as some crops, such as oilseed rape remove only a small proportion of the nitrogen needed for growth in the harvested product, therefore the remaining nitrogen is returned to the soil and is at risk of leaching over the winter.

Although ammonium nitrogen is held by the clay particles in the soil and is therefore less prone to leaching, ammonium-N is readily converted to nitrate-N and therefore in practice has a similar risk of leaching.

Nitrate leaching is a major environmental issue, with legislation such as the nitrate directive aimed at reducing the levels of nitrate found in groundwater. Recent research has shown that at optimum applications of fertilizer, the risk of leaching is minimal.

Denitrification

Denitrification is the reverse of mineralization, where nitrate is converted to nitrogen gas and occurs when the soil is subjected to anaerobic conditions, usually in waterlogged or compacted soils. Soil organisms, short of oxygen use that from nitrate. Incomplete denitrification produces nitrous oxides, a very potent greenhouse gas.

Ammonia Volatilisation

Volatilisation is a surface problem, where ammonia is lost to the atmosphere and is mainly associated with urea and manures. Warm dry conditions after application of urea or manures increases the risk of volatilization occurring. A recent Defra funded project found that volatilization from urea on arable crops varied up to 43%, compared to that from ammonium nitrate fertilizer, which ranged from 1-5%. To reduce the risk manures should be incorporated as soon as possible after application, and urea fertilizers should not be applied when the risk is high.

Another process by which nitrogen is 'lost' from the soil is through a process known as immobilization. Through this process nitrogen is not actually lost from the soil, but is made unavailable to the crop as soil mineral nitrogen is converted back to nitrogen held in organic matter. This occurs when there is a high carbon:nitrogen ratio (a high supply of carbon-rich crop residue, such as straw). This is one of the main reasons autumn nitrogen may be needed for oilseed rape crops following a cereal where the straw is incorporated.

Soil Mineral Nitrogen

The Deep-N soil sampling service has been developed by Yara to enable farmers to accurately assess the amount of nitrogen and sulphur in the soil down to a deep of 90cm. Sampling to this depth ensures accurate recommendations based on the nitrogen and sulphur available in the whole soil profile. It is particularly valuable to measure in early spring before any fertilizer nitrogen has been applied.

Advisory Package

- Soil sampling to a depth of 90cm
- Analysis of the sample for nitrogen and sulphur
- Nitrogen and sulphur recommendation for each field

Scientific Package

- Soil sampling to a depth of 90cm, with sample divided into 30cm horizons
- Analysis of the sample for available nitrogen and sulphur
- Nitrogen and sulphur recommendation for each field

For further enquiries on soil sampling please contact either your local Yara Area Manager or contact the Deep-N service manager on:

Tel: 07775 558920
Fax: 01284 851028
Email: iain@envirofield.co.uk

SNS Index

The SNS Index can be predicted according to rainfall, soil type, and previous cropping. Refer to Figure 8 and Tables 1 to 3 for further details.

Figure 8. Annual rainfall in England and Wales

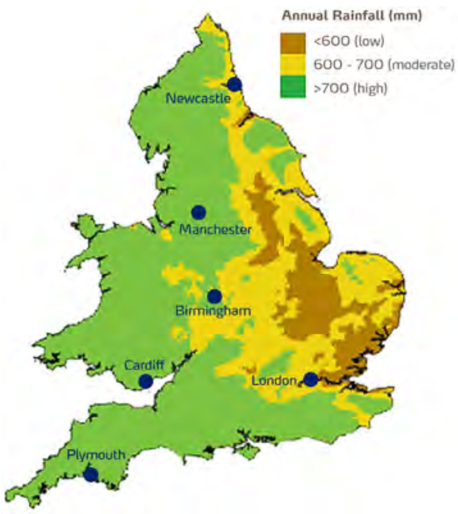


Table 1. Soil Nitrogen Supply (SNS) Indices for Low Rainfall (500-600 mm annual rainfall, up to 150 mm excess winter rainfall) - based on the last crop grown

Soil Type	SNS INDEX						
	0	1	2	3	4	5	6
	SNS (kg/ha N). SNS = SMN (0 - 90cm soil depth) + crop N + estimate of mineralisable N						
	<60	61 - 80	81 - 100	101 - 120	121 - 160	161 - 240	Over 240
Light sands or shallow soils over sandstone	Cereals, Low N veg, Forage Crops (cut)	Sugar Beet, Peas, Beans, Oilseed Rape, Potatoes, Medium N Veg, uncropped land	High N Veg	*	*	*	*
Medium soils or shallow soils not over sandstone	*	Cereals Sugar Beet Low N Veg Forgae Crops (cut)	Oilseed Rape, Potatoes, Peas, Beans, uncropped land	Medium N Veg	Medium N Veg[a]	*	*
Deep clayey soils	*	*	Cereals, Sugar Beet, Low N Veg, Forage Crops (cut)	Oilseed Rape, Potatoes, Peas, Beans, Med. N Veg[a], uncropped land	High N Veg[a]	*	*
Deep silty soils	*	*	Cereals, Sugar Beet, Low N Veg, Forage Crops (cut)	Oilseed Rape, Potatoes, Peas, Beans, Med. N Veg[a] uncropped land	High N Veg[a]	*	*
Organic soils					All crops		
Peat soils						All crops	

[a] Index may need to be increased by up to 1 where significantly larger amounts of leafy residues are incorporated.

Table 2. Soil Nitrogen Supply (SNS) Indices for Moderate Rainfall (600-700 mm annual rainfall, or 150-250 mm excess winter rainfall) - based on the last crop grown

Soil Type	SNS INDEX						
	0	1	2	3	4	5	6
	SNS (kg/ha N). SNS = SMN (0 - 90cm soil depth) + crop N + estimate of mineralisable N						
	<60	61 - 80	81 - 100	101 - 120	121 - 160	161 - 240	Over 240
Light sands or shallow soils over sandstone	Cereals, Oilseed Rape, Potatoes, Sugar Beet, Low/medium N Veg (cut)	Sugar Beet, Oilseed Rape, Potatoes, Peas, Beans, Medium N Veg, Uncropped Land	*	*	*	*	*
Medium soils or shallow soils not over sandstone	*	Cereals, Sugar Beet, Forage Crops (cut), Low N Veg	Oilseed Rape, Peas, Beans, Potatoes, Med N Veg, Uncropped Land	High N Veg	*	*	*
Deep clayey soils	*	Cereals, Sugar Beet, Low/med N Veg, Forage Crops (cut)	Oilseed Rape, Peas, Beans, Potatoes, Low N Veg, Uncropped Land	Medium N Veg	High N Veg	*	*
Deep silty soils	*	Cereals, Sugar Beet, Low N Veg, Forage Crops (cut)	Oilseed Rape, Potatoes, Uncropped Land	Peas, Beans, Medium N Veg	High N Veg	*	*
Organic soils				All crops			
Peat soils						All crops	

Table 3. Soil Nitrogen Supply (SNS) Indices for High Rainfal (over 700 mm annual rainfall, or over 250 mm excess winter rainfall_ - based on the last crop grown

Soil Type	SNS INDEX						
	0	1	2	3	4	5	6
	SNS (kg/ha N). SMN (0 - 90cm soil depth) + crop N + estimate of mineralisable N						
	<60	61 - 80	81 - 100	101 - 120	121 - 160	161 - 240	Over 240
Light sands or shallow soils over sandstone	Cereals, Oilseed Rape, Potatoes, Sugar Beet, Peas, Beans, Low/Med Veg, Forage Crops (cut) Uncropped Land	High N Veg [a]	*	*	*	*	*
Medium soils or shallow soils not over sandstone		Cereals, Oilseed Rape, Potatoes, Sugar Beet Peas, Beans, Low/Med N Veg, Forage Crops (cut), Uncropped Land	High N Veg	*	*	*	*
Deep clayey soils		Cereals, Sugar Beet Oilseed Rape, Potatoes, Low/Med N Veg, Forage Crops (cut), Uncropped Land	Peas, Beans, High N Veg	*	*	*	*
Deep silty soils		Cereals, Sugar Beet, Low N Veg, Forage Crops (cut)	Medium N Veg, Oilseed Rape, Potatoes, Peas, Beans, Uncropped Land	*	*	*	*
Organic soils					All crops		
Peat soils						All crops	

[a] Index may need to be lowered by 1 where residues are incorporated in the autumn and not followed immediately by an autumn-sown crop.

Phosphate

Phosphate is an essential nutrient for crop growth and development. It plays a major role in the energy behind many plant metabolic processes, enzyme activity and in root development. This energy is needed for the active uptake of other nutrients and even though its demand is small compared to nitrogen, its availability is essential.

The major phosphorus deficiency symptom is poor growth, normally associated early on before the roots have fully developed. Purpling round the edges of leaves is often seen in deficient plants, especially when temperatures are low. Other than stunted plants, phosphorus deficiencies can be difficult to visually diagnose in-field, therefore it may be necessary to conduct soil and or plant tissue analysis.

Years of applications in the UK have led to most soils having adequate supplies, however this should not lead to complacency. The large yields now expected from today's agriculture remove nutrients from the soil so if applications are not made, the soils reserves will decline over time.

Figure 10. Schematic diagram of the phosphorus cycle

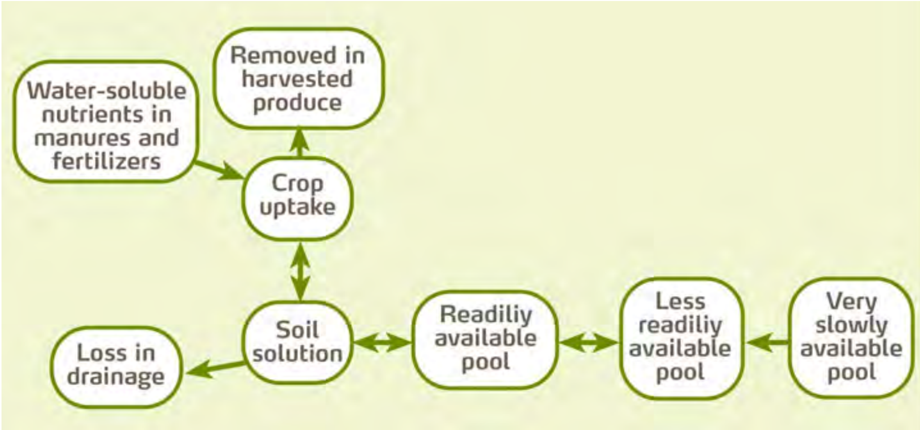


Figure 11. Phosphate uptake (kg/ha) of winter wheat (8.5t/ha)

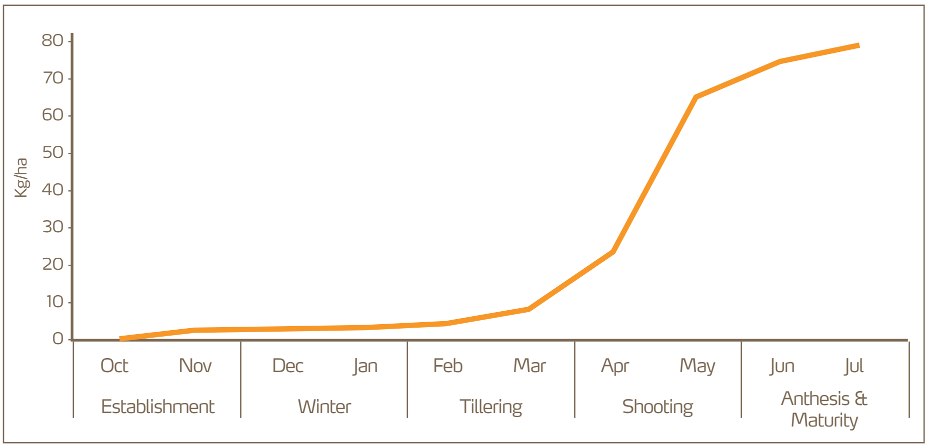
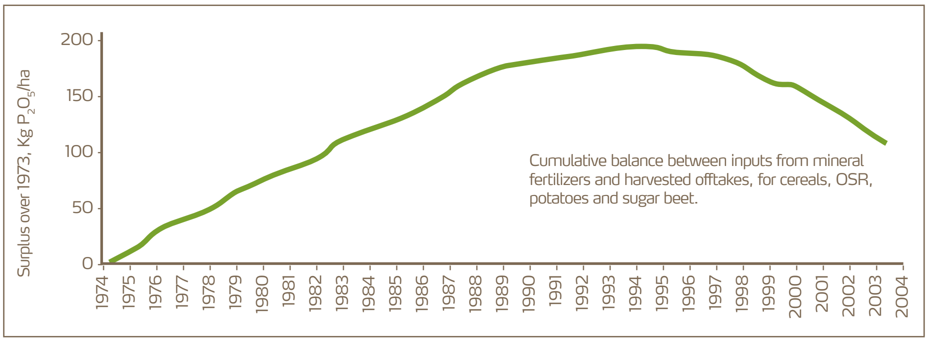


Figure 9. Cumulative phosphate balance of non-manured arable soils in England and Wales, 1974-2004 (DEFRA)



Yara recommend that at reasonable soil indices (2), applications should match rotational off take. Yara trials have shown benefits of applying phosphate in the spring rather than the auntumn so that at an Index of 1 +, adopting an 'InCrop' approach is recommended applying phosphate within a uniform compound grade with the first top-dressing in the spring.

Plants are only able to take up phosphate from soil solution, however very little phosphate in the soil is held in this form. Phosphate uptake from the soil is highest during the spring (Figure 11), however only a fraction of the stable P will be released into the soil solution. Movement of phosphate from the stable pool to the soil solution can be adversely affected by:

- low concentration of phosphate in the soil
- poor soil structure/compaction
- insufficient soil aeration
- very low or high soil pH
- low temperatures
- wet/dry periods

Polyphosphates

YaraMila™ NPKs contain 20-25% of total phosphate available as polyphosphate. The benefits of polyphosphates (PPs) against common phosphate forms are:

- PPs are less fixed in the soil
- PPs release plant available phosphate
- Prolonged phosphate supply
- Prolonged mobility of PPs allowing deeper penetration into soil
- PPs increase availability of micronutrients

Environmental Issues

Recently there has been increasing concern surrounding phosphorus losses to watercourses, as it is one of the major contributors to eutrophication. The effects of eutrophication include algal blooms, excessive weed growth, which when it dies uses oxygen from the water to decompose, killing living organisms. These effects are visually unattractive and can be hazardous to animal and human health.

Agriculture is not the main source of phosphorus pollution in watercourses in the UK, however, it only requires 0.035kg P/ha to cause problems, and therefore run-off from agricultural land is sufficient to cause eutrophication. It is therefore important to take measures to reduce the risk of phosphorus pollution.

- Full account of all nutrients supplied from organic manures should be taken into account when calculating how much inorganic fertilizer to apply.

- Phosphorus is held tightly by the soil and is therefore not leached in the same was nitrate is. The problems are caused by run-off washing soil into watercourses and solutions should therefore focus on minimising the risk of soil erosion.

- Applications of phosphate and potash on soils with an index 1+ can be made in the spring with no yield penalty. This helps to mach applications to crop demand.

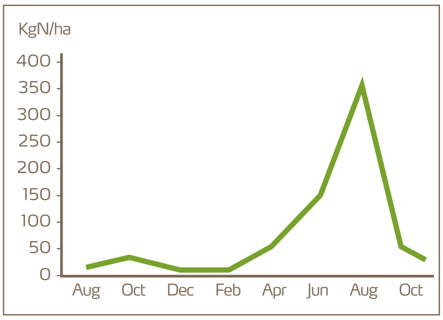
Potash

Potassium acts within the transport system of plants and has a number of important functions in plant growth including protein production and the efficiency of photosynthesis. It also affects turgor pressure in the plant helping to strengthen it, reducing lodging and making it less susceptible to disease.

Subclinical deficiency symptoms include weakened stems, which can lead to lodging, flaccid leaves and increased drought susceptibility. More severe symptoms can include scorching along leaf tips and margins.

Potassium is one of the major soil cations and is held on the charged sites of clay minerals, thus its presence in soil is largely determined by the clay content and soil texture. As with nitrogen it is taken up in large quantities by most arable crops during the rapid growth phases in spring and early summer (see nutrient uptake graph Figure 12).

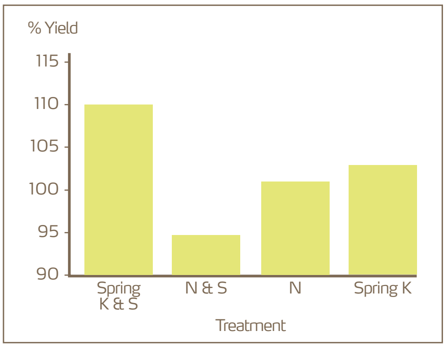
Figure 12. Potash uptake in Winter Wheat



In cereals most of the potassium will have been taken up by ear emergence. On many medium and heavy soil types, the K Index is typically 1 or above. On such sites Yara trials have shown no difference between autumn and spring application, thus an 'InCrop' approach can be adopted, applying potash as a uniform compound grade with the first top-dressing in the Spring. Recent research is focusing on the possible benefits of spring-applied potash on sites known to be deficient. 2003 trials gave improvements where potash was applied throughout the growing season to a cereal crop. (Figure 13.)

Figure 13. Response by Winter Wheat to spring applied potash

(Yara UK Ltd, 2003)

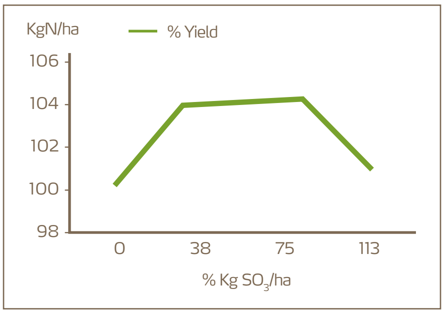


Sulphur

Sulphur is essential for protein metabolism and the functioning of enzymes. With environmental cleanup (See Figure 17) the deficiencies first seen in the 1970's are now common, especially in Oilseed Rape crops and other brassicas. The deficiency symptoms in plants are similar to nitrogen symptoms, with yellowing of the leaves, however sulphur deficiency occurs on the younger leaves first. The flowers of oilseed rape may also appear paler or white. Deficiencies in many crops are subclinical and can often give a yield response to applications of sulphur.

Yara trials conducted since 1984 have clearly demonstrated the economic benefits from applying sulphur. Application rates for cereals show that 40 – 50 kg SO3/ha is likely to be sufficient in cereals (Figure 14) whilst 75 – 100 kg SO3/ha may be required in Oilseed Rape. Sulphur is required by the plant in a sulphate form, and not as elemental sulphur, throughout March, April and May (Figure 15). Sulphate, like nitrate is leachable and care must be taken in the timing of application.

Figure 14. Response of Winter Wheat to sulphur



An application of sulphur at each nitrogen timing (little and often) is Yara's approach to alleviate any risk of inadequate supplies of sulphate being available during the grand growth phases (mid April-early June) and to avoid the risk of leaching loss, which is highest at the time of early spring applications.

Figure 15. Nitrogen and sulphur uptake graph

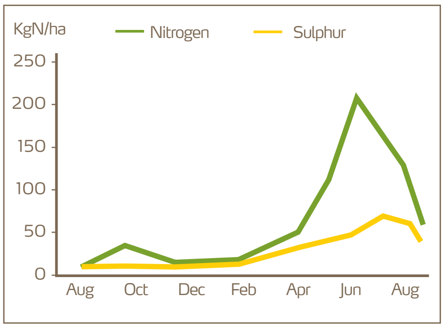


Figure 16. The value of sulphur (wheat at £85/t and OSR at £170/t)

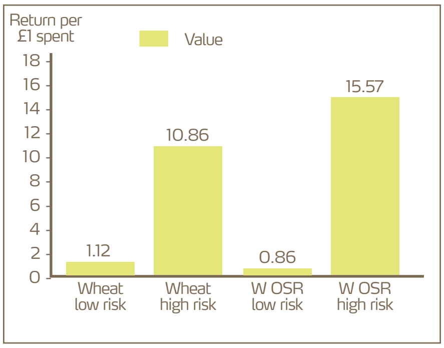
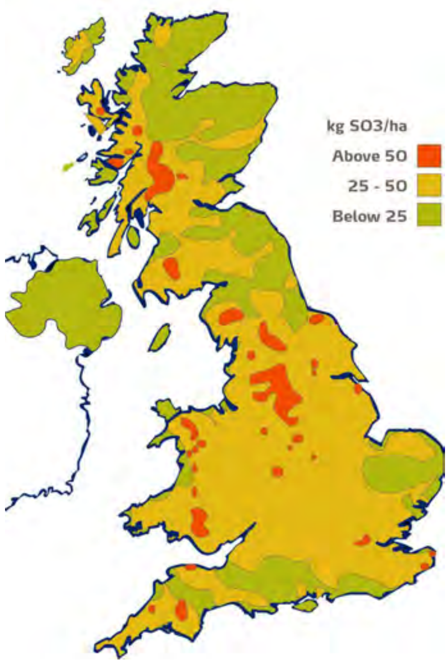


Figure 17. Sulphur deposition in the UK



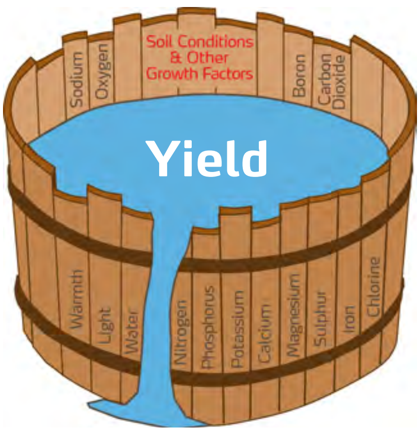
Yara have established a risk assessment method that addresses the factors that will impact on the need for sulphur. The risk assessment table below, in conjunction with the deposition map (Figure 17) is Yara's preferred approach to determining sulphur application decisions.

Risk Assessment Table		Risk factor
Soil Type	Light Medium Heavy	
Slurry/FYM Applied	This year Last year None	
Sulphur deposition (see map)	0 - 25kg SO3/ha 25 - 50kg SO3/ha >50kg SO3/ha	
Crop	Oilseed rape & Other Brassicas Winter cereals Other	
Total Score	-5 - 0 No response likely 0 - 15 Response possible but unlikely 15 - 25 Response probable	

Micronutrients

Although nitrogen, phosphate, potash and sulphur are the four main nutrients applied to agricultural crops, they are not necessarily the only nutrients that may be limiting yield. The Law of the Minimum (Figure 18) states that a crop can only grow to its most limiting factor, which could be any nutrient, or could simply be soil conditions or growth factors. Micronutrients are fundamental to profitable farming and Yara specialise in the formulation and production of micronutrients for a wide range of crops from cereals and potatoes to every kind of fruit.

Figure 18. Liegbigs Law of the Minimum



Calcium

Calcium is immobile in plants and is required for cell walls, increasing the mechanical strength of the plant. It also stimulates root and shoot development, as well as having a quality benefit in some crops such as potatoes. Where the soil pH is adequate calcium is likely to be in sufficient supply. Deficiencies can be seen as distortion of young leaves and brown spots in fruits or tubers, such as bitter pit in apples and internal rust spot in potatoes.

Magnesium

Magnesium is very important in plants as it is the central atom in the chlorophyll molecule and is therefore actively involved in photosynthesis. Magnesium also aids in protein synthesis and the activation of many enzyme systems. Deficiency symptoms generally occur on the older leaves first, showing yellowing between veins, whilst the veins remain green.

Manganese

Manganese deficiency appears as pale yellow mottling on the most recently matured leaves in cereals and oilseed rape and as discrete brown/black spots along veins of young leaves in potatoes. Usually seen in patches across a field, deficiency is aggravated by wet, cold conditions and high pH, peaty and sandy soils liming and cropping of old pastures.

Copper

Copper deficiency can be seen as a spiralling of younger leaves and a shrivelling of leaf tips in cereals. Deficiency frequently occurs following nitrogen application and on peaty and sandy soils. Ears show blind grain sites or poor grain formation.

Boron

Boron deficiency is often linked to 'lock up' of nutrient due to high soil pH conditions. Serious deficiency causes lengthwise cracking of main and secondary stems and leaf petioles with poor flowering, reduced pod set and pod fill and uneven maturity in oilseed rape crops. Sugar beet deficiency symptoms show patchy leaf yellowing with the texture of older leaves becoming rubbery. Growing points die (heart rot) and small bunches of new leaves may develop around the neck of the root.

Molybdenum

Molybdenum deficiency in oilseed rape shows as a reduced leaf blade area and extended midrib, with leaves becoming pale and limp. The result can lead to a lower pod yield compared with healthy plants

Zinc

Zinc deficiency shows as parallel yellow bands at either side of the leaf midrib. In wheat this is followed by necrotic blotches and in barley it is followed by orange/brown blotches.

Recommendations:
Cereals

Winter Wheat

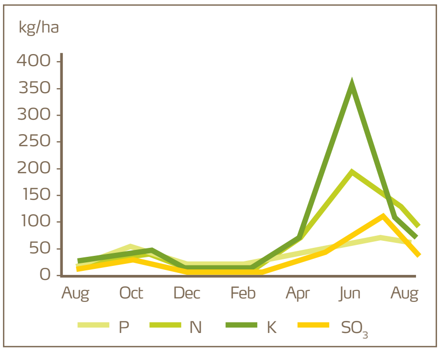
Physiological Development

The winter wheat crop has five distinct development phases all having an importance in the production of dry matter (grain and straw). The phases can be defined as follows:

1. Establishment phase, which is from germination through to early leaf development.
2. Tillering phase during which the yield potential of the crop is set. This phase ceases when the day length increases to a critical time (mid March).
3. The Grand Growth period is the rapid development stage where the tillers and mainstem elongate and the flowering head develops ready for anthesis. This period starts in mid April and lasts till early June.
4. Anthesis, or flowering when grain sites are fertilized and grain development begins.
5. Grain fill, and ripening.

Each phase has specific physiological requirements but the overall aim is to produce a canopy that intercepts as much photosynthetically active radiation as possible during May/June that will optimize dry matter production (yield t/ha). Considering each of these physiological phases in conjunction with the crop's nutrient uptake (Figure 19) helps to ensure the fertilizer programme does not compromise yield.

Figure 19. Nutrient uptake graph (kg/ha) of Winter Wheat



In the establishment phase when the crop has reached 2 leaves it will be relying on nutrient from the soil. Availability of phosphate can be an issue on low index sites (< 1) therefore fresh phosphate applied pre drilling can help to alleviate this.

During the establishment and early tillering phase the crop will need 80 – 100 kg N/ha, which in most cases can be supplied by the soil. Occasionally second wheat crops can show nitrogen deficiency in the autumn, however this is often transient and application is only required if the crop is likely to fail because of this. In Nitrate Vulnerable Zones (NVZ) approval should be sought from the local Environmental Agency office if an application is deemed necessary (see guidelines to NVZ's in Legislation section on page 21).

As the crop moves through tillering towards the Grand Growth phase demand for nitrogen, potash and sulphur begins to rise. Potash can restrict yield if the soil index is low (Index < 1) and the soil texture is light and poor at retaining nutrient. The main constraint to yield will be nitrogen deficiency, so applications need to be made to ensure adequate supplies are available to meet the 3 - 3.5 kg N/ha/day demand during late April, May and early June. Sulphate will also be needed during this phase in a ratio of 1 kg SO_3 to every 4 kgs of nitrogen.

As the crop develops towards anthesis it must have been adequately fed for yield and quality, with a requirement of 4% nitrogen in the flag leaf at flowering to achieve its full potential. This can be monitored using foliar testing or a chlorophyll meter like the Yara N-Tester (for further detail see the Precision Nitrogen management section on page 19) to fine-tune the final application of nitrogen in the growing crop.

Fertilizer Recommendations - Feed Wheat

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
P & K							
Index >1	YaraMila™ Actyva S	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Extran / Prilled N	725	6	250			
	Axan followed by	625	5	170			60
	Extran / Prilled N	250	2	80			
Index 1	Extran / Prilled N	625	5	220			
	Axan	815	6.5	220			70
Index 2	Extran / Prilled N	560	4.5	190			
	Axan	690	5.5	190			60
Index 3	Extran / Prilled N	460	3.5	160			
	Axan	600	5	160			55
Index >3	Extran / Prilled N	315	2.5	100			
	Sulphur Plus	315	2.5	100			60

If soil indices are low for P or K consider applying Super PK 24:24 @ 380 kg/ha (where straw is incorporated) or Super PK 20:30@ 450 kg/ha (where straw is removed) in the autumn.
Additional P&K may be required in the rotation, however routine soil analysis should help identify the need.

Light soils - Reduce nitrogen rates by 80-90 kg/ha
Shallow soils - Increase nitrogen rates by 20-30 kg/ha

During the growing season it is essential to monitor for other nutrient deficiencies such as manganese, magnesium, sulphur and copper, as they can all undermine and reduce the return on investment from other key elements.

The UK Energy Act of 2004 introduced a Renewable Transport Fuels Obligation (RTFO) requiring inclusion of biofuels.

Application Timing

1st Wheat	Feb / early Mar Mid April Early May Mid May / June	GS 25-30 GS 31-32 GS 32-37 GS 39-61	25% 50% 25% 40-60 kgN/ha for milling wheat
2nd Wheat	February End March Mid April	GS 25 GS 30 GS 32-37	35% 45% 20%
Continuous wheat	February End March Mid April	GS 25 GS 30 GS 32-37	25% 50% 25%
Bioethanol	March April	GS 25-30 GS 31-32	40% 60%

Where YaraMila™ Actyva S is used, apply as the first dressing and reduce total nitrogen rates from recommendations in the table above by 55 kgN/ha

Winter Barley

Physiological Development

Being a cereal, winter barley develops similarly to wheat, going through the following distinct phases:

1. Germination and establishment
2. Leaf production and tillering
3. Stem elongation
4. Pollination
5. Grain ripening

Each one of these phases represents a critical time in the plants development and agronomic requirements. The crop will produce a canopy to capture radiation that is essential for photosynthesis and accumulation of dry matter. During the first 60 days of the crops life many of the components for maximum yield will be set, with leaves, tillers, and grain sites all established.

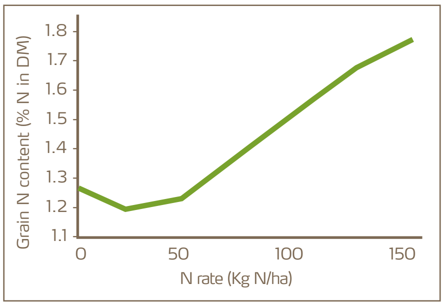
Once the stem elongation phase has started in March nutrient demand peaks with a large requirement for nitrogen and potash throughout April and May. Unlike wheat, low populations can deliver high yields, with tillers being more productive.

Optimum barley canopies are more associated with the soil's potential/ fertility and its ability to support a high plant population. Large canopies on light/poor potential soils will produce low yields of poor quality grain. It is fundamentally important to establish the correct population according to soil type, with seed rates being increased as the site potential increases.

As the stem elongates the ear develops inside the stem, emerging shortly after the flag leaf has unfolded. The later leaves, and especially the flag leaf are considerably smaller than those of the wheat plant, and therefore less productive in terms of photosynthetic efficiency. The ear (more specifically, the awns) in barley contributes 25 – 30% towards final yield with the rest coming from the final two leaves. Inputs that can protect the photosynthetic capacity of the ear/ awns and the duration of the final two leaves are essential.
Pollination begins as the head emerges from the leaf sheaths. As the grain sites are fertilized and kernal development begins, active photosynthesis is required to fill the grain. Barley is poor at remobilising previously stored photosynthate, relying heavily on the awns and final two leaves for maximum grain fill. If nutrient or water become limiting, yields will be significantly affected.

Premature senescence caused by drought, disease, etc will normally lead to poor grain quality with low specific weight and high nitrogen levels, the latter being very important when growing for a malting sample. This highlights again the need to be very aware of the market requirements and tailor inputs through timing and rates to meet these. Figure 20 below demonstrates the effect nitrogen has on the grain nitrogen level.

Figure 20. Effect of nitrogen rate on grain N content



Fertilizer Recommendations - Feed Barley

The values in the table below are approximate and have been rounded for simplicity.

	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
P & K							
Index >1	YaraMila™ Actyva S	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Extran / Prilled N	560	4.5	190			
	Axan	690	5.5	190			60
Index 1	Extran / Prilled N	460	3.5	160			
	Axan	600	5	160			55
Index 2	Extran / Prilled N	400	3	140			
	Axan	500	4	140			45
Index 3	Extran / Prilled N	315	2.5	100			
	Sulphur Plus	350	3	100			70

If soil indices are low for P or K consider applying Super PK 24:24 @ 380 kg/ha (where straw is incorporated) or Super PK 20:30@ 450 kg/ha (where straw is removed) in the autumn. Additional P&K may be required in the rotation, however routine soil analysis should help identify the need.

Light soils - Reduce nitrogen rates by 40-50 kg/ha **Shallow soils** - Increase nitrogen rates by 10-20 kg/ha

Fertilizer Recommendations - Malting Barley (up to 1.8% grain N)

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
P & K							
Index >1	YaraMila™ Actyva S	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Extran / Prilled N	460	3.5	160			
	Axan	600	5	160			55
Index 1	Extran / Prilled N	400	3	140			
	Axan	500	4	140			45
Index 2	Extran / Prilled N	315	2.5	100			
	Axan	315	2.5	100			60
Index >2	Extran / Prilled N	200	1.5	70			
	Sulphur Plus	250	2	70			50

If soil indices are low for P or K consider applying Super PK 24:24 @ 380 kg/ha (where straw is incorporated) or Super PK 20:30@ 450 kg/ha (where straw is removed) in the autumn. Additional P&K may be required in the rotation, however routine soil analysis should help identify the need.

Application Timing

Feed	Early March Late March/April	GS 31 GS 32-37	40% 60%
<1.65% Malting	Early March Late March/April	GS 31 GS 32-37	60% 40%
1.65-1.8% Malting	Early March Late March/April	GS 31 GS 32-37	40% 60%

Where YaraMila™ Actyva S is used, apply as the first dressing and reduce total nitrogen rates from recommendations in the table above by 55 kgN/ha

Light soils - Reduce nitrogen rates by 40-60 kg/ha

To ensure grain nitrogen concentrations meet the requirements of the target market careful consider-ation should be taken over nitrogen rates. Previous experience is important for deciding the rate to be used. Where premiums are expected to be low, slightly higher nitrogen rates will maximise the yield potential of the crop.

Winter Oats, Rye and Triticale

The majority of oat crops grown in the UK are winter varieties, especially in England and Wales, with more spring varieties being grown in Scotland. Oats currently account for around 4% of the total cereal area in the UK.

Being a cereal, winter oats develop similarly to both winter wheat and barley, going through the same distinct phases.

The biggest drawback with oats is the high risk of lodging, which can cause difficulties with harvesting, increase disease and lead to lower yields, therefore it is important to manage the crop carefully.

Fertilizer Recommendations - Oats, Rye & Triticale

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
P & K							
Index >1	YaraMila™ Actyva S	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Extran / Prilled N	460	3.5	160			
	Axan	600	5	160			55
Index 1	Extran / Prilled N	350	3	120			
	Axan	440	3.5	120			40
Index 2	Extran / Prilled N	260	2	90			
	Sulphur Plus	315	2.5	90			60
Index >2	Extran / Prilled N	175	1.5	60			
	Sulphur Plus	200	1.5	60			40

If soil indices are low for P or K consider applying Super PK 24:24 @ 380 kg/ha (where straw is incorporated) or Super PK 20:30@ 450 kg/ha (where straw is removed) in the autumn. Additional P&K may be required in the rotation, however routine soil analysis should help identify the need.

Light soils - Reduce nitrogen rates by 50 kg/ha

Application Timing

<100 kgN/ha	End March	100%
>100 kgN/ha	Feb / Early March End March	30% 70%

Where YaraMila™ Actyva S is used, apply as the first dressing and reduce total nitrogen rates from recommendations in the table above by 55 kgN/ha.

Cereal Crop Programme

<table>
<tr><th></th><th>Seed Treatment</th><th>Seedbed</th><th>2 - 6 leaf stage</th><th>Tillering</th><th>Growth Stage 31 - 32</th><th>Growth Stage 39</th><th>Growth Stage 55 - 69</th></tr>
<tr><td>Super PK 24 -24</td><td></td><td>375 kg/ha</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Super PK 20 - 30</td><td></td><td>438 kg/ha</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Extran</td><td></td><td></td><td></td><td colspan="2">Depending on SNS index</td><td></td><td></td></tr>
<tr><td>Axan</td><td></td><td></td><td></td><td colspan="2">Depending on SNS index</td><td></td><td></td></tr>
<tr><td>YaraVita Seedsman</td><td>3 litres/ tonne seed</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YaraVita Teprosyn Mn</td><td>3 - 6 litres/ tonne seed</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YaraVita Bortrac 150</td><td></td><td></td><td colspan="2">1 litre/ha</td><td></td><td></td><td></td></tr>
<tr><td>YaraVita Coptrel 500</td><td></td><td></td><td colspan="3">0.5 litres/ha (repeat as necesssary)</td><td></td><td></td></tr>
<tr><td>YaraVita Croplift</td><td></td><td></td><td></td><td colspan="4">2.5 - 5 kg/ha</td></tr>
<tr><td>YaraVita Gramitrel</td><td></td><td></td><td></td><td colspan="2">1 - 3 litres/ha</td><td>1 litre/ha</td><td></td></tr>
<tr><td>YaraVita Foliar Potash</td><td></td><td></td><td></td><td colspan="2">5 litres/ha</td><td></td><td></td></tr>
<tr><td>YaraVita Liquid Manganese 15%</td><td></td><td></td><td colspan="3">3 litres/ha (repeat as necesssary)</td><td></td><td></td></tr>
<tr><td>YaraVita Magflo 300</td><td></td><td></td><td colspan="3">2 - 4 litres/ha</td><td colspan="2">2 litres/ha</td></tr>
<tr><td>YaraVita Magphos-K</td><td></td><td></td><td></td><td>5 litres/ha</td><td></td><td></td><td>5 litres/ha</td></tr>
<tr><td>YaraVita Mancozin</td><td></td><td></td><td colspan="3">1 -2 litres/ha</td><td></td><td></td></tr>
<tr><td>YaraVita Mancuflo</td><td></td><td></td><td colspan="3">1 -2 litres/ha</td><td></td><td></td></tr>
<tr><td>YaraVita Mantrac Pro</td><td></td><td></td><td colspan="3">1 litre/ha (repeat as necesssary)</td><td>0.25 litres/ha</td><td></td></tr>
<tr><td>YaraVita Mantrac DF</td><td></td><td></td><td colspan="3">3 kg/ha (repeat as necesssary)</td><td></td><td></td></tr>
<tr><td>YaraVita Safe - N 300</td><td></td><td></td><td></td><td colspan="4">10 - 20 litres/ha</td></tr>
<tr><td>YaraVita Sulphur F3000</td><td></td><td></td><td></td><td colspan="2">5 litres/ha</td><td colspan="2">5 litres/ha</td></tr>
<tr><td>YaraVita Zintrac 700</td><td></td><td></td><td colspan="3">1 litre/ha (repeat as necesssary)</td><td></td><td></td></tr>
<tr><td>Nufol</td><td></td><td></td><td></td><td></td><td></td><td></td><td>150 - 200 litres/ha</td></tr>
</table>

Soil applied products   Foliar applied products

Spring Cereals

Spring cereals are grown on a smaller acreage than winter cereals in the UK with areas often fluctuating with seasonal weather. If autumn establishment is poor, then the area devoted to these crops increases as winter cereals are replaced. The area is also often concentrated where root crops are in the rotation, such as Sugar Beet and Potatoes, where the later lifting of these crops does not always allow for good winter cereal establishment. With the lower yield potential of spring cereals, achieving good grain quality for premium market opportunities is a key aspect that should be focussed on in their management.

Physiological Development

The growth and development of the spring cereal crop follows the same pattern as winter varieties, but concentrated in a much narrower growth window. The other fundamental difference is that they have no need for experiencing cold temperatures (vernalisation) to trigger the move from vegetative growth (leaf and tiller production) to sexual development (stem elongation). With the short season, establishment is critical to achieve a large Green Area Index (GAI) as soon as possible to capture the light through May/June/July. Good seedbed preparation following a root crop is important, together with an early fertilizer programme to encourage vigorous

Fertilizer Recommendations - Spring Wheat (Most soils)

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed	YaraMila™ Actyva S *followed by*	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Prilled N / Extran or	450	3.5	155			
	Axan	575	4.5	155			50
Index 1	Prilled N / Extran or	360	3	125			
	Axan	460	3.5	125			40
Index 2	Prilled N / Extran or	275	2	95			
	Axan	350	3	95			30
Index >2	Prilled N / Extran or	180	1.5	65			
	Axan	225	2	65			45

Top-dressing	Mid April / Early May
Light soils	Reduce nitrogen rates by 50kg/ha
High SNS index	Apply YaraMila™ New 52 in seedbed (375 kg/ha) to provide 80 kgN/ha, 30 kg P_2O_5/ha and 40 kg K_2O/ha
Low K soils	Replace YaraMila™ Actyva S with YaraMila™ Maincrop (400 kg/ha) to provide 55 kgN/ha, 55 kg P_2O_5/ha and 85 kg K_2O/ha
Late drilled	Apply all nitrogen in seedbed

Fertilizer Recommendations - Spring Feed Barley (Most soils)

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed	YaraMila™ Actyva S *followed by*	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Prilled N / Extran or	300	2.5	105			
	Axan	375	3	105			35
Index 1	Prilled N / Extran or	250	2	85			
	Axan	315	2.5	85			30
Index 2	Prilled N / Extran or	180	1.5	60			
	Axan	200	2	60			20

Top-dressing	GS 13-25 Early April to Early May (apply remaining nitrogen prior to stem extension)
Light soils	Reduce nitrogen rates by 40-60 kg/ha
Low K soils	Replace YaraMila™ Actyva S with YaraMila™ Maincrop (400 kg/ha) to provide 55 kgN/ha, 55 kg P_2O_5/ha and 85 kg K_2O/ha

Fertilizer Recommendations - Spring Malting Barley (Most soils)

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed	YaraMila™ Actyva S *followed by*	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Prilled N / Extran or	250	2	85			
	Axan	315	2.5	85			30
Index 1	Prilled N / Extran or	200	1.5	65			
	Axan	250	2	65			20

Top-dressing	GS 13 End March
Light soils	Reduce nitrogen rates by 40-50 kg/ha
SNS Index 2	Increase rate of YaraMila™ Actyva S to 450 kg/ha to provide 70 kgN/ha, 65 kgP_2O_5/ha, 65 kg K_2O/ha and 30 kgSO_3/ha
Low K soils	Replace YaraMila™ Actyva S with YaraMila™ Maincrop (400 kg/ha) to provide 55 kgN/ha, 55 kgP_2O_5/ha and 85 kg K_2O/ha
All N in seedbed	Apply YaraMila™ New 52 at 250-620 kg/ha (2-5 bags/ac)

To ensure grain nitrogen concentrations meet the requirements of the target market careful consideration should be taken over nitrogen rates. Previous experience is important for deciding the rate to be used. Where premiums are expected to be low, slightly higher nitrogen rates will maximise the yield potential of the crop.

Fertilizer Recommendations - Spring Oats, Rye and Triticale

The values in the table below are approximate and have been rounded for simplicity.

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed	YaraMila™ Actyva S *followed by*	350	3	55	50	50	25
YaraBela™ Nitrogen							
Index 0	Prilled N / Extran or	250	2	85			
	Axan	315	2.5	85			30
Index 1	Prilled N / Extran or	180	1.5	60			
	Axan	200	2	60			20

Top-dressing	GS 13 End March
Light soils	Reduce nitrogen rates by 40-50 kg/ha
SNS Index 2	Increase rate of YaraMila™ Actyva S to 450 kg/ha to provide 70 kgN/ha, 65 kg P_2O_5/ha, 65 kg K_2O/ha and 30 kgSO_3/ha
Low K soils	Replace YaraMila™ Actyva S with YaraMila™ Maincrop (400 kg/ha) to provide 55 kgN/ha, 55 kg P_2O_5/ha and 85 kg K_2O/ha
All N in seedbed	Apply YaraMila™ New 52 at 250-620 kg/ha (2-5 bags/ac)

Oilseeds

Winter Oilseeds

The oilseed crop features in many UK arable rotations to provide a valuable 'break crop' and its early harvest allows for timely establishment of following crops. Being a broadleaved crop, it assists with weed control and prevents carryover of such cereal diseases as 'Take All'. Plant breeding has produced a diverse choice of varieties ranging from conventional lines to full hybrids. Not only has breeding led to agronomic improvements, but also to varieties suited for different markets, e.g. industrial uses.

Physiological Development

Winter oilseed has a large yield potential. Some varieties in trials have achieved yields of 7.5 t/ha whilst currently 'on farm' figures average 3.5 t/ha and at best 5 t/ha suggesting there is scope for a better contribution to the farm business from this crop. The physiological basis for yield is producing a leaf canopy that will intercept radiation, allowing maximum photosynthesis and yield development. The components of yield are the number of pods /m^2 and the number of seeds/pod, which are both strongly influenced by the plant population. In the management of the crop careful consideration should be given to all aspects that influence canopy size and structure. The crop will go through some key stages of development as follows:

1. Establishment
2. Leaf and floral initiation.
3. Stem elongation
4. Flowering
5. Ripening

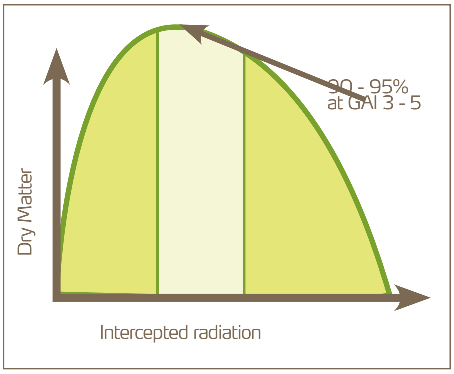
Seedbed nutrition is essential. On soils with a low index of phosphate and potash (Index 0) seedling growth will be affected and fresh applications should be made pre drilling. With more straw being incorporated, young plants often come under nutrient stress as bacterial breakdown of the straw utilizes nitrogen normally available to the developing crop, leaving a transient deficiency. An open crop will often result, exposing it to risk of pigeon attack so this could be addressed by the application of a compound fertilizer (N P and K) or nitrogen in the seedbed.

Like all brassicas, the oilseeds plant has a very high sulphur requirement and sufficient sulphur must be applied to meet the demand. Typically oilseeds require applications of approximately 1kg SO_3 with every 2kg N/ha. In addition to the major elements mentioned, some key micronutrients are important, namely boron, managanese and magnesium. Boron is a key nutrient for the oilseed crop which should be incorporated into any programme at the key timings in autumn and spring.

Canopy Management

Research has shown that the optimum Green Area Index for oilseeds is between 3.5 and 4 at flowering (figure 21). At very high canopy levels competition between plants and shading can give rise to a very inefficient canopy with large amounts of respiration using up energy from photosynthesis that should normally be contributing towards final yield. Large canopies produce a large number of pods but a high pod density gives a low number of seeds/pod. This is why the very forward, large canopy crops very often give a disappointing performance.

Figure 21 Schematic representation of the relationship between canopy size, intercepted radiation and dry matter (yield) for oilseeds.



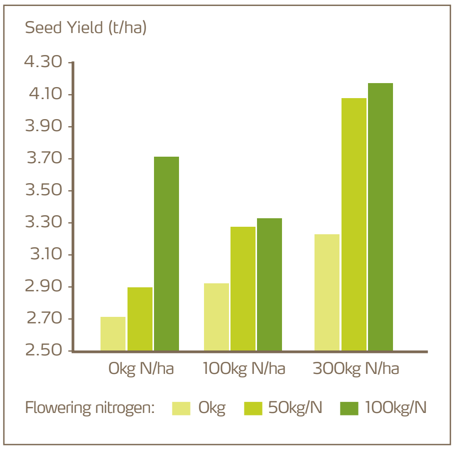
It is important to consider all aspects of agronomy that will enable control of the canopy size, including seed rate, drilling depth, seedbed nutrient availability, spring nitrogen application rates and timing, and growth regulators.

The established crop will grow throughout the winter months, initiating flower buds ready for spring, and then start to elongate as it moves through March, with flowering commencing mid April. A good crop will have accumulated around 80 kg N/ha in its canopy by January. To reach the optimum GAI of 3-4 the crop will need to contain 175 to 200kg N/ha. Spring nitrogen applications should be aimed at applying the balance of what is needed, taking soil nitrogen reserves into account. Efficiency of nitrogen uptake needs to be considered when calculating inorganic fertilizer requirements, with book values varying from 55% on shallow soils over chalk and limestone, to 70% on light sand soils with all other soils at 60%. However caution is required when using this calculation as actual efficiencies can vary greatly in-field.

Once February starts, it is important to consider the canopy size in terms of nutrient application as too much nitrogen too early can encourage a large canopy to be too big. A low dose in mid- February will ensure adequate supplies are in place for early spring growth, this may also be coupled with some phosphate as in cold, late winters phosphate supply can restrict early spring development. As the crop establishes through March, April and May adequate supplies of nitrogen and sulphur need to be in place to optimise yield.

The oilseed crop has two canopies: the leaf and pod; both need to be considered. Applying all nutrient early in the season could leave the nitrogen and sulphur supply short by the time the pod canopy is developing in June/July. This can be dealt with via an application of Nufol towards the end of flowering, or where liquid applications are not an option, through delaying the final nitrogen application as long as practically possible into April. A trial conducted on behalf of Yara in 2008 showed the benefits of applying Nufol post flowering on plots fertilized both sub and supra optimally in spring (figure 22).

Figure 22. Relationship between canopy size, intercepted radiation and dry matter (yield) for oilseeds



The crop's yield potential will also affect the fertilizer requirement, as the Fertiliser Manual recommendations indicate, suggesting that for every 0.5t/ha above 3.5t/ha up to 4.5t/ha, an additional 30kg/ha should be applied. It is important to aim at a realistic yield for the season and site.

Fertilizer Recommendations - Autumn

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
YaraBela™ Nitrogen							
SNS Index 0-3	Extran / Prilled N	90	0.75	30			

Fertilizer Recommendations - Spring

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
P & K							
Index >1	YaraMila™ Actyva S	375	3	60	53	53	25
YaraBela™ Nitrogen							
Index 0	Sulphur Plus *followed by*	550	4.5	160			110
	Extran / Prilled N	175	1.5	60			
Index 1	Sulphur Plus *followed by*	500	4	150			100
	Extran / Prilled N	115	1	40			
Index 2	Sulphur Plus	550	4.5	160			110
Index 3	Sulphur Plus	400	3.5	120			80
Index >3	Sulphur Plus	275	2	80			55

If soil indices are low for P or K consider applying Super PK 24:24 @ 380 kg/ha (where straw is incorporated) or Super PK 20:30 @ 450 kg/ha (where straw is removed) in the autumn. Additional P&K may be required in the rotation, however routine soil analysis should help identify the need.

Application Timing

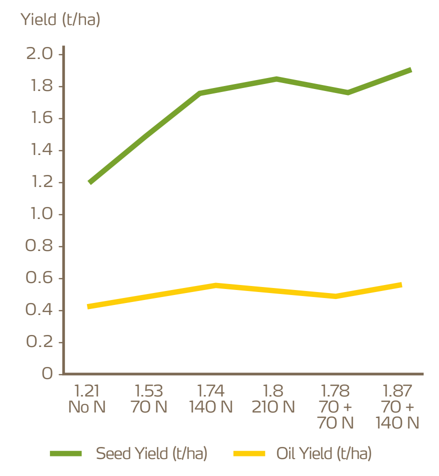
< 100 kg/ha	February – Early March
100-200 kg/ha	40% February – Early March 60% Mid – End March
>200 kg/ha	30% February – Early March 50% Mid March 20% Early April

Where YaraMila™ Actyva S is used, apply as the first dressing and reduce total nitrogen rates from recommendations in the table above by 60 kgN/ha

Spring Oilseeds

Spring oilseeds follow a similar development pattern to the winter crop but has a much shorter time frame, going from drilling to harvest in 7 months. The yield potential for the spring crop is much lower and is largely determined by seasonal weather conditions. Nutrient work in spring rape has been limited in recent years but findings from Yara's R & D programme shows it to respond well to nitrogen (Figure 23).

Figure 23. Effect of N treatments on yields of Spring Oilseed



Physiological Development

The key to success with the spring oilseeds crop is rapid establishment, with no check in early growth. Early drilling in Feb is often practised, although this does put the crop at potential risk to adverse weather conditions. Early drilling rarely leads to a yield benefit and delaying to mid March when soil temperatures are warmer will often give a more uniform establishment. Spring oilseed plants do not branch like winter oilseeds so seed rates need to reflect this. As with the winter crop, achieving ground cover as soon as possible will enable the canopy to capture light and produce dry matter (yield). It is therefore important to ensure that the nutrient supply from the soil is adequate, and that applications of nitrogen and sulphur are sufficient to meet the demands of vigorous spring growth.

Fertilizer Recommendations - Spring Oilseeds

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed	YaraMila™ Actyva S *followed by*	375	3	60	40	50	
YaraBela™ Nitrogen							
Index 0	Sulphur Plus	315	2.5	90			65
Index 1	Sulphur Plus	200	1.5	60			40

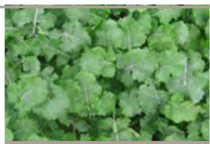
Light soils - Reduce nitrogen rates by 30-40 kg/ha

All N in seedbed - Apply YaraMila™ New 52 at up to 700 kg/ha

Fertilizer Recommendations - Spring Linseed

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed							
YaraBela™ Nitrogen							
Index 0	YaraMila™ New 52	475	4	100	40	50	
Index 1	YaraMila™ New 52	375	3	80	30	40	

Oilseed Rape Crop Programme					
	Seedbed	4 - 6 leaf stage	Stem extension	Start of flowering	During flowering
Super PK 24-24	205 kg/ha				
Super PK 20-30	250 - 312 kg/ha				
Extran	94 kg/ha		Depending on SNS index		
Axan			Depending on SNS index		
YaraVita Teprosyn Mn	Up to 22 litres/t				
YaraVita Bortrac 150		3 litres/ha	3 litres/ha		
YaraVita Brassitrel Pro		3 - 4 litres/ha	3 - 4 litres/ha		
YaraVita Croplift		2.5 - 5 litres/ha			
YaraVita Foliar potash		5 litres/ha			
YaraVita Liquid Manganese 15%		3 litres/ha	3 litres/ha		
YaraVita Magflo 300		2 - 4 litres/ha	2 - 4 litres/ha		
YaraVita Magphos K		5 litres/ha	5 litres/ha		
YaraVita Molytrac 250		0.25 litre/ha	0.25 litre/ha		
YaraVita Mantrac Pro		1 litre/ha	1 litre/ha		
YaraVita Mantrac DF		3 kg/ha	3 kg/ha		
YaraVita Photrel		3 kg/ha	3 kg/ha		3 kg/ha (end of petal fall)
YaraVita Rapitrel		Up to 4 litres/ha	Up to 4 litres/ha		
YaraVita Safe-N 300		10 - 20 litre/ha	10 - 20 litre/ha		
YaraVita Sulphur F3000			5 - 10 litre/ha		
Nufol				150 - 250 litres/ha	

Soil applied products   Foliar applied products

Potatoes

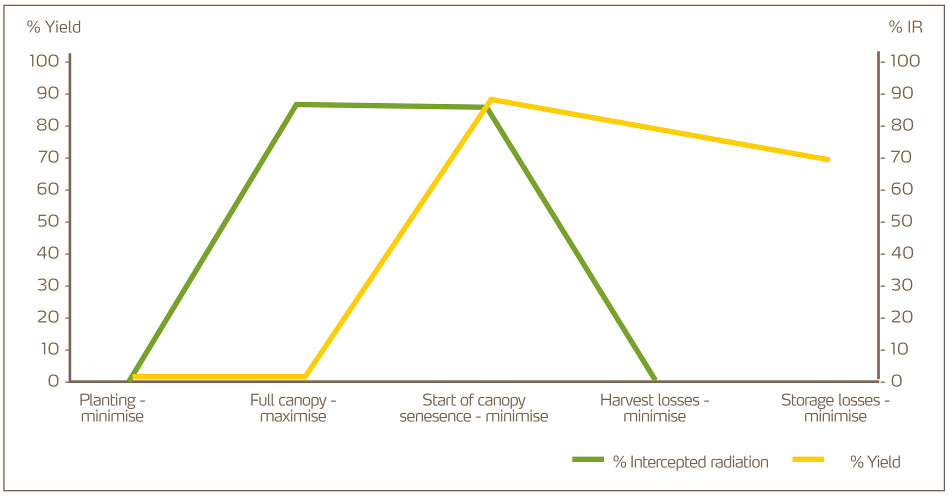
It is critical to manage crops according to their end use: seed or consumption, with a key requirement being the need to achieve crop quality, as the profitability is very sensitive to market value with poor quality tubers having very little market value. A 13% drop in the price achieved could lead to a 46% drop in Gross Margin. Quality should be the focal point to the successful management of the potato crop.

Physiological Development

At harvest the tuber is dormant, but as time progresses cell activity is resumed and buds begin to elongate as 'sprouts'. The dormant period varies by variety and is largely influenced by genetics. Dormancy can be broken using chemical treatments and adequate supplies of water. Sprout growth is largely a function of temperature with the apical bud growing first; hence sprout growth can be controlled and manipulated by temperature management in the store.

The final number of shoots will depend on when the apical sprout achieves full dominance, care must be taken at planting to avoid damage to the apical sprout, as further sprouting will resume with high numbers giving inter-shoot competition. The purpose of manipulating this phase of tuber development is primarily to influence the emergence phase of the crop growth. Following stem emergence the aim is to get a Leaf Area Index (LAI) of 4/5 as soon as possible to maximize light interception following tuber initiation and throughout the bulking phase of growth. Once canopy senescence has begun, harvest needs to be as soon as possible providing the tuber is in the correct condition. Figure 24 below schematically represents the phases of crop growth:

Figure 24. Schematic diagram concerning attainment of yield.



For the attainment of yield:

1. Minimise sprout emergence time and time to full canopy. The smaller the Leaf Area Index at tuber initiation, the slower the rate of bulking resulting in a lower final yield. Applications of large quantities of nitrogen at planting will encourage excessive haulm growth, delaying tuber initiation.
2. Maintain a canopy (LAI of 4-5) for as long as possible.
3. Minimise the time from canopy senescence to harvest.
4. Minimise storage losses.

Crop nutrition clearly has a major role, from encouraging early canopy development, to preventing skin set/maturity problems at harvest. 'Getting it right' is essential for optimising crop performance. Nitrogen is the most important nutrient with a crop taking 125 – 250 kg N/ha depending on yield, closely followed by phosphate with crops removing only 20 – 50 kg/ha. However, up to 350 kg P_2O_5/ha may be needed to support a well developed canopy. Finally, potash will be needed at up to 300 kg K_2O/ha for a 50 t/ha crop. Its role in control of osmotic potential (water movement) is vital in terms of canopy architecture to optimise photosynthetic efficiency.

Sulphur continues to be discussed with claims around scab control through manipulation of the pH around the developing tuber. Yara's own trials in 2003 and 2004 showed a transient pH effect, but no scab control was observed. Further work in 2006 demonstrated no clear evidence for sulphur improving quality, however a yield benefit was observed with YaraMila™ Complex giving the best yield and quality results.

ha for a 50 t/ha crop. Its role in control of osmotic potential (water movement) is vital in terms of canopy architecture to optimise photosynthetic efficiency.

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'Getting it right' is essential for optimising crop performance.

quality, however a yield benefit was observed with YaraMila™ Complex giving the best yield and quality results.

Fertilizer Recommendations - Potatoes

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed							
Maincrop	YaraMila™ Maincrop or	1250-1500	10-12	175-210	175-210	260-315	
- Heavy soils	YaraMila™ Universal 16 or	1000-1375	8-11	160-220	160-220	160-220	
- SOP based	YaraMila™ Complex	1375-1875	11-15	165-225	150-210	250-340	275-375
Early	YaraMila™ Universal 16 or	1000-1250	8-10	160-200	160-200	160-200	
- SOP based	YaraMila™ Complex	1000-1250	8-10	120-150	110-140	180-225	200-250
Seed	YaraMila™ Universal 16 or	750-1000	6- 8	120-160	120-160	120-160	
- SOP based	YaraMila™ Complex	750-1000	6-8	90-120	80-110	135-180	150-200
Crisping	YaraMila™ Universal 16 or	1000-1250	8-10	140-175	140-175	140-175	
- SOP based	YaraMila™ Complex	1000-1350	8-11	120-165	110-150	180-245	200-270
Tuber Initiation	YaraLiva™ Tropicote	375-500	3-4	65-85			

If top-dressing is planned, apply 60-70% of the nitrogen requirement in the base dressing and the rest at tuber initiation.

Sugar Beet

Physiological Development

Sugar Beet seeds are very small and require a fine seedbed. Establishment is slow (4-6 weeks) and every effort is needed to achieve shallow drilling to prevent capping. Plant development speeds up after 4-6 leaves have developed. Each successive leaf is bigger than its previous one, with leaves 15-20 being the largest. 4-5 leaves will be initiated each week, although this will reduce with low temperatures and poor nitrogen supply. Sugar concentrations in the developing root have very stable values, with the two most influencing factors being nitrogen supply and night temperatures. Research has shown that nitrogen deficiency can increase apparent sugar content from 12.4 to 16.8%, however the change is thought to be more associated with changes in water content, rather than an actual increase in sugar. With the harvest of roots being in the autumn cool nights and nitrogen deficiency at this stage is very likely, thus sugar concentrations increase as the autumn/winter progresses.

Fertilizer Recommendations - Sugar Beet

The values in the table below are approximate and have been rounded for simplicity

Index	Product	Rate		Nutrients			
		kg/ha	bags/ac	N	P_2O_5	K_2O	SO_3
Seedbed							
	Superbeet	400	3	70	25	10	
	YaraMila™ Complex	600	5	70	65	120	120
Total YaraBela™ Nitrogen Requirement							
Index 0	Extran / Prilled N or Axan	350 450	3 3.5	120 120			 40
Index 1	Extran / Prilled N or Axan	300 375	2.5 3	100 100			 35
Index 2	Extran / Prilled N or Axan	225 300	2 2.5	80 80			 30

Application Timing

Seedbed	70-100% depending on SNS
Top-dressing	100% emerged - Remainder

Sugarbeet Crop Programme						
	Seedbed	Before 4 leaf stage	4 - 6 leaf stage	8 - 12 leaf stage	16 leaf stage	6 weeks before harvest
YaraMila Complex	780 - 875 kg/ha					
YaraMila New 52	575 kg/ha					
Superbeet	688 kg/ha					
Extran		Depending on SNS index				
YaraVita Beetrac			5 kg/ha	5 kg/ha		
YaraVita Bortrac 150			3 litres/ha	3 litres/ha		
YaraVita Coptrel 500			0.5 litres/ha	0.5 litres/ha		
YaraVita Croplift			2.5 - 5 kg/ha	2.5 - 5 kg/ha		
YaraVita Liquid Manganese 15%			3 litres/ha	3 litres/ha		
YaraVita Magflo 300			2 - 4 litres/ha			
YaraVita Magphos K			5 litres/ha	5 litres/ha		
YaraVita Mantrac Pro			1 litre/ha	1 litre/ha		
YaraVita Mantrac DF			3 kg/ha			
YaraVita Photrel			3 kg/ha	3 kg/ha		
YaraVita Brassitrel Pro			3 litres/ha	3 litres/ha		
YaraVita Sulphur F3000			5 litres/ha	5 litres/ha		
YaraVita Zintrac 700			1 litre/ha	1 litre/ha		

Soil applied products   Foliar applied products

Yara Crop Nutrition

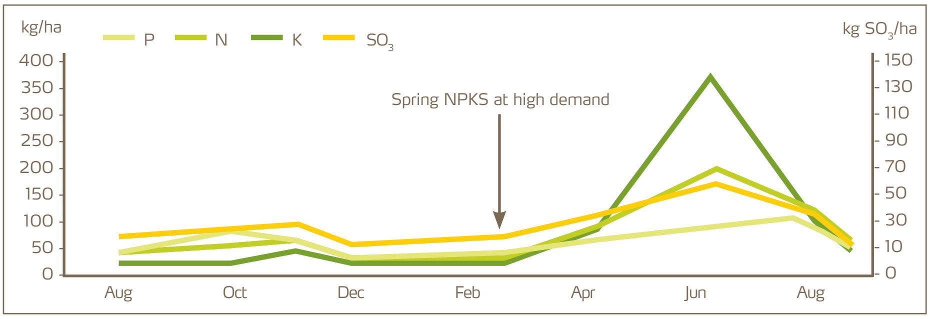
Delivering more profit through increased yield, improved quality and reduced application costs.

The traditional method of managing the major nutrients has been a very soil focused approach with less attention given to the crop regarding what and when its requirements for these nutrients are. Yara Crop Nutrition (YCN) seeks to address this imbalance, bringing all of its unique strengths in Crop Knowledge, Product Combinations and In-field Expertise together to produce a robust and reliable programme of crop nutrition that delivers the key nutrients at the times when crop demand is high.

Arable crops have their greatest demand for nutrients during the spring when rapid growth and development occurs. YCN programmes supply crop available nutrients to develop crops with large efficient root systems to explore the soil profile, and canopies to exploit incoming radiation.

During the early growth, nutrient deficiencies that impede root development must be avoided (e.g. Manganese in cereals, Boron in oilseeds). Crop available nutrients are the Crop available nutrients are the cornerstone of the YCN programme and their uptake is optimized by applications of the correct nutrient form (e.g. nitrate, phosphate, sulphate) as close to demand as possible, i.e. early spring

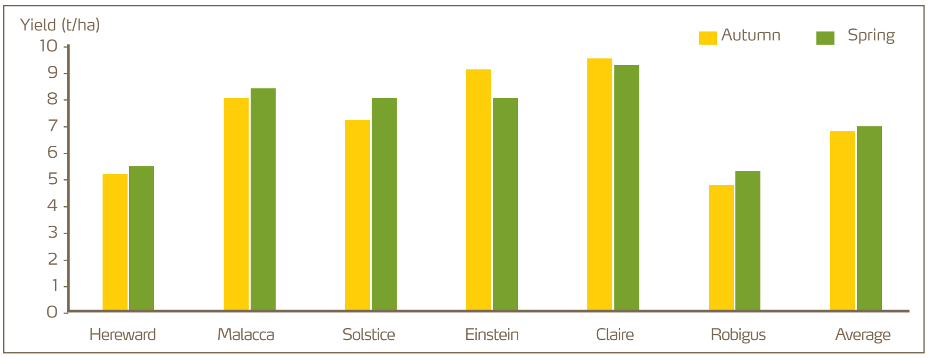
Figure 25. Nutrient uptake graph (kg/ha) of Winter Wheat



(Figure 25). The longer the time between application and crop uptake, the greater the potential for losses through leaching or fixation to soil constituents (e.g. clays and organic matter). Many soils are unable to satisfy early spring demand; therefore spring applications of essential nutrients prevent those becoming limiting factors.

Trials conducted on wheat have highlighted the benefits from a spring application of NPK compared to P&K applied in the autumn. A recent trial showed that from the wheat varieties that responded to a switch in timing there was an average 2.7% yield increase, with a response of up to 5.1% (Figure 26).

Figure 26. Comparison of Autumn and Spring P&K application in winter wheat (Yara, 2007)



Winter Wheat Crop Programme

	Growth Stage 25-30	Growth Stage 31-32	Growth Stage 32-33	Growth Stage 37	Growth Stage 39-45
YaraMila®	**ACTYVA S*** 350 kg/ha**				
YaraBela®		**AXAN*** 650 kg/ha**			**EXTRAN** 120 kg/ha
YaraVita®	**MANTRAC PRO** 1 l/ha				
YaraVita®	**MAGFLO 300** 2-4 l/ha	**MANCOZIN** 1 l/ha		**MAGFLO 300** 2-4 l/ha	
YaraVita®	**GRAMITREL** 1-3 l/ha		**GRAMITREL** 1 l/ha		

*** Alternative N+S or NPK+S grades are available as required**
**** Rate depending on SNS and N-Plan recommendation**

Read label before application of any YaraVita product

Soil applied products | Foliar applied products

Winter Oilseeds Crop Programme

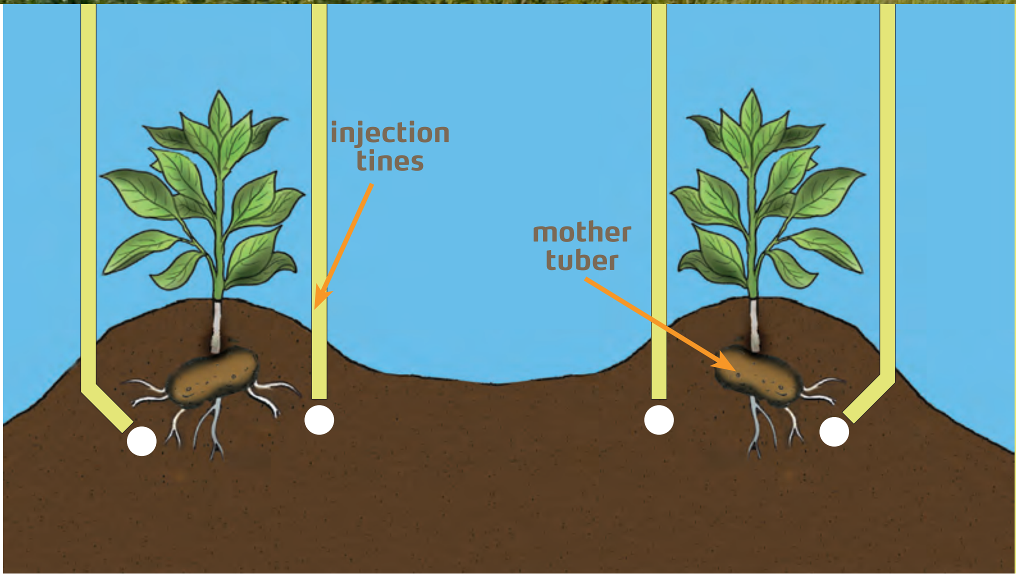
	Autumn	February	Spring	Stem extension	During flowering
YaraBela®	**EXTRAN or CAN*** **				
YaraVita®	**Bortrac 150** up to 3 l/ha				
YaraVita®				**BRASSITREL PRO** up to 4 l/ha	
YaraMila®		**ACTYVA S*** **			
YaraBela®			**SULPHUR PLUS or SULPHAN*** **		**EXTRAN*** **

*** Alternative N+S or NPK+S grades are available as required**
**** Rate depending on SNS and N-Plan recommendation**

Read label before application of any YaraVita product

Soil applied products | Foliar applied products

Potato Placement



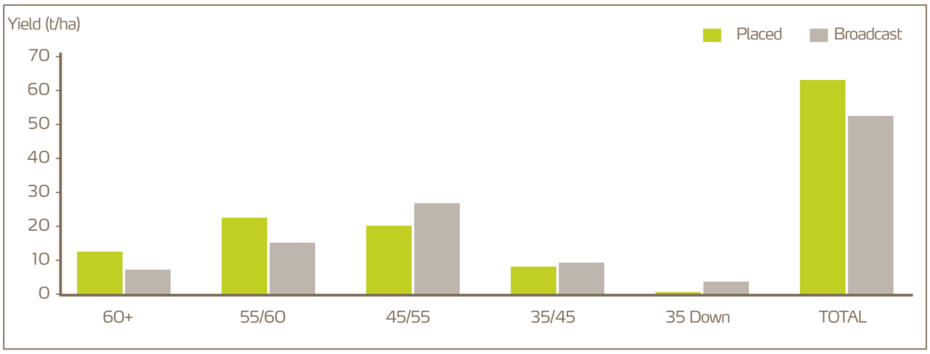
During the last 30 years the Yara Chafer liquid fertilizer placement technique has become accepted as best practice by the UK's leading growers. A controlled supply of nutrient produces both increases in marketable yield and a more even sample size.

Placement of fertilizers at planting offers:

- Improved Agronomy
- Unbeatable Accuracy through:
  - Reduced CV
  - Only applying fertilizer to cropped areas of the field
- Increased Efficiency

For more information on potato placement please refer to the Chafer Liquid Fertilizers 'Profit from Placement' leaflet. To order a copy of the brochure please email: ukagrimarketing@yara.com

Figure 27. Yield – Broadcast vs Placed (2009)



Precision Nitrogen Management

Yara has been committed to investigating and identifying methods of improving the returns on the investment made in Yara products. Our Research Centre at Haninghof in Germany continues to guide R&D projects towards developing tools that utilize new technologies available to aid nitrogen management.

From this Yara has produced a system of nitrogen management tools available to growers that improve farm profitability, and demonstrate environmental responsibility in the application of nitrogen fertilizer.

The system involves the use of three main tools that can be utilized in a three step approach:

N-Plan

N-Plan is Yara's computer based nitrogen recommendation system for the main arable crops, based on years of trials work carried out by the company, and taking into account site-specific details.

N-Sensor

The variable application of nitrogen fertilizer (solid and liquid). Suitable for farmers and growers who can variably apply nitrogen.

Crop sensing was established as a method of assessing the nitrogen status of a crop in the early 90's by measuring the reflectance from the crops canopy. This technology was developed by Yara to address the issue of 'in field' variation in nitrogen supply. The N-Sensor is now well established across Europe, and specifically in the UK. Mounted on the tractor cab, it enables nitrogen fertilizer to be applied at differing rates according to crop demand, bringing yield and quality benefits, combine performance benefits and reduced lodging.

Remote sensing has been identified as a key driver in Precision Farming. The Yara N-Sensor was originally developed for the management of nitrogen application, but has since been successfully expanded to include variable rate application of PGR's and plant protection products.

The N-Sensor determines a crop's nitrogen demand by measuring the crop's light reflectance. Using this information N-Sensor can measure the crop, translate the data into an application rate and send a signal to the spreader or sprayer rate controller, which will adjust the levels of application. The average application rate is always determined by the operator before spreading begins.

The result - improved gross margins of 3% and greater nitrogen efficiency.

The whole process of determining the crop's nitrogen requirement and application of the correct fertilizer rate happens instantaneously, with no time delay. This enables 'real time agronomy' to be possible.

N-Sensor does not have time to rely on historical information, such as past yield maps, as it uses the growing crop and its conditions at the time of application as the basis for nutrient application. This means the growing conditions of the crop that particular year can be accounted for.

The Yara N-Sensor® ALS was developed in 2006. Rather than relying on ambient light, the N-Sensor ALS has its own built in light source, increasing the working hours during the day.

N-Sensor has recently moved towards a windows based system allowing the ability to cope with much more besides just variable rate fertilizer application. The new terminals have the ability to carry out tasks such as parallel tracking and autosteer, as well as controlling drills for varying seed rates. With all the extra options beyond variable rate nitrogen application, the Yara N-Sensor is fast becoming the complete solution for precision farming.

The Yara N-Tester

N-Tester is a hand held tool, which enables quick and easy measurements to be taken through a growing crop to establish its exact nitrogen requirement.

This enables fast and accurate field specific recommendations to help fine-tune nitrogen application during the growing season (from GS 33). The result is more accurate field scale nitrogen recommendations, improving profitability and minimising environmental effect.

N-Tester operates by measuring the chlorophyll content of the leaf, as this is related to the nitrogen status of the plant. Thirty random measurements from across the field, taken using the usual 'W' pattern, give an average value that is used to indicate how much nitrogen the crop requires. Alternatively different areas of the field can be targeted, using an N-Sensor map and taking 30 samples from each area, they can be compared and rates for those areas altered accordingly.

The N-Tester measurements are strongly influenced by crop variety and growth stage. For this reason the N-Tester measurements must be calibrated to take account of this variation. The N-Tester telephone recommendation service makes this calibration procedure quick and simple. The service is a fully interactive telephone system accessible by tone phone. The service enables the user to enter information on crop variety, growth stage and N-Tester values and uses this data to give an instant nitrogen recommendation for over 50 varieties of winter wheat and winter barley.

For more details on Yara's range of decision making tools, visit our website at www.yara.co.uk/tools-and-services.

YaraMila™

The Yara brand sets the standard in fertilizer quality. The aim is to provide consistency from bag to bag, and from year to year. The majority of Yara's NPK grade range of products are true uniform compounds where all the nutrients are contained in each granule or prill which assures accurate spreading of nutrients. For easy identification, these grades are clearly branded **YaraMila™** followed by the brand name and analysis. All Yara products are formulated to the declaration and the analysis is guaranteed giving confidence that "What is on the bag is in the bag". On occasions Yara may blend some products. Yara's high quality blends are produced with size and moisture matched components to give good spreading characteristics. Some of Yara's uniform products (eg NK SULPHUR 25-0-13+7%SO_3) are formulated to not contain all three NPK nutrients. These grades do not carry the **YaraMila™** branding.

All **YaraMila™** grades are produced in Yara factories which have installed Yara's developed N_2O catalytic abatement technology - reducing our emissions by 90% - with further reductions targeted. They have a guaranteed carbon footprint < 4 kg CO_2-eqv / kg N. This in conjunction with our in-field advice means using Yara 's nitrate based fertilizers can reduce the fertilizer carbon footprint by ~ 50% (taking account of the life cycle approach (LCA) to their use).

A **YaraMila™** granule containing all nutrients

Competitor Blend Survey

Our recent competitor blender survey showed that although our activity of comparing competitor products has lead to improvements in their performance, there were still significant findings which could lead to the risk of not getting what you pay for when purchasing blends. For findings of 2010 survey please see chart Typical blended product. Any product bearing the **YaraMila™** brand is a uniform product where the analysis is guaranteed.

Typical YaraMila™ True Uniform Compound

- Consistency from bag to bag
- Consistency from year to year
- Accurate spreading
- Guaranteed analysis

To maximise the return from your investment ✓

Typical Blended Product

- 39% of analysis failed to meet the declaration
- 38% of bags underweight
- Segregation in the spreader
- Thinner liners with poor storage capability

Therefore lower yields and poorer returns ✗

YaraBela™

YaraBela™ is the term used to describe Yara's range of nitrate based fertilizers AN and CAN (with and without sulphur), providing a cost-efficient source of nitrogen to help increase growth and productivity. All YaraBela™ grades are produced in Yara factories which have installed Yara's developed N_2O catalytic abatement technology - reducing our emissions by 90% - with further reductions targeted. They have a guaranteed carbon footprint < 4 kg CO_2-eqv / kg N. This in conjunction with our in-field advice means using Yara 's nitrate based fertilizers can reduce the fertilizer carbon footprint by ~ 50% (taking account of the life cycle approach (LCA) to their use). When compared to pure ammonium or urea-based fertilizers, YaraBela™ products are significantly more effective on an equal nitrogen basis.

A well timed application of a YaraBela™ grade minimises nitrogen losses compared to straight urea or ammonium fertilizers. This in turn brings optimum return on investment.

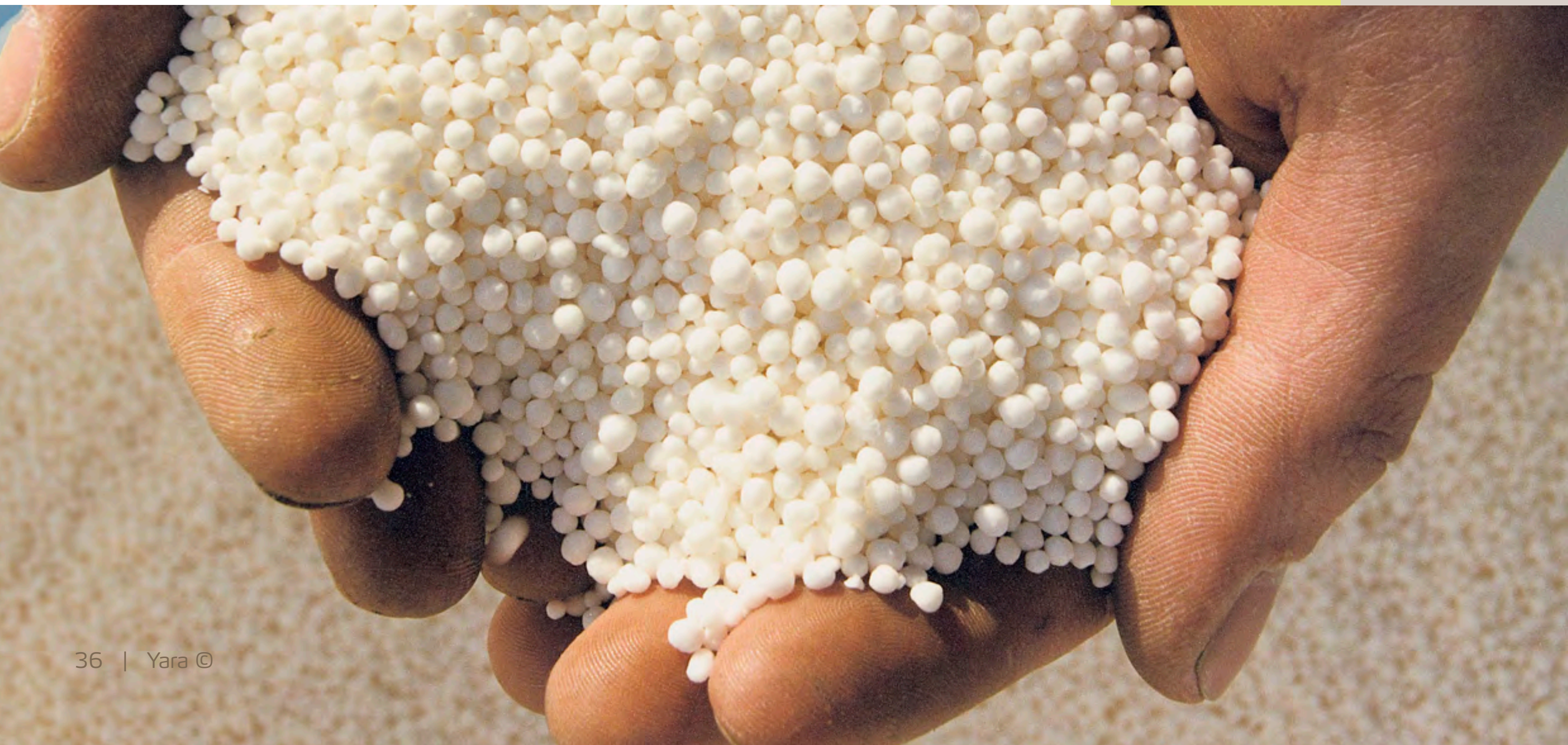
Key attributes of the YaraBela™ range of fertilizers:

1) Balanced nitrogen nutrition
- Nitrate and ammonium-N supply
- Immediate availability
- Sustained supply from ammonium
- Nitrate supports cation uptake

2) Improved soil conditions
- Reduced soil acidification compared to urea or ammonium sulphate
- Less nitrogen fixation and immobilization with nitrates

3) Reduced nitrogen loss
- Reduced N loss to ammonia emissions
- Less leaching risk when used with a correct application strategy in season
- Reduced environmental impact
- Economic benefit

4) Low carbon footprint
- due to being abated fertilizers



Legislation

Nitrate Vulnerable Zones Guide for England and Wales

Why NVZ's?

To protect fresh water from having nitrate concentrations of 50mg/ltr or greater.

Where are the NVZ's?

See the map on DEFRA' s website for the latest areas www.defra.gov.uk

Summary of Rules

Closed periods

	Arable	Grassland
Manufactured Nitrogen Fertilizers (on all soils)	1 Sept - 15 Jan	15 Sept – 15 Jan
Organic Manures (high available N)		
Sandy & Shallow soils	1 Aug - 31 Dec	1 Sept – 31 Dec
All other soils	1 Oct - 31 Jan	15 Oct – 31 Jan

Manufactured Nitrogen Closed Period Exemptions

	Max N Rate (kg / ha)
Winter Oilseed Rape	30
Grazed Grass in some dairy systems	80
Asparagus	50
Broccoli, purple sprouting broccoli	100
Cabbage, over-wintered spring	100
Cauliflowers, winter hardy / Roscoff	100
Leeks, Onions, bulb / over-wintered salad & Parsley	40

Applications of manufactured fertilizer during the closed period will be permitted to the crops in the table above at the specified rates.
There will be a cut-off date of the end of October for applications to grass and oilseeds to reflect that these crops take up very little N after this date.

Maximum Nitrogen Requirement for Crops (Nmax)

Crop	N Max Standard (kgN / ha) [a]	Standard Yield (t / ha)
Wheat, autumn or early winter sown	220 [b, c, d]	8.0
Wheat, spring sown	180 [c, d]	7.0
Barley, winter	180 [b, c]	6.5
Barley, spring	150 [c]	5.5
Oilseed rape, winter	250 [e]	3.5
Sugar beet	120	n/a
Potatoes	270	n/a
Forage Maize	150	n/a
Field beans	0	n/a
Peas	0	n/a
Grass	300 [fg]	n/a

a) An additional 80 kg N/ha is permitted to all crops grown in fields where the previous or current crop received an application of straw for mulching or paper sludge.
b) An additional 20 kg N/ha is permitted on fields with a shallow soil type (not shallow soils over sandstone).
c) An additional 20 kg N/ha is permitted for every tonne that the expected yield exceeds the standard yield.
d) An additional 40 kg N/ha is permitted to milling wheat varieties.
e) This consists of a maximum autumn application of 30 kg N/ha. If no autumn nitrogen is applied, the full 250 kg N/ha may be applied in the spring. The spring application can be increased by up to 30 kg N/ha for every half tonne that the expected yield exceeds the standard yield.
f) An additional 40 kg N/ha is permitted to grass that is cut at least 3 times in a year. From 1st January 2012, the N max rate for grass drops to 300 kg N/ha. Where grass is grown to achieve a protein content of at least 16% of the dried product, nitrogen may be applied up to the level recommended by a FACTS advisor. A FACTS advisor may recommend no more than 700 kg N/ha per year if the grass is irrigated, and 500 kg N/ha per year if the grass is not irrigated. In addition, for the second and subsequent years, the FACTS advisor must be supplied with soil analyses from representative autumn soil samples (taken between 1 Sept and 31 Oct) to be incorporated into the calculation of N demand.
g) An additional 40 kg N/ha is permitted to grass cut at least 3 times in a year.

Whole Farm Manure N Loading Limit

Livestock manure loadings shall not exceed 170 kg/ha of total nitrogen each calendar year averaged over the farm This limit applies to:

- All livestock manures, including those deposited by grazing animals
- All the agricultural land on the farm, located within the NVZ boundaries
- All farms using livestock manures, whether producing them or importing them

It should be noted that:

- Areas of woodlands, roads and hardstanding must be excluded from the calculation of land available for spreading
- Imports and exports of manure must be taken into account
- Standard manure N production figures must be used

The field limit for organic manures is 250 kg/ha total Nitrogen (not including grazing deposits)

Slurry Storage

Farms that produce livestock manures with high available N (>30%) content must provide the following storage capacity requirements:

- Pig Slurry: 6 months
- Other Livestock Slurry: 5 months

Dirty water (rainwater or wash water) is not regarded as slurry and should be collected separately to reduce slurry quantities

Manure Storage

Poultry litter and solid manures with low readily available N content (<30%) must be stored in an appropriate manner:

- In the livestock house
- On concrete constructed to the appropriate standard
- At a suitable temporary field site
  - Not within 50m of a spring/well /borehole
  - Not within 10m of a watercourse/ field drain
  - Not located in a single position for greater than 12 months
  - There must be a 2 year gap before returning to the same field site

Spreading Controls

- Do not apply fertilizer or organic manures when the soil is:
  - Waterlogged, frozen, flooded or snow covered
- Do not apply nitrogen fertilizer or organic manures to steeply sloping fields (an incline >12° / 20% / 1 in 5)
- Do not apply nitrogen fertilizer within 2m of a watercourses
- Do not apply organic manures within 10 metres of a watercourse
- Do not apply organic manures within 50 metres of a spring / well / borehole
- Do spread fertilizers and organic manures evenly and accurately
- Do keep records for at least five years covering all necessary aspects

N.B. This is only a guide;
full details of the rules are available at www.defra.gov.uk

Nitrate Vulnerable Zones for Scotland

Closed periods

	Arable	Grassland
Manufactured Nitrogen Fertilizers		
Aberdeenshire, Banff, Buchan, Moray	1 Sept – 20 Feb	15 Sept – 20 Feb
Other NVZ area	1 Sept – 15 Feb	15 Sept – 15 Feb
Organic Manures (high available N)		
Sandy & Shallow soils	1 Aug – 31 Dec	1 Sept – 31 Dec
All other soils	1 Oct – 31 Jan	15 Oct – 31 Jan

Organic manures with high available N content may only be applied to bare ground and stubble during the months of July, August and September if the land to which it is applied is drilled with a crop within 6 weeks of the first application.

A period of at least 3 weeks must elapse between each completed application of livestock manure to an area on the farm.

Maximum Nitrogen Requirement for Crops (Nmax)

The amount of nitrogen fertilizer applied on the farm to any crop must not at any time exceed the maximum figure allowed for the crop type.

The tables included below show the maximum nitrogen application by crop based on the standard yield in that table for:
a) The crop grown immediately previously;
b) soil type; and
c) any other relevant adjustments al lowed, if selected for inclusion

The relevant adjustments relate to some crops with a predicted yield above the standard yield, milling wheat varieties and high grain N distilling varieties.
For calculating maximum nitrogen applications for grassland, it is first necessary to identify the site class, based on:
a) soil type and
b) average rainfall (April-September)

For each crop grown on the farm, a total sum of all the individual maxima needs to be calculated , to show the overall maximum nitrogen figure which may be applied to each crop on the farm.

Fertilizer and manure management Plan

Before 1 March each year, a fertilizer and manure management plan must be prepared in respect of the farm for that year.

The purpose of the plan is to assess the crop requirement for nitrogen fertilizer for each crop on each year and to establish the quantities of livestock manure produced and safe methods of collection, storage and land-application.

No nitrogen fertilizer is to be applied to any crop in any year prior to the calculation being completed for that crop and that year.

Annual Farm & Field Limit of Nitrogen in Livestock Manure

In any year the total nitrogen in livestock manure applied to the utilisable agricultural land area of the whole farm, whether directly by an animal or by spreading, must not exceed 170 kg/ha of that area.

Organic manure shall not be applied to any field where the application would result in the total nitrogen contained in organic manure applied in any 12 month period to any field exceeding a rate of 250 kg/ha excluding that deposited by animals whilst grazing.

Minimum nitrogen available to crop from livestock manure

In calculating the overall quantity of nitrogen fertilizer which may be applied, the percentage of nitrogen taken up by the crop from livestock manure should be calculated using the appropriate figures for manure type, method of application, total nitrogen content of the manure, percentage of dry matter in the manure and soil type.

Slurry Storage

A farm must have capacity to store the total quantity of slurry likely to be produced by housed pigs or housed cattle and manure from housed poultry calculated by adding up the total figures produced for each type of livestock.

Manure Storage

Storage of solid manure must-
- be only on an impermeable surface which prevents drainage to the water environment and either-

a) be covered by a waterproof covering; or
b) have a run-off facility with a means of collecting, storing and recovering run-off water and particulate matter.

Temporary sites must not be stored in any field heap for more than 12 consecutive months.

Spreading Controls

- **Do not** apply fertilizer or organic manures when the soil is:
  - Waterlogged, frozen, flooded or snow covered
- **Do not** apply nitrogen fertilizer or organic manures to steeply sloping fields (an incline >120 / 20% / 1 in 5)
- **Do not** apply nitrogen fertilizer within 2m of a watercourses
- **Do not** apply organic manures within 10 metres of a watercourse
- **Do not** apply organic manures within 50 metres of a spring / well / borehole
- **Do** spread fertilizers and organic manures evenly and accurately
- **Do** keep records for at least five years covering all necessary aspects

Fertilizer Storage

The 10 Point Plan
This advice has been developed by the Agricultural Industries Confederation (AIC), National Farmers Unions and the National Counter Terrorism Security Office (NaCTSO).

1. **Do not** store fertilizer where there is public access
2. **Do not** leave fertilizer in the field overnight
3. **Do not** store fertilizer near to, or visible from, the public highway
4. **Do not** sell fertilizer unless the purchaser is personally known by you to be a bona-fide farmer user and is aware of the need to follow this guidance
5. **Do** record fertilizer deliveries and usage
6. **Do** wherever possible, and with regard to HSE safety guidance, store fertilizer inside a locked building or compound
7. **Do** fully sheet fertilizer stock stored outside and regularly check to ensure that the stack has not been tampered with
8. **Do** carry out regular stock checks
9. **Do** report immediately any stock discrepancy or loss to the police
10. **Do** record any manufacturers code numbers from the bags and if available the number of the detonation resistance test certificate

Storekeeping

No fertilizer should be stored within 10 metres of a watercourse or field drain and 50 metres from a borehole, well etc

- where possible fertilizer should be stored undercover
- for stability, big bags should be stacked in a “bricked” overlapped pattern

Inside:

- The store should be single storey and constructed of non-combustible material eg. concrete, brick or steel with a level smooth, dry floor eg. on pallets and be well ventilated
- no incompatible eg. chemicals, oil or combustible eg. wood, straw materials or heat source should be present
- the store should be cleaned before, during and after product is delivered and regularly inspected and audited so an accurate inventory of stock is available
- limit stacks to 300 tonnes maximum and store at least 1 metre from walls, eaves and beams and other stacks of fertilizer
- do not store other fertilizers in the same stack it is strongly recommended not to store urea in the same building as ammonium nitrate

Outside:
Note: As bags are not waterproof, they will not protect the product from degradation caused by extreme temperature change and will not prevent piercing from sharp objects eg. stones.

- store on a raised level, dry, smooth surface (eg. on pallets)
- stacks should be sheeted and secured to cover the bottom layer of the stack to prevent chaffing
- a layer of pallets should be placed on top of the stack and under the sheeting to prevent product deterioration

Safety Data Sheets containing valuable information required to carry out COSHH (Control of Substances Hazardous to Health Regulation 2002) risk assessments are available from our website: www.yara.co.uk

Waste Packaging Disposal

The Waste Management Regulations came into force in England and Wales on the 15th May 2006 and encompasses all waste produced from farms. They affect whether farmers are able to burn, bury or store waste on farm, or if it needs disposing of elsewhere. The burning of plastics, such as fertilizer bags, was one area that was banned when the regulations came into place.

For more details go to:
http://www.yara.co.uk/fertilizer/uk_regulations/waste_disposal/index.aspx

The options available to farmers are as follows:

Option 1
Store the waste on the farm where it was produced, pending collection, for no longer than 12 months. The Environment Agency need not be informed of this.

Option 2
Take the waste for recovery or disposal off-farm at an appropriately licensed site. There is no need to register as a waste carrier for this.

Option 3
Transfer the waste elsewhere for recovery or disposal off-farm at an appropriately licensed site. There are waste management companies who can visit the farm to do this.

Option 4
Register a licence exemption with the Environment Agency to recover or dispose of waste on-farm.

Option 5
Apply to the Environment Agency for a waste management licence or a landfill permit to recover or dispose of waste on-farm.

There are several companies nationwide that have set up to deal with disposal and recycling of farm waste plastics.

Environment and Planning

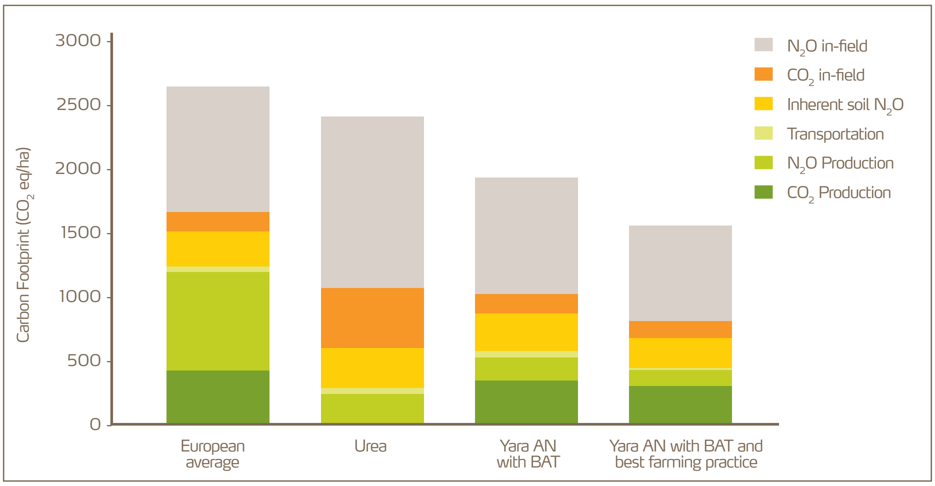
Fertilizer Carbon Footprint

In the UK, mineral fertilizer is responsible for around 6 million tones of CO_2 equivalents per annum. This equates to just 1.1% of the UK's total greenhouse gas (GHG) emissions, however it is an important factor of the GHG calculation and one that is currently being addressed by Yara. All YaraMila™ and YaraBela™ grades are produced in Yara factories which have installed Yara's developed N_2O catalytic abatement technology - reducing our emissions by 90% - with further reductions targeted. They have a guaranteed carbon footprint < 4 kg CO_2-eqv / kg N. This in conjunction with our in-field advice means using Yara's nitrate based fertilizers can reduce the fertilizer carbon footprint by ~ 50% (taking account of the life cycle approach (LCA) to their use).

Nitrogen source

Yara has always advocated the use of nitrate based fertilizers, such as AN and UAN, as the most efficient nitrogen source for UK farmers due to the agronomic benefits over urea; however it is not only in its agronomic performance where AN supersedes urea. When looking at the lifecycle assessment of the different fertilizer products from production through to in-field use, AN with abatement technology shows a better carbon footprint than urea (Figure 28).

Figure 28 Carbon footprint of different fertilizer products and practices



Future Improvements

As well as looking to further reduce the N_2O emissions from nitric acid production, Yara is also looking at ways in which in-field N_2O can be reduced. Soils inherently release nitrous oxide at an assumed rate of approximately 1kg N_2O/ha, however under certain situations this is likely to increase, such as anaerobic soil conditions as a result of poor soil structure or waterlogging. Soil structure is a very important and easily overlooked issue which is not only essential for good crop production through good root growth leading to improved nutrient efficiency, but also for GHG emissions.

Other methods of reducing emissions as a result of fertilizer use include those which help to improve nitrogen use efficiency, therefore not just of benefit to the environment, but to the crop as well. Yara is looking at several solutions, including:

- the correct nitrogen rate
- the correct timing and most appropriate number of dressings
- the correct nitrogen source
- the most efficient method of application, including precision farming technology

With the application, the use of the Yara N-Sensor can help to decrease fertilizer requirement whilst leading to an increase in crop yield, therefore leading to an improved nitrogen use efficiency.

Nutrient Management Plan

Yara has developed a computerised nutrient recommendation and recording tool based on the Fertiliser Manual to aid regulatory requirements surrounding nutrient management.

The aim is to provide a quick and easy to use option to create a full nutrient management report by field producing a recommendation and allowing inputs of organic manures and fertilizers to be easily recorded. Once a number of fields have been entered for a farm, further reports can then be created, including a fertilizer summary for total farm requirements and an N Max report for NVZs.

The Yara Nutrient Management Plan can be accessed through Yara-i, for more information please contact your local Yara distributor.

Soil Sampling

Soil sampling an important step in fertilizer planning, as it is necessary to asses the soil before further applications can be made. As build up or run down of nutrients is a slow process, it is unnecessary to sample every field each year, generally every 3-4 years is sufficient. It is important that the correct procedure is followed when collecting samples, otherwise the results produced can be misleading and result in incorrect fertilizer applications.

Sample areas

A minimum of 25 cores should be taken from a maximum of a 10 ha block. However, where there are distinct changes in soil types, or where areas of the field have been treated differently in the past, different samples from each area should be taken and analysed separately, rather than mixing the samples.

Sample Timing

Sampling should not be conducted when the soil is very dry, or within 3-6 months of a lime or fertilizer application. Where manures have been applied sampling should be left for at least 6 months and ideally following cultivation. Sampling should also occur at the same point in the rotation to give consistent results.

Sample depths

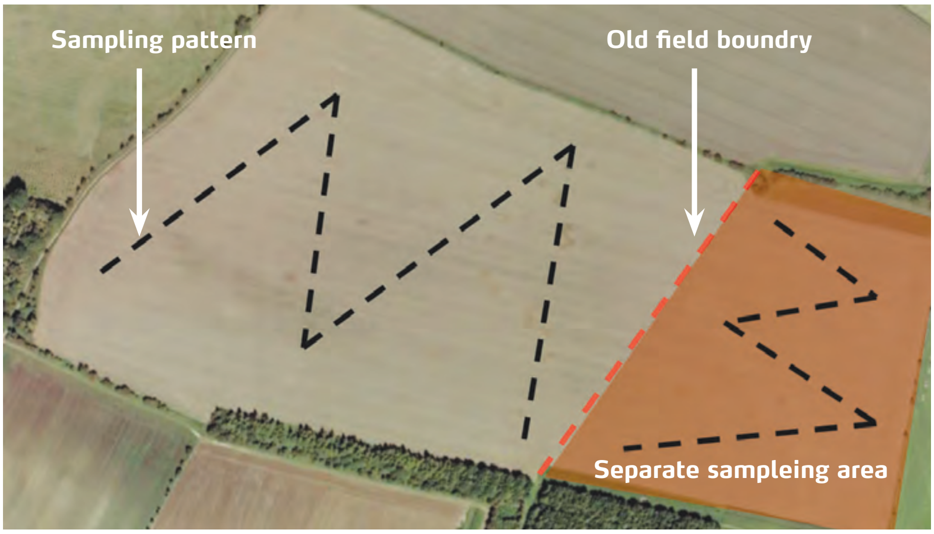
Arable or short term grassland:
0-15cm
Long term leys or permanent pasture:
0-7.5cm

Soil Analysis

Soil samples can be sent to Lancrop Laboratories for analysis, ranging from basic, which will measure pH, P, K and Mg to Broad Spectrum, which also samples for a range of micronutrients.

For more information on soil analysis or for sampling packs, contact Lancrop Laboratories on 01759 305116.

Soil sampling pattern

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GRAMITREL


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ZINTRAC 700


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16.15.15 + 6.5%SO3
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About Yara

Yara's knowledge, products and solutions grow farmers and industrial customers' businesses profitably and responsibly, while nurturing and protecting the earth's resources, food and environment.

Our fertilizers, crop nutrition programmes and technologies increase yields, improve produce quality, and reduce environmental impact from agricultural practices. Our industrial and environmental solutions reduce emissions and improve air quality from industry and transportation, and serve as key ingredients in the production of a wide range of goods.

Founded in 1905 to solve emerging famine in Europe, Yara today has a global presence with more than 12,000 employees and sales to more than 150 countries. **www.yara.com**

YARA

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