Knowledge grows

The Nutrition of Grassland

Yara's Complete Guide

Forward

***"Do you grow grass or do you let your grass grow?"*.**

All too often the answer is that grass is just left to grow, without using the fundamental principles that are adopted for growing other crops. Just as with those other crops, grass has a huge yield and quality potential that should be exploited by livestock producers.

UK grass yields are half of their potential which has been demonstrated through The Yara Grass Prix competition. The winner produced 203,150 MJ/ha compared to the UK and Ireland average at 115,885 MJ/ha.

Yara Grass Prix Winner 2015 - Results	David Murphy, County Armagh, NI	
	Grass Prix	UK Average
Yield (DM t/ha)	18.72	10
Energy (MJ/ha)	203,150	115,885
Protein (kg CP/ha)	2,680	1,475

This energy yield is a combination of the dry matter yield per hectare and energy per tonne. With grass representing the most cost effective feed available, it's optimal use through high productivity and high % utilisation will underpin farm profitability. The Anderson's Report 2015 "Modelling the Financial Effects of the Yara Grass Prix Results on Dairy Farms" describes and compares the economics of three typical Dairy enterprises and concludes that having high levels of milk produced from forage will give the highest profitability.The objective therefore is to produce high yields of high quality grass. The quality should be considered in terms of feed value (energy, protein etc) as well as a carrier of essential nutrients for animal health (e.g. Selenium).

Both these components, yield and quality, are greatly influenced by the mineral nutrient supply, so it is essential to have a structured approach to managing these nutrients within the grass management plan. Such an approach will give considerations towards: the nutrient demand by the crop, the nutrient supply from the soil and other organic material applied, and the fertilizer requirement to fill this gap. The Yara 1-2-3 Step Approach helps to bring structure to this process:

Step 1. Do you measure to help manage your nutrients?

The best way to manage is first to measure. Step 1 is all about measuring to understand the nutrient supply chain. Samples of the soil, manures/slurries and previous forage (e.g. silage) that are available should be sent to Lancrop Laboratories for broad spectrum analysis giving values to the pH and nutrient content (including Selenium). This will build knowledge of the soil and organic manures and coupled with grass nutrient requirement figures can be used to produce a Nutrient Management Plan.

Step 2. How accurate is your fertilizer application?

Taking the results from Step 1 (a Nutrient Management Plan), Step 2 considers the products that are available to best fulfil the gap in nutrient requirement and their application. The latter being both the rate of use and spreader set up. Accuracy of application is an essential component and is best achieved using quality, uniform fertilizers.

Step 3. Is your fertilizer plan giving you results?

A good management process needs to have a review element to it, enabling adjustments that lead to continual improvements. Step 3 therefore is about further measurement and monitoring through the season to understand the level of success being achieved. Measurements should include grass/forage leaf tissue analysis for nutrient content and quality which will help towards better management of the livestock diet and enable adjustments to the fertilizer plan. Regular monitoring of grass growth will raise awareness and act as an alert to issues that might be restricting productivity.

Mark Tucker
Marketing & Agronomy Manager

Step 1. Do you measure to help manage your nutrients?

Soil pH

Soil pH plays an important role in the availability of nutrients. A soil pH of around 7 is optimal for the maximum availability of all nutrients, which is in line with the optimum pH for silage growth of 6 to 7. The pH of samples tested by Yara Analytical Services in the 2014 season showed that 55% were below the target pH of 6.0. This will have an adverse effect on nutrient uptake as at a pH of less than 6, the availability of most nutrients is restricted, especially phosphorus.

Soil pH has a direct influence on nutrient availability

Liming is an important part of crop production and monitoring the soil pH should be a part of an annual soil management plan or nutrient budget, with samples being taken every 3 to 4 years, to ensure that the soil is kept at an optimum. Each year there is likely to be an increase in acidity from the build up of hydrogen ions in the soil, which will lead to a reduction in soil fertility unless measures are taken to correct it.

Figure 1. The range of pH in UK grassland soils, 2012 - 2014

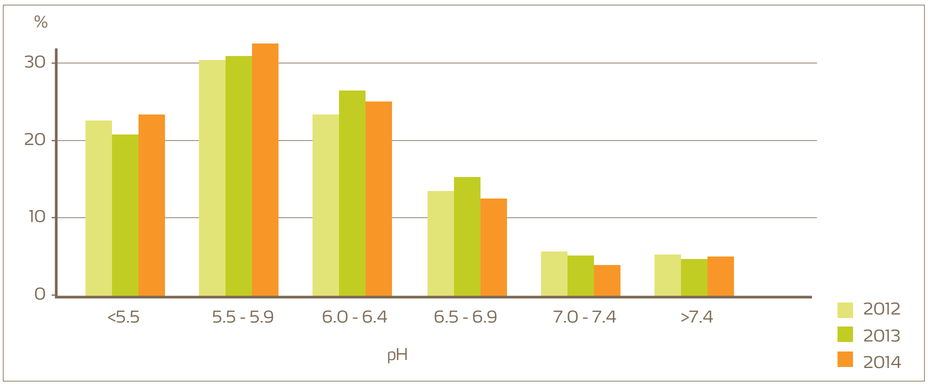
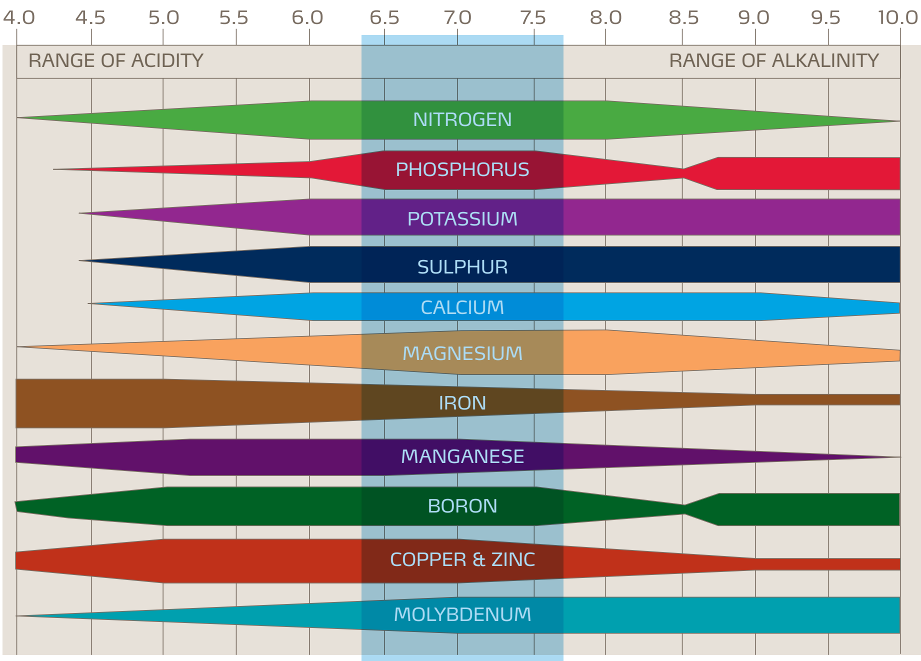


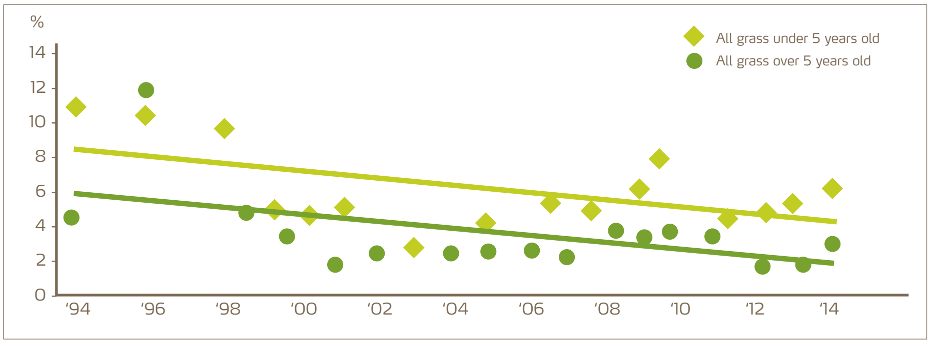
Figure 2. The Influence of Soil pH on Nutrient Availability



Lime Use

Figures from the British Survey of Fertiliser Practise show there has been a steady decline in the area of crops in the UK receiving lime over the last 20 years. Figures for grassland less than 5 years old have dropped during this time from 11% in 1994 to just over 3% receiving lime in 2014.

Figure 3. Crop area in Great Britain receiving lime dressing (%)



Yara Analytical Services

The Yara laboratories in Yorkshire have over 30 years of experience in the production of analytical data from many different materials. Specialising in the agricultural, environmental, horticultural and amenity sectors - soils, plant tissue and organic materials. Around 1 million samples per year are analysed from over 50 countries worldwide. Analysis provides the information required to ensure any decisions made are accurate, efficient and cost effective. The laboratory has worked to the internationally recognised accreditation scheme ISO9001 since 1993. The scheme externally monitors all systems on a regular basis and coupled with internal quality controls and others such as the International Plant Exchange Scheme, ensures precision and consistency at all times.

What are the key nutrients to manage?

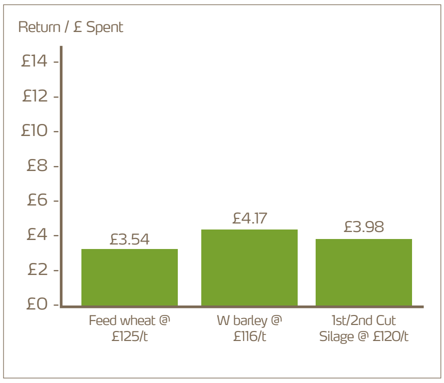
Nitrogen

The major nutrient nitrogen is required in the greatest quantity by many crops including grass. It is the key to achieving high dry matter yields of the correct quality as it is a component of all proteins and chlorophyll, which drives photosynthesis; the conversion of light energy, water and carbon dioxide to sugar.

Field trials measuring the crop's response to applied nitrogen give information that can be used to calculate the return for every £1 spent. Figure 4 illustrates this typical return by various UK crops including Silage.

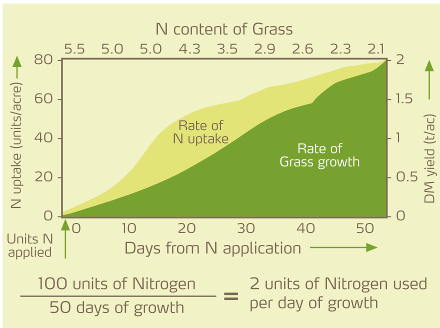
Figure 4. The Return on Investment in Nitrogen Fertilizer

The value of fertilizer based on 34.5% nitrogen @ 68p/kg



The key to achieving the optimum return is to apply the correct amount of nitrogen, from the right source, at the right time. The amount of plant available nitrogen is determined by the Nitrogen Cycle which involves very complex soil processes and calculating the correct rate to apply can be difficult. However a series of Yara trials over a number of years concluded that the typical requirement of nitrogen to optimize grass yield and quality could be described by **'The Grassland Rule' of: 2 units N /acre/day (2.5kg N/ha/day)**(see Figure 5). Yara grass recommendations are based on this rule.

Figure 5. The correct level of Nitrogen to apply



Nitrogen from organic manures should be deducted from the requirement before mineral nitrogen recommendations are calculated.

Nitrogen Timing

The timing of application at the start of the season is also important. It should be calculated by assessing soil conditions and temperature.

Grass will only start to grow (and thus require fertilizer) when soil temperatures consistently reach 5-6°C.

Nitrogen Source

The source of nitrogen is important, with the two principle choices being between ammonium nitrate and urea. Trials conducted by Yara over the last 60 years have shown ammonium nitrate to be more effective, with crops of 1st Cut Silage yielding on average 7% more than urea. In this trial series, yield losses occurred even on sites thought to be suitable for urea i.e. wet and low pH.

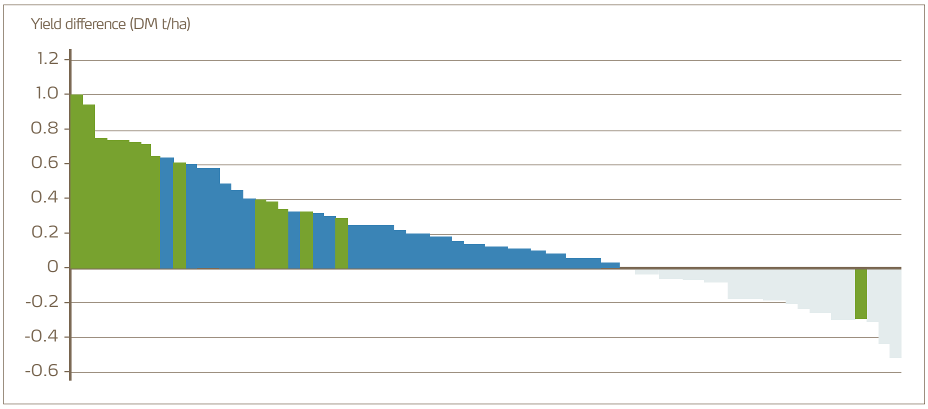
Differences in product performance are even greater in second and subsequent cuts, with 93% of the statistically significant results in trials from 1985 showing in favour of Ammonium Nitrate over urea.

'The Grassland Rule' of: 2 units N /acre/day (2.5kg N/ha/day)

For intensive systems a 6:1 ratio of N: P_2O_5 has been found to be required, whilst on less intensive systems a 2:1 ratio product is adequate. Yara trials have found that applying fertilizer with these ratio's has given up to a 17% yield improvement compared with applications of straight nitrogen.

Phosphorus excreted by livestock is all in the dung. Even after two years of intensive grazing, only approximately 16% of the pasture surface will be affected by the dung, so the effect on fertilizer requirement is small. Consequently, there is little difference in fertilizer phosphorus requirement between cut and grazed swards.

Figure 6. Grass DM yield difference between Ammonium Nitrate and Urea in second cut silage (Levington Agriculture, 1985 - 91).



Phosphorus

Phosphorus plays a major role in the energy supply for many plant metabolic processes, and enzyme activity, forming the central part of the energy bonds in ATP. This energy is needed for the active uptake and internal redistribution of other nutrients, so even though phosphorus demand is small compared to that of nitrogen, its availability is essential.

Phosphorus is very immobile in the soil and transient deficiencies can show up in early spring when soils are cold and wet. Trials have shown that spring applied phosphate improves the response to applied nitrogen, even on soils with a high P Index (3+).

Figure 7 highlights the status of UK soils, with 68% at Index 2 or below.

Figure 7. UK soils Phosphate Index distribution, (Lancrop Lab, 2014)

Potassium

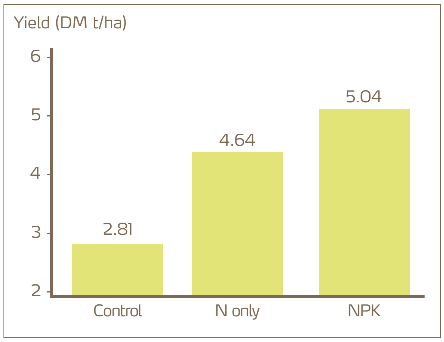
Potassium is vital for regulating water supply and cell turgidity and, like nitrogen, is taken up in large quantities during the rapid growth phases in the spring and early summer. An adequate supply is essential for maximizing yields from applied nitrogen, however there can be dangers to animal health if excess potassium is supplied with an increased risk of hypomagnesaemia. Grass management (i.e. grazing or cutting) will affect the rate required.

Potassium excreted by livestock is mostly water-soluble and in the urine. Recycling of Potassium must be taken into account and fertilizer recommendations will subsequently differ between cut and grazed swards.

Under intensive grazing, the $N:K_2O$ ratio required in fertilizer is typically around 6:1. Where grass is cut for Silage or Hay, removal of Potassium in the crop can be large and the rate of following applications must be matched to the future management of the Grass, i.e. whether it is to be grazed or subsequent cuts taken. In Silage systems a 1st Cut will typically require up to 140 kg K_2O / ha depending on the soil index, whilst a 2 Cut system yielding 9.5t DM/ ha will remove 228 kg K_2O /ha. The final amounts will vary according to soil type and soil index. Figure 8 highlights that 83% of UK soils are at Index 2+ or below.

Figure 8. UK soils Potassium Index distribution, (Lancrop Lab, 2014)

Figure 9. Average yield response to fresh Phosphate and Potassium applications (Yara 1998-2015)



Sulphur

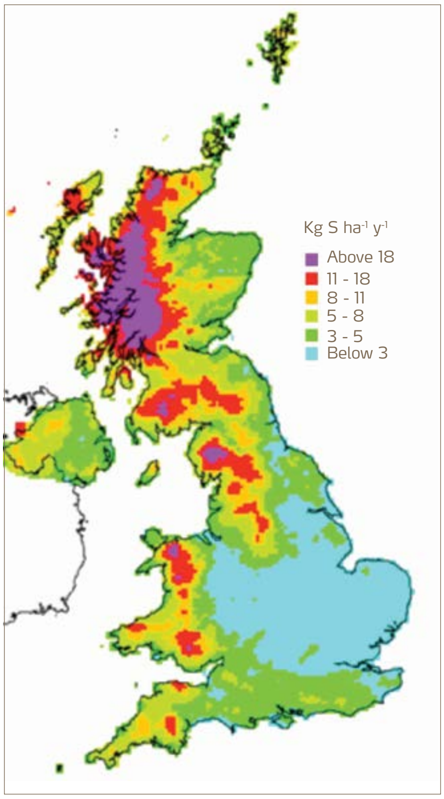
The importance of sulphur as a nutrient for crops has been well documented in the past. It has been linked to the following:

Sulphur...

- is the building block of protein helping to improve growth & development
- improves nitrogen use efficiency
- reduces nitrate leaching
- is essential for N fixation by legumes
- is essential for the synthesis of the essential amino acids, methionine and cysteine
- is essential for the synthesis of chlorophyll
- low S and high N leads to nitrate accumulation in plants interfering with iodine uptake by the thyroid (Till, 2002)
- increases sugar content
- improves dry matter digestibility

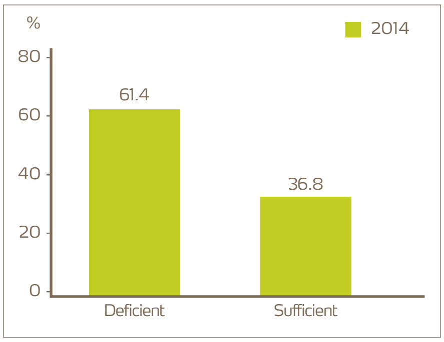
The amount of sulphur available to crops through atmospheric deposition has reduced dramatically since the 1980's due to industrial clean up, however there have also been further reductions more recently. The recent average sulphur deposition figure has dropped to just 7.2 kg SO_3/ha (see Figure 10).

Figure 10. Sulphur Deposition (2011)



Sulphur is similar to nitrogen, in that it is taken up by plants in the sulphate form, and as such in this form is highly leachable. On light soils under grass in the UK, 30-75 kg SO_3/ha can be leached in a year, therefore the amount that is lost from the soil through leaching is likely to be significantly higher than the amount gained through atmospheric deposition. Lancrop Laboratory data highlights that in 2014 61% of soils were below the current guidelines (Figure 11).

Figure 11. UK soil Sulphur status expressed as a % of soils under the guideline

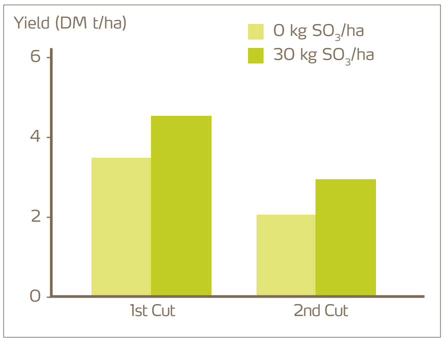


This indicates that there is a large number of situations where grassland crops in the UK are likely to benefit from applying sulphur fertilizer. Even fields receiving organic manures may require additional sulphur due to the very low availability of sulphur in manures. A 40m³/ha application of dairy slurry may only be supplying 1-3 kg/ha of available sulphate.

The impact of Sulphur on grass yield

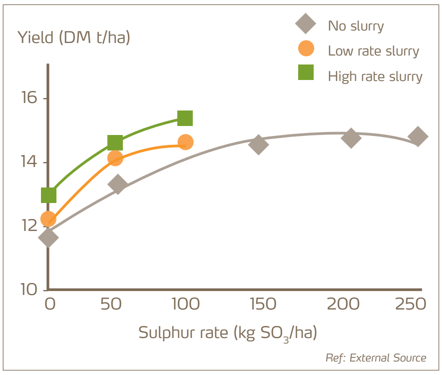
Within the UK, yield responses to sulphur in grass silage were first seen in Northern Ireland, England and Scotland in the mid 1980's. These responses were typically in the range of 5-30%, with 2nd and 3rd cuts of silage proving to be more responsive to sulphur applications than 1st cut. By the mid 1990's even 1st cut silage in England was highly responsive to sulphur and in 2012 good responses were seen in 1st and 2nd Cut. (see Figure 12).

Figure 12. The effect of sulphur on grass yield (Yara, 2012)



A series of trials in the late 1980's highlighted the benefit of fresh applications of sulphur on silage crops where manures had been applied. Applying 100 kg SO_3/ha increased silage yield by 2.35 t/ha where low rates of slurry were applied and by 2.05 t/ha following high rates. Increasing the rate of slurry applied increased the yield of silage, however there was still a benefit from applying sulphur in each case (see Figure 13).

Figure 13. Interaction between sulphur and slurry application



Sulphur Silage Trials (1985 – 1998)

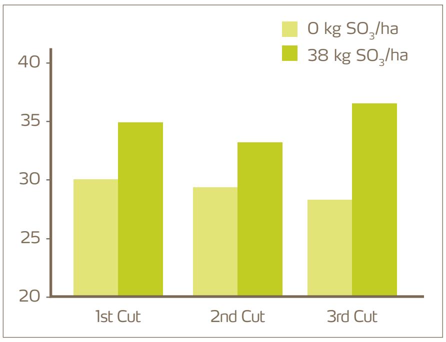
	1st Cut	2nd Cut
Responsive trials	6/8	17/32
Range of yield increase (t/ha)	0.3 - 2.46	0.5 - 1.49
Yield increase %	6-29	6-56

The impact of Sulphur on grass quality

Sulphur deficient grass is usually associated with a total sulphur concentration of less than 0.2%. Grass with levels lower than this will have poor nutritional quality. Sulphur applications increase the proportion of total nitrogen in grass present as protein-N, decreasing the nitrate and free amino N content of the silage.

Trials work looking at quality aspects from sulphur applications have also shown a 15% increase in crude protein, increased sugar content (Figure 14) and increases in vitro dry matter digestibility, from 55.1% to 57.2%.

Figure 14. The effect of sulphur on % sugar



The interaction between sulphur and other elements

Heavy over application of sulphur may induce copper deficiency in cattle by forming compounds in the rumen which bind copper making it unavailable to the animal. This is due to the complex interactions between sulphur, copper and molybdenum. Such a situation is likely to occur when the copper status of the diet is marginal and both molybdenum and sulphur levels are high, with critical concentrations for the two elements at greater than 3 mg/kg for molybdenum and greater than 0.3-0.4% for sulphur.

Trials by Yara showed that sulphur fertilisation at recommended rates (50-75kg SO_3/ha) did not increase herbage sulphur concentration above 0.3%.

Sodium

Sodium (Na) is an essential nutrient for animals, but not for plants, needed for important physiological functions in animal metabolism such as:

- Osmotic substance in body liquids (with Ca and P)
- Polarization of nerve membranes and nerve stimulation in muscle fibres (with potasium)
- Maintaining the membrane potential of cell-walls with impact on nutrient transport (with potassium)
- Component of strongly alkaline substances in the saliva of ruminants
    - Important for maintaining optimum pH in the rumen for optimum fermentation and maximum fodder uptake

Sodium also helps to improve the D-Value and palatability of forage, whilst increasing sodium content reduces potassium thus increases magnesium availability.

It is highly leachable and as such it is not possible to build up soil reserves.

Sodium Deficiency
The sodium demand of grazing animals is between 0.15 and 0.2 % Na in forage DM.

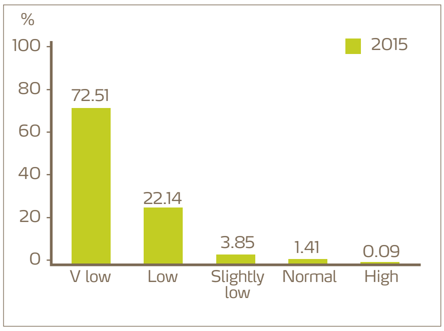
For dairy cows, severe or long lasting Na deficiency causes:

- Low appetite
- Reduced fertility
- Reduced milk production

Factors determining the sodium content of grassland swards and the efficacy of sodium fertilization are:

- Sward composition - Na concentration in herbs is usually higher than in grasses
- Physiological age of the sward
- Potassium content of the soil and potassium fertilization - due to a strong cation uptake antagonism, Na uptake is low if soil potassium is high

Figure 15. Grassland Soil Samples Na Levels 2015



Benefits of increasing sodium content of grassland by fertilization
As sodium is mobile in soils, split application (with NPK fertilizer) prevents it from leaching and ensures sufficient supply throughout the season.

Sodium treated grass gave a 14.9% milk yield increase (Haninghof Research).

- 18.6% improvement in Dry Matter Intake
- 23 minutes longer grazing per day
- Sodium treated grass also improved grass quality (University of Wales, 1990)
- 20.3% increase in butterfat yield
- 11.1% increase in protein yield
- soil potassium is high

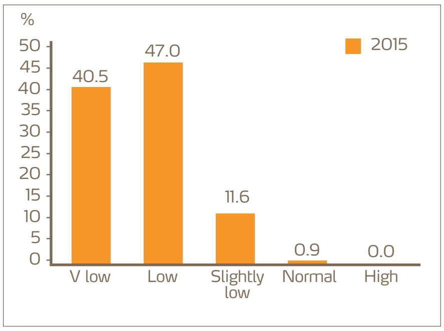
Sodium efficiency is higher from enriched herbage than from feed supplements

	-Na	+Na (feed supplement)	+ Na (applied as fertilizer)
Grazing (minutes/day)	521	522	544
Milk Yield (kg/day)	17,5	18,0	20,1
Weight Gain (kg/day)	-0,09	0,14	0,22

Selenium

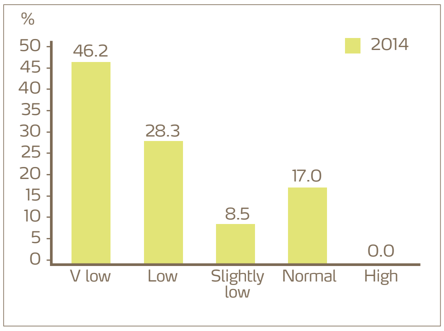
Selenium is an essential trace element for all ruminants, with links to fertility and milk cell counts for example. In the past Yara have conducted extensive herbage surveys, showing over 70% of samples below the target of 0.1mg/kg DM. Of the soils analysed in 2015, 87% were in the low to very low category (Figure 16).

Figure 16. UK Grassland Soil Selenium status 2015



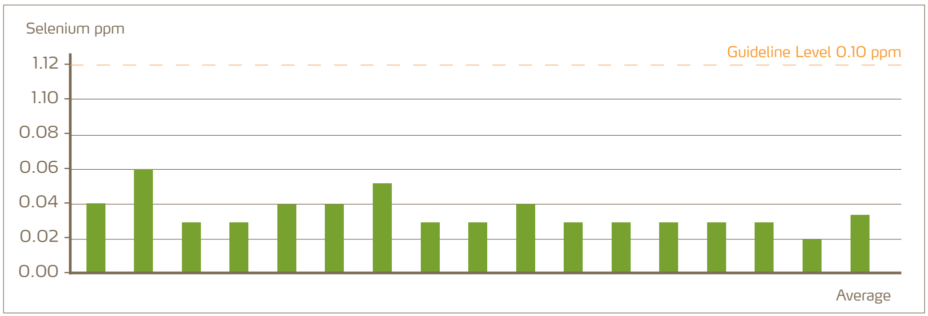
This poor soil status is also observed in the grass leaf samples analysed, where 75% were either low or very low (Figure 17).

Figure 17. UK Grassland Leaf Selenium status 2014



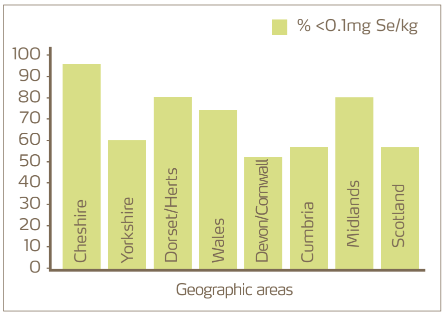
In the Yara Grass Prix competition all samples were below the 0.1 ppm guideline, with the average less than 0.04 ppm (see Figure 18). Cows feeding on this would be unlikely to maintain their blood selenium content above the typical guide of 0.1 mg/g blood.

Figure 18. Selenium levels in all samples collected during Yara Grass Prix competition



The table below shows how this deficiency is spread throughout the livestock areas.

Figure 19. % of grass samples with <0.1mg Se/kg (Yara grass survey)



Plants take up selenium as the selenate (SeO_4^{2-}) or selenite (SeO_3^{2-}) ions. Selenate is the form more easily taken up and therefore its inclusion in fertilizer makes it the ideal method of fortifying grass to achieve the daily intake requirements.

Following uptake it is incorporated into amino acids and proteins, in these forms, the selenium is available to the livestock. This is a very efficient way of transferring selenium into the blood of the animal.

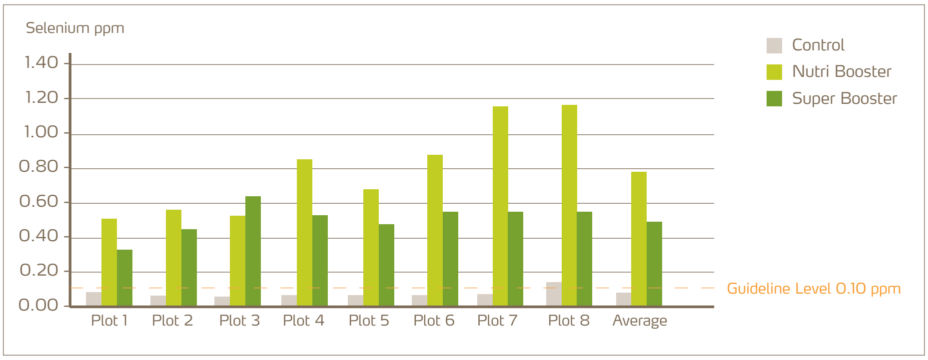
The solution therefore is to apply selenium (as selenate) to the soil through the fertilizer, which in turn will enrich the herbage for the grazing animal or the housed animal fed the conserved grass. The Yara Booster range of fertilizers have been developed specifically to address this problem. Figure 20 shows demonstration work confirming an increase in selenium concentration of herbage following application of selenium enhanced fertilizer.

Selenium herbage test

Selenium is more reliably measured using a herbage analysis.

The herbage test will give a result in mg/kg DM, the target figure is 0.1mg/kg DM. As previously presented selenium has many animal health benefits to ensure optimum animal performance. Enriching the herbage with selenium provides a simple cost effective solution, where deficiency is known.

Figure 20. Grass biofortification through the application of Selenium via the fertilizer (Yara demo 2014)



Step 2 – How accurate is your fertilizer application?

The product choice will directly affect the ability to spread the fertilizer accurately and evenly, and therefore apply the correct amount of the key nutrients to meet the requirements of the growing grass . The ability to which this can be achieved is measured by a products Coefficient of Variation (CV). A high CV (20-30%) is associated with a poor quality, whilst a low CV (5-10%) is that of a high quality fertilizer. Product quality is a measure of both the chemical (nutrient analysis) and physical (particle size distribution and density) makeup of the product.

Quality - ***'Guaranteed by Yara'***

Nutrient Analysis Quality – are you getting what you pay for?

Yara has always set the standard, producing high quality granular and prilled complex compounds which can be recognised by the YaraMila™ logo, a new quality mark guaranteeing that the product is a 'true uniform compound' with every granule containing the correct , declared, nutrient analysis.

To quote a phrase used for many years to describe Yara products: ***"What's on the bag is in the bag!"***

Over the years Yara has conducted a number of surveys investigating the quality of blended fertilizer products available to farmers in the UK. Results continually show a significant percentage of products fail to meet the statutory declared nutrient levels and that bags are underweight. The average from the surveys is approximately 50%, with the most recent being 64% of products being illegal in terms of their nutrient declaration.

Small deviations in analysis can have a significant financial penalty. Consequential yield penalties as a result of under application of the key nutrients can have a greater financial penalty still. Care therefore must be taken when considering which product to buy, as a cheaper poorly blended alternatives are most likely to be a false economy.

"What's on the bag is in the bag!"

Example cost of incorrect analysis:

Cost of nutrients (September 2015):

- Nitrogen: 70p/kg
- Phosphate: 65p/kg
- Potash: 45p/kg

A 20-10-10 fertilizer was analysed at 17.6% NITROGEN

- **£16.80**/tonne less nitrogen than declared
- At Optimum 1st cut silage rates (130 kg N/ha) this could also lead to a reduction in silage dry matter yield costing **£12.20**/ha (£21.05/ha loss of milk yield).
- In order to maintain the same Return On Investment as a YaraMila NPK fertilizer the product needed to be **£35.58 - £49.18** cheaper depending on how the yield penalty is costed.

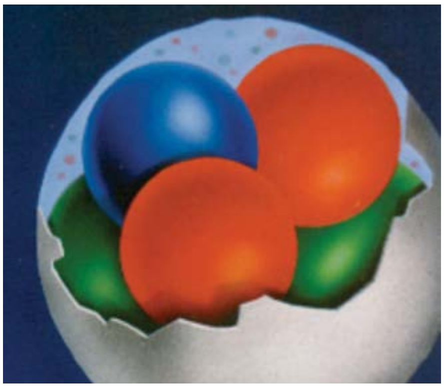
Physical Quality – Can you achieve an even spread pattern?

Segregation

With poorly blended products, segregation can occur during transport, handling and application leading to large variations in the required application rate of each nutrient for the crop.

Segregation of fertilizer blends can occur on loading into ships or bulk heaps as larger particles will fall to the edge of the heap. With true uniform compound products segregation of individual nutrients is not possible.

A YaraMila™ granule containing all nutrients



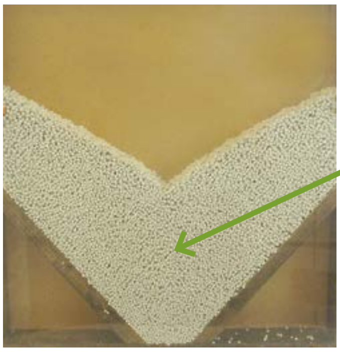
Which would you rather use?

POOR BLEND

Larger particles bridging

Smaller particles (often the nitrogen source) rushing through

Yara TRUE COMPOUND



All nutrients in every particle

Spreading

In order to achieve the lowest CV possible (coefficient of variation – a measure of inaccuracy of spreading) it is important to set the spreader correctly for the product to be spread.

To achieve this, spreaders should be calibrated and tray tested annually for each product used that season in accordance with the NVZ regulations and the Codes of Good Agricultural Practise as each product will have different physical properties which will affect the spread pattern.

Spreading patterns of poor blends – Nutrient concentration in product collected from trays after spreading (target 20-8-11). This data demonstrates the extreme variation in applied nutrient possible when applying poorly blended fertilizer.

Product	N%	P_2O_5%	K_2O%
Blend (AN+TSP+MOP)	17.4 - 24.3	7.2 - 15.5	5.0 - 18.8
Blend (UREA+TSP+MOP)	1.0 - 26.0	2.9 - 19.0	5.5 - 15.5

Ref: Levington Agriculture

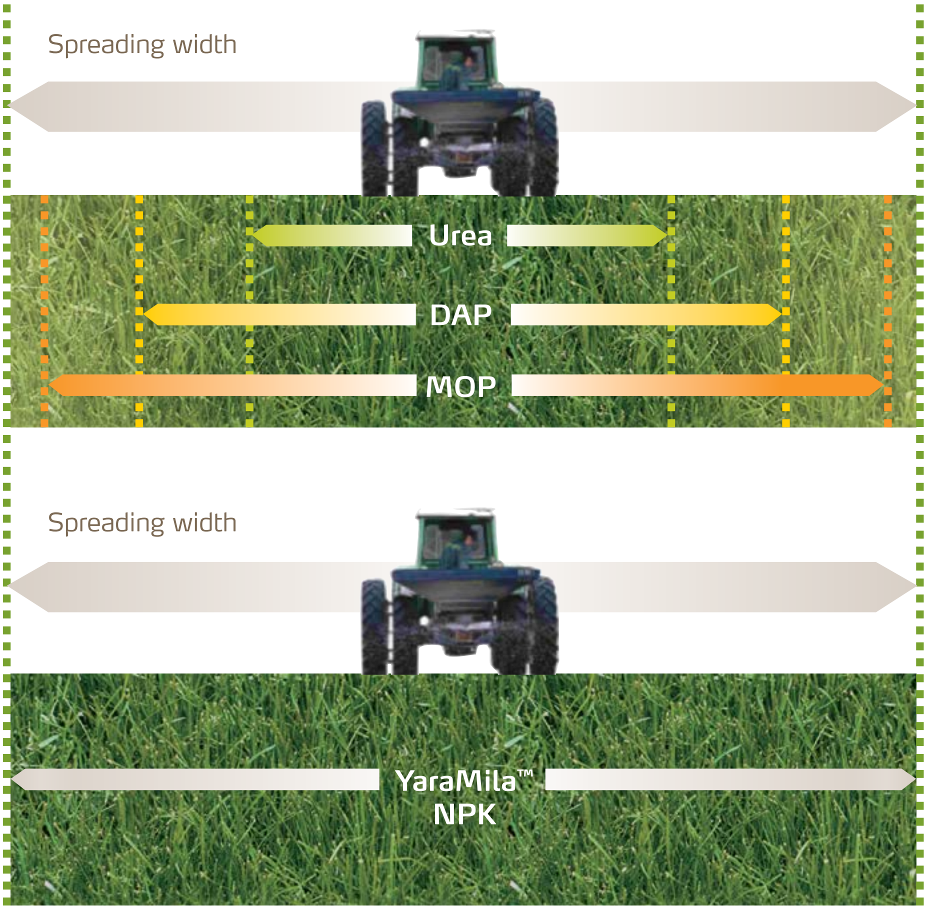
When applying poorly size-matched blended products with more than one separate raw material, even when properly calibrating the spreader, the setting selected becomes a compromise as it is likely the individual component materials will have different optimum settings due to their size and bulk densities. Where calibration for the product is not conducted these differences may become exaggerated.

Larger, denser particles will spread further, and smaller lighter particles will spread the least distance. Where different sized particles have different nutrient content, this leads to segregation of nutrients upon spreading. In turn this will create uneven crop growth, and at extreme levels will show up as striping in crops.

The variation in spread patterns caused by segregation and particle properties were tested on farm by SCS Ltd. A blended 22-4-14 with sulphur and a blended 27-5-5 were tested against equivalent YaraMila compounds at 500kg/ha application rates across a 24m bout width.

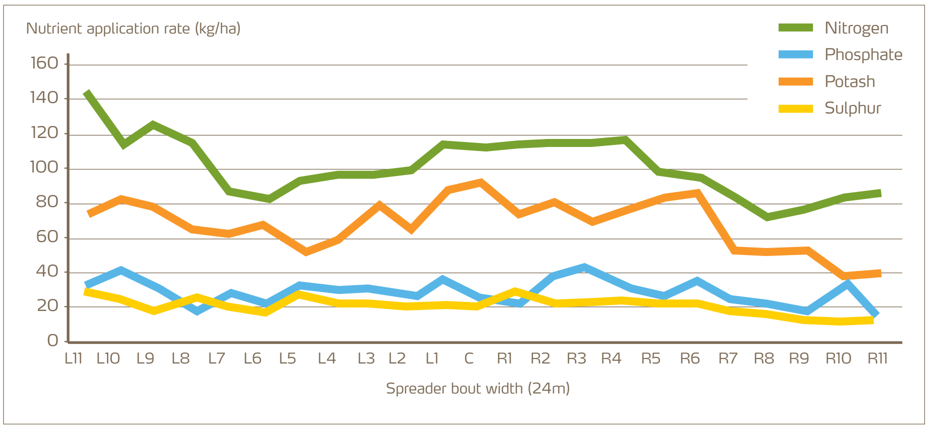
The products were tested over the trays and the components that landed in each were collected and sent to Lancrop Laboratories to be weighed and analysed.

Spreading of poor quality blends compared to uniform compounds



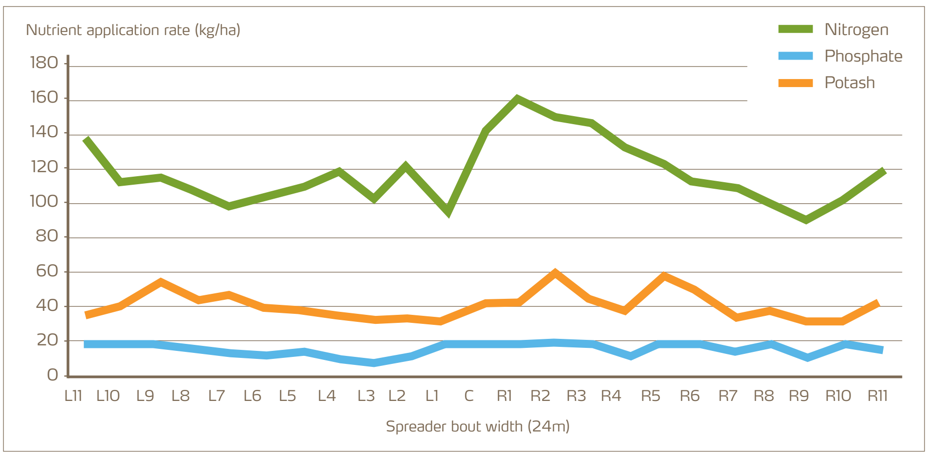
Test Results from the 22-4-14 + 6.5% SO_3 blended NPKS fertilizer				
Target Application Rate	T 500 kg/ha			
Actual Application Rate	515 kg/ha (varying from 380 kg/ha to 676 kg/ha across the bout width)			
Nutrient	**N (kg/ha)**	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**	**SO_3 (kg/ha)**
Target	110	20	70	32.5
Actual Average	99	29	68	21
Variance	71 - 139	17 - 40	38 - 91	13 - 29
% Area where nutrient under applied	54%		50%	100%
% Area where nutrient over applied		92%		

Figure 21. Nutrient application rate across the spreader bout width of the blended 22-4-14 + 6.5% SO_3 NPKS fertilizer



Test Results from the 27-5-5 blended NPK fertilizer				
Target Application Rate	500 kg/ha			
Actual Application Rate	503 kg/ha (varying from 400 kg/ha to 648 kg/ha across the bout width)			
Nutrient	**N (kg/ha)**	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**	**SO_3 (kg/ha)**
Target	135	25	25	0
Actual Average	118	16	42	0
Variance	91 - 160	10 - 19	34 - 59	0
% Area where nutrient under applied	75%	100%	50%	0
% Area where nutrient over applied			100%	

Figure 22. Nutrient application rate across the spreader bout width of the blended 27-5-5 NPK



Landing sites and the uptake of nutrients

Uniform application and distribution of nutrients is one of the key benefits of using a true uniform compound fertiliser, as found in the YaraMila range. Every prill or granule contains all the stated nutrients, whereas blends are a mixture of fertiliser components, usually based on AN, MAP or DAP and MOP, using limestone chips to bring the product up to weight.

The particle distribution maps are a representation of a spread pattern based on 5cm squares, shown at different product application rates.

YaraMila compounds have been compared to a blend of the same analysis, with the distribution profiles based on the particle weights of the YaraMila compound, and the individual blend components.

The formulation for the 25-5-5 blend is based on:
AN 71.2%, MAP 9.6%, MOP 8.3%, Limestone chips 10.9%.

Components with a high nutrient density such as MAP (52%P_2O_5) and MOP (60%K_2O) need to be included at low rates to achieve the target analysis.

This in turn will lead to a low number of particle landing sites for phosphate and potash. The number of nitrogen landing sites for blends is only relevant at low application rates.

With YaraMila compounds, each particle, wherever it lands, will provide every nutrient being applied, and also provide more landing sites overall.

Depending on the rooting structure of the plant, the distance between nutrient landing sites could restrict nutrient uptake.

On well structured soils, plants will have some lateral rooting, but will mostly root vertically seeking nutrient and water, giving the plant maximum potential to achieve optimum yield and quality. A distance of 5cm between each nutrient landing site could be considered to be a reasonable maximum, although higher soil fertility and frequent fertiliser applications will to some extent mitigate the impact of wider particle spacing.

Quality

YaraMila compounds will:

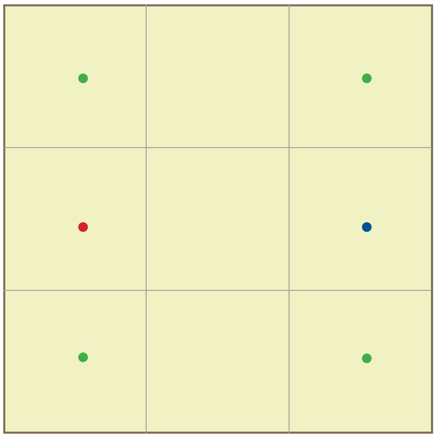
- Provide more particle landing sites per m^2
- Provides all required nutrients at every landing site
- Improve yield and quality

Poor quality blends will:

- Provide less particle landing sites per m^2
- Have a poorer nutrient distribution profile
- Segregate
- Be difficult to calibrate due to differences in size and bulk density
- Often be underweight and below the stated analysis, as shown in our Blender Survey
- Reduce yield and quality

YaraMila™ compound - all the nutrients in every prill!

Example Particle distribution maps



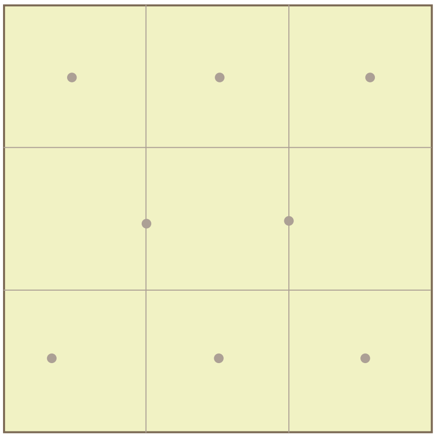
125 kg/ha 20-10-10 Blend

Particles/m²

- N - 146
- P - 96
- K - 57

Average distance between particles (cm)

- N - 6.8
- P - 10.2
- K - 13.2



125 kg/ha YaraMila New 52

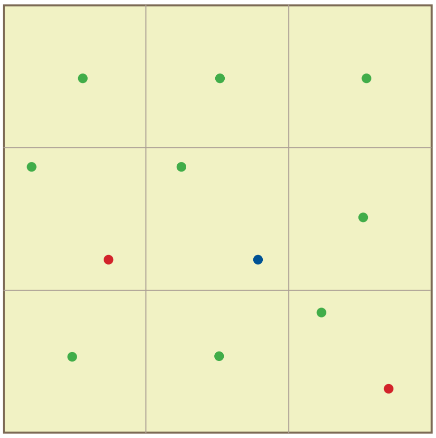
Prills/m²

- NPK - 334

Average distance between prills (cm)

- NPK - 5.5

Area - 15cm square



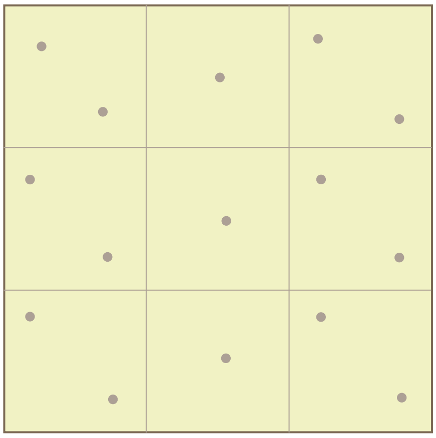
250 kg/ha 20-10-10 Blend

Particles/m²

- N - 291
- P - 192
- K - 114

Average distance between particles (cm)

- N - 5.9
- P - 7.2
- K - 9.4



250 kg/ha YaraMila New 52

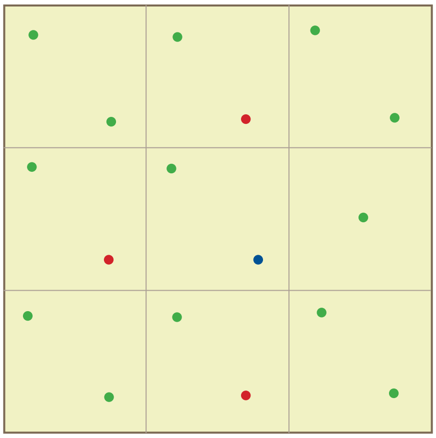
Prills/m²

- NPK - 668

Average distance between prills (cm)

- NPK - 3.9

Area - 15cm square



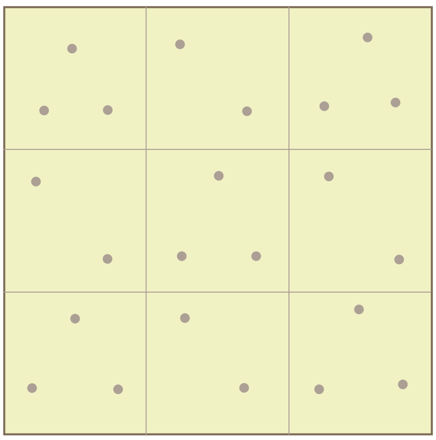
375 kg/ha 20-10-10 Blend

Particles/m²

- N - 437
- P - 288
- K - 171

Average distance between particles (cm)

- N - 4.8
- P - 5.9
- K - 7.6



375 kg/ha YaraMila New 52

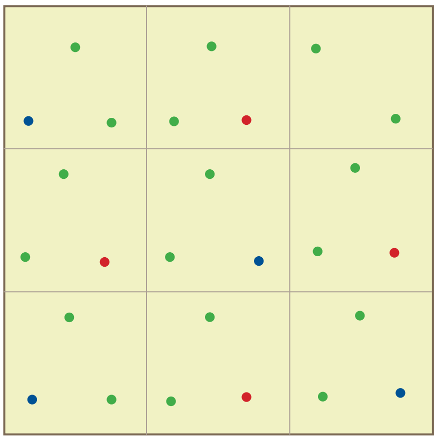
Prills/m²

- NPK - 1002

Average distance between prills (cm)

- NPK - 3.2

Area - 15cm square



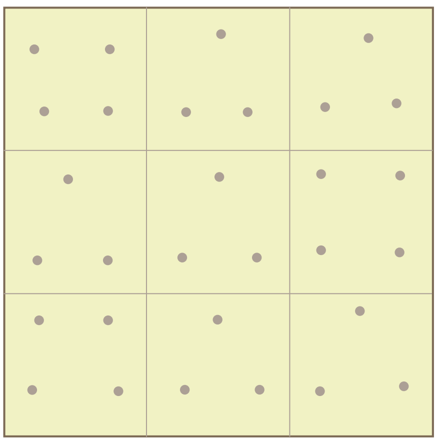
500 kg/ha 20-10-10 Blend

Particles/m²

- N - 582
- P - 384
- K - 229

Average distance between particles (cm)

- N - 4.1
- P - 5.1
- K - 6.6



500 kg/ha YaraMila New 52

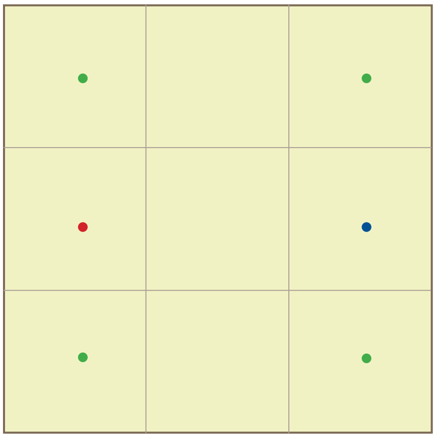
Prills/m²

- NPK - 1336

Average distance between prills (cm)

- NPK - 2.7

Area - 15cm square



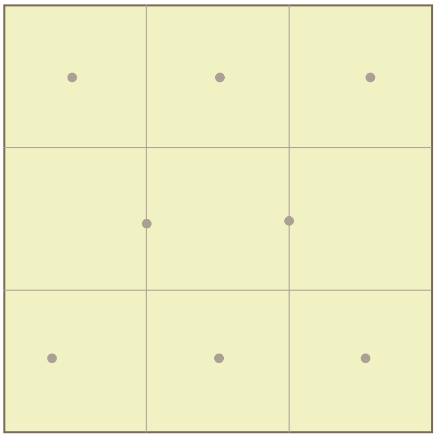
125 kg/ha
25-5-5 Blend

Particles/m²

- N - 197
- P - 48
- K - 29

Average distance between particles (cm)

- N - 7.1
- P - 14.4
- K - 18.7



125 kg/ha
YaraMila
Super Grass

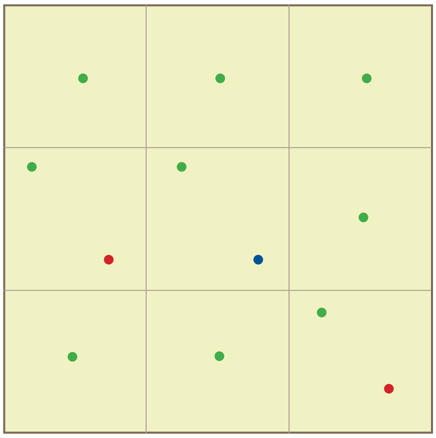
Prills/m²

- NPK - 334

Average distance between prills (cm)

- NPK - 5.5

Area - 15cm square



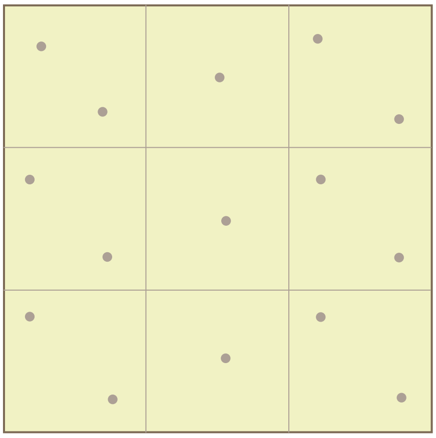
250 kg/ha
25-5-5 Blend

Particles/m²

- N - 393
- P - 96
- K - 57

Average distance between particles (cm)

- N - 5
- P - 10.2
- K - 13.2



250 kg/ha
YaraMila
Super Grass

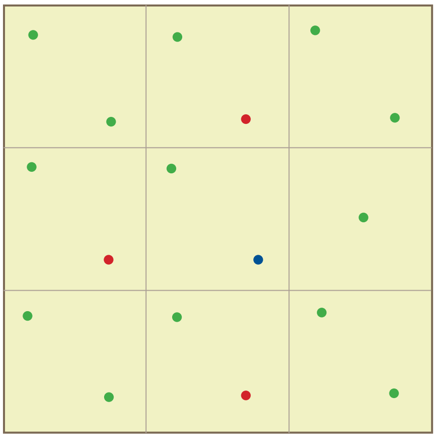
Prills/m²

- NPK - 668

Average distance between prills (cm)

- NPK - 3.9

Area - 15cm square



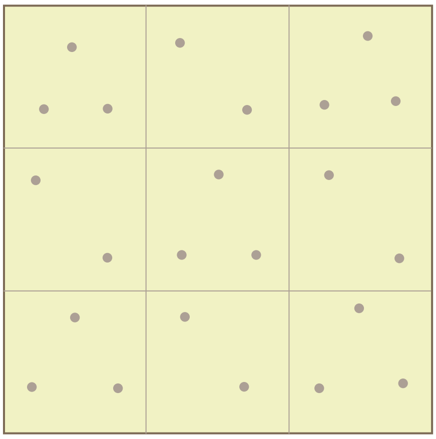
375 kg/ha
25-5-5 Blend

Particles/m²

- N - 590
- P - 144
- K - 86

Average distance between particles (cm)

- N - 4.1
- P - 8.3
- K - 10.8



375 kg/ha
YaraMila
Super Grass

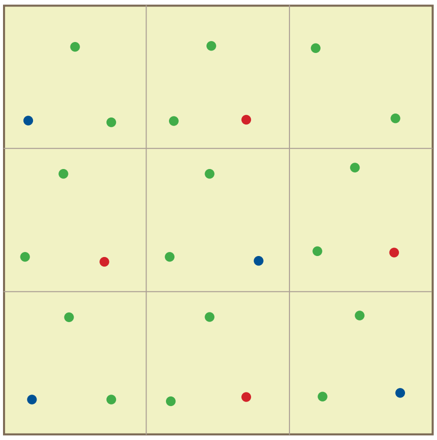
Prills/m²

- NPK - 1002

Average distance between prills (cm)

- NPK - 3.2

Area - 15cm square



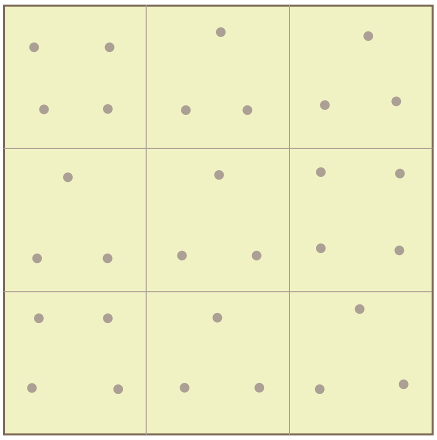
500 kg/ha
25-5-5 Blend

Particles/m²

- N - 786
- P - 192
- K - 114

Average distance between particles (cm)

- N - 3.6
- P - 7.2
- K - 9.4



500 kg/ha
YaraMila
Super Grass

Prills/m²

- NPK - 1336

Average distance between prills (cm)

- NPK - 2.7

Area - 15cm square

Grassland Fertilizer Programme - Silage with Selenium

	March	After First Cut	After Second Cut
YaraMila®	**SILAGE BOOSTER** **650 kg/ha**	**SILAGE BOOSTER** **600 kg/ha**	**SILAGE BOOSTER** **425 kg/ha**

** These recommendations are based on Yara research to optimise yield and quality of silage grass*
Rate should be adjusted if the forage demand is higher or lower

*** If slurry or manures are applied a full **Nutrient Management Plan** should be conducted in order to assess specific application rates*

Grassland Fertilizer Programme - Silage without Selenium

	March	After First Cut	After Second Cut
YaraMila®	**SULPHURCUT** **600 kg/ha**	**SULPHURCUT** **525 kg/ha**	**SULPHURCUT** **375 kg/ha**

** These recommendations are based on Yara research to optimise yield and quality of silage grass*
Rate should be adjusted if the forage demand is higher or lower

*** If slurry or manures are applied a full **Nutrient Management Plan** should be conducted in order to assess specific application rates*

Grassland Fertilizer Programme - Grazing with Selenium

	Feb/Mar	April	May	June	July	August
YaraMila®	STOCK BOOSTER 145 kg/ha		STOCK BOOSTER 200 kg/ha		STOCK BOOSTER 135 kg/ha	
YaraBela®		NUTRI BOOSTER 240 kg/ha		NUTRI BOOSTER 135 kg/ha		NUTRI BOOSTER 100 kg/ha

* *This fertilizer programme supplied a total nitrogen requirement of 240 kg N/ha*
Rate should be adjusted if the forage demand is higher or lower

* * *If slurry or manures are applied a full **Nutrient Management Plan** should be conducted in order to assess specific application rates*

Grassland Fertilizer Programme - Grazing without Selenium

	Feb/Mar	April	May	June	July	August
YaraMila®	EXTRAGRASS 130 kg/ha	EXTRAGRASS 225 kg/ha	EXTRAGRASS 185 kg/ha	EXTRAGRASS 125 kg/ha	EXTRAGRASS 115 kg/ha	EXTRAGRASS 100 kg/ha

* *This fertilizer programme supplied a total nitrogen requirement of 240 kg N/ha*
Rate should be adjusted if the forage demand is higher or lower

* * *If slurry or manures are applied a full **Nutrient Management Plan** should be conducted in order to assess specific application rates*

Grassland Fertilizer Programme - Hay

	March	April	May	June	July	August
YaraMila®	**NEW 52 475 kg/ha**					

* *If manures are applied a full **Nutrient Management Plan** should be conducted.*

** *Additional potash may be required at low soil indices.*

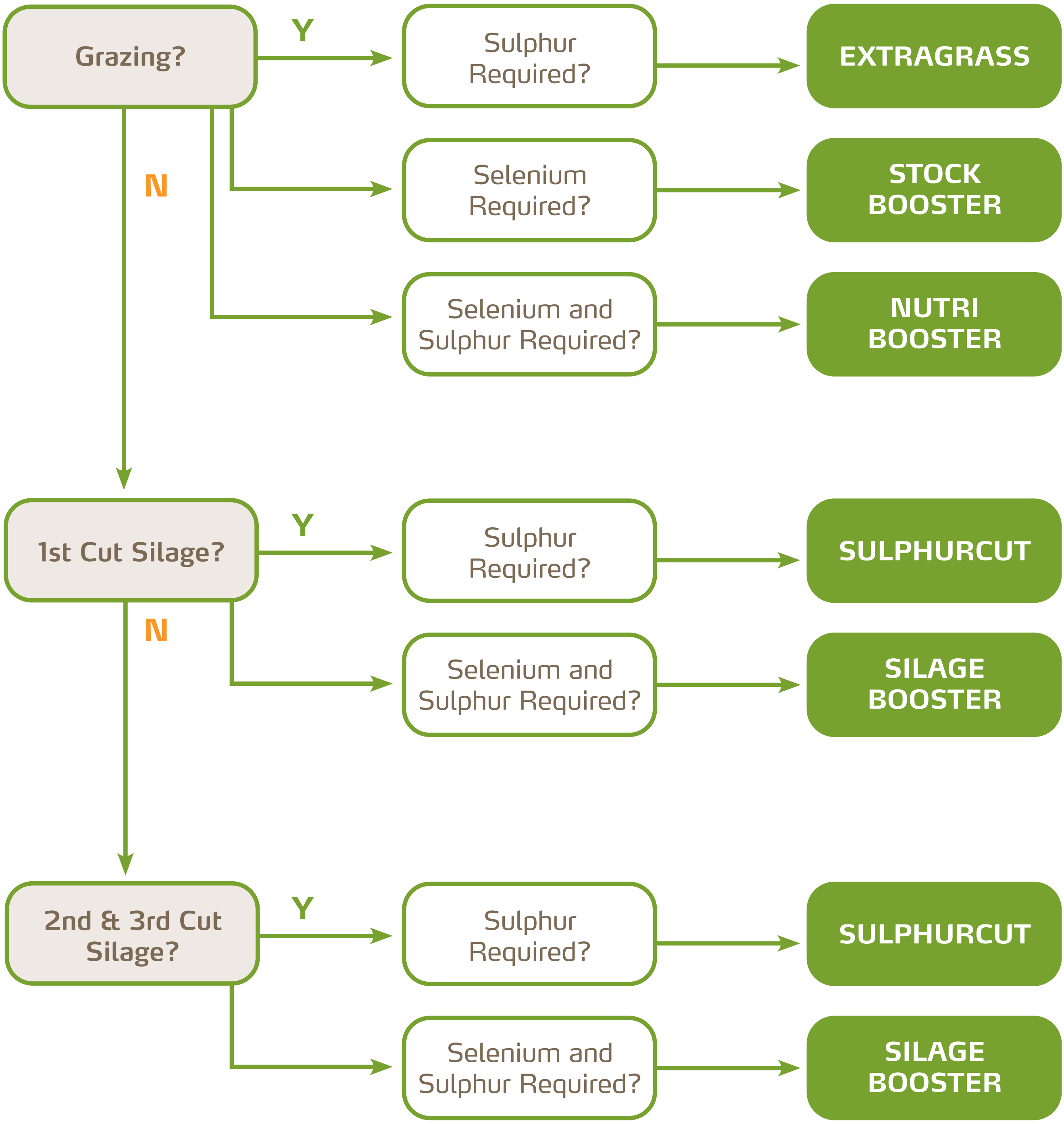
Grassland Fertilizer Programme - Establishment

	March	Seedbed (April sown)	May	June	July	Seedbed (August sown)
YaraMila®	**ACTYVA S 375 kg/ha**					
Yara						**SUPER PK 250 kg/ha**

* *If manures are applied a full **Nutrient Management Plan** should be conducted.*

** *The amount of phosphate and potash applied for establishment should be deducted from the season's grazing or silage/hay requirement.*

Grassland Fertilizer Programmes Decision Tree

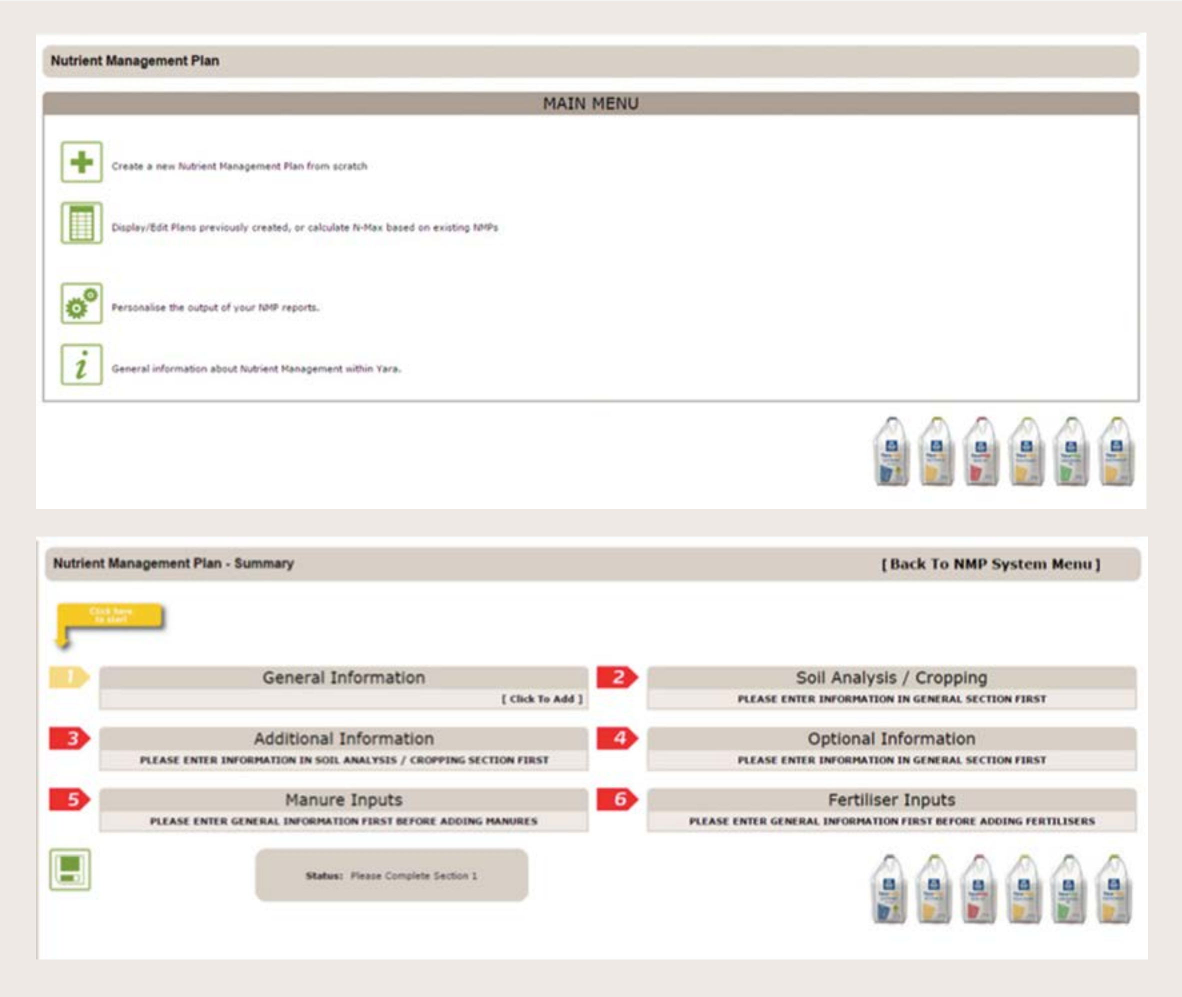


We recommend a full Nutrient Management Plan should be undertaken based on soil and manure analysis. The decision tree above will take you to a general recommendation for cutting or grazing

Yara Nutrient Management Planner

The Yara Nutrient Management Planner is a flexible recommendation tool for all crops based on the Fertiliser Manual and allows the easy completion of a full farm based Nutrient Management Plan.

For further details go to : **www.yara.co.uk/tools-and-services**



Product Summary

YaraMila EXTRAGRASS
(27-5-5 + 6% SO_3) is a quality granular compound fertlizer with sulphur, ideal for most grazing situations getting the grass off to a good start early in the season. With NPK and Sulphur in each granule the grass crop is assured the best start possible for every blade.

Available in England and Wales, Scotland and Northern Ireland.

YaraBela NUTRI BOOSTER
(25% N + S, Na and Se) is a unique fertilizer for use on grass. This fertilizer which is based on CAN as the nitrogen source offers the farmer the option of applying nitrogen and sulphur coupled with selenium which has proven health benefits for breeding stock and sodium which increases grass intake and increase liveweight gain.

Available England and Wales, Scotland and Northern Ireland.

YaraMila STOCK BOOSTER
(25-5-5 + Na + Se) is a compound prilled NPK fertilizer containing sodium and selenium for use on grassland to supplement selenium levels. Selenium is vital to the fertility in most mammals and prevents issues such as placental retention, increased white cell counts and white muscle disease. Sodium aids the uptake of selenium into the grass.

Only available in England and Wales, and Scotland.

YaraMila SILAGE BOOSTER
(20-5-15 + 7.5 SO_3 + Se) is a compound prilled NPK fertilizer containing selenium for use on grassland to supplement selenium levels. Selenium is vital to the fertility in most mammals and prevents issues such as placental retention, increased white cell counts and white muscle disease.

Available in England and Wales, Scotland and Northern Ireland

YaraMila ACTYVA S
(16-15-15 + 6.5% SO_3) is a uniform granular fertilizer ideal for establishing a new ley, supplying freshly available potassium and phosphate for the germinating seed, when soils are often cold and nutrient availability at its lowest.

Available in England and Wales, Scotland and Northern Ireland.

YaraMila SULPHUR CUT
(22-4-14 + 7.5% SO_3) is a quality NPK compound fertilizer with sulphur. This grade is ideal for replacing the large amount of potash removed after silage, whilst kick starting fresh grass growth.

Available in England and Wales, Scotland and Northern Ireland.

YaraMila NK SULPHUR
(25-0-13 + 7.5% SO_3) is a compound fertilizer that can be utilised for high phosphate, low potash soils deficient in sulphur. Often used to replace potash removed during silage off take.

Available in England, Wales and Scotland.

YaraMila SPRING CROP S
(20.6-8-8 + 7.5% SO_3) is a compound NPK + S fertilizer ideally suited to a wide range of crops including grassland.

Only available in England and Wales

Other grades are available and to check on the website **www.yara.co.uk/crop-nutrition/products** for full details.

Step 3 – Is your fertilizer plan giving you results?

Any management planning process should be monitored with constant reviews and adjustments made to achieve continual improvement.

During the season send-off grass foliage for laboratory analysis (e.g. to Lancrop Laboratories). A full broad spectrum analysis including Selenium will reveal any issues that need further attention, and changes in fertilizer practise can be made if needed. Grass should also be analysed for its nutritional quality as this will act as an alert to potential issues that could arise with a poor nutritional diet for the livestock.

For further detail go to:
www.yara.co.uk/tools-and-services

Manure analysis

A variation of manures can be tested from dirty water to poultry manure. The table below shows the range in dry matter and nutrient value in in 1361 'slurry' samples received over the last five years.

Manure average analysis (Lancrop Laboratory)

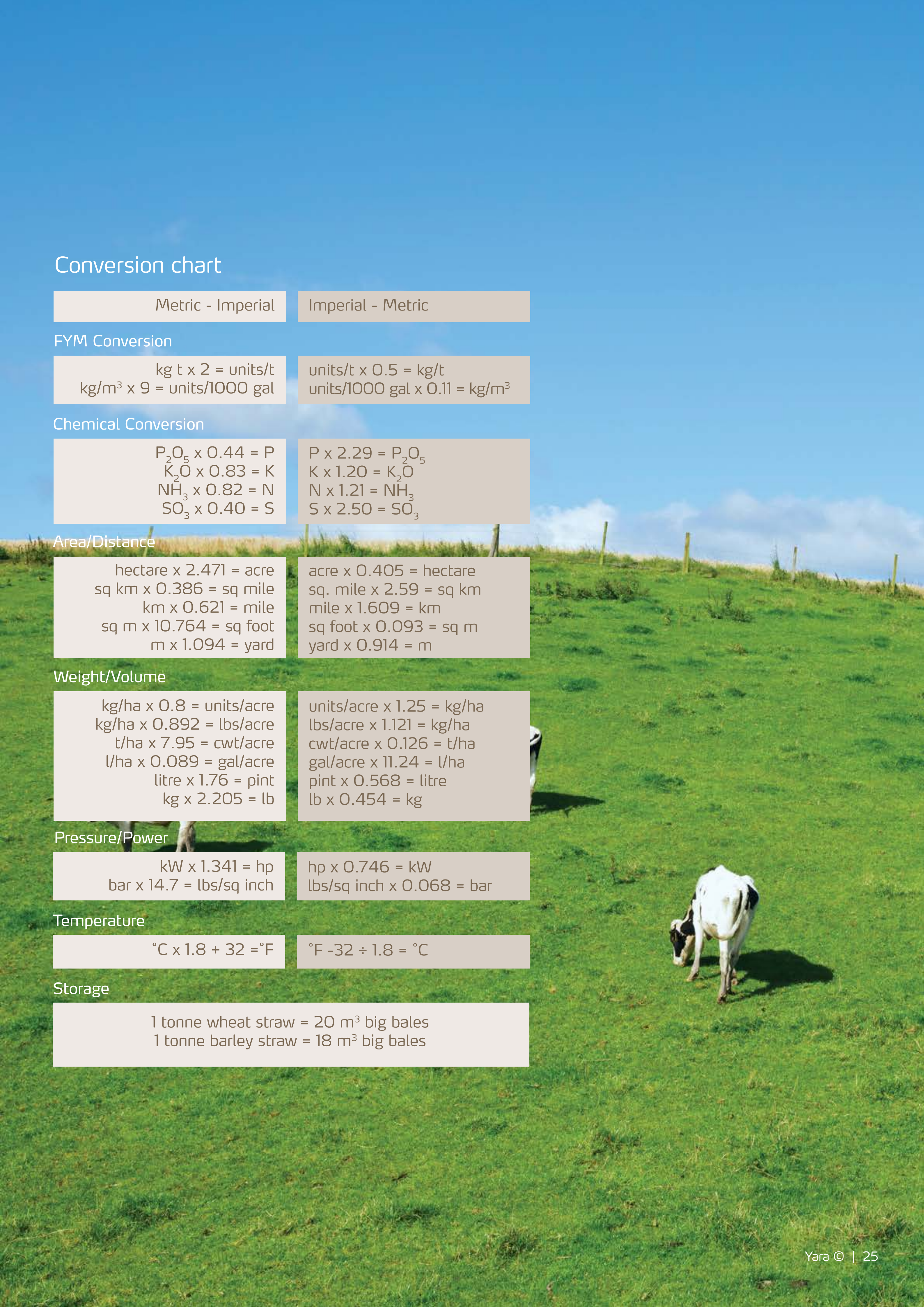
Element	Av	Max
Dry matter %	5.2	40.8
Nitrogen kg/t	2.8	14.3
Phosphorus kg/t	1.2	16.7
Potassium kg/t	2.4	17.1
Magnesium kg/t	0.6	5.5

Manures can supply large quantities of plant nutrients. The financial value of these can become increasingly important as fertilizer prices rise.

30 m³ (2750galls/acre) dairy slurry applied to a medium soil in winter.

NPK	N	P	K
Total kg/m³	2.6	0.5	2.7
Available kg/m³	0.8	0.3	2.4
Available kg/ha	23	7.8	72

Analysis may show your farm's manure to be higher or lower than these typical averages used. The diet, bedding type and dilution will alter the nutrient value. It is important the application rate is known, and that the manure is evenly spread to gain full benefit of the nutrients supplied.



Conversion chart

Metric - Imperial	Imperial - Metric
FYM Conversion	
kg t x 2 = units/t	units/t x 0.5 = kg/t
kg/m^3 x 9 = units/1000 gal	units/1000 gal x 0.11 = kg/m^3
Chemical Conversion	
P_2O_5 x 0.44 = P	P x 2.29 = P_2O_5
K_2O x 0.83 = K	K x 1.20 = K_2O
NH_3 x 0.82 = N	N x 1.21 = NH_3
SO_3 x 0.40 = S	S x 2.50 = SO_3
Area/Distance	
hectare x 2.471 = acre	acre x 0.405 = hectare
sq km x 0.386 = sq mile	sq. mile x 2.59 = sq km
km x 0.621 = mile	mile x 1.609 = km
sq m x 10.764 = sq foot	sq foot x 0.093 = sq m
m x 1.094 = yard	yard x 0.914 = m
Weight/Volume	
kg/ha x 0.8 = units/acre	units/acre x 1.25 = kg/ha
kg/ha x 0.892 = lbs/acre	lbs/acre x 1.121 = kg/ha
t/ha x 7.95 = cwt/acre	cwt/acre x 0.126 = t/ha
l/ha x 0.089 = gal/acre	gal/acre x 11.24 = l/ha
litre x 1.76 = pint	pint x 0.568 = litre
kg x 2.205 = lb	lb x 0.454 = kg
Pressure/Power	
kW x 1.341 = hp	hp x 0.746 = kW
bar x 14.7 = lbs/sq inch	lbs/sq inch x 0.068 = bar
Temperature	
˚C x 1.8 + 32 =˚F	˚F -32 ÷ 1.8 = ˚C

Storage

1 tonne wheat straw = 20 m^3 big bales
1 tonne barley straw = 18 m^3 big bales

About Yara

Yara grows knowledge to responsibly feed the world and protect the planet. Supporting our vision of a world without hunger and a planet respected, we pursue a strategy of sustainable value growth, promoting climate-friendly crop nutrition and zero-emission energy solutions. Yara's ambition is focused on growing a climate positive food future that creates value for our customers, shareholders and society at large and delivers a more sustainable food value chain.

To achieve our ambition, we have taken the lead in developing digital farming tools for precision farming, and work closely with partners throughout the food value chain to improve the efficiency and sustainability of food production. Through our focus on clean ammonia production, we aim to enable the hydrogen economy, driving a green transition of shipping, fertilizer production and other energy intensive industries.

Founded in 1905 to solve the emerging famine in Europe, Yara has established a unique position as the industry's only global crop nutrition company. We operate an integrated business model with around 17,000 employees and operations in over 60 countries, with a proven track record of strong returns. In 2020, Yara reported revenues of USD 11.6 billion

@Yara_UK Yara UK 01472 889250 agronomy.uk@yara.com www.yara.co.uk

Yara UK Limited
January 2023