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ABC Guide to Mineral Fertilizers

A basic handbook on fertilizers and their use

"Half the world's population is being fed from the added production resulting from mineral fertilizers." UNESCO

After soil and water, mineral fertilizer is the most important factor in providing food for a growing world population. The world's demand for food and consequently for fertilizers will increase in the years to come. Yara encourages Best Fertilizer Practice through developing comprehensive information on usage and application.

This work book has been produced to give a clearer understanding of what fertilizers are, the role they play in the growth of the crop, how they are used and how we all can benefit from them.

It has been designed in a way which will help you learn the facts contained within it. From time to time you will be asked to answer questions to make sure you understand the material you have read. Your answers should be written in the space provided. Correct answers are given on pages 27 and 28.

The ABC Guide to Mineral Fertilizers - a basic handbook on fertilizers and their use

This work book has introduced some of the most important issues related to NPK fertilizers. Many of the examples can be adapted to meet the needs of specific markets. More detailed information on the topics covered in this book can be found in Yara's publication 'Agriculture, Fertilizers and the Environment' ISBN 0 85199 385 3.

The book covers all aspects of fertilizer use including alternative nutrient systems. Further information on the subject of Fertilizers and the Environment can be found in the Yara publication 'Important Questions about Fertilizers and the Environment" or on the UK website - www.yara.co.uk

Question 11

Part 1. NO the cheaper NPK would not be a good buy. A 5% loss in yield from using a poor quality NPK fertilizer would lose the farmer 60 USD per ha. To be acceptable you would have to offer the cheaper fertilizer at a price of 120 USD per tonne less than Yara.

The answer was calculated as follows:

Part 2 - Value of 5% loss in yield.

Yield loss = Yield (t/ha) x percentage loss in yield (%)

$= 8 \times \frac{5}{100}$

= 0.4 t/ha

Value of yield loss (USD/ha) = Yield loss x crop price
= 0.4 x 150 (USD/ha)
= 60 USD/ha

Why not try the calculation for a crop in your market. You can use different yield losses and fertilizer prices. Use the outline below to complete the calculation.

Yield loss (t/ha) x % yield loss / 100 =

Value of yield loss (USD/ha) = yield loss (t/ha) x crop value (USD/t) =

Saving on fertilizer (USD/ha) = difference in price (USD/t) x application rate (tlha) =

The cheaper fertilizer is worth buying only if the saving on fertilizer is greater than the value of yield loss.

Question 12

Higher yields, better profit.

Question 13

Lower food costs, more secure food supplies.

Question 14

To calculate the answer use Figure 11 as a basis for the calculation.

	Usual Yield	5% Lower Yield
Yield (t/ha)	7	6.65
Value of yield (USD/ha)	1190	1130
Variable costs (USD/ha)	400	390
Gross margin (USD/ha)	790	740
Fixed costs (USD/ha)	600	600
Net Margin (USD/ha)	**190**	**140**

(a reduction of 26%)

Question 15

Part 1 - Leaching of nitrate, loss of phosphorus enriched particles and loss of ammonia or nitrogen oxides.

Part 2 - Ensuring the amounts of nutrients applied, match crop requirement, taking account of all sources of nutrients.

Question 16

By increasing crop yields on existing agricultural land and minimising the need to convert natural land to agriculture.

Increased organic matter from residues from higher crop yields.

Contents

What are fertilizers and why do we need them?

What are fertilizers?

The simple answer is that fertilizers are food for plants.

Why do we need fertilizers?

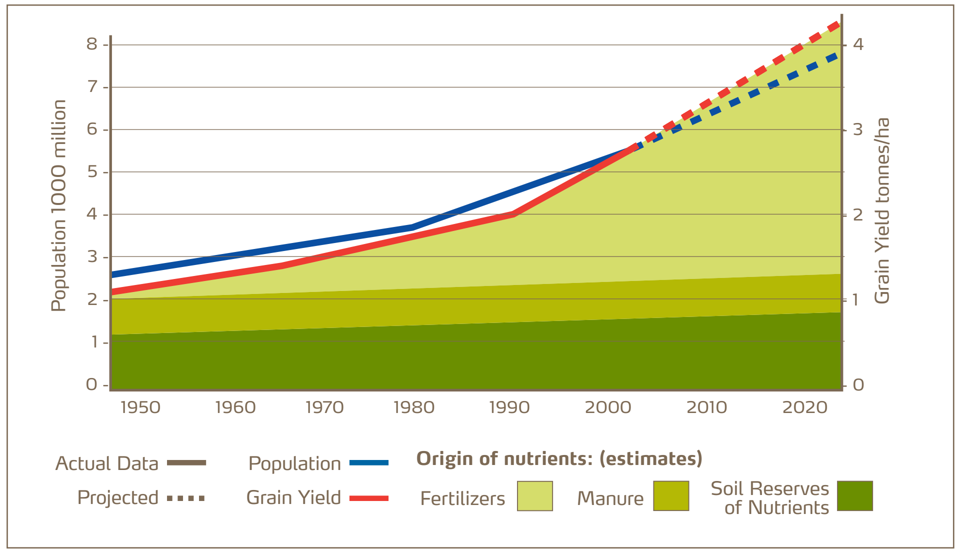
The role of fertilizers in food production is usually underestimated, even by those selling or using the products. Put very simply, fertilizers replace the nutrients that crops remove from the soil. Without the addition of fertilizers crop yields would be significantly reduced.

"If for some reason fertilizer use were abruptly discontinued, the world food output would probably plummet some 40 percent or more." (Worldwatch Institute, 1990)

The value of fertilizers can be shown by considering the consequences if fertilizer use was to stop. The best estimates are agricultural output in Western Europe would be reduced by 40 - 50% in the short term and in North America, Eastern Europe, Asia and Australasia by around 30%. Better re-cycling of wastes might alleviate the problem somewhat but an overall reduction in output of some 30% would be inevitable.

Figure 1

Global Trends in Population Growth, Grain Yield, and Origin of Plant Nutrients



SOURCE: STAPEL (1982) WITH LATEST DATA ADDED

Question 1

If fertilizer use was stopped what population could the world support using soils reserves and manure? (Figure 1. should help you decide).

....

Check your answers on pages 27 and 28

What are the main nutrients?

What are the main nutrients?

In order to grow and develop, plants need a supply of carbon, hydrogen and oxygen, which they get from the air and water, plus thirteen essential mineral elements (nutrients) which they normally get from the soil.

If the supply of these nutrients is insufficient for maximum crop growth, the crop would respond positively to the deficient nutrient (or nutrients) being added (Figure 2).

This means that any substance which contains one or more of these thirteen nutrients (in a form that is available to plants) will act as a fertilizer.

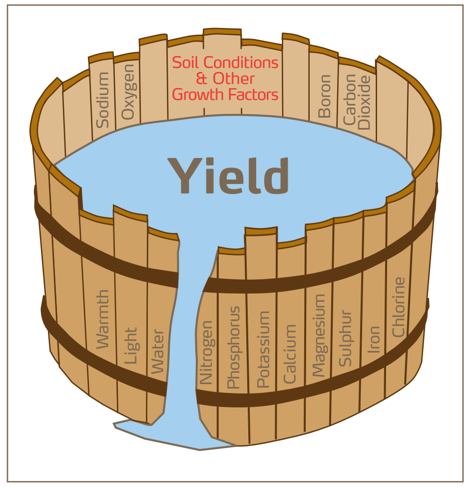
Table 1

The Thirteen Essential Nutrients

	Chemical symbol	Importance to plant
Nitrogen **Phosphorus** **Potassium**	(N) (P) (K)	Major or Primary Nutrients
Sulphur **Calcium** **Magnesium**	(S) (Ca) (Mg)	Secondary Nutrients
Iron **Manganese** **Zinc** **Boron** **Copper** **Molybdenum** **Chlorine**	(Fe) (Mn) (Zn) (B) (Cu) (Mo) (Cl)	Micro Nutrients

Figure 2

A Deficiency of any Single Nutrient is Enough to Limit Yield



(JUSTUS VON LIEBIG 1803 - 1873)

The 'law of the minimum' illustrated by barrel staves of varying lengths representing growth-controlling factors.

Question 2

Which are the 3 major nutrients?

1. ....

2. ....

3. ....

Check your answers on pages 27 and 28

Nutrient forms

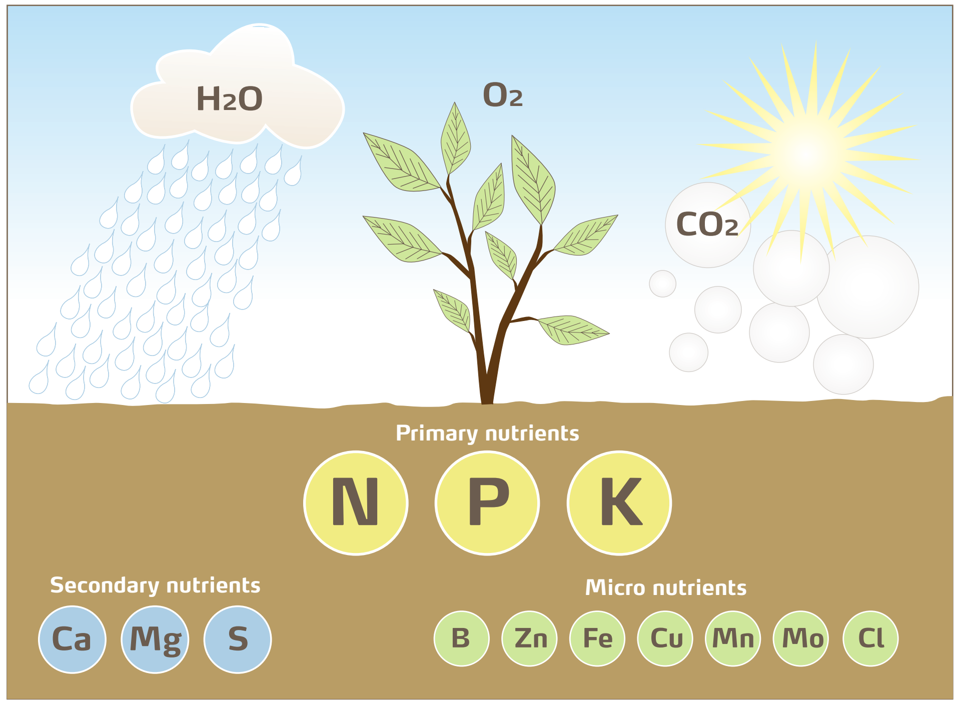
When inorganic molecules dissolve in water, they break apart into two or more parts, called ions, each with an electrical charge (+ or -). For example, when potassium chloride (KCl) dissolves, it forms a positively charged potassium ion (K^+) and a negatively charged chloride ion (Cl^-). Positively charged ions are called cations and negatively charged ions are anions. Examples of cations are ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and manganese (Mn^{2+}). Examples of anions are sulphate (SO_4^{2-}), chloride (Cl^-) and nitrate (NO_3^-).

Apart from boron, plants take up nutrients in the form of ions. Nitrogen is taken up as ammonium (NH_4^+) and nitrate (NO_3^-) (with nitrate the preferred N-form taken up by plants), potassium as potassium ions (K^+) and phosphorus mainly as phosphates ($H_2PO_4^-$ and HPO_4^{2-}). Boron is taken up mainly as boric acid (H_3BO_3) rather than as a charged ion.

Fertilizers are usually declared with the content of the three major nutrients N, P and K (e.g. 15 (N), 17 (K), 20 (P)) but fertilizer declarations do not always reflect the form in which a nutrient is taken up by plants, or the form that is present in the fertilizer. For example, potassium often is declared as K_2O and phosphorus as P_2O_5 though these are neither present in fertilizers nor taken up by plants. The use of K_2O or P_2O_5 as an indicator of the amount of potassium or phosphorus in a fertilizer is a convention that was established many years ago. Nitrogen is declared as N though it is present in mineral fertilizers as ammonium (NH_4^+), nitrate (NO_3^-) or urea ($CO(NH_2)_2$).

Declaring some nutrients in forms that are not present in fertilizers can cause confusion. For example, it might appear that ammonium nitrate contains just 34% nitrogen and that the remaining 66% is a filler. In fact, ammonium nitrate fertilizer consists almost entirely of the ammonium and nitrate that are taken up by plants. Apart from very small amounts of anti-caking agents, it consists entirely of nutrients and contains no filler. As another example, a 15-17-20 fertilizer could be made by mixing ammonium nitrate (NH_4NO_3), monoammonium phosphate ($NH_4H_2PO_4$) and muriate of potash (KCl) in equal proportions.

Figure 3
Primary, secondary and micro nutrients



This fertilizer apparently would contain a total of 52% nutrients (15 + 17 + 20) and the remaining 48% might seem to be inert filler. However, this product is very close to maximum nutrient concentration and will contain virtually no inert filler.

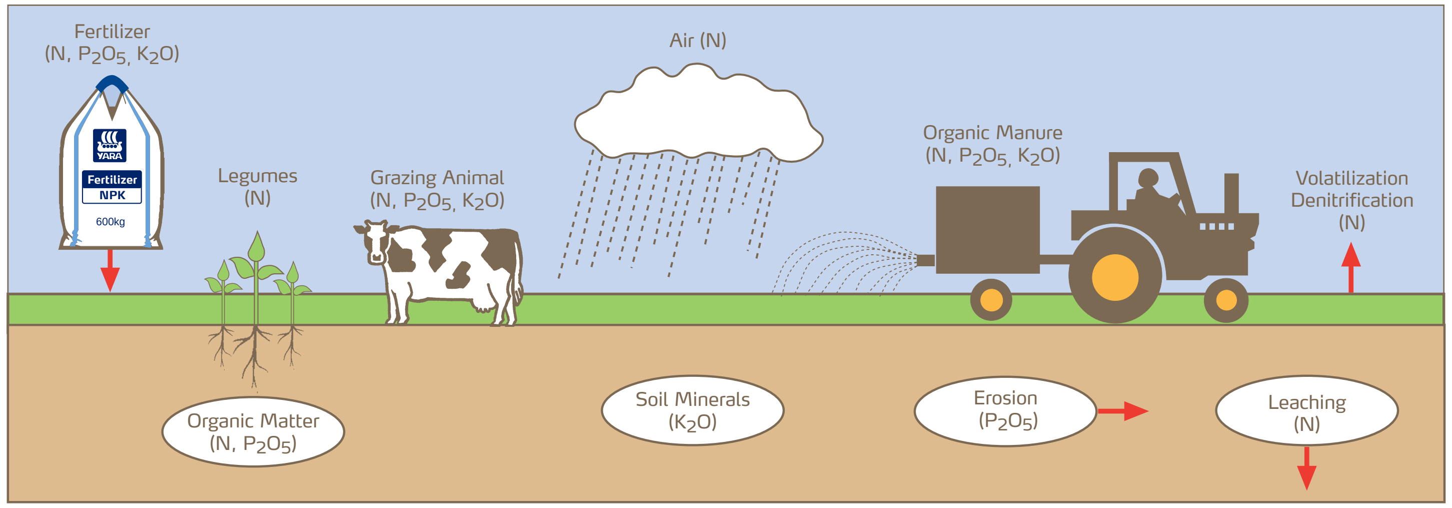
The 'active ingredients' of this fertilizer (that are taken up by plants) are NH_4^+, NO_3^-, $H_2PO_4^-$ and K^+ and the remaining part of the fertilizer comprises just the chloride ion in the muriate of potash.

The forms of nutrients that are taken up by plants and that are often declared for fertilizers are shown in Table 2. Whatever form of fertilizer or manure is used, it must breakdown to release the nutrients shown if it is to benefit crops.

Table 2
The Forms of Nutrients Taken up by Plants

Nutrient	Chemical symbol	Taken up mainly as	Usually declared as
Major or Primary Nutrients			
Nitrogen	(N)	NH_4^+, NO_3^-	N
Phosphorus	(P)	$H_2PO_4^-$, HPO_4^{2-}	P or P_2O_5
Potassium	(K)	K^+	K or K_2O
Secondary Nutrients			
Sulphur	(S)	SO_4^{2-}	S or SO_3
Calcium	(Ca)	Ca^{2+}	Ca or CaO
Magnesium	(Mg)	Mg^{2+}	Mg or MgO
Micro nutrients			
Iron	(Fe)	Fe^{2+}	Fe
Manganese	(Mn)	Mn^{2+}	Mn
Zinc	(Zn)	Zn^{2+}	Zn
Boron	(B)	H_3BO_3	B
Copper	(Cu)	Cu^{2+}	Cu
Molybdenum	(Mo)	Mo^{2+}	Mo
Chlorine	(Cl)	Cl^-	Not declared

Figure 4
The main pathways of nutrient supplies to soils



Question 3

Part 1. In what form is nitrogen taken up by plants?

....

Part 2. What is the preferred form of nitrogen taken up by plants?

....

Check your answers on pages 27 and 28

What are the roles of the main nutrients and what are their main sources of supply?

Nitrogen (N)

Nitrogen is the nutrient with the greatest influence on crop yield through the effect on chlorophyll and protein production.

Nitrogen

- Intensifies the green colour (chlorophyll).
- Increases leaf size.
- Increases growth rate.
- Increases final yield.
- Increases protein content.

Plants deficient in nitrogen have pale green or yellow leaves because of the lack of chlorophyll and become stunted through lack of leaf expansion.

Nitrogen deficiency in spring barley

Although nitrogen constitutes nearly 80% of the earth's atmosphere, most plants are unable to make use of it in this form.

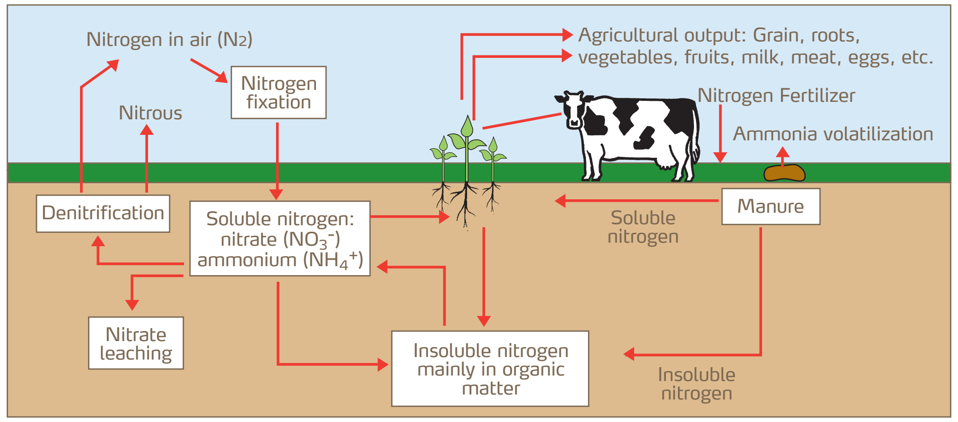
Leguminous crops e.g. peas and beans can fix nitrogen from the atmosphere, and need smaller or no additions of fertilizer nitrogen.

The soil contains a significant amount of nitrogen but this is largely present in complex organic forms. These are slowly converted to nitrate which will be absorbed by plants.

The quantity of this natural nitrogen supply varies considerably with different soils and climates. On average between 40 and 60 kg N per hectare per year is supplied - mainly from the breakdown of organic matter.

Agricultural outputs such as meat, milk, eggs, grain etc. all remove nitrogen from the field. Nitrogen can also be lost from the soil by nitrate leaching, denitrification, and volatilisation.

Figure 5
The Soil Nitrogen Cycle



The most common nitrogen fertilizers are;

NP/NPK Complex fertilizers	(5 - 30% N)
Ammonium Nitrate (AN)	(33.5 - 34.5% N)
Calcium Ammonium Nitrate (CAN)	(26 - 28% N)
Ammonium Sulphate (AS)	(21% N)
Calcium Nitrate (CN)	(15.5% N)
Urea (U)	(46% N)
Urea Ammonium Nitrate Solution (UAN)	(28 - 32% N)

Phosphorus (P)

Phosphorus is important in root development , the ripening process and particularly in the manufacture and use of sugars and complex carbohydrates. A good supply of phosphorus is essential in the early stages of a plant's life and for early maturity.

Phosphorus

- Stimulates root development.
- Helps plants to become established early in the season.
- Encourages maturity.

Phosphorus helps plants to produce a large effective root system that absorbs water and nutrients from the soil. The application of sufficient phosphorus also results in better setting of seeds and fruits and aids crop ripening.

Phosphorus in the soil is only sparingly soluble in water. This means that very little of it is dissolved in the soil water at any one time, limiting the availability to the plant. Because of the low solubility, very little phosphorus is leached from the soil and movement is restricted.

Some of the phosphorus residues left in the soil are gradually fixed or converted into unavailable forms by combination with other elements. Some of this stored phosphorus will be available to feed future plants.

Too little phosphorus is usually indicated by dull, bluish green leaves with purple or bronze tinting, but may be indicated only by reduced growth. This makes the identification of phosphorus deficiency difficult in many crops.

The root system will be poorly developed, maturity and ripening could be delayed. Deficiency is more pronounced in highly acidic soils (i.e. peat or sands) or alkaline soils (i.e. chalk).

Phosphorus deficiency in sugar beet

Phosphorus (P) is commonly referred to as phosphate (P_2O_5). The most common phosphate fertilizers are:

NP/NPK Complex Fertilizers	(5 - 23% P_2O_5)
Diammonium Phosphate (DAP)	(46 - 53% P_2O_5)
Monoammonium Phosphate (MAP)	(48 - 55% P_2O_5)
Single Superphosphate (SSP)	(16 - 20% P_2O_5)
Triple Superphosphate (TSP)	(42 - 50% P_2O_5)

Potassium (K)

Potassium is associated with the regulation of water within the plant and with the control of water loss from the leaves. It is particularly important in plants that store large amounts of sugar and starch e.g. potatoes. It is also vital for the root nodule bacteria on legumes which fix nitrogen from the air.

Potassium

- Encourages healthy growth.
- Renders crops more resistant to drought and disease.
- Improves the quality of the produce.

Potassium is a particularly important nutrient for potatoes, sugar beet, lucerne, tomatoes, bush and tree fruits.

The Potassium (K) content of fertilizers is commonly expressed as potash (K_2O). The most common fertilizers are;

Too little potassium leads to restricted growth producing leaves which are very dark green in colour. Later they develop yellow patches on the edges, which turn brown and die back. Potassium deficiency occurs more frequently on light sandy soils than on heavier clay soils.

Potassium deficiency in wheat

NP/NPK Complex Fertilizers	(5 - 30% K_2O)
Potassium Chloride (MOP)	(60 - 62% K_2O)
Potassium Sulphate (SOP)	(50% K_2O)
Potassium Nitrate	(46% K_2O)

Question 4

The major plant nutrients perform several essential roles in plants. For each of the major nutrients, nitrogen, phosphorus and potassium, list two essential roles they perform in the plant.

Nitrogen 1) .... 2) ....

Potassium 1) .... 2) ....

Phosphorus 1) .... 2) ....

Question 5

Which fertilizer nutrient increases protein content in crops? ....

Check your answers on pages 27 and 28

Secondary nutrients

Do the terms secondary and micro imply that some nutrients are less important to plants?
Certainly not, each of the 13 nutrients is essential because each has a specific function in plant growth. The terms major, secondary and micro tell us about the quantity of a nutrient that is necessary to carry out its specific task.

Magnesium (Mg)

This nutrient is an important constituent of chlorophyll and a large number of enzymes necessary for normal growth. It plays an active part in the movement of nutrients, especially phosphate, within the plant and is associated with the control of water within plant cells.

Magnesium deficiency symptoms are first seen on the older leaves. The commonest symptom is yellowing between the veins of the leaf. On soils which are low in magnesium deficiency symptoms may increase in severity when excess potassium is applied.

The most common magnesium fertilizers are;

NPK Complex Fertilizers .... (2 - 4%Mg)
Dolomite Limestone .... (12% Mg)
Kieserite .... (16% Mg)
Epsom Salts (bittersalz) .... (10% Mg)

Magnesium deficiency

Sulphur (S)

Sulphur is an essential component of several plant amino acids, the building blocks of protein. Deficiency of this element shows as pale leaves, and stunted growth. This results in reduced yields and protein contents. In parts of the world, air pollution has been reduced as cleaner industries emit less sulphur dioxide and there has been an increasing incidence of sulphur deficiency. This has especially occurred in crops with higher sulphur requirements such as oilseed rape, legumes, and grass cut for silage or hay.

Sulphur deficiency in maize (left)

The most common sulphur fertilizers are:

NP/NPK Complex NPK .... (2 - 10% S)
Ammonium Sulphate (AS) .... (24% S)
Gypsum .... (18% S)
Potassium Sulphate .... (18%S)

Calcium (Ca)

Calcium is required for plant growth, cell division and elongation. Root and shoot tips and storage organs are affected by calcium deficiency as it is part of cell membranes. Calcium is also vital for pollen growth.

Calcium is of particular importance to horticultural crops. An adequate calcium supply to the leaves and fruits is required to prevent disorders during crop growth, handling and storage.

Whilst some calcium is applied to crops as a nutrient, most is added to the soil as lime to correct soil acidity. Most crops grow best between pH 6 and 7 (7 is neutral, below 7 is acid, above 7 is alkaline) pH is a measurement of soil acidity.

Most common source of calcium as a fertilizer is Calcium Nitrate (CN 19% Ca).

Influence of soil pH

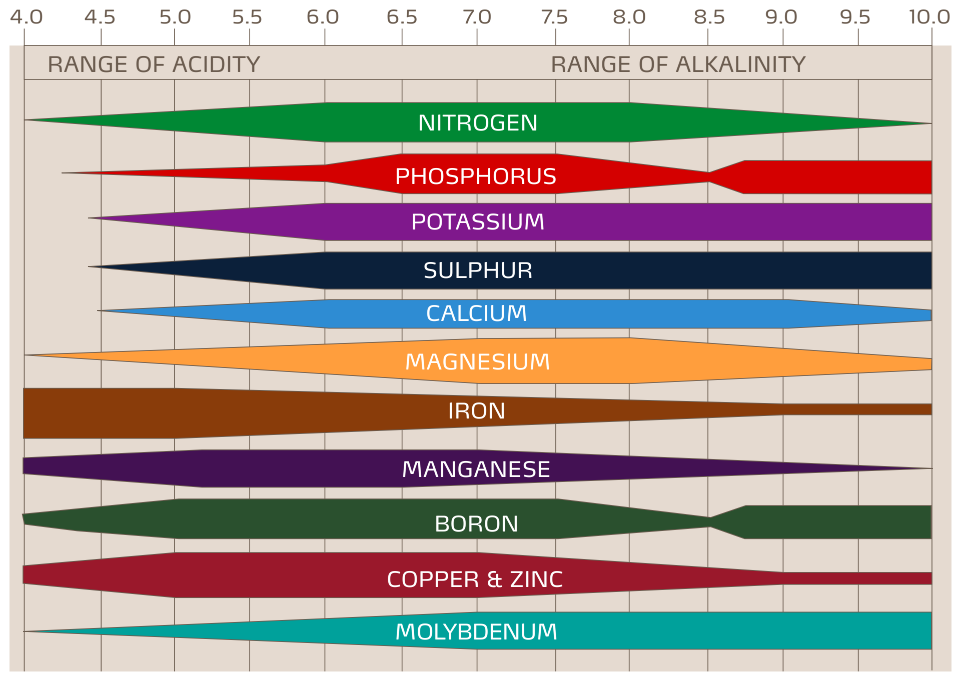
Both acid and alkaline conditions can reduce the availability of major, secondary and micro nutrients (Figure 6). It is almost impossible to do anything on a practical scale about soils which are alkaline to bring them down to a pH of 6 to 7. On acid soils lime can be added to bring the pH up to the required level.

Application of micro nutrients as foliar sprays to soil can correct deficiencies due to low nutrient availability at high pH.

In Figure 6, the broader the band the more available the nutrient.

Without Calcium

Figure 6
The Influence of Soil pH on Nutrient Availability



Question 6

For which crops is calcium particularly important?

....

Question 7

Why is sulphur deficiency becoming more common?

....

....

Check your answers on pages 27 and 28

Micro nutrients

The micro or trace elements include boron, manganese, iron, copper, zinc, molybdenum and chlorine.

Boron deficiency is widely recognised and gives rise to disorders in several important root crops and vegetables. These disorders can make the product unsaleable.

Boron deficiency

Manganese deficiency is particularly prevalent on organic soils with high pH content. The symptoms of manganese deficiency include yellowing of the leaves and sometimes grey specks on leaves.

Deficiencies of iron, copper, zinc and molybdenum are less common in Europe.

Manganese deficiency

Outside Europe, this deficiencies are widespread in semi arid and in calcerous soils. Molybdenum deficiency is a problem e.g. in Australia.

Copper deficiency in lettuce (right)

Zinc deficiency

Organic manures

Organic manures can be of plant or animal origin or a mixture of both. The largest source is the dung and urine from farm animals.

The nutrient content of manure is dependent on the source, particularly the species of animal, type of feed and the method of storage. Some manures are a mixture of wet or dry forms and are called slurries. As well as nutrients, manures are also a source of organic matter which helps to improve the soil structure.

Most manures produced on farms have a high water content and a low and variable nutrient concentration.

Only part of the nutrients in manure are immediately available to a crop. The rest has to be broken down by micro-organisms in the soil. The availability of these nutrients is difficult to predict as their release depends on many different factors. The effectiveness of the nutrients also depends on the time of application. Manures applied just before the winter or rainy season lose a significant proportion of their available nutrients via leaching. It is difficult to spread manures evenly over a field.

The nutrients in manure must be taken into account when farmers decide on the fertilizer they are going to use. In most countries information is published to help farmers take account of the nutrients in a range of manures.

Table 3

Average Nutrient and Dry Matter Content of Manures

	Nutrients kg/tonne of slurry or manure			
	Dry matter (%)	**Total N**	**Total P_2O_5**	**Total K_2O**
Slurry from dairy cows	6	3.0	1.2	3.5
FYM from dairy cows [1]	25	6.0	3.5	8.0
Slurry from pigs	4	4.0	2.0	2.5
FYM from pigs [1]	25	7.0	7.0	5.0
Manure from chickens [2]	30	16.0	13.0	9.0
Broiler litter [3]	60	30.0	25.0	18.0

1 - FYM is farm yard manure and is a mixture of slurry and straw used for bedding
2 - Manure from layer hens with no wood shavings or other litter
3 - Manure from chickens raised for meat and including litter

Question 8

If a cow produces 23t/year of slurry, how much nitrogen, phosphate and potash will a single cow supply over a year in kg?

Nitrogen: .... *Phosphate:* .... *Potash:* ....

Question 9

If a farmer has 150 cows and 100ha of land, how much of his land could he fertilize only with manure if the plants need 240kg N/ha/year and the nitrogen loss from manure is 30%?

....

Check your answers on pages 27 and 28

What is an NPK?

An NPK is the normal term for a product which contains all three of the major nutrients. These fertilizers can have a wide range of formulations that can be tailored to the needs of a market or crop sector. Similar fertilizers are also available which contain only two of the major nutrients e.g. NK, NP, or PK. Some NPKs are also specially formulated to contain secondary or micro nutrients. These are either manufactured as a complex product or as a blend.

Is there a difference between a complex NPK and a blended NPK?

With a complex NPK, all the ingredients are mixed before being formed into particles. Each particle contains N, P and K. The particles are screened to ensure that the product size range conforms to a tight specification. Complex NPK's tend to have a consistent bulk density.

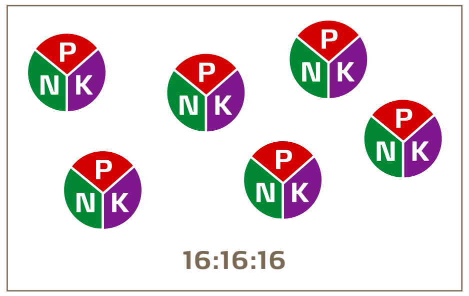
Blending entails the physical mixing of the dry fertilizer materials. For example, in NPK blended fertilizers, all three nutrients can be in completely separate particles. With poorer quality blended fertilizers, there is often a large variation in the bulk density and particle size between the components, and they can be incompatible in moisture and chemical nature.

This can cause segregation and caking of the individual components during handling and spreading, resulting in uneven application of the nutrients. This can result in reduced yields and crop quality.

Most of Yara's NPK fertilizers are complex NPK's produced by the nitrophosphate process. For some markets, Yara produces a range of high quality blended NPKs based on size, moisture, chemical compatability and density matched ingredients.

Figure 7

Complex NPK e.g. Yara Fertilizers



Complex NPK e.g. Yara Fertilizers

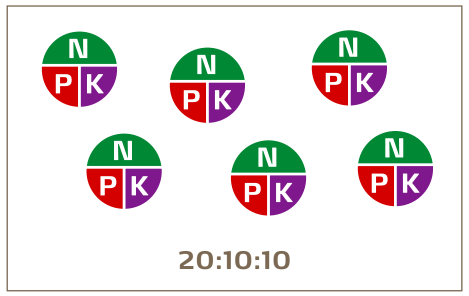
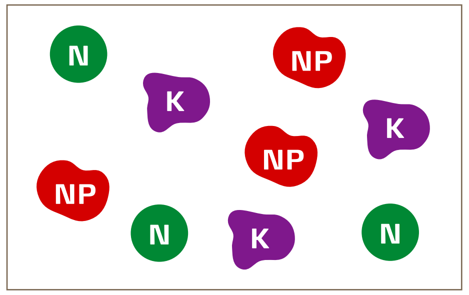


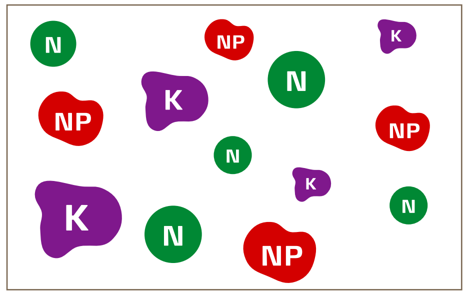
Figure 8

Blended NPK

Evenly Blended - Good quality blend



Unevenly Blended - Poor quality blend



Why is there a need for a wide range of fertilizers?

For healthy growth the plant must have access to all the right nutrients, at the right time, in the right amounts and in the correct proportions.

Fertilizer recommendations take into account the requirements of the crop (which depend on crop species, variety and yield potential) and the estimated supply of nutrients from other sources. Of most importance is the supply from the soil which varies from field to field. Published recommendations are usually available from official advisory services to help farmers arrive at the right application. It is possible to make some fertilizer recommendations based only on the amounts of nutrients removed by a crop (Table 4).

Table 4

Typical Removal of Nutrients

	kg per ha		
	N	P_2O_5	K_2O
Paddy Rice (grain + straw)	110	35	150
Maize	120	60	70
Wheat (grain + straw)	220	80	90
Potato	200	75	300
Sugar Cane	200	90	100
Vegetables	80	80	100

Farmers grow crops in sequences (called a rotation) depending on local customs and good farming practice.

In some cases this practice is essential to control weeds, pest and diseases. When fertilizers are unavailable, rotations are used to build up supplies of nutrients in the soil. Typical rotations for a single field could be (Table 5).

Table 5

	North West Europe	Africa
Year 1	Cereal crop e.g. Wheat	Maize
Year 2	Root crop e.g. Potatoes	Groundnut
Year 3	Cereal crop e.g. Barley	Millet
Year 4	Grass for grazing animals	Fallow
Year 5	Grass for grazing animals	

Question 10

What are the main sources of nutrients for plants?

....

....

Check your answers on pages 27 and 28

The place of each crop in the rotation has a significant effect on the fertilizers the farmer will need to apply. With the use of modern fertilizers and pesticides there is less need to rotate crops. Many farmers now use very simple rotations and some even grow a single crop on a continuous basis.

Because soils, crops, weather conditions and crop rotations vary widely in the world, there is a corresponding need for a range of fertilizer grades.

Yara meet this need by making a range of fertilizer grades and fertilizer systems for specific applications.

What are fertilization systems?

The farmer has to choose the best system to supply the nutrient requirements of his crop. Nitrogen, is the dominant factor in crop nutrition, other nutrients are needed in the right ratio to release the full yield potential.

The main choices are:

- Straights - N, P, K.
- An NPK plus straight nitrogen N.
- An NPK tailored to the crop's needs.

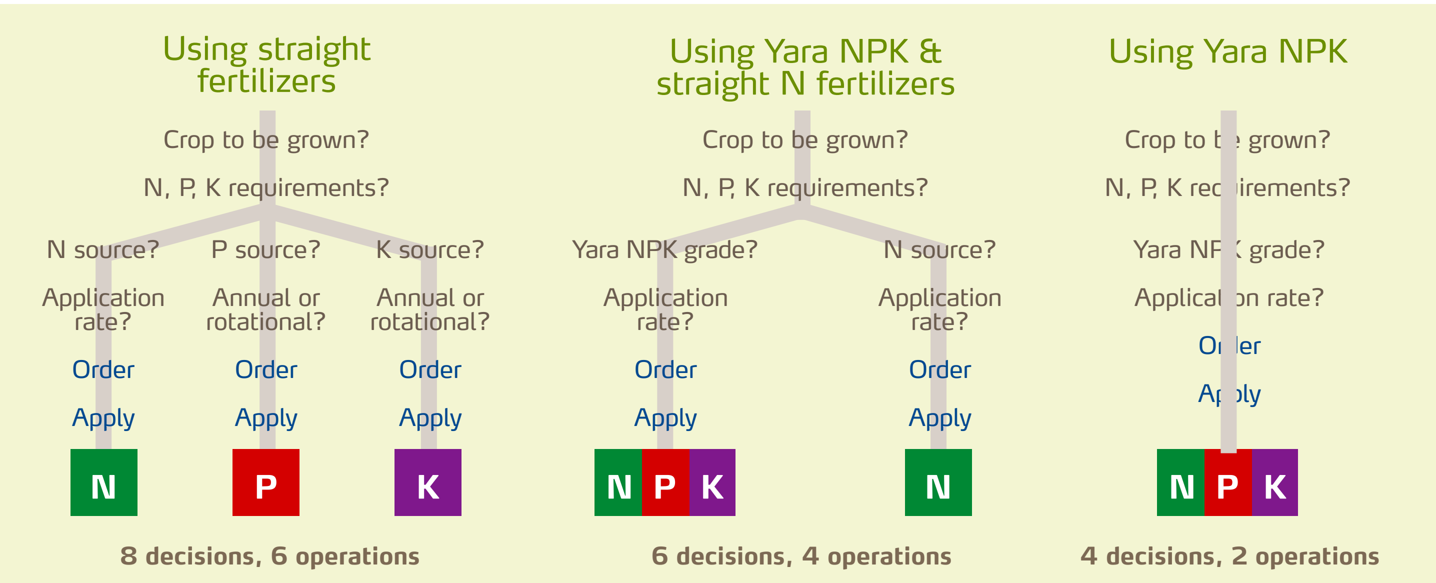
In most situations, a fertilizer system based on either an NPK fertilizer or an NPK + straight nitrogen is most practical and economic.

To be successful, a fertilizer system should offer the farmer some or all of the following:

- Easy decisions on the rate and timing of fertilizer applications.
- Better crop yields and/or quality per tonne of yield.
- Reduced per tonne of yield cost for producing crops.
- Improvement in cash flow.
- Higher profits.

Figure 9

Fertilizer Systems Examples



What is meant by the quality of a fertilizer?

The quality of fertilizer refers to;

- Its bulk density
- The nutrient content.
- Its moisture content.
- The particle strength.
- Whether or not the fertilizer is free flowing.
- Particle size distribution.

Bulk density

The bulk density is the weight of a given volume of fertilizer. This affects the time needed to spread fertilizer. The lower the bulk density the less fertilizer can be held in the spreader hopper. Consistency in bulk density is also important to maintain spreading accuracy.

Nutrient content

When a customer purchases fertilizer, the nutrient content i.e. NPK, should be as declared. With some cheap, low quality products, this is not always the case. In other words, the customer does not get what he pays for.

Moisture content

A high moisture content can cause caking. Caking means that the fertilizer has hardened into lump. Caked fertilizer is difficult to use and can cause spreading problems. This can lead to a reduction in yield and crop quality.

Particle strength

A material that has a low particle strength is more likely to be crushed and turned into dust. This will cause problems with storage, wasted fertilizer, lost time, poor spreading and lost profit.

Free flowing fertilizer

A free flowing fertilizer will be easier to spread and will give a predictable spread pattern.

Particle size distribution

The particle size distribution affects both the evenness of spreading and the maximum spreading width. There should be little dust that can block spreaders.

All Yara's NPK fertilizers are especially formulated and are routinely checked to ensure they meet the needs of the customer. The quality checks start with the raw materials and continue through the production system out into the market place.

Homogeneous fertilizer

Poor blend fertilizer

Caked fertilizer

Is fertilizer economic to use?

The fact that fertilizer application reduces food production costs is seldom appreciated. When fertilizer is used at the optimum rate, the production cost per tonne of the crop is at its lowest (Figure 10). Using an amount of fertilizer above or below the optimum increases the cost of production. Above the optimum the extra revenue from applying more fertilizer does not cover the cost of the increased fertilizer rate. Below the optimum, the value of the lost yield is greater than the saving on fertilizer used.

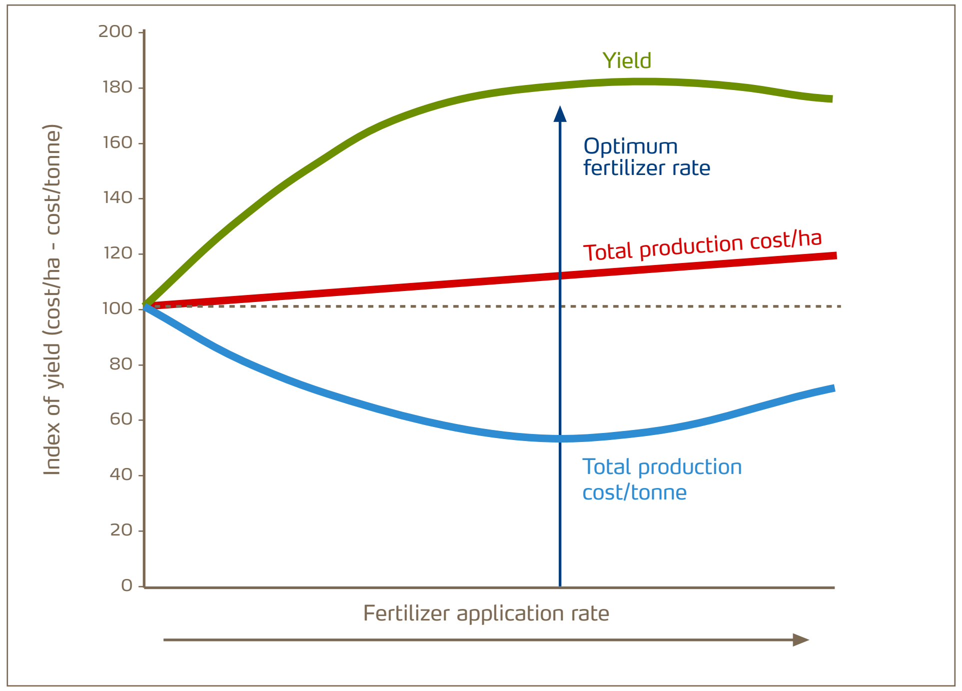
Figure 10, is based on the results of 36 trials on wheat in the UK. It shows that fertilizer resulted in an 80% increase in yield but only a 20% increase in production costs per ha. Production cost per tonne of grain produced falls by some 40%.

Both farmers and consumers benefit from the use of fertilizers

- The farmer benefits through higher yields and profit margins.
- The consumer benefits through increased food supplies and lower prices.

Figure 10

Effect of total fertilizer on wheat yield and production costs per ha and per tonne



Although Figure 11 illustrates the relationship between fertilizer input, yield and costs is based on UK data for wheat, the principal relationship is valid for all other crops and countries. It can readily be calculated provided:

- Fertilizer response data is available from a reasonable number of field trials.
- Reliable data on typical farm costs of production for a particular crop can be obtained.

Question 11

A farmer growing a crop of wheat with an expected yield of 8 tonnes per hectare is offered an NPK at a price which is 15 USD per tonne cheaper than a Yara NPK. The low quality of this product could reduce his yield by 5% because of poor spreading. (The value of the crop is 150 USD per tonne, one tonne of NPK fertilizer will be sufficient for two hectares).

Part 1 - Is the cheaper NPK a good buy for the farmer?

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Part 2 - What is the value of the 5% reduction in yield?

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Question 12

What benefits do fertilizers bring to farmers?

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Question 13

How do fertilizers benefit consumers?

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Check your answers on pages 27 and 28

What is meant by optimum yield?

Optimum yield usually refers to maximum economic yield, this is normally slightly less than maximum biological yield. To achieve maximum biological yield, the additional cost of fertilizer may be higher than the value of the additional production (see Figure 11).

The profits of any farmer are dependent on the yield of the crops he grows. A small yield loss due, for example, to a poor quality fertilizer, incorrect grade, or uneven application, can have a disproportionate effect on gross margin (gross output minus variable costs) and on net margin (gross margin minus fixed costs). The variable costs include fertilizer and plant protection chemicals, the fixed costs include machinery, labour, etc.

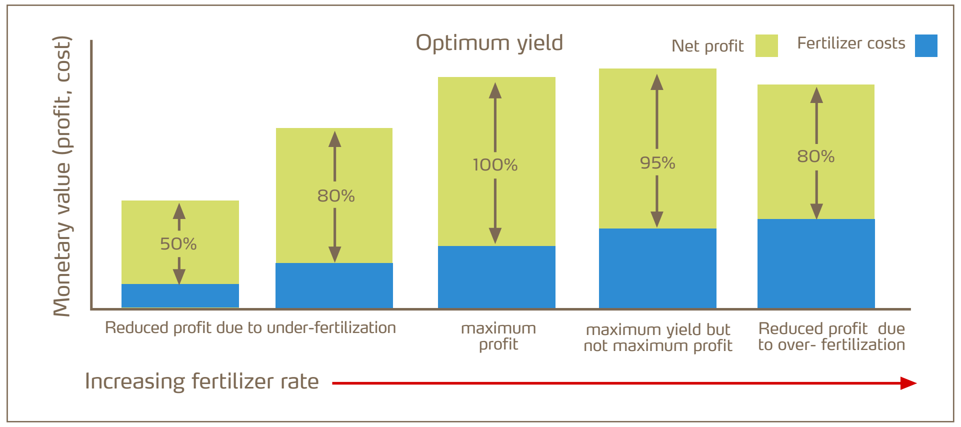
Table 6

Gross Margin and Net Margin for Potatoes

	Optimum Yield	5% Lower Yield
Yield (t/ha)	40t/ha	38t/ha
Value of yield (A) (USD/ha)	4387	4168
Variable costs (B) (USD/ha)	2775	2775
Gross margin (A - B = C) (USD/ha)	1612	1393 (14% reduction)
Fixed costs (D) (USD/ha)	1050	1050
Net Margin (C-D) (USD/ha)	562	343 (39% reduction)

Figure 11

Costs and Profits of Fertilizers



The example (Table 6) shows, that a 5% loss in yield in potatoes results in a 14% reduction in gross margin and a 39% reduction in net margin.

These are typical figures from European agriculture, similar examples can be calculated for other areas.

Question 14

A farmer normally achieves a yield of 7t/ha from his crops of wheat. He is looking to buy a cheaper fertilizer. If you assume he will get a 5% lower yield, **what will be the effect on his gross margin and net margin per hectare?** His fixed costs are 600 USD/ha. His variable costs will be 400 USD/ha with Yara product and 390 USD/ha where he uses the cheaper product. The crop price is 170 USD/ha.

Check your answers on pages 27 and 28

Does fertilizer represent a major part of the variable cost of growing a crop?

It is important to put the cost of fertilizer into context. A farmer buys a range of inputs to increase the yield and profitability of his crops.

The three major inputs are seed, fertilizers and plant protection chemicals which constitute the bulk of the variable costs of growing a crop. In general for arable crops in Western Europe fertilizer accounts for 20 to 35% of the variable costs (see Figure 12).

On vegetables, the fertilizer only accounts for about 5 to 10% of the variable costs. The return from the investment in fertilizer is so large (see page 16) that the farmer can afford the best quality fertilizer without significantly increasing his costs.

In Africa, the percentage of the variable costs from fertilizer is very similar to Western Europe (see Figure 13).

Figure 12

Fertilizer as a Percentage of the Total Variable Cost of a Growing Crop

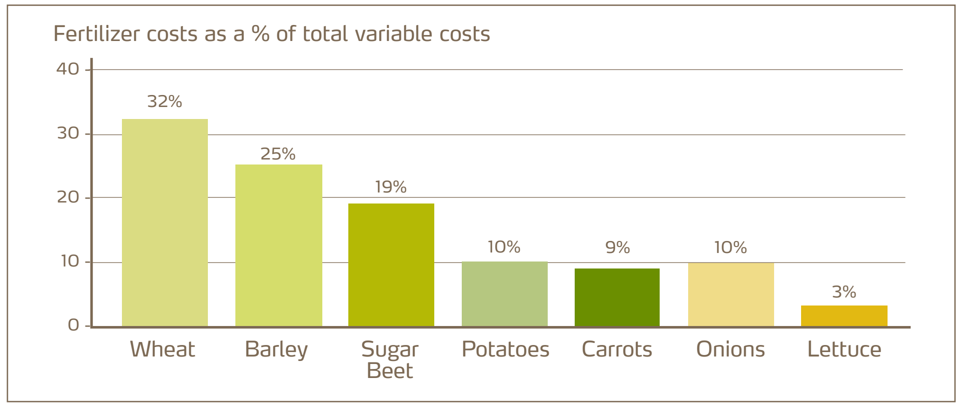
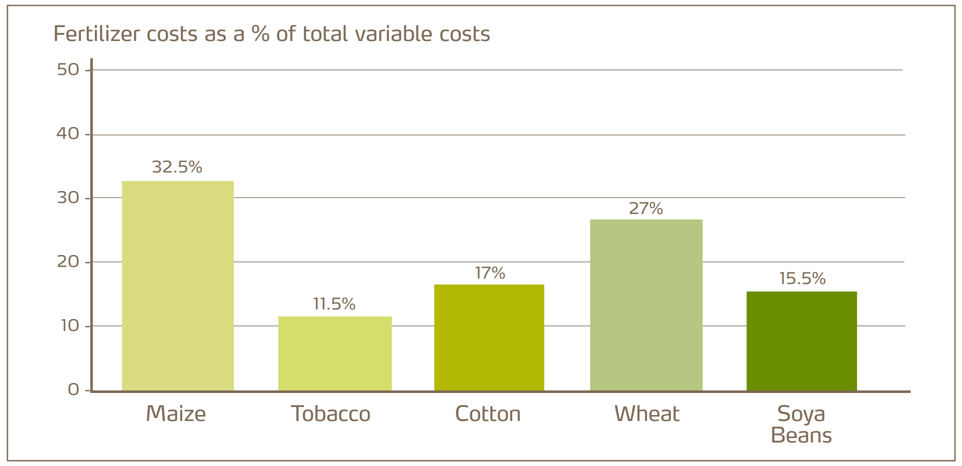


Figure 13

Fertilizer as a Percentage of the Total Variable Cost of a Growing Crops in Africa



What are the main application methods?

The objective of fertilizer application is to get the intended dose of nutrients to every plant in the crop. There is a number of different methods in use that attempt to get an even spread of nutrients at minimum cost.

Hand application

Hand application

Hand application is used in countries where labour is plentiful and the majority of the population is involved in agriculture. Plants can be given individual applications of fertilizer. Rates tend to be variable and application can be very uneven.

Machine application of solid fertilizers

Mechanical spreading of fertilizers has been progressively developed to cope where labour is scarce or expensive. The aim has been to increase the accuracy and speed of fertilizer application.

Box spreaders

These are similar to seed drills. They have a long box which forms the hopper and some mechanism, driven by the land wheels, to dribble the fertilizer out through holes along its length. The spreading (bout) width is narrow, perhaps 2 metres. Reasonably even application is achieved.

The area fertilized per day by such a spreader is quite small. As farms have become larger and tractors more powerful, new methods have been developed. These give wider spreading widths and increase the area spread per day. In most countries box spreaders are now rarely used with most farmers using the higher output machines.

Oscillating spout spreaders

With these machines the fertilizer is spread by means of an oscillating spout imitating hand spreading. They effectively spread the fertilizer in a wide band behind the machine. The spreading widths which can be achieved depend on the physical properties of the fertilizer but on average spreading widths of 6 - 12 metres can be expected.

Oscillating spout spreader

Spinning disc spreaders

In these machines the fertilizer is spread by one or two spinning discs which have raised vanes. The fertilizer makes only brief contact with the disc. However the energy the fertilizer picks up is sufficient to spread the fertilizer over very large distances. With good quality fertilizer, spreading widths of up to 36 metres can be achieved. This increases the number of hectares which can be spread in a day, cutting the cost of fertilizer application.

A hopper which can hold more than 4 tonnes of fertilizer is usually mounted above the discs. The rate of application is controlled by varying the flow rate from this hopper. In some countries this type of spreading system has been mounted on large self propelled machines. These machines are used by retailers or contractors to spread fertilizer for a large number of farmers.

Spinning disc spreader

Pneumatic spreader

Liquid fertilizer spreader

Pneumatic spreaders

Pneumatic spreaders use air to distribute fertilizer along a fixed boom similar to those used in plant protection chemical / liquid fertilizer sprayers. Outlets are set at intervals along the boom usually with some form of spreader plate to give an even spread pattern. These machines were developed in an attempt to improve the accuracy and evenness of application. Spreading widths of up to 24 metres can be achieved. Pneumatic spreaders tend to be significantly more expensive than disc or oscillating spout machines and usually require more maintenance. It is widely thought that the physical quality of the fertilizer used in pneumatic machines is not important. However, inconsistencies in the quality of the fertilizer can affect its flow through the machine producing poor spread patterns, and it has been proved that the spreading characteristics of poor quality fertilizer cannot be compensated by investment in a pneumatic spreader.

Mechanical spreaders which reach the market have been well designed and tested. This ensures that they spread fertilizer evenly at the correct rate, and the right bout width provided they are correctly calibrated and operated.

They must be properly maintained, correctly adjusted and the fertilizer must be of good quality.

Machine application of liquid fertilizers

These are spread through booms which can be greater than 36m wide. The fertilizer is held in a tank and forced under pressure through nozzles set along the boom. The tank may be mounted or pulled by a tractor or may be on a self propelled sprayer machine.

Can fertilizers affect the environment?

The role of fertilizers is to supplement naturally occurring plant nutrient supplies to levels that support economic crop yields. Fertilizers do not add chemicals to the soil that are not already present. Properly used therefore, fertilizers should have very little adverse effect on the environment.

The aim of the farmer is to use just enough fertilizer to match total nutrient supply to the requirements of the crop. Various recommendation methods including trained advisers, booklets, computer programmes and 'expert systems' are available to help in decisions. Matching nutrient supply to crop requirement leaves very little nutrient unused that can then be lost to the wider environment.

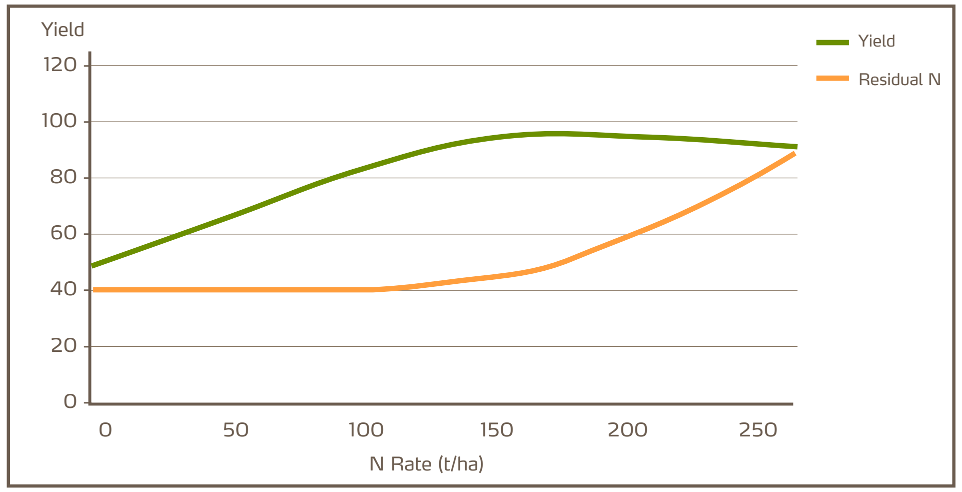
For example, the amount of nitrate in the soil (that is at risk of leaching later) after harvest of cereals remains almost unchanged as fertilizer nitrogen is applied up to the optimum amount (Figure 14).

Problems can occur where:

- More nutrient is applied than the crop needs, either over the whole field or over part of a field (due, for example, to uneven spreading).
- A deficiency in one nutrient is left uncorrected leading to unbalanced nutrition and poor utilisation of other nutrients.
- Nutrients applied in manures are not taken into account when applying fertilizer.

Figure 14

Cereal Yield, Residual Soil N After Harvest and Rate of Fertilizer N Applied



The problems that can then occur are:

- Leaching of nitrate into aquifers or surface waters.
- Loss of phosphorus-enriched soil particles to surface waters that can cause eutrophication.
- Loss of ammonia or nitrogen oxides to the air by volatilisation or denitrification.

All of these processes occur naturally but fertilizer can contribute to them. It is important therefore that fertilizer use is properly managed and Yara has developed a range of farmer services to help.

One other specific issue is the cadmium in fertilizers that derives from the phosphate rock used in manufacture. Amounts of cadmium added to soil in fertilizers are small compared to those already present or added in some organic wastes. Nevertheless, Yara fertilizers are manufactured from phosphate rock sources that are low in cadmium.

Striping due to uneven fertilizer spreading

Can fertilizers have a beneficial impact on the environment?

When used correctly fertilizers improve and protect the environment in several ways:

- Improved productivity from cropped land avoids the need to destroy further areas of natural forest and grassland.
- Sustained green crop growth essential for maintenance of the atmosphere.
- Reduced losses of soil due to wind or water erosion. Erosion is where small particles of soil are lost from fields by the action of wind or water. Many of these soil particles end up in watercourses potentially causing pollution of surface waters.

Soil erosion

Erosion is reduced by the maintenance of green crop cover with active healthy root system.

- Improved crop rooting systems which can make better use of both the soils nutrient supply and applied fertilizers. This reduces the risk of nutrients entering ground water.
- Land reclamation and safe disposal of degradable wastes is improved by fertilizers encouraging active crop growth.
- Increased soil organic matter through incorporation of greater amounts of stubble, straw and stalk residue associated with higher crop yields.

Healthy rooting system

Question 15

Part 1. What are the main environmental issues associated with fertiliser use?

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Part 2. What is the key to overcoming these problems?

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Question 16

How can fertilizer use benefit the environment?

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Check your answer on pages 27 and 28

Conversion factors

Chemical Conversions

P_2O_5	x	0.44 = P
K_2O	x	0.83 = K
Na_2O	x	0.74 = Na
CaO	x	0.71 = Ca
MgO	x	0.60 = Mg
NH_3	x	0.82 = N
SO_3	x	0.4 = S
CaO	x	1.78 = $CaCO_3$
P	x	2.29 = P_2O_5
K	x	1.20 = K_2O
Na	x	1.35 = Na_2O
Ca	x	1.40 = CaO
Mg	x	1.66 = MgO
N	x	1.23 = NH_3
S	x	2.50 = SO_3
$CaCO_3$	x	0.56 = CaO

Measurement Conversions

Km	x	0.621	=	Miles
Miles	x	1.609	=	Km
Metres	x	1.094	=	Yards
Yards	x	0.914	=	Metres
Metres	x	3.28	=	Feet
Feet	x	0.304	=	Metres
Hectare	x	2.47	=	Acre
Acre	x	0.405	=	Hectare
Square Km	x	247	=	Square Acre
Square Acre	x	0.00405	=	Square Km
Square Km	x	0.386	=	Square Mile
Square Mile	x	2.590	=	Square Km
Square Metre	x	0.000247	=	Square Acre
Square Acre	x	4050	=	Square metre
Kilogram / ha	x	0.893	=	Pound / ha
Pound / ha	x	1.12	=	Kilogram / ha
Litre / ha	x	0.09	=	Gallon / acre
Gallon / acre	x	11	=	Litre / ha
Milligram / kg	x	1	=	Part / million
Parts / million	x	1	=	Milligram / kg

Glossary

Agronomy: The branch of agriculture dealing with crop production.

Alternative or organic agriculture: A collective term for agricultural practices that reject the use of soluble mineral fertilizers and plant protection chemicals.

Ammonium nitrate: NH_4NO_3, made from nitric acid and ammonia. Common fertilizer, with 33.5% - 34.5% nitrogen, one half as ammonium, one half as nitrate.

Ammonium sulphate: $(NH_4)_2SO_4$, ammonium salt of sulphuric acid. Traditional fertilizer supplying both nitrogen and sulphur, first produced as by-product in coal-gas manufacture.

Anaerobic: Oxygen deficient conditions.

Anion: A negatively charged atom or group of atoms, e.g. nitrate (NO_3^-) or sulphate (SO_4^{2-}).

Application: General term covering all processes for giving fertilizers to crop or soil.

Aquifer: A layer of rock which holds water and allows water to percolate through it.

Arable: Farming based on annual ploughing or cultivation of the land and sowing of an annual crop.

Calcareous: Containing calcium usually in the form of chalk or limestone. Normally a description of soils.

Calcination: Heating to high temperature.

Calcium ammonium nitrate: A mixture of ammonium nitrate and pulverized limestone or related material, made into particles. Contains 26% - 27% nitrogen.

Calcium nitrate: Calcium salt of nitric acid, a non-acidifying fertilizer with 15.5% nitrogen.

CAP: Abbreviation for Common Agricultural Policy of the European Union.

Catch crop: An extra crop, usually quick-growing, grown between two main crops in a rotation.

Cation: Positively charged atom or group of atoms, e.g., potassium (K^+), ammonium (NH_4^+).

Cereal: Cultivated member of the grass family whose seeds or grain are used for food or animal feed: wheat, barley, rye, oats, rice.

Clay: A constituent of soil comprising very fine particles less than 0.002 mm in diameter.

Compaction: Crushing and compression of the soil caused by vehicles or animal treading.

Complex fertilizer: Mineral fertilizer containing two or more of the major nutrients, N, P and K and all particles have a similar composition.

Compound: Mineral fertilizer containing two or more of the major nutrients, N, P and K

Conventional agriculture: Another name for current agriculture.

Cover-crop: A crop which provides protection to a second crop grown beneath it.

Cultivation: A tillage operation on the land involving inversion or mixing of the surface layers of the soil.

Drilling: Sowing of seed in rows at the required depth in the soil. Fertilizer may be placed simultaneously with the seed.

Denitrification: Conversion of nitrate in the soil by bacteria to nitrogen oxide that is lost to the air.

Enzymes: Proteins which act as a catalyst for chemical changes, e.g., urease catalyses the splitting of urea to ammonia and carbon dioxide.

Fallow: Land left unsown, usually for whole or part of a season during which it is ploughed or cultivated to kill weeds.

Fungicide: A chemical used to kill fungi and so control fungal disease, usually in crops.

GATT: Abbreviation for General Agreement on Trade and Tarriffs.

Green manure: A crop specifically grown for subsequent ploughing-in.

Heavy metal: Metallic element with high specific weight, often toxic to mammals, e.g., cadmium, lead.

Herbicide: A chemical used to kill weeds.

Inter-crop: Growing of two or more different crop species in the same field at the same time.

Leaching: Washing out of nutrient (especially nitrate) from the soil root zone.

Legume: A plant of the pea family.

Ley: Land temporarily (from one up to ten years) sown to grass or grass-clover mixture.

Liming: Application to land of a material containing calcium, usually chalk or limestone, in order to reduce soil acidity.

Loamy: Soil with a balanced particle mixture, approximately 25 % clay, 40 % sand and 35 % silt.

Mineralisation: Conversion of soil organic matter through microbiological and chemical processes into inorganic crop nutrients.

Mixed farming: Maintenance of arable and livestock enterprises on the same farm.

Minimum Cultivation: use of disc or tine cultivation without ploughing.

Monoculture: Growing of the same crop on the same field year after year.

Nitrophosphates: Fertilizers made from phosphate rock and nitric acid, alone or mixed with other acids, usually with ammonia added.

No-till: Arable cropping where soil cultivation is not practiced.

Optimum-Optimal: Combination of factors giving best result. In fertilizer recommendations usually used for the application rate to a crop which gives the greatest economic return.

Potassium chloride: Potassium fertilizer material, produced from natural deposits of the mineral.

Perennial: A plant or crop which continues growth from year to year.

Pesticide: A chemical used to kill pests in crops or animals, primarily insects: sometimes the term also used include fungicides and herbicides.

pH: A measure of hydrogen ion activity and so of acidity or alkalinity, pH 7 is neutral reaction in water. Values below 7 indicate acidity, above 7 alkalinity.

Photosynthesis: The process by which green plants synthesize carbohydrates from carbon dioxide and water.

Plant Protection Chemicals: Chemicals used to control weeds, pests and diseases. Includes, pesticides, herbicides and fungicides.

Ploughing: Mechanical inversion of the topsoil.

Sand: A mineral constituent of soils with a particle size in the range of 0.05 to 2.0 mm.

Silt: A constituent of soil comprising particles intermediate in size between clay and sand - 0.002 to 0.05 mm in diameter.

Slurry: Mixture of urine and dung, with or without dilution with water.

Specialised arable agriculture: Continuous growth of arable crops over a whole farm or large area of land.

Spring crops: Crops sown in the late winter or spring.

Sub-tropical: Areas just outside the tropics.

Superphosphate: Phosphate fertilizer made by treating phosphate rock with sulphuric acid to make a water soluble product. When phosphoric acid is used, the product is called triple superphosphate.

Sustainable: Practice or process that meets the needs of the present without compromising the ability to meet those of the future (World Commission on Environment and Development).

Sward: The carpet of grasses or clovers covering the ground in a pasture or meadow.

Tillage: Practice of cultivation of soil. Also used to describe arable land.

Topsoil: Top layer of the soil, some 20 - 30 cm deep.

Undersowing: Sowing two crops in combination so that one (a low undercrop) can continue growing after the main (cover) crop is harvested. Usually a grass or grass-clover seed mixture with cereals.

Urea: $(NH_2)_2CO$, the end product of nitrogen metabolism in mammals excreted with urine. Also produced industrially as a fertilizer material from ammonia and carbon dioxide. Contains 46% nitrogen.

Volatilisation: Loss of ammonia to the air.

Waterlogged: Soil saturated with water so that all pore space is completely filled with water.

Weathering: Processes by which rocks disintegrate, eventually producing soil particles.

Winter crops: Crops sown in the late summer, autumn or early winter.

WTO: World Trade Organisation.

Answers to questions throughout the workbook

Question 1
2 to 3 billion people. This is the number of people the world could support using manures and soil reserves alone. In the longer term the productivity of agriculture would fall still further as nutrients are lost from the system.

Question 2
Nitrogen, phosphate and potash.

Question 3
Part 1.
Ammonium (NH_4^+) and nitrate (NO_3^-)

Part 2.
Nitrate (NO_3^-)

Question 4
Nitrogen
1) Chlorophyll production or green colour.
2) Leaf or plant growth.
Phosphorus
1) Root development or early season growth.
2) Ripening or maturity.
3) Sugar/carbohydrate production.
4) Seed setting.
Potassium
1) Healthy growth or disease resistance.
2) Drought resistance or control of water loss.
3) Produce quality.
4) Nitrogen fixation by legumes.

Question 5
Nitrogen

Question 6
Horticultural crops.

Question 7
Reducing sulphur dioxide pollution from industry.

Question 8
69kg of nitrogen
Example - (23t x 3kg/t of nitrogen)
from Table 3.

27.6kg of phosphate

80.5kg of potash

** Manures can supply considerable quantities of the major nutrients. In addition they supply a wide range of minor or trace elements.*

Question 9
30% of his land with manure.

69 kg N/year x 150 cows
= 10350 kg N/ha
-30% N loss = 7245

N need = 240 kg N x 100 ha
= 24,000 kg N/ha
So 30% from manures

Question 10
The main source of the supply of plant nutrients are:

- soil organic matter

- breakdown of soil minerals

- organic manures

- biological N fixation by legumes

- deposition from atmosphere

- applied fertilizers