Agronutrition

Expert in nutrition:
Soil, Seeds and Plants

Guide to
Crop Nutrition

Our **job:**

100% Specialist in Plant Nutrition

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Agronutrition is totally dedicated to **plant nutrition** and to **the optimisation of agricultural production.**

Armed with over 45 years of solid experience, our teams design, manufacture and market **nutritional and biostimulant solutions** which guarantee **adapted and targeted nutrition from planting to harvest.**

100% MADE IN FRANCE

// INNOVATION

3 French research laboratories for the development of new, sustainable agronomic solutions.

// DESIGN

300+ tests per year to create new agro and eco-environmental approaches

// PRODUCTION

3 French production plants for total control of the manufacturing process and certified products

Our **nutritional technologies** // 3 technological ranges, derived from physio-efficiency

NutriCare technologies

Look after the **functional** and **nutritional balance** of crops in order to **improve** the **development** and **growth** of plants.

Precision technologies

Precise and targeted nutrition to **optimise the potential** yield and quality of crops.

BioFertiliser technologies

Use the resources of nature for crop **nutrition.**

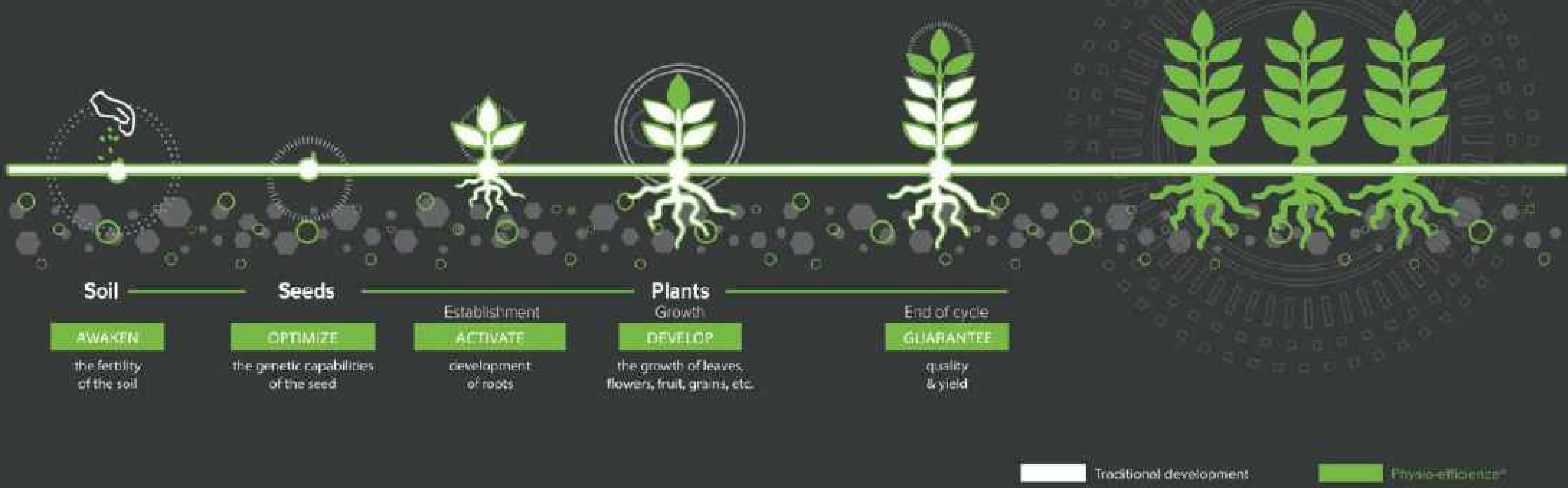
We **respond to your agronomic issues** by providing **the right nutritional response, in the right dose, at the right time** and with the **most suitable method of application.**

physio efficience®
by Agronutrition

Our **expertise**

Physio-efficiency involves **optimising the biological balance** of cultivated plants by **proper, targeted nutrition**, so that they can reveal their **full natural potential.**

Our expertise supports you so that **at each stage of growth**, we can define a **nutritional solution adapted** to **the agronomic, economic and environmental concerns** of your farmers.



Crop Nutrition

Plant nutrition - Minerals - Deficiency indicators

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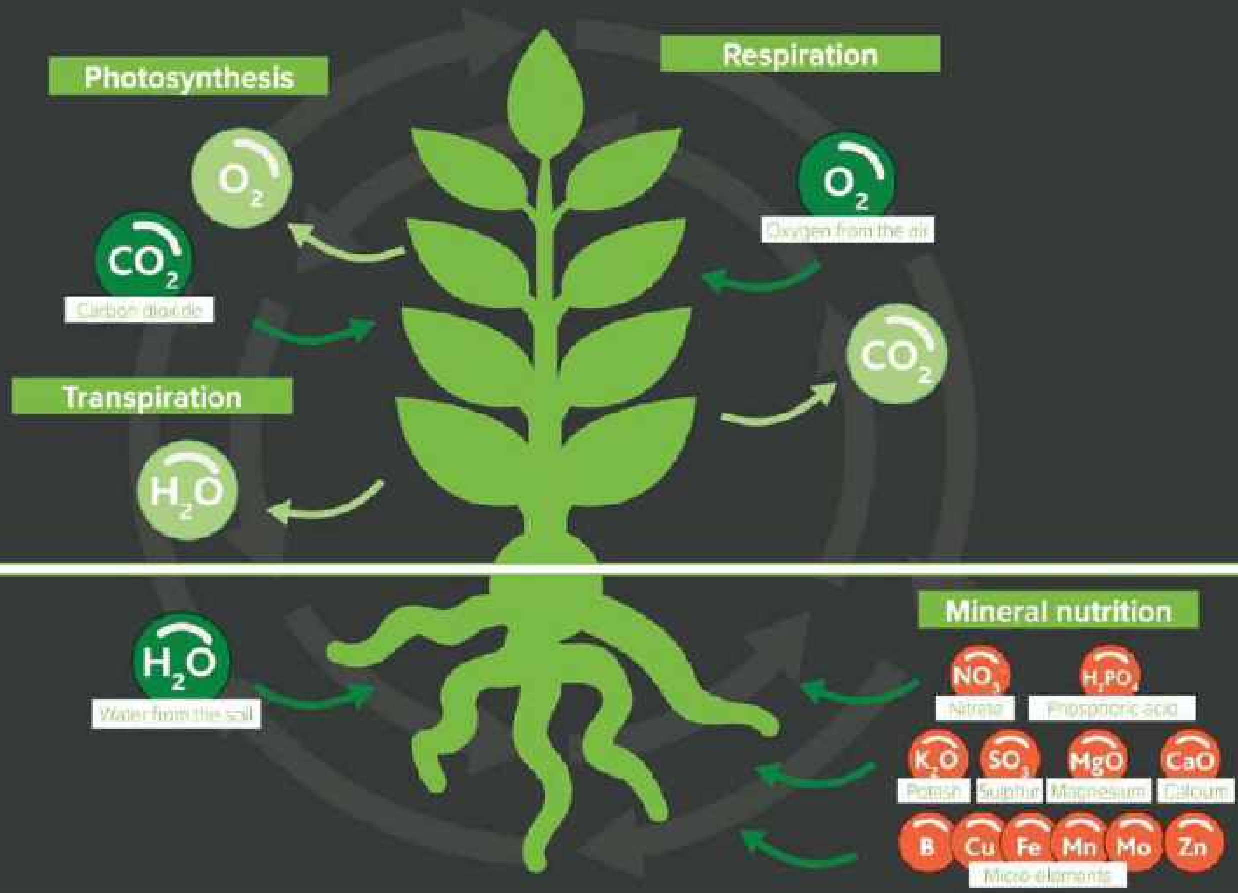
Plant nutrition

Physiology of the plant

A plant needs light, water, oxygen, CO_2 and minerals to develop.

If one of these factors is missing, the growth of the plant would therefore be **reduced and its potential altered.**



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Minerals

All plants require minerals to develop. They draw these nutrients through their roots at the same time as water. **Soils are unable to provide the ingredients necessary** for the current production of food products **without supplementation**. A **lack of nutrients will limit the growth of the plant.** It is therefore indispensable to add fertilising materials to cultivated soil which will feed the crops sustainably.

Macro elements

N P K

Nitrogen, Potassium and Phosphorus are **essential to the synthesis of living matter,** and therefore to the **growth of aerial and vegetative parts.**

Meso elements

Ca S Mg

These minerals ensure **qualitative and structural balance in plants.** Sulphur acts, for example, during the process of making wheat protein.

Micro-elements

B Cu Fe Mn Mo Zn

Micro-elements are absorbed in very small quantities. **However, they play an essential role** because **they are active in all of the plant's major reactions** *(photosynthesis, synthesis of chlorophyll, sugars, amino acids, etc)*

ABSORPTION OF MINERALS

Depending on environmental conditions *(climate and soil)* and the **sensitivity of plant species, the supply** of minerals can be **severely disrupted:**

1. **Sandy soils:** Very low mineral stock
2. **Heavy rain:** Leaches nitrogen and other elements
3. **Extreme drought:** Prevents feeding via the roots
4. **Cold temperatures:** Block the absorption mechanisms
5. **Rate of organic matter too high:** Limits the bioavailability of the elements in the soil
6. **acidic or high PH:** Blocks the assimilation of certain nutrients

The supply of each nutrient must be managed according to the crop, the soil and its relative importance to the plant.

The objective is to best balance the supply of elements to cultivated plants to preserve their qualitative and quantitative potential.

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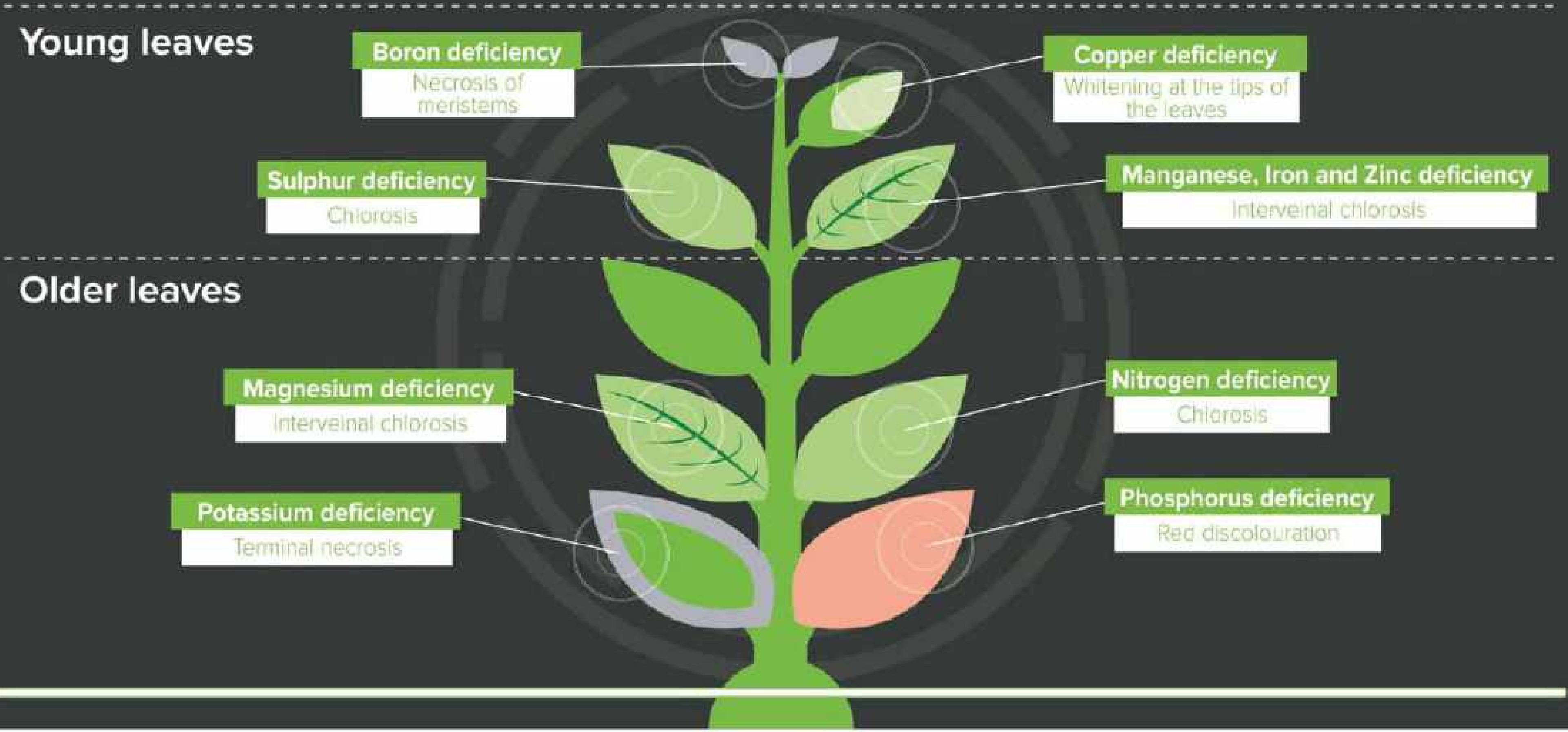
Deficiency indicators

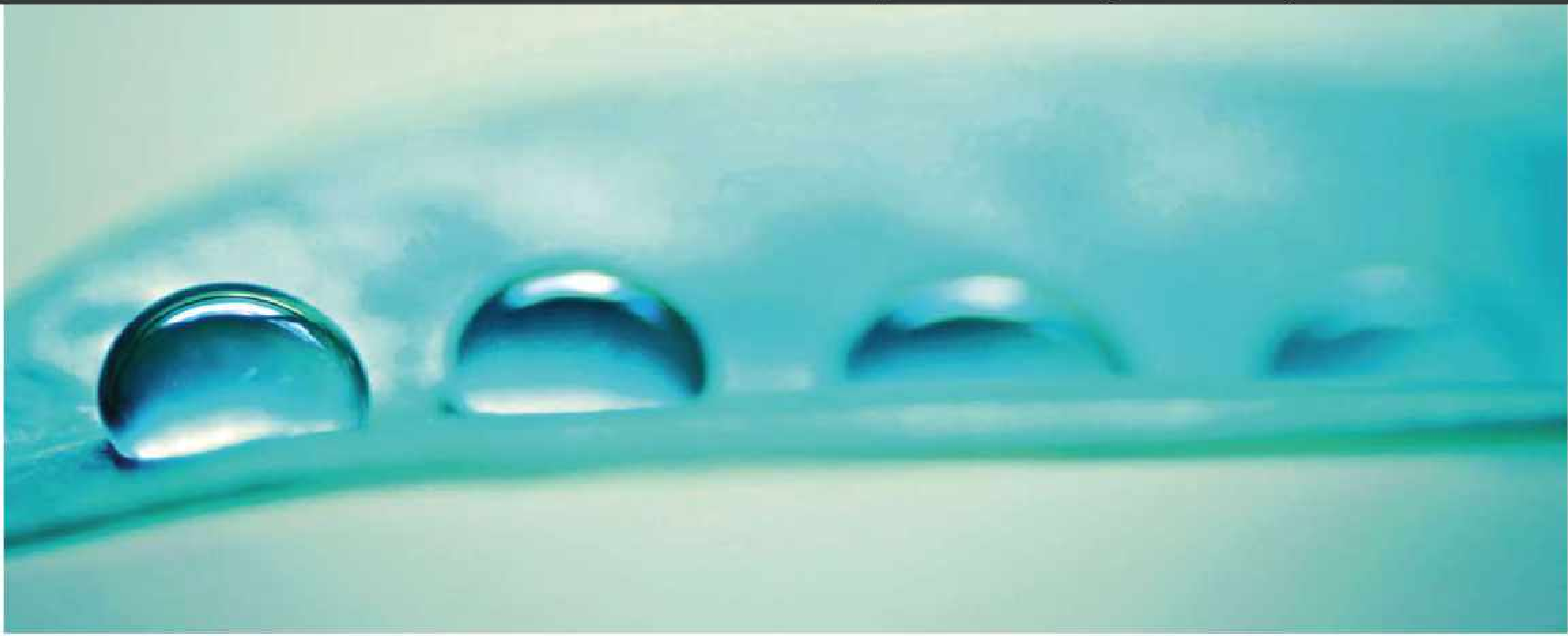
A plant can end up with **deficiencies** because of **poor nutrition. Analysis of the plant** then makes it possible to **detect the onset of visual symptoms, identifying the type of deficiency**. To avoid correcting the nutritional supply too late, it is preferable to **adopt a preventative approach to nutrition.**

The age of the leaves affected provides information on the types of deficiencies



Elements **& the Plant**

Nitrogen - Phosphorus - Potassium - Calcium - Sulphur - Magnesium
Boron - Copper - Iron - Manganese - Molybdenum - Zinc



Nitrogen & the plant

The role of **Nitrogen**

N

For plants, major sources of nitrogen in natural conditions are ammonium *(NH_4^+)* **and nitrate** *(NO_3^-)*, although other forms of nitrogen such as nitrite (NO_2^-) and amino acids can also be used.

Nitrogen is an essential element for plant growth. It is an important component of protein, enzymes and nucleic acids and is at the heart of the molecule responsible for **photosynthesis**, **chlorophyll.**
On average, 80% of a plant's nitrogen is allocated to protein, 10% to nucleic acids, 5% to soluble amino acids and 5% to other compounds.

A plant's nitrogen levels vary between 1% and 5% of its dry matter.
Most often, there is a direct relationship between nitrogen availability and growth or yield.

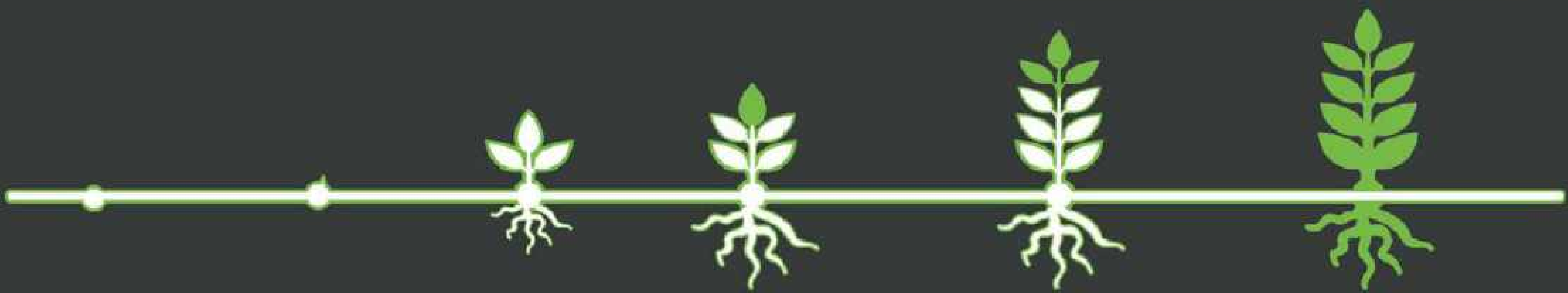
PROBLEMATIC CONDITIONS

Nitrogen deficiency is found in all types of soil with situations more or less favourable to this type of stress. Light or skeletal soils are more prone to nitrogen deficiency *(sandy soils with less 1% of organic matter).*

Inadequate availability of nitrogen in the soil is the source of stress.

There are different causes for this deficiency:

- Absence of nitrogen fertilisation
- **Low organic reserves** *(less than 1% of organic matter),*
- **Low mineralisation** *(nitrification)* of organic reserves due to:
  // soil compaction,
  // soil temperatures being too low,
  // excess water,
- continuous production of non-leguminous crops and impoverishment.



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Phosphorus and the plant

The role of **phosphorous**

P

After nitrogen, **phosphorous is one of the main nutritional elements of plants.** Phosphorous concentrations in plant tissues range between 0.1% and 0.5%. It is absorbed in two forms: $H_2PO_4^-$ and HPO_4^{2-}.

Phosphorous is essential for the **synthesis of living plant matter:**

- **A component of cellular energy. ATP supplies all the energy necessary** for all the reactions (synthesis, formation of protein and other reactions requiring energy such as the absorption of nutrients through the membranes of root cells during active absorption.)

- **A structural component of cells**, phosphorous is necessary for:

// The synthesis of **all plant cell membranes**, constituting lipids,
// The replication and transcription **of the DNA** that constitutes nucleic acids,
// The synthesis **of sugars** which are involved in photosynthesis and respiration,
// The activation of **cell elongation.**

Phosphorus plays numerous roles in plants:
// Stimulation of **root growth** and assimilation of **nutrients.**
// **Precocity and maturity.**
// Increased **resistance to cold and diseases.**
// Contribution to **stiffness of tissues** and lodging resistance.
// Role in reproduction: **pollination**

PROBLEMATIC CONDITIONS

// Drought
// Cold temperatures limiting root activity
// Compacted, poorly structured or poorly drained soils
// Soils that are acidic (sandy) or alkaline (calcareous-clay rather light)
// Soils with high fixing power (> 90%)
// Soils with low P_2O_5 reserves (< to 0.1 g/kg)
// Soils with low organic matter content
// Soils rich in iron hydroxides (borderline acidic)
// Crops with poor root development:
even when its fixing power is low and the soil is rich in P_2O_5, the roots may not have reached a sufficient volume (30 mm) to properly feed the plant.

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Potassium and the plant

The role of **potassium**

K

Potassium is present in the plant in the form of K+, it is very mobile and dissolves in intracellular fluid. Its average level in plants is the highest of the elements known as "minerals": 2% to 4% of dry matter.

Good potassium nutrition **activates overall plant growth** (as long as the plant has adequate nitrogen nutrition). Potassium increases **reserves**, improves **fertility** and advances **maturity**. In the case of perennial crops, potassium encourages the fruit to set and enlarge.

The roles of potassium are of great importance:

// It **maintains osmotic pressure** (its concentration draws water into the vacuoles);
// It **maintains the acid/base balance within the cell** by preventing acidification;
// It decreases transpiration in certain cases (reducing the risk of wilting);
// It **serves as a supporting mineral that helps with transportation within the plant**
// It helps the "hydrogen-potassium pump" to function.

Potassium also plays a **catalytic role** in enzyme reactions:
// Protein synthesis;
// ATP synthesis;
// Photosynthesis.

Potassium is a **regulator** of plant functions: **syntheses, transportation, growth, storage.**

PROBLEMATIC CONDITIONS

Potassium deficiency can occur:
// In soils where there is insufficient potassium available;
// In light soils with a low CEC (<80 meq/kg);
// In soils with high potassium fixing power (peat soils, clay).

The K/CEC ratio (in meq) must be between 3% and 4% (2% and 3% for sandy soils). A value lower than this indicates a deficiency.

Factors that may cause a potassium deficiency:

- A very dry summer or a very rainy period at the start of autumn;
- Excessive nitrogen fertilisation developing an increase in plant growth and diluting the potassium in the plant;
a yield that is too high;
- Excessive manganese fertilisation leading to an antagonistic effect on potassium assimilation.
- In the case of perennial crops using rootstocks, some rootstocks do not assimilate potassium well.

Magnesium and the plant

Role of **magnesium**

Magnesium is **the central atom of chlorophyll, which is essential to photosynthesis**. 20% of the Mg of the plant is found in the chloroplasts. It is therefore essential to its physiological functioning.

Magnesium is active in the **transportation and storage capacities of the assimilates** (storage of carbon and nitrogen compounds).

Magnesium is an **activator of several enzymes in the metabolism of protein**, carbohydrates and the synthesis of vitamins and lipids and carboxylase co-enzymes for CO_2 fixation.

PROBLEMATIC CONDITIONS

- In many calcareous areas, Ca-Mg antagonism limits magnesium availability even after liming and vinasse intake.

- Light soils are generally low in MgO and can be leached very easily.

- In the presence of nitrogen ammonia fertiliser (liquid manure, solution, urea), there is strong antagonism between NH_4^+ and Mg^+.

- In dry or very wet soils, the plant extracts very little from the soil.

Sulphur and the plant

Role of **sulphur**

Sulphur is assimilated in the form of sulphate SO_4^{2-}. It is an **essential constituent of plants**. A coenzyme component, it is necessary for the formation of chloroplasts and is therefore **essential to photosynthesis.**

It is an essential constituent **of amino acids containing sulphur** (cysteine, cystine and methionine). When there is a deficiency, nitrogen compounds remain in nitrate form.

In grains, the sulphur content of the grain **influences the quantity and quality of the protein** and also the hardness of the grain (loss of vitreous aspect).

The quality of the grains is measured by the presence of: glutenin, gliadin, globulin and albumin. The first two are synthesised only in the presence of sulphur and are desired by millers for dough elasticity.

PROBLEMATIC CONDITIONS

- Soils low in organic matter
- Leaching (as with nitrogen)
- Cold and wet spring times

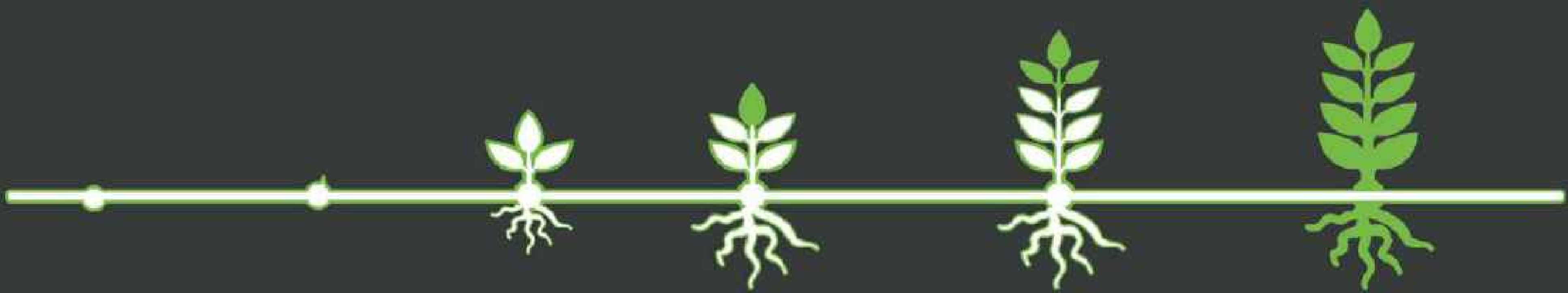
Soils today are not as rich in sulphur. Increasing winter leaching and significant plant extraction linked to an increase in yield lead to a loss per ha of 100 kg to 300 kg of sulphur.

This phenomenon has been emphasised over the years:

// by low atmospheric sulphur

// by the abandonment of single superphosphate with sulphur

// the reduction of organic manure in large-scale farming areas without livestock farming



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Calcium and the plant

Role of **calcium**

Along with nitrogen and potassium, calcium is part of the elements **which are essential for the growth** of a plant and for which the content in plant tissues is high. Unlike other minerals, calcium plays its main role **outside the cells**. One of the primary functions of calcium is to **create bonds between the cell walls** by cementing them to each other.
By its structural role, calcium contributes **to the maintenance of the quality** of flowers, fruits and vegetables after harvest and during storage.

Calcium is also present **inside the cells**. It is particularly abundant in the vacuoles (structures within a cell which contain various compounds). Calcium is found in various other places (cytoplasm, chloroplasts, mitochondria), or it is associated with essential plant activities:
// **Root growth** (cell elongation)
// **Ripening of fruit** (relationship between calcium and ethylene synthesis - a compound involved in ripening)
// Activation of certain **enzymes**.

Calcium absorption is considered passive since its entrance into the plant is mainly linked to **the absorption of water by the roots**. Pedo-climatic imbalances play a role in the correct and balanced assimilation of calcium by the root.

PROBLEMATIC CONDITIONS

Conditions that have a negative effect on the absorption of calcium are the following:

- Low soil moisture limiting root development
- Too much water in the soil reducing the availability of oxygen for root growth.
High levels of moisture also encourages the development of a layer of suberin on the roots. Suberin is a waxy, impermeable substance. Water and calcium cannot get through it.
- Low soil temperature
- High levels of certain cations in the soil such as NH_4^+, Mg^{++}, K^+ and Na^+
- High salinity
- An acidic soil pH which restricts the absorption of calcium due to competition with aluminium (Al^{3+}).
- Poor soil preparation inhibiting the penetration and expansion of roots in the soil.

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Boron and the plant

Role of **boron**

B

Boron is closely associated with **plant growth.** It influences the growth of **roots, leaves and the development** of the plant.

Boron also has an impact on a **tuber's fitness for storage** because after calcium and magnesium, it is the most important anion in the cell membrane. Boron plays an essential role in the **construction of cell membranes and the metabolism of water**. Indeed, it acts like cement between the pectins providing the cohesive strength of plant tissues. It's a factor in quality.

Boron is indispensable for **the activity of the meristems**: the tips of the forming rootlets and leaves.

The range of requirements between the stages of deficiency and optimum nutrition is very narrow. A fertiliser which is well adapted to the needs of the plant is indispensable.

Boron deficiency causes a disturbance in the balance of phytohormones and is expressed through necrosis in areas of growth, the deformation and death of the youngest shoots, a general reduction in growth, thicker stems, a cracked texture and a reduced foliar surface.

Boron plays and essential role in the quality of flowering and the fertility of the pollen. It is also involved during fruit setting in the transportation and use of sugars.

PROBLEMATIC CONDITIONS

// Its availability decreases above a pH of 6.5

// After liming which increases boron fixation

// Light soils where it is easily leached

// Acidic soils in high rainfall areas. In effect, in rainy conditions, lower levels of boron can be found in the soil as with sulphur and nitrogen, so it is difficult to assimilate.

// In cases of water stress in spring and summer which limits the diffusion of boron through the soil solution. In fact, in dry conditions, boron is nearly on the surface. The roots can no longer absorb it.

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Copper and the plant

Role of **copper**

Cu

Copper is very involved in the **photosynthetic chain**: 70% of the copper available in the plant is found in the **chloroplasts**.

Copper is involved in the formation of **lignin**, an element which gives the cell its **elasticity** as well as its **stability**. In addition, copper plays an important role in the process of **the biological fixation of nitrogen** and in the **regulation of the absorption of manganese**.

When there is a copper deficiency, the absorption of manganese accelerates which leads to toxicity in the plant. This phenomenon is observed especially in acidic soils.

In general, copper is a **catalyst for enzymes** and is active in **the synthesis of protein**, **lignin** (structure of the stems), and in **photosynthesis**.

Copper also participates in the reduction of nitrates and the assimilation of nitrogen by the plant.

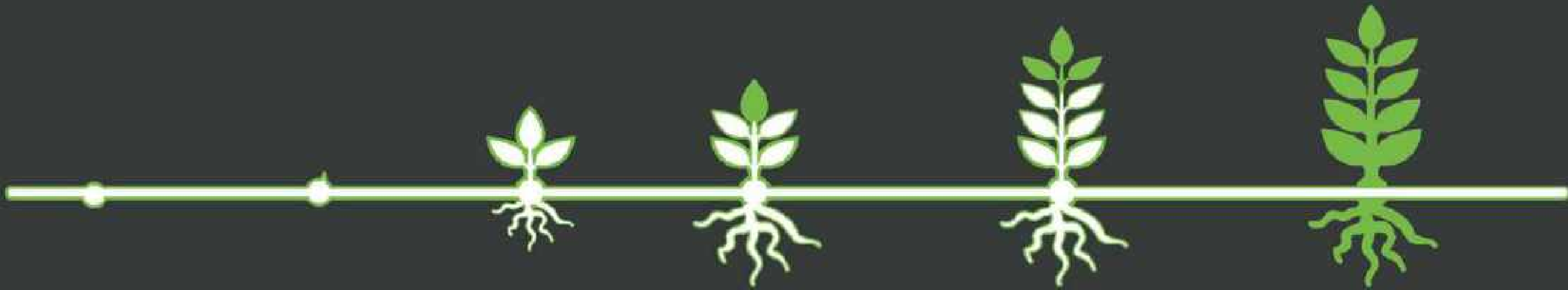
PROBLEMATIC CONDITIONS

// Soils rich in organic matter

// Soils with a high pH or after liming

// Soils rich in potassium and magnesia

// The concentration of copper (Cu) that can be assimilated varies considerably in the soil (DPTA-extractable Cu), so that various locations can be deficient within a field. It is therefore difficult to spot these areas by analysis of composite soil samples.



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Iron and the plant

Role of **iron**

Fe

Iron is a micro-element that is very important for the **health and growth of plants**. Although it is abundant in the soil, the absorption of iron by the roots sometimes turns out to be difficult given that its availability depends to a great degree on the pH of the growing medium.

Iron plays an important role in:

// **Photosynthesis**
// The **synthesis of chlorophyll**
// The **plant's** respiration
// The **metabolism of protein** (production of plant tissue)
// **Nitrogen fixation** (mineral nutrition)
// The redox **process**
// The **quality** of the fruits

PROBLEMATIC CONDITIONS

// Limestone and alkaline soil

In oxidising conditions or alkaline pH, the Fe++ cation disappears and is transformed into ferric oxide which cannot be assimilated.

// Water-logged soils

// Root loss by lack of oxygenation of the soil or growing medium

// Excess phosphate, manganese and zinc

Manganese and the plant

Role of **manganese**

The plant absorbs manganese through its roots in the form of Mn^{2+} cations or manganese chelate. Manganese, in synergy with molybdenum, plays an important role in the transformation of the nitrate absorbed by the plant. Manganese stimulates growth and is involved in controlling sugar metabolism.

It is involved in:

// The activation of certain **enzymes**

// The **synthesis of chlorophyll**

// **Photosynthesis**

// **Nitrate reduction**

// **Respiration**

// The **assimilation of nitrogen**

// The **synthesis of amino acids and protein**

PROBLEMATIC CONDITIONS

// In heavily leached, acidic, sandy soils (significant deficiency)

// Soils rich in organic matter and peaty soils

// After maintenance or corrective liming. *A pH higher than 6 is a determining factor in the appearance of a manganese deficiency.*

// During difficult climatic periods (wet or cold soil)

// In soils with a high pH (blockage of manganese)

// In very well-ventilated soils with a very loose structure (oxidation of manganese and transition to an insoluble non-absorbable form)

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Molybdenum and the plant

Role of **molybdenum**

Mo

Plants do not need a lot of molybdenum but its functions are very specific. Molybdenum **activates the enzyme nitrate reductase** which is responsible for the **reduction of nitrate in the leaves.**

It is also involved in **nitrogen fixation** in the air as well as the transformation of nitrates inside the plant tissue. It is therefore directly involved in the process of **protein synthesis**.

Molybdenum is also involved in iron and phosphoric acid metabolism.

A molybdenum deficiency leads to a decrease in enzyme activity and can also cause chlorosis because of poor synthesis of chlorophyll. Yield losses can be significant.

PROBLEMATIC CONDITIONS

// Light soils and acidic soils
// Soils rich in organic matter
// Cold and wet springs

The absorption of the molybdenum is limited by phosphorus and restricted by sulphur. **Excessive applications of sulphates** can thus be detrimental to the assimilation of molybdenum.

There is also **antagonism** between copper and molybdenum and between manganese and molybdenum: an **excess of manganese** can lead to a molybdenum deficiency.

Zinc and the plant

Role of **zinc**

The plant mainly absorbs the zinc from the soil solution in the form of Zn ion. In soils with a pH lower than 6, the provision of zinc is generally adequate. In fact, the lower the pH, the higher the amount of zinc available.

Zinc activates various enzymes or constitutes part of them, and thus influences various metabolic processes in the plant. It is necessary for:

- **Auxin synthesis**: growth hormones required for root development, stem elongation, the maturity of the plant and the breaking down of sugars.

- **The formation of chlorophyll**: the photosynthetic activity most supported.

- **The synthesis of protein**: essential component of RNA polymerase, which acts as a catalyst for protein synthesis.

Zinc also protects the plant from **oxidative stress** in conditions of bright sunshine and drought.

PROBLEMATIC CONDITIONS

// Sandy soils (leaching)

// Calcareous soils, soils with a high pH and soils with too high a lime content

// Low temperatures (decreased zinc solubility)

// Soils rich in P_2O_5 (Zn blockage)

// Soils low in organic matter

// Wet soil

Grain **nutrition**

Nutritional Diagnosis - Agronomic Data

Cereals are the most extensive arable crops in the world (more than 700 million ha including rice) Although sensitive to hydromorphy (wheat, barley..), **cereals can be growen in a very wide variety of soils and weather conditions.**
The grains production as well as the vegetative development are **very sensitive to the status of nitrogen availability** in the soil and can be affected by **meso and trace elements deficiency.**

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Grains

Deficiency symptoms

Nitrogen deficiency

Expresses itself in premature regression in tillers and in growth, short stems, erect leaves and the yellowing of the extremity of old leaves in a 'V' shape along the midrib.

Reddening of the stems and the leaf sheaths.

> **Problematic conditions:** Soils with low or high pH. Sandy or light soils *(leaching)*. Soils with a low organic matter content. Certain weather conditions including drought, heavy rainfall *(leaching)* and intensive irrigation.

Magnesium deficiency

Usually appears as strings of dark green marks between the veins which are clearly visible against the light.

> **Problematic conditions:** Soils that are sandy, acidic, rich in potassium, receiving high quantities of potash. Cold, wet periods. Soils suffering from excess driving rain. Soil with a low MgO content.

Sulphur deficiency

Appears during tillering and results in a reduction of plant growth and the yellowing of the leaves which begins at the tip and subsequently spreads over the entire blade.

> **Problematic conditions:** Pervious soils, wet winters, potentiality of low mineralisation

Copper deficiency

Is first expressed in the yellowing of the edge of the leaves and the curling of narrower leaves. This kind of deficiency is also known as "white tip disease" or "mouse ear disease".

> **Problematic conditions:** Soils that naturally have a low copper content *(sandy soils, etc.)*, or an unavailable return *(high content of Org.Mat., calcareous soils or highly limed soils)*. Consumption: 1 g of Cu per quintal.

Manganese deficiency

Causes interveinal necrosis in the central parts of leaves. The leaves have continuous discolouration between the veins which makes them look striped and ribbed.

> **Problematic conditions:** Soils rich in Org.Mat., peaty, with a high pH, very wind-blown and very well-ventilated soils, sandy soils, acidic and very leached soils, cold weather

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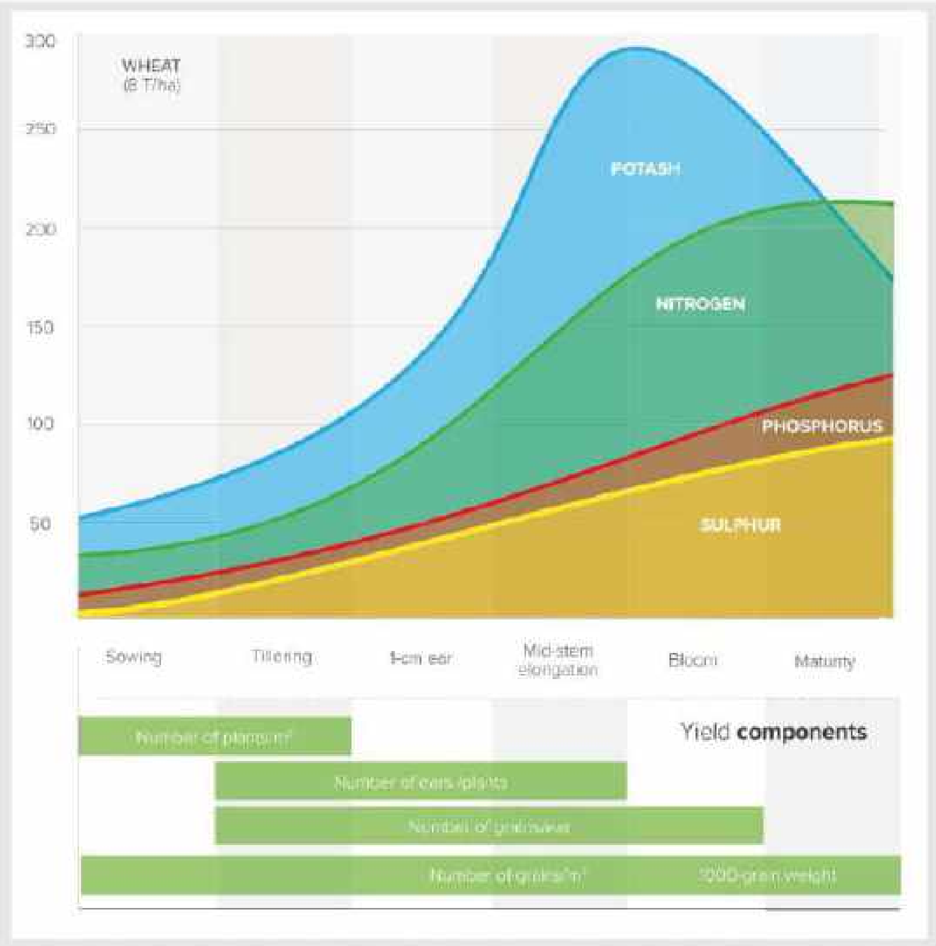
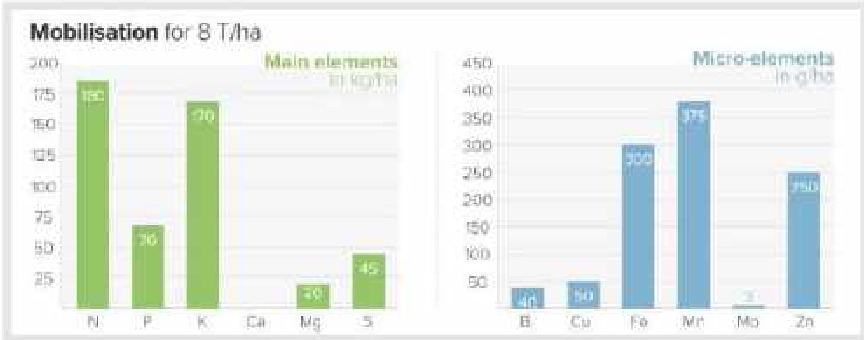
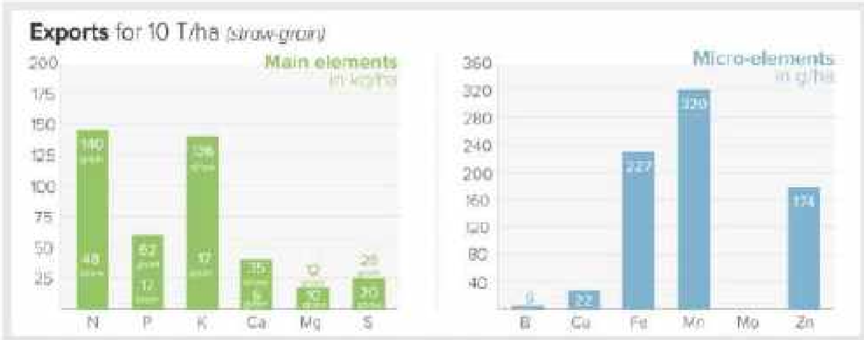
Grains

Key development stages



Mineral requirements





Sensitivities to deficiencies

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Nutrition of **Maize**

Nutritional Diagnosis - Agronomic Data

Maize grows quickly and mobilises large quantities of nutrients in just a few days.

From the 10 leaf stage up to flowering, the plant absorbs **4 kg of nitrogen, 1 kg of phosphate and 10 kg of potassium per day.** This is why **successful sowing** which promotes sturdiness from the start **provides the crop with the best conditions for its nutrition**

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Maize

Deficiency symptoms

Nitrogen deficiency

The plant is small, the leaves are a yellowish green to yellow colour to begin with and then become more or less orange before they then fall from the plant.

> **Problematic conditions:** Under fertilised soils, soils that are often sandy, pervious soils, acidic soils, soils low in humus.

Phosphorus deficiency

Causes the reddening *(wine colour)* of the leaves starting with the areas close to the midrib and the drying out of the oldest leaves. It causes delays in male flowering and in the maturity of the ear.

> **Problematic conditions:** Soils with a low P content, under fertilised soils, soils with a high phosphorus fixing power, cold and wet climates, notably at the beginning of the growing season.

Zinc deficiency

Appears in leaf stage 5-6 and causes the bleaching of longitudinal strips on either side of the midrib of the leaves. These symptoms first appear at the base of the leaves.

> **Problematic conditions:** It is usually the leaves in the middle of the plant that are the worst affected, with, in the most severe cases, the bleaching of young leaves *(white bud)*. The internode is shorter than usual and plant maturity is delayed.

Potassium deficiency

Manifests itself in old leaves, causing them to become wavy and yellow, which spreads from the tip along the edges of the leaf and leads to these areas drying out. We also note the absence of turgor pressure in the plant, the shortening of the internodes and the tendency towards lodging.

> **Problematic conditions:** Soils with a low K content, under fertilised soils, soils with a high K fixing power *(soils in the Grand Ried, clay soils)*, soils rich in Mg.

Manganese deficiency

Causes the leaves to turn an olive green colour, which is sometimes accompanied by interveinal discolouration. This interveinal discolouration is visible on the oldest leaves and is often accompanied by marginal necrosis on the blade of the leaves.

> **Problematic conditions:** Soils rich in Org.Mat., peaty, with a high pH, very wind-blown and very well-ventilated soils, sandy soils, acidic and very leached soils, cold weather.

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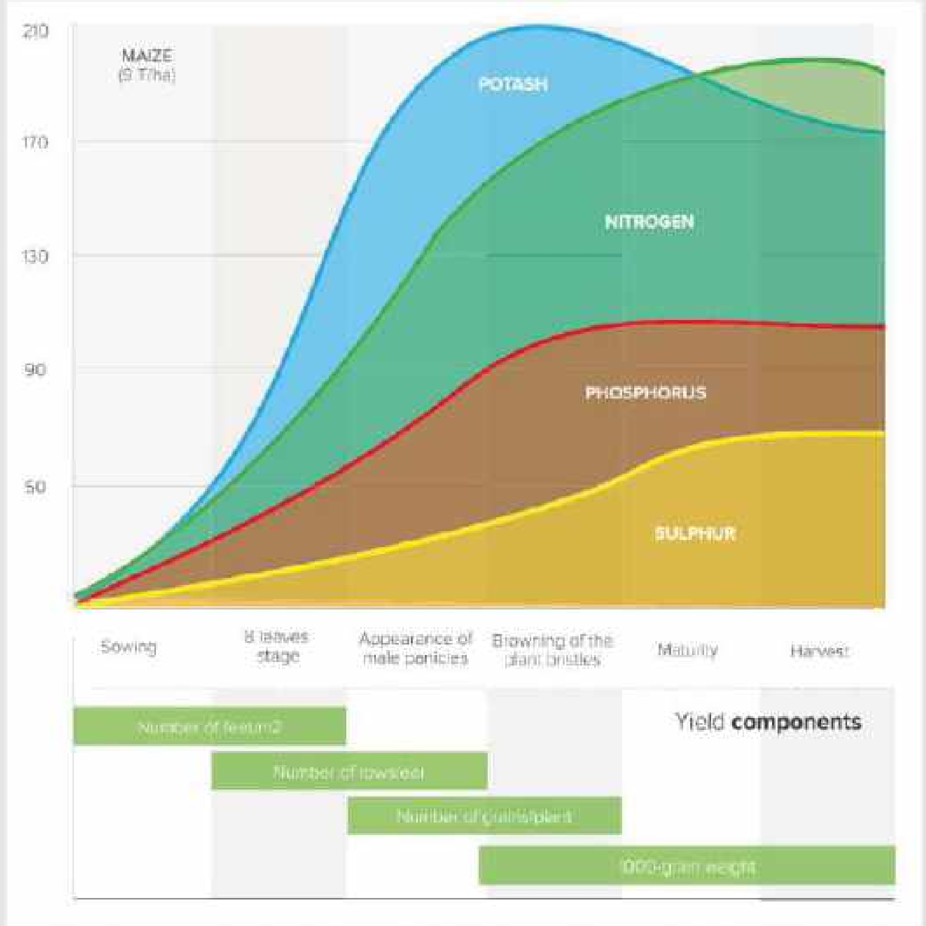
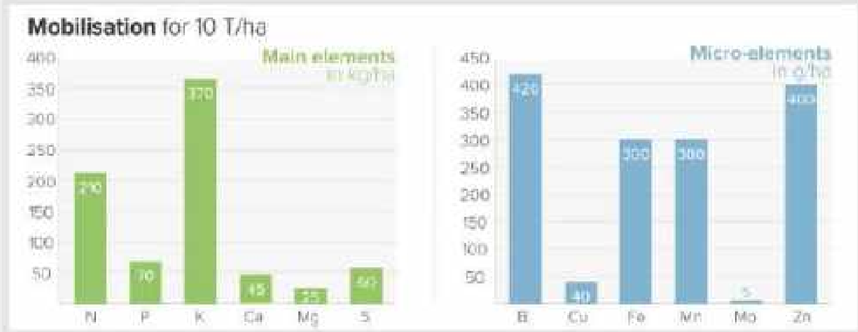
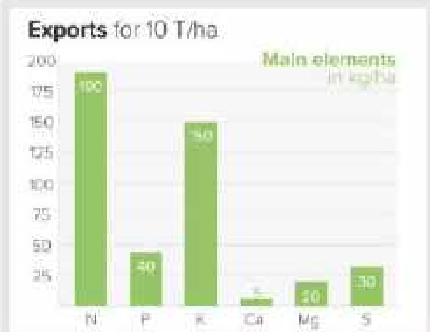
Maize

Key development stages



Mineral requirements





Sensitivities to deficiencies

N · P · K · Ca · Mg · S · B · Cu · Fe · Mn · Mo · Zn

High sensitivity · Medium sensitivity · No sensitivity

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Rape

Deficiency symptoms

Boron deficiency

The most common symptom is the appearance of brown necrotic spots on the stem, which develop into longitudinal splits. The curling of the edges of young leaves is common. The plants are small, their growth often even stunted. Flowering and pollination are limited and there are very few siliques, often during the 'hook' phase. The root system is smaller, and the collar and the taproot are thicker. The taproot may show symptoms of brown necrosis at its core or even a cavity.

> Problematic conditions: Sandy soils with a high active calcium content, cold and wet autumns, very dry conditions.

Sulphur deficiency

Is expressed by interveinal yellowing of young leaves and premature ageing of plants in which growth has greatly slowed down. This kind of deficiency appears around March/April time and causes yellow spots which are clearly visible in the plot of land from far away. In general, it corresponds to areas where mineralisation is difficult *(hydromorphy, headlands, changes in slopes, surface soil, etc.)*. Flowers are very pale and either drop or develop large, empty siliques.

> Problematic conditions: Sandy soils, acidic soils, asphyxiating soils, surface soils, wet winters, cold springs *(the symptoms are therefore temporary but the consequences they have on the yield are permanent)*

Molybdenum deficiency

Is observed in pale leaves with yellow-green marbling. The plantlets look similar to a rosette. The leaves present deformations: asymmetrical leaf blade, splitting of the tip, strap-shaped leaves. Marked deficiencies cause typical deformations: fragmenting of the blade perpendicular to the leaf from the midrib, apical bud dies, appearance of new stems. Flowers are rarer and are held by particularly elongated stems.

> Problematic conditions: Light and acidic soils, soils with a high organic matter content, cold and wet springs.

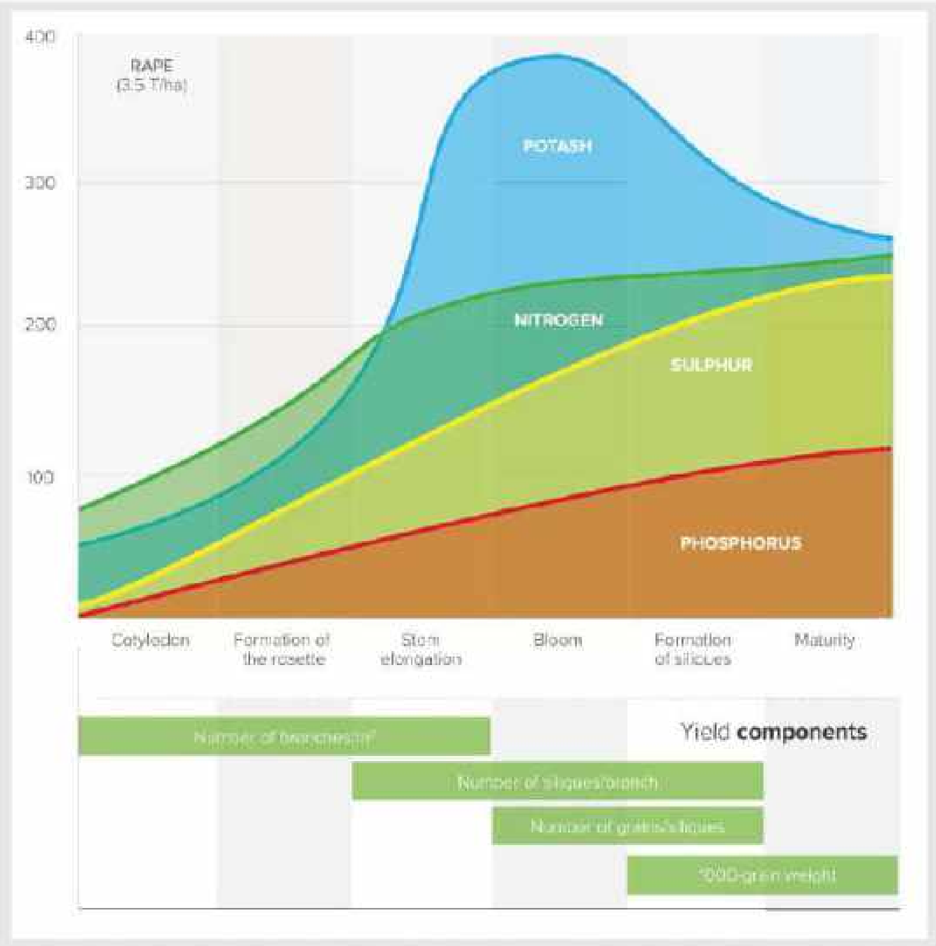
Potash deficiency

Phosphorus deficiency

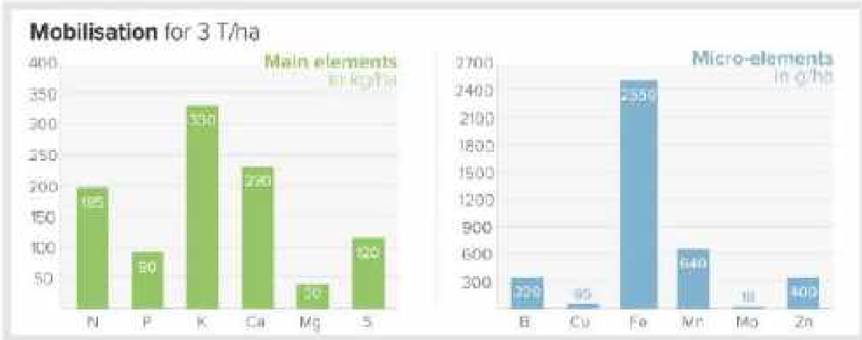
Agronutrition

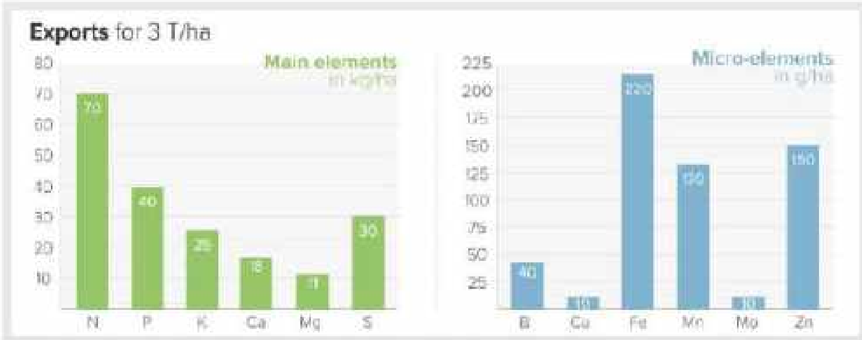
Rape

Key development stages



Mineral requirements





Sensitivities to deficiencies

N · P · K · Ca · Mg · S · B · Cu · Fe · Mn · Mo · Zn

- High sensitivity: P, K, S, B, Mn
- Medium sensitivity: N, Mg, Mo
- No sensitivity: Ca, Cu, Fe, Zn

Sunflower

Deficiency symptoms

Boron deficiency

Causes young leaves to have a bumpy surface ('embossed') and they remain small in size. Patches of chlorosis then appear at the base of blades, developing into the characteristic 'scorch' marks, while the rest of the leaf remains green. The petioles turn brown on their underside and become fragile. In the case of a severe deficiency, the leaves shrivel up completely. During the growth period, the apical bud withers. Generally, these symptoms appear a short time before flowering. They are seen in the youngest leaves.

> Problematic conditions: Alkali soils containing more than 10% active calcium, light soils, pervious soils and surface soils containing more than 15- 20% sand, clay soils and silty, acidic soils with a low B content *(less than 0.5 ppm)*, drought stress and long periods of intense sunshine or very heavy rainfall *(leaching)*.

Sulphur deficiency

The midrib turns a pale yellow colour, the secondary veins remain green.
Random areas of the blade become discoloured and chlorosis makes the leaf look blotchy. Photosynthesis is disturbed and the functioning of the chloroplasts is reduced.

> Problematic conditions: Acidic soils, light and sandy soils *(leaching)*, soils with a low organic matter content, soils that are not very well-ventilated *(waterlogged)*.

Molybdenum deficiency

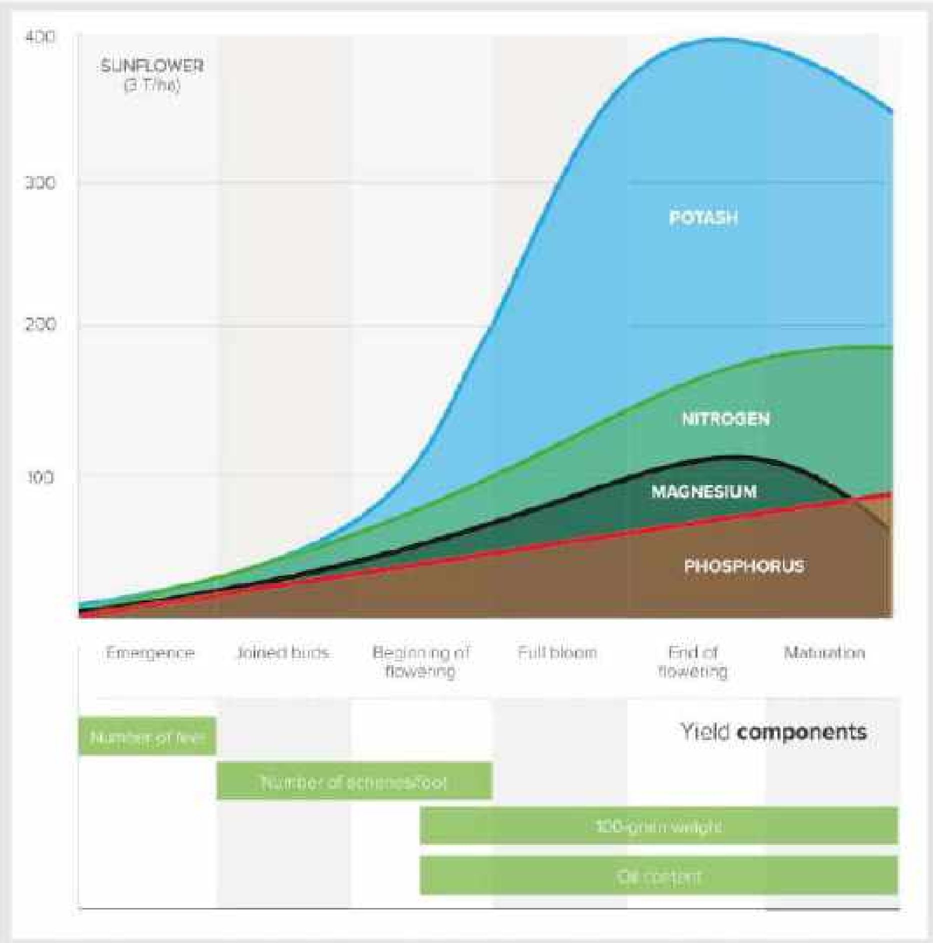
The leaves, of a green-lemon colour, take the shape of a spoon, with the edges of the blade suffering from necrosis and turning a light brown colour *(see photo)*.
Note that this kind of deficiency can be confused with a potassium deficiency, but the symptoms of a molybdenum deficiency can generally be seen as of the appearance of the first leaves, while those of a potassium deficiency usually become apparent at a later stage.

> Problematic conditions: Light and acidic soils, soils with a high organic matter content, cold and wet springs.

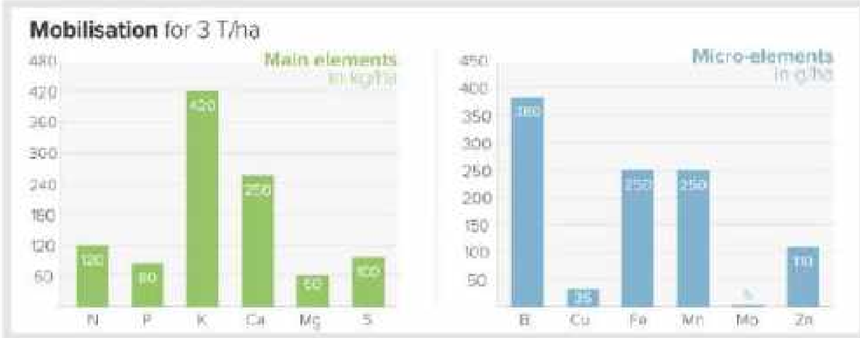
Magnesium deficiency

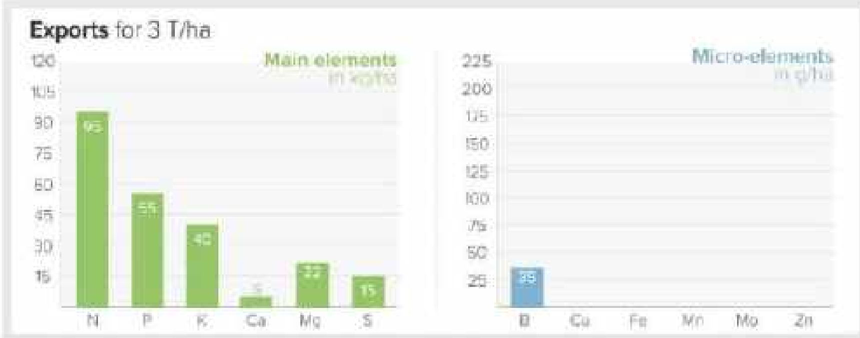
Sunflower

Key development stages



Mineral requirements





Sensitivities to deficiencies

Agronutrition

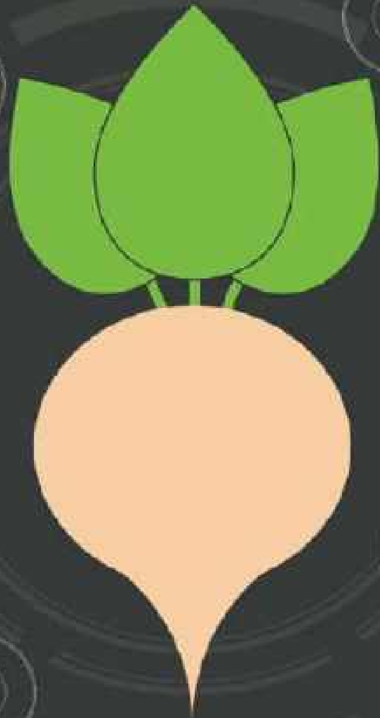
Beet

Deficiency symptoms

Boron deficiency

The first symptoms can appear as soon as the first adult leaves. The main sign is a blackening of the heart *(blackheart disease)*. The leaves crack, thicken, become brittle and a silvery metallic sheen appears.
For older leaves, these symptoms are accompanied by distortion and fine cracks with drooping in the affected area. The root itself is also very affected by this deficiency. Suberised dry rot reaches the tegument and gradually affects the flesh. Gaps appear at the collar which turns black.

> Problematic conditions: Pervious soils (sandy or silty-sand) high in active calcium, or severe summer drought and a lot of sunshine.



Magnesium deficiency

With beets, the edge and the tip of the older leaves undergo temporary yellowing that turns into the formation of necrotic areas. This deficiency is often associated with a development of Alternaria on the edge of the blade and sometimes between the veins leading to the appearance of black necrotic spots.

> Problematic conditions: Wet years, compacted soils, acidic soils, highly calcareous soils.

Manganese deficiency

Beets show a delay in development that can be recognised by erect, triangular leaves. The youngest leaves turn yellow, become distorted and their tips curve. The older leaves are also distorted but it's mainly their edges that curve inward. The yellowing is speckled and only affects the interveinal areas. The necrotic pits tend to spread and form spots and subsequently to perforate the leaves. If the deficiency disappears, the leaves show several small holes against an apparently normal green background.

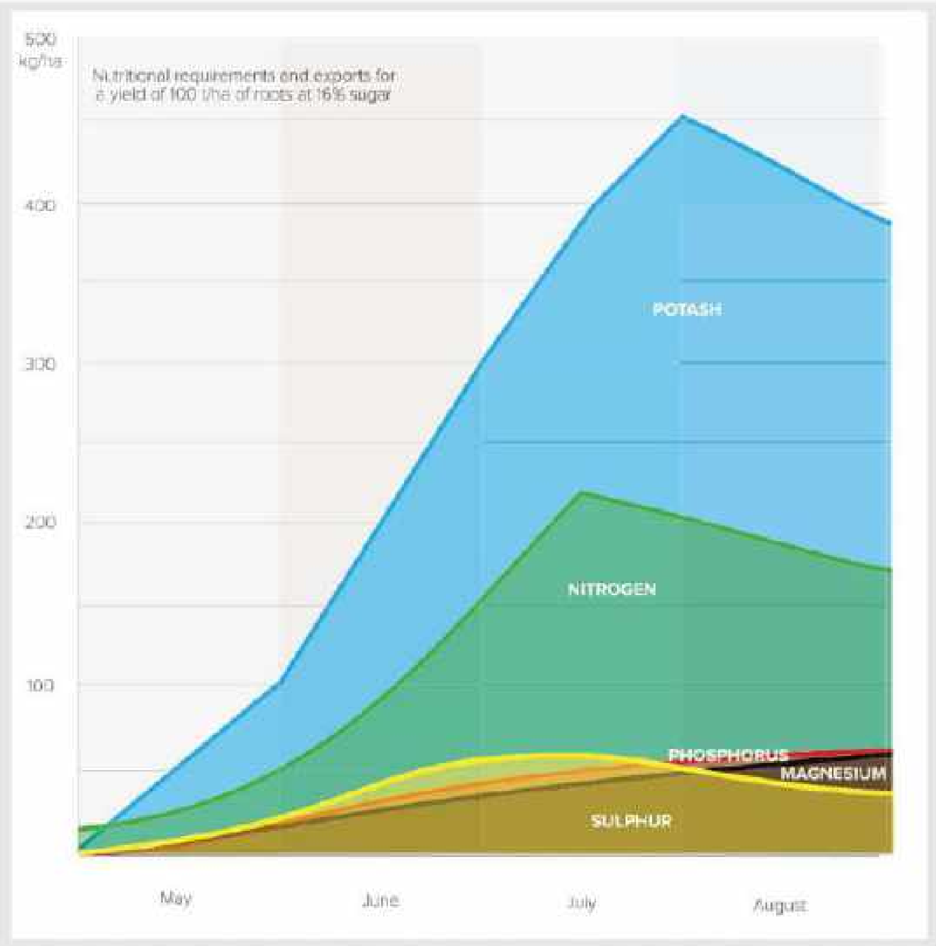
> Problematic conditions: Soils with a pH of 6.5 which are rich in organic matter, well-ventilated soils with too high a lime content. In fact, in the plot, greener strips *(less affected)* can be seen on the more compressed areas where wheels pass.

Potassium deficiency

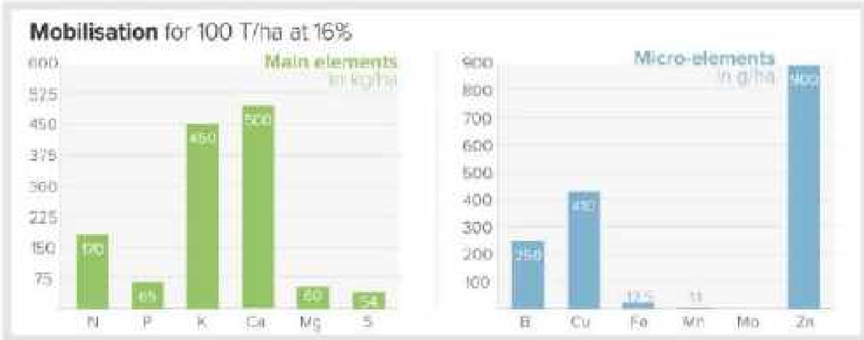
Is expressed in the yellowing of the edges of young leaves that turn brown little by little. The blade turns dark green, becomes distorted *(waves)* and the leaves droop.
The oldest leaves dry out.

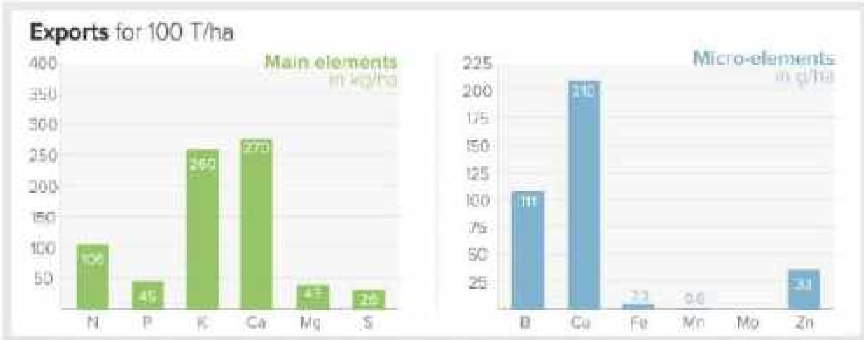
Beet

| Key development stages



| Mineral requirements





| Sensitivities to deficiencies

Potato

Deficiency symptoms

Calcium deficiency

Results in the blackening of the end of one or a few sprouts emerging from a tuber. This damage arrests the growth of the affected sprouts as well as the development of secondary sprouts that grow from the base of the damaged ones.

> Problematic conditions: Sandy soils with an acidic pH, the use of acidifying fertilisers *(ammonium sulphate)* or high intakes of potassium *(in the case of corrective fertiliser)* or magnesium.

Magnesium deficiency

It starts with the lightening in colour of the lowest hanging leaves. Following that, the interveinal areas of the centre of the blade become yellow, a symptom that progresses towards the outer part of the leaves. These yellowed areas become necrotic. At an advanced stage, the leaf is very fragile and falls off prematurely. It is not rare to note that the edges of the leaf remain green and then turn yellow very quickly at the final stage.

> Problematic conditions: Soils poor in available Mg, acidic soils *(pH <6)*, wet weather in June - July *(through a K/Mg imbalance)*.

Manganese deficiency

Potatoes are sensitive to this deficiency because they have a large vegetative mass and the transportation of manganese is very slow. This deficiency can be observed in calcareous, organic soils and especially in sandy soils that are very light and very well-ventilated. It shows itself through the presence of dark necrotic points along the veins. Manganese deficiencies are then marked by a yellowing of the leaves between the veins. Unlike iron deficiencies, the yellowing appears like spots that may show necroses. The veins, however, remain green. These deficiencies can be observed first on the upper leaves of the plant.

> Problematic conditions: Soils rich in Org.Mat., peaty, with a high pH, very wind-blown and very well-ventilated soils, sandy soils, acidic and very leached soils, cold weather.

Potassium deficiency

Is expressed by a decrease in plant development and reduced flowering. The vegetation takes on a blue-green metallic look. During flowering, the internodes shorten and the leaves curve downwards and the oldest ones fade. Necrotic areas appear on the edge of the leaves and extend towards the centre through the interveinal spaces. Finally, the tubers may show brownish or bluish lesions.

> Problematic conditions: Very dry summers, too-heavy magnesium fertilisation *(particularly in light soils with a CEC lower than 80 meq/kg)*, soils with strong K fixing power *(e.g., peaty soils)*.

Phosphorus deficiency

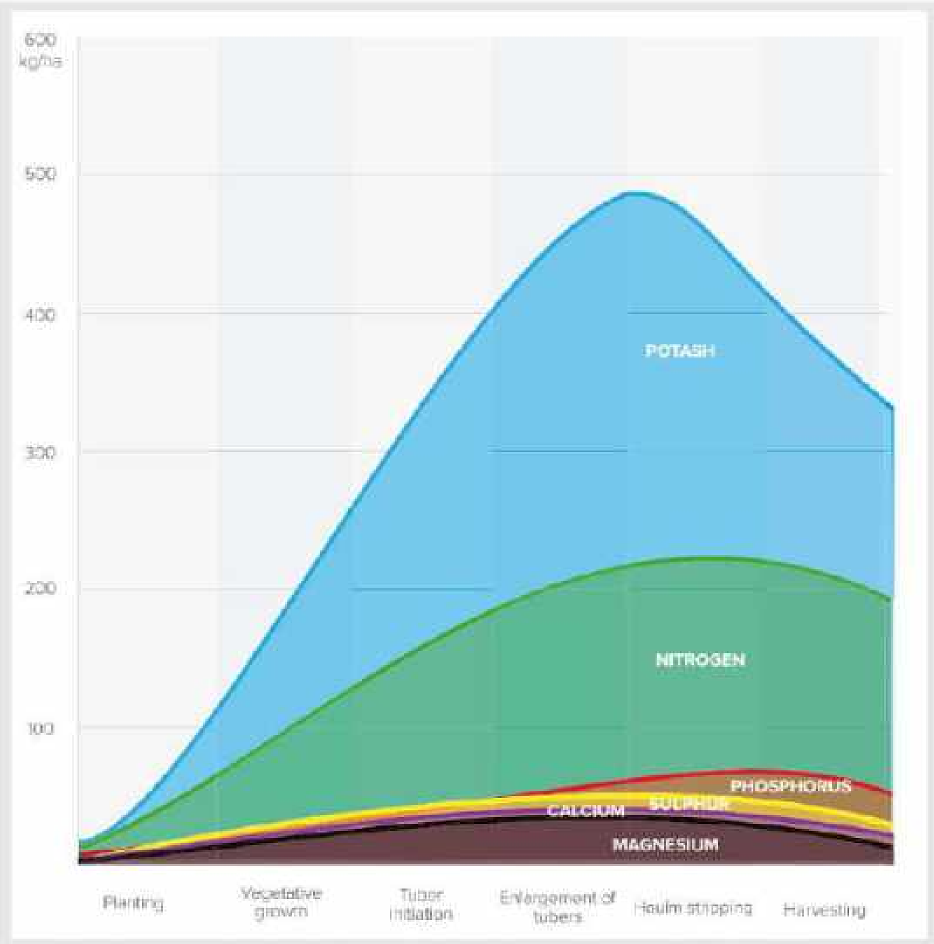
Is manifested by a decrease in the development of the root system which leads to reduced vegetative development with dark green leaf colouring and wavy leaflets. In some cases, the oldest leaves take on a purple colour, become necrotic and fall off prematurely. In addition, tuberisation is poor and the tubers may show rusty brown internal lesions.

> Problematic conditions: Sandy, shallow soils (over 95% sand, e.g., on the Mediterranean coast), very acidic *(pH <5)* or very alkaline *(pH >8) soils*, soils with high P fixing power, heavy soils and rainy springs, poor tillage *(plough pan, seedbeds blowing away)*.

Agronutrition

Potato

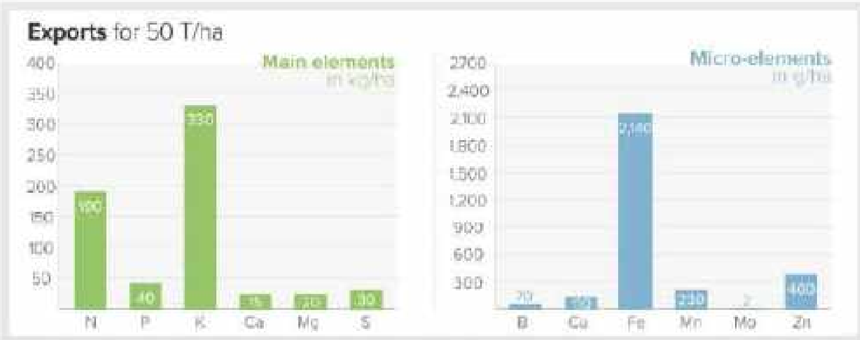
| Key **development stages**



| Mineral **requirements**

Mobilisation for 50 T/ha

Exports for 50 T/ha



| Sensitivities to **deficiencies**

N P K Ca Mg S B Cu Fe Mn Mo Zn

High sensitivity — Medium sensitivity — No sensitivity

Agronutrition

Soybean

Deficiency symptoms

Manganese deficiency

This is the most common deficiency to the soybean. It causes interveinal yellowing of the young leaves which leaves prominent green veins *(like a small fir tree)* except in cases of very severe deficiency. The blade is covered in numerous black necrotic pits. If Mn nutrition conditions are restored, the new leaves will be normal but the affected leaves will retain the appearance of a small fir tree.

> Problematic conditions: Soils with a pH of 6.5 which are rich in organic matter, well-ventilated soils with too high a lime content. In fact, in the plot, greener strips *(less affected can* can be seen on the more compressed areas where wheels pass.

Magnesium deficiency

Is manifested by yellow interveinal marbling on the entire blade accompanied by necrotic spots.

> Problematic conditions: Wet years, compacted soils, acidic soils, highly calcareous soils.

Molybdenum deficiency

Leads to delayed flowering and a reduction in the size of the pods. The leaves are pale and lightly twisted, necrosis forms along the main vein and the edges of the leaf. The nodes are white and few in number.

> Problematic conditions: Highly acidic soil, poorly supplied soils.

Iron deficiency

The symptoms appear via spots in the plot. Young leaves show interveinal chlorosis which may grow into a complete discolouration of the leaf. Necrotic spots may be observed starting from the edge of the blade. The deficiency leads to growth defects: nodes are rare or entirely absent.

> Problematic conditions: Poorly drained calcareous soils.

Agronutrition

Vine & Grapes

Deficiency symptoms

Nitrogen deficiency

Nitrogen incites storage for the following year. Facilitates ripening.

> Deficiency symptoms:

- Principal stage deficiency becomes apparent: From 8 leaves to ripening
- Organ affected first: All leaves
- Dominant colour: Pale green (white)
- Specific signs: The petiole turns purple
- Max. requirements: 40 to 70 and 50 to 80 (1) kg/ha N
- Max. duration of requirements: Before flowering and at the onset of ripening

Magnesium deficiency

Magnesium effectively protects the vine by stopping the stalk from drying out. Supports photosynthesis effectively (*protein synthesis and sugar development*) to ensure a high quality grape harvest.

> Deficiency symptoms:

- Principal stage deficiency becomes apparent: Ripening
- Organ affected first: Older leaves
- Dominant colour: Red (*red*) or yellow (*white*)
- Specific signs: Delayed maturity
- Max. requirements: 15 to 40 and 40 to 100 (1) kg/ha MgO
- Max. duration of requirements: From flowering to ripening

Boron deficiency

Boron ensures successful flowering and perfect setting. Plays a role in pollination (*Pollen development and fertility*).

> Deficiency symptoms:

- Principal stage deficiency becomes apparent: Bloom
- Organ affected first: Young leaves
- Dominant colour: Yellow or dark red
- Specific signs: Three colours – Leaves curled downwards
- Max. requirements: 80 to 200 (1) g/ha B
- Max. duration of requirements: From budding to harvesting

Iron deficiency

Iron plays an essential role in the formation of chlorophyll (*respiration, etc.*) and in protein metabolism.

> Deficiency symptoms:

- Principal stage deficiency becomes apparent: From 5 leaves
- Organ affected first: Young leaves
- Dominant colour: Lemon yellow
- Specific signs: Green veins turn yellow
- Max. requirements: 600 to 900 (1) g/ha Fe
- Max. duration of requirements: From budding to ripening

Potassium deficiency

Potassium increases sugar synthesis and the migration of sugars into the fruit. It prevents nutritional imbalances during the growing season and helps with the transfer of substances developed from the leaves to the fruit or the berries. It also helps fight against flavescence, rougeau and browning.

> Deficiency symptoms:

- Principal stage deficiency becomes apparent: From 5 leaves to ripening
- Organ affected first: Young leaves
- Dominant colour: Glossy green then purple (*in the sun*) or yellow
- Specific signs: Leaves curled upwards, maturity
- Max. requirements: 50 to 100 and 70 to 200 (1) kg/ha K_2O
- Max. duration of requirements: Before flowering and before ripening

Manganese deficiency

Manganese improves the overall functioning of the vine. It plays an essential role in photosynthesis (*the synthesis of chlorophyll*) and plays a part in the enzymatic processes.

> Deficiency symptoms:

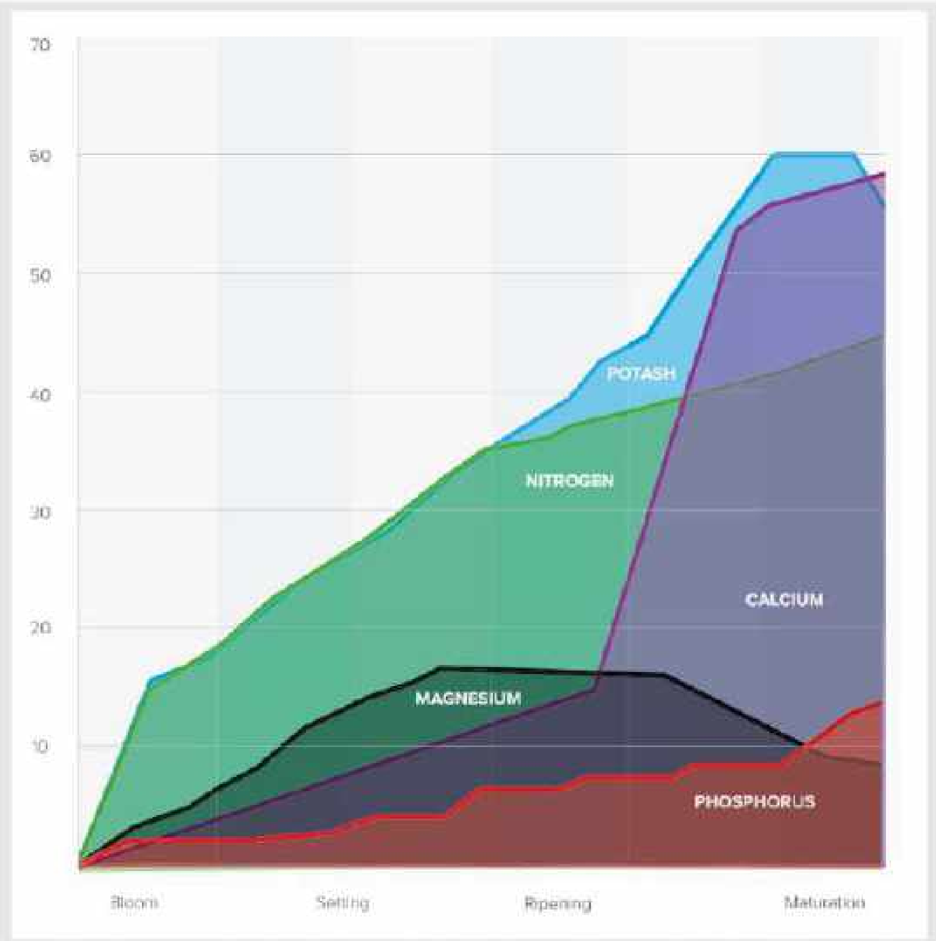
- Principal stage deficiency becomes apparent: Bloom
- Organ affected first: Middle leaves
- Dominant colour: Yellow-orange
- Specific signs: Finely traced veins
- Max. requirements: 100 to 250 (1) g/ha Mn
- Max. duration of requirements: From budding to ripening

Requirements for wine grapes (80 hL/ha) and requirements for table grapes (25 T/ha)

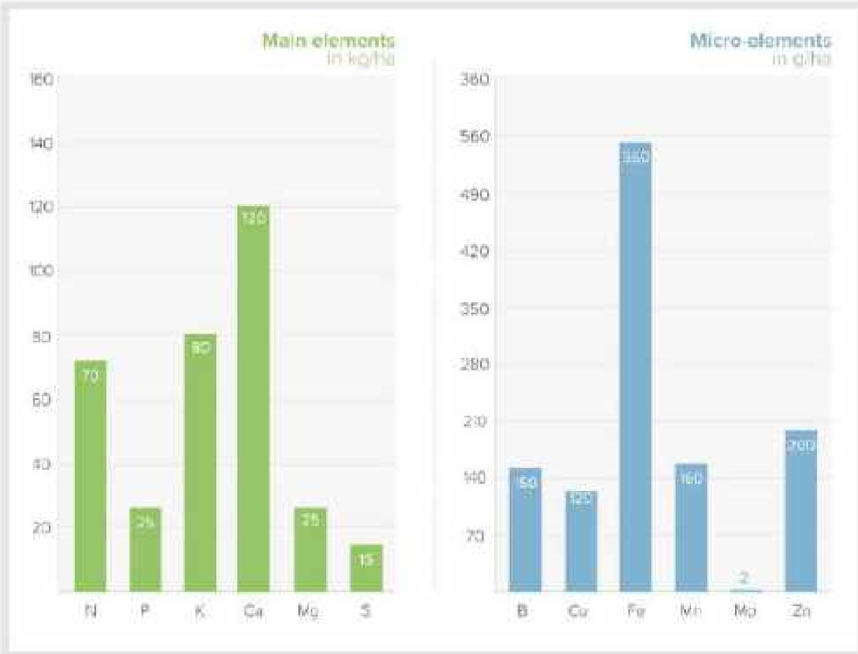
Agronutrition

Vine & Grapes

Key **development stages**



Mineral **requirements**



Sensitivities to **deficiencies**

NUTRITIONAL DIAGNOSIS

Agronutrition

Apple trees & Pear trees

Deficiency symptoms

Calcium deficiency

The application of calcium as of the beginning of the setting phase improves cell resistance *(rigidity and cohesion)* and acts as a protection against physiological disorders associated with a lack of calcium *(bitter-pit, storage diseases, etc.)*. It makes the fruit resistant to bursting/*cracking)*.

> Deficiency symptoms:

Although it is very rarely observed in foliage, a calcium deficiency can lead to the deformation of young leaves, which curve upwards. The fruit develops normally, then the skin becomes covered with brownish, suberised marks which first appear round the fruit bud (bitter pit) during ripening and even during storage. Marks form under the skin and, by cutting the fruit, we can see that these marks remain under the skin and do not spread to the inside of the fruit.

Boron deficiency

Boron is involved in the development, stabilisation and lignification of the cell wall. It is essential to the proper development of plant tissues, which includes the roots, flowers and fruit. In stone fruits, it is above all responsible for pollen germination and the development of the pollen tube and its activation. It ensures successful flowering and perfect setting. Boron also helps to increase the resistance of buds to the cold *(as does zinc)*.

> Deficiency symptoms:

Appears at the beginning of spring with the gradual dying off of the buds in the middle of the branches *(which are sometimes up to 50 cm long)*. While the extremities are normal at first, these also end up withering. Reddish nodules appear on the wood, which puffs up *(scabs)*. Under the bark there are suberised black dots *(measles)*. At the end of the cycle, the fruit's green skin becomes suberised. In some cases, the fruit splits and the scar takes on a brownish, cracked appearance *(external)*. Note that a B deficiency severely limits the translocation of calcium in the tree.

Magnesium deficiency

Magnesium is the central atom of chlorophyll, which is essential to photosynthesis.

> Deficiency symptoms:

Firstly, chlorosis develops on old leaves, leaving a central, green area. The area affected by the chlorosis then dries out, often causing premature leaf drop. The fruits ripen prematurely.
This in turn causes increased fruit drop before the harvest.

Iron deficiency

Plays an essential role in the development of chlorophyll *(Respiration, etc.)*. Protein metabolism.

> Deficiency symptoms:

In spring, symptoms start with the yellowing of the leaves at the extremity of the branches, in the areas farthest away from the veins. The leaves become increasingly discoloured, eventually turning a white colour. The veins stand out against the pale background of the blade. When the deficiency reaches a more advanced stage, the discoloured areas suffer from necrosis, the edges of the leaves dry out and the veins then turn yellow.

Potassium deficiency

Potassium increases sugar synthesis and the migration of sugars into the fruit. It prevents any nutritional imbalances during the growing season and facilitates the transfer of developed substances from the leaves to the fruit.

> Deficiency symptoms:

This deficiency usually occurs in the middle of the vegetative cycle, when the fruit is starting to grow. With regard to the leaves, it starts with the upward curling of the leaves *(cigar shape)*, and progresses with the reddening of the leaf edges which develops towards the interveinal areas. It is usually older leaves that are affected first, although this is not an absolute rule. The colour of the fruit is less intense and they stay green even after being harvested.

Zinc deficiency

Zinc is required for auxin synthesis *(growth hormones required for root development, stem elongation, the maturity of the plant and the breaking down of sugars)*, the development of chlorophyll and protein synthesis.

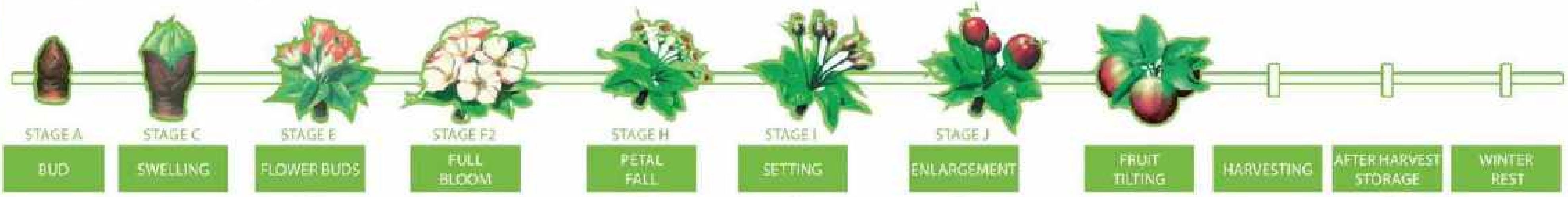
> Deficiency symptoms:

The symptoms appear early in the season and are usually characterised by a shorter distance between the internodes at the extremities of the branches, while the parts of the branch closest to the stem are sometimes completely bare. The leaf edges are wavy and the blade becomes lance-shaped *(becomes narrower and longer)*. The petiole is very short or sometimes does not form at all. The leaves stay grouped together (rosette). On the same tree, some branches may be affected while others remain healthy.

Agronutrition

Apple trees & Pear trees

| Key assimilation **phases**



Boron
Boron helps to increase the resistance of buds to the cold *(by increasing the salinity and sugar content of cells)*. Boron improves pollination and the development of flowers (germination and activation of the pollen tube). It is essential to the viability of the pollen. It limits the effects of the fluctuating availability of this element and facilitates thinning operations.

Iron
Maintains and restores sturdiness in the event of ferric chlorosis

Magnesium
Magnesium improves the photosynthesis process and prevents premature leaf drop.

Potassium
Potassium plays an important role in the production, transportation and storage of sugars in the plant

Phosphorus
Phosphorous improves cell division and facilitates calcium assimilation: the fruit is more dense, firmer, more resistant to bruising and is larger and more regular in size.

Calcium
Calcium improves cell resistance *(rigidity and cohesion)* and acts as a protection against physiological disorders. It makes the fruit resistant to bursting.

Boron
Boron is required by the buds in spring in order to ensure budding, flowering and setting. The level of boron in the buds must be sufficient from the start of the season.

Zinc
Zinc is involved in carbohydrate metabolism and the development of growth hormones. All zinc deficiencies have a negative impact on yield and quality (rugosity) and can even go so far as to cause leaf drop in summer and root dieback.

Nitrogen
The application of nitrogen during the post-harvest stage (cold hardening in the branches) constitutes the potential "nutrition" which will be used to feed the floral organs and will therefore help to prepare the batch for the next harvest.

| Sensitivities to **deficiencies**

B · Cu · Fe · Mn · Mo · Zn

High sensitivity · Medium sensitivity · No sensitivity

Agronutrition

Stone fruit

Deficiency symptoms

Potassium deficiency

Potassium increases sugar synthesis and the migration of sugars into the fruit. It prevents any nutritional imbalances during the growing season and facilitates the transfer of developed substances from the leaves to the fruit.

Potassium deficiency in peach trees

> Deficiency symptoms:
A potassium deficiency can be recognised from the development of chlorosis on the leaf edges, which is then followed by necrosis *(burnt leaves)* and the curling of the leaves. The symptoms begin at the extremities of the shoots. The yield is often reduced.

Magnesium deficiency

Magnesium is the central atom of chlorophyll, which is essential to photosynthesis.

> Deficiency symptoms:
Mg deficiency causes interveinal yellowing which in turn causes some areas to dry out and spreads to the edges of the oldest leaves. It also causes premature defoliation of the base of the annual shoots. With regard to cherry trees, the leaves turn a reddish colour.

Iron deficiency

Plays an essential role in the development of chlorophyll (respiration, etc.). Protein metabolism.

Iron deficiency in plum trees

> Deficiency symptoms:
A Fe deficiency, most often linked to problems absorbing this element, is often called "chlorosis". It generally appears two to three months after budding. One characteristic of this deficiency is gradual interveinal discoloration on the leaves, the blade of which turns a pale green colour and then yellow, while the veins maintain their green colour. In serious cases of this deficiency, the blade turns white and the veins may also become discoloured. In these extreme cases, the leaf edges suffer from necrosis, causing leaf drop. These symptoms affect young leaves first and can then spread to the rest of the tree.

Manganese deficiency

Manganese is involved in the activation of numerous enzymes, chlorophyll synthesis, photosynthesis, the reduction of nitrates, and amino acid and protein synthesis.

Manganese deficiency in cherry trees

> Deficiency symptoms:
A Mn deficiency usually affects the older leaves at the bottom of the shoot first, although this is not an absolute rule. It causes interveinal discolouration on the leaves, leaving a narrow, green strip on either side of the main veins.

Boron deficiency

Boron is involved in the development, stabilisation and lignification of the cell wall. It is essential to the proper development of plant tissues, which includes the roots, flowers and fruit. It ensures successful flowering and perfect setting. Boron also helps to increase the resistance of buds to the cold.

> Deficiency symptoms:
A B deficiency leads to the death of the terminal bud.
A number of buds develop underneath the dead wood, causing a "witches broom" effect. The leaves take the form of a rosette; they are small, thick and deformed. Sometimes, the young leaves are deformed and have discoloured margins or random discoloured patches. The extremity of the branch loses its leaves prematurely. The wood puffs up and looks scabrous.
Flowering is abundant but the flowers drop off; there are few fruits and the fruit that does develop is small, deformed, split and suffers from internal necrosis. In cherry trees, the leaves are a spoon shape. They may also feature some interveinal discolouration.

Zinc deficiency

Zinc is required for auxin synthesis *(growth hormones required for root development, stem elongation, the maturity of the plant and the breaking down of sugars)*, the development of chlorophyll and protein synthesis.

> Deficiency symptoms:
The branches of trees suffering from a Zn deficiency experience reduced growth and have short internodes. Young leaves are therefore grouped together to form a rosette. There is interveinal discolouration on the leaf edges and the leaves are small, narrow and pointy. The leaf edges are sometimes wavy. The flowers drop off.

Agronutrition

Stone fruit

Key assimilation **phases**

STAGE E – VISIBLE STAMENS

STAGE F – BLOOM

STAGE G – PETAL FALL

STAGE H – SETTING

STAGE I – CALYX FALL

STAGE J – YOUNG FRUIT

ENLARGEMENT OF FRUIT UPON HARVESTING

AFTER HARVEST STORAGE

Boron

Boron helps to increase the resistance of buds to the cold (by increasing the salinity and sugar content of cells). Boron improves pollination and the development of flowers (germination and activation of the pollen tube). It is essential to the viability of the pollen. It limits the effects of the fluctuating availability of this element and facilitates thinning operations.

Iron

Maintains and restores sturdiness in the event of ferric chlorosis

Potassium

Potassium plays an important role in the production, transportation and storage of sugars in the plant.

Phosphorus

Phosphorous improves cell division and facilitates calcium assimilation, the fruit is more dense, firmer, more resistant to bruising and is larger and more regular in size.

Calcium

Calcium improves cell resistance (rigidity and cohesion) and acts as a protection against physiological disorders. It determines the resistance of fruits to bursting (cracks or microcracks of the skin).

Boron

Boron is required by the buds in spring in order to ensure budding, flowering and setting. There must be a sufficient level of boron in the buds right from the beginning of the season.

Zinc

Zinc is involved in carbohydrate metabolism and the development of growth hormones. All zinc deficiencies have a negative impact on yield and quality (rugosity) and can even go so far as to cause leaf drop in summer and root dieback.

Nitrogen

The application of nitrogen during the post-harvest phase (cold hardering in the branches) provides the "nutritional" potential which will serve to feed the floral organs and will therefore help to prepare the batch for the next harvest.

Sensitivities to **deficiencies**

CHERRY TREES

N P K Ca Mg S B Cu Fe Mn Mo Zn

PEACH TREES

B Cu Fe Mn Mo Zn

PLUM TREES/APRICOT TREES

B Cu Fe Mn Mo Zn

High sensitivity — Medium sensitivity — No sensitivity