**(Slide 4)**

Clays

Organic materials

**(Slide 5)**

(blue) Known species

(green) Unknown species

Vascular plants

Earthworms

Termites

Ants

Springtails

Mites

Nematodes

Protozoa

Bacteria

Fungi

Number of species (x 1000)

Size

**(Slide 9)**

Atmospheric nitrogen

11)Nutrition Exportation

3)Synthesis

Mineral nitrogen fertilizers

1)Deposition

2)Fixing bacteria

4)Organic N

Biological activity = organization

mineralization

(5)Mineral N

Humus

Labile organic material

10)Urea

Ammoniacal

nitrification

Nitrate

6)Leaching

9)Volatilization

7)Denitrification

8)Livestock effluents Harvest residues

Nitrogen outputs from the soil

Nitrogen inputs into the soil

Transfer to water or air

**(slide 11)**

Deficiency in N Yellowing of old leaves

Deficiency in S Yellowing of young leaves

**(Slide 12)**

2) Mineral fertilizers

3)Crop protection products

4)Deposition

5) Organic S

Biological activity = organization

mineralization

(6)Mineral S

Humus

Labile organic material

7)Leaching

1)Livestock effluents

Harvest residues

10)Nutrition Exportation

Sulfur outputs from the soil

Sulfur inputs into the soil

Transfer to water

**(Slide 13)**

*In this slide, every comma needs to be replaced by the decimal point in each number.*

**(Slide 14)**

Mar Apr May Jun Jul Aug Sep Oct Nov

(yellow line) Canola

(green line) Wheat

(orange line) Beets

(brown line) Potatoes

**(slide 15)**

Updated advice about sulfur?

Do not confuse **sulfur deficiency** with nitrogen deficiency!

Towards a new adjustment grid for sulfur fertilizer on straw cereals?

**Conclusions**

Sulfur has become more frequently limiting.

An increasing number of trials show a response to sulfur, with an increased number of quintals.

Admittedly, the response is weaker in the event of a dry winter because the sulfur does not leach as much, but it all depends on previous practices (mineral and organic inputs).

But the grid needs to be updated to take into account changes in yield potential and exports.

Towards a sulfur budget

+20 to 30u more S

**(Slide 18)**

1)Mineral phosphorus fertilizers

2)Phosphate mines

3)Organic P

Biological activity = organization mineralization

Humus

Labile organic material

Soluble P Soil solution

Absorbed P

Fixed P

(4)Mineral P

5)Leaching

1)Livestock effluents Harvest residues

8)Nutrition Exportation

6)Erosion runoff

Phosphorus outputs from the soil

Phosphorus inputs into the soil

Transfer to water

**(Slide 19)**

**Assimilable phosphorus**

Dissolved phosphorus in the soil solution

Non-assimilable phosphorus: phosphorus fixed on iron and aluminium oxides

Non-assimilable phosphorus: Fe, Al, Mn precipitation

Relatively assimilable phosphorus: fixation on clays

Non-assimilable phosphorus: crystallization of calcium phosphates

pH of the soil

**(Slide 21)**

**II – What happens when you apply a water-soluble phosphorus fertilizer?**

1. **The water-soluble fertilizer completely dissolves** in the soil solution. The plant can draw nutrition from it: it has an “immediate effect”.
2. **At the same time, the absorbent complex is recharged** with PO43- ions which balance with those of the soil solution: this is “absorption”.
3. **But other PO43- ions are combined with other mineral forms**, increasingly accessible: this is “retrogression” or “fixation”.

In total, for the entire crop duration, **the Real Utilization Coefficient of the water-soluble phosphorus fertilizer does not exceed 15-20%**.

1. 80-85% of this soluble fertilizer, although qualified as “assimilable”, will be added to the **mineral reserve** from the very first year. This reserve is not lost, of course, but is equivalent to that of insoluble or only slightly soluble fertilizer. This is the residual effect.
2. The availability of this “reserved” fertilizer varies from soil to soil. In calcareous or very acidic soil, “retrogression” or “fixation” is more energetic than in neutral or only slightly acidic soil. Hence the compartmentalized representation of the mineral reserve (A B, C), with a fraction being quickly exchangeable, and others more and more slowly exchangeable. Compartments which the analysis has trouble measuring.

(Diagram)

Water-soluble phosphorus fertilizer directly applied to the ground (superphosphates, ammonia phosphates)

ORGANIC reserve

MINERAL reserve

80-85% of P drawn from the bioavailable reserve

**HOW ROOTS EXTRACT PHOSPHORUS**

A root is not a simple absorbent strand, but a very complex living being, or rather an association of living beings. The “rhizosphere” is the space surrounding every single root like a sleeve. This sleeve, teeming with bacteria, fungi and protozoa, contributes in a surprising way to the nutrition of the plant, notably regarding phosphorus.

1 – The root secretes acids which attack the insoluble phosphates

In order for the roots to absorb K, NH4, Ca2 and Mg2 cations, they need to discharge H ions which acidify the area close to the absorbent bristles. This acidification then enables the root to attack the insoluble phosphates of the mineral reserve, even the most resistant (tricalcium phosphate).

In addition, the root excretes organic acids R-COOH and CO2 (carbonic acid), further intensifying the acid attack.

This acid reaction is clearly visible on this limestone plate (left) which has been attacked by roots and on this surprising **pH map of the rhizosphere** (right) of a canola root deficient in P. Only the absorbent areas are acidified.

*(Map obtained by video spectrodensitometry, Ruiz, 1992, in Techniques Agricoles No. 1210, by B. Jaillard and Ph. Hinsinger).*

The darkest area: pH 5.7

The lightest area: pH6.9

**(Repeated info for Slides 23 and 29)**

A = Increase

I = Undefined

D= Reduction

EI= Not enough data

**(Slide 27)**

Table 8.4 Effects of nitrogen, phosphate and potassium nutrition on some qualitative criteria of the potato. (Laurent and Gravoueille, 1997)

Quality criteria

Proportion of marketable tubers

Damage (fracture)

Internal blackening

Dry matter content

Protein content

Nitrate content

Heat tolerance

Farinosity

Blackening after cooking

Browning on frying

Storage losses

Effects of fertilizer on the criteria considered: + increase; zero effect; decrease

Potassium

Dose

Form

Sulphate

Chloride

Variable

**(Slide 28)**

2)Potash mines

Mineral potassium fertilizers

1)Livestock effluents Harvest residues

3)Mineral K Exchangeable pool Soluble K

4)Leaching loss

5)Erosion runoff

7)Nutrition Exportation

Potassium outputs from the soil

Potassium inputs into the soil

Transfer to water

**(Slide 32)**

|  |  |  |  |
| --- | --- | --- | --- |
| Form | Denomination | Solubility in water | Observations |
| Nitrates | Magnesium nitrate | Immediate and total | Foliar application |
| Sulphates | Epsom salt | Immediate and total | Foliar application |
|  | Magnesium sulfate | Fast and total | Can be used for all soil types |
| Hydroxides and oxides | Hydroxide  Oxide  Magnesium lime | Slow and negligible for oxides | Effectiveness varies greatly depending on the mode of calcination of oxides useable for all soil types |
| Carbonates | Dolomite | Very slow and very weak | Reserved for acidic soils |

Choice of magnesium fertilizer

Comparison between magnesium oxide and sulfate on potatoes

Significant difference

**(Slide 33)**

2)Dolomite quarry Kleserite mines

Basic mineral amendments

Mineral fertilizers

1)Livestock effluents Harvest residues

3)Mineral Mg Exchangeable pool Soluble Mg

4)Leaching loss

5)Erosion runoff

7)Nutrition Exportation

Magnesium outputs from the soil

Magnesium inputs into the soil

Transfer to water

**(Slide 34)**

**Physiological role of calcium in the plant’s development**

Calcium is part of the constitution of the cell wall. Transported within the xylem, it does not move within the phloem and cannot be redistributed.

Role of calcium (Ca)

In plant physiology, calcium (Ca) has several functions. It is composed of membranes and cell walls (calcium + pectic acid + calcium pectato). It activates several enzymes and neutralizes organic acids.

Calcium slows down the aging of tissue, gives fruit a better consistency and makes it more resistant to parasite attacks.

Calcium (Ca) deficiency

Calcium deficiency is evidenced by the drying out of terminal buds and therefore stunts their growth. A lack of calcium or the inhibition of its action can lead to serious physiological problems (the wilting of terminal buds, the yellowing of young leaves and perhaps a greater risk of vitrescence).

**(Slide 35)**

**Amendment**

1. (instructive, relating to an amendment)Few common fertilizers contain a proportion of matter (of varying degrees) that is not likely to contribute directly to the nutrition of plants, just as it is also very rare to find and use purely **amending** materials, completely devoid of nutritional principles.

**(Slide 36)**

2)Calcium carbonate quarry Lime kiln

Basic mineral amendments

1)Livestock effluents Harvest residues

3)Mineral Ca Exchangeable pool Soluble Ca

4)Leaching loss

5)Erosion runoff

7)Nutrition Exportation

Calcium outputs from the soil

Calcium inputs into the soil

Transfer to water

(Slide 37)

Phosphorus displacement

Other dissolved ions (nitrate, chloride, sulfate)

Phosphorus and certain trace elements are not very mobile and slow to reach the roots

Phosphorus and certain trace elements are not very mobile and slow to reach the roots

**(Slide 38)**

Deficiency in a non-mobile element mainly affects young organs:

A non-mobile or not very mobile element (\*) cannot be retrieved from older organs and transported to young organs. The deficiency therefore shows up in the **young organs** whose **growth is stunted**. The symptoms appear on the **young organs**.

The lowest levels of elements with little mobility are observed in young leaves.

Deficiency in a non-mobile element

\*Elements which are not totally immobile, with some degree of mobility.

Deficiency in a mobile element triggers symptoms in older leaves:

A fraction of the element invested in **old leaves which are still active and in the old parts (trunk, roots)** can be **mobilized** and transported via the xylem or phloem to new leaves **for continued plant growth**.

**Symptoms appear on** the leaves that have run out of the element: these are the **old leaves** mostly located at the base of the plant.

The lowest levels of mobile elements are observed in old leaves.

Conclusion

The immobile element is transported in the plant by the raw sap according to the rate of transpiration during the day and root growth at night.

Immobile elements cannot be redistributed (e.g. Ca, Fe, B in certain species) and their shortage or problems of water supply cause significant nutritional problems: growth arrest, necrosis, death.

The redistribution of mobile elements N, P, K, and Mg through the phloem regulates the concentrations of these elements in the different organs.

(Diagram)

LEAVES

Light

Vessels of the phloem (conduction of elaborated sap)

Vessels of the xylem (conduction of raw sap)

Atmosphere

Soil

ROOTS

Water and mineral salts

**(Slide 40)**

BREAK

PHEW!

**(Slide 44)**

*(words in green)*

Sulfur Magnesium Potassium Nitrogen Phosphorus

**(Slide 45)**

(Diagram)

NITROGEN NEEDS

Accessible yield X requirement per unit of output

NITROGEN SUPPLIES

Soil + organic effluents + mineral fertilizers

**(Slide 46, info in table)**

Sulfur fertilization of wheat, decision matrix (Bouthier)

1. Pedoclimatic conditions
2. Recent history of fertilization

Soils

Rainfall in mm from 1st October to 1st March

Organic input during rotation (at least every 3 years)

Bioavailability at the critical stage

Need for mineral sulfur fertilization

Always

As diagnosed

Always

As diagnosed

Unnecessary

As diagnosed

Unnecessary

Superficial clay limestone

Chalk earth on filtering subsoil

Gravelly soil on flint clay

Sandy soil

Deep clay limestone

Cold silt

Loamy soil

Freeform silt

No

Yes

1. Low
2. Average
3. High

(Slide 55)

**New results of the P + K trials network (2013 edition)**

55

The application of phosphate and potassium fertilizer calculated according to reference methods is cost-effective in the production of canola and cereals. These were the findings of a network of 15\* trials conducted by the UNIFA and member cooperatives of InVivo.

These multi-year trials were conducted on soil types initially rather low in phosphorus and with medium levels of potassium. They were located in arable farming areas and did not receive organic inputs.

**Agronomic results**

Average yield gain after application of P + K compared to the control without application

Yield gain reaches 8q in canola, 4q in common wheat and 7q in winter barley.

On average the supply is 85kg of P2O5 and 65kg of K2O/ha for cereals and canola.

Common wheat (13 trials)

Canola (10 trials)

Winter barley (9 trials)

Spring barley (8 trials)

Durum wheat (6 trials)

Corn (1 trial)

**Start-up vigour enhanced by the application of P + K**

With regard to canola, the application of P + K fertilizer at the sowing stage encourages the initiation of the crop and root system. This effect on vigour is also observed in other crops such as spring barley and corn. It promotes fast growth and better resistance to stress.

**Nitrogen enhanced by the application of P + K**

In these trials, nitrogen input was the same in all conditions. The yield gain achieved by the application of P + K results in extra nitrogen which is absorbed by the whole plant and which can be estimated from the protein content of the cereals and canola.

The application of P + K leads to the absorption of an extra 42 kg on average of nitrogen for canola and 13 kg for cereals. Balanced nutrition in P + K means that more nitrogen is absorbed. The saving for the farmer also benefits the environment.

UNIFA and InVivo aim to develop this network of P + K trials in the years to come to address the issue of the capping of canola and straw cereal yields. Indeed, reasoned fertilization has a decisive effect on crop productivity and the competitiveness of farmers.