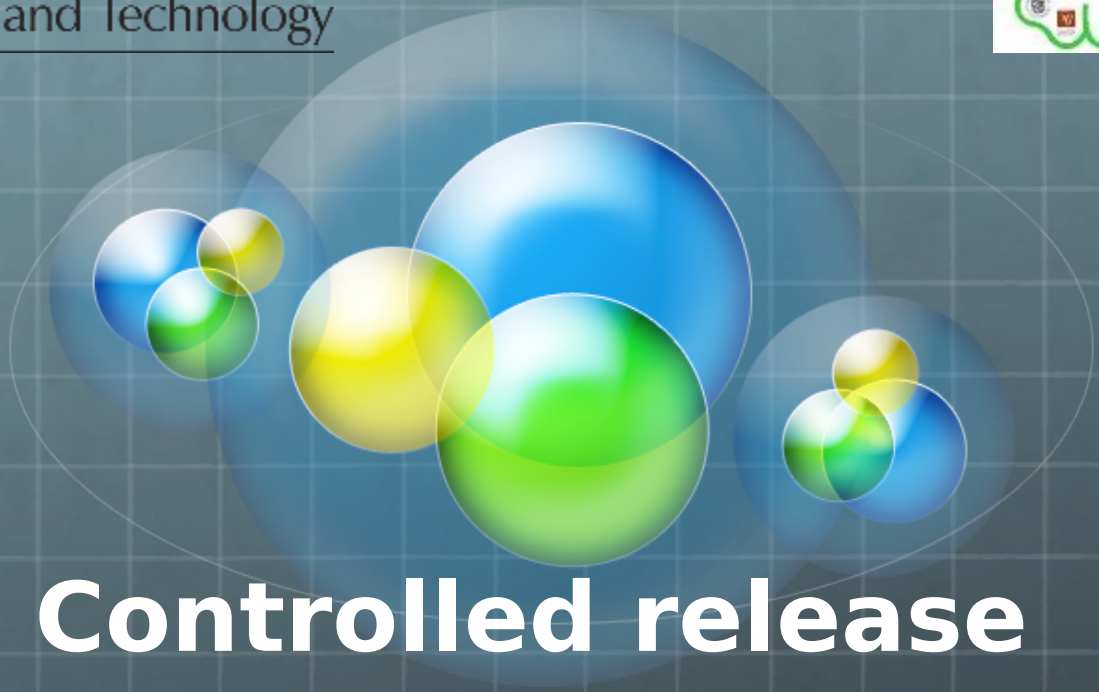
Wrocław University of Science and Technology

Plantarum



Controlled release micronutrient fertilizers for precision agriculture

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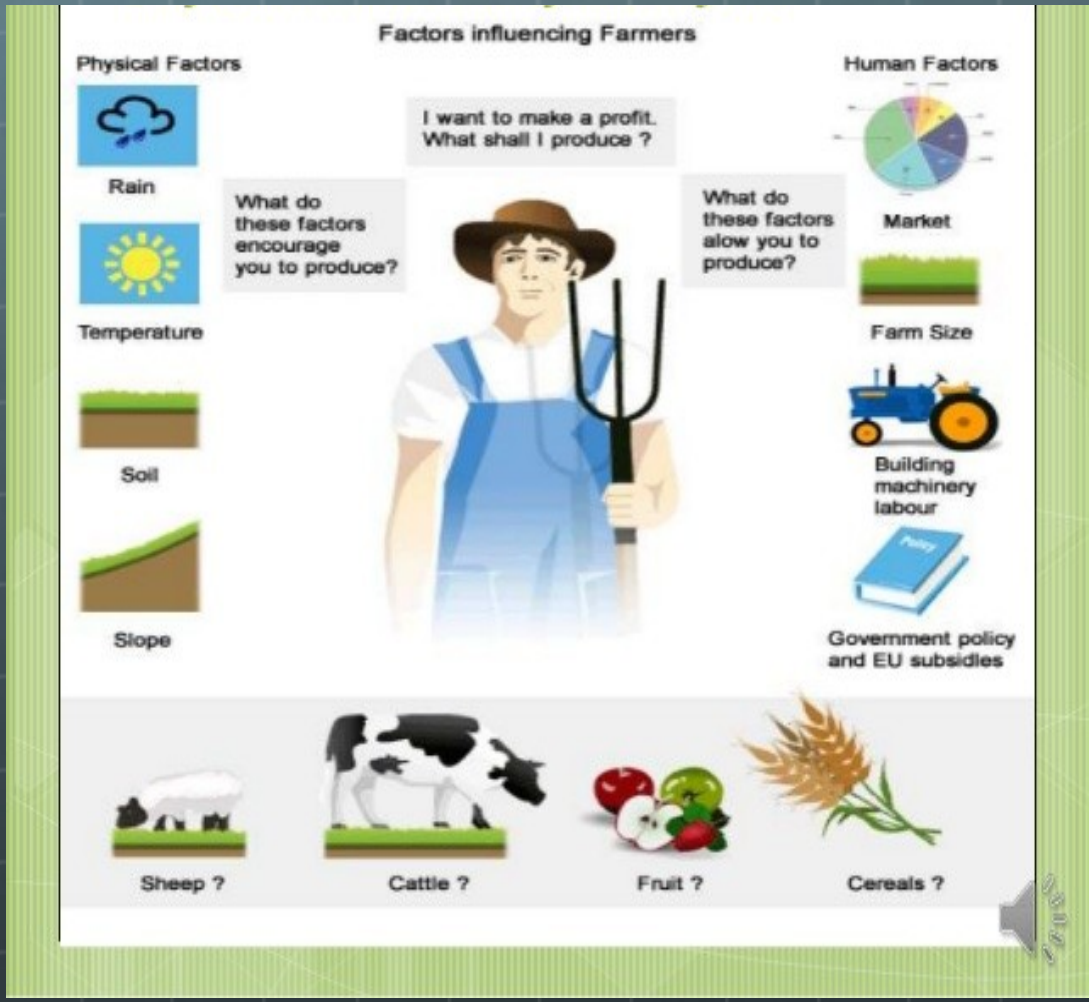
Precision agriculture

- 1980's: 'site-specific agriculture/crop management'.
- The term appeared first in 1990.
- Aims to optimize field level management:
  - Crops – matching farming practices with crop needs (fertilizer inputs)
  - Environmental protection – reduces environmental risks and footprint of farming (limiting leaching of nutrients)
  - Economics – competitiveness by more efficient practices (improved management of fertilizer use)

Definition

- PA utilizes innovative, **site-specific techniques** for management of spatial and temporal variability by affordable technologies to enhance:
  - **output,**
  - **efficiency**
  - **and profitability**
- of agricultural production in **environmentally responsible** manner.
- Assessment of nutrient content of **soil and plants**.

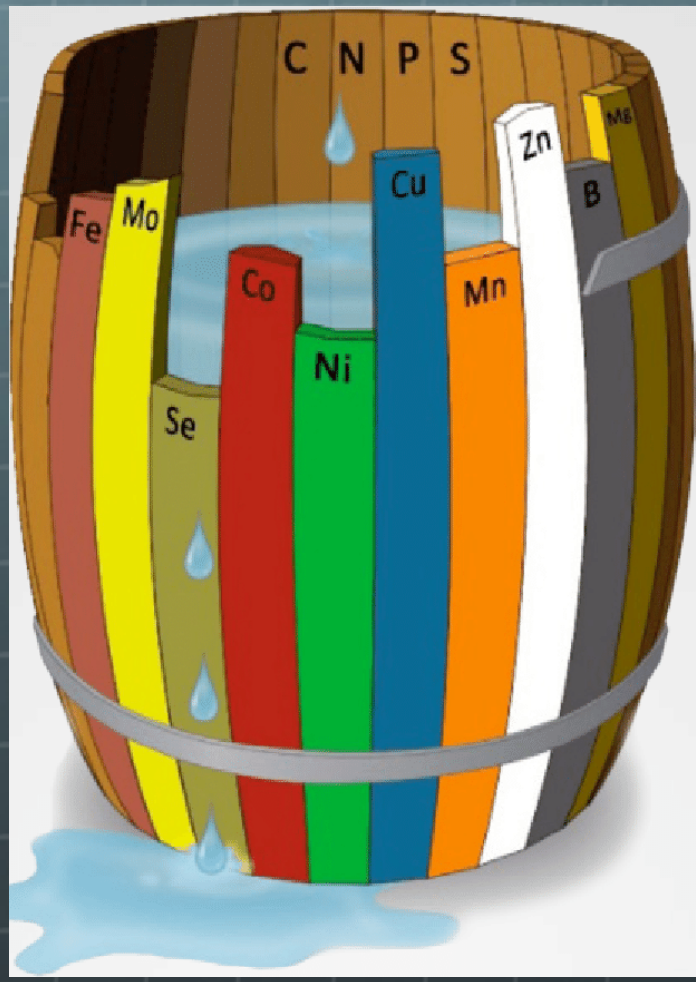


- **Fertilizers** are responsible for approximately **half** of the world's **crop** production – important for global food security.
- Most fertilizers - **concentrated minerals** from **ore deposits**; exception – N.
- Sufficient crop production depends on efficient fertilizers.
- Integrated system.
- Challenge – to provide:
  - the right **nutrients**,
  - at the right **rate,**
  - at the right **time**
  - and in the right **place**.

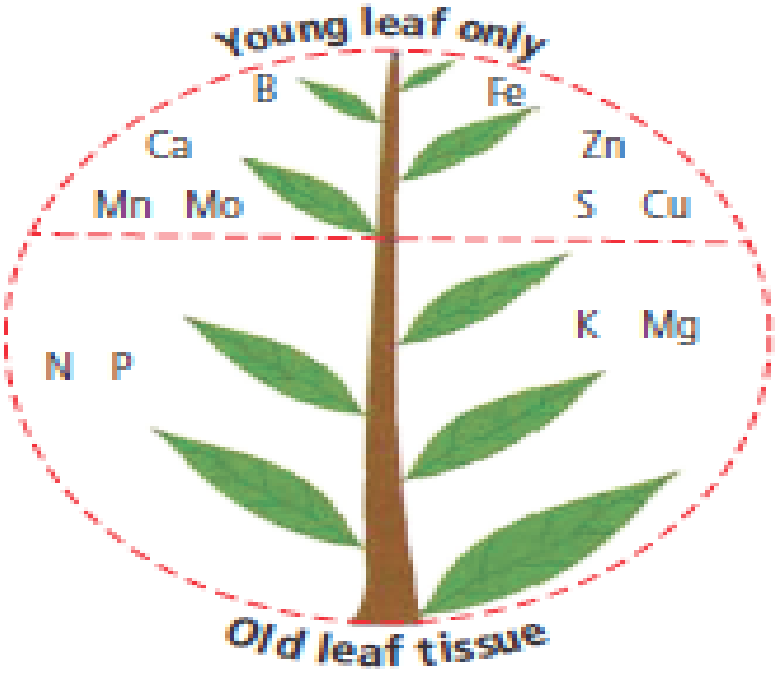
NUE – Nutrients Use Efficiency

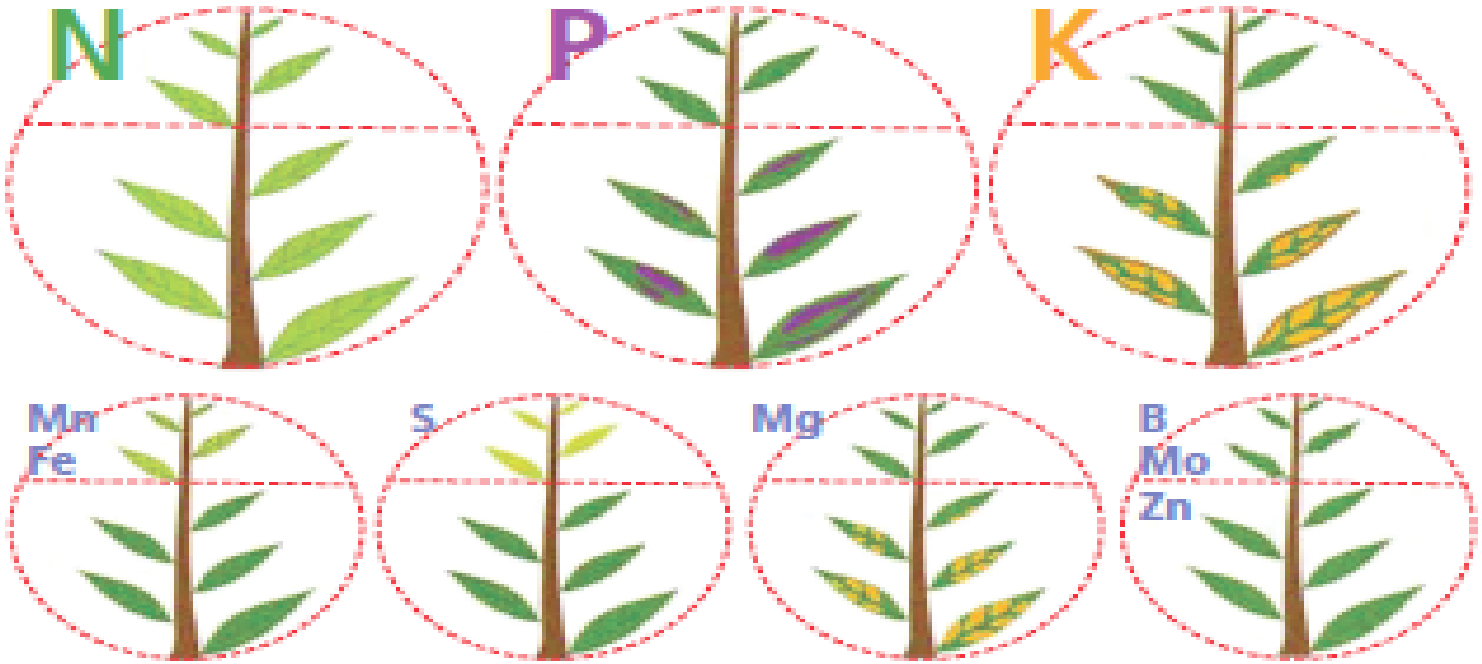
- N use efficiency 10-30 % (urea),
- P use efficiency 30-40 % (single superphosphate)
- Micronutrients 30-50 %
- Only 40-50 % of applied fertilizer is used by the plants.
- Losses of fertilizer nutrients depend on soil processes:
  - microbiological transformations
  - chemical – exchange, precipitation, hydrolysis
  - physical – leaching, runoff, volatilization

- There are **17 essential nutrients** for crop growth.
  - **C, H, O** – air & water
  - **macronutrients**—NPK
  - **secondary nutrients**—S, Ca, Mg
  - **micronutrients**—B, Fe, Mn, Zn, Cu, Mo, Cl, Ni - small amounts, catalysts in metabolic processes



Locations of nutrient deficiency symptoms on plants



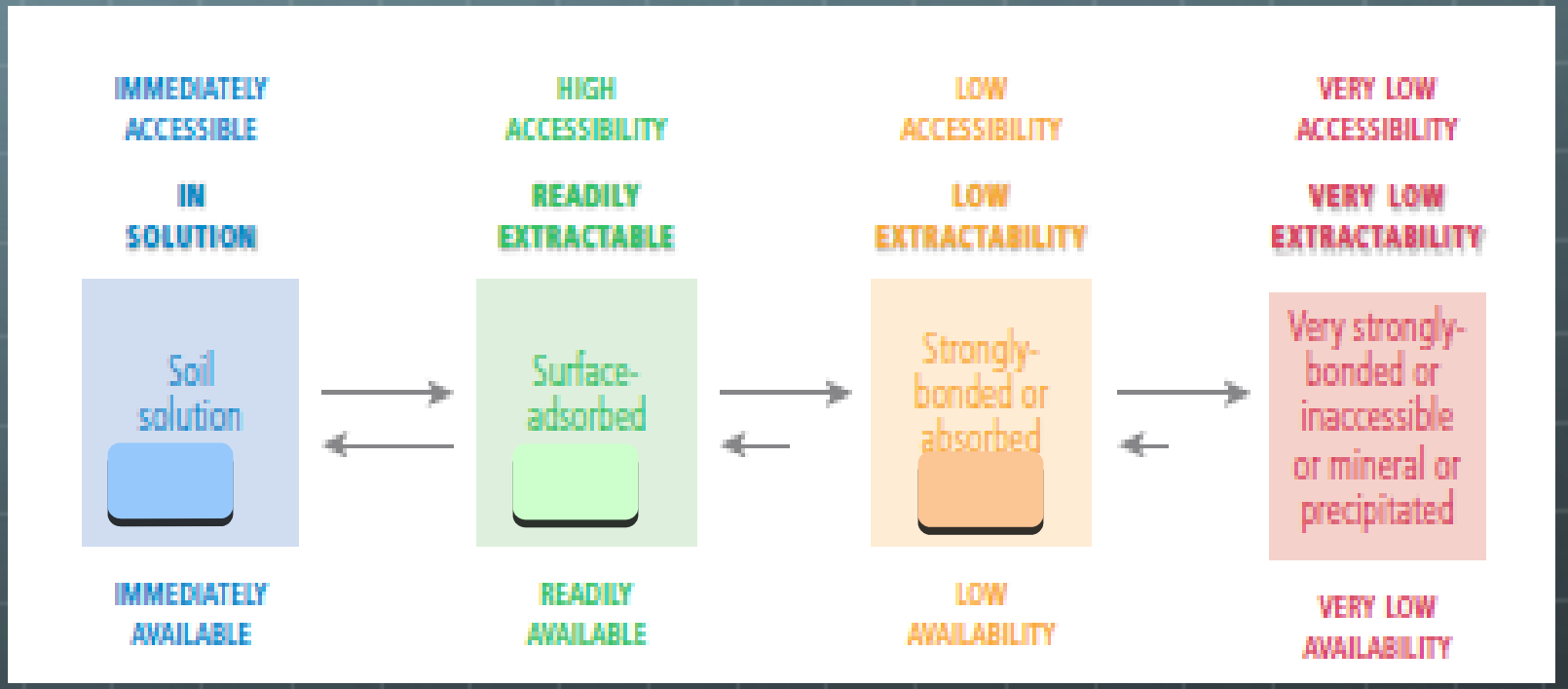


Controlled release micronutrient fertilizers

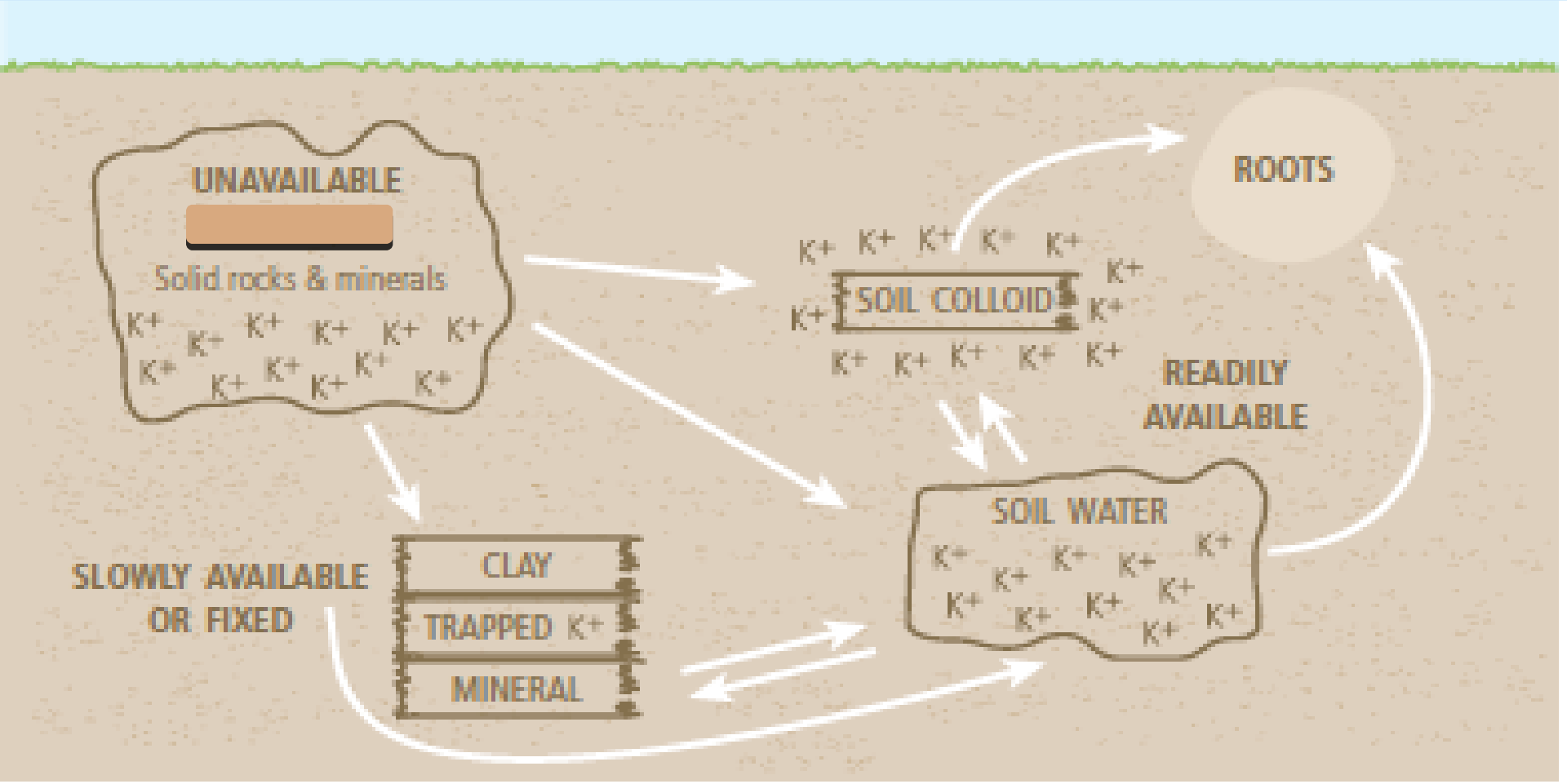
- The research focuses on **increasing efficiency** of the **existing** fertilizers.
- Doubling efficiency of the fertilizer means **reduction** of the **applied fertilizer by 50 %**
- **Micronutrients** – essential components of enzymes/proteins important to increase crop yield and nutritional quality of food.
- Conventional - bulk micronutrients – water soluble: **sulfates or chelated** forms, DTPA (diethylene triamine penta acetic acid), EDTA.

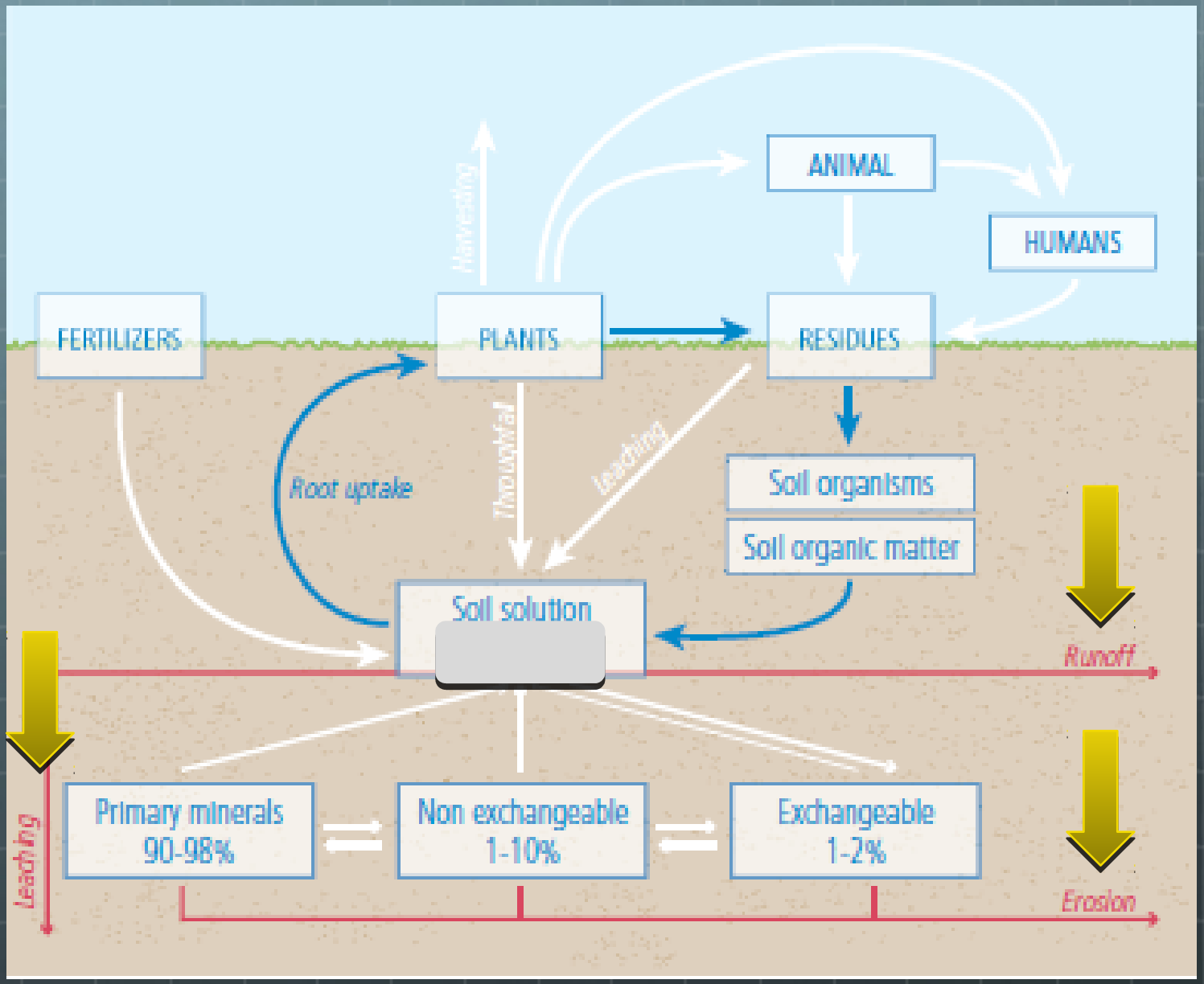
soil.

With conditions change (pH, concentration) – amounts in each pool change



- Cation nutrients in various **equilibrium** positions in soil.
- As cation is taken up by plants, the equilibrium **shifts** to release more cations into the soil solution
- **Plant roots** can decompose insoluble compounds by ion exchange with the root hairs or by **extracellular organic acid** that extract nutrients by **chelation**.

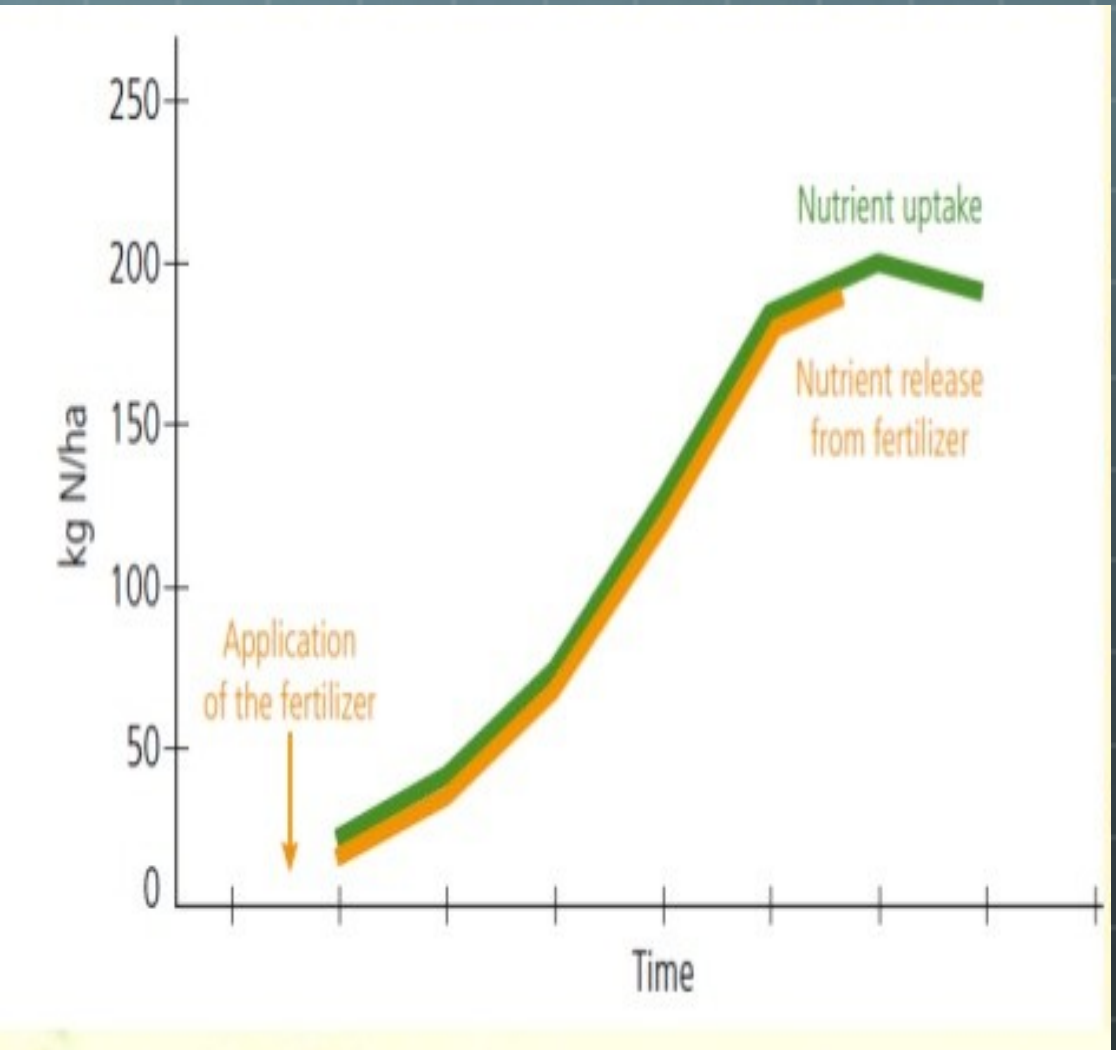



ANIMAL
HUMANS
Harvesting
FERTILIZERS
PLANTS
RESIDUES
Root uptake
Throughfall
Leaching
Soil organisms
Soil organic matter
Soil solution
Runoff
Leaching
Primary minerals
90-98%
Non exchangeable
1-10%
Exchangeable
1-2%
Erosion

Optimal Plant Development – nutrients are precisely supplied according to specific plant needs

- The goal: optimal nutrition throughout the growing season
- Granular soluble fertilizer:
  - daengerous excess at the beginning
  - followed by deficiency towards the end of the growing season

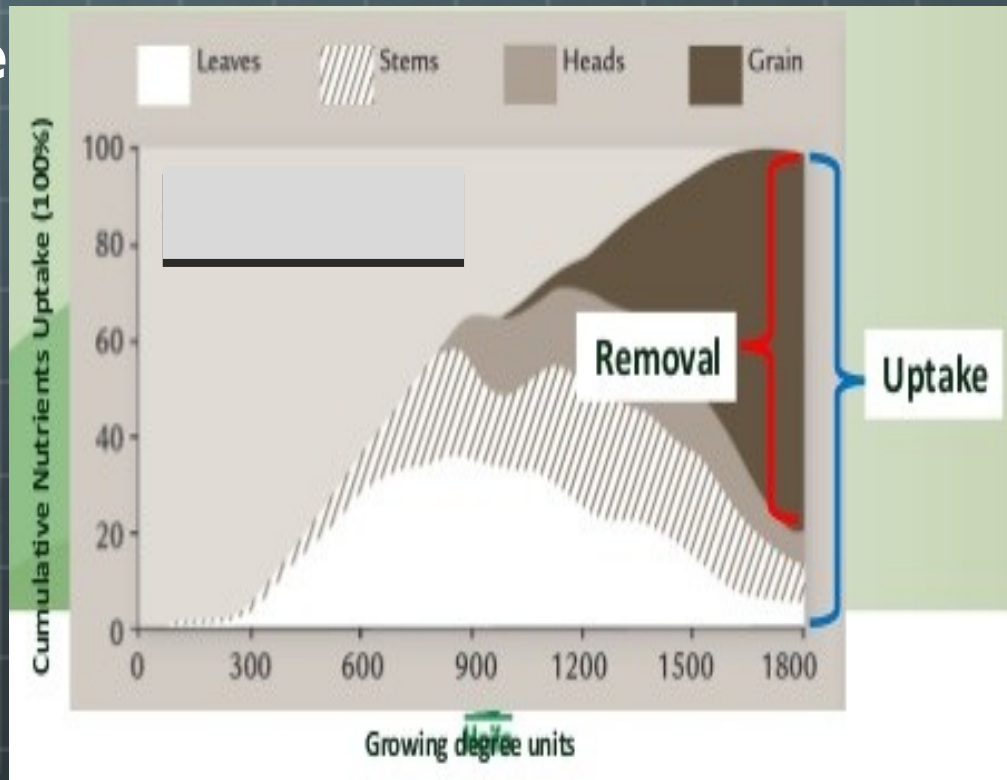
The nutrient release should be synchronized with plant nutrient requiremens



- The nutrient release patterns should **match exactly** the nutrient uptake curve of the crop
- Any excess nutrients shall remain in the soil for the next crop

NUTRIENTS FATE

- **Precise dosing**: real removal
- Nutrient **removed** by the harvest
- Nutrient absorbed during the whole vegetative cycle
- **uptake** – absorbed from plants during the crop cycle; nutrients must be available
- **removal** – removed with the harvested plants
- **losses** - leaching



Fertilizers on top the soil

Urea

Rain

Penetration and distribution of dissolved nutrients

Ammonium nitrate + lime

Rain

Lime

Ammonium nitrate

Separation of components after rain

NPK fertilizer

Rain

NPK

NK

N

Components penetrate differently

Fertilizers into the soil

Placement

Nutrients disperse spherically

Seed

Fertilizer

Fertilizer below seed

Box 3. Types of mineral fertilizers (according to different criteria)

Method of production

- natural (as found in nature or only slightly processed);
- synthetic (manufactured by industrial processes).

Number of nutrients

- single-nutrient or straight fertilizers (whether for major, secondary or micro nutrients);
- multi-nutrient (multiple nutrient) or compound fertilizers, with 2, 3 or more nutrients:

Type of combination

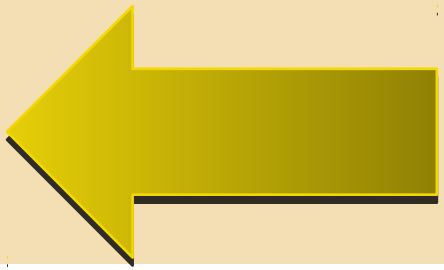
- mixed fertilizers, i.e. a physical mixture of two or more single-nutrient or multi- nutrient fertilizers (for granular products this may comprise a blend of separate granules of the individual ingredients, or granules each containing these ingredients);
- complex fertilizers, in which two or more of the nutrients are chemically combined (e.g. nitrophosphate, ammonium phosphates).

Physical condition

- solid (crystalline, powdered, prilled or granular) of various size ranges;
- liquid (solutions and suspensions);
- gaseous (liquid under pressure, e.g. ammonia).

Mode of action

- quick-acting (water-solubleand immediately available);
- slow-acting (transformation into soluble form required).



IFA definition

Term	Definition	Technology	Example of product
Controlled Release Fertilizer (CRF)	Fertilizer in which nutrient release is controlled, meeting the stated release rate of nutrient and the stated release time at a specified temperature.	Fertilizer coated with a polymeric coating	Osmocote, Agroblen, Sierrablen (Everris) ESN (Agrium), Duration, POLYON (Koch Agronomic Services) Multicote (Haifa) Nutricote (JCAM Agri) Apex (Simplot)
Slow Release Fertilizer (SRF)	Fertilizer, of which, by hydrolysis and/or by biodegradation and/or by limited solubility, the nutrients available to plants is spread over a period of time, when compared to a "reference soluble " product e.g. ammonium sulphate, ammonium nitrate and urea.	Use of less water soluble nutrients and/or compounds which are degraded in soil over time	N-Sure (Tessenderlo Kerley) Sierraform (Everris) Nitroform (Koch Agronomic Services) Floranid (IBDU) (Compo) IBDU (JCAM Agri) Sazolene and Sirflor (Sadepan Chimica) CDU (JCAM Agri)

Water-soluble	Slow-release	Controlled-release
	Non-coated 	Coated 
Dissolves all at once	Slowly decomposes to soluble	Nutrients "leak" through coating

- Concept of **slow/controlled release** fertilizers: release at gradual rate that permits **maximum uptake** and utilization with **minimization of leaching**, volatilization or excessive growth.
- **Fertilizer use efficiency** is higher and regulated by **supply/release** rate of nutrients that is synchronized with **crop demand**.

Why SLOW/CONTROLLED RELEASE fertilizers?

- Lower toxicity
- Lower losses of nutrients – leaching/runoff, evaporation
- Lower environmental pollution
- Plants take up most of fertilizer nutrients
- Less frequent application required
- Only 2 applications/year; no other fertilizer needed
- Act weeks-months
- Time savings
- Economical

High efficiency of the applied fertilizer

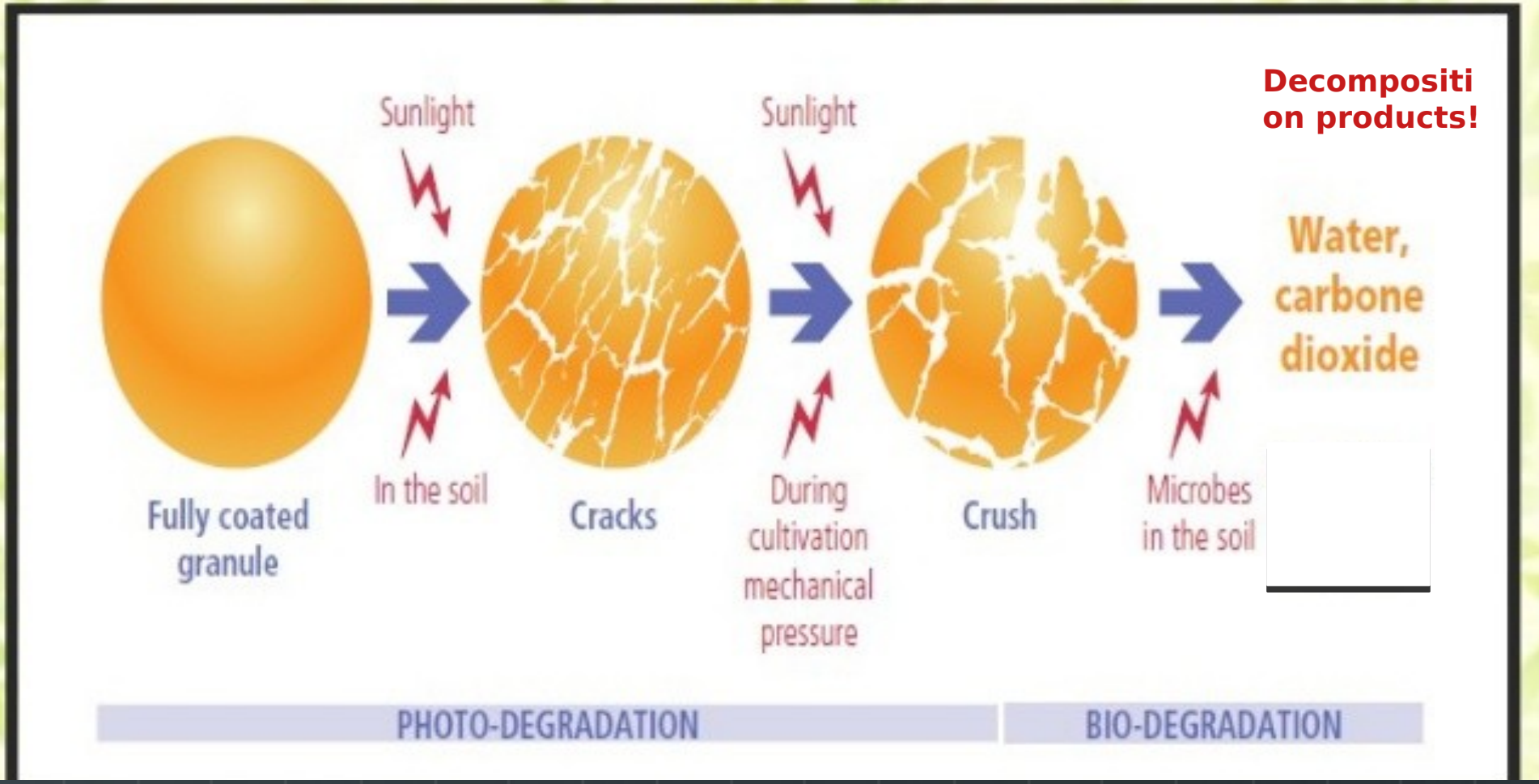
- A significant **reduction of nutrient losses => NUE increases.**
- **Physical barrier or coating protects the fertilizer granules from dissolving.**
- **Depending on the thickness of the coating and its components, the protection can be for a few days to a few months.**
- **Conversion pathways are regulated by soil bacteria.**

Coatings and controlled-release fertilizers

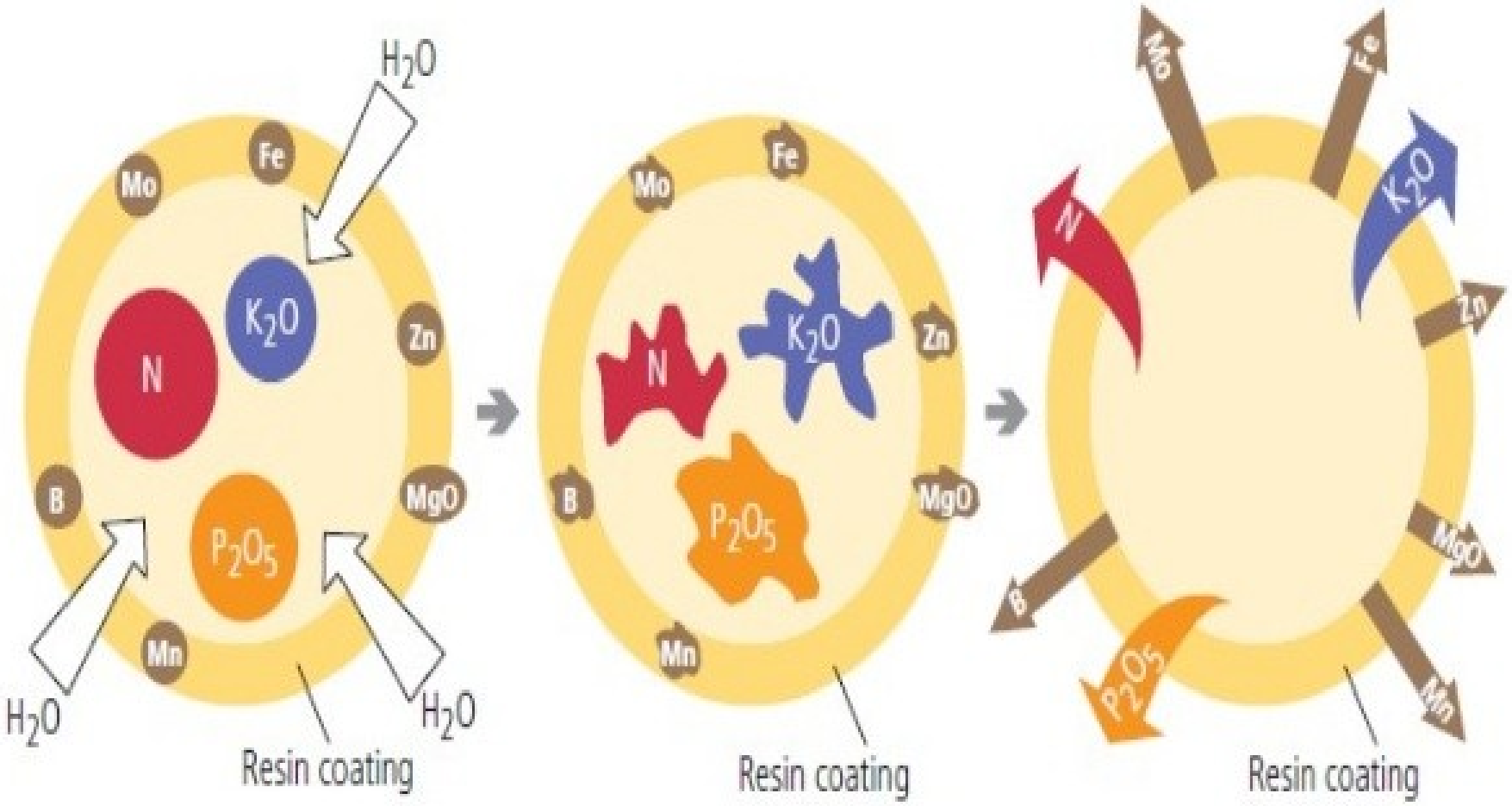
- Coatings on soluble fertilizers physical barrier.
- Polymer coatings - to control nutrient release and improve nutrient use efficiency - from a few weeks to several months depending on the coating and the conditions in the soil.
- Coated - lower losses from the root zone, and releasing the nutrients at a time of uptake required by the plant.
- Used in:
  - vegetable, orchards, ornamental systems;
  - possible for cereal grain system

- Polymer-coated fertilizers – more recent technology for controlling nutrient release and reducing losses by leaching
- Different types of coatings – plaster of paris, wax, polymer – polyacrylamide – reduces soil erosion
- Environmentally smart coating - flexible polymer coating, which controls the permeability to water absorption and dissolved nutrient release. Applied at different thicknesses to adjust the rate at which water can be absorbed and the nutrients dissolved.
- Polymer coated multi-nutrient fertilizers can supply all required fertilizer elements

Decomposition model of the coating polymer of CONTROLLED release fertilizer



Mode of action of coated/encapsulated fertilizer



SLOW RELEASE

- Release by diffusion/hydrolysis – depends on soil parameters:
  - water content,
  - pH,
  - ionic content,
  - temperature.
- Insoluble compounds can be effective fertilizers if release rate matches plant requirement in the growth period.
- The mechanism of nutrients release can be different.
- The compounds should have low solubility in water and high in organic acids (citrate) and DTPA.

- **Micronutrient SRF:**
  - **insoluble oxides**
  - **metaphosphates/glassy phosphates/glass beads**
  - **liquid polymers**
- **Glassy phosphate is produced by fusing oxides of micronutrients in phosphoric acid at 8000 ^{o}C.**
- **Dissolve by slow hydrolysis to release nutrients to soil.**
  - make the nutrients easier to apply uniformly and also help control the rate of release.
  - bind with soil cations and help maintain solubility under some conditions.

Conclusions

- **Fertilizers can be made more efficient by:**
  - **slowing the release of nutrients,**
  - **inhibiting conversion to forms that are less stable in the soil,**
  - **or enhancing availability of nutrients to plants.**
- **in terms of agronomic, economic and environmental factors.**
- **Enhancing fertilizer use efficiency**

- Adding these control systems usually adds to the costs, but may be justified if sufficient enhancement of nutrient efficiency and

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