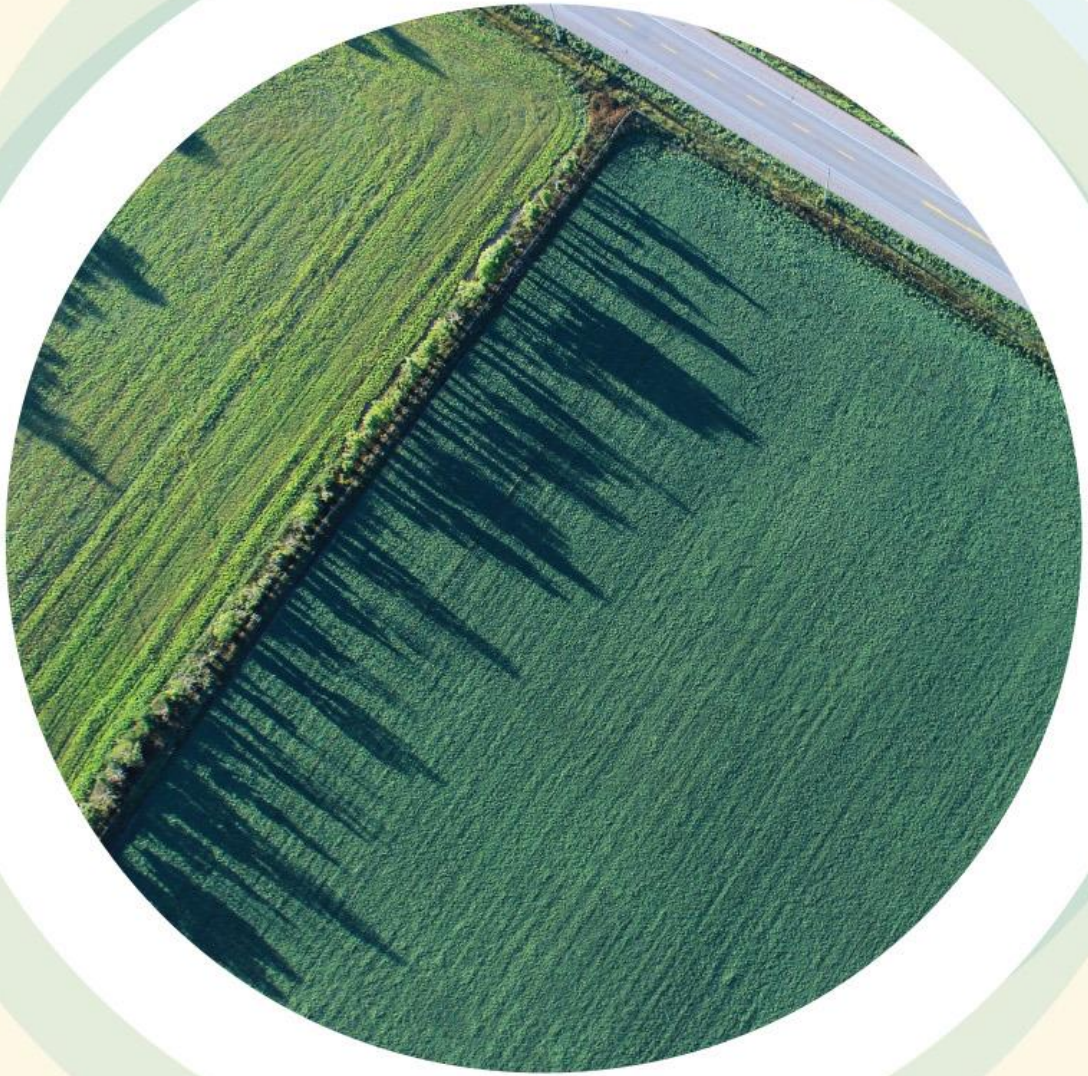
# How to select the best fertilizer types, forms, doses, application timing, and application methods?



**Vladimir Nosov**
Head of the Competence Centre at Apatit,
PhD in Biology
vvnosov@phosagro.ru

PHOSAGRO®

# ENVIRONMENTAL PARAMETERS

Biodiversity

Energy, labor, water, and fertilizer efficiency

Nutrient losses

Water and air quality

Soil erosion

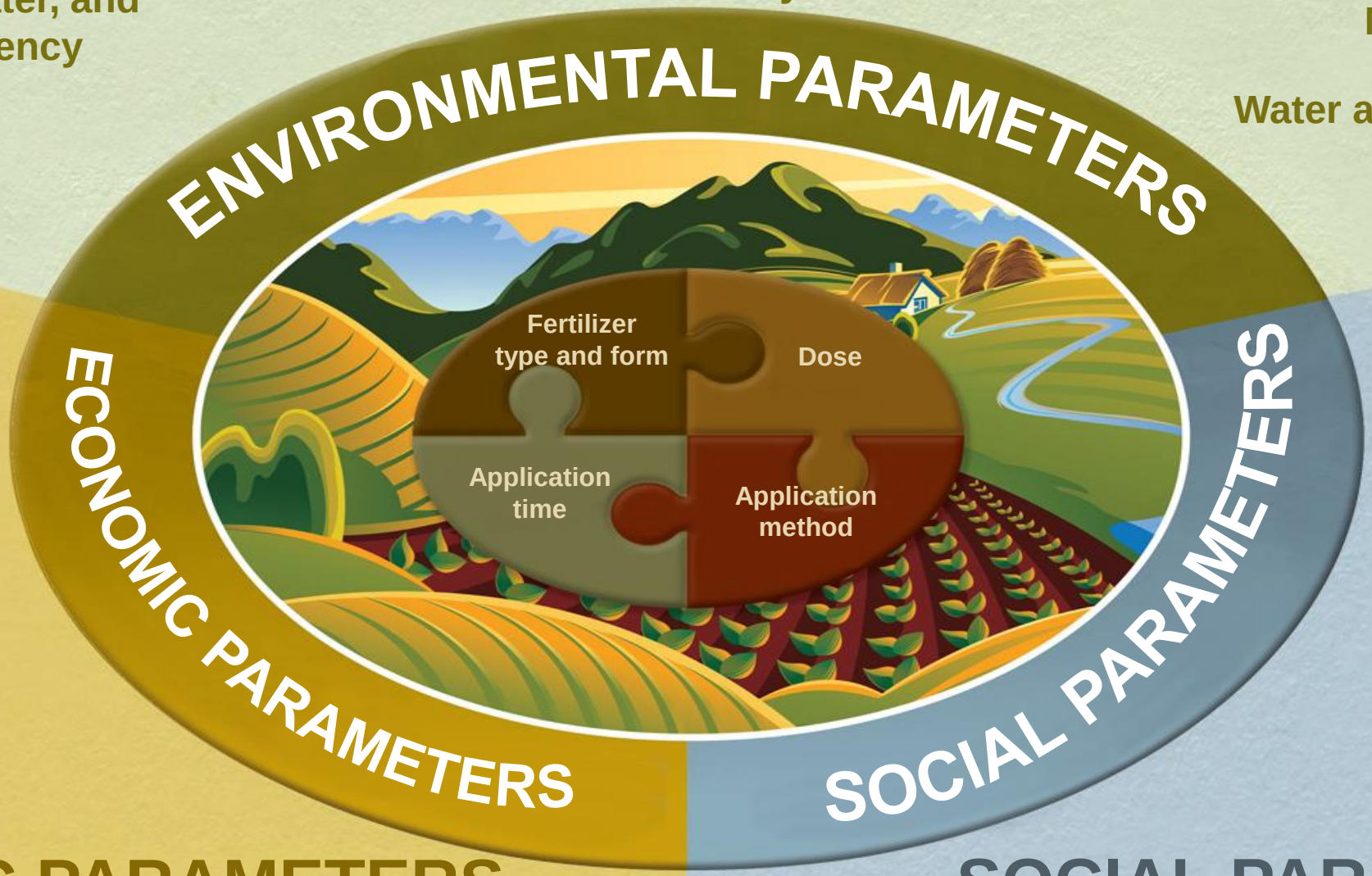
Food availability

Nutrient balance

Ecosystem services

Crop yield
Net income

Farm income




# ECONOMIC PARAMETERS

Return on investment

Yield quality and stability

# SOCIAL PARAMETERS

Working conditions

# Basic principles

| Fertilizer type and form | Dose | Application time | Application method |
|---|---|---|---|
| ◆ Ensuring a balanced supply of nutrients<br>◆ Matching the soil properties | ◆ Assessment of nutrient supply from all sources<br>◆ Assessment of nutritional requirements of crops | ◆ Assessment of changes in nutrient uptake and availability in the soil<br>◆ Assessment of the risk of soil nutrient losses and their timing | ◆ Assessment of root architecture<br>◆ Accounting for spatial variability in soil fertility |

PHOSAGRO®

# Examples of practical solutions

| Fertilizer type and form | Dose | Application time | Application method |
|---|---|---|---|
| ◆ Mineral fertilizers<br>◆ Manure<br>◆ Compost<br>◆ Crop residue | ◆ Agrochemical analysis of the soil<br>◆ Calculation of economic parameters<br>◆ Balance with crop nutrient removal | ◆ Presowing application<br>◆ Application at seeding<br>◆ Application at the flowering stage<br>◆ Application at the fruit ripening stage | ◆ Broadcasting<br>◆ Banding, drilling, liquid fertilizers<br>◆ Variable rate application |



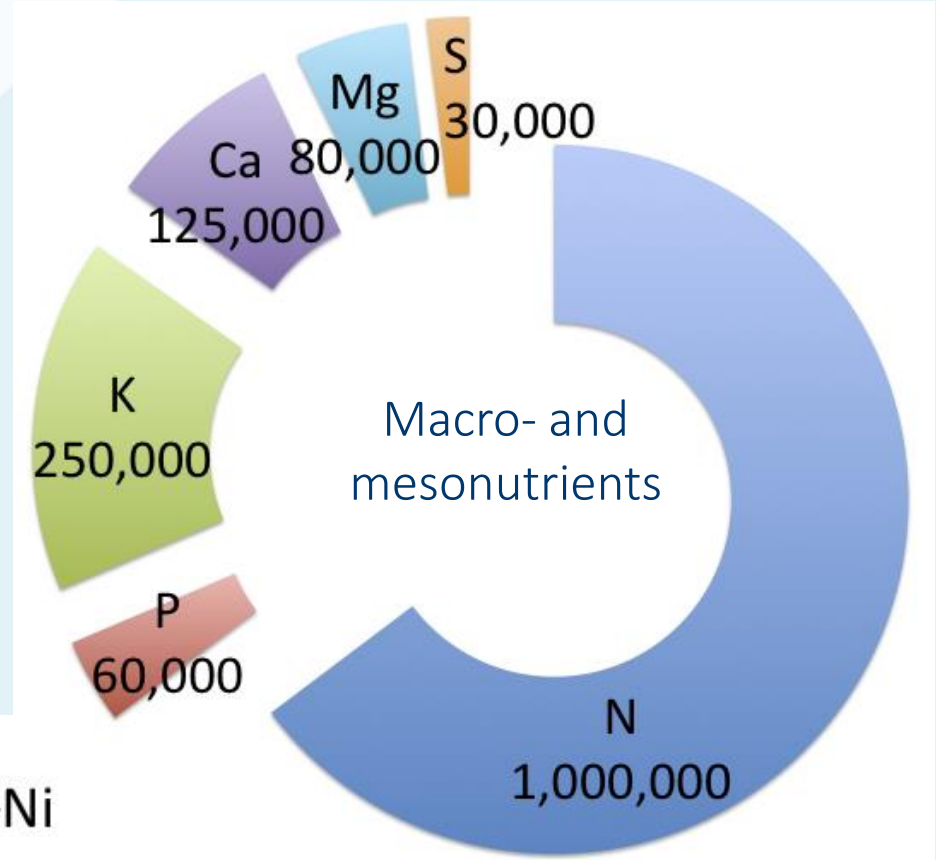

# Selecting the type and form of fertilizers

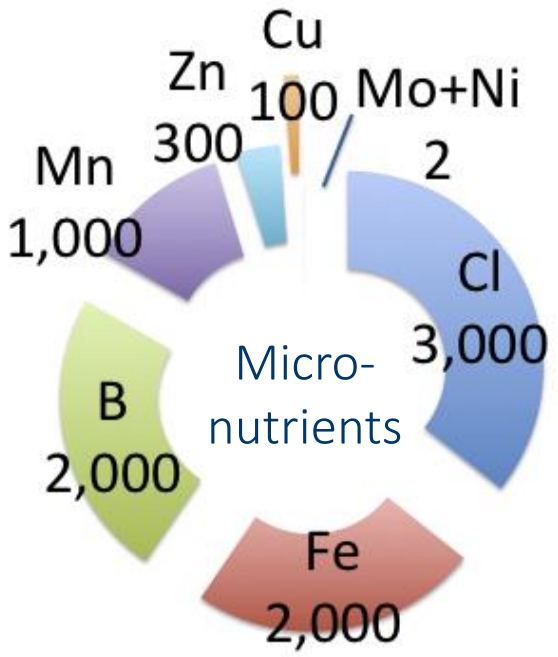
PHOSAGRO®

# Each nutrient performs its own functions in the plant

- 14 of the 17 nutrients essential for mineral nutrition of plants come from the soil

- Micronutrients are as important as macronutrients, but plants need them in much smaller amounts



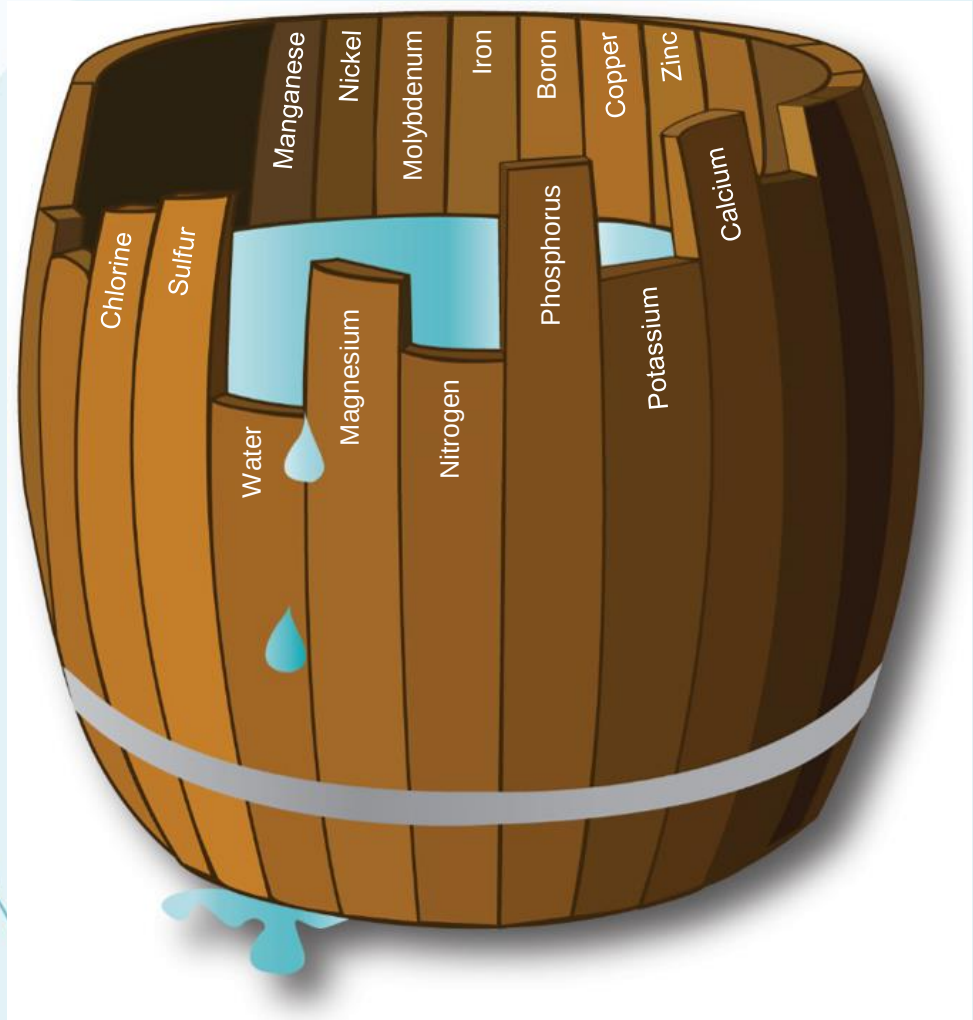

*Relative content in plants*

# Balanced plant nutrition

It is not enough to focus on one nutrient.

Nutrients must work together to provide high yields and high-quality products.

If plant growth and development are hampered by a deficiency of one nutrient, other nutrients cannot be used effectively.




*Liebig's law of the minimum: growth is dictated not by total resources available, but by the scarcest resource.*

PHOSAGRO®

# Nutrients must be in an available form so that plants can absorb them

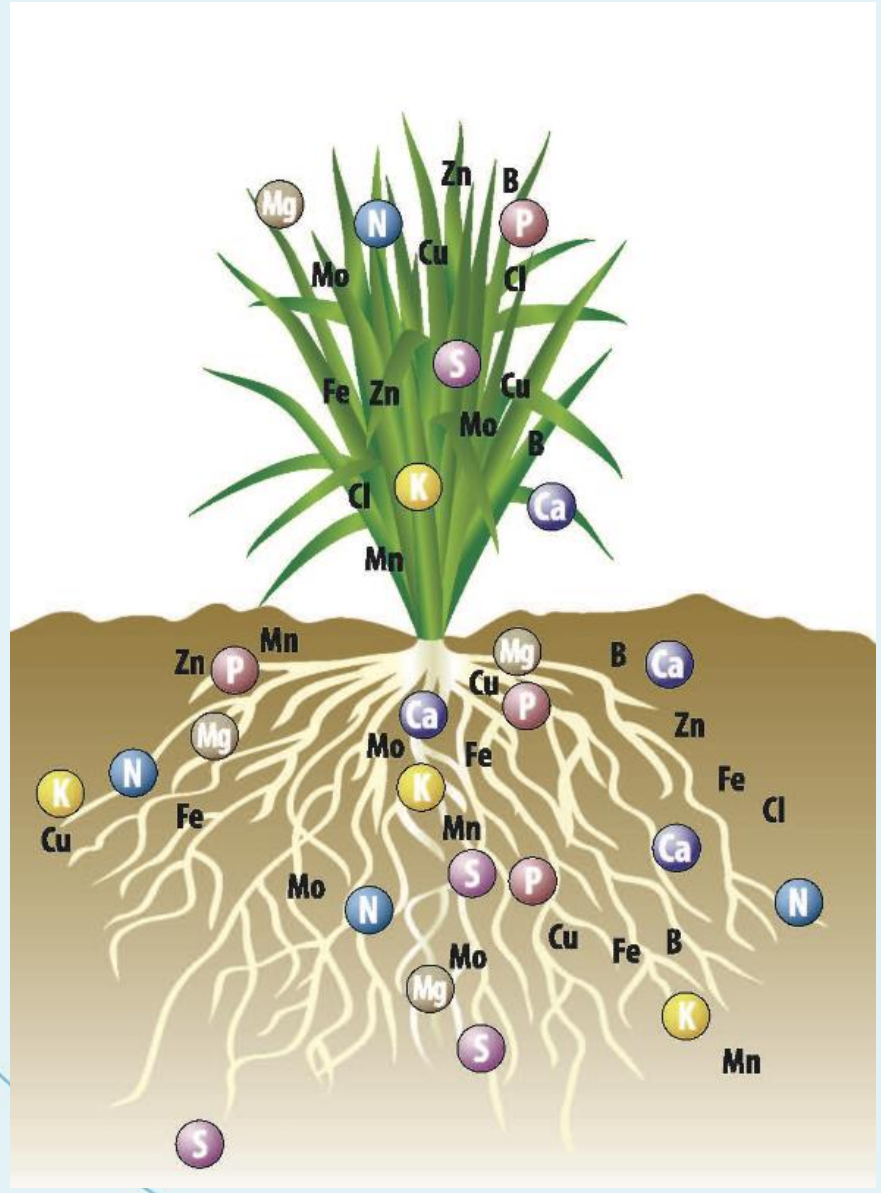
The root system of plants primarily absorbs inorganic compounds.

Only dissolved nutrients are absorbed by the roots.

Insoluble compounds cannot be directly used by plants.

The source of nutrients is not important for plant nutrition. For example, nitrates from mineral fertilizers, manure, and humus are equivalent.

There is no single “correct” form of fertilizer for all soils and crops. Each crop, soil, and agricultural producer requires an individual approach.




PHOSAGRO®

# Algorithm for selecting the type and form of fertilizers

First, the nutrients required to achieve the desired yield are determined.

Nutrients that limit yield are determined based on the results of agrochemical soil analysis and leaf analysis.

If laboratory tests are not performed, plots with NPK fertilizer and those without individual nutrient application can be compared.

It is necessary to ameliorate unfavorable soil properties that limit nutrient uptake by plants, such as acidity, compaction, or salinization.

# Visual diagnosis of phosphorus deficiency in wheat

A reddish-purple color spreads throughout the entire width of the leaf, starting at the top.

Impaired growth and a reddish-purple color of older leaves in a wheat plant with phosphorus deficiency.

PHOSAGRO®

M.K. Sharma, P. Kumar

# Nitrogen sources

Ammonia is the starting compound for all nitrogen fertilizers. It is synthesized through a reaction between hydrogen (derived from methane) and atmospheric nitrogen.

Ammonia is liquefied under pressure and applied directly to soil or used for the production of various solid and liquid fertilizers.

Nitrate, ammonium, and amide fertilizers are the most commonly used nitrogen fertilizers.

Different forms of nitrogen fertilizers behave differently in the soil, thus their application must be carefully considered.


PHOSAGRO®

# Phosphorus and potassium sources

Phosphorus and potassium fertilizers are made from mineral raw materials.

Mineral raw materials are processed to produce water-soluble forms of fertilizers.

Phosphates ($H_2PO_4^-$ or $HPO_4^{2-}$) are the main form in which plants absorb phosphorus.

Potassium is represented by the $K^+$ ion in all potassium fertilizers. The properties of potassium fertilizers depend on the accompanying nutrients.


PHOSAGRO®

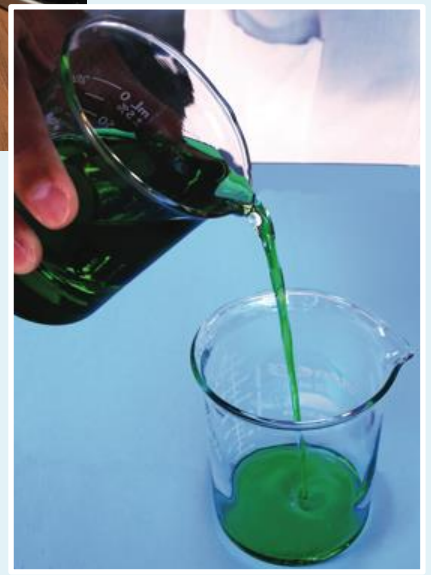
# Liquid fertilizers

Many nutrients are mixed as homogeneous, transparent liquids.

They are frequently used with irrigation water.

They are frequently used for foliar dressing; herbicides and pesticides may be added.

Not all liquid fertilizers can be mixed with each other. It is recommended to first check their compatibility in a small container.

PHOSAGRO®

# Selecting fertilizer application rates

# **Nutrient uptake per ton of yield, taking into account by-products** (averaged data for North America)

| Crop | kg of nutrients/ton of yield | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Maize | 18 | 9.6 | 25 |
| Rice | 16 | 8.4 | 24 |
| Soybean | 82 | 18 | 38 |
| Spring wheat | 37 | 13 | 26 |
| Winter wheat | 32 | 11 | 33 |

# Nutrient requirements depend on the planned yield

The planned yield must be realistic.

Achievable yield = 80% of potential yield in specific climatic conditions.

The planned yield should be higher than the long-term average yield, but lower than the maximum yield achieved in a specific field.

**It is recommended to plan yield at +10% of the average yield over the last 3–5 years, with climatic conditions close to normal for the region.**

# Soil nutrient supply and crop response to fertilizer application

| Soil nutrient supply | Probability of increased yield and fertilizer cost recovery |
|---|---|
| Very low | Pay off in most cases, with rare exceptions |
| Low | Pay off in most years |
| Moderate | Generally pay off |
| High | Pay off in some years |
| Very high | Fertilizer cost recovery in the year of application is unlikely |

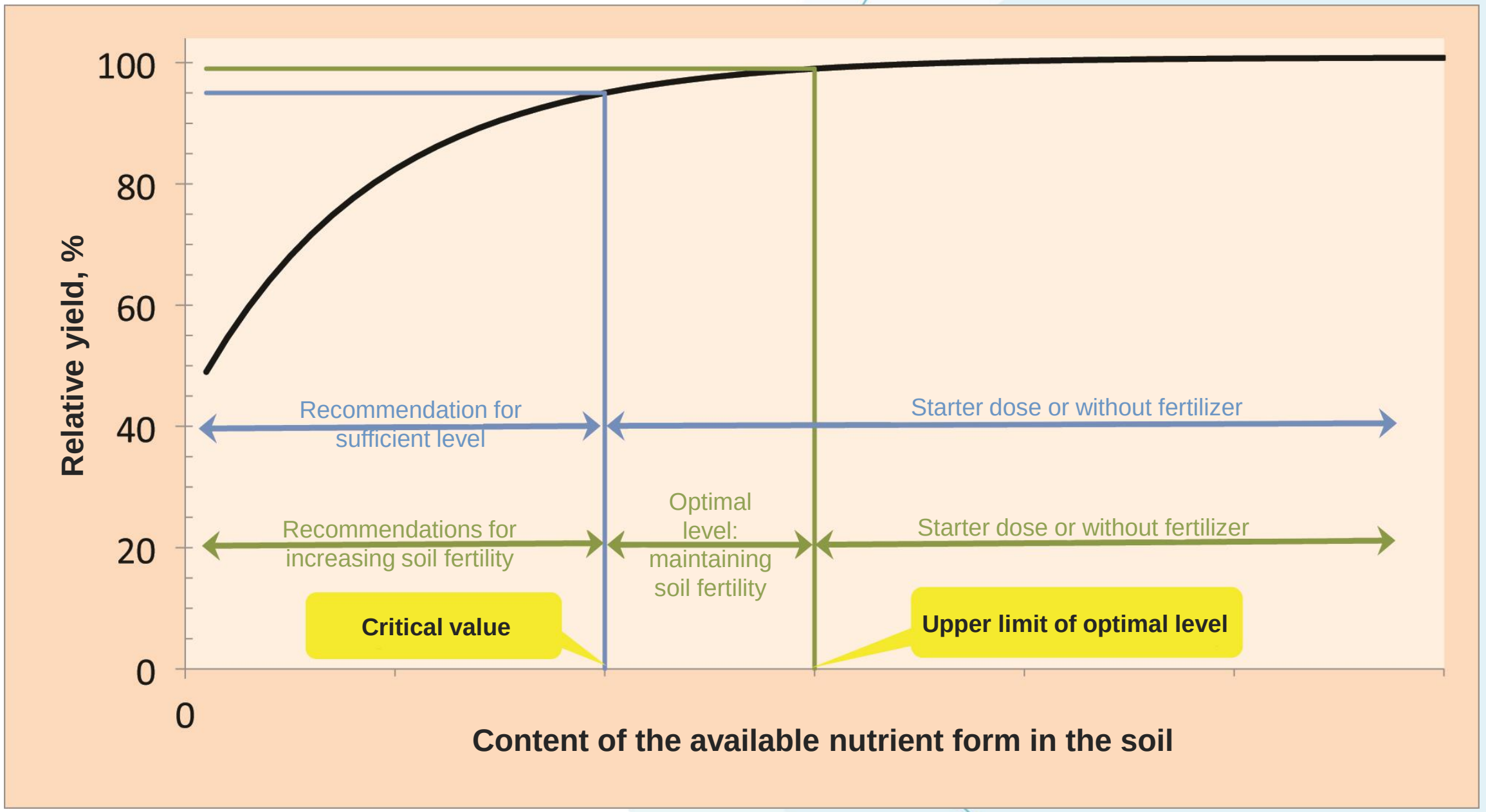
# Plant nutrition management strategies

## 1) Ensuring sufficient levels of nutrients in the soil

Obtaining maximum profit in the year of fertilizer application while minimizing fertilizer costs (short-term land lease).

## 2) Achieving and maintaining optimal soil fertility

Compensation for crop nutrient removal from the soil and increasing soil fertility to an optimal level, ensuring 90–95% of maximum yield (long-term land use).




Adapted from: Leikam et al., 2003

# EFAR, economical fertilizer application rate
# AFAR, agronomical fertilizer application rate

EFAR is preferred over AFAR for nutrients that are easily removed from the soil (N, S, etc.).

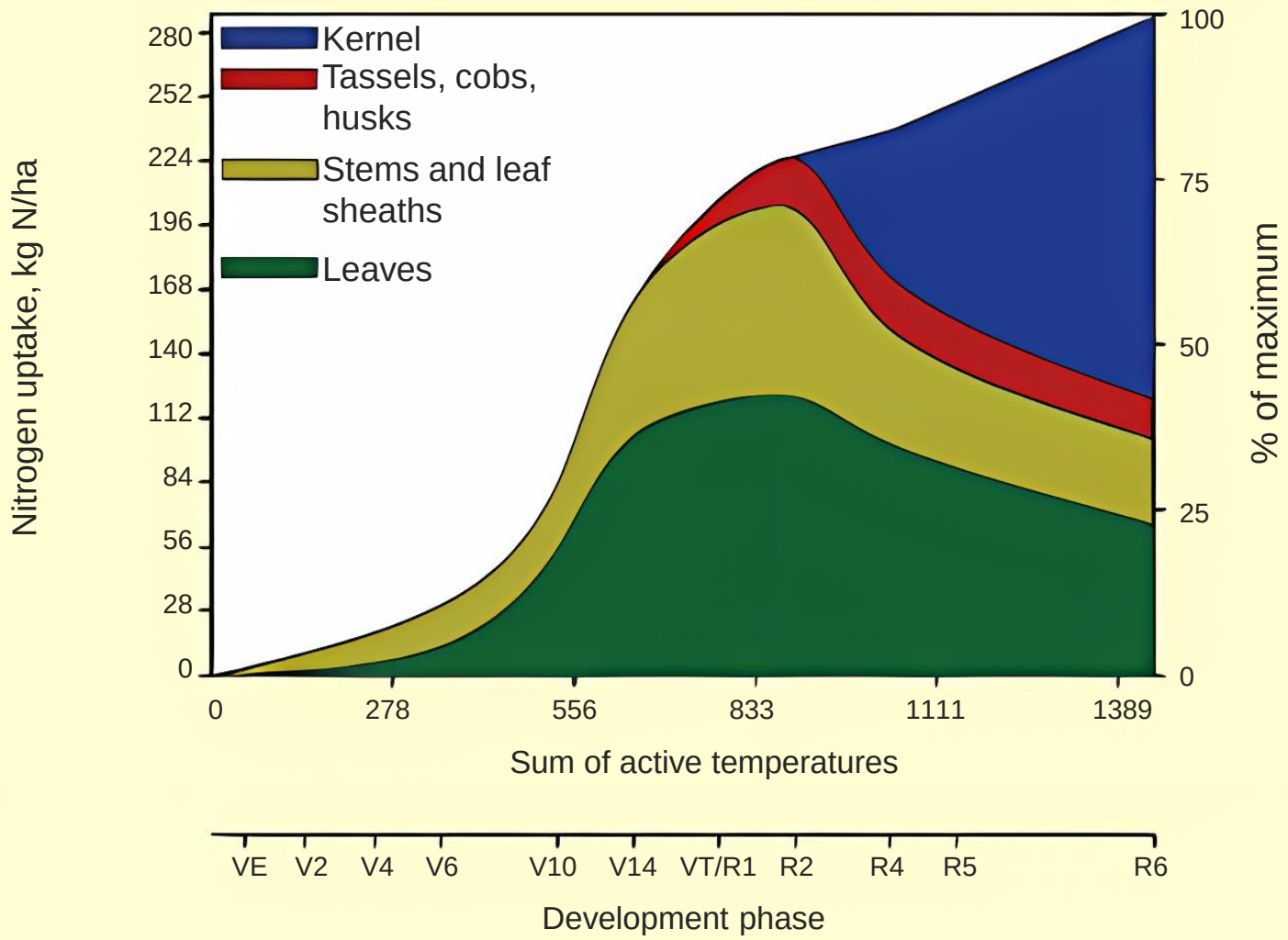
For nutrients that can be fixed by the soil, application rates above the EFAR range can improve fertility in the long term.

Maintaining soil fertility with the optimal nutrient supply allows for greater flexibility in fertilizer application timing and methods.

The correct fertilizer application rate ensures both optimal profitability and minimal environmental impact.

# Selecting fertilizer application timing

# Changes in nitrogen uptake by maize plants




Average for 6 hybrids from 2 field trials (Illinois, USA, 2010).

**Development phases:** VE, emergence;
Vn, the nth leaf has a visible leaf collar;
VT, tassel emergence;
R1, silk is visible outside the husk;
R2, watery ripeness;
R3, milky ripeness;
R4, waxy ripeness;
R5, kernels are dented;
R6, physiological ripeness (black dot visible at the base of kernels).

Sum of active temperatures (>10 °C):
(tmax + tmin)/2 - 10,
where tmax = maximum daily temperature (set as 30 °C if above this value);
tmin = minimum daily temperature (set as 10 °C if below this value).



Bender R.R., Haegele J.W. Ruffo M.L., and Below F.E.

# Fertilizer application taking into account wheat growth phases

The main amount of nitrogen should be applied before the stem elongation phase.

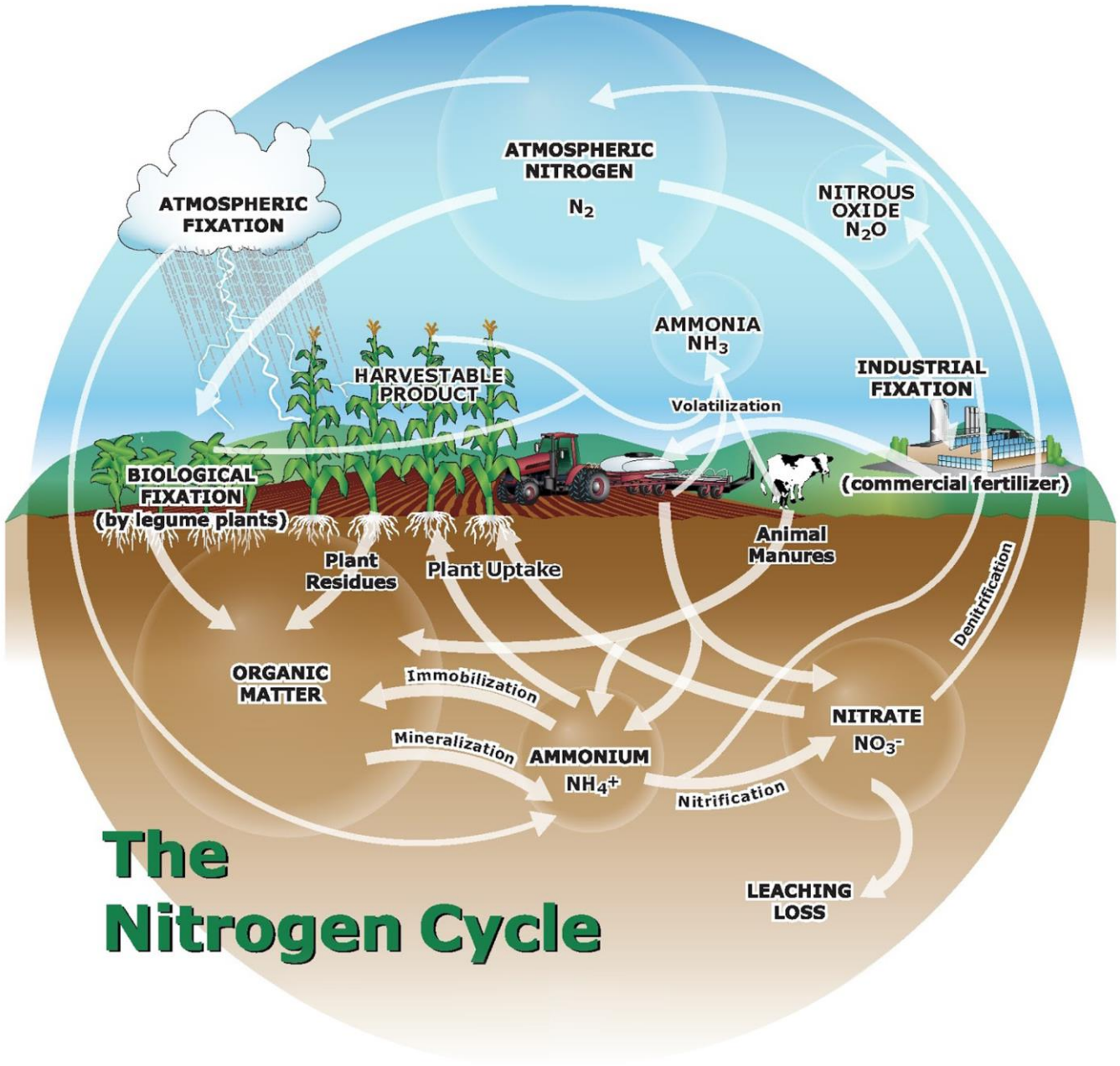
Late nitrogen dressing during the heading phase increases protein content in grain.

PHOSAGRO®

# The application time is selected taking into account the nutrient cycle

Plants absorb nitrogen either as nitrates ($NO_3^-$) or as ammonium ($NH_4^+$).

Other forms of nitrogen must be converted to nitrates or ammonium to make it available to plants.



# Logistics of field work

Fertilizer application timing is selected based on practical considerations.

As the farm expands, the logistics of sowing and fertilizer application timing change.

Fertilizer application in the autumn, where appropriate, saves valuable time in the spring.

Considering the behavior of phosphorus and potassium in the soil, they can be applied in advance (in the autumn).

PHOSAGRO®

# Nitrogen application in the autumn

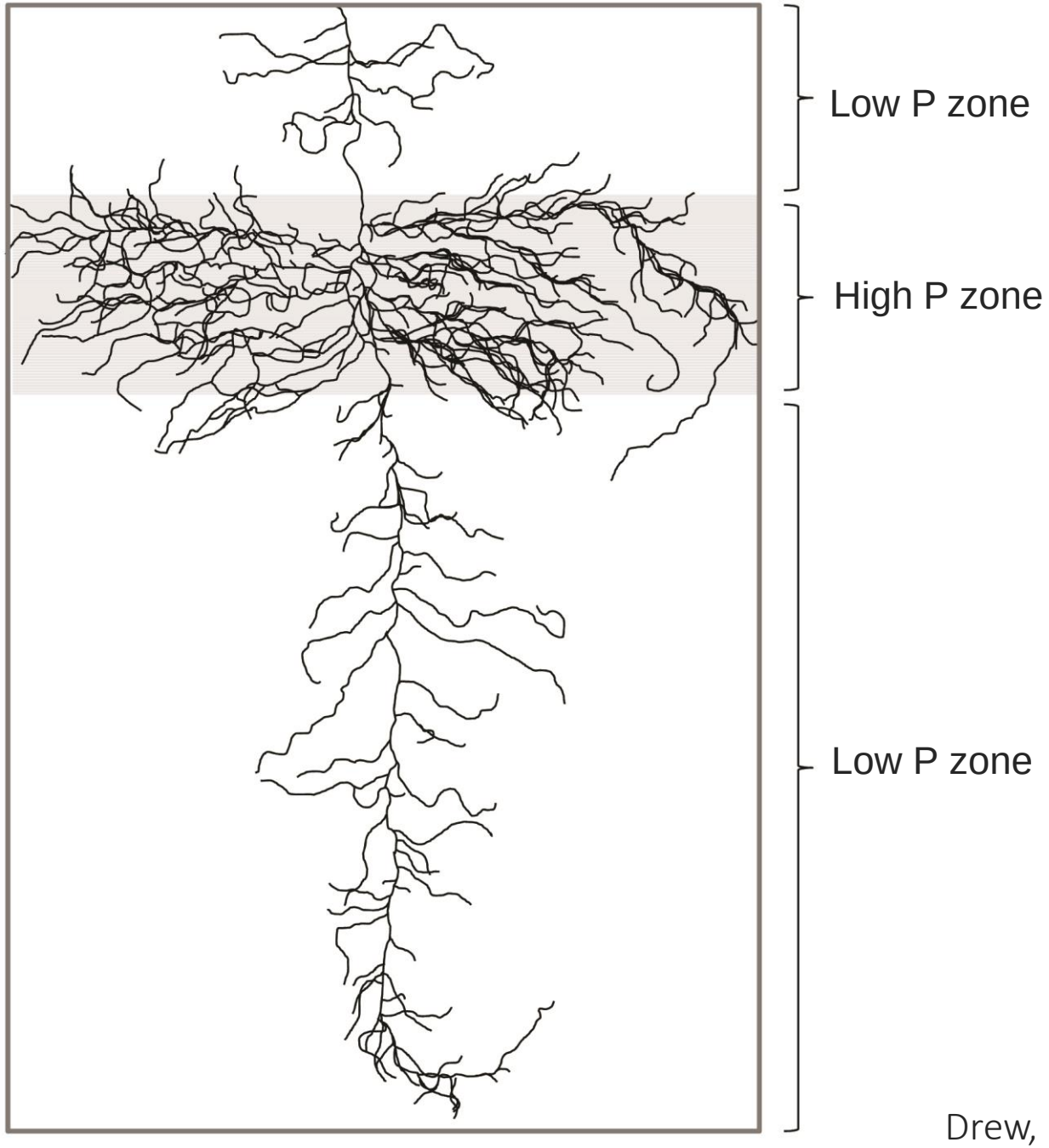
It is preferable to apply nitrogen fertilizers in the spring, but application in the autumn is also possible:

- Soil temperature should be below 10 °C;
- It is advisable to use stabilized nitrogen fertilizers (with nitrification inhibitors and urease inhibitors).

PHOSAGRO®

# Selecting fertilizer application methods

# Root system plasticity



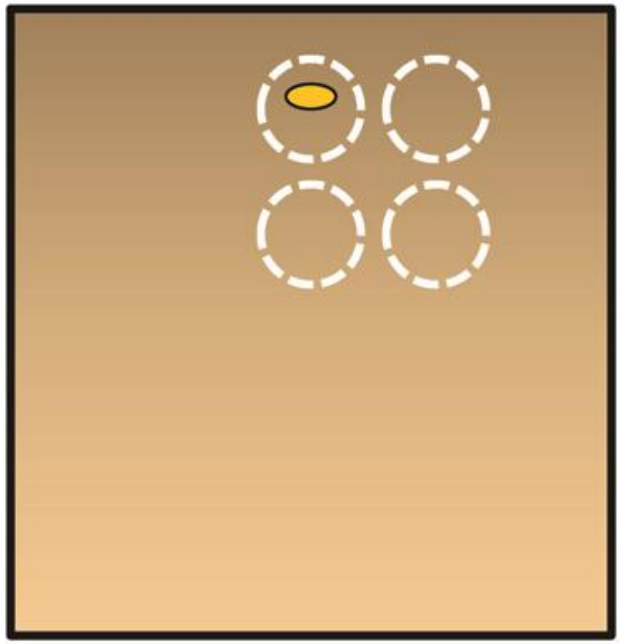

Drew, 1975

PHOSAGRO®

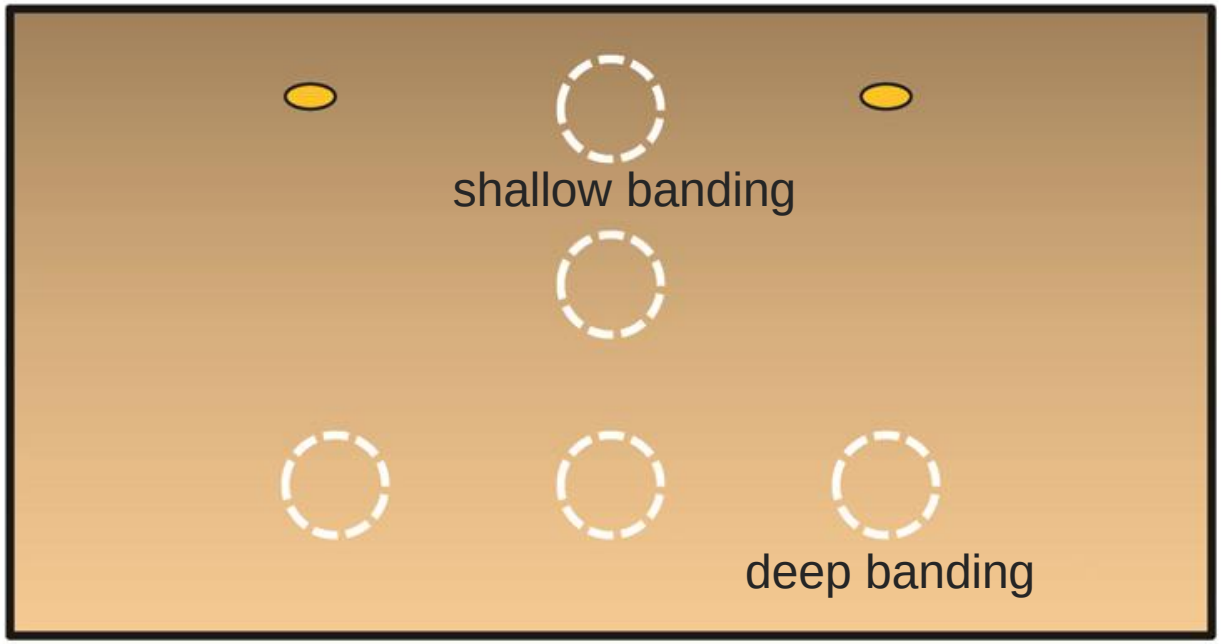
# Fertilizer application methods

- Broadcasting
- Banding
- Hole fertilization
- Combined fertilization

# Fertilizer placement methods



Deep-banded placement together with seeds or nearby




Band position at different distances between or deeper than seed rows

# Application at seeding

- Seedling sensitivity
- Fertilizer salt index
- Seed furrow width
- Soil texture
- Soil moisture
- Planting density

Risk of damage to seedlings

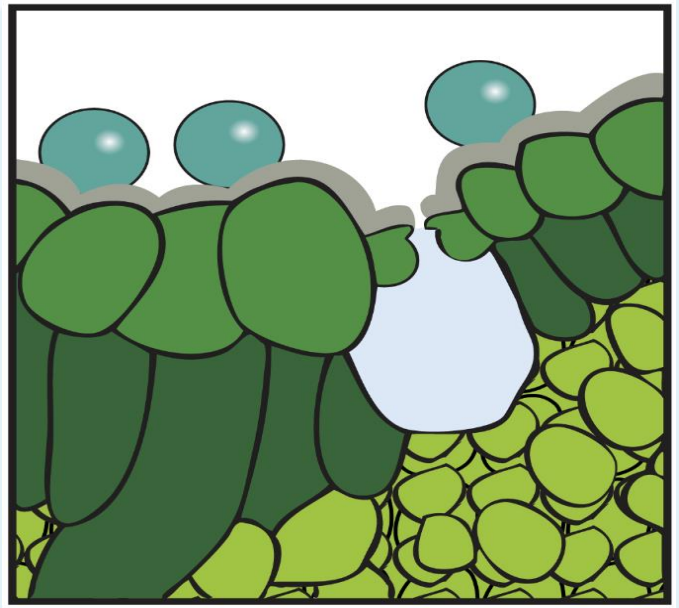
# Foliar dressing

Gaseous nutrients enter the leaves through the stomata.

Dissolved nutrients enter the leaves through small pores in the cuticle of the epidermis.

Foliar dressing provides localized mineral nutrition for a limited period of time.

It is especially effective when the content of available nutrient forms in the soil is limited.



# Moistening the leaf surface

**Reducing the liquid tension**

*Pay equal attention to each component: forms, doses, timing, and methods of fertilizer application*

*Keep in mind that all components are interconnected*

PHOSAGRO®


Thank you!