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Higher Education Modernization to boost Uzbekistan Agricultural system and promote excellence and regional development

ERASMUS+ GA number 101179517

ORCHARD FERTILIZATION

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AIMS OF FERTILIZATION:

- ✓ Constant and regular yield
- ✓ Enhancement of fruit quality (colour, taste, storability, susceptibility to pathogen and insects)
- ✓ Environment

SYNCHRONIZE NUTRIENT SOIL AVAILABILITY WITH PLANT NEEDS

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What we need to know….

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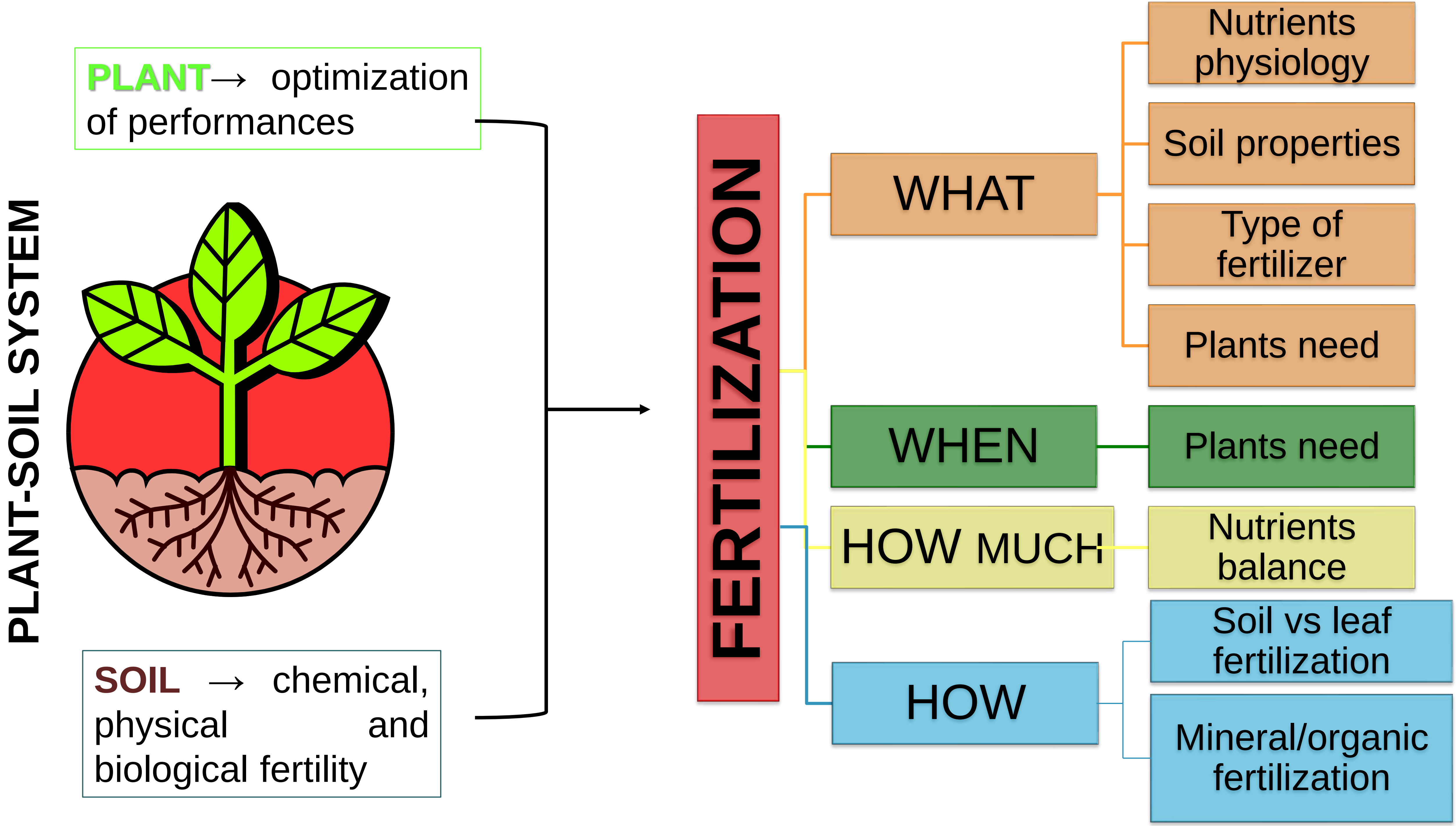
- soil and environmental conditions

Chemical and physical soil analysis

Rain, temperature, vulnerability to nitrate

- nutrient requirements by plants (quantity and kinetics)

Leaf analysis


PLANT → optimization of performances
PLANT-SOIL SYSTEM
SOIL → chemical, physical and biological fertility
FERTILIZATION
WHAT
Nutrients physiology
Soil properties
Type of fertilizer
Plants need
WHEN
Plants need
HOW MUCH
Nutrients balance
HOW
Soil vs leaf fertilization
Mineral/organic fertilization

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NUTRIENT PHYSIOLOGY

- ✓ Macro and micronutrients

N, P, K, S, Ca e Mg

Fe, Cu, Zn, Mn, B, Cl, Mo, Ni

FUNCTION OF NUTRIENTS

- **PLASTIC:** components of structural molecules
  - C, H, O → carbohydrate, lipid and proteins (95% of plants organic matter)
  - N, P, S → proteins and nucleic acids
  - Mg, Fe → chlorophyll
  - Ca → cell wall

- **ELECTROCHEMICAL E OSMOTIC:** keep cell sap chemical-physical (osmotic) equilibrium (K, N-NO_3^-, Ca, Na, Cl)

- **CATALYTIC:** regulate enzymatic activity (microelements, K, Ca, Mg)

NUTRIENT PHYSIOLOGY

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✓ Macro and micronutrients

N, P, K, S, Ca e Mg

Fe, Cu, Zn, Mn, B, Cl, Mo, Ni

✓ Mobility within plants

SOURCE	MOBILE	INTERMEDIATE	IMMOBILE
Marschner, 1995	K, N, Mg, P, S	Fe, Zn, Cu, B	Ca, Mn
Epstein and Bloom, 2004	K, N, Mg, P, B, S	Fe, Mn, Zn, Cu	Ca

NITROGEN INTERNAL CYCLE

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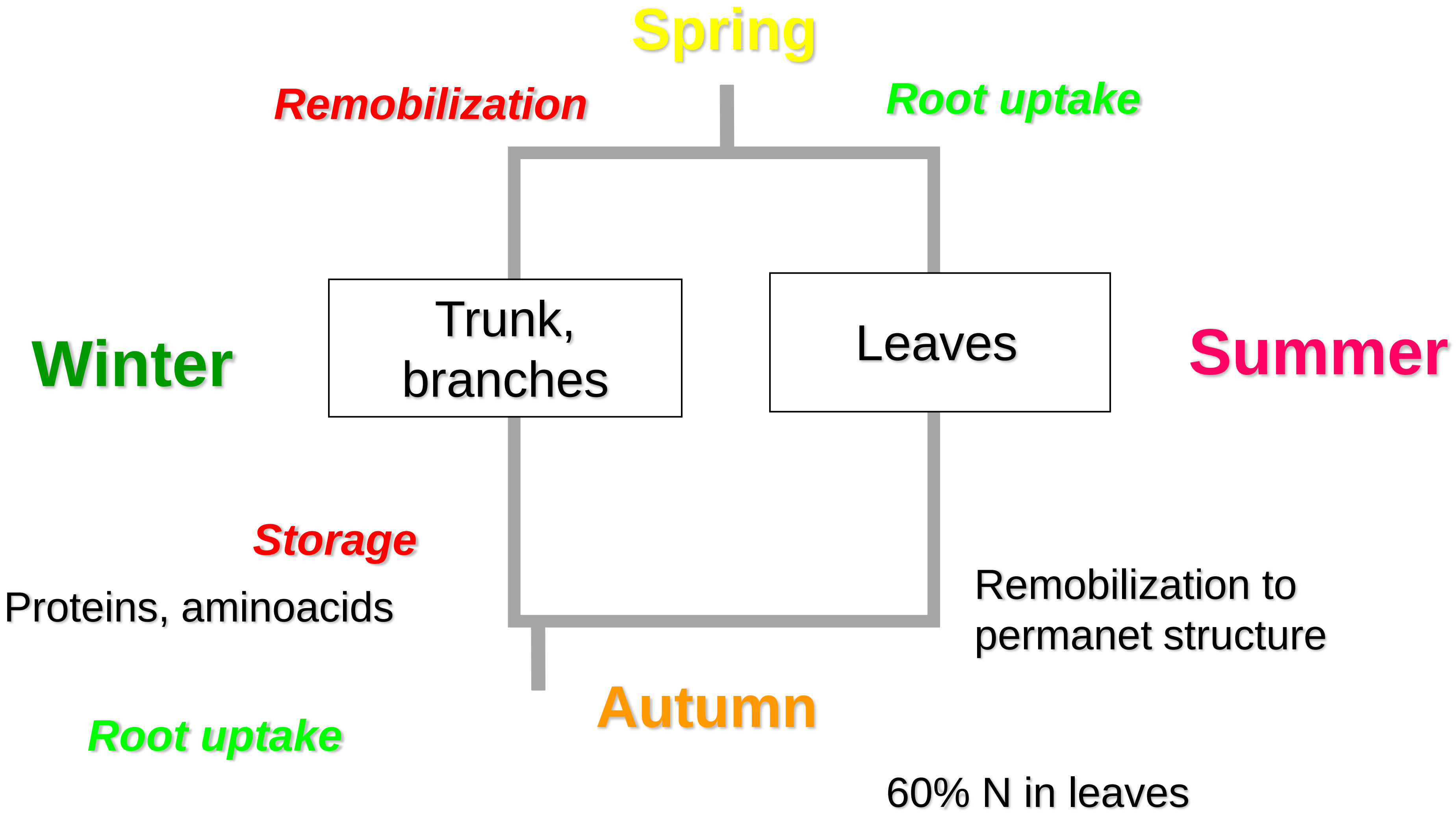

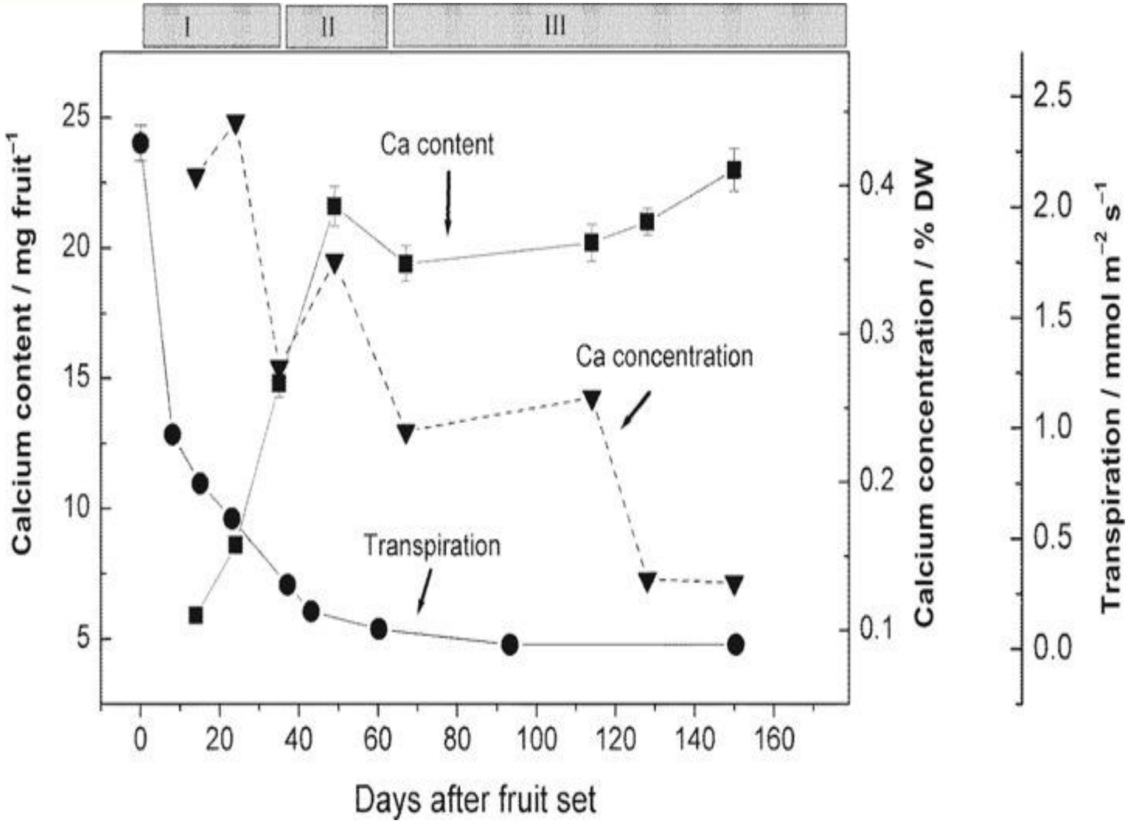

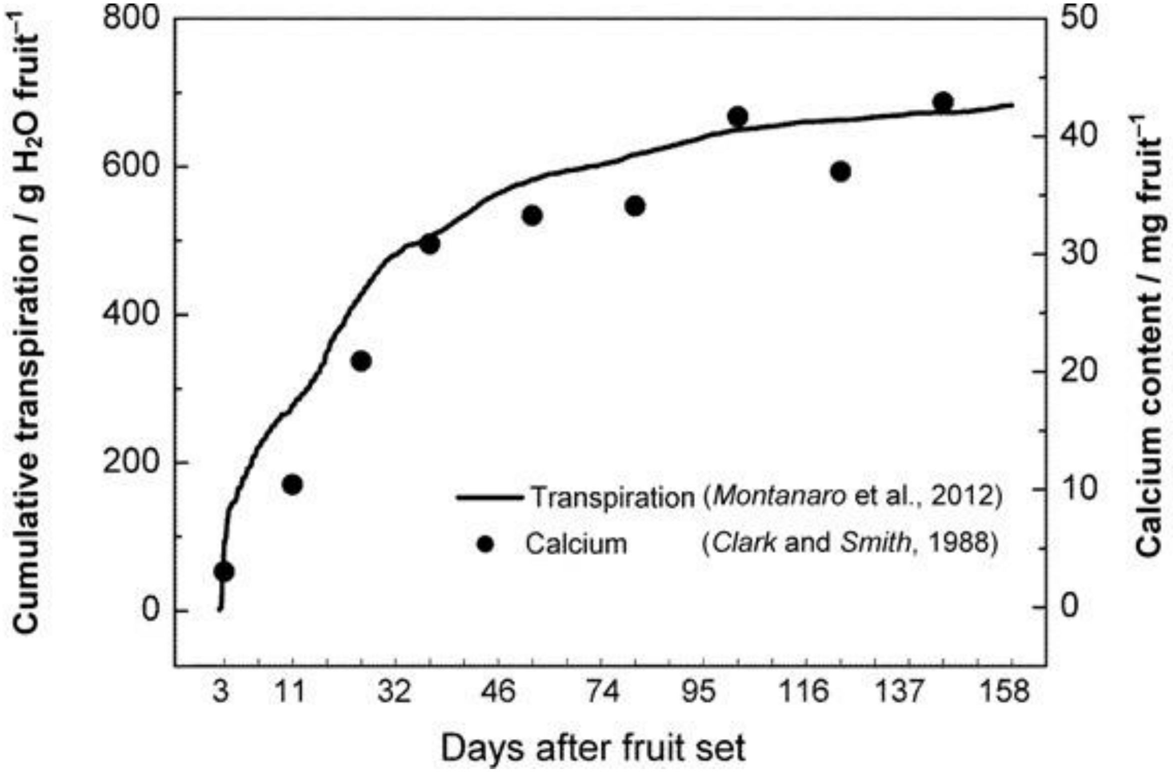

CALCIUM MOVES UPWARD IN THE PLANT EXCLUSIVELY IN THE XYLEM SAP, DRIVEN BY TRANSPIRATION

Montanaro et al., 2014. J. Plant Nutrition and Soil Science, 177 (6): 819-830

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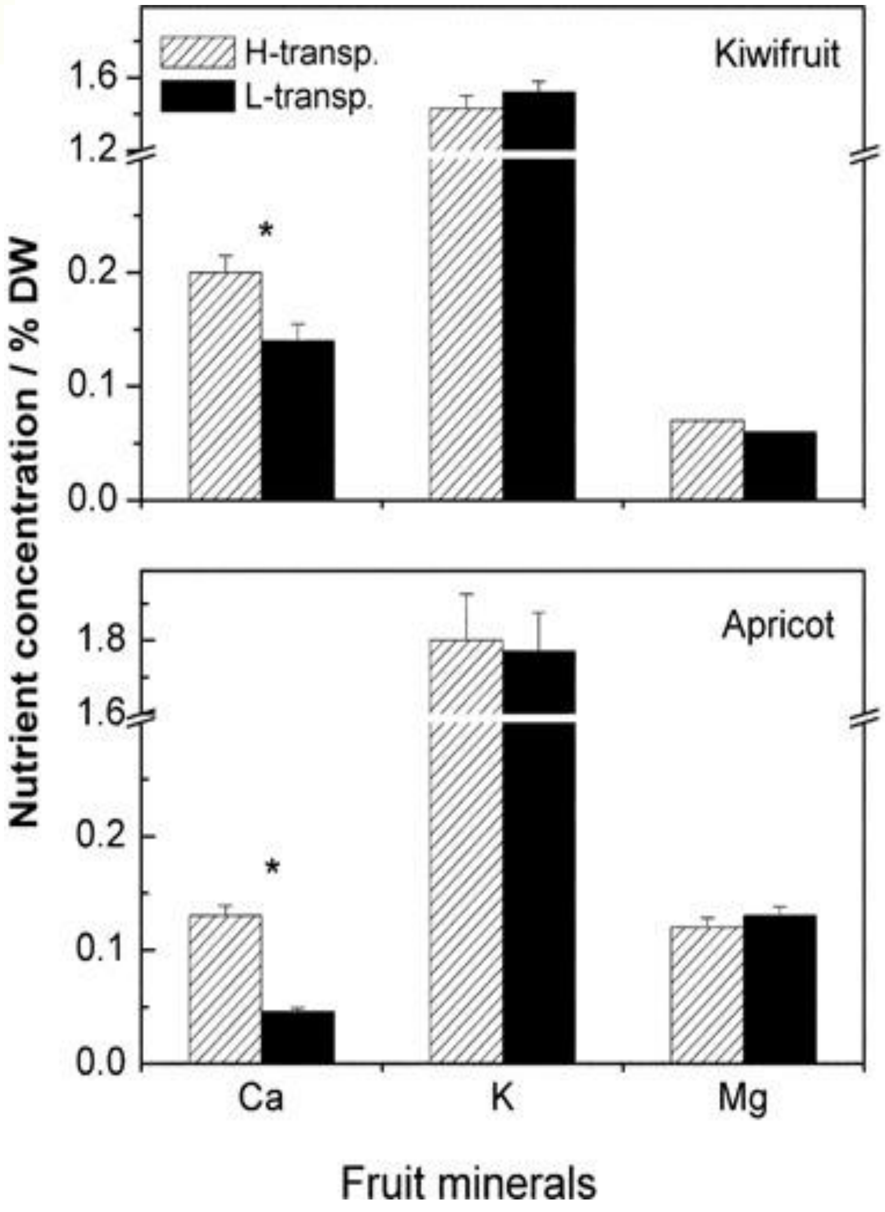

Calcium, potassium and magnesium concentrations measured at harvest in low (L) and high (H)-transpiring berries of kiwifruit and apricot fruit.

Montanaro et al., 2014. J. Plant Nutrition and Soil Science, 177 (6): 819-830

MOBILE NUTRIENTS

- delay application until flowering or fruit set, depending on the magnitude of the element stored in the perennial organs;
- supply throughout the season according to plant needs and soil availability;
- apply small quantities in autumn stimulates storage.

IMMOBILE NUTRIENTS

- supply during the vegetative season starting from fruit set according to plant needs and soil availability;
- leaf application in case of lack.

NUTRIENT PHYSIOLOGY

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✓ Macro and micronutrients

N, P, K, S, Ca e Mg

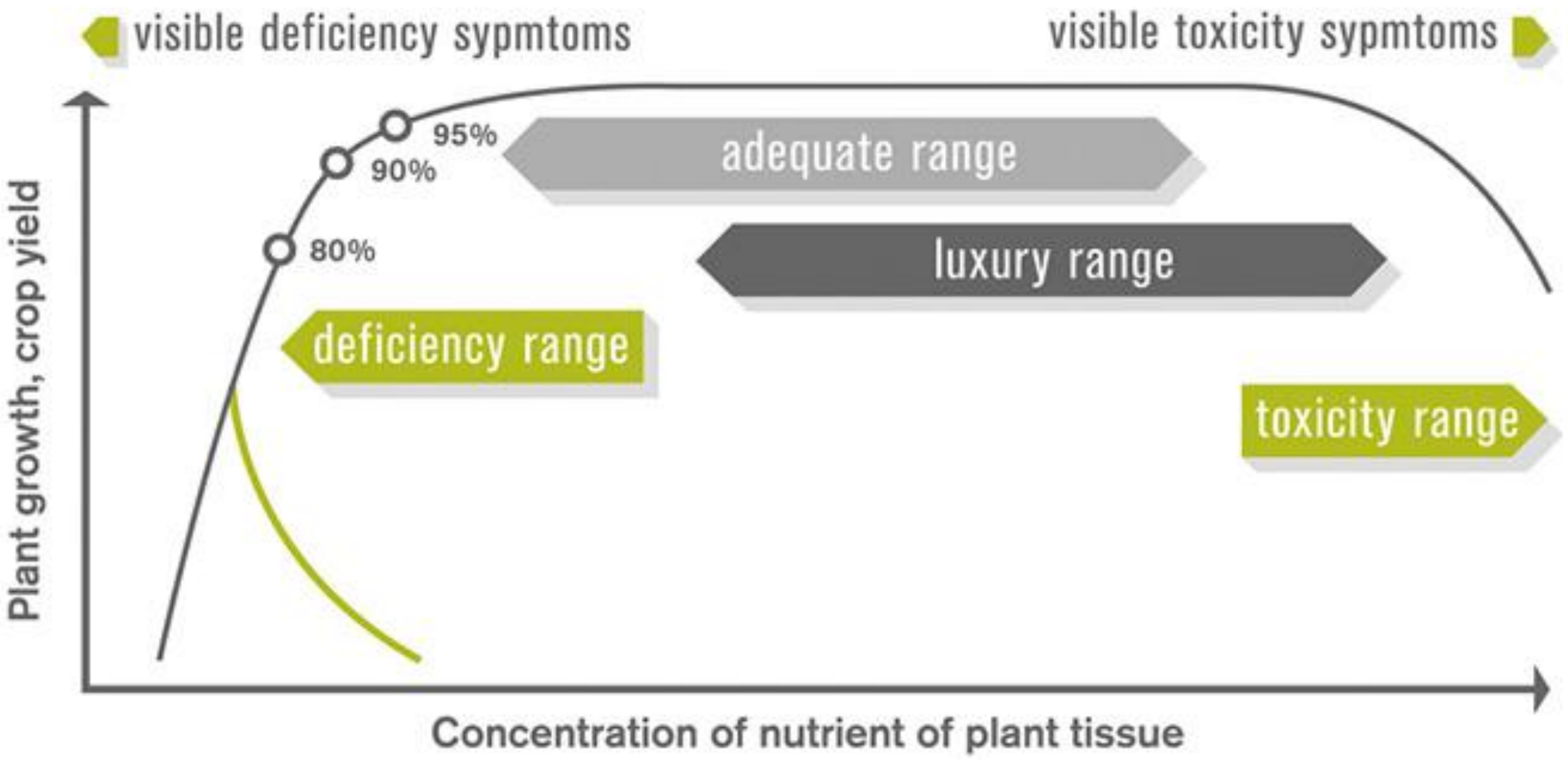
Fe, Cu, Zn, Mn, B, Cl, Mo, Ni

✓ Mobility within plants

SOURCE	MOBILE	INTERMEDIATE	IMMOBILE
Marschner, 1995	K, N, Mg, P, S	Fe, Zn, Cu, B	Ca, Mn
Epstein and Bloom, 2004	K, N, Mg, P, B, S	Fe, Mn, Zn, Cu	Ca

✓ Soil availability and plant uptake

PLANT RESPONSE TO NUTRIENT AVAILABILITY



Source: adapted from Marschner, 1995

Leaf analysis should be done on mature leaves:

- ✓ can give valuable information on plant nutritional status
- ✓ useful to optimize fertilization plan in the year of analysis
- ✓ comparison with leaf index (species, variety, sampling time, area)

Periodically, during vegetative season, nitrate and other nutrient availability could be monitored

NUTRIENT CONCENTRATION IN LEAVES

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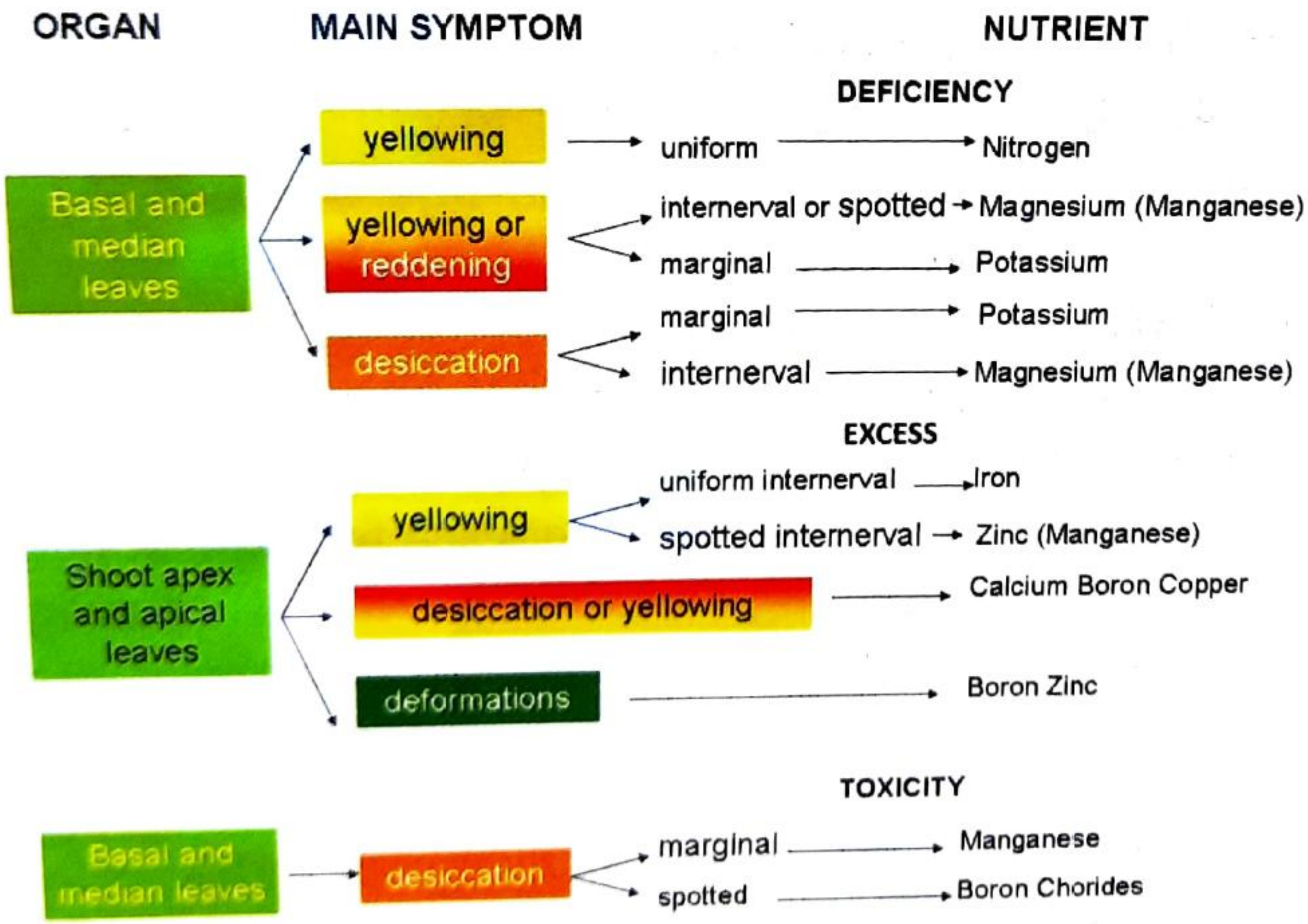
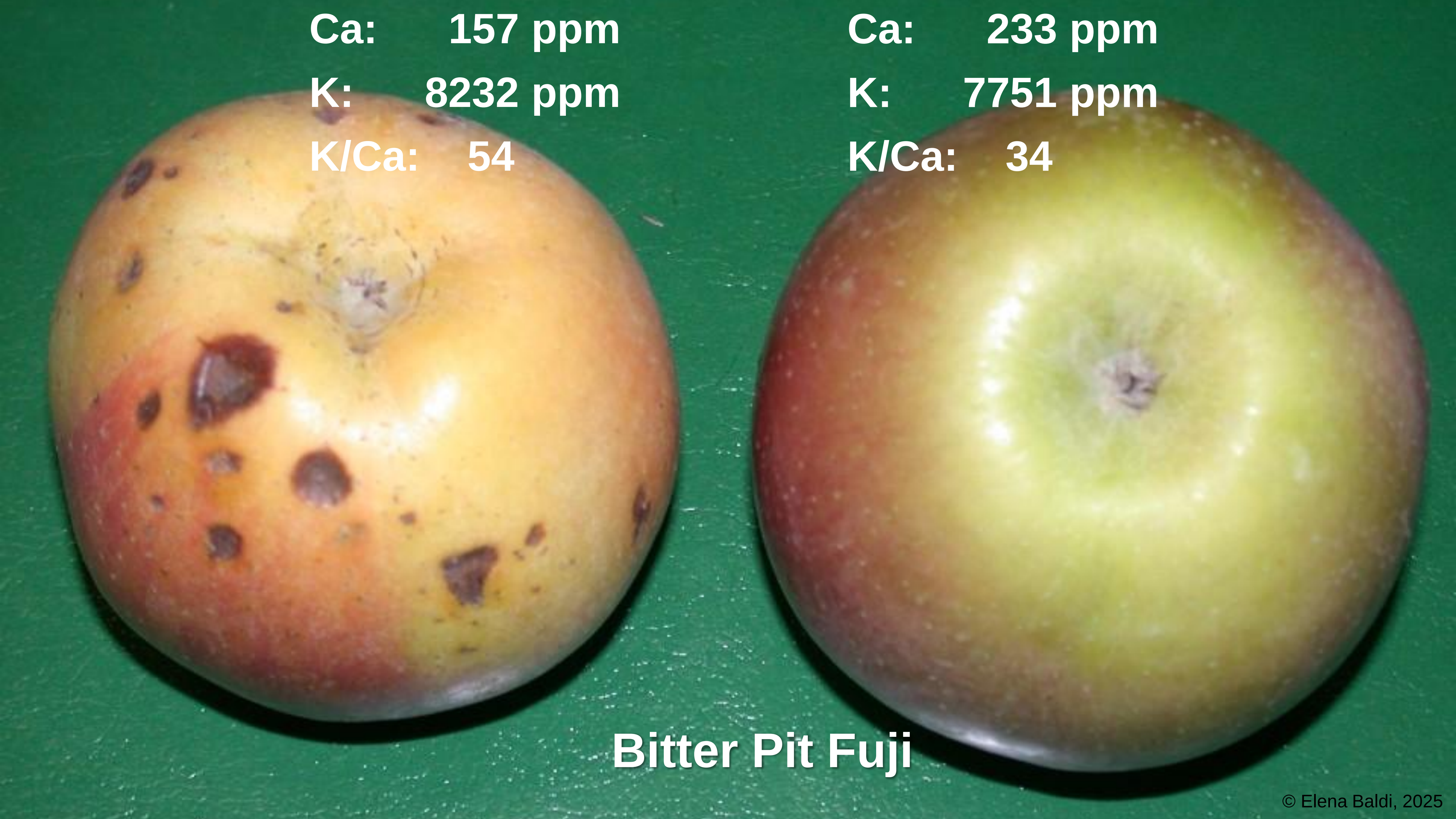
NUTRIENT	Apple	Pear	Peach	Cherry	Kiwifruit
N (%)	2.10-2.80	2.10-2.80	2.60-3.60	1.90-2.50	1.90-3.00
P (%)	0.16-0.28	0.16-0.28	0.18-0.30	0.18-0.37	0.16-0.35
K (%)	1.20-1.80	1.20-1.80	2.00-3.50	1.00-2.00	1.10-2.70
Ca (%)	1.20-2.00	1.20-2.20	1.80-3.30	1.80-3.20	2.30-4.30
Mg (%)	0.20-0.40	0.20-0.40	0.40-0.65	0.42-0.70	0.27-0.62
Fe (ppm)	40-100	40-120	50-120	40-110	40-150
Mn (ppm)	20-100	15-100	10-60	15-75	15-100
B (ppm)	20-45	15-30	22-45	32-63	18-68
Zn (ppm)	15-150	10-100	10-50	15-60	15-50
Cu (ppm	> 5	> 5	> 5	> 5	> 5

Source: Grignani, 2016



Sansavini et al. 2019. Principles of modern fruit Sciences


Ca: 157 ppm
K: 8232 ppm
K/Ca: 54
Ca: 233 ppm
K: 7751 ppm
K/Ca: 34
Bitter Pit Fuji

Iron excess

Manganese deficiency

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SOIL

- ✓ Fertility → ability of a soil to provide water and nutrients for plants avoiding toxic elements (chemical, physical and biological soil properties)
- ✓ Type of soil
- ✓ pH

NUTRIENTS IN THE SOIL

- Mineral nutrients are acquired primarily in the form of organic ions from the soil

- Soil is a complex physical, chemical and biological substrate.

- Soil phases (liquid, solid and gaseous) interact with mineral elements.

SOIL SOLUTION

dissolved mineral ions

INORGANIC PHASE

K, Ca, Mg and Fe

ORGANIC PHASE

N, P, S

O_2, CO_2, N_2

CATION EXCHANGE CAPACITY (CEC)

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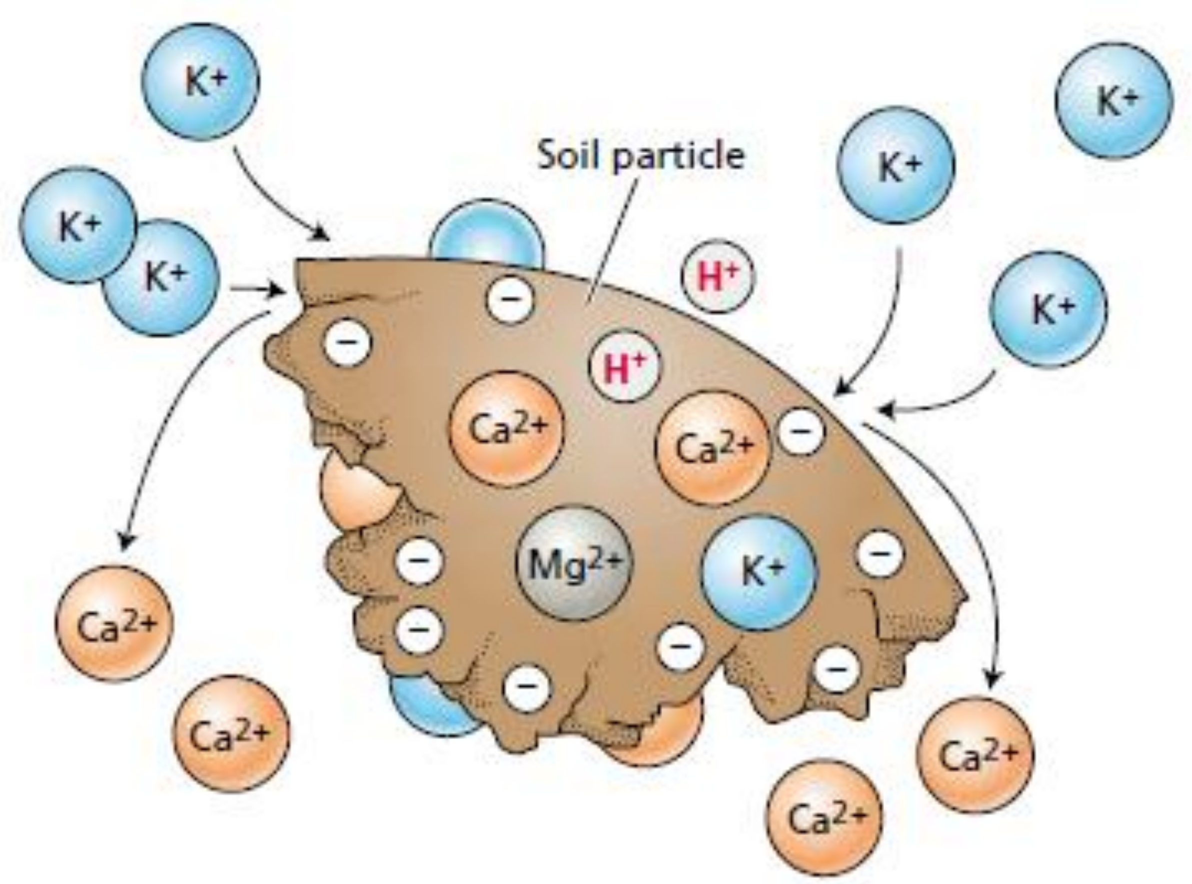
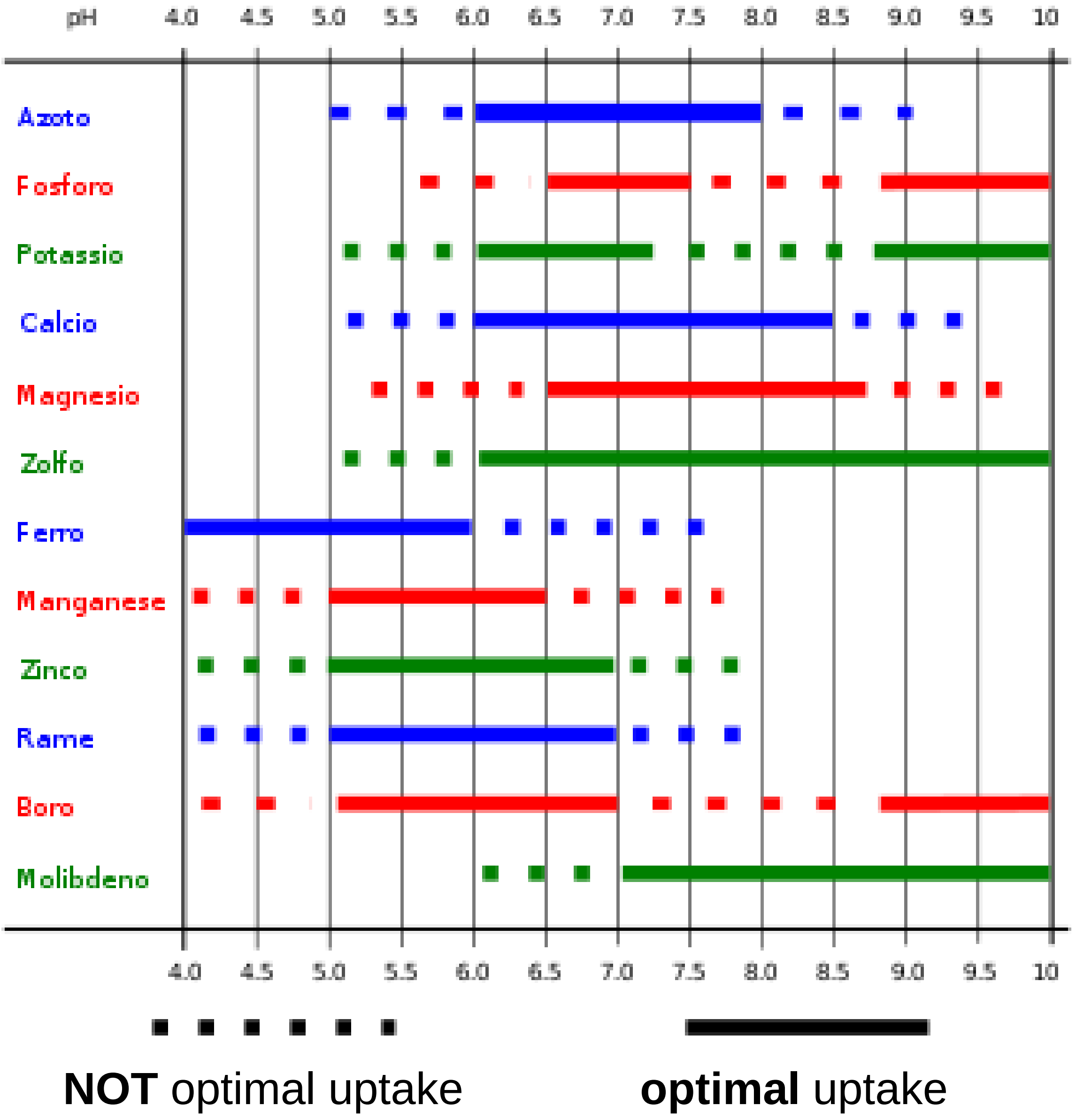
Degree to which soil can absorb and exchange ions.





- ✓ **Low pH** high mobility of metals (Fe, Cu, Mn e Zn).
- ✓ **High pH** induced mobility of Ca and NH_4^+, but can lead to chlorosis (Fe, Mn) and other deficiency

https://it.wikipedia.org/wiki/Reazione_del_terreno

N, P and K behaviour in sandy and clay soil

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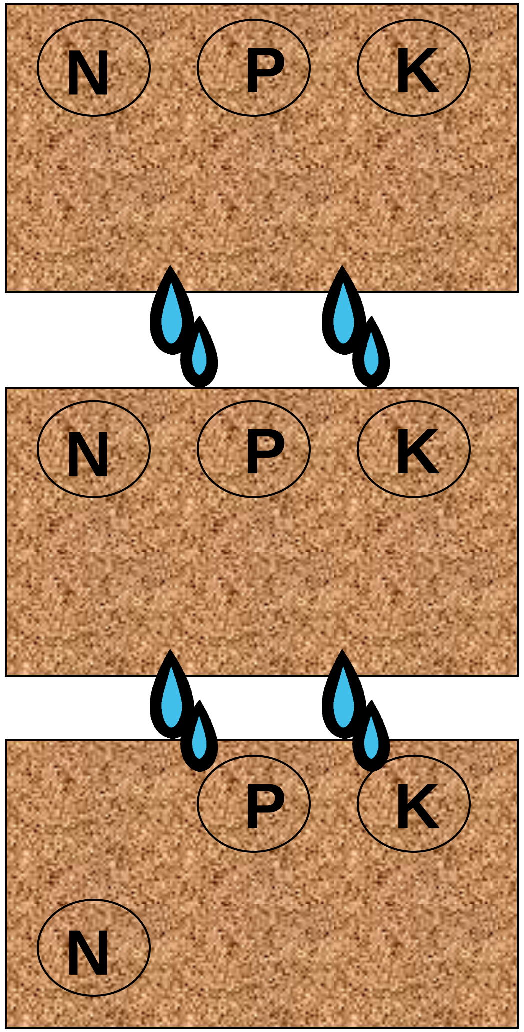

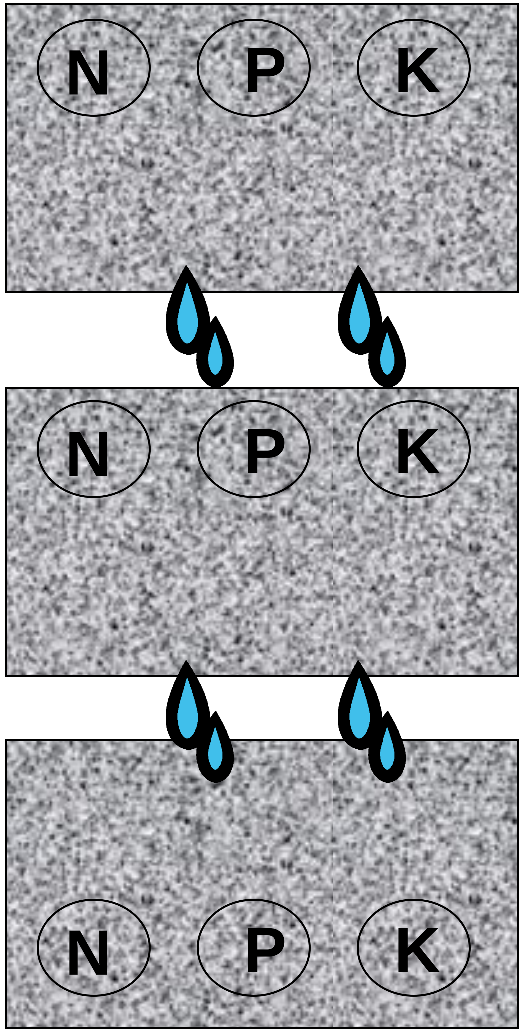

Water percolation and nitrate leaching

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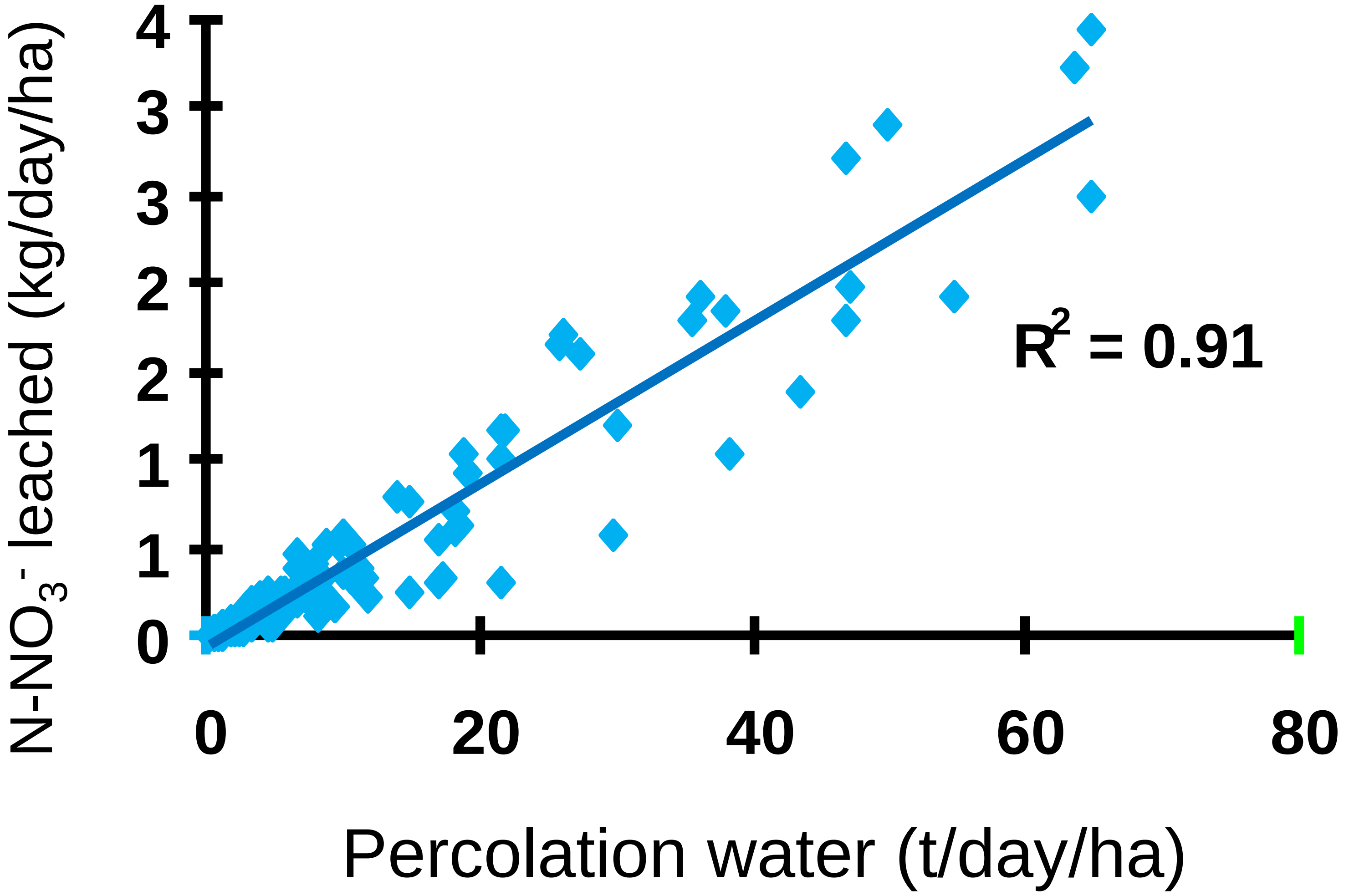

❑ CLAY SOILS:

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- ✓ High CEC → high capacity of holding positively charged ions;
- ✓ Hight water retention capacity → difficulties in getting warmer in spring → microbiological process slow at the begining of the season
- ✓ Limited loss of nutrients;
- ✓ Risk of soil anoxia, cracks, erosion
- ✓ Slow organic matter mineralization

❑ **SANDY SOILS**:

- ✓ High permeability;
- ✓ High nutrient mobility;
- ✓ Fast organic matter mineralization.

❑ **LOAMY SOILS:**

- ✓ Low nutrient mobility;
- ✓ Risk of soil anoxia;
- ✓ Crust formation.

TYPES OF FERTILIZERS

- ✓ Mineral fertilizers
- ✓ Organo –mineral fertilizers
- ✓ Amendments

CHEMICAL FERTILIZERS

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- Any substance able to supply crops with the main element(s) of fertility required for their vegetative and productive cycle (Italian law 787/84).
- The elements of fertility are in chemical form

STRAIGHT FERTILIZERS

Supply only one primary plant nutrient (urea, ammonium sulphate, potassium chloride and potassium sulphate)

COMPLEX FERTILIZERS

Contain two or three primary plant nutrients of which two primary nutrients are in chemical combination (diammonium phosphate, nitrophosphates and ammonium phosphate).

MIXED FERTILIZERS

Physical mixtures of straight fertilizers containing two or three primary plant nutrients.

FAST RELEASE

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Mineral fertilizers could be coated to release nutrients more slowly

AMENDMENTS

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Derive from the decomposition of organic vegetal or animal materials; elements are chemically bound each other in an organic form.

- ✓ Macronutrient concentration > 2-3%
- ✓ Not always easy to apply
- ✓ Often low cost
- ✓ Able to improve not only chemical, but also physical and biological soil properties

SLOW RELEASE

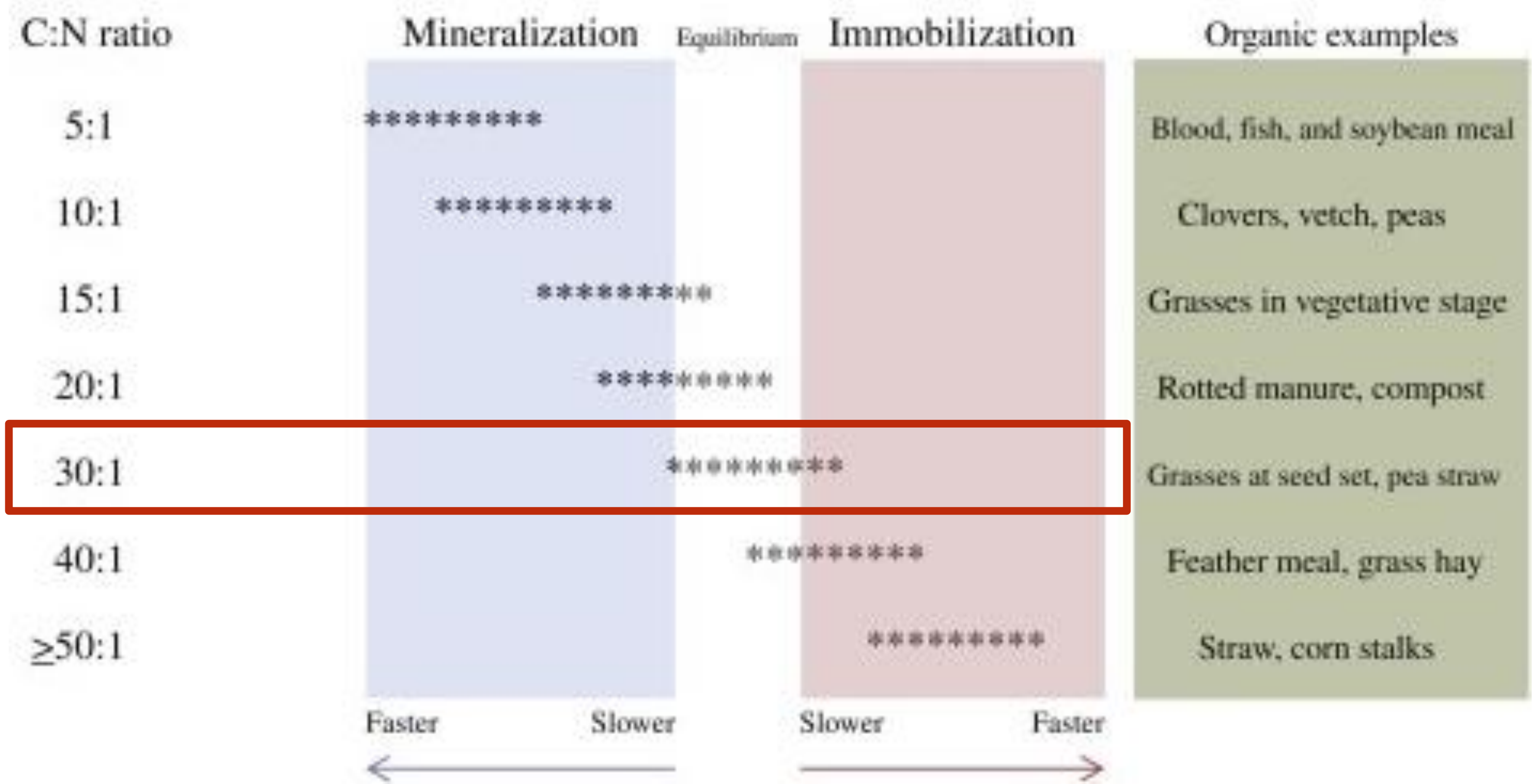
depending on C/N ratio

C/N RATIO

< 20 → fast decomposition and rapid N release

Between 20 and 35 → decomposition less fast and immobilization of part of N

> 35 → low decomposition and N immobilization in microbial biomass



Source: Gerald E. Brust, in Safety and Practice for Organic Food, 2019

PLANTS NEEDS

- ✓ Species
- ✓ Rootstock
- ✓ Age
- ✓ Phenological phase

TOTAL NUTRIENT REMOVED (kg ha^{-1})

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SPECIES	N	P	K	Ca	Mg
Kiwifruit	130-140	15-20	100-120	200-235	10-12
Cherry	90-100	10-20	85-100	90-95	15-18
Persimmon	150-170	15-20	115-125	100-115	18-21
Apple	90-100	10-20	115-150	120-135	18-21
Pear	70-90	5-10	65-85	135-140	12-15
Peach	90-150	10-20	100-125	110-130	21-24
Grape	60-100	10-15	65-85	40-90	9-15

Fonte: Cobianchi, 1995

NITROGEN UPTAKE DURING SEASON

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Species	Period	N % in relatio to tatal uptake
Grape	by full bloom	25
	full bloom – veraison	50
	veraison – harvest	25
Peach	kernel hardening	10
	kernel hardening – post-harvest	65
	Post-harvest – leaf abscission	25

POMEGRANATE

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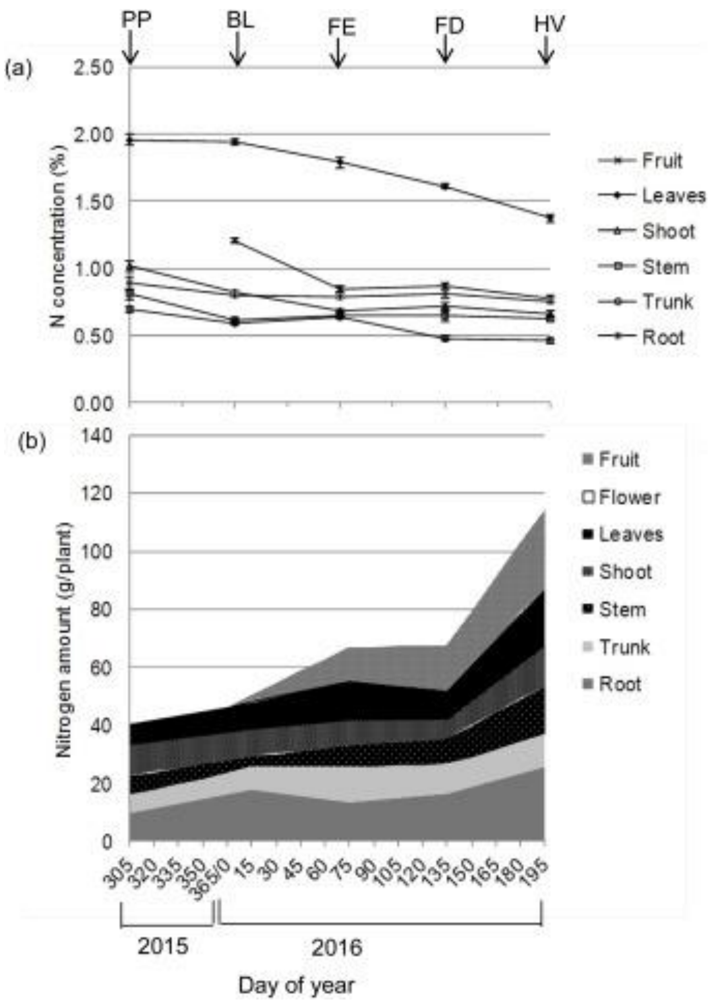
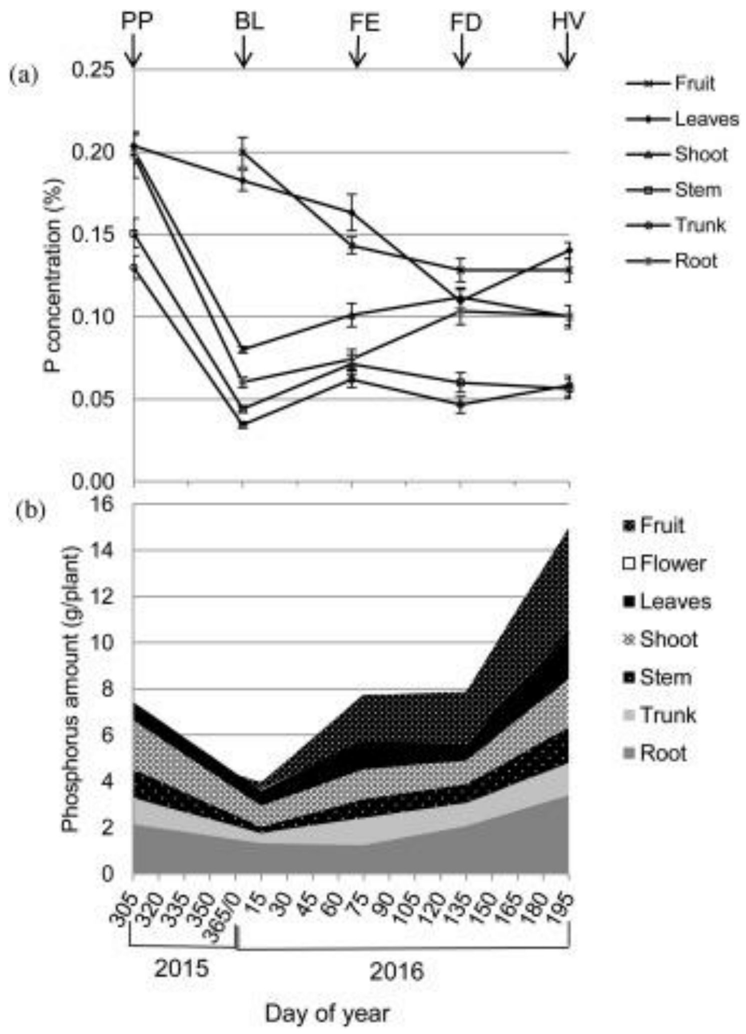
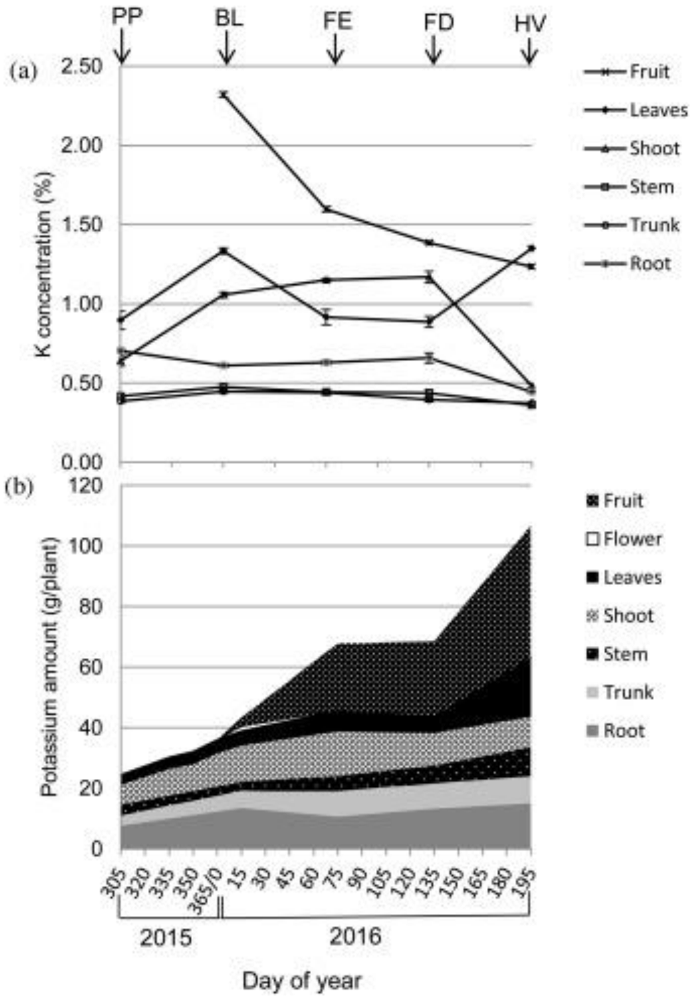
pre-pruning (PP), bloom (BL), fruit enlargement (FE), fruit development (FD) and harvest (HV)



N



P



K

Maity et al., (2019). *Scientia Horticulturae*, *252*, 138-148.

PEACH

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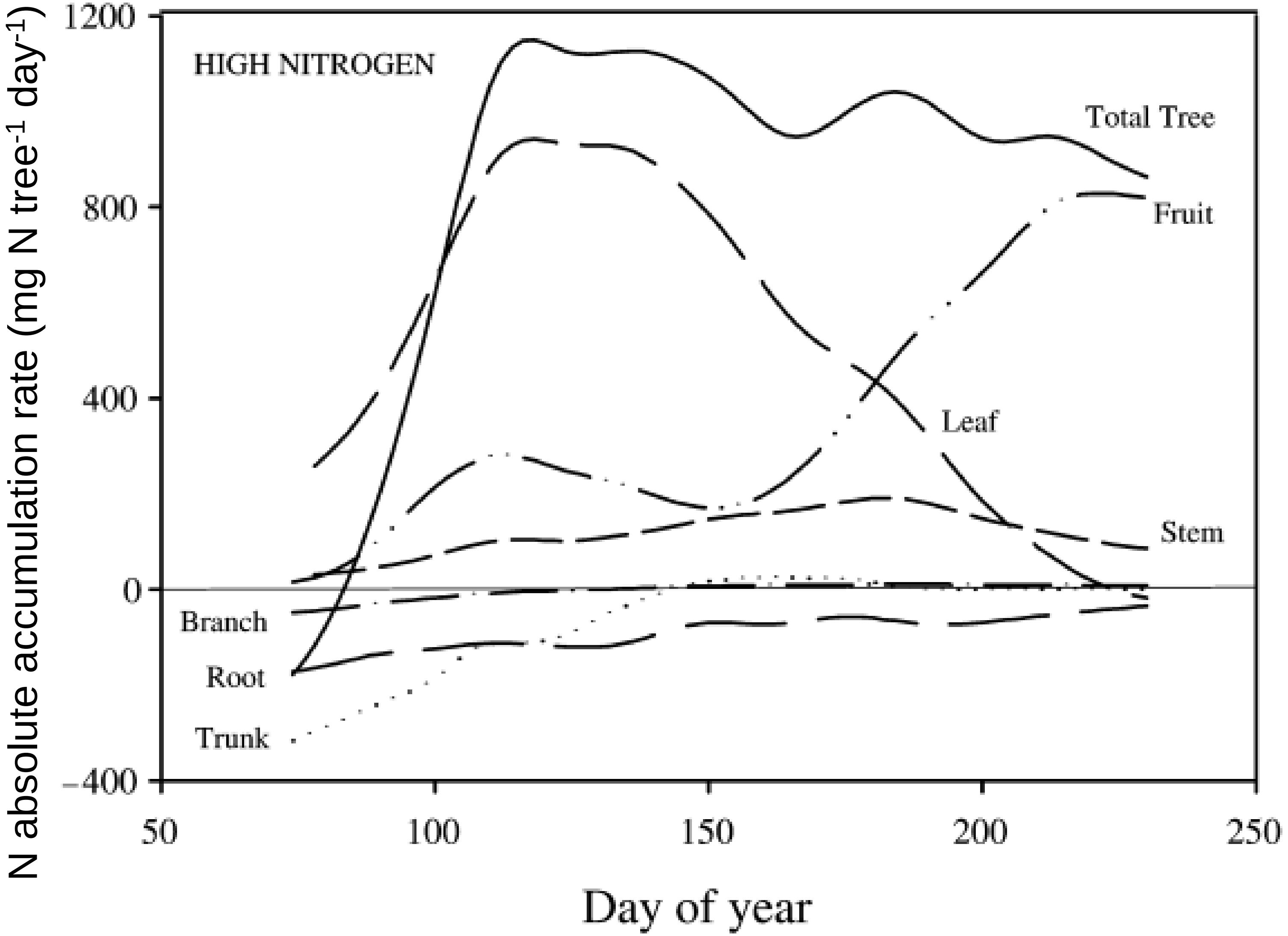

Rufat, J., & DeJong, T. M. (2001). *Tree physiology*, *21*(15), 1133-1140.

During the vegetative season **nutrient requirement** changes in relation to the **needs of organs** and their **development phase** → NOT CONSTANT REQUIREMENTS OF NUTRIENTS

N → mainly in shoots → the highest requirements are in spring/beginning of summer **K** → mainly in fruits → the highest requirements are during fruit growth and next to harvest

Better avoid lack of **B** and **Fe** during flower fecundation and fruit set

PEACH

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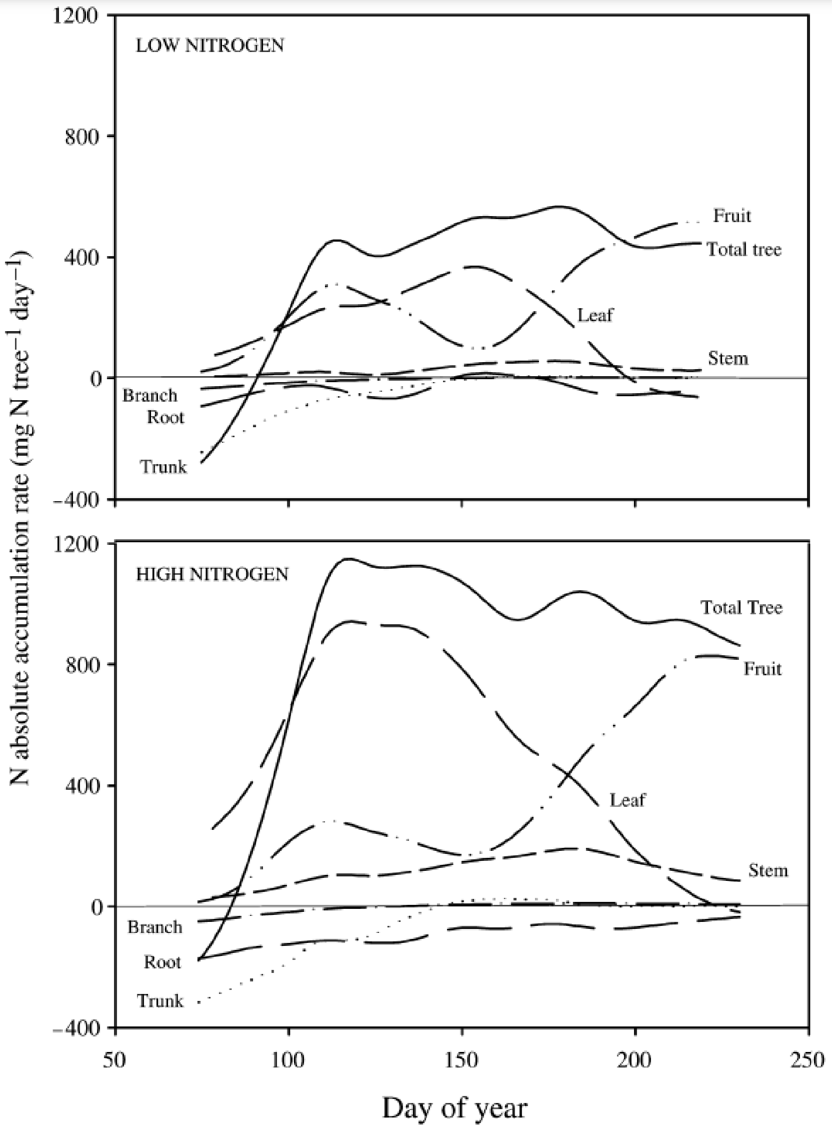

Nutrient uptake and allocation in plant organs in **PROPORTIONAL** to soil availability

Rufat, J., & DeJong, T. M. (2001). *Tree physiology*, *21*(15), 1133-1140.

Relation between nutrients in soil and in plant

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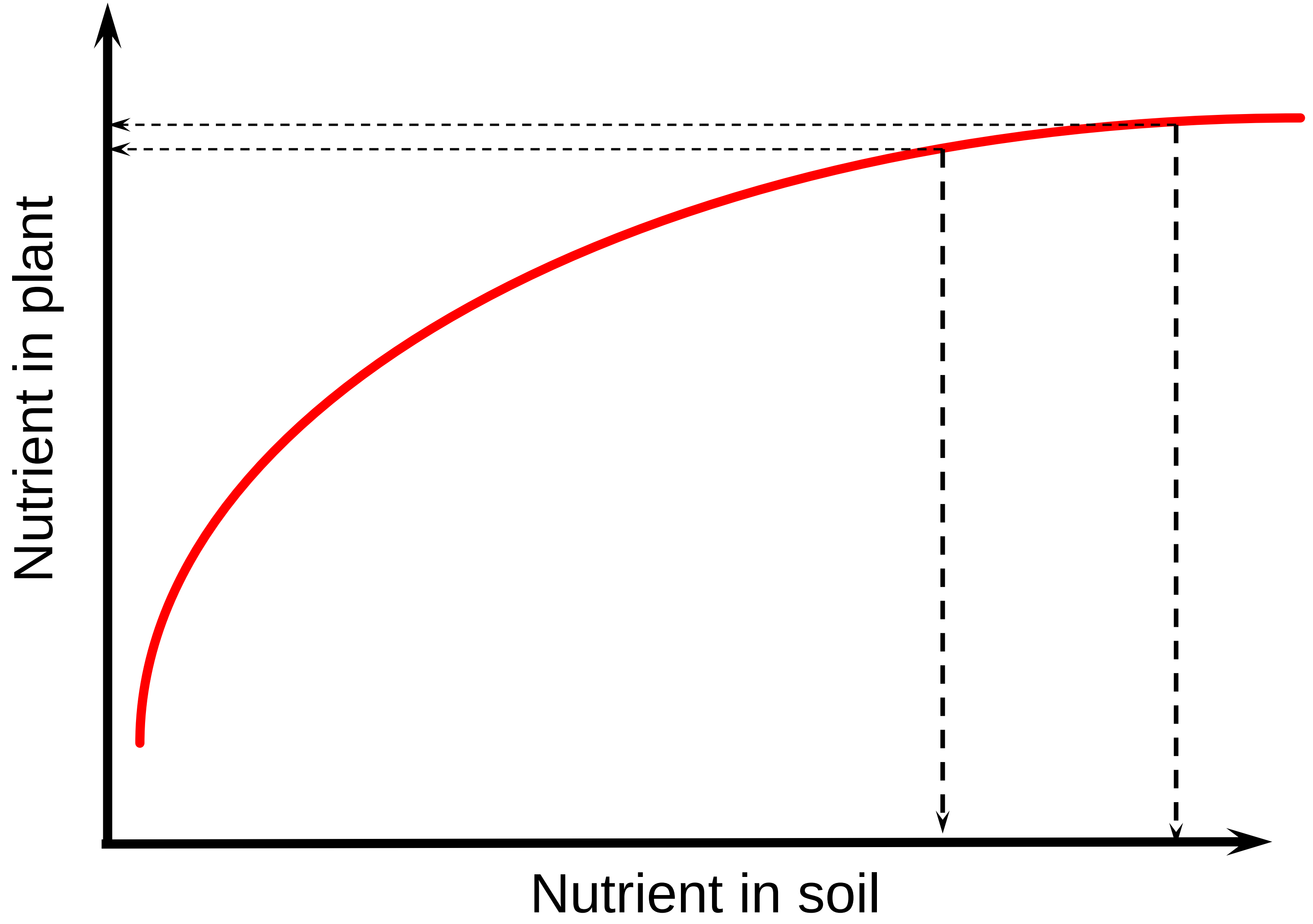

Fonte: Mengel, 1986

SUSTAINABLE FERTILIZATION

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SYNCHRONIZATION

SOIL NUTRIENT AVAILABILITY ⟷ **PLANTS NEEDS**

OBJECTIVES

- ✓ Constant yield
- ✓ Optimal fruit quality (harvest and post-harvest)
- ✓ Environmental issue

NUTRIENT BALANCE

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- Natural: rain, soil OM, animal residues
- Anthropic: **fertilization**

INPUT

OUTPUT

- **Removal** by plants (yield, skeleton, roots)
- **Loss** (leaching, erosion, immobilization, volatilization)

Aim of fertilization is to keep INPUT=OUTPUT, taking into consideration yields.

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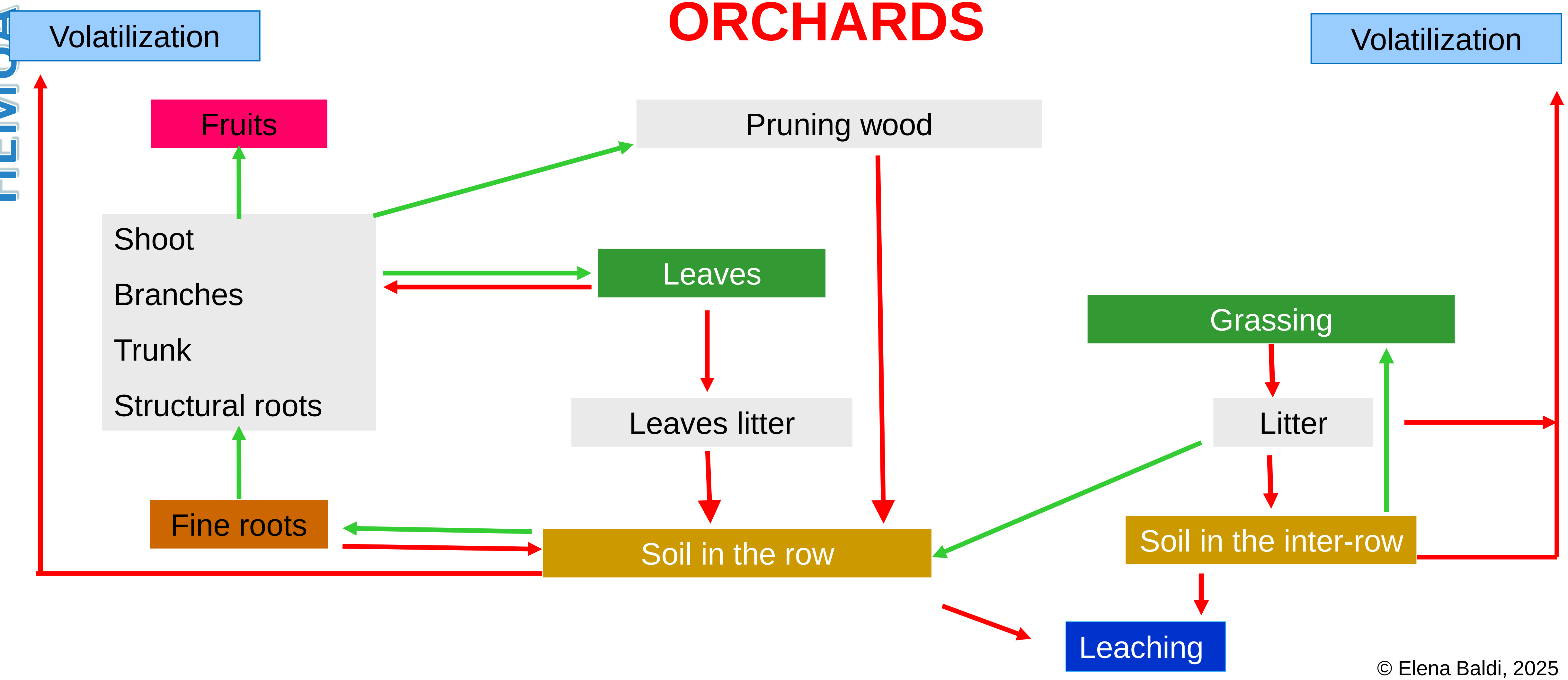
NUTRIENT FLUXES IN ORCHARDS



IN SUMMARY…..

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❑ NUTRIENT BUDGET - ORCHARDS

- ✓ Rates removed (**output**) by fruits and immobilized in the skeleton
- ✓ Rates supplied (**input**) by irrigation water, atmospheric deposition, animal residues

❑ NUTRIENT BUDGET - SOIL

- ✓ Rates up-taken by trees
- ✓ Rates available in soil (analysis to monitor)

WAY TO REACH THESE OBJECTIVES

- ✓ Rate in relation to fruit load, season, species and rootstock → removal and kinetics

SPECIES	N	P	K	Ca	Mg
	kg t^{-1} fruit harvested				
Kiwifruit	4.5	0.6	5.8	5.3	1.2
Olive	22	2.7	47	8.2	2.6
Walnut	10	5.4	12.3	8.9	2.8
Apple	0.9	0.2	1.3	0.5	0.2
Peach	3.3	1.2	3.9	0,4	0.3
Orange	3.7	0.4	1.9	2.8	0.4

Peano e Sottile, 2019. Principi di Arboricoltura

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WAY TO REACH THESE OBJECTIVES

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- ✓ Rate in relation to fruit load, season, species and rootstock → removal and kinetics
- ✓ Supply considering soil management techniques
- ✓ Avoid lack or excess
- ✓ Monitoring availability (soil and leaves analysis)
- ✓ Optimize fertilizers efficiency

Fertilization is efficient if:

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- the fertilizer reach the root zone, consequently :
  - ✓ soluble in water;
  - ✓ fertilization before rain or fertigation.

- the soil must have an adequate moisture level to keep the salts (fertiliser) in solution and to allow their absorption.

- plant should be receptive (active roots and efficient).

FERTILIZER APPLICATION TECHNIQUES

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❑ TRADITIONAL FERTILIZATION

- ✓ pre-planting
- ✓ during the vegetative season

❑ FERTIGATION

- ✓ small quantities, supplied often
- ✓ during the vegetative season easy to synchronize plants needs with soil availability

❑ FOLIAR

- ✓ micronutrients
- ✓ During the vegetative season to fix deficiencies

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PRE-PLANTING FERTILIZATION

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- ✓ Supply of farmyard manure or compost at a rate of 30-40 t ha^{-1} improves soil fertility being a good investment for the future performances of the orchard
- ✓ When necessary used to increased K, P, Ca and Mg in the deeper layer
- ✓ Could be done in the entire field or in the planting hole

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TRADITIONAL MINERAL FERTILIZATION

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- ✓ Limited number of applications with high quantities → nutrient availability strongly increases after rain event
- ✓ Should be done in view of a rain
- ✓ Difficult to synchronize with plant needs

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FERTIGATION

- highly-efficient fertilization technique used in orchards under drip irrigation system
- nutrients are dissolved in water and distributed in the wetted soil volume where most roots are located
- reduced water volume, frequent applications and low nutrient concentration = EASY TO SYNCHRONIZE
- Improves nutrient mobility in the soil profile

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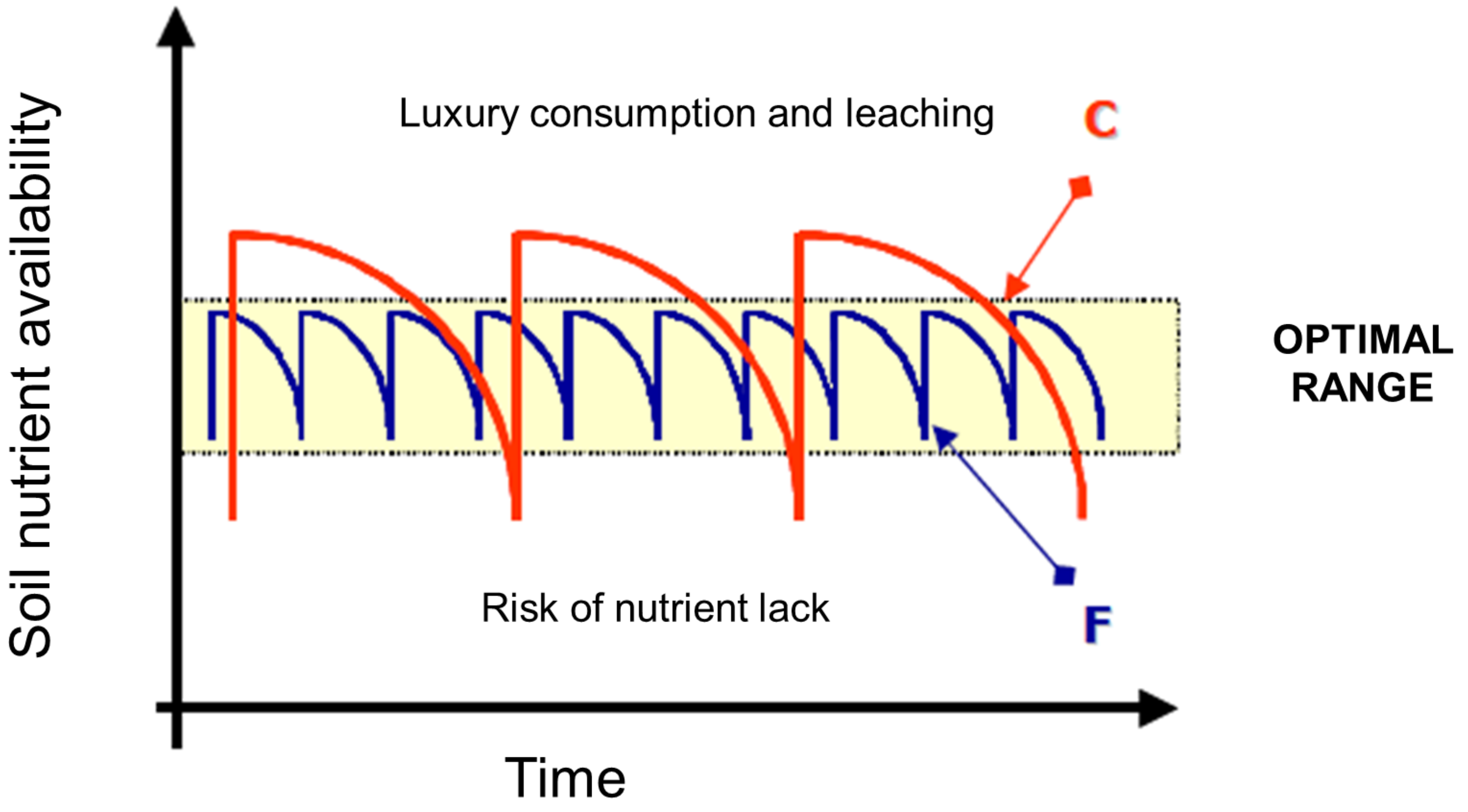

F = fertigation

C = pre-plant fertilization + (few) soil application

SALINITY

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Risk of ”secondary” salinization due to direct supply (with irrigation water or fertigation); nutrient solution should have EC < 1,8 dS/m

FOLIAR FERTILIZATION

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- ✓ Application of soluble fertilizers to aerial plant organs (flower, leaves, fruits)
- ✓ Can not replace soil fertilizers application for macronutrients; could be enough for some micronutrients
- ✓ Useful in case of unfavourable soil conditions
- ✓ If favourable environmental condition leaf absorption is fast (~ 48 h) and has an efficiency of 75-90%

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DEPENDS ON:

- ✓ Plant nutritional status → at spring break ureic N is slowly mobilized *(Fallahi et al., 2002);* in autumn it is accumulated in reserves organs *(Weinbaum et al., 2002)*
- ✓ Micronutrient usually supplied in case of lack
- ✓ Fertilizer type
- ✓ Period of application
- ✓ Leaf anatomy and age

Leaf age

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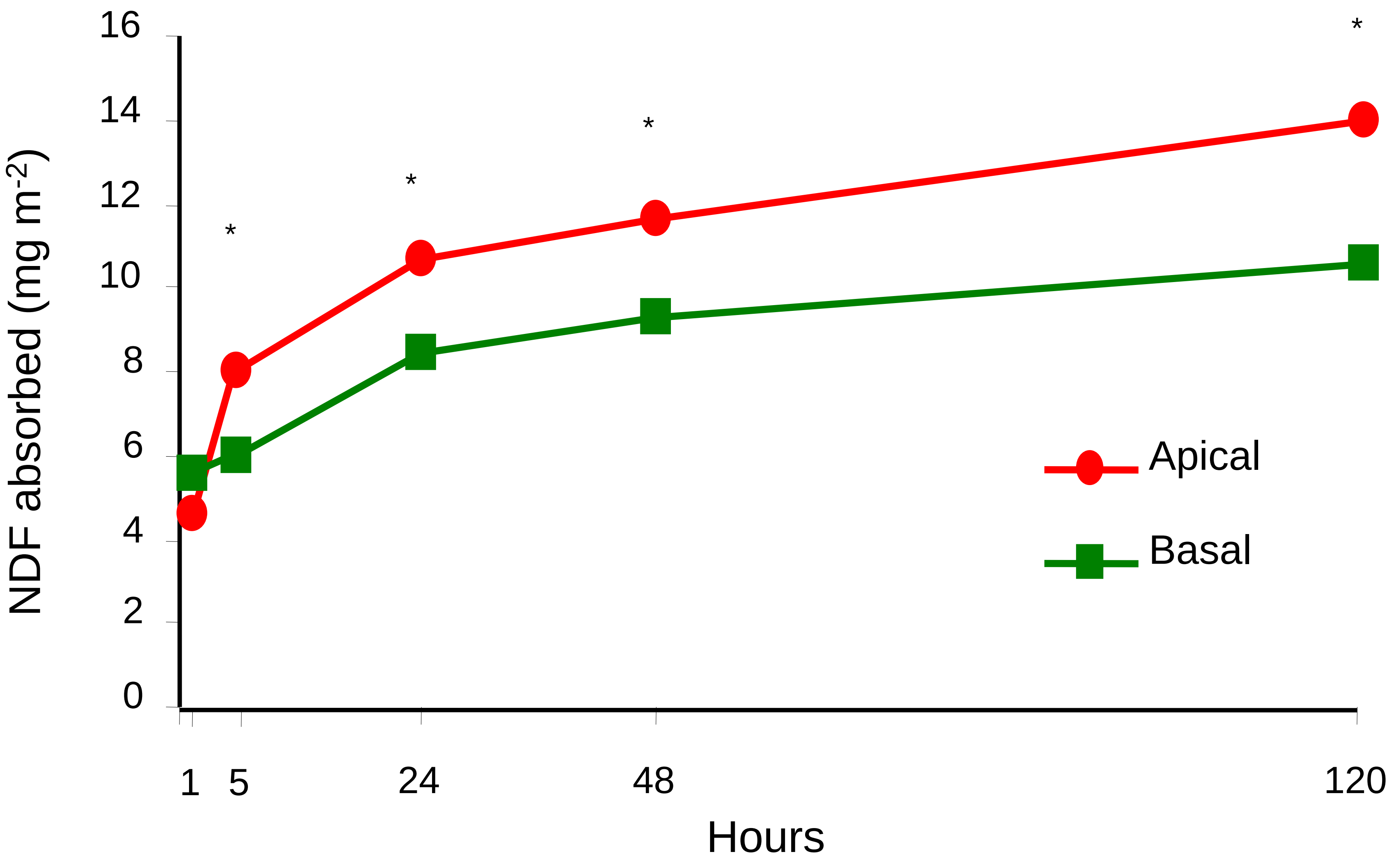

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TABLE 1. Essential plant nutrients, forms taken up and their typical concentration in plants (adapted from Roy et al. 2006; Kabata-Pendias 2011; El-Ramady et al. 2014a)

Nutrient (symbol)	Essentiality established by scientist	Forms absorbed	Typical concentration in plant dry matter
Macronutrients			
Nitrogen (N)	de Saussure (1804)	NH_4^+, NO_3	1.5 %
Phosphorus (P, P_2O_5)	Sprengel (1839)	$H_2PO_4^-$, HPO_4^{2-}	0.1–0.4 %
Potassium (K, K_2O)	Sprengel (1839)	K^+	1–5 %
Sulphur (S)	Salm-Horstmann (1851)	SO_4^{2-}	0.1–0.4 %
Calcium (Ca)	Sprengel (1839)	Ca^{2+}	0.2–1.0 %
Magnesium (Mg)	Sprengel (1839)	Mg^{2+}	0.1–0.4 %
Micronutrients			
Boron (B)	Warington (1923)	H_3BO_3, $H_2BO_3^-$	6–60 µg/g (ppm)
Iron (Fe)	Gris (1943)	Fe^{2+}	50–250 µg/g
Manganese (Mn)	McHargue (1922)	Mn^{2+}	20–500 µg/g
Copper (Cu)	Sommer, Lipman (1931)	Cu^+, Cu^{2+}	5–20 µg/g
Zinc (Zn)	Sommer, Lipman (1931)	Zn^{2+}	21–150 µg/g
Molybdenum (Mo)	Arnon & Stout (1939)	MoO_4^{2-}	below 1 µg/g
Chlorine (Cl)	Broyer et al. (1954)	Cl^-	0.2–2 %
Nickel (Ni)	Eskew et al. (1983)	Ni^{2+}	10 – 100 mg/kg

Env.Biodiv. Soil Security **Vol.1** (2017)

Alshaal, T., and El-Ramady, H. (2017). *Environment, Biodiversity and Soil Security*, *1*, 71-83.

TABLE 2. Meteorological conditions favoring foliar applications (adapted from MWL 1994)

Time of Day	Late evening; after 6 p.m. or early morning; before 9 a.m.
Temperature	65 – 85 ºF; 70º ideal (21 ºC)
Humidity	Greater than 70% relative humidity
Temperature/Humidity Index	140-160
Wind Speed	less than 5 mph

Alshaal, T., and El-Ramady, H. (2017). *Environment, Biodiversity and Soil Security*, *1*, 71-83.

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TABLE 3. Rates of nutrients absorption or entry into the plant leaf tissue (adapted from MWL 1994).

Nutrient	Time for 50% absorption
Nitrogen (as urea)	1/2 – 2 hours
Phosphorus	5 – 10 days
Potassium	10 – 24 hours
Calcium	1 – 2 days
Magnesium	2 – 5 hours
Sulfur	8 days
Zinc	1 – 2 days
Manganese	1 – 2 days
Iron	10 – 20 days
Molybdenum	10 – 20 days

Alshaal, T., and El-Ramady, H. (2017). *Environment, Biodiversity and Soil Security, 1*, 71-83.

SOIL vs FOLIAR

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- macronutrient requirement can be satisfied by only foliar fertilization (1 application max 5% N and 6% K on annual requirements) *(Weinbaum, 1988)*
- Roots need nutrients to grow and produce cytokinin *(Weinbaum et al., 2002)*
- nutrients with low phloem mobility (Ca, Fe, Zn, B) are not well mobilized

- higher efficiency that soil fertilization
- Nutrient availability is almost immediate
- Overcome root stress
- Limited environmental impact

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