Practical Nutrient Management (I)

Nutrient Cycling

Essential for all life

& its availability (or lack thereof) controls the distribution of flora and fauna

Its availability is controlled by 3 things

1. Sources
2. Sinks (pools)
3. Fluxes

For use by organisms, nutrients must be in a specific form –

each to its own…

The largest sinks of nutrients are generally unavailable to organism,

But there is a large group of specialized organisms that can transform this “unavailable” pool to usable form – and thus make it available for all organism.

Much of this transformation is soil related and controlled by soil characteristics!

Practical Nutrient Management (1)

- Nutrient Cycling
- Nutrient Uptake
- Nutrient Management
- Fertilizers
- Environmental Dynamics & Quality

Plants are made of - water (75%)
- dry matter (C,H,O, mostly)

"Essential" plant nutrients -
Definition: those elements necessary for the plant to complete its life cycle.

Each essential nutrient has at least one function for which other nutrients cannot substitute.

18 Essential Elements:

C, H, O, N, P, K, Ca, Mg and S - Macronutrients

Fe, Mn, B, Zn, Cu, Cl, Co, Mo & Ni - Micronutrients

(some plant species need Na, Si)

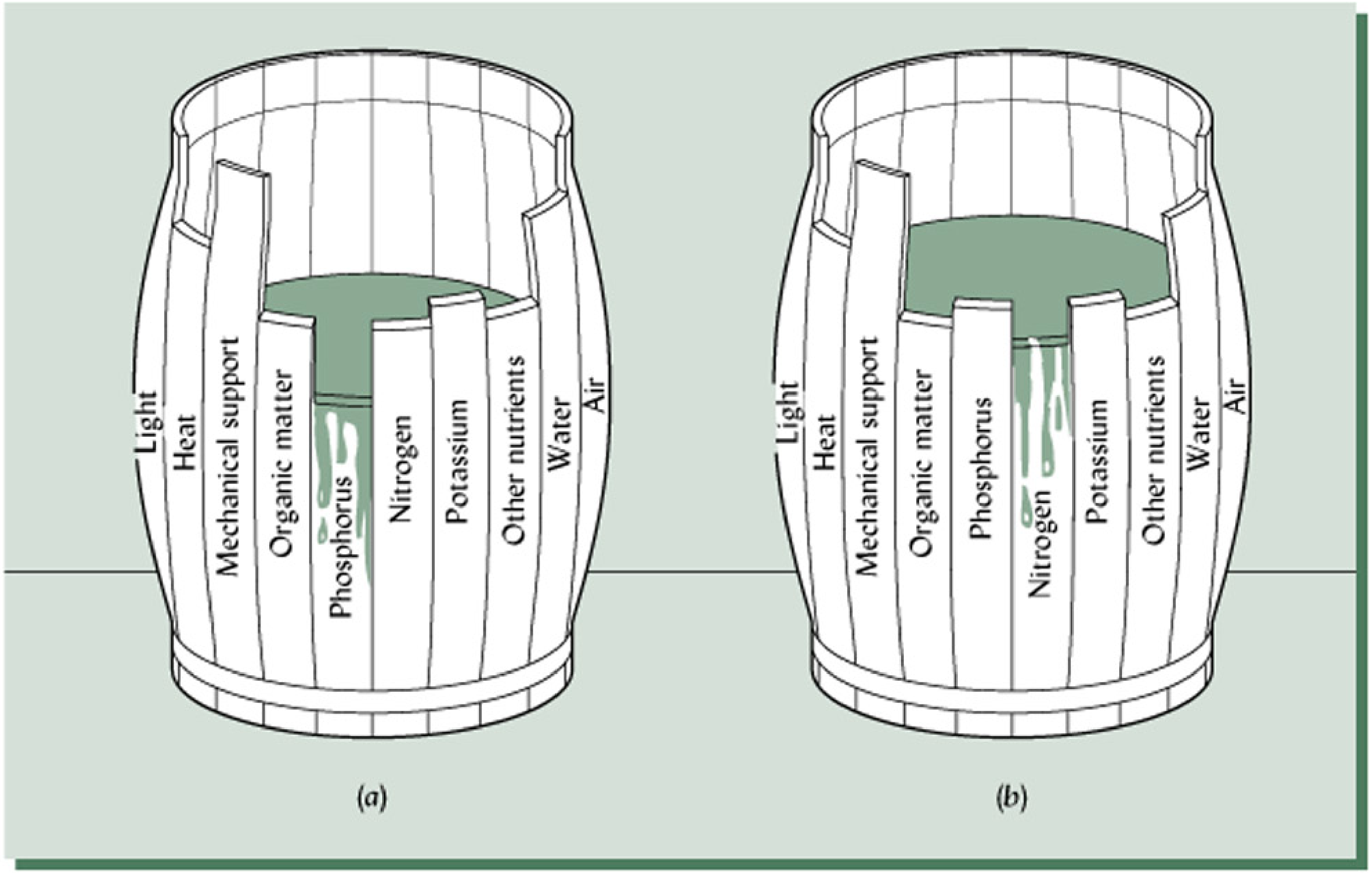
(Legumes dependent on symbiotic N fixation need Co)

Non-deficient plants can provide deficient diets to animals:

esp. Mo, Se, Co, Cu, P, Na, Ca, I

Plants can contain high (even toxic) concentrations of essential or nonessential elements:

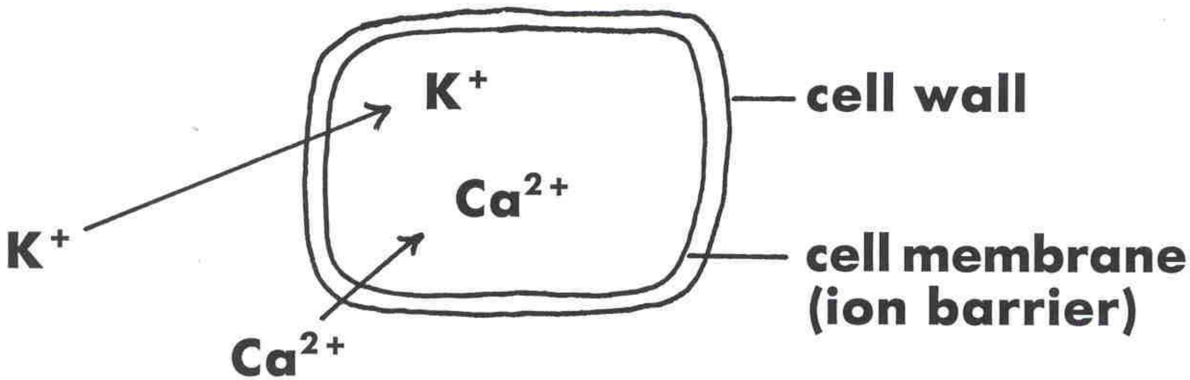
	e.g.	Al, Mn	(acid soils)
Plant-Toxic		Na, Cl	(saline soils)
		B	(saline soils)
Animal Toxic		Cu, Pb, Cd, Se, As, Mo	


Light
Heat
Mechanical support
Organic matter
Phosphorus
Nitrogen
Potassium
Other nutrients
Water
Air
Light
Heat
Mechanical support
Organic matter
Phosphorus
Nitrogen
Potassium
Other nutrients
Water
Air
(a)
(b)

Plant Uptake of Nutrients

Foliar uptake (aquatic plants, or when foliar spray is used)

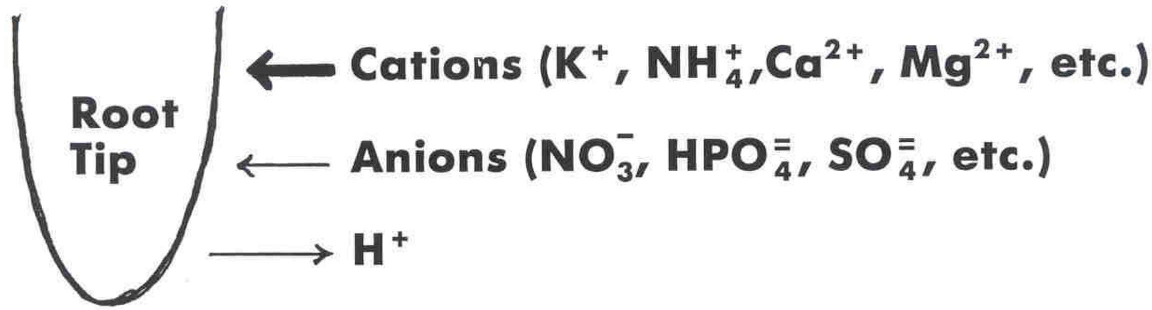
Root uptake (usual)



Membrane - concentrates nutrient ions (using energy from respiration)
- discriminates among ions

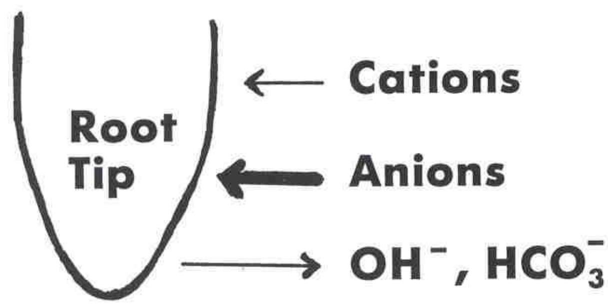
Result: Uptake of nutrients is sensitve to cold and lack of oxygen

Plant cells must maintain charge balance:



Rhizosphere pH drops

Σ Cations (mmoles charge) - H^+ exuded = Σ Anions



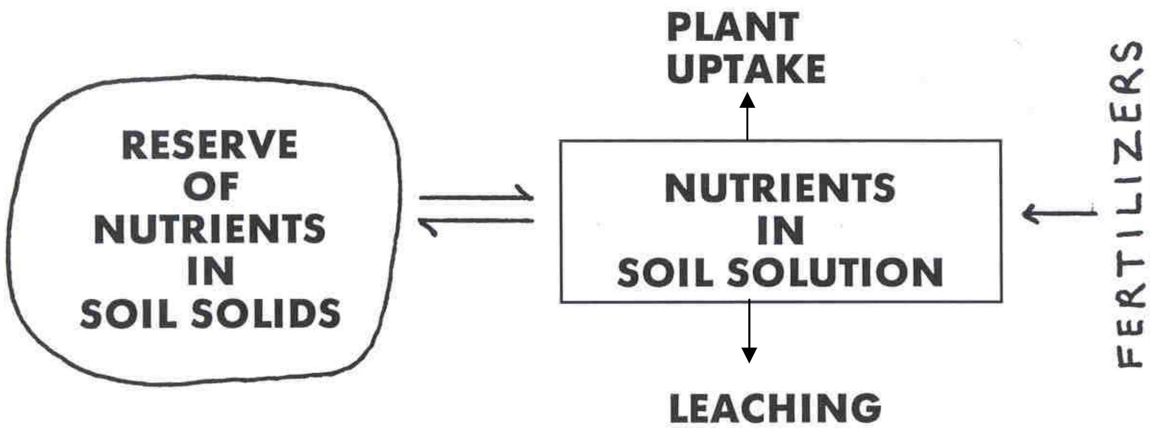
Rhizosphere pH rises

Σ Cations = Σ Anions - OH^- (or HCO_3^-) exuded

Result: Plants using nitrate --> raise pH

Plants using ammonium --> lower pH

Retention and Release of Soil Nutrients



Release mechanisms:

- cation exchange (fast)
- organic matter decay (slow)
- dissolution (slow --> fast)

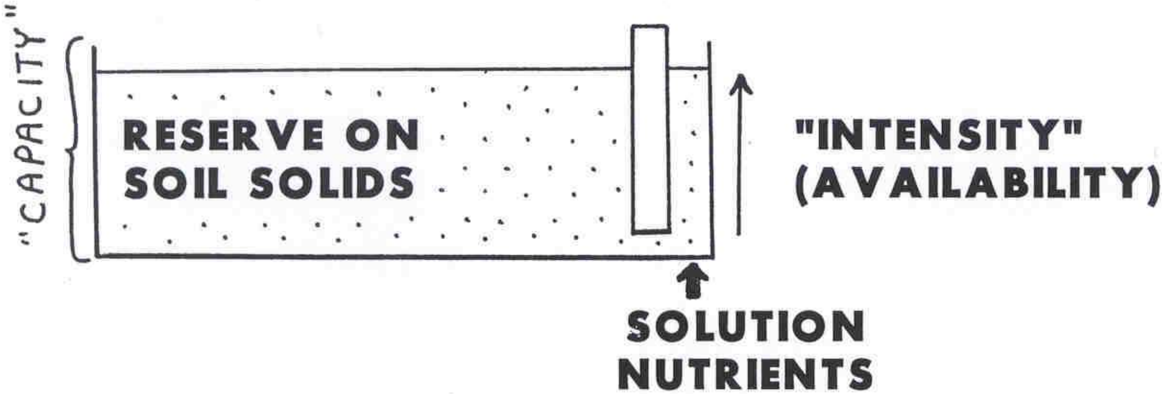
Result:

1. Amount of nutrient in soil solution depends on <u>recent</u> history of soil (rainfall events, cropping sequence, etc.)

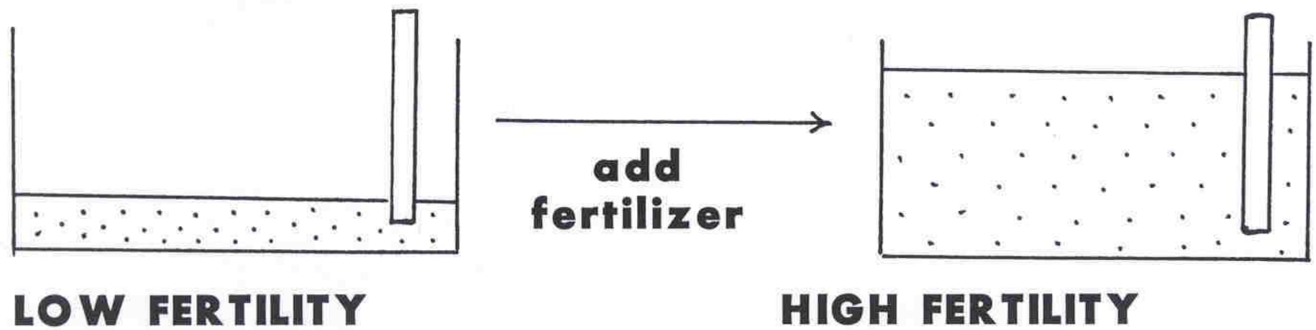
2. Each nutrient behaves differently e.g. Ca^{2+} in soil solution ~ constant

N, S in soil solution vary with time.

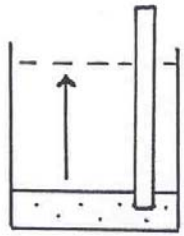
TANK MODEL



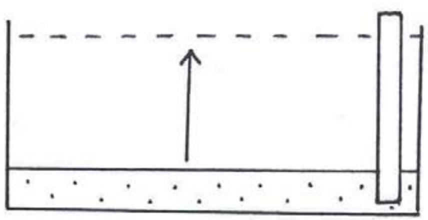
FERTILITY LEVEL:



SORPTION CAPACITY:

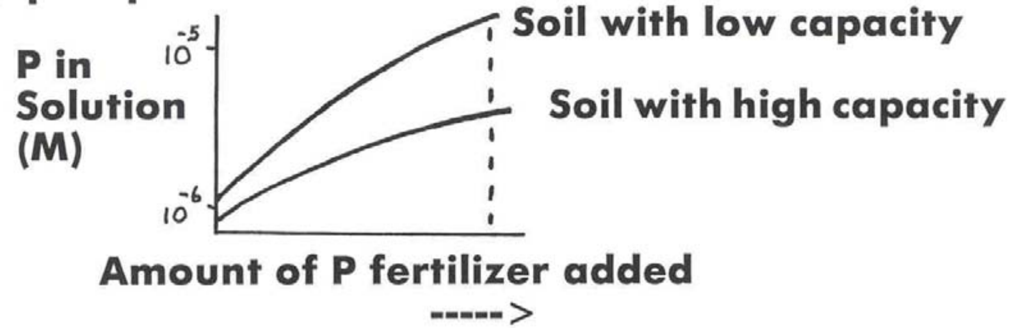


Raise fertility
of low-capacity soil



Raise fertility of
high-capacity soil

e.g. phosphorus



Rapid Uptake from Fertile Soil (e.g. nitrogen)

Replenishment of Solution Pool (slow for N)

Release Processes

1. **Organic Matter Decay**

   esp. N, S (sometimes P)

   features - great fluctuations in concentrations of dissolved NO_3^-, $SO_4^=$

   fastest release - moist, warm, aerated soils

2. **Cation Exchange**

   esp. Ca, Mg, K

   features - little fluctuation from equilibrium level (rapid process)

3. **Mineral Dissolution (Weathering)**

   esp. K, Ca, Mg, etc. (from primary minerals)
   Fe, Mn, Al (from oxides)
   S (from oxidation of metal sulfides)

   features - most important in young soils, acid conditions.

4. **Specific Adsorption/Desorption**

esp. P, Mo, B, Cu, Zn

features - involve strong bonding processes, particularly on oxides and volcanic ash material.

- slow release rates

5. **Surface Chelation/Release**

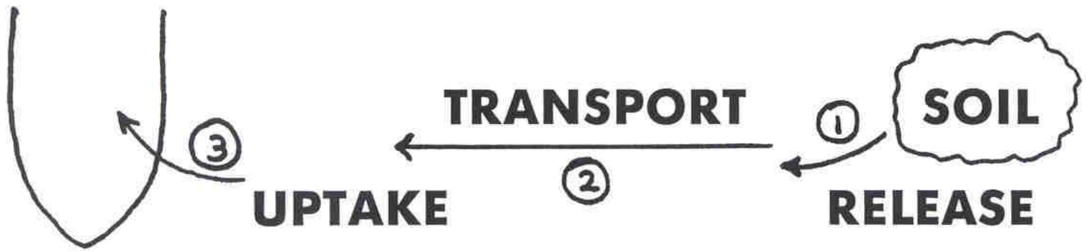
esp. Fe, Cu, Zn, Mn, etc.

features - strong bonding processes on humus

- release rates are slow

All of these processes are affected by pH.

MOVEMENT OF IONS TO ROOTS



3 processes involved in adequate plant nutrition

TRANSPORT

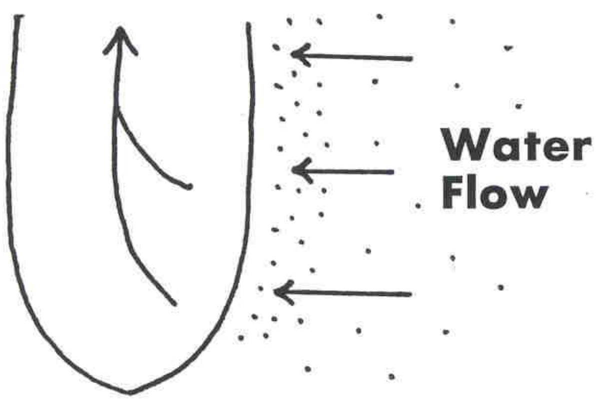
Nutrient ions move in soil by:

1. MASS FLOW

moving soil water carries along solutes.

Responsible for - NUTRIENT LEACHING
- TRANSPORT TO ROOTS (in part)

TRANSPIRATION

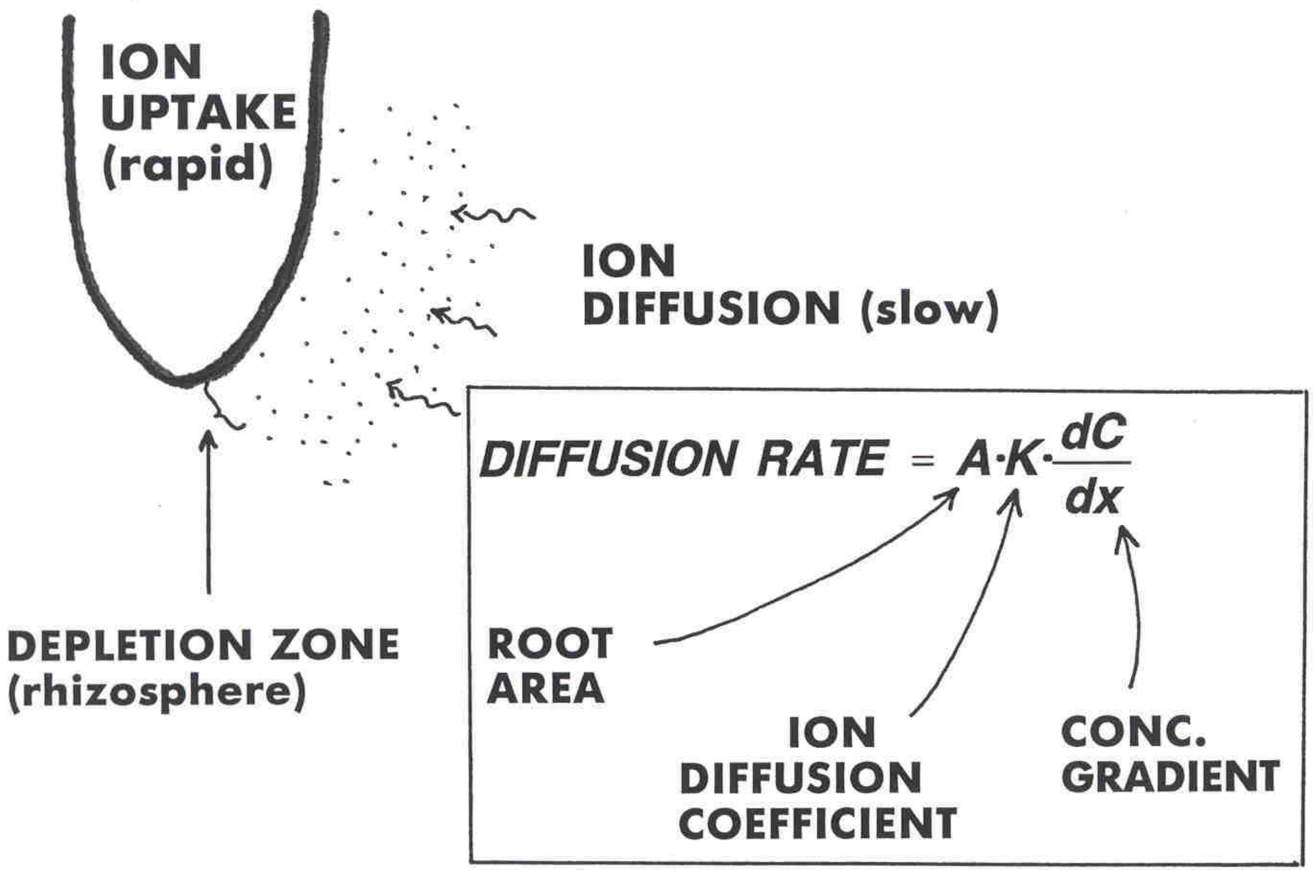


Q = V x C
Mass flow rate =
water flow rate x
ion conc. in solution

ACCUMULATION (DEPLETION) ZONE

2. DIFFUSION

Movement of individual molecules or ions along a concentration gradient.



OPTIMUM NUTRIENT TRANSPORT when:

1. **Transpiration is rapid (mass flow)**
2. **Soil solution concentrations are high (relative to plant's needs) (mass flow & diffusion)**
3. **Soil is moist and warm (diffusion)**

NUTRIENT MOBILITY -

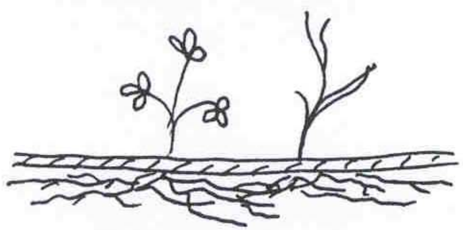
Mobile Nutrients - sufficient nutrient ion supplied to plant by mass flow (e.g. Ca^{2+}, NO_3^-, if not deficient)

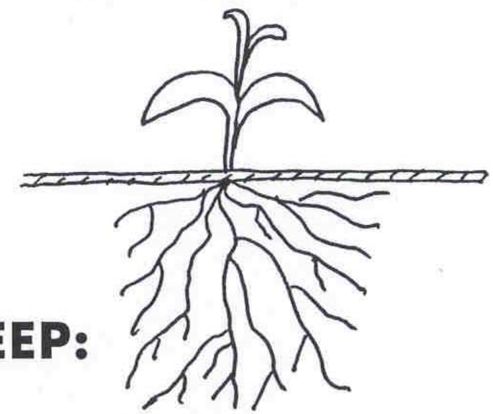
Immobile Nutrients - rhizosphere depletion makes diffusion an important suply mechanism (e.g. P, Fe, Zn, Mo) --> extended root system is necessary

ROOT GROWTH FOR OPTIMUM NUTRIENT UPTAKE

Extended Root System - depletes nutrients from large soil volume

High Root Surfce Area - esp. root hairs and mycorrhizae





SHALLOW:		DEEP:	
+	exploits fertile soil	+	taps subsoil water
-	little nutrient, water uptake in drought	-	may meet physical, chemical barriers

Soil Impediments to Root Growth

PHYSICAL	-	high penetration resistance of dry, structureless soils (dense soils, few macropores)
CHEMICAL	-	oxygen deficiency (poor drainage)
		Ca deficiency Al excess stunted roots
		organic toxins (eg. phenols)
BIOLOGICAL	-	root disease organisms (eg. root rot)