Hort 5504

POTASSIUM

Chapter 10
MENGEL et al, 5th Ed

POTASSIUM CYCLE

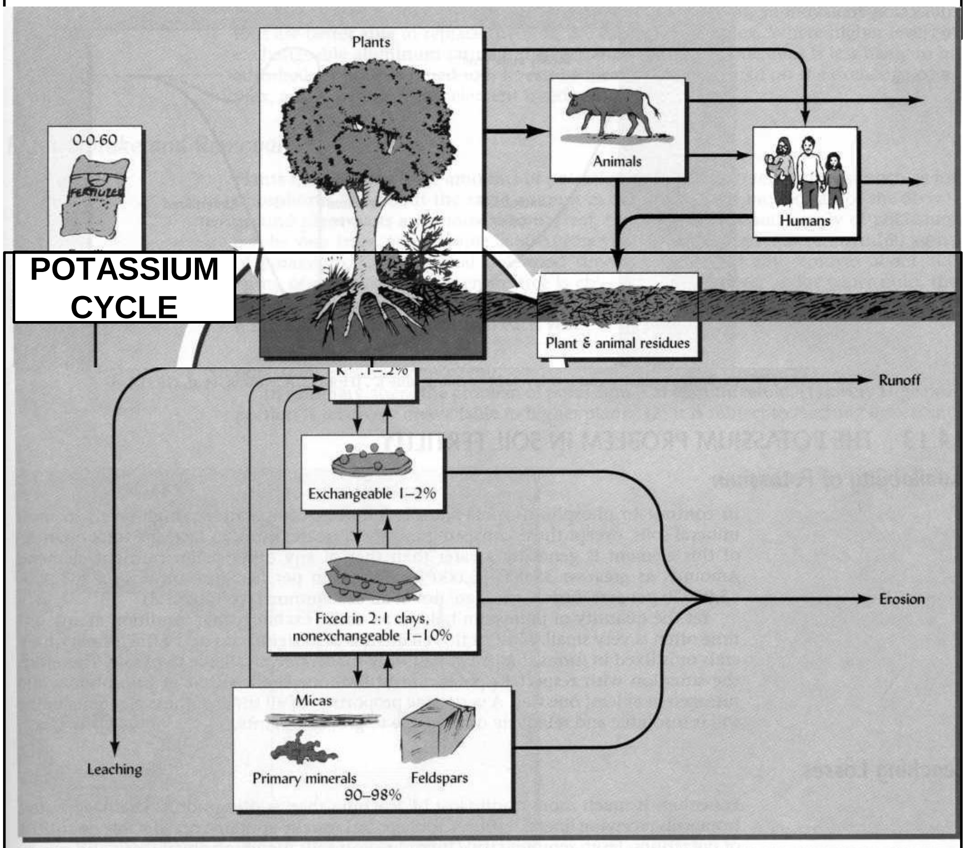

FIGURE 14.21 Major components of the potassium cycle in soils. The inner circle emphasizes the biological cycling of potassium from the soil solution to plants and back to the soil via plant residues or animal wastes. Primary and secondary minerals are the original sources of the element. Exchangeable potassium may include those ions held and released by both clay and humus colloids, but potassium is not a structural component of soil humus. The interactions among solution potassium, exchangeable, nonexchangeable, and structural potassium in primary minerals is shown. The bulk of soil potassium occurs in the primary and secondary minerals, and is released very slowly by weathering processes.

SOIL POTASSIUM

- K minerals and K release
  - ~2 - 3% of earth's crust is K
  - K tied to clay particles (< 2 μm size)
  - Frequently soils high in clay are high in K
    - Up to 4%
  - Mature well-weathered soils usually low in K but may have high clay content.

WEATHERING

- Young soils of volcanic origin may have high K
  - Range downward from there
    - Micas 10% K
    - Hydromicas 6 - 8% K
    - Illite 4 - 6% K
    - Montmorillinite < 2% K

K REPLACED IN MINERALS

- As weathering continues
  - Na^+, Mg^{2+}, Ca^{2+} replace K^+
- Larger ions drive wedge between silicate layers
  - More K^+ is released.
    - The longer this process lasts, the rate becomes slower

K FIXATION

- The depleted i layers = strong K^+ abs Contraction results in distance between layers to ~ 1nm.
- p (surface) and e (edge) positions are limited
- i position is site for K fixation NH_4^+ and H^+ compete with K^+
  - Is K fixation more a growth limiting problem in an acid or alkaline soil?

SOIL K BUFFER FACTOR

- **Ability of a soil to maintain**
  - **nutrient conc in soil solution**
- **Fig. 2.27 Mengel et al., (abs vs sol'n)**
  - **Equal amount K^+ removed from A & B shown as equal decrease in quantity**
  - **A better able to maintain K^+ conc in soil solution than B**

(A - high CEC; B - low CEC)

SOIL K BUFFER FACTOR

Refer to Fig. 2.27:

- **Soil A is better buffered than Soil B**

$$B_k = \Delta Q / \Delta I$$

- **The higher the ratio of $\Delta Q / \Delta I$, the more the soil is buffered**

K FRACTIONS

- **K structural element in soil minerals**
- **K adsorbed in exchangeable form to soil colloids**
  - **clay minerals**
  - **organic matter**
- **Analysis of i K layer - 1 *M* HNO_3 extract Extractable K^+ - $CaCl_2$ extraction**
- **Fixed K available under low soil K**

K MOBILITY

- **Hydrated K^+ radius 0.331 nm**
- **Active uptake**
- **Highly mobile**
  - **Within cells**
  - **Within tissue**
  - **Long distance trans xylem & phloem**
  - **Most abundant cation in cytoplasm**
- **K^+ and co-anion - osmotic potential**

K MOBILITY

- Hydration “water boy of plant”
- K^+ not metabolized
  - weak complexes, highly exchange
- Does not compete for divalent sites
- K^+ neutralizes organic acid & inorganic anions in cytoplasm
- Stabilizes pH from 7 to 8, opt for enzy
- A pH decr. from 7.7 to 6.5 inhibits NO_3^- Reductase

COMPARTMENTATION

- Cytoplasmic K^+ concentrations
  - Maintained at 100-200 mM
  - Not replaced by Na or any other cations
  - Vascular K^+ conc 10 - 200 mM
  - Guard cell K^+ may reach 500 mM
  - K^+ turgor-driven processes in vacuole (e.g.cell extension)

K^+ CHANNELS IN MEMBRANES

- Required for rapid transport between
  - Cell compartments & cells in tissue
- 3 orders faster than catalyzed by
  - Pumps and carriers
  - K^+ acts directly as solutes, changing osmotic potential thereby controlling turgor

ENZYME ACTIVATION

- Why does soluble CHO, soluble N increase & starch dec in K defic plants?
  - Fig. 10.11 (K & other ion $\Rightarrow$ ADP prod'n)
  - Regulatory enzymes
  - Starch synthase
  - K^+ necessary for activation of ATPase. Why is that important?

PROTEIN SYNTHESIS

- 130 mM K^+ opt for protein synthesis
  - Only 50 mM needed for enzyme activation
- K^+ needed in transl proc binding tRNA to ribosomes
- Synthesis of RuBP carboxylase impaired under K deficiency
- K def plants accumul AA, amides, NO_3

PHOTOSYNTHESIS

- K^+ counterion to light induced H^+ flux across thylakoid membranes.
- Establishment of transmembrane pH gradient necessary for ATP synthesis.
- K^+ necessary for CO_2 fixation (Tab. 10.5)
- K^+ influx from cytosol mediates
  - H^+/K^+ counterflow; K^+ needed to keep pH neutral to alkaline

OVERCOMING DROUGHTS

- K^+ loss from chloroplasts during drought can be counteracted with K^+
  - PS increased with inc K^+ supply
- PS decrease of *in vivo* plants less severe at high K^+

CELL GROWTH

- Formation of large central vacuole (80-90%) of cell volume
  - consequence of accum of K^+ in the cells necessary for:
    - stabilizing pH in cytoplasm
    - inc osmotic potential in vacuoles

CELL EXTENSION

- Increase in cell wall extensibility
  - 1950s answer- IAA causes loosening of microfibrils in cell wall
  - 1990s understanding- IAA-simulated H^+ efflux is electrochemically balanced by stoichiometric K^+ influx.
- GA needs K^+ to enhance stem elong

SOLUTE ACCUMULATION

- Creation of internal osmotic potential increases growth
- K^+ and reducing sugars act together
  - Produce potential required for cell extension

STOMATAL MOVEMENT

- K^+ assoc with an anion responsible:
  - For turgor changes in guard cells
  - Increase in K^+ conc in guard cells increases their osmotic potential
  - Water uptake from adjacent cells
  - Increase in turgor in guard cells
  - Results in stomata open, Fig. 10.8 text

STOMATAL CLOSURE

- In dark correlated with K^+ efflux.
  - Dec in osmotic guard cell pressure
- Light induced accum of K^+ in grd cell driven by proton pumping ATPase
- Closure of stomata induc by ABA or darkness assoc rapid efflux of K^+ & accompanying anion from guard cells

K^+ MOVES TO APOPLASM

- **Stomatal closure assoc - steep inc in K^+ and Cl^- in apoplasm of guard cells**
  - **Open stomata = 3 mM K^+ & 4.8 mM Cl^-**
  - **Closed stomata = 100 mM K^+ & 33 mM Cl^-**

NO PHLOEM - NO K^+ EFFLUX

- **Stomates remain perm open in parasites such as *Striga* & *Loranthus***
- **Do not resp to darkness, ABA, drought**
- **Lack of phloem in leaves so:**
  - **Lack of capability to dispose of K^+ from guard cells**
  - **So guard cells remain open**

UPTAKE & TRANSLOCATION

- **K mobile in plant. Moves toward meristem from older plant leaves**
  - **Because needed in protein synthesis and growth**
- **Bulk of K taken up during veg growth phase up to flowering**
- **Citrus during March, June, Sept flushes**

K IN ROOTS AND FRUIT

- **K in root cells not often translocated out as in older leaves.**
- **80% of cations in phloem sap are K^+**
- **Bananas, apples, & grapes are high in K because fed by phloem sap.**

K DEFICIENCY

- Growth rate reduction
- Older leaves necrotic margins
- Leaf scorch in pecans
- Peach leaves appear silver gray film
- Decrease in turgor, subject to drought, frost, salinity

K IN CROP NUTRITION

- Crop requirements & response
  - Soil K is being depleted
  - Removal by crops Kg K/Ha/Yr
    - Bananas 224
    - Stone Fruits 65
    - Oranges 120
    - Celery 350
    - Most Vegetables ~125

HOW MUCH K FERTILIZER?

- Amount of K application depends on
  - Crop removal of K
  - Leaching of K
- More K available from heavier highly buffered soils
- A medium textured soil responded to K if < 80 ppm but not if > 160 ppm

HOW MUCH K FERTILIZER?

- Higher N application increases need for K
- Response to K more noticeable 2^{nd} Yr
- Tomato production increased with K application up to 1600 Kg/Ha
- Panama disease (Fusarium oxysporium) of bananas more serious when K is limited.

DEFICIENT SOILS & FIXATION

- Sandy & organic soils have few K-bearing minerals
  - Depend mostly on fertilizer sources
  - Become deficient easily w/o fertilization
  - Little fixation capacity
- Soils with K-bearing minerals
  - After K depletion, have fixation capacity
- The more K is depleted
  - The more it is fixed

FERTILIZERS & APPLICATION

- KCl most common K fertilizer
  - 50% K and 60% K_2O
- Lower grade KCl contains
  - 41% K and 58% K_2O or
  - 33% K and 40% K_2O
  - Also contains NaCl
- Use K_2SO_4 for Cl sensitive crops

KMag

- Potassium magnesium sulfate
  - $K_2SO_4,MgSO_4$
  - 18% K, 22% K_2O
  - 11% Mg, 18% MgO

TIME OF APPLICATION

- If soils fix high amounts of K the application should be at planting time
  - May use banded application
- Even side dressing may be necessary
- Leaching only in sand