SOILS AND FERTILIZERS
MODULE 8
POTASSIUM FERTILIZER – MANUFACTURE, MATERIALS, AND USES

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1. Potassium fertilizer production and consumption
   a. The top five potash-producing countries in 1996 were: Canada, Russia, Germany, United States, and Israel.
   b. Top five potash-consuming states in 1997 were: Illinois (727,088 tons), Iowa (479,811 tons), Indiana (398,026 tons), Minnesota (315,893 tons), and Wisconsin (303,275 tons).
   c. Florida consumed 228,495 tons of potash in 1997 (ranked 9th among states).

2. Functions of potassium (K) in plants
   a. Water relations - Role of K^+ in osmotic regulation within plants; K provides much of the osmotic "pull" that draws water into plant roots; K-deficient plants are less able to withstand water stress; the opening of stomata in leaves occurs with an increase in turgor pressure of the guard cells surrounding the opening; this is brought about by an influx of K^+
   b. Co-factor for some enzymes - K is required to activate many plant enzymes; mechanism involves the attachment of K ions to the surface of the enzyme molecule, changing the molecule's shape or exposing the active site.
   c. Promotion of flowering, fruiting, fruit size, and maturity.
   d. General plant K concentration: usually >1% K in the plant is adequate.

3. Sources of potassium for fertilizer production
   a. Potassium is abbreviated with the letter <u>K</u> from the Latin word <u>Kalium</u>.
   b. The preparation of potassium carbonate, or **potash**, by leaching and concentrating wood ashes was the subject of the first U.S. patent, issued in 1790 and signed by George Washington; the process used about 5 acres of timber to produce 1 ton of potash; the term potash was derived from the manufacture of this product by the leaching of hardwood ashes in large iron pots.
   c. Commercial-scale production of K fertilizers began in Germany around 1861; salt deposits from old inland seas were mined for the production of common table salt, but mined material also contained KCl; the KCl needed to be upgraded (**beneficiated**) before it could be used as fertilizer. Beneficiation processes were developed by German chemists.
   d. Potassium deposits were discovered in the U.S. in the California Mojave Desert in 1916, and later at Carlsbad, New Mexico and in Utah; the world's largest deposits are in southeastern Saskatchewan, Canada, discovered in the 1960s.
   e. Principle sources for world potash production today originate in Canada, Russia, USA, Germany, Israel, Jordan, France, Spain, and South Africa.
   f. Potassium chloride is known as **sylvite**; other important K minerals include **langbeinite** (potassium-magnesium sulfate mixture), **sylvinite** (a mixture of KCl and NaCl), and **kainite** (a mixture of KCl and $MgSO_4$).

4. Mining systems
   a. Mined salts can be several hundred to several thousand feet beneath the surface.
   b. Ore is either mined as a solid and brought to the surface to be processed, or dissolved underground and brought to the surface as a solution to be evaporated.

5. Production of potassium fertilizer materials
   a. Potassium chloride (KCl)
      i. The direct product of the mining/purification process; KCl is 60 to 63% K_2O.
      ii. KCl varies in color from pink or red to white, depending on the mining and recovery processes used; there is no agronomic difference between these.
      iii. Marketed in five particle sizes: 1) special standard, 2) white soluble, 3) standard, 4) coarse, and 5) granular.
   b. Potassium sulfate (K_2SO_4)
      i. Produced by the reaction of KCl with sulfuric acid:

$$2\ KCl + H_2SO_4 \rightarrow K_2SO_4 + 2\ HCl$$

      ii. Can also be produced from langbeinite:

$$K_2SO_4 \bullet 2\ MgSO_4 + 4\ KCl \rightarrow 3\ K_2SO_4 + 2\ MgCl_2$$

      iii. Agricultural grade K_2SO_4 contains 50 to 53% K_2O, 18% S, and a maximum of 2.5% chloride.
      iv. K_2SO_4 **is produced mainly to satisfy the trade requirement for a potash source containing a low percentage of chloride**, e.g. for tobacco, and potatoes grown for chips.
      v. Potassium sulfate can also be formed by the decomposition of the kainite mineral to form **schoenite** ($K_2SO_4 \bullet MgSO_4 \bullet 6H_2O$); the K_2SO_4 component of this product is extracted by chemical manipulation.
   c. Potassium-magnesium sulfate ($K_2SO_4 \bullet MgSO_4$) (Sul-Po-Mag or K-Mag)
      i. Produced by mixing langbeinite with sodium and potassium chlorides.
      ii. Contains about 22% K_2O, 11% Mg, 22% S, and a maximum of 2.5% Cl; good for use on crops that require both magnesium and sulfur as well as K.
   d. Langbeinite
      i. Agricultural langbeinite has minimum K of 18.3%, minimum Mg of 10.8%, and maximum chloride of 2.5%.
      ii. Langbeinite ore that does not contain enough recoverable KCl undergoes a process which removes the NaCl in the ore; the resulting product can be used for agricultural purposes.
      iii. Langbeinite ores which contain substantial KCl are first used as raw material for KCl production.

e. Potassium nitrate
    i. Produced by the reaction of KCl and nitric acid:

$$KCl + HNO_3 \rightarrow KNO_3 + HCl$$

    ii. KNO_3 contains 44% K_2O and 13% N.
f. Other products
    i. Waste products from tobacco processing (stems and ribs of leaves) are ground and sold for use as fertilizers; these contain 4 to 8% potassium and 2 to 4% nitrogen.
    ii. Seawater contains vast amounts of K (one cubic mile contains the equivalent of 1.6 million tons of K); extraction of K from this source is not yet economically feasible.
    iii. Most of the world uses KCl as a source of K fertilizer; In Florida, certain crops such as potatoes, tomatoes, and other vegetables have shown a sensitivity to applications of KCl (i.e. sensitivity to chloride), thus KNO_3 and K_2SO_4 are popular sources of K in these situations.

6. Sources of K in the soil
    a. K-bearing minerals (These occur in midwestern soils, which can be high in native K; Florida has little native K because of weathering).
        i. Mica
        ii. Feldspars
        iii. Clay micas (illite)
        iv. Minerals may be 5,000 to 25,000 ppm total K; can be as high as 1.5% in a given soil.
    b. Exchangeable K
        i. K is held on the cation exchange complex of the soil (clay and organic matter).
        ii. Can range from 60 to 200 ppm K in the soil.
        iii. K^+ can be replaced by H^+, Ca^{2+}, Mg^{2+}, Al^+, etc. at the exchange site (acid weathering will remove K from the soil).
    c. Non-exchangeable K
        i. Exists within the lattice crystal structure of clay minerals (K is **fixed** within the mineral and is not available to plants).
        ii. Can range from 50 to 700 ppm K in the soil.
    d. Soil solution K
        i. Can range from 1 to 10 ppm K in the soil (contrast to soil solution P, which ranges from 0.03 to 0.5 ppm).
        ii. Potassium in the soil moves to the plant root by:
            (1) <u>Diffusion</u> - Movement in response to a concentration gradient, i.e. away from fertilizer bands (movement only 1 to 4 mm)
            (2) <u>Mass flow</u> - Movement of dissolved K^+ ions with the flow of soil water; amount taken up in this manner depends on the amount of water used by plants.

(3) Direct contact - Interception of soil K by a growing root (roots only encounter about 10% of required K via direct contact).

iii. Direct contact does not provide sufficient K for plant growth, thus must have increased K in solution through mass flow and diffusion.

iv. In Florida, soil K exists mainly in the exchangeable form and the soil solution form from fertilizers; Florida has no mineral K or non-exchangeable K.

v. Potassium leaches in Florida soils rather quickly because of the lack of clay and organic matter; soil analysis for K may not provide useful results due to the mobility of K in the soil (i.e. what is present this month may not be present next month).

7. Plant availability of soil K
   a. K status in soil
      i. Exchangeable **K^+** and **soil solution K^+** comprise the **"immediately-available" K** in the soil; plant roots excrete H^+ ions and exchange them for K^+ ions in the uptake process.
      ii. Non-exchangeable K comprises "slowly-available" K in the soil.
      iii. Mineral K comprises "very slowly-available" K in the soil.
   b. K fertilization of south Florida crops
      i. Because low organic matter sandy flatwoods soils are low in CEC, K will leach almost as fast as nitrogen. For acceptable production of most crops, a potassium (K_2O) rate in the same range as the nitrogen rate is required.

         For example:
         Tomato or pepper - 180 lbs/acre N, 180 lbs/acre K_2O
         Watermelon - 120 lbs/acre N, 120 lbs/acre K_2O
         Golf course fairway - 2 lbs/1000 sq. ft. N, 2 lbs/1000 sq. ft. K_2O

      ii. Citrus groves also usually require N and K_2O applications in a 1:1 ratio. (Example: 200 lbs/acre N, 200 lbs/acre K_2O). K is usually applied with N in a mixed fertilizer. If dry fertilizer N is applied 3 or 4 times per year, the K fertilizer is also applied on the same schedule.