The Essential Role of Potassium In Plant Nutrition

- Metabolism
- Growth
- Yield
- Quality
- Resistance
Romaine lettuce
(Lactuca sativa L.)
Fundamentals of 4R Nutrient Stewardship
Scientific principles for **Right Source**

- Consider rate, time, and place of application
- Consider plant-available form
- Suit soil physical and chemical properties
- Recognize synergisms among nutrient elements and sources
- Recognize blend compatibility
- Recognize benefits and sensitivities to associated elements
There is no one “right source” for every soil and crop condition.

Each crop, soil, and farmer has different needs and objectives …for example:

**Farmer issues:**
- Fertilizer availability?
- Product price?
- Application options?
- Environmental concerns?

**Soil and crop issues:**
- Proper mix of nutrients?
- Plant demand?
- Solubility?
- Salt Index?
- Amount required?
Selecting the “Right Source”?

- First determine what nutrients are needed to achieve the production goals.
- Identify potential nutrient limitations with soil and plant analysis.
- Nutrient omission plots may be useful where laboratory testing is not available.
Balanced plant nutrition - when selecting K source

- Insufficient to focus on potassium in isolation
- All nutrients must function together for yield and quality goals
- If one essential nutrient is limiting growth, then none of the other nutrients will be efficiently utilized
Where does potash come from?

Commercial potash deposits come from marine sources:

**Ancient seas**: Canada, Germany, U.K., Russia, etc.

**Salt water brines**: Great Salt Lake, Dead Sea
Various mineral salts are separated and purified
Potassium Chloride

**Formula:** KCl
**K Content:** ~60% K₂O
**Solubility (20°C):** 344 g/L

**Production:**
- Sylvite and sylvinite mining
- Solution mining
- Evaporation of brines
- Red color from traces of iron

**Agronomic Use:**
- High K concentration
- Low-cost K source
- High solubility makes it useful
- Many grades available
Additional Considerations: Grade (size)

- **Granular**: Direct application & bulk blends (0.8 to 3.4 mm)
- **Coarse**: Direct application & bulk blends (0.6 to 2.4 mm)
- **Standard**: Direct application, granulation in compound fertilizer (0.2 to 1.2 mm)
- **Fine**: For granulation, etc. (0.1 to 0.4 mm)
- **Soluble**: White KCl, dissolved for liquid applications (0.1 to 0.4 mm) produced dissolution and recrystallization.
Potassium Sulfate

**Formula:** $\text{K}_2\text{SO}_4$

**K Content:** 48-53% $\text{K}_2\text{O}$

**S Content:** 17-18%

**Solubility (20°C):** 120 g/L

**Production:**
- Reaction of KCl with sulfuric acid
- Processing of mixed K minerals (kainite, schoenite, polyhalite)
- Surface brines

**Agronomic Use:**
- Often used where chloride is undesirable
- Provides valuable source of sulfur
- Fine–sized material used for foliar spray, irrigation
- Chemically compatible (except Ca)
- Hard granules easy to spread
Potassium Nitrate

**Formula**: KNO₃
**K Content**: 46% K₂O
**N Content**: 13% N
**Solubility (20 C)**: 316 g/L

**Production**: Reaction of potassium chloride with a nitrate source

**Agronomic Use**:
- High solubility makes it useful for many purposes
- Excellent source of soluble nitrate
- Often used where chloride is undesirable
- Valuable source of potassium and nitrate for fertigation, foliar, hydroponics
Potassium Thiosulfate

Production:
- Thiosulfate made by reaction of S dioxide and elemental S
- Then reacted with ammonia, K, Ca, or Mg

Agronomic Use:
- High solubility makes it useful for many purposes, soil, irrigation, and foliar
- Low-chloride K source
- Thiosulfate produces acidity after S oxidation, may influence N processes
Potassium Magnesium Sulfate (Langbeinite)

- Mined directly
- Prepared by dissolving MgSO₄ and adding KCl

Formula: $K_2SO_4 \cdot MgSO_4$
K Content: $\sim 22\% K_2O$
S Content: $\sim 22\% S$
Mg Content: $\sim 11\%$
Solubility (20 C): 240 g/L
Polyhalite

U.K.:
$K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$

$[K_2Ca_2Mg(SO_4)_4 \cdot H_2O]$

U.S.A.:
$K_2SO_4 \cdot 2MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$

K Content: 14% $K_2O$
S Content: 19%
Ca Content: 12%
Mg Content: 4%

Solubility (20 C): $\sim 25$ g/L
Kainite (magnesia kainit)

Formula: KMgSO₄Cl·3H₂O + Na salts
K Content: 11% K₂O
S Content: 4% S
Mg Content: 3%
Cl Content: 43%
Na Content: 20%

Schoenite

Formula: K₂SO₄·2MgSO₄
K Content: ~22% K₂O
S Content: ~22% S
Mg Content: ~11%
Other Potash Fertilizers

**Monopotassium phosphate** (KH$_2$PO$_4$)  
(0-52-34) Reaction of KCl and phosphoric acid  
for fertigation, foliar spray, hydroponics (pH 4-5)

**Dipotassium phosphate** (K$_2$HPO$_4$)  
(0-41-54) Reaction of KCl and phosphoric acid  
for fertigation, foliar spray, hydroponics

**Potassium hydroxide** (KOH)
Less-soluble K minerals

Many geologic minerals contain K, but low solubility is challenging for agronomic use.

Possible to accelerate dissolution of K-bearing minerals through chemical, biological, and physical processes.

Transportation limitations of low-K materials may restrict use to fields near their production site.
Potassium is not a structural component of plant cells, remaining soluble in urine and animal manure (urine fraction not recovered?)

The nutrient value of K in animal manures is generally equivalent to soluble K fertilizers (or slightly greater?)

Solid manures frequently contain between 5 to 25 kg $K_2O$/ton, while liquid pit manures typically contain 1 to 4 kg $K_2O$/1000 L
What happens to K fertilizers in the soil solution?

- KCl $\rightarrow$ $K^+$ + Cl
- $K_2SO_4$ $\rightarrow$ $2K^+$ + SO$_4$
- $KNO_3$ $\rightarrow$ $K^+$ + NO$_3$
- $K_2S_2O_3$ $\rightarrow$ $2K^+$ + S$_2$O$_3$
- $KH_2PO_4$ $\rightarrow$ $K^+$ + H$_2$PO$_4$

$2K^+$ + 2 Mg $\rightarrow$ $K_2SO_4$

$2K^+$ + S$_2$O$_3$ $\rightarrow$ $K_2S_2O_3$
If there is no difference in the K, how do I decide which one to use?

The added anion/cation that accompanies the K

- **Plant Nutritional Effects**
  - Chloride
  - Sulfate
  - Nitrate
  - Thiosulfate
  - Phosphate
  - Potassium
  - Calcium
  - Magnesium
  - Sodium
Nutritional Deficiencies

Sulfur deficiency

Magnesium deficiency

Calcium deficiency

Phosphorus deficiency
Some crops sensitive to excess chloride
Some crops responsive to chloride
# Salt Index of K fertilizers

<table>
<thead>
<tr>
<th>K Fertilizer Source</th>
<th>Salt Index - per unit of K₂O</th>
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</thead>
<tbody>
<tr>
<td>Potassium Sulfate</td>
<td>0.9</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>1.6</td>
</tr>
<tr>
<td>Potassium Chloride</td>
<td>1.9</td>
</tr>
<tr>
<td>K/Mg Sulfate</td>
<td>2.0</td>
</tr>
<tr>
<td>Potassium Thiosulfate</td>
<td>2.6</td>
</tr>
</tbody>
</table>
Practical Example of Salt Damage: Seed-Placed Fertilizer Calculator

**Relative Injury Potential**
- 10-34-0 (9.6) (*low*)
- TSP (12.8)
- Langbeinite (17.1)
- K₂SO₄ (18.4)
- DAP (22.3)
- 28-0-0 (30.9)
- KCl (34.5)
- ATS (66.7)
- Urea (78.3) (*high*)

**Relative Crop Sensitivity**
- Maize (6.5) (*low*)
- Barley (11.3)
- Wheat (14.1)
- Sunflower (16.5)
- Sorghum (21.8)
- Cotton (23.8)
- Soybean (40.6)
- Canola (41.7)
- Alfalfa (47.6) (*high*)

Fertilizer material applied
Seed furrow opening
Tolerated stand loss
Row spacing
Soil moisture and soil texture coefficients

How much safe to apply?
Forms of fertilizer: Dry bulk blends

• Various combinations of dry fertilizers are mixed to meet specific crop and soil conditions

• Bulk blends are popular because the lowest-cost materials can be combined using inexpensive equipment

• Not all solid fertilizers are compatible for mixing

• Care needed to avoid separation (segregation) of the individual components during handling and spreading
Forms of fertilizer: Compounds

- Each fertilizer granule contains a mixture of nutrients
- Provides a uniform distribution of nutrients surrounding each particle
- Easy to handle and apply
- The selection of nutrient ratios may be limited to market availability
Forms of fertilizer: Fluids

- Clear liquids are mixed into a homogenous blend of nutrients
- Many can be added to irrigation water
- Commonly used for foliar nutrition or as a carrier for agricultural chemicals
- Not all fluids are compatible. Test a small batch first to avoid precipitation
There are many forms of soluble K fertilizer available. Each one has unique characteristics. It is important to know their properties so they can be used most effectively.
Forms of fertilizer: Suspensions

• A small amount of clay is added to fertilizer solutions to make a fluid suspension (higher viscosity)

• Suspensions allow a higher concentration of nutrients and chemicals than clear fluid fertilizers

• Agitation is generally required in the tank to keep suspension well mixed
Foliar K applications
Nutrient interactions

Whenever any potassium source is added to soil, it will impact the behavior of other nutrients for examples:

- Potassium, calcium, & magnesium all interact (synergism or antagonism)
- Nitrate can restrict chloride uptake
- Changes in rhizosphere pH
Economics:

California Prices: FOB

KCl: $395/ton (60% K$_2$O)

K$_2$SO$_4$: $585/ton (50\% \text{ K}_2\text{O})$

KNO$_3$: $880/ton (44\% \text{ K}_2\text{O})$

Langbeinite: $310/ton (22\% \text{ K}_2\text{O})$

Greenmarkets, Jan 2017
Conclusions

Selecting the “Right Source” of K is highly dependent on specific circumstances

Decisions based on local markets, farming practices, agronomic options, crop behavior

Farmers expect a Return on K Investment

K Frontiers of Science gathering will advance the likelihood of getting “Right Source” correct