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INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Selecting the Right Source of Potassium Fertilizer

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The Essential Role of Potassium In Plant Nutrition

- Metabolism
- Growth
- Yield
- Quality
- Resistance

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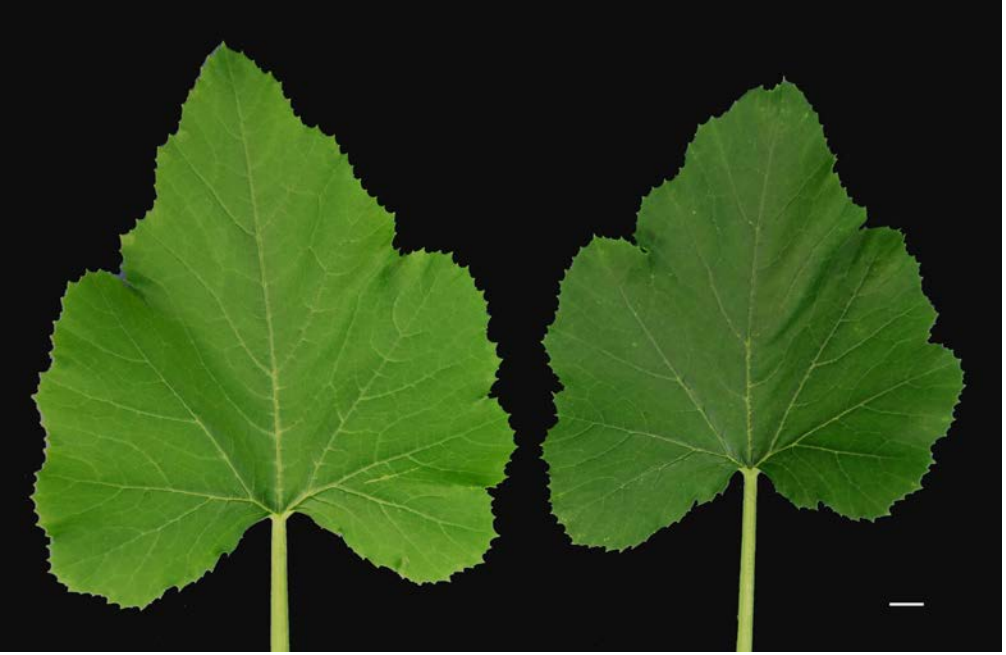
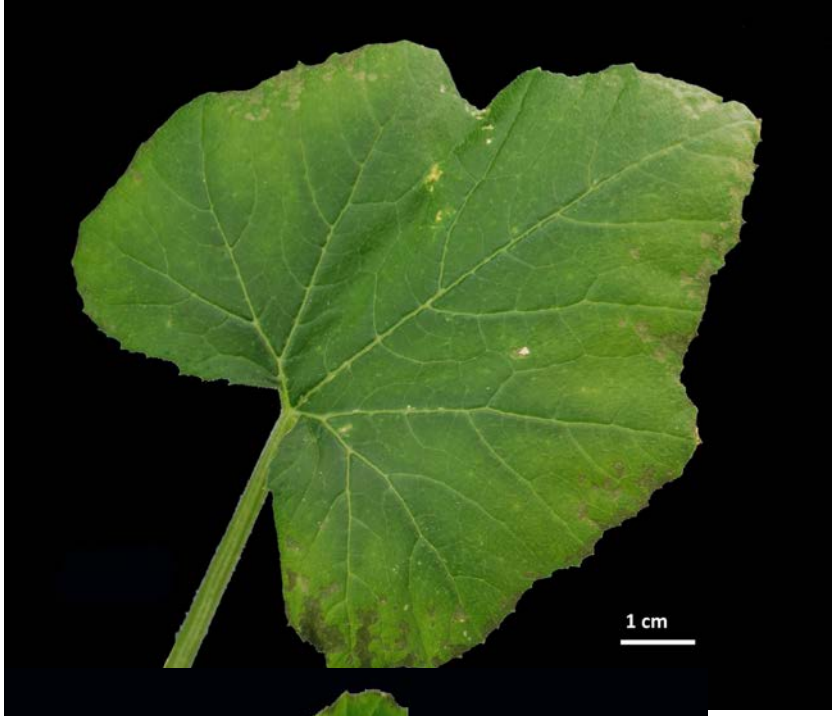
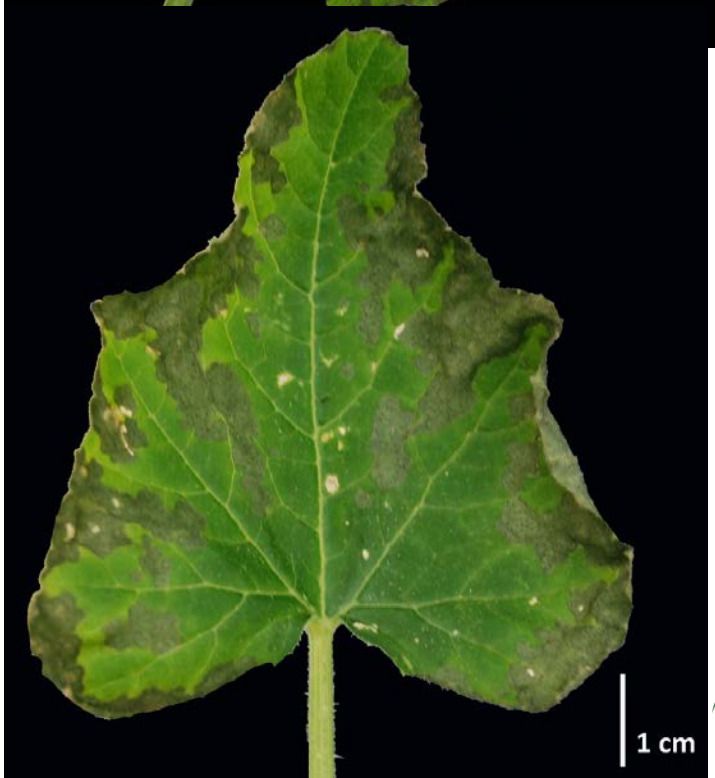




Squash (*Cucurbita pepo*)

Pitchay



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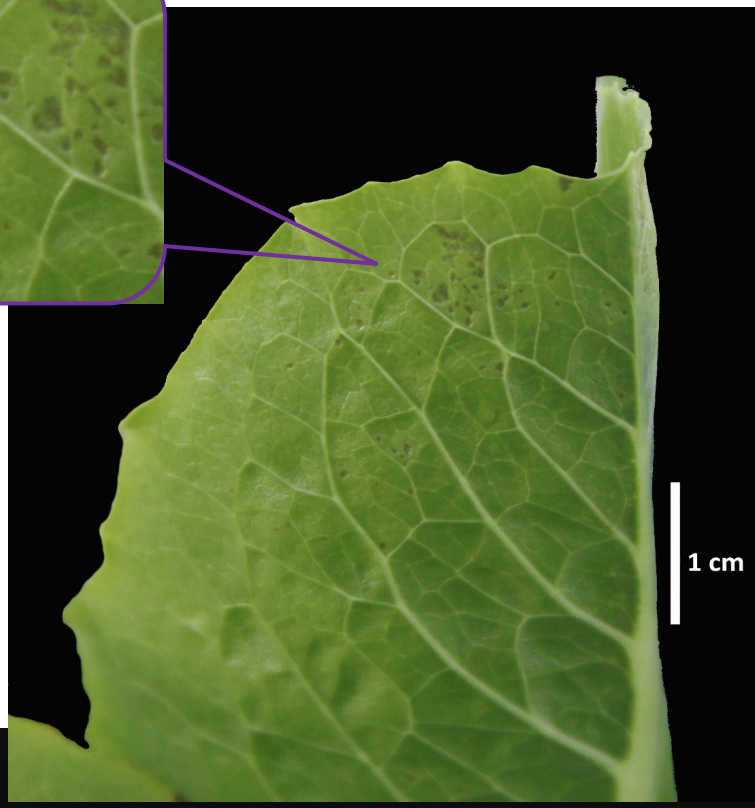
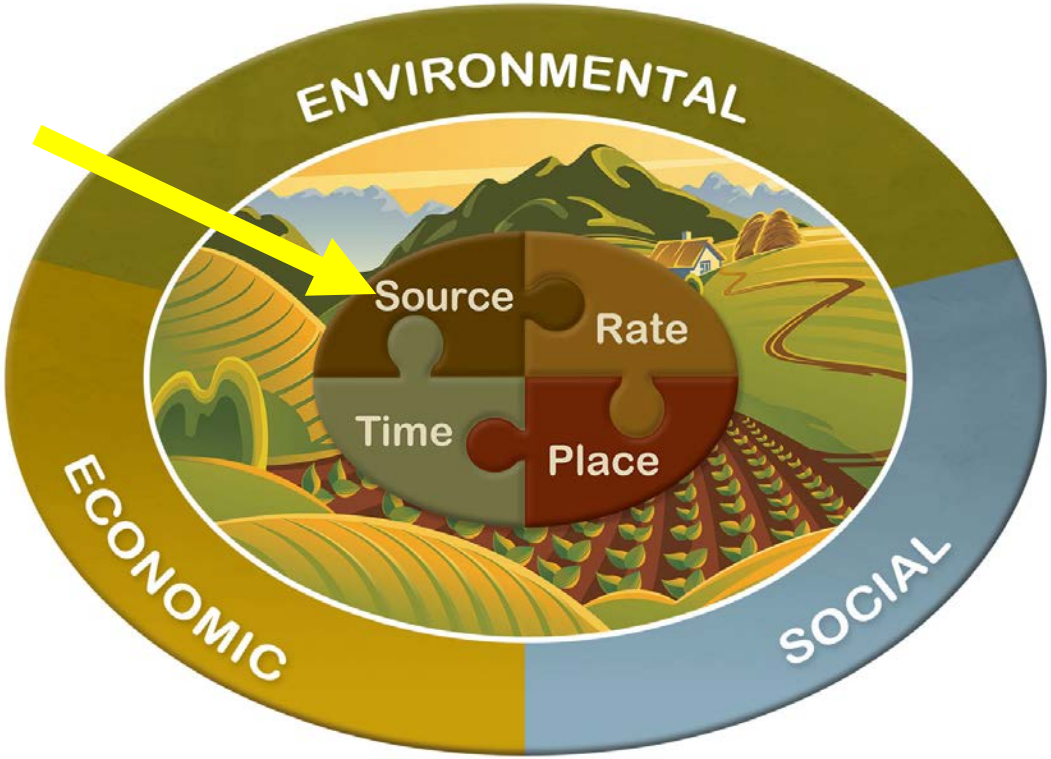
Romaine lettuce
(Lactuca sativa L.)



Fundamentals of 4R Nutrient Stewardship



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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”?

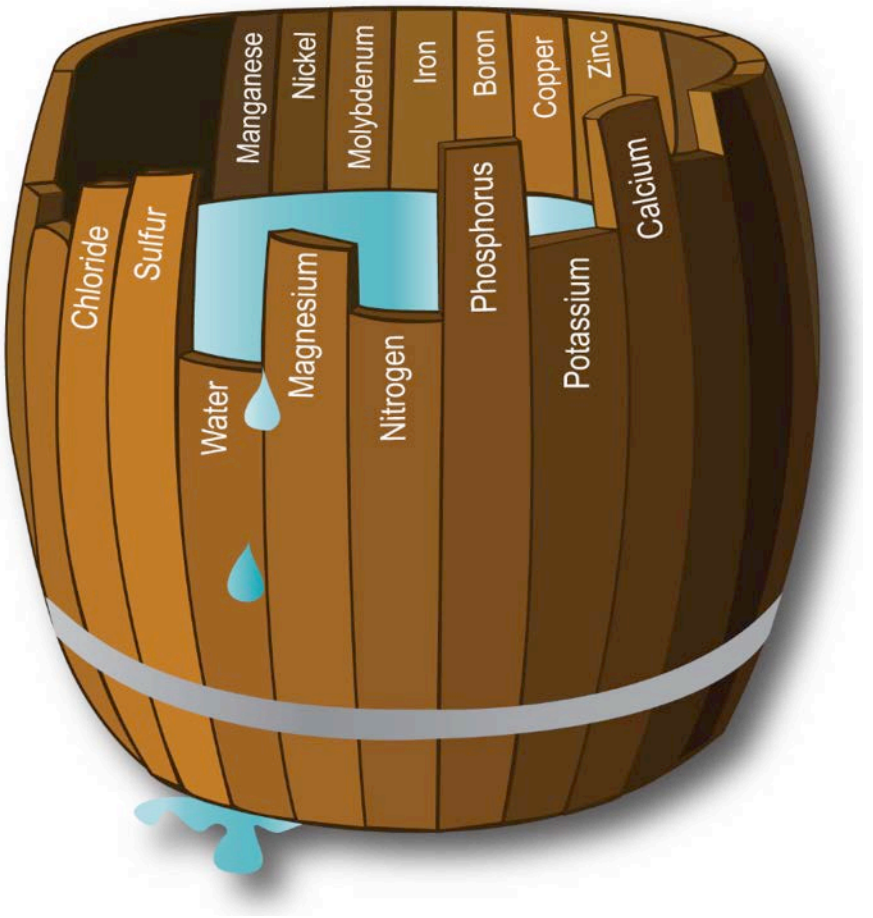
- First determine what nutrients are needed to achieve the production goals

- 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:

<u>Ancient seas</u>: Canada, Germany, U.K., Russia, etc.

<u>Salt water brines</u>: Great Salt Lake, Dead Sea

Various mineral salts are separated and purified

Potassium Chloride

Formula: KCl
K Content: ~60% K_2O
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

Potassium Chloride

Example

<u>Additional Considerations</u>: Grade (size)

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

Potassium Sulfate

Formula: K_2SO_4
K Content: 48-53% K_2O
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

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Potassium Nitrate

Formula: KNO_3
K Content: 46% K_2O
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

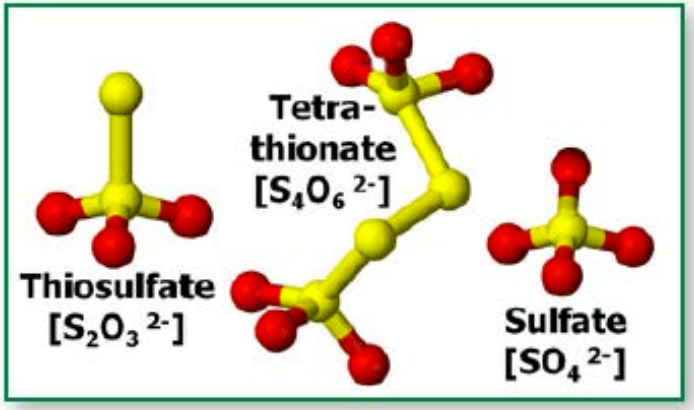
Formula: $K_2S_2O_3$
K Content: 25% K_2O
S Content: 17% S
Soluble fluid

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)

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

- Mined directly
- Prepared by dissolving $MgSO_4$ and adding KCl

Polyhalite

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

Solubility (20 C): **~25** g/L

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:
$K_2SO_4 \cdot 2MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$

Kainite (magnesia kainit)

Formula: $KMgSO_4Cl \cdot 3H_2O$ + Na salts
K Content: 11% K_2O
S Content: 4% S
Mg Content: 3%
Cl Content: 43%
Na Content: 20%

Schoenite

Formula: $K_2SO_4 \cdot 2MgSO_4$
K Content: ~22% K_2O
S Content: ~22% S
Mg Content: ~11%

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Other Potash Fertilizers

Monopotassium phosphate (KH_2PO_4)
(0-52-34) Reaction of KCl and phosphoric acid
for fertigation, foliar spray, hydroponics (pH 4-5)

Dipotassium phosphate (K_2HPO_4)
(0-41-54) Reaction of KCl and phosphoric acid
for fertigation, foliar spray, hydroponics

Potassium hydroxide (KOH)

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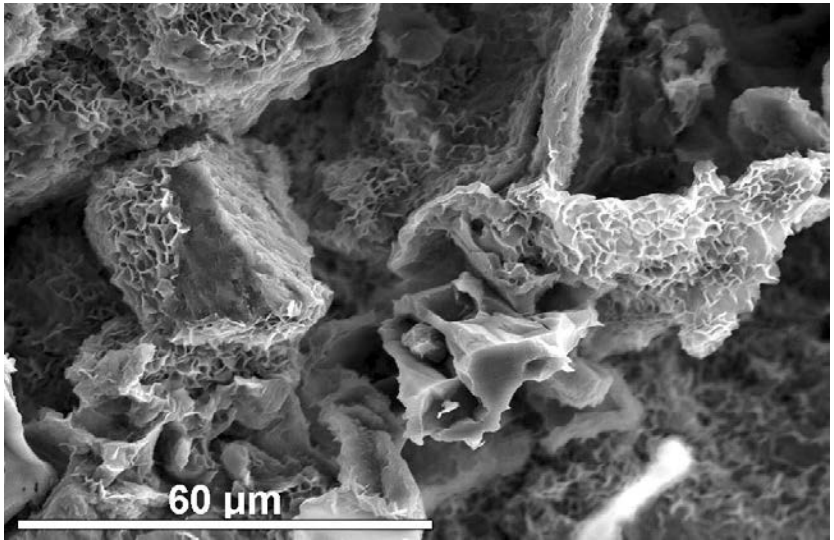
Less-soluble K minerals

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

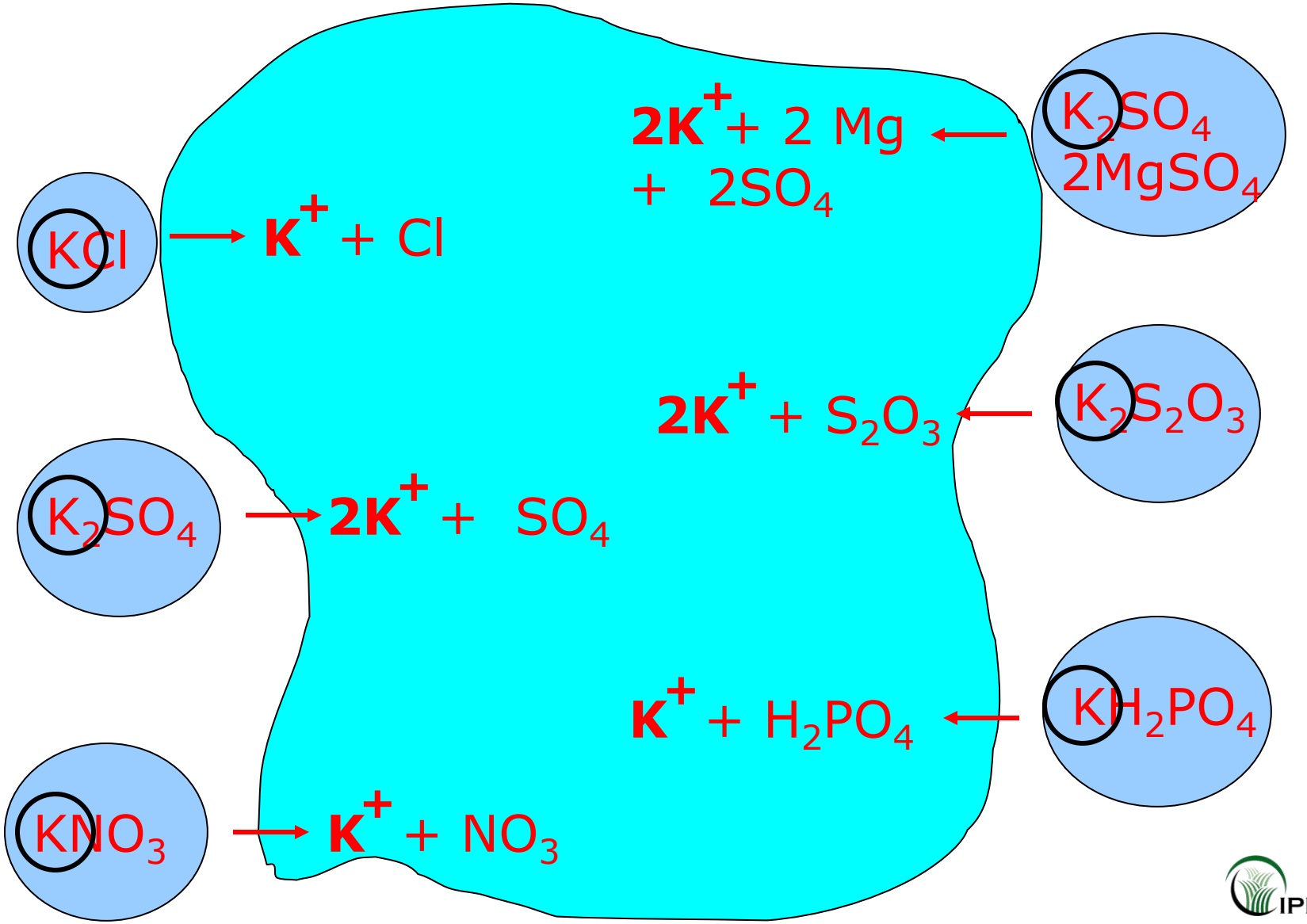


Montmorillonite:
Mineralogical Society of Great Britain

Organic materials

- 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?



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

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Nutritional Deficiencies

Sulfur deficiency

Magnesium deficiency

Calcium deficiency

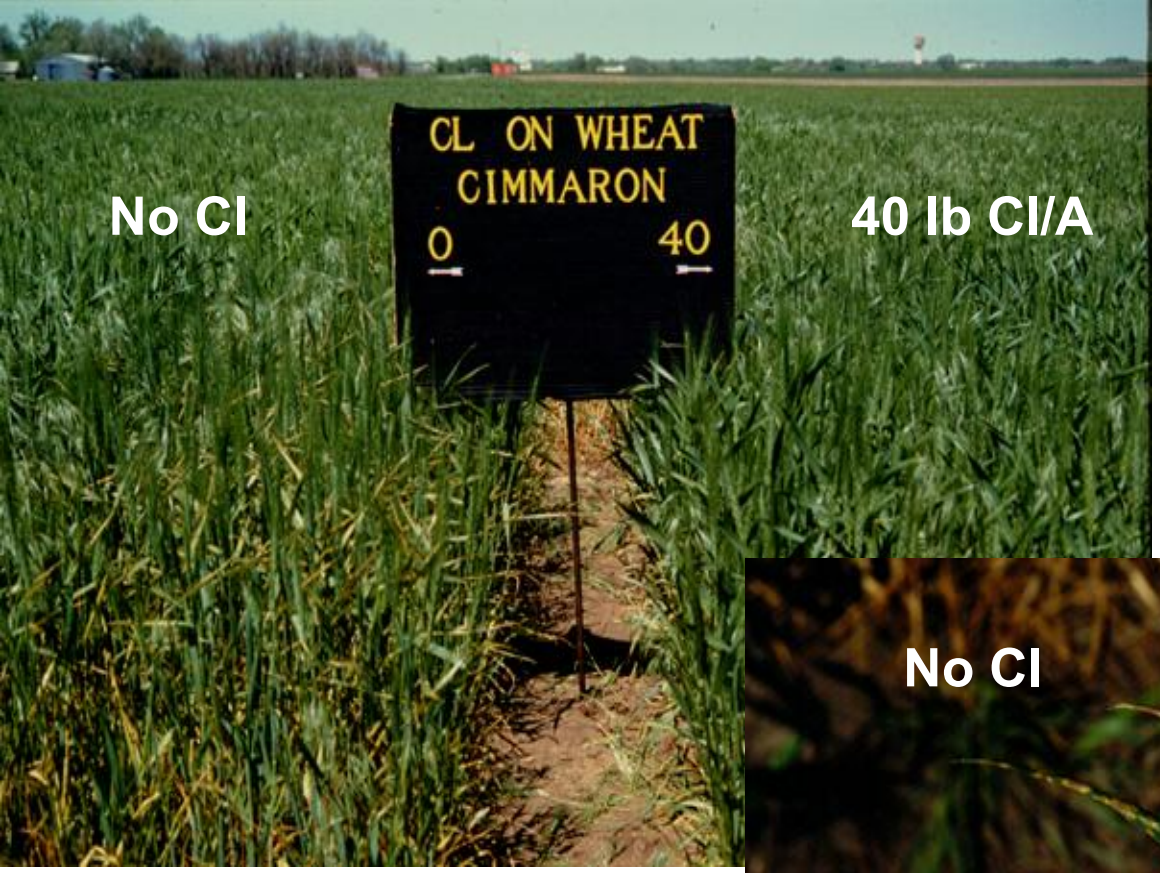
Phosphorus deficiency

grape

avocado

Some crops sensitive to excess chloride

Some crops responsive to chloride



Salt Index of K fertilizers

K Fertilizer Source	Salt Index - per unit of K_2O -
Potassium Sulfate	0.9
Potassium Nitrate	1.6
Potassium Chloride	1.9
K/Mg Sulfate	2.0
Potassium Thiosulfate	2.6

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Practical Example of Salt Damage:

Seed-Placed Fertilizer Calculator

Relative Injury Potential

10-34-0 (9.6) (*low*)
TSP (12.8)
Langbeinite (17.1)
K_2SO_4 (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?

Gelderman: Seed Damage Calculator (seed-damage-calculator.herokuapp.com)

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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

Not all fertilizer sources can be blended together

Fluid Fertilizer Foundation — Solutions for AGRICULTURE

FluidFertilizer.com

- 'Compatible', results in generally acceptable mixture.
- 'Limited Compatibility', generally compatible within solubility limits.
- Very Limited Compatibility', generally unsuitable mixtures.
- 'Incompatible', unsuitable mixture and/or hazardous combination.
- Δ Significant heat generated.

	Anhydrous Ammonia	Aqua Ammonia	Urea Solution	Ammonium Nitrate Solution	UAN Solution	Ammonium Sulfate Solution	Ammonium Polyphosphate Solution	Ammonium Chloride Solution	Ammonium Thiosulfate	Potassium Thiosulfate	Calcium Thiosulfate	Magnesium Thiosulfate	Calcium-Ammonium Nitrate Solution	Calcium Nitrate Solution	Potassium Carbonate Solution	N-pHuric 28/27	N-pHuric 15/49	N-pHuric 10/55	Water	Nitric Acid	Phosphoric Acid (white)	Phosphoric Acid (green)	Sulfuric Acid	Urea; 46-0-0	Ammonium Nitrate; 34-0-0	Calcium Nitrate; 15.5-0-0-19Ca	Potassium Chloride; 0-0-62	Potassium Nitrate; 13-0-46	Magnesium Nitrate; 10-0-0-9Mg	Monoammonium Phosphate (Technical, 12-61-0)	Monopotassium Phosphate (0-52-34)	PeKacid (0-60-20)
Anhydrous Ammonia ; 82-0-0																																	
Aqua Ammonia; 20-0-0	Δ																																
Urea Solution; 23-0-0	Δ																																
Ammonium Nitrate Solution; 20-0-0	Δ																																
Urea Ammonium Nitrate Solution; UAN 28/32-0-0	Δ																																
Ammonium Sulfate Solution; 8-0-0-9S	Δ	Δ																															
Ammonium Polyphosphate Solution; 10-34-0	Δ	Δ																															
Ammonium Chloride Solution; 6-0-0-16Cl	Δ																																
Ammonium Thiosulfate Solution; ATS, 12-0-0-26S	Δ																																
Potassium Thiosulfate Solution; KTS, 0-0-25-17S																																	
Calcium Thiosulfate; CaTS, 6%Ca 10%S								?																									
Magnesium Thiosulfate; MgTS, 10%S 4%Mg								?																									
Calcium-Ammonium Nitrate Solution; 17-0-0 8.8Ca																																	
Calcium Nitrate Solution; 8-0-0-11Ca								?																									
Potassium Carbonate Solution; 0-0-32								?																									
N-pHuric 28/27; 28-0-0-9S		Δ																															
N-pHuric 15/49; 15-0-0-16S		Δ																															
N-pHuric 10/55; 10-0-0-18S		Δ																															
Water	Δ																																
Nitric Acid	Δ	Δ	Δ	Δ		Δ	Δ																										
Phosphoric Acid (white)	Δ	Δ	Δ			Δ	Δ							Δ																			
Phosphoric Acid (green)	Δ	Δ	Δ			Δ	Δ							Δ																			
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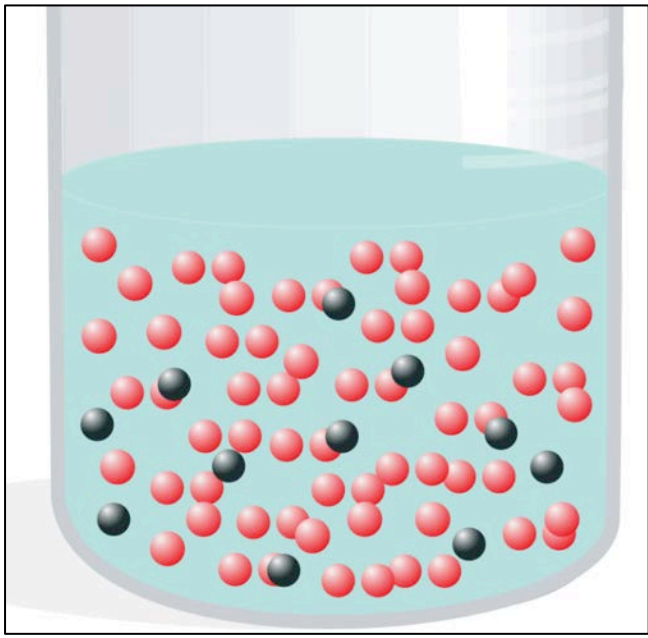
PeKacid (0-60-20)								?																									

- 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 <u>any</u> 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_2O)

K_2SO_4: \$585/ton (50% K_2O)

KNO_3: \$880/ton (44% K_2O)

Langbeinite: \$310/ton (22% K_2O)

Greenmarkets, Jan 2017

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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

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