Potassium: Use and Application and Availability in Soils

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Plant Physiology of Potassium

- Activator of enzymes
- Involved in stomatal function
- Helps to regulate ion balances in cells
- Involved in sugar synthesis
- Increases oil content in pistachio fruit
- Contributes to cold hardiness

Potassium Deficiency

- Leaves become pale during summer
- Leaflets fold upward and curl in
- Yellow tips that progress inward; tissue eventually browns
- Slow growth
- Small leaves
- Low yield

Physiology of Potassium

- Most potassium needed by bearing trees is to supply the fruit
- Most of K uptake in bearing trees is for kernel fill
- 29 lbs K_2O removed per 1000 lbs of nuts removed
- 27 lbs K_2O needed to supply tree growth

Physiology of Potassium

Table 3. Uptake of N, P, and K (g per tree) duri… postharvest–leaf senescence periods and removal in fruits and leaf litter in on- and off-year trees.[1]

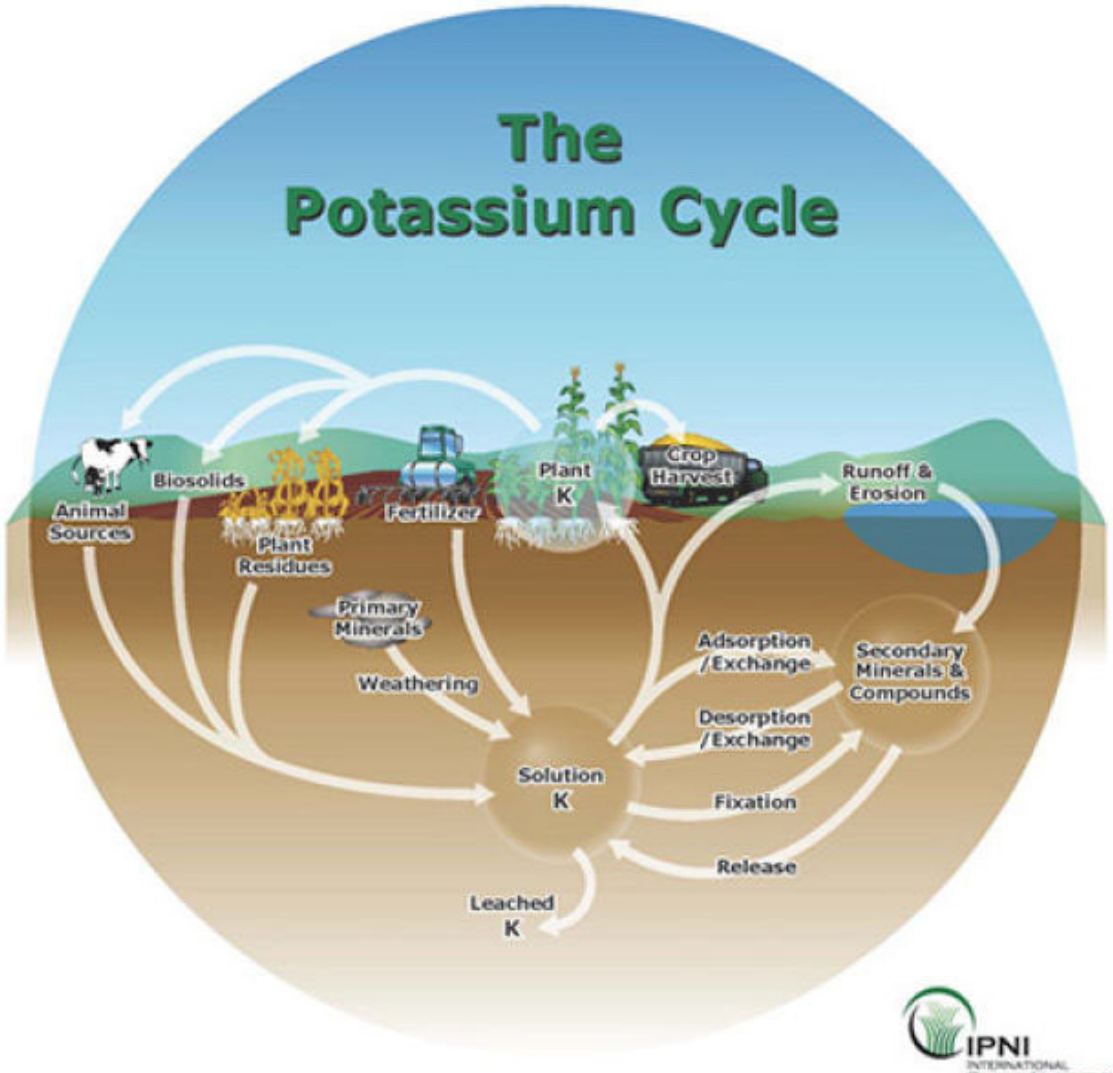
Grams nutrient/tree

Cropping	Nutrient uptake				Nutrient removal	Annual change[2]
	Spring flush	Nut fill	Postharvest	Total		
Nitrogen						
On-year	243	543	3	789	1167 a[3]	–378
Off-year	317	403	0	720	264 b	+456
Phosphorus						
On-year	3	54	0	57	113 a	–54
Off-year	26	47	0	73	18 b	+55
Potassium						
On-year	0	1014 a	74 a	1088 a	1019 a	+69
Off-year	3	479 b	0 b	482 b	387 b	+95

[1] Nutrient uptake determined from differences in tree nutrient contents from sequential tree excavations.
[2] Difference between total annual nutrient uptake and removal in fruits and abscised leaves.
[3] Within a column, values followed by different letters are significantly different at $P \leq 0.05$, according to the F test.

Leaf analysis levels

Critical Value	Adequate
1.6%	1.8 – 2.2%



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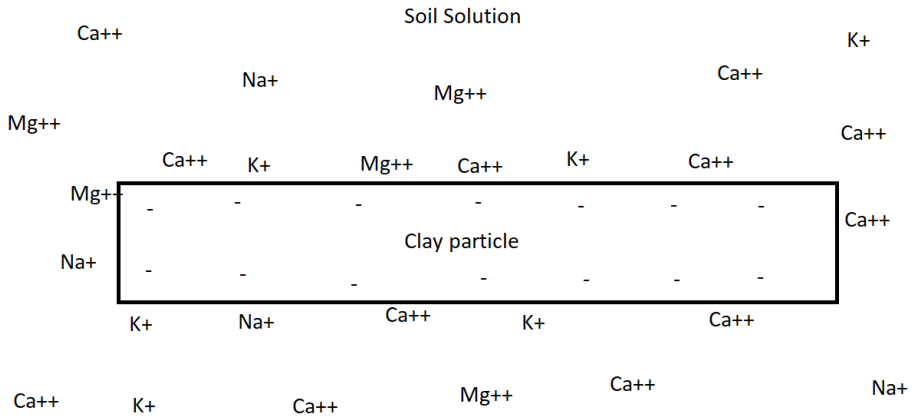
IPNI International Plant Nutrition Institute

Potassium in Soils

- Potassium is immobile in soils because it is loosely bound onto negatively charged clay and organic matter
- Clay and organic matter forms the “CEC”
- The size of your CEC is dependent on how much clay and organic matter you have



Cation Exchange Capacity

- The CEC acts as a reservoir for positively charged ions
  - K, Ca, Mg? Good!
  - Na: bad!
- When thinking about cations, you also must be thinking about the CEC size
- Lab tests will give you ppm K, %K on the CEC, or both
  - %K is usually more useful, since it gives you an idea of how much of the CEC is taken up by K
- *Rough* rule of thumb: soils are "deficient" in K with either less than 200 ppm OR 2% of the CEC
- It's best to just apply what has been lost via crop removal

Potassium Fixation: a special concern in Vermiculite or mica rich soils

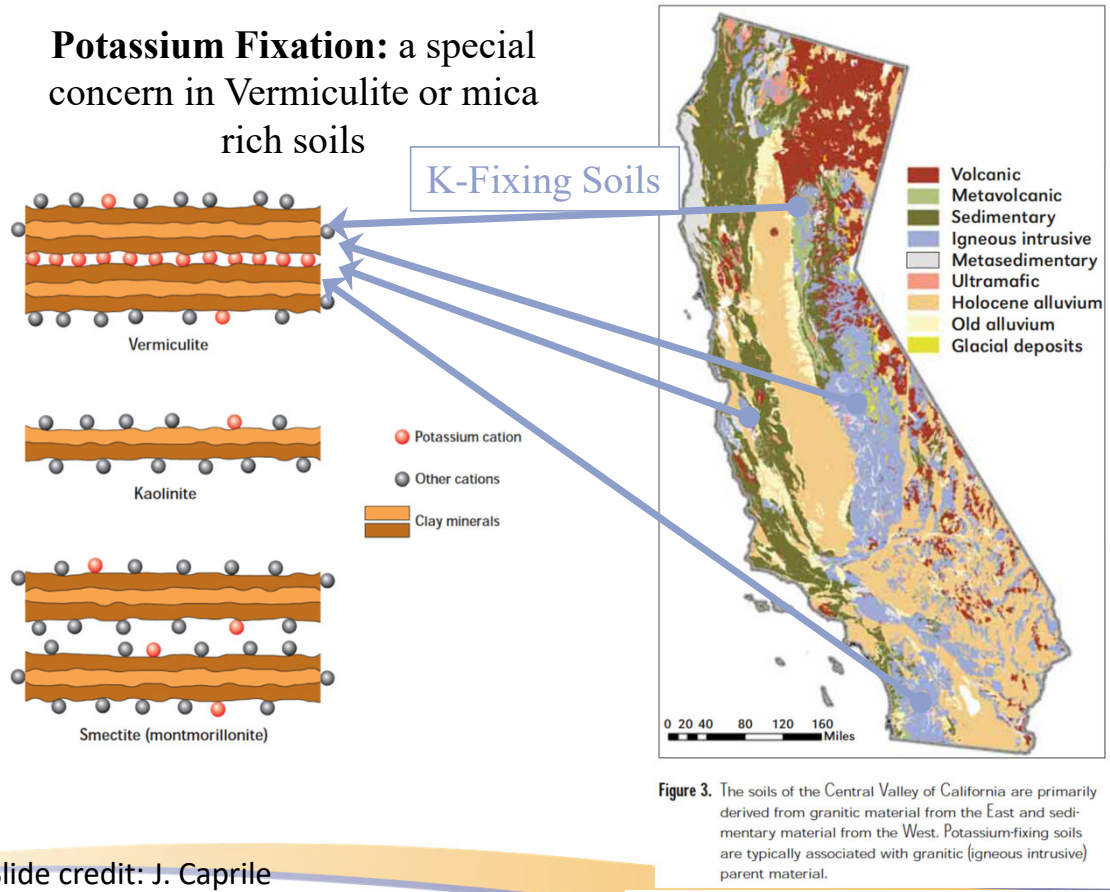


Figure 3. The soils of the Central Valley of California are primarily derived from granitic material from the East and sedimentary material from the West. Potassium-fixing soils are typically associated with granitic (igneous intrusive) parent material.

Slide credit: J. Caprile

Pettygrove et al, Better Crops 2012

Potassium Fixing Soils

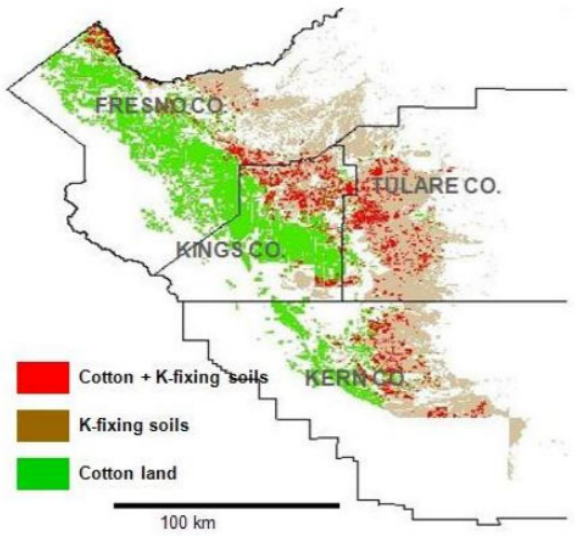


Figure 1: Potentially K-fixing soils based on model and land in cotton production at least one year during 1998-2000 [6].

Geissler and Horwath. 2016. Potassium Fixation in the San Joaquin Valley

- Ammonium acetate test not appropriate for soils that fix K
- Fixed K becomes available over time
  - Rate can change based on soil
- Do not add K fertilizers far in advance of tree needs in K fixing soils

Cation antagonism

- Carrier proteins for nutrient uptake is not always specific to an ion
  - Worse for cations of similar charge and/or size
  - Example: K^+ and Na^+, K^+ and NH_4^+
  - Also Ca^{2+}, Mg^{2+}, K^+
  - Cl^- and NO_3^-
- But you can have ion antagonism in extreme cases
  - E.g. Ca deficiency in high Mg soils such as serpentine
  - Depression of one cation with application of fertilizer containing another
- Not much evidence that there is an ideal cation 'ratio' that is perfect across all sites
  - Maintaining this may be expensive

Soil Tests

- Ammonium Acetate extraction:
  - Supposed to measure available K
  - Not great at estimating available K in fixing soils
- Water soluble (saturated paste extraction):
  - Only removes water soluble K
  - No sufficiency standards developed
- AA tests will tell you ppm in soil
- Labs will calculate %K for you
- CEC in most cases is estimated
  - Can be VERY inaccurate if recently applied gypsum, lime and sampler took no steps to exclude it

Potassium Fertilizers

- K_2O: Potassium Oxide, known as potash. Not actually in fertilizers! 83%K

Source	Formula	% K_2O	Solubility@ 20 C° (grams/liter)	% K_2O in a saturated solution	Cost per lb K_2O
Potassium Chloride	KCl	63	255	16.1	$0.41
Potassium Sulfate	K_2SO_4	54	111	5.4	$0.67
Potassium Nitrate	KNO_3	47	209	11.2	$1.33
Potassium Thiosulfate	$K_2S_2O_3$	25	complete	25	$1.38

Solubility data may differ by manufacturer, or if the amount of impurities is high

Costs are quotes from 2019, and actual prices may differ

Previous Research

- Patrick Brown, Brent Holtz, and Quipeng Zeng looked at K fertilization in a mature pistachio orchard in a San Joaquin series soil
- They added 0, 100, 200, 300 lbs of K/acre
- Looked at three different sources: K_2SO_4, KCl, KNO_3
- Trial lasted 3 years, with K split into 4 applications per year

Zeng, Brown, and Holtz.

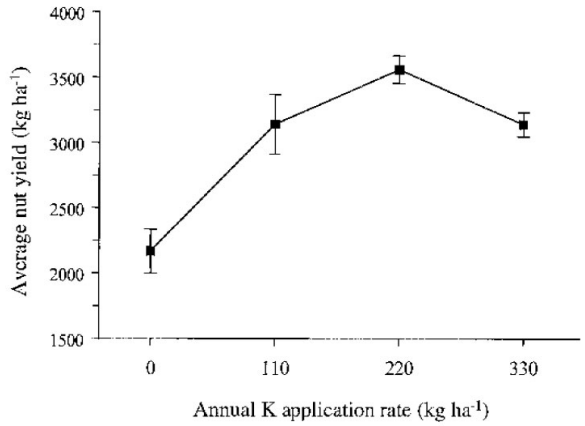


Fig. 4. Yield of in-shell pistacio nuts (average of 3 years) as affected by K applied as K_2SO_4. Each value is the average of five replicates ± SE

- No difference between K source
- Yield maximized at 200 lbs/year

Zeng, Brown, and Holtz (2001)

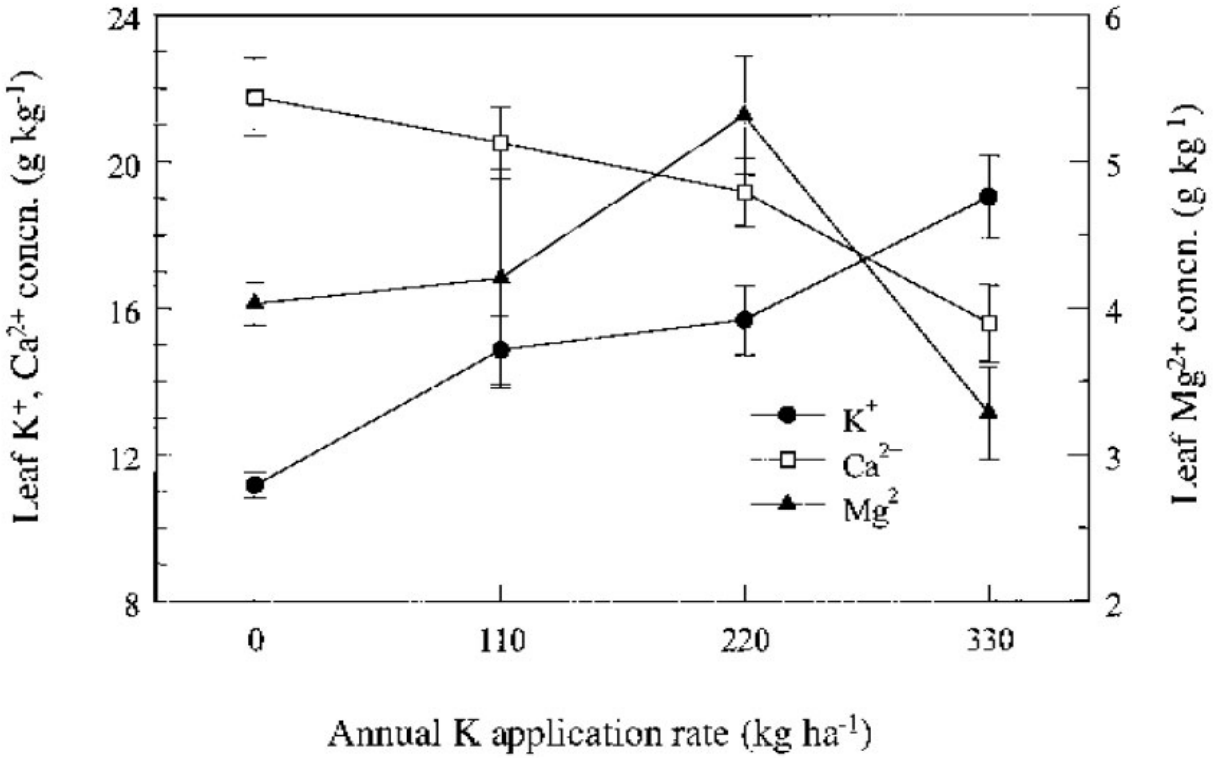


Fig. 3. Changes in leaf K^+, Ca^{2+}, and Mg^{2+} concentrations in pistachio leaves sampled in July 1998 in response to K applied as K_2SO_4 at various rates. Each value is the average of five replicates ± SE.

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Solubility

- Tells you the maximum amount of a salt that will dissolve in pure water at a given temperature
- Solubility of potassium fertilizer does not change how potassium ultimately behaves in the soil
  - But there are tricks that can reduce the importance of fixation
- **Easily soluble fertilizer applied early in the season (or last year) in potassium fixing soils can still be fixed**
- The key to potassium fertilizer application is applying a product that works for you in a way that is *appropriate for your soil*

Solubility of Fertilizers and Application

- Solubility can become be an issue in fertigation, particularly if you like to apply all of your K over a small number of applications
- Higher soluble fertilizers are more efficient lb/lb, (You can deliver the same amount of dissolved K_2O in less water than lower soluble fertilizers) but there are no differences in 'available' potassium

Fertigation vs Banding?

Treatment	1996	1997	1998	1999
No K	2192	2500	2868	2904 d
0.38 kg SOP	2382	2719	2916	3313 bc
0.75 kg SOP	2305	2797	2792	3335 abc
0.38 kg MKP	2251	2862	3067	3727 a
0.38 kg KTS	2345	2867	2824	3015 cd
0.75 kg SOP banded	2275	2978	2585	3534 ab

Adapted from: Edstrom, J.P. and Meyer, R.D., 2006, August. Potassium fertilizer application in drip and micro-jet irrigated almonds. In *V International Symposium on Irrigation of Horticultural Crops 792* (pp. 257-263).

- Banded SOP achieved similar yields in year three to fertigated SOP (same rate)
- MKP was (not significantly) best – unknown if this was due to P or something else

Fertigation vs soil application?

ppm potassium (via ammonium acetate extraction) of soils after 2.5 lbs K had been 'broadcast' under the emitter or fertigated									
	0 feet from emitter			1 foot from emitter			2 feet from emitter		
Soil depth	Broadcast	Fertigated	Control	Broadcast	Fertigated	Control	Broadcast	Fertigated	control
0-6"	2131	520	270	164	512	250	164	305	289
6-12"	2714	414	141	137	395	137	141	180	98
12-18"	3284	332	113	109	258	102	121	117	70
18-24"	3288	230	74	78	407	70	78	94	94
24-30"	1634	100	70	74	228	66	74	63	106
30-36"	176	66	90	86	90	82	98	86	86

Uriu, K., R.M. Carlson, D.W. Henderson, H. Schulbach, and T.M. Aldrich. 1980. Potassium fertilization of prune trees under drip irrigation. J. Amer. Soc. Hort. Sci. 105:508–510.

Fertilizer Application Strategies

- Banding SOP works in any soil type, as long as it is banded in the *wetted zone* of your irrigation system
  - Because surface-applied K mostly stays put, fertilizer that can only be dissolved by rain will not be in the root zone
- In K-fixing soils: banding saturates the fixation capacities of a soil, ensuring K is available for uptake
- Fertigation can avoid fixation, *but only if it's applied in season*
- Banding can be a great addition to fertigation, especially in non-fixing soils

When to fertilize

- If your trees are very deficient (< 1.6% K):
  - Apply high rates and monitor leaf levels closely
  - 100-200 lbs K_2O/acre overcame deficiencies in a loam soil
- If your trees are not deficient, apply to replace what's been removed
  - It's always better to maintain levels rather than remedy deficient trees

Maintenance fertilization rates

Yield (kernel lbs/acre)	K_2O/acre
1000	55
2000	84
3000	113
4000	142
5000	171

29 lbs K_2O removed with every 1000 lbs kernels

27 lbs K_2O needed for tree growth

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Table 3. Uptake of N, P, and K (g per tree) during spring flush, nut fill and postharvest–leaf senescence periods and removal in fruits and leaf litter in on- and off-year trees.[1]

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When to fertilize

- Non-potassium fixing soils
  - Apply whenever you like, however you like
  - Band? Make sure it's in the wetted zone
- Potassium fixing soils
  - Fertigation: start a little before trees need it (nut fill/Stage 3), split applications between April-August
  - If soil applying, **BAND** to overcome fixation, and ensure the fertilizer is in the wetted zone
  - You can do both!

Thank you!

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