MODIFICATION OF CITRUS IRRIGATION WATER

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Immokalee

Bicarbonate bad guy in Western soil, water

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- Water from deep aquifers often contains elevated levels of bicarbonates.
- Bicarbonates can accumulate in irrigated area.
- High levels of bicarbonates pull calcium out of solution, reducing the presence of calcium on soil exchange sites.
- Bicarbonate levels in irrigation water are:
  - 0-100 ppm (low)
  - 100-180 ppm (moderate
  - 180-600 ppm (severe)

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Alkalinity

- Primarily determined by presence of bicarbonates (HCO_3^-), Carbonates (CO_3^-), and hydroxides (OH^-) in water.
- A measure of the capacity of water to neutralize acids.
- Alkaline compounds in water remove H^+ ions and lower the acidity of water (increase pH).
- Limits nutrient availability in soils

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Bicarbonate Levels in Irrigation Water

- Dissolved CO_2 in water exists in two forms:
  - CO_2 + H2O   H2CO3 (carbonic acid)
  - $H2CO_3 + OH^-$ $H_2O + HCO_3$- (bicarbonate)
- Carbonic acid (H_2CO_3) dominate in water below pH 6.
- Bicarbonates dominate in water between pH 6 and 10.

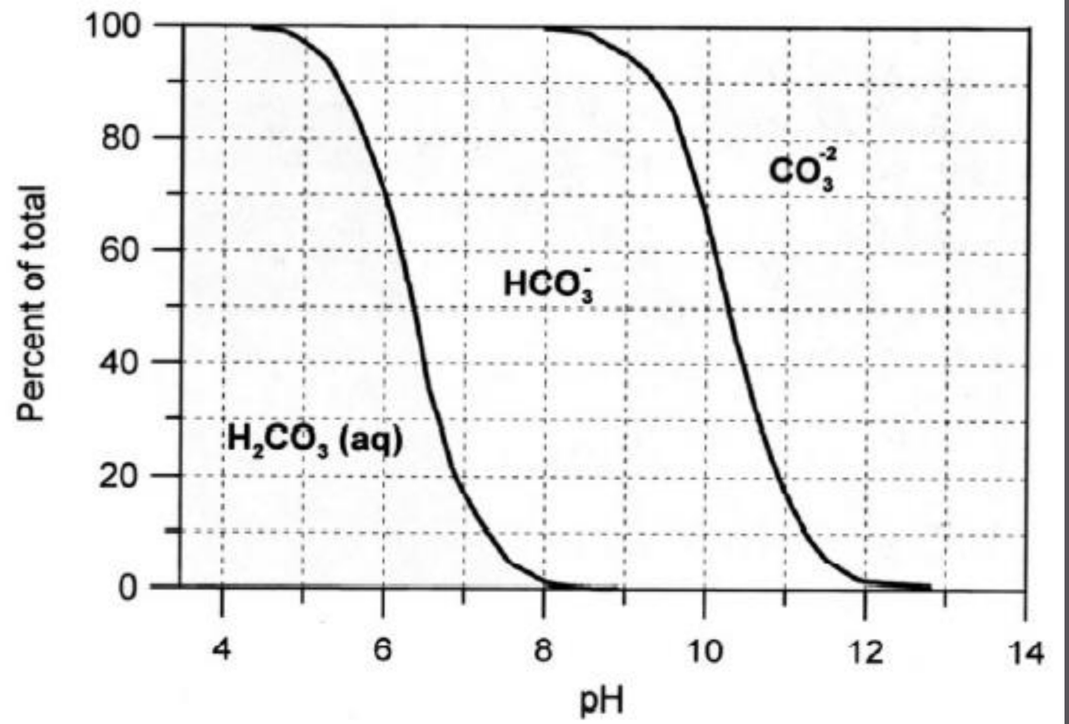

Figure 2. Percentages of total dissolved carbon species in solution for various pH ranges at 25°C and

Source: Boman, B.J., P.C. Wilson and E.A. Ontermass. Understanding Water Quality Parameters for Citrus Irrigation and Drainage Systems. IFAS Circular 1406

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Bicarbonates in Water

- Water above pH 7.5 is usually associated with high bicarbonates.
- Recommend levels of 2 mg/l or less
- Forms bicarbonate salts with Ca, Mg, Na, and K.
- High Ca concentrations will react to form Calcium carbonate or line.
- Particulates can drop out of water and plug emitters or microsprinklers.
- Soils with excess Ca forms $CaCO_3$ (lime).

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Bicarbonates in Soil

- Makes phosphorus more available by tying up calcium, increasing the solubility of calcium phosphates.
- Higher calcium carbonate in soils increases pH making many nutrients less available.
- Bicarbonates have a physiological affect on roots reducing nutrient absorption.
- Treatments:
  - calcium or gypsum (calcium sulfate) to increase calcium availability to plants and soil,
  - elemental sulfur can be used to reduce soil pH,
  - applications of acidified water or acidic fertilizer.

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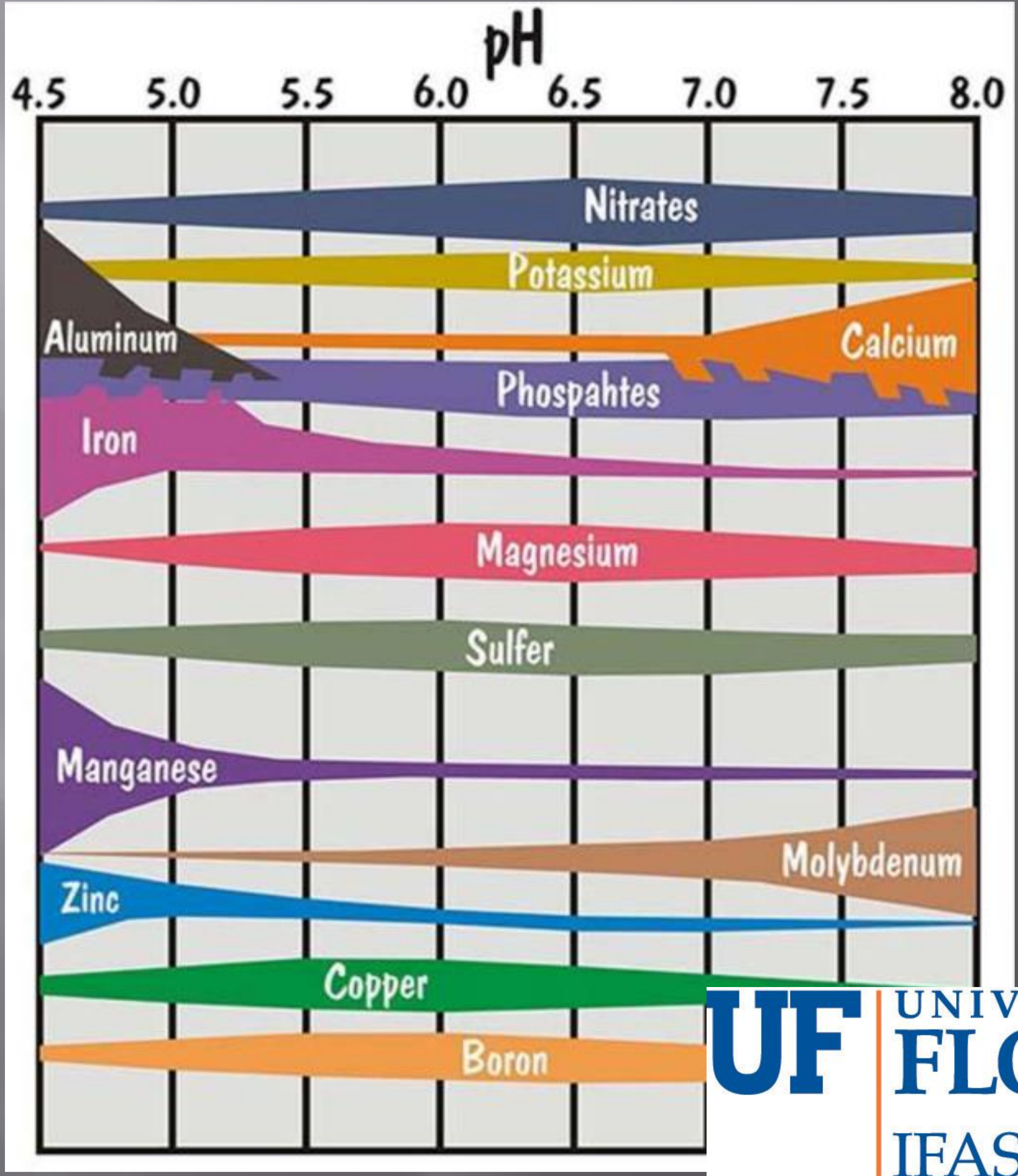

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Plant Uptake

- Soil pH and bicarbonates affect nutrient availability and root uptake.
- Bicarbonate induced chlorosis is caused by transport of bicarbonate into the plant leading to reduced nutrient uptake.
- Lime-induced chlorosis affects many annual crops and perennial plants growing on calcareous soils.
- The reduction of plant biomass in susceptible plants is related to a reduced root growth leading to a lower photosynthesis rate which also depends on the reduced leaf area per plant and chlorophyll concentration encountered under iron stress conditions.

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Conclusions from Literature

- Many commercial root stocks do not perform well in high-carbonate soils.
- Inability to sufficiently extract micronutrients, including Fe, Zn and Mn.
- Limitation greatest for Poncirus trifoliata and its hybrids (e.g. Troyer, Carrizo and Swingle).
- Best adapted rootstocks are Sour Orange and Rough Lemon that have Tristeza and blight issues.

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Impact of Bicarbonates on Citrus Rootstocks

- Growth rate in soil amended with CaCO3
  - Cleo > sour orange > Volk. > Rangpur > Carrizo > Swingle

Table 8. Plant growth and changes in leaf greenness (n = 6) among rootstocks in the Summer 1999 iron nutrition trial conducted in soil amended with $CaCO_3$.

Selection	Fresh wt (FW) (g) Initial	Fresh wt (FW) (g) Final	FW rel. growth rate ($g \cdot g^{-1}$)	HT rel. growth rate ($cm \cdot cm^{-1}$)	Leaf greenness ratio[z]
Cleopatra mandarin	3.4 f[y]	87.2 de	24.4 a	6.7 a	1.1 c
Sour orange	5.8 cd	122.5 a	20.6 b	4.5 b	1.4 c
Sour orange + Carrizo citrange	6.5 bc	111.5 ab	16.5 c	3.7 bcd	1.4 c
Kinkoji	7.3 a	120.5 a	15.7 cd	4.5 b	1.0 c
Volkamer lemon	6.5 bc	105.9 abc	15.7 cd	4.4 b	1.4 c
Rangpur	5.8 cd	92.2 cde	15.0 cd	2.6 e	1.8 bc
Sunki × Benecke TF	5.1 d	78.4 e	14.5 cd	2.9 de	1.5 bc
Carrizo citrange	5.3 d	78.4 e	14.1 cd	3.0 cde	1.7 bc
Smooth Flat Seville	6.6 ab	95.5 bcd	13.8 cd	3.9 bc	1.7 bc
Cleo × Trifoliate orange	4.2 e	56.6 f	12.5 de	3.9 bc	2.0 bc
Swingle citrumelo	5.2 d	51.6 f	9.1 e	2.4 e	5.8 a
TF 50-7	5.6 d	33.8 g	5.1 f	1.1 f	2.5 b
$CaCO_3$ means					
0.4			15.6 a	3.8 ab	1.4 c
1.4			16.0 a	3.9 a	1.8 b
2.2			15.0 ab	3.7 ab	1.9 b
4.2			13.5 c	3.5 b	2.1 ab
5.9			13.9 bc	3.4 b	2.3 a
P values					
Rootstock	<0.0001	<0.0001	<0.0001	<0.0001	<0.000
$CaCO_3$	0.5244	<0.0001	<0.002	0.0135	0.001
Interaction	0.3816	0.5243	0.5688	0.086	0.099

[z]Readings taken with a SPAD meter. Ratio of lower:upper leaves after 14 weeks. Ratios 1.0 or greater generally indicate decreasing greenness of the upper leaf relative to the lower leaf.
[y]Mean separation by Tukey's honestly signi

Source: Castle, W.S., J. Nunnallee, and J.A. Manthey. 2009. Screening Citrus Rootstocks and related Selections in Soil and Solution Culture for Tolerance to Low-iron Stress. HortScience 44(3):638-645.

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Effect of Bicarbonate on Grape Production

- Conclusion, decreased photosynthesis, grape yield and total dry matter.

Table 3. Fruit (grape) yield and quality, at harvest time, in relation to the soil.

	Low-carbonate soil	High-carbonate soil
Grape cluster yield (kg plant^{-1})	2.56 a	0.36 b
Grape clusters per plant^{-1}	8 a	3 b
Cluster weight (g cluster^{-1})	320 a	140 a
Rachis length (cm)	13.4 a	6.5 b
Berries per cluster^{-1}	64 a	38 b
Berry weight (g berry^{-1})	5.0 a	3.7 b
Juice soluble solids (°Brix)	14.7 a	16.4 b
Juice titratable acidity (g L^{-1})	5.1 a	4.7 a
Juice pH	3.63 a	3.49 a

Note: Values followed by the same letter are not significantly different at 5% level by Tukey test.

Source: Bavaresco, L. and S. Poni. 2007. Effect of Calcareous soil on Photosynthesis Rate, Mineral Nutrition and Source-Sink Ratio of Table Grapes. Journal of Plant Nutrition 26:10-11.

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Water Treatment

- Standard treatment is to lower the water's pH by adding an acid. Lowering the pH to 6.5 neutralizes about half the bicarbonate in the water.
- Injection of acidified water instead of a dry material to a wide area will reduce bicarbonate accumulation in the irrigated area where irrigation may cause to accumulation.
- Most common acids to inject are sulfuric acid, phosphoric acid,

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Water Treatment (cont.)

- N-pHuric (urea and sulfuric acid) all the acidity of sulfuric acid but much less corrosive.
- N-pHuric or sulfuric acid acidification reacts with bicarbonates to form gypsum and H_2CO_3, which rapidly converts to H_2O and CO_2.
- Phosphoric acid and N-pHuric supplies fertilizers in addition to acidification.

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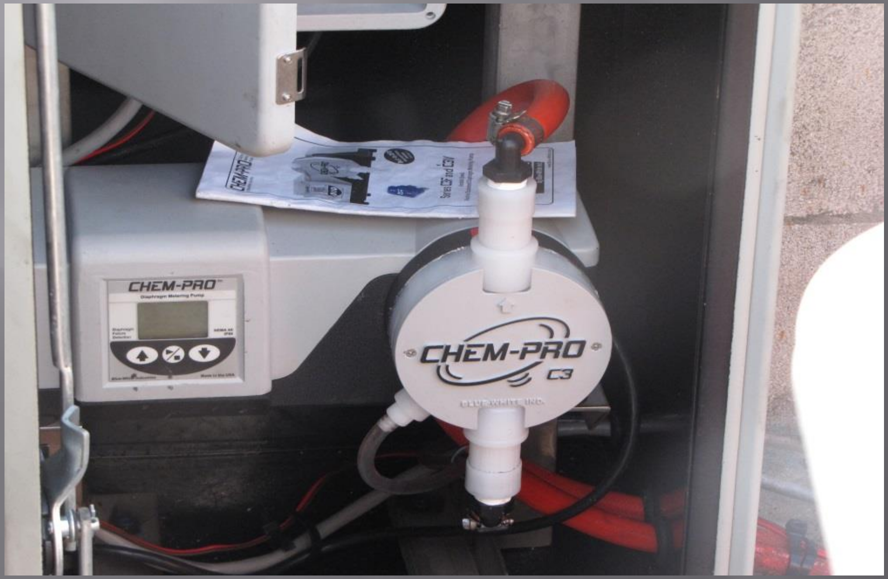
Water Acidification

INJECTION PUMP

- Direct injection of acid into irrigation water.
- Can be used to apply nutrients.



SULFUR BURNER

- Burns elemental sulfur to create SO_2 gas.
- Oxidized sulfur blends with irrigation water to create sulfurous acid (H_2SO_3).
- The solution is very mild compared to concentrated sulfuric

Conclusions

- Water from deep wells in limestone aquifers contain bicarbonates.
- Forms bicarbonate salts with Ca, Mg, Na, and K.
- Higher calcium carbonate in soils increases pH making many nutrients less available.
- Bicarbonates have a physiological affect on roots reducing nutrient absorption.
- Limitation greatest for Poncirus trifoliata and its hybrids (e.g. Troyer, Carrizo and Swingle).

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