Understanding the Potential Problem with High Bicarbonates in Irrigation Water

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Bicarbonate bad guy in Western soil, water

Reprinted from California-Arizona Farm Press, June 20, 1998

- 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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Bicarbonates in Water

- Water above pH 7.5 is usually associated with high bicarbonates.
- 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 effect 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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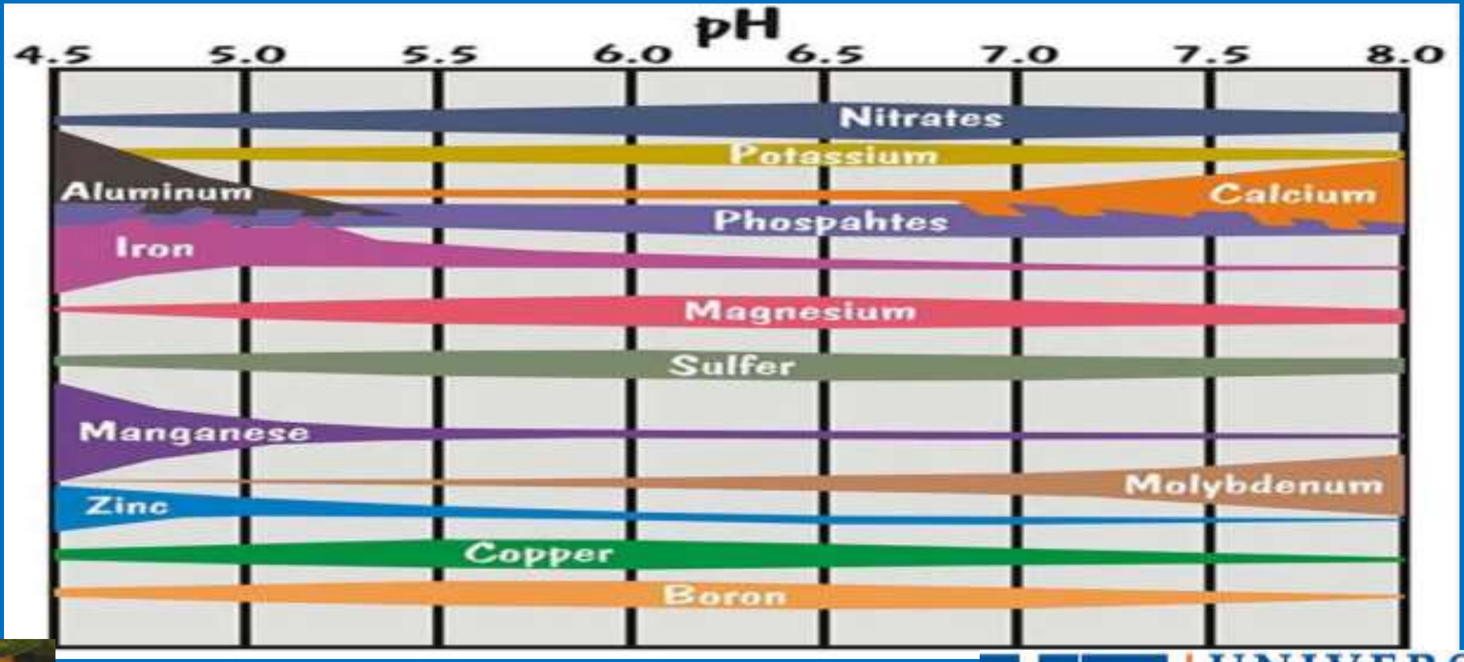
Nutrient Availability

- Soil pH and bicarbonates effect nutrient availability and root uptake.



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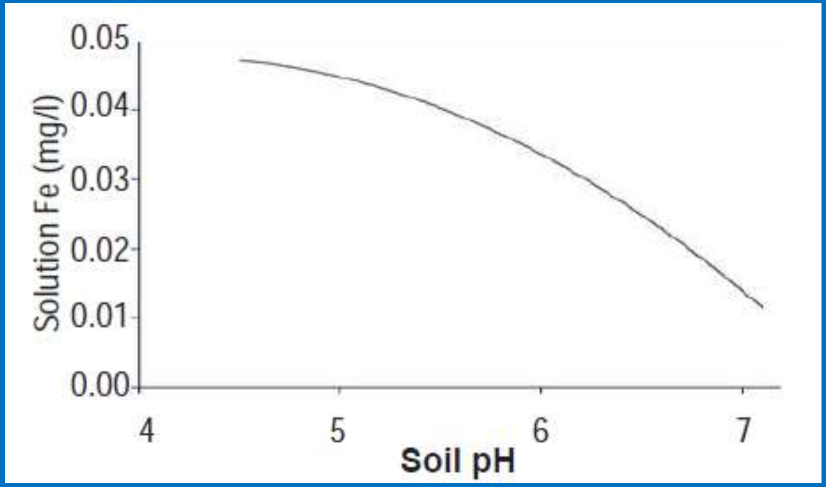
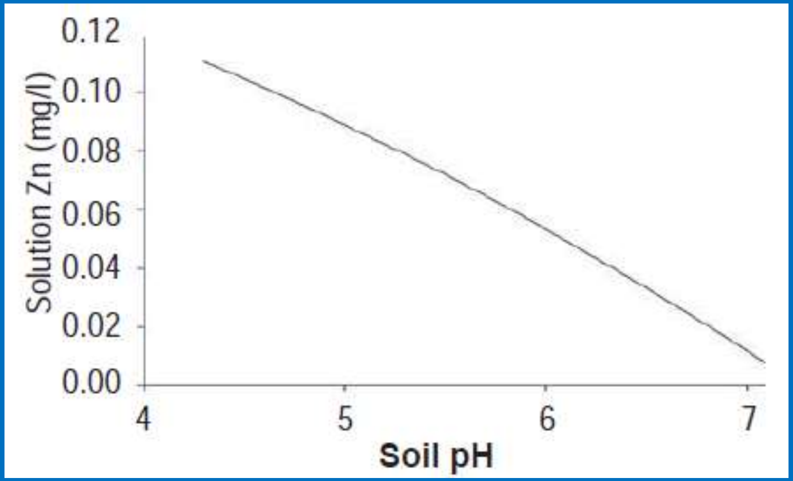
Plant Uptake

- Bicarbonate induced chlorosis is caused by transport of bicarbonate into the plant leading to reduced nutrient uptake.
- Lime-induced chlorosis effects many annual crops and perennial plants growing on calcareous soils.





Horneck, D. 2006. Acidifying Soil for Crop Production East of the Cascades. Oregon State

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Effect of Carbonates on Growth

- 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 significant difference test ($P \leq 0.05$).

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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Water Quality Limits

Test/analysis/ parameter	Suitability range	
pH	suitable for all plants	5.5 to 7.0
	possible phytotoxicity	< 5.0
	possible precipitation of salts, consequent blockages in irrigation system; problems with effective chlorination	> 7.5
Alkalinity (mg/L $CaCO_3$)	suitable for most plants	< 40
	increasing problems	90 to 120
	generally not suitable	> 125
Bicarbonate (mg/L)	suitable for most plants	< 90
	increasing problems with plant growth, staining and blockages in irrigation equipment	90 to 120

Yiasoumi, W. 2005. Farm Water Quality and Treatment, Agfact AC.2

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.
- Most common acids to inject are sulfuric acid, phosphoric acid.

Three acids are primarily used in western irrigation waters are listed in Table 1.

Table 1

Acid	Percent Acid	Chemical Formula	pounds per gallon
Phosphoric Acid	52-54%	P2O5	13.7-14
Sulfuric Acid	93-98%	H2SO4	15.3
Urea-Sulfuric Acid Fertilizer	27-55%	[(NH2)2 CO] H2SO4	11.87-12.80

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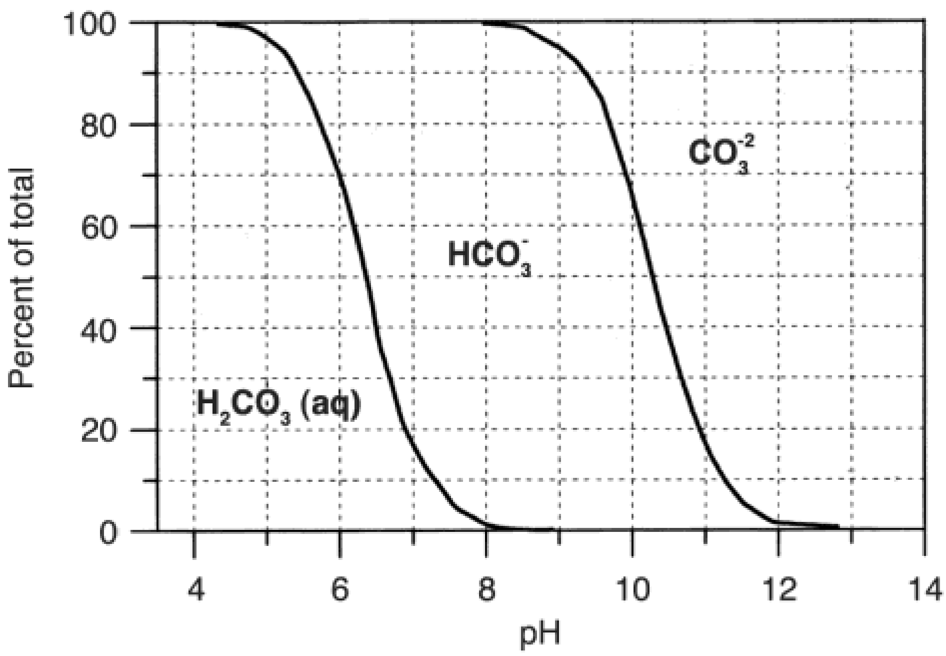
Water Treatment

- 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.



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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.

$$2HCO_3 + H_2SO_4 \longrightarrow SO_4 + 2H_2O + CO_2$$

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Sulfur Required to Reduce Soil pH

Approximate Pounds per Acre

Table 1. Rates of elemental sulfur required to decrease soil pH to a depth of 6 inches.

Desired change in pH	Application rate based on soil texture[1]		
	Sand	Silt loam	Clay
	---------------------- lb S/A ----------------------		
8.5 to 6.5	370	730	1460
8.0 to 6.5	340	670	1340
7.5 to 6.5	300	600	1200
7.0 to 6.5	180	360	720
8.5 to 5.5	830	1660	3310
8.0 to 5.5	800	1600	3190
7.5 to 5.5	760	1530	3050
7.0 to 5.5	640	1290	2580

Mullen, R, E. Lentz and M. Watson. Soil Acidification: How to Lower Soil pH.
Ohio State University FactSheet AGF-507-07

Conclusions

- BMPs are being developed for bicarbonate treatment.
- Water and soil bicarbonates should be addressed to allow for proper nutrient uptake.
- This appears to not have been a problem prior to HLB except in extreem cases.
- Micronutrient uptake may improve with soil bicarbonate treatment and provide sufficient tree health.

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Managing Fibrous Root Loss due to HLB

Jim Graham

Citrus Institute
April 8, 2014

Citrus Research and Development Foundation, Inc.

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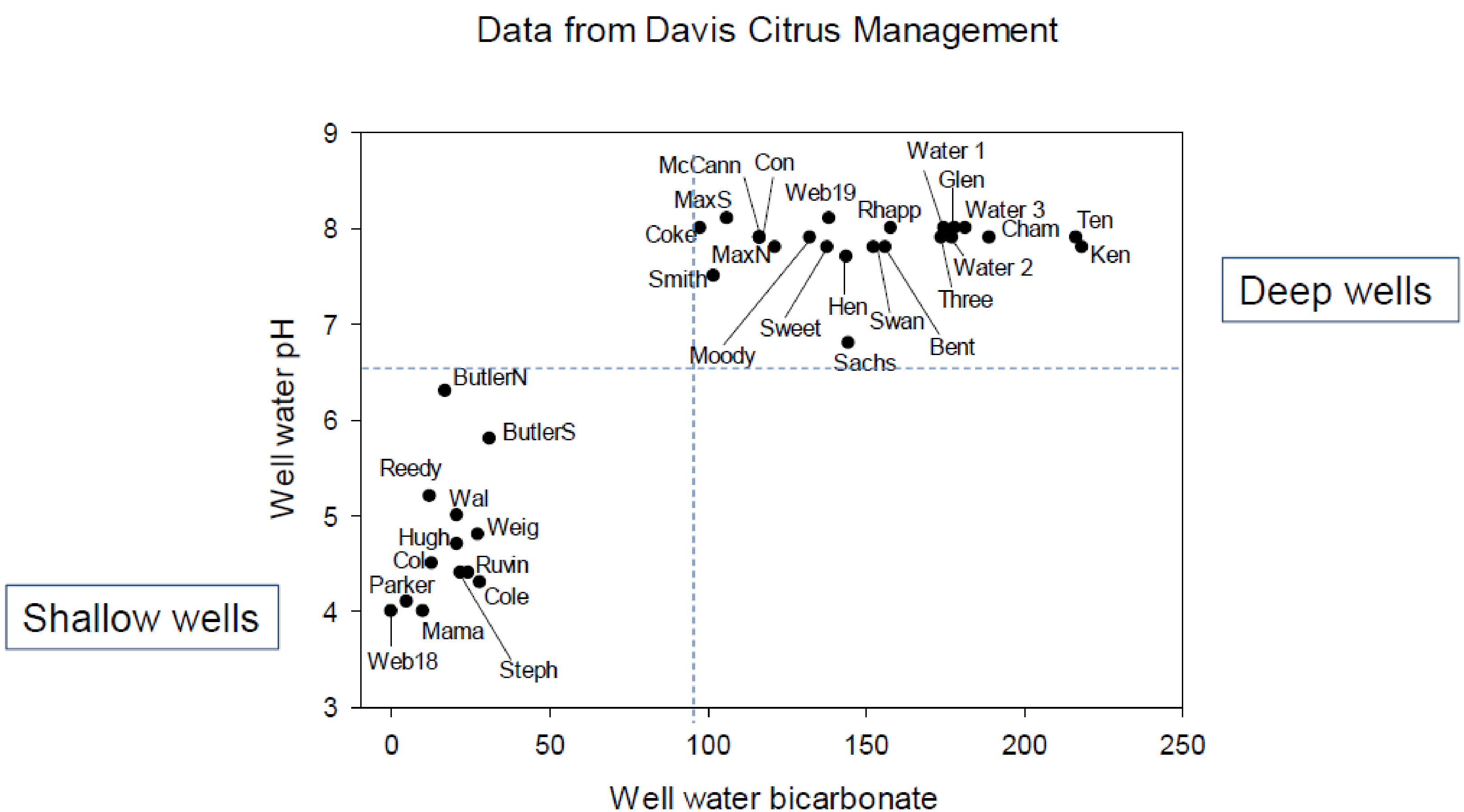
Health and fruit drop for 6 yr old Valencia/Swingle trees planted in different sub-blocks in 2007 from same nursery

Reset in Valencia half of block	Solid set in former grapefruit half of block)

<u>Soil pH 6.4: Fruit drop minimal</u>   **<u>Soil pH 7.2: Fruit drop result in early harvest</u>**

Compared 39 grove locations in Highlands and Desoto Co with varying liming history and irrigation with deep vs. shallow wells on Swingle and Carrizo



Relationship between bicarbonate status, root mass density and change in yield from 2009-12*

Grove status	No. of blocks surveyed	Root mass density (mg/cm^3)	Change in block yield from 2009-12
Low pH stress Ridge	14	0.6	Increased 6%
High pH stress Ridge	10	0.4	Decreased 3%
High pH stress Flatwoods	13	0.2	Decreased 20%

*Yield data kindly provided by Davis Citrus Management

Future Research Work

- Support by CRDF, SWFWMD and FDACS
- Current Research Work
- Determine benefits of bicarbonate treatment of HLB+ and HLB- greenhouse trees, and mature groves
- Water management of infected trees

Questions

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