Micronutrients:
The little guys matter too

Andrew G. Ristvey

UNIVERSITY OF MARYLAND
EXTENSION
Solutions in your community

Making the Plant Happy

Objectives for this topic include:

- What you should know before fertilizing – water quality
- pH affect on nutrient availability
- Nutrient interactions - direct and indirect deficiencies and toxicities
- The micronutrients

	Nutrient	%	ppm
Macronutrients	Nitrogen	1.5	
	Potassium	1.0	
	Calcium	0.5	
	Magnesium	0.2	
	Phosphorus	0.2	
	Sulfur	0.1	
Micronutrients	Chlorine		100
	Iron		100
	Manganese		50
	Boron		20
	Zinc		20
	Copper		6
	Molybdenum		0.1
	Nickel		0.05?

Factors that affect nutrient uptake

Where monitoring should start

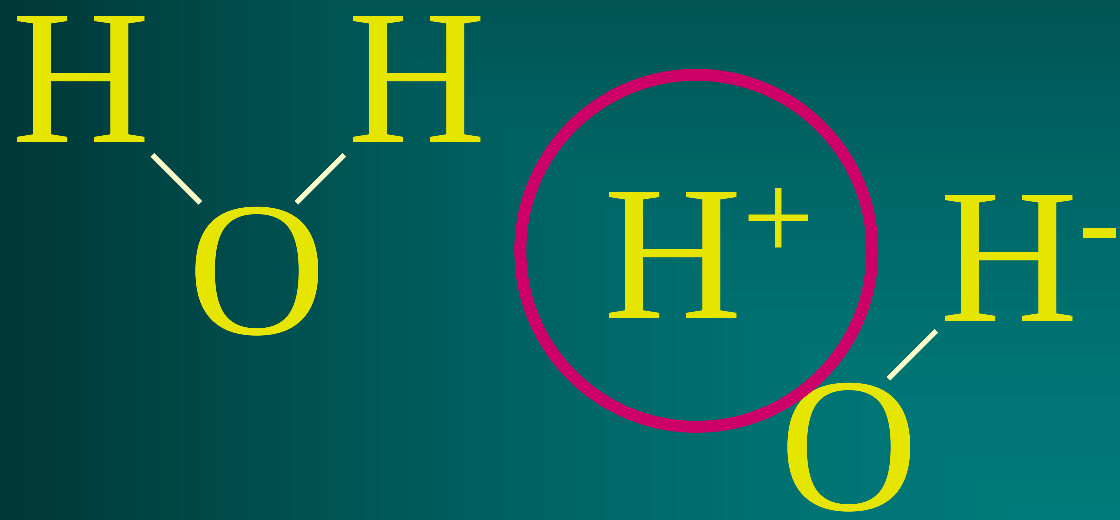
- What factors affect nutrient availability
  - water quality
  - pH
- Getting nutrients to the plant roots
  - Irrigation management - nutrients are water soluble

Water Quality

* pH and the effects on micros
* water quality and alkalinity

pH

H_2O



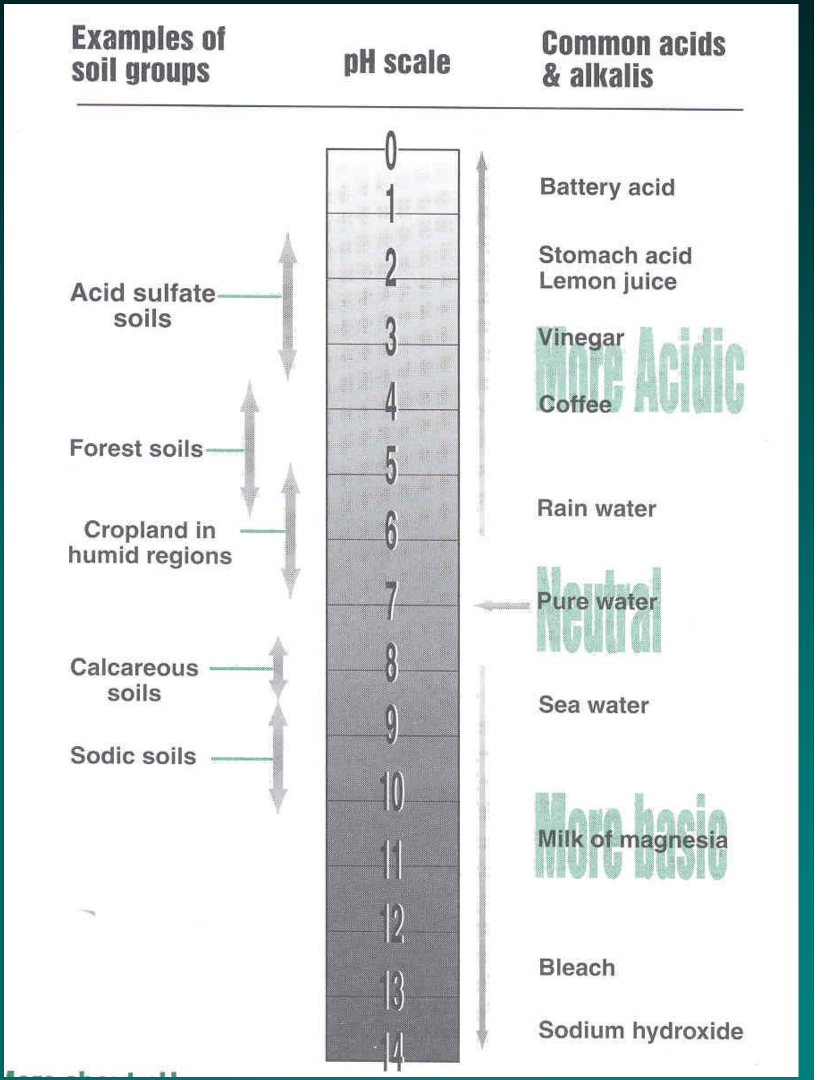
Properties Affecting Nutrient Availability

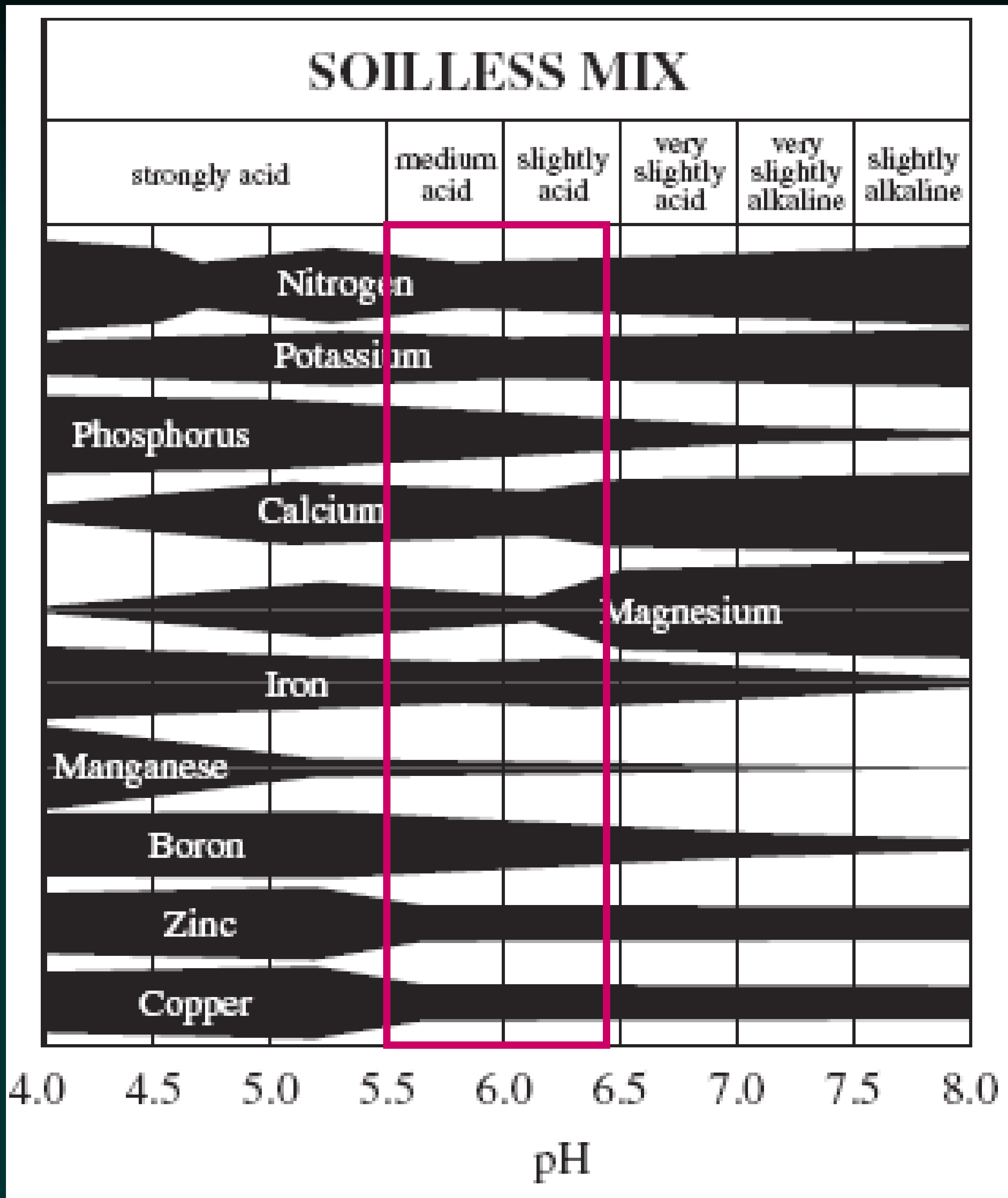
- Chemical Properties - pH

  p = potential or power

  H = hydrogen

  - pH and hydrogen ion concentration are inversely related.
  - As pH decreases, hydrogen ion concentration increases.





SOILLESS MIX
strongly acid
medium acid
slightly acid
very slightly acid
very slightly alkaline
slightly alkaline
Nitrogen
Potassium
Phosphorus
Calcium
Magnesium
Iron
Manganese
Boron
Zinc
Copper
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
pH

Irrigation Water Quality

It is essential
to have your water tested!

Irrigation Water Quality

Alkalinity

is a measure of a water's capacity to neutralize acids

is not a measure of calcium and magnesium

…that's Hardness

Irrigation Water Quality

Alkalinity

is a measure of a water's capacity
to neutralize acids

Major chemicals contributing to alkalinity:

Bicarbonate ions (HCO_3^-)

- calcium bicarbonate ($Ca(HCO_3)_2$)
- sodium bicarbonate ($NaHCO_3$)
- magnesium bicarbonate ($Mg(HCO_3)_2$)

Carbonate ions (CO_3^{--})

- calcium carbonate ($CaCO_3$)

High Alkalinity

May cause a gradual increase in the growing media pH. It may be necessary to inject mineral acid (phosphoric or sulfuric) into the water or acidic media amendments, such as sulfur or “acid-forming” fertilizers, may be needed.

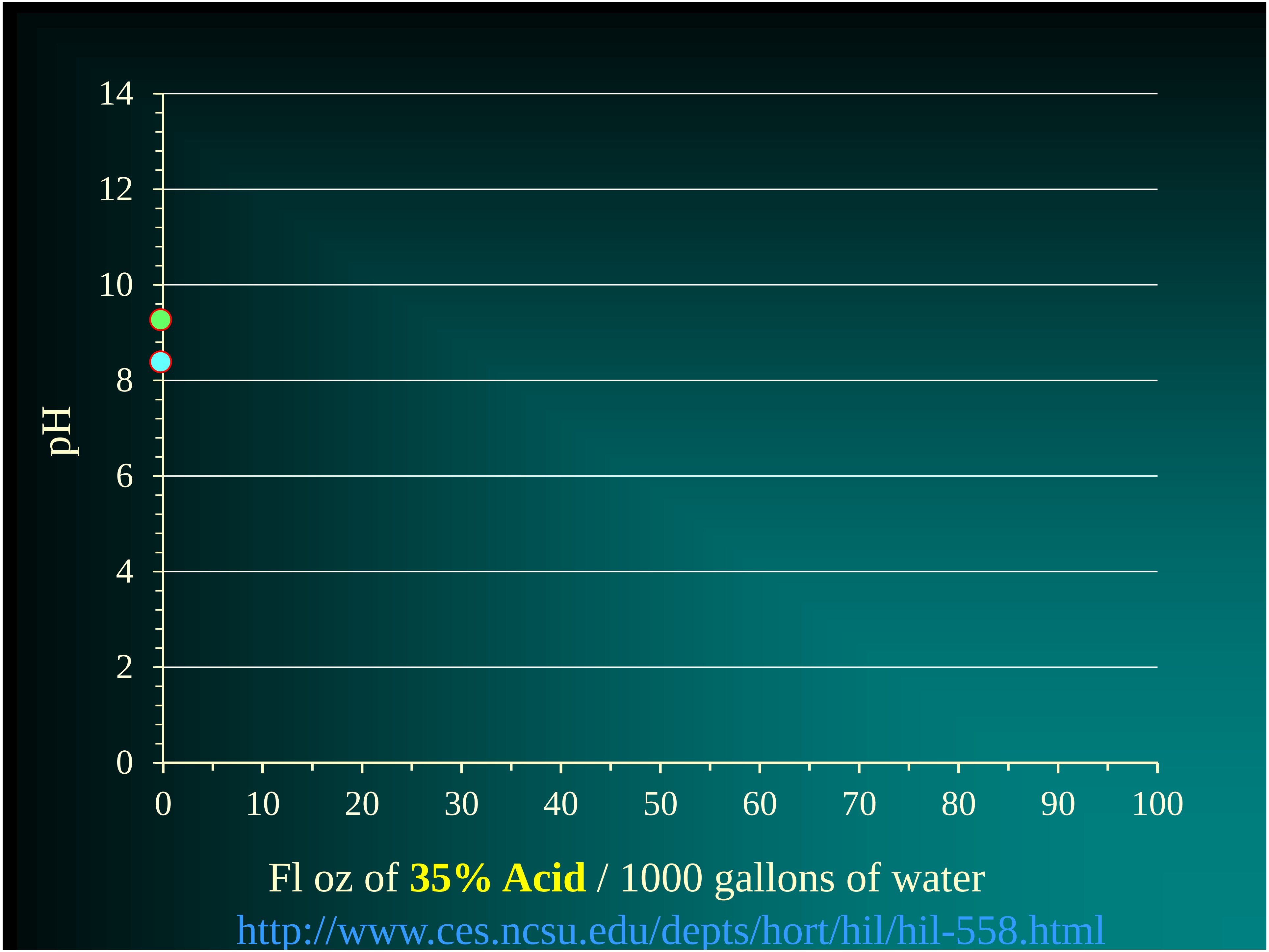
Low Alkalinity

May be deficient in calcium, magnesium or sulfate and additional supplements may be needed. A fertilizer program that alternates a potentially basic fertilizer with a low potential acidity fertilizer can help prevent pH crashes in the growing media.

Water Acidification Scenario

Grower A's Water		Grower B's Water	
pH	9.3	pH	8.3
Alkalinity	71 mg/l	Alkalinity	310 mg/l

http://www.ces.ncsu.edu/depts/hort/hil/hil-558.html



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Fl oz of **35% Acid** / 1000 gallons of water
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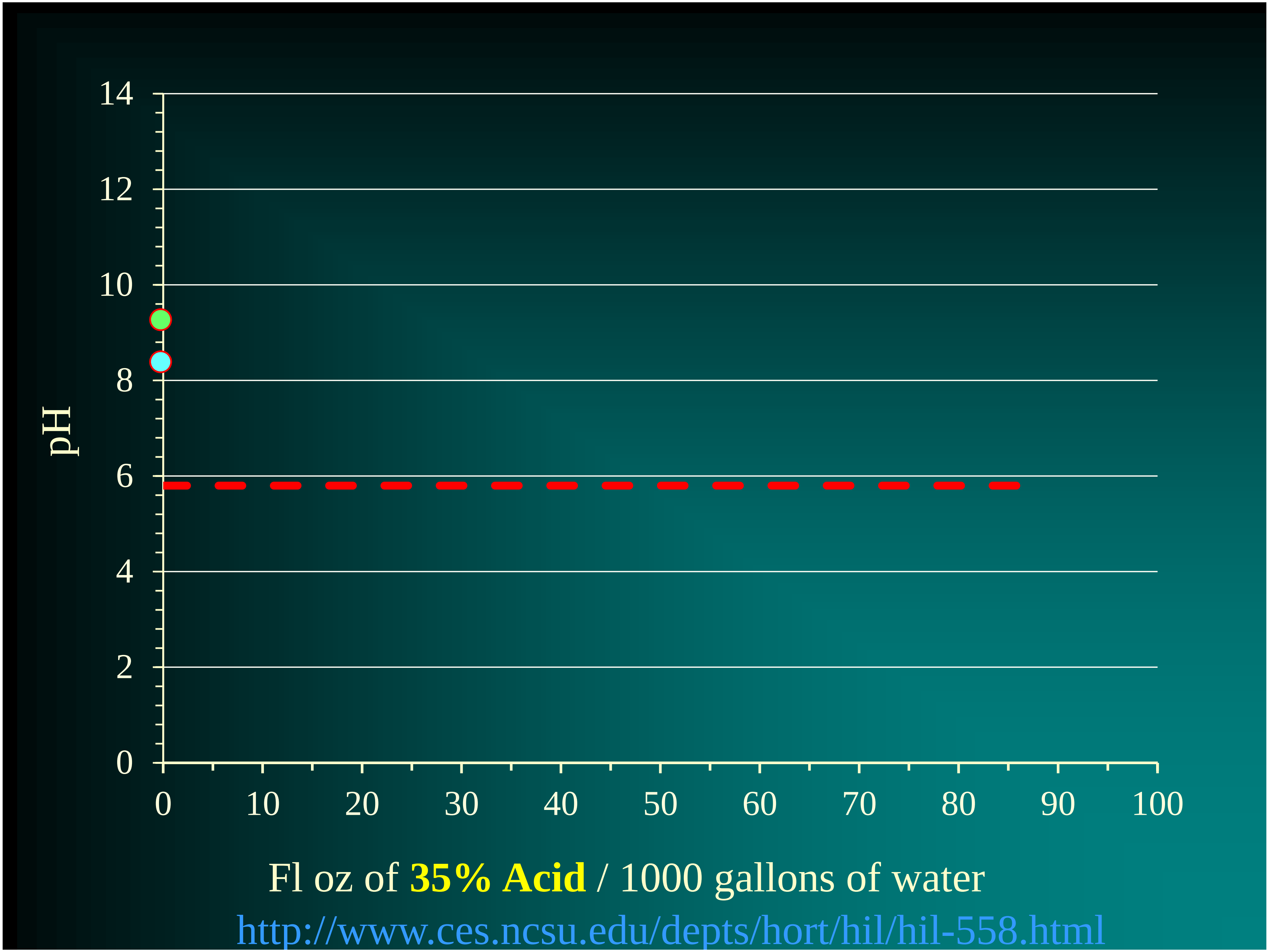
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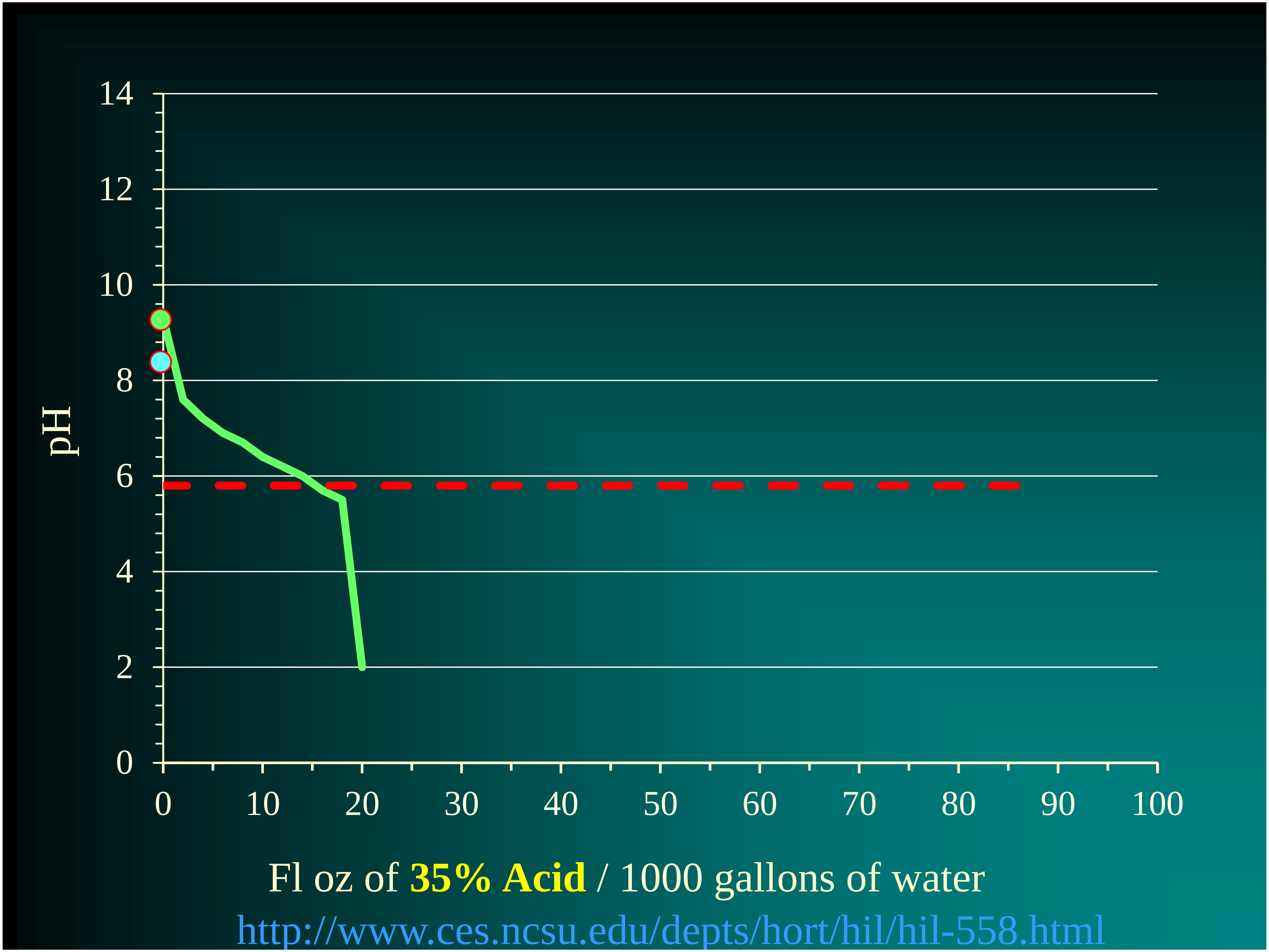
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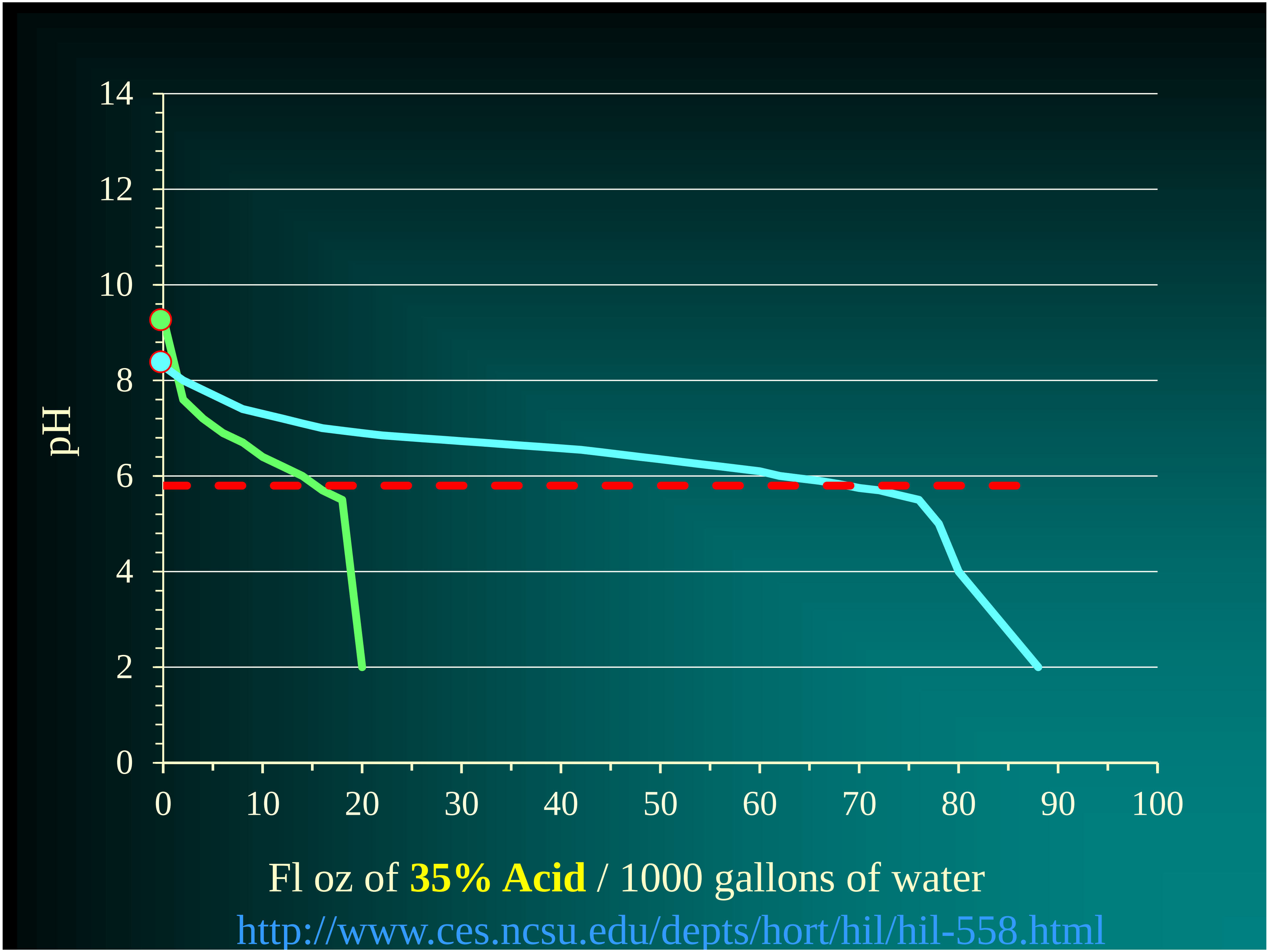

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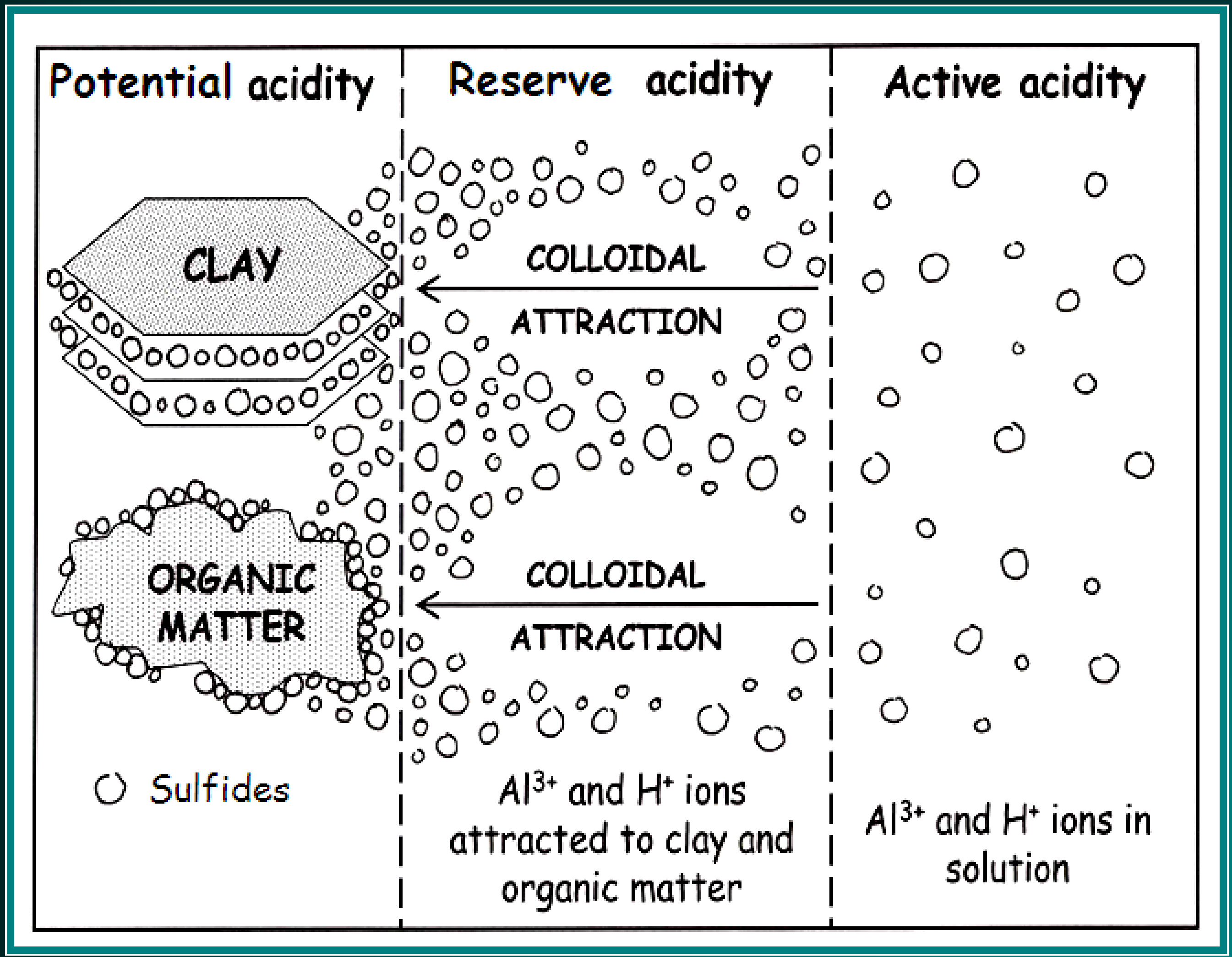
Chemical Properties

Soil Acidity



Suggested alkalinity guidelines (mg $CaCO_3$/liter)[z].

Container size	Acceptable alkalinity	Concern level[y]
Plugs	60-100	<40, >120
Small pots	80-120	<40, >140
4-5" pots	100-140	<40, >160
>6" pots	120-180	<60, >200

[z] Alkalinity levels recommended through Scotts Testing Lab. Actual levels may vary depending on crop type and desired plant response.

[y] Low levels may result in media pH decrease, and high levels may result in media pH increase. These trends are highly dependent upon fertilization rate.

http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/adjalkal.html

Other concerns of irrigation water quality
Dissolved Micronutrients

Capacity factor	Upper limit for greenhouse use
Aluminum (Al)	0 to 5.0 ppm is normal range
Boron (B)	0.5 ppm
Copper (Cu)	0.2 ppm
Fluoride[H] (F^-)	1.0 ppm
Iron[I] (Fe)	0.2 to 4.0 ppm
Manganese (Mn)	1.0 ppm
Molybdenum	----
Zinc (Zn)	0.3 ppm

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An important nutrient but too much is toxic

Toxicity shows as orange-brown necrosis along the margins of older leaves

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Safe for most crops but toxic for many members of the lily family

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Chamaedorea
Chlorophytum
Ctenanthe
Dracaena
Marantha
Spathiphyllum

Toxic levels of fluoride causes scorch of the tips of older leaves.

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Although 4 ppm is maximum for plants, even as little as 0.3 ppm can lead to iron rust stains on foliage if water is used for overhead irrigation

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Other concerns of irrigation water quality
Dissolved Micronutrients

Check levels and assure that concentrations are below those indicated.

If the water source does contain high concentrations of these micronutrients, adjustments in the fertilization program should be made to prevent an overabundance of the elements.

Micronutrient toxicities are more probable when the pH of the substrate solution is low, rendering the micronutrients more available for plant uptake.

Nutrient Interactions: Relationships of elemental excess in growing media to potential nutrient deficiencies in plant tissue.

Element in excess in media	Element possibly deficient in plant tissue
Nitrogen as ammonium	Potassium, Calcium, Magnesium
Potassium	Nitrogen, Calcium, Magnesium
Phosphorus	Copper, Zinc, Iron
Calcium	Magnesium, Boron
Magnesium	Calcium, Potassium
Sodium	Potassium, Calcium, Magnesium
Manganese	Iron, Molybdenum
Iron	Manganese
Zinc	Manganese, Iron
Copper	Manganese, Iron, Molybdenum
Molybdenum	Copper

Aluminum: this element is not essential and high levels are rare in artificial soils. High Aluminum will precipitate Phosphorus as Aluminum Phosphate and can highly reduce short term Phosphorus availability.

Fertilizers and pH

Role of fertilizer source (N) and other nutrients on pH

Decrease pH

- ✓ Fertilizers with 50% or more of ammonium ($NH4^+$)

Increase pH

- ✓ Fertilizers wit 50% or more of nitrate ($NO3^-$)
- ✓ Cal-Mag fertilizers

Fertilizer (N-P2O5-K2O)	NH4 (%)	Potential Acidity (lb calcium carbonate to neutralize per 100 lb of fertilizer)	Potential Basicity (lb calcium carbonate equivalent)	Ca (%)
21-7-7 acid	90	85.0	-	0
24-9-9	50	41.1	-	0
20-2-20	69	40.0	-	0
20-18-18	73	36.5	-	0
24-7-15	58	30.6	-	0
20-18-20	69	30.5	-	0
20-20-20	69	29.2	-	0
20-9-20	42	25.5	-	0
20-20-20	69	23.7	-	0
16-17-17	44	22.0	-	0
17-0-17	20	-	3.8	4
15-5-15	28	-	6.8	5
13-2-13	11	-	10	6
14-0-14	8	-	11	6
15-0-15	13	-	16.0	11
15-0-15	13	-	21	11

Micronutrients

Chlorine (Cl)

Cl^-

- Chlorine naturally occurs in soils as constituents of many soil minerals and is made available through natural weathering.
- Taken actively and passively depending on soil concentrations, active when low and passive when concentrations are high
- Utilized in several processes of photosynthesis.
- Mobile in plant

Chlorine (Cl)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Deficiencies are uncommon

- Toxicity

  Yellowing and burning of leaf tips, with interveinal areas being bleached, scorched and necrotic in severe cases.

Iron (Fe)

Fe^{2+}

- Iron is ubiquitous in many soils, yet availability depends on soil chemistry.
- Actively taken up by the plant and is transported by xylem to the leaves.
- Utilized in several processes of photosynthesis.
- Not mobile in plant

Iron (Fe)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Iron deficiency is similar to magnesium deficiency symptoms (interveinal chlorosis), but occurs on youngest leaves first
- Toxicity
  - iron interferes with manganese uptake manganese deficiency (mottled yellowing between veins developing as necrotic lesions later).

Manganese (Mn)

Mn^{2+}

- Availability depends on pH and organic colloid content. Increased in low pH
- In the plant manganese is transported in the xylem and delivered to mertistematic tissue where it is largely immobilized.
- Cofactor for many metabolic enzymes and is important factor in photosynthesis. Used to split water.
- Not mobile in plant

Manganese (Mn)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Interveinal chlorosis, similar to iron and zinc.
- Toxicity
  - Toxicity varies among species.
  - Occurs in acid soil conditions when manganese is most available
  - Dark purple or brown spots within the leaf margins and/or leaf tip necrosis
  - Toxicity varies among species. Plants associated with acid soils are naturally tolerant to high manganese conc.
  - Severe toxicity results in stunted and yellowed meristems.

Boron (B)

H_3BO_3

- Availability depends on pH and organic colloid content. Increased in low pH
- Boron moves into the plant, passively taken up in solution by the roots via evapotranspiration, moving through xylem
- Factor in cell growth, including division, differentiation, and elongation
- Cell processes like carbohydrate metabolism and other metabolic pathways
- Concentrated at growth areas including reproductive structures.
- Not mobile in plant

Boron (B)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Since boron is associated with cell growth, deficiencies usually show up in new growth as wrinkled and withered leaves, with tip death soon after.
  - Like calcium, deficiencies may be caused by drought or high humidity.
- Toxicity
  - Toxicity can develop quickly, the range between deficient and toxic supply is small.
  - Different tolerances among plant species.
  - Yellowing of the leaf tips, interveinal chlorosis and leaf margin scorching.

Copper (Cu)

Cu^{2+}

- Optimally available in slightly acid conditions where the copper ion exchanges with other cations on soil colloids
- Root uptake is active and copper moves in the xylem, complexed with amino acids and other nitrogenous compounds.
- Copper is utilized with enzymes for metabolic activities and photosynthesis.
- Not mobile in plant

Copper (Cu)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Deficiencies of copper show up on the youngest leaves first
  - Depressed and twisted growth
  - New leaves appear pale along the margins but green at the end of the veins.
  - Spotty necrosis occurs in the leaf margins. Stems may become distorted and twisted.
- Toxicity
  - Toxic levels of cooper induce iron deficiency and accompanying symptoms along with depressed root growth.

Molybdenum (Mo)

MoO_4^{-2}

- Molydenum uptake is dependent on solubility of the ion. Unlike many micronutrients, molybdenum becomes more available in higher pH.
- In the leaf, used for an important enzymatic process called nitrate reduction, the first of two important physiological steps that make nitrate usable in the plant
- Relatively mobile in plant

Molybdenum (Mo)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Since molybdenum is essential for nitrate reduction, a deficiency in molybdenum manifests as a nitrogen deficiency
  - leaf chlorosis in older leaves
  - then leaf margin wilting
  - leaf and meristem death

- Toxicity
  - rare in soils and plants can tolerate relatively high levels of molybdenum

Zinc (Zn)

Zn^{+2}

- Zinc is actively taken up by plants and transported through the xylem
- metabolic functions including auxin (growth hormone) production, a cofactor in protein synthesis, enzyme activity and carbohydrate metabolism and regulation.
- chlorophyll production
- may enable plants to tolerate colder temperatures
- Slightly mobile in plant, mainly stored in roots

Zinc (Zn)

Symptoms of Deficiency and Toxicity

- Deficiency
  - Symptoms on older leaves first
  - Include interveinal chlorosis, curled and dwarfed leaves and then leaf scorch and necrosis.
  - excessive phosphorus can interfere with zinc uptake

- Toxicity
  - May occur in low pH soils (< pH 5) or where municipal sludge has been added to soils
  - Toxicity concentrations are species dependent
  - interfere with iron uptake

Nickel (Ni)

Ni^{+2}

- Nickel is the newest recognized essential plant nutrient
- requirement was not known because impurities in irrigation water and fertilizers supplied the very low requirements of this nutrient
- required for the enzyme urease to metabolize urea, releasing the ammoniacal nitrogen for plant use
- for iron absorption and seeds production and germination
- evidence to suggest that carbon respiration and nitrogen metabolism are sensitive to Ni nutrition
- Possibly mobile in plants

Nickel (Ni)

Symptoms of Deficiency and Toxicity

- Deficiency
  - rounded, blunt and slightly curled leaves known as "mouse-ear"
  - seen on spring growth and is a result of accumulation of urea to the point of toxicity
- Toxicity
  - At a level of 100 ppm or higher, nickel is considered to be phytotoxic
  - toxicities typically exist in areas where industrial waste has been concentrate
  - In beets severely stunted growth; young leaves at early stage show chlorotic iron deficiency symptoms, followed by severe necrosis, collapse and death

Suggested Readings

Growing Media for Ornamental Plants and Turf.

Handrek, K and N. Black. Uni. of New South Wales Press

ISBN 0 86840 333 4

Water Considerations for Container Production of Plants Doug Bailey, Ted Bilderback, and Dick Bir

http://www.ces.ncsu.edu/depts/hort/hil//hil-557.html

Contact Me

aristvey@umd.edu