

# Begin with the End Result that you want: i.e., Healthy Soil = Healthy & Productive Trees



**Diaz Pecan Orchard (South of Las Cruces, NM)**



Presentation prepared  
by:

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# Soil Improving Practices

**(1) Build soil carbon:**  
Apply High Quality Compost  
& grow Cover Crops

Feed the Soil Food Web

Increase Biodiversity

Promote optimal soil structure

Reduce Compaction

Manage Salinity

**(2) Precision Irrigation & laser leveling**

**(3) Monitor Soil Conditions (lab analyses & Soil Health)**

**(4) Nutrient Mgt.**  
(Manage N/P/K)

**We began by developing a  
Soil Health Management  
Roadmap to Guide our  
decisions.**

## Soil Health Planning Principles:

- 1) Crop diversity
- 2) Living Roots
- 3) Cover the Soil
- 4) Less Disturbance

Decrease soil-borne pests/diseases/insect pressures

Build aggregates, feed soil food web

Reduce extremes in soil temperature; reduce evaporation

Reduce soil disturbance (i.e., Physical, Chemical, & Biological)

# Conventional Tillage in Pecans (Wind erosion: a problem on this sandy soil)

## Transitioning from Conventional Farming to a Soil Health Mgt. System



**Fields were laser leveled before applying  
compost & planting a grass cover.**

**Fields were converted from flood irrigation to micro-sprinklers or sub-surface drip (depending on soil type).**

# Conventional Tillage (Typical for most Pecan Orchards)

Photo taken on September 8, 2013 (Anthony, NM)

Before beginning Soil Health Practices



Photo of soil several days after irrigation



Soil Health: Restoring a Living Skin

Pecan Orchard growing in a coarse sandy soil that was amended with compost and has Bermuda grass growing as a cover

**GOAL:**  
Reduce Biological, Physical  
& Chemical disturbances

- Physical Disturbance
  - Tillage
  - Compaction
- Biological Disturbance
  - Lack of Plant Diversity
  - Over grazing
- Chemical Disturbance
  - Misuse of fertilizer, pesticides, manures and soil amendments

Applying compost (2<sup>nd</sup> application; top dressed)



**Applied a total of 10 tons/acre**

## COMPOSTING



High quality Fungal-driven compost.  
(Made with pecan wood chips, pecan shells,  
bales of Bermuda grass, and dairy manure.)

# Before Mowing



**3-year old pecan trees  
growing in sandy soil:  
Photos taken on April 20, 2015  
(south of Las Cruces, NM)**

# After Mowing

**(used flail mower; mowed  
4 to 5 times per/year)**



**After two irrigations following mowing, grass  
residues are broken down (we need to consider  
not mowing so low).**

## Cover Crop: Clover, Black Medic and Orchard Grass (photos taken on April 21, 2015)



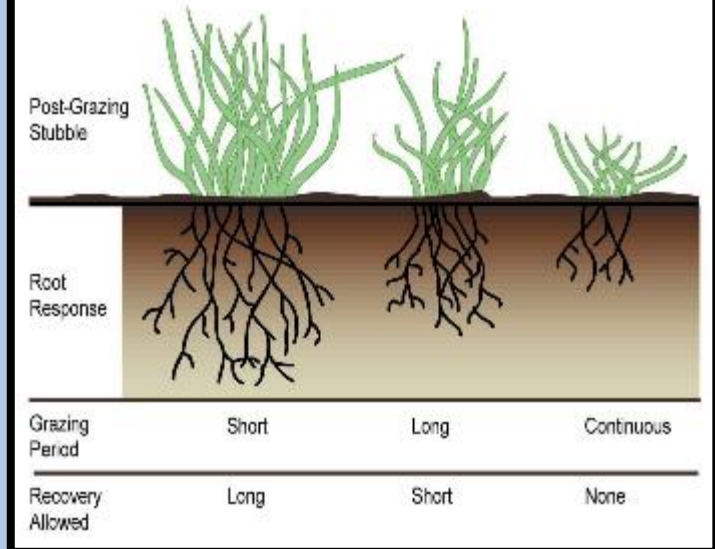
In order to increase diversity, the above cover crops have been planted; their performance will be evaluated this year (the seeds were inoculated with mycorrhizal spores & appropriate N-fixing bacteria).



Cover is mowed (to mimic grazing); residues decompose quickly.

## GOAL: Restoring Soil Health Function

### Stubble/Pasture Health



### Soil Health What is It?



- The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans
  - Nutrient cycling
  - Water (infiltration & availability)
  - Filtering and Buffering
  - Physical Stability and Support
  - Habitat for Biodiversity

# Sandy Soil is beginning to develop soil structure & a Living Skin.



Restoring the living skin of the Soil



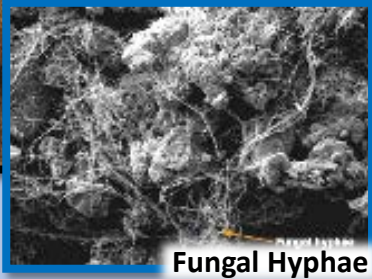
The Living Skin of the Top Soil  
RESTORES the Biological Spheres:

- 1) Rhizosphere
- 2) Aggregatusphere
- 3) Porosphere
- 4) Drilosphere
- 5) Detritusphere

## Managing the Soil Food Web:

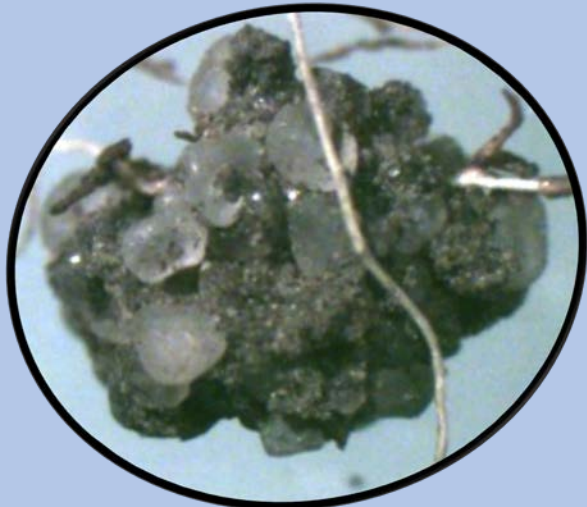
This entails working to maintain favorable conditions of [moisture](#), [temperature](#), [nutrients](#), [pH](#), and [aeration](#). It also involves providing a steady food source of [raw organic material](#).

## Rhizosphere (including Mycorrhizosphere)

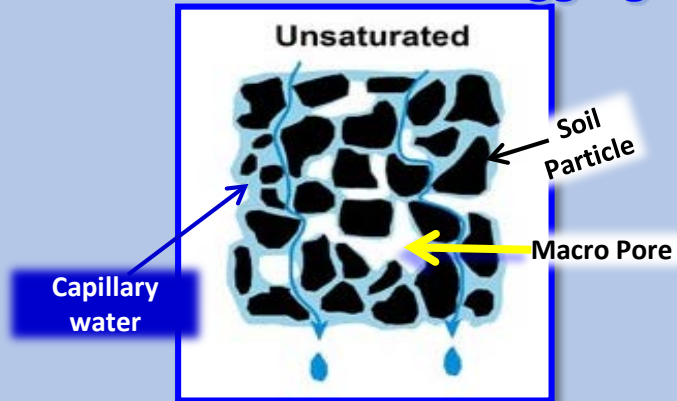


Fungal Hyphae

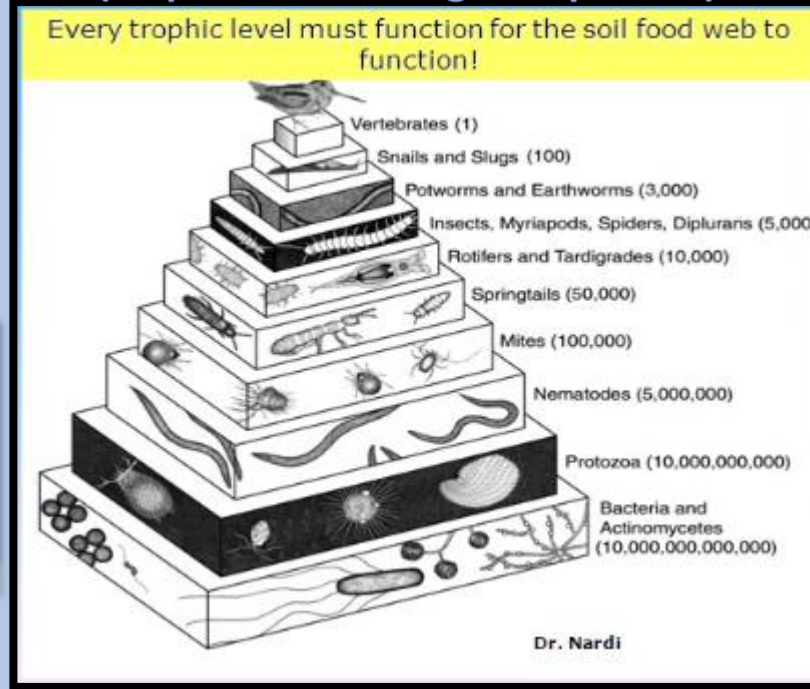
## Aggregatusphere (Macro- and Micro-Aggregates)



## Porosphere (pores within & between aggregates)



# Soil Food Web (requires all Biological Spheres)



## Detritusphere (Surface Residues)



## Drilosphere: Zone of earthworm influence



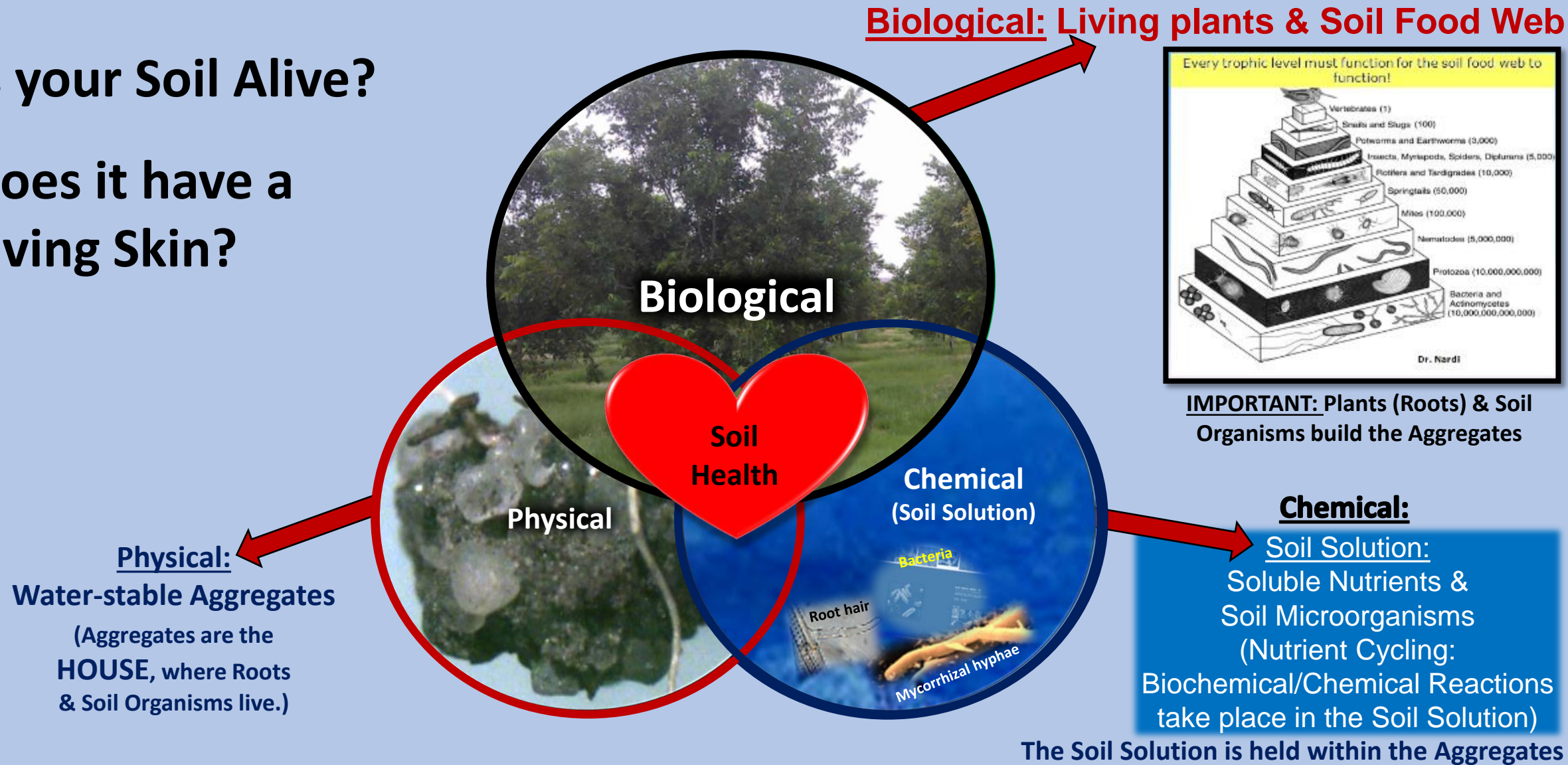
### The soil food web:

- 1) Is complex
- 2) Individual organisms are small in size
- 3) Individual organisms are numerous
- 4) Is greatly impacted by temperature and moisture
- 5) Is most active near the soil surface



# Is your Soil Alive?

# Does it have a Living Skin?



Water-stable Aggregates provide for the “Optimal” Chemical/Biochemical environment needed for Nutrient Cycling.

**Philosophy of Soil Health:** is an attempt to **bring together** different aspects of the soil with the understanding that they are **inter-related** and that they must **operate in synergy** for optimum and sustainable functioning of the soil media (Dr. John Idowu)

Questions?

# Typical Flood Irrigation (disked between irrigations?)



Pecan Orchard irrigated with sub-surface drip

Water Conservation:  
Transitioning from Flood  
Irrigation  
to  
Subsurface Drip &  
Micro-sprinkler Irrigation



Subsurface Drip Irrigation

**Soil Carbon & Water Management:  
Implementing a Soil Health Mgt. System  
to meet your Resource Concerns**



“Managing” for  
Soil Health (Soil  
Organic Matter);  
increasing  
“Water-Holding”  
capacity, &  
improving Water-  
use Efficiency.

Major Emphasis: Manage for Optimum Soil Health (SOM),  
use Efficient Irrigation System & Irrigation Water Mgt. Plan



Rio Grande: Photo taken April  
21, 2015, at Anthony, NM



**Drought is a  
Major Concern  
for NM**

# **DROUGHT: New Mexico's Challenge**



**Reduction in Irrigation  
Water from our Reservoirs.**

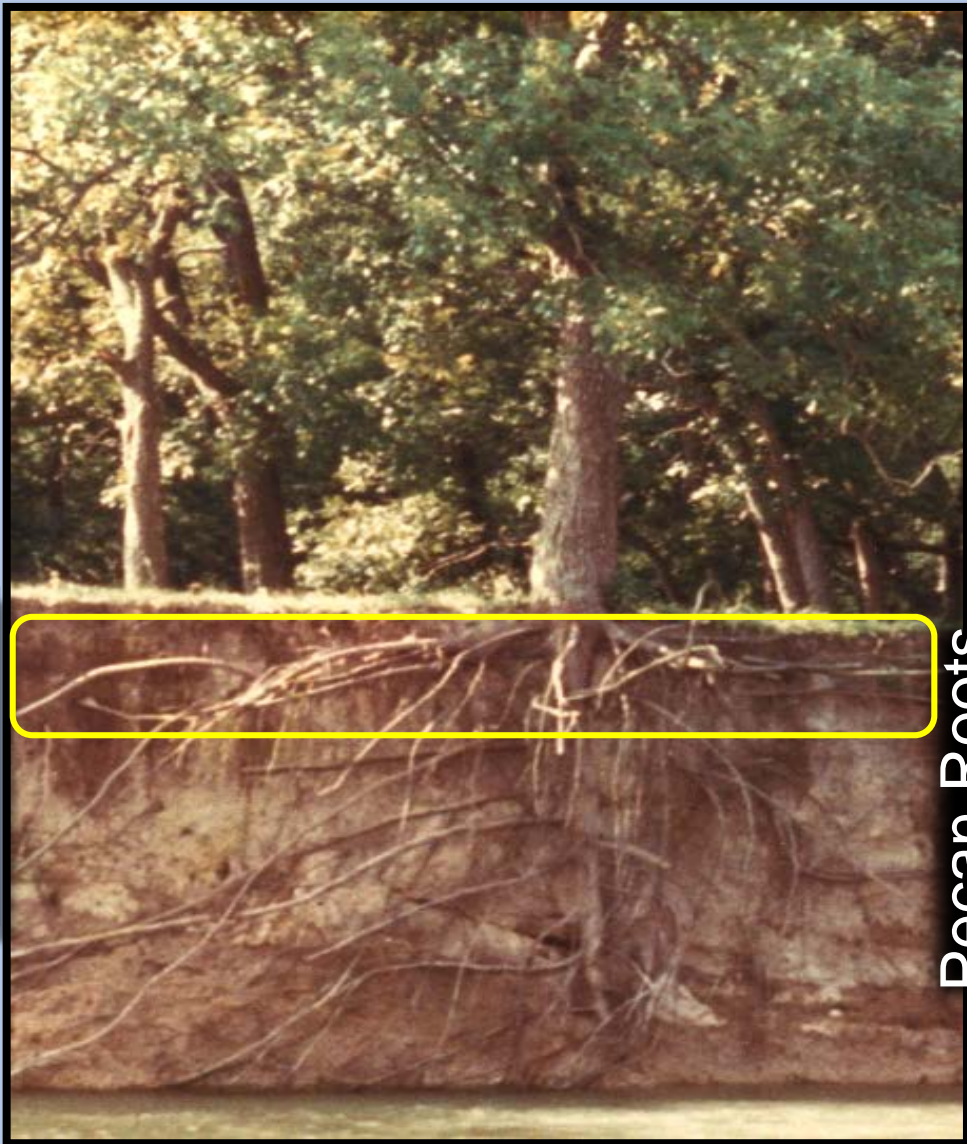
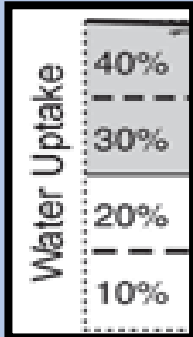
- **Less River Water available**
- **Relying more on our Aquifers**

## **Aquifer (Well Water)**



**Some Wells have Higher Salinity & SAR**

**Sodium Adsorption Ratio (SAR)**



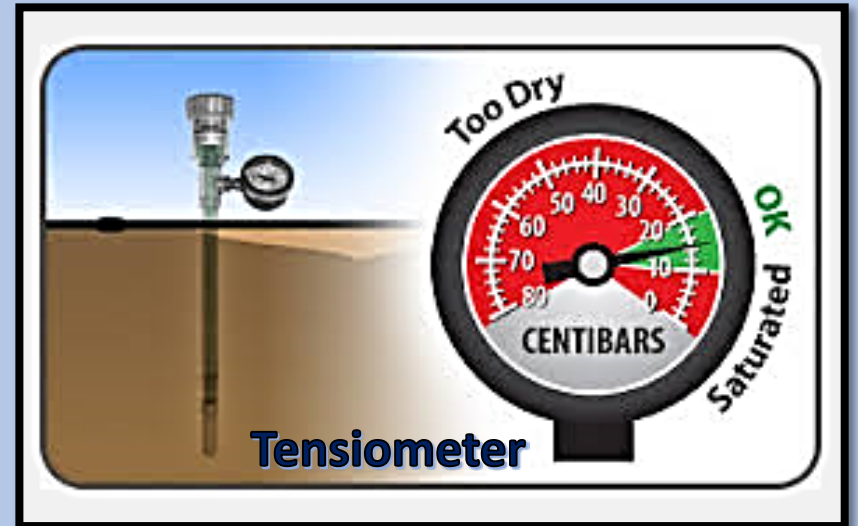
Pecan Roots

Most of the soil moisture taken up by the tree is from the 0-12" depth.



**Tensiometers:**

Are a soil moisture measurement device used to schedule irrigations.



Surface Temperature: 77 °F



Sandy Soil

Surface Temperature: 133 °F



Bare Soil

**Air Temperature  
was 76 °F.**

**Bare Soil and  
Soil with  
Cover were  
only a few feet  
apart.**

**Soil with Cover**



**Soil Moisture was  
at Field Capacity**



**Soil Temperature: 74 °F at 1 inch depth**

**Soil Moisture was  
at about 50% of  
Field Capacity**



**Soil Temperature: 100 °F at 1 inch depth**

**Fruit Orchard with New Zealand White Clover as a permanent ground cover.  
(Plant Material Center, Los Lunas, NM)**



**In NM, we have found temperature difference of about 20 degrees Fahrenheit (with cover vs. bare soil)**

**Evapotranspiration (ET)  
Irrigation Water Mgt.  
Goal: Manage ET for T,  
with minimal losses to E.**

**GOAL: In a Healthy Soil,  
we want soil moisture  
to leave the system  
through  
“Transpiration,” NOT  
Evaporation. Also, we  
want cooler soil  
“Temperatures” during  
our hot growing  
season.**

- Conserve moisture and reduce temperature.
- Crop yields are limited more often by hot and dry, not cool and wet.

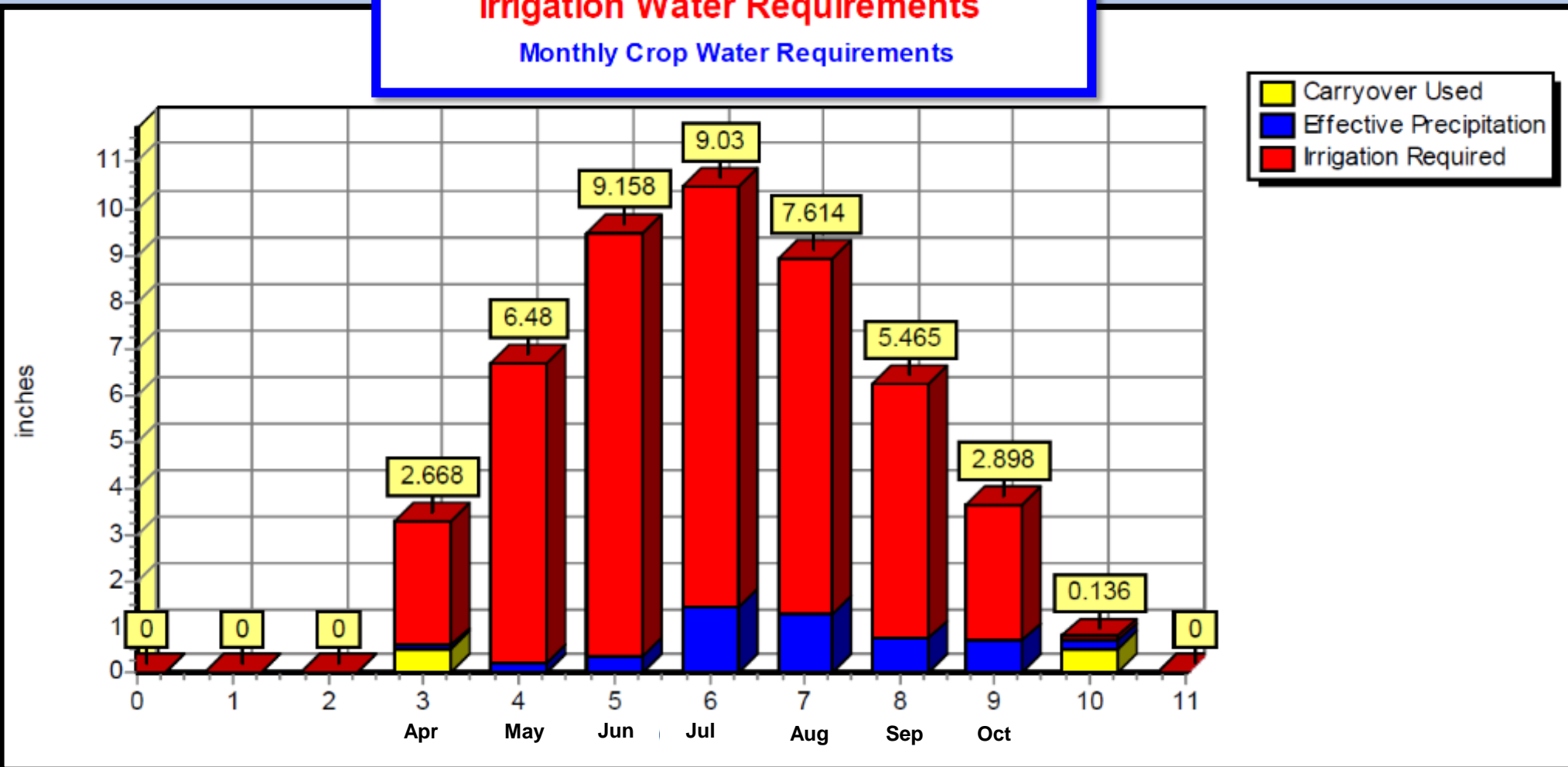
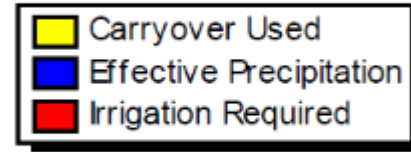
# Consumptive Use

Net Irrigation Requirements = 44.0 inches/year

## Pecan

3.67 acre-feet

Irrigation Water Requirements  
Monthly Crop Water Requirements



## Well Water Quality



**Water Quality from the various wells on these Pecan Orchards:  
Electrical Conductivity of the Irrigation Water (ECiw) and  
Sodium Adsorption Ratio (SAR)):**

**ECiw Range: 0.48 mmhos/cm to 2.31 mmhos/cm**

**SAR Range: 4.91 to 8.95**

# Soil Stability (Slake Test)

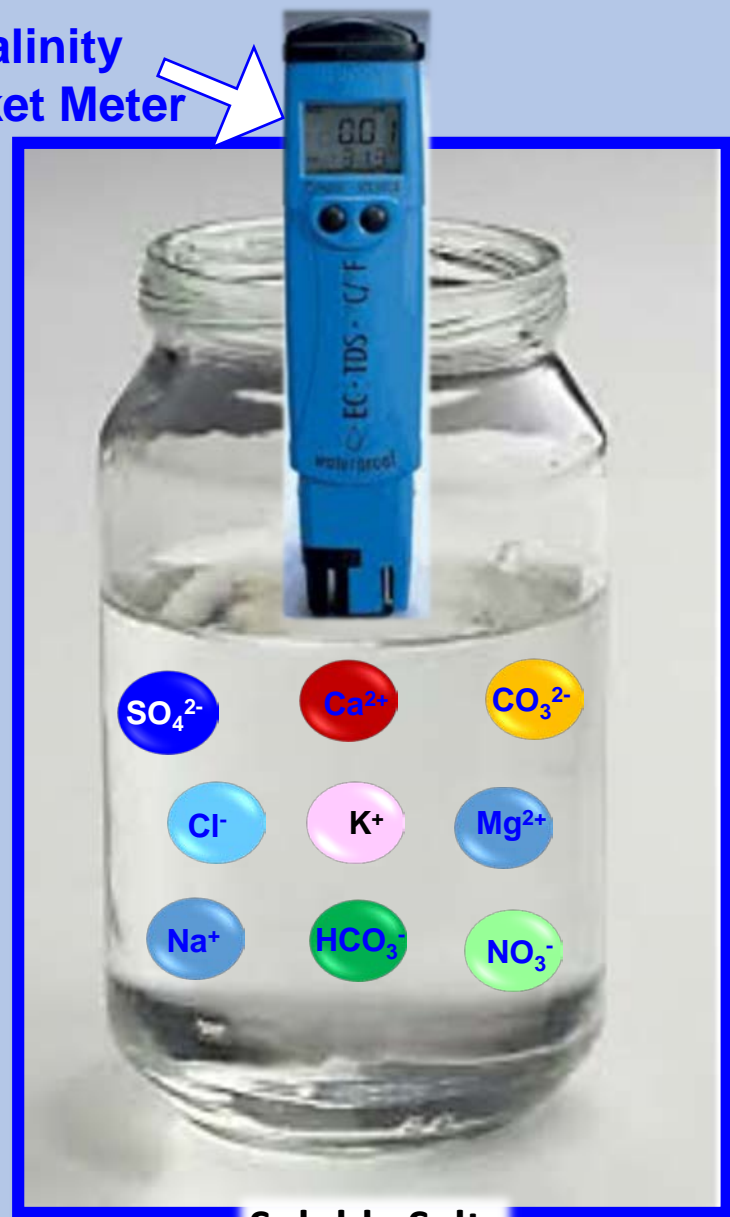


# Soil Structure



# Evaluate your Irrigation Water Quality (e.g. Salinity, SAR, pH) & its Effects on Soil and/or Plants.

Salinity  
Pocket Meter



Soluble Salts

## Soluble Salts:

(i.e., Standard Lab test needed for evaluating mg/l of individual ions)

- Ca<sup>2+</sup>** Calcium
- Mg<sup>2+</sup>** Magnesium
- K<sup>+</sup>** Potassium
- Na<sup>+</sup>** Sodium
- SO<sub>4</sub><sup>2-</sup>** Sulfate
- Cl<sup>-</sup>** Chloride
- HCO<sub>3</sub><sup>-</sup>** Bicarbonate
- CO<sub>3</sub><sup>2-</sup>** Carbonate
- NO<sub>3</sub><sup>-</sup>** Nitrate

# Soil Texture



Dr. Jamie Iglesias, with Texas Agrilife Center, discussing soil profile characteristics, drainage, water & salinity management, and water table.

**In this Pecan Orchard, water table was at about Six foot depth (The importance of proper drainage)**



**Do you understand your soils profile characteristics?**

**Open Drain: Adjacent fields have a shallow water table (i.e., within two-feet)**



**Due to our on-going drought, many open drains are no longer running with water.**

**Open Drain: Photo taken April 20, 2015, south of Las Cruces, NM.**



Adding Compost and growing a Cover has restored a “Living Skin” to the upper 2” of the Soil Surface

**Sandy Soil with Cover**



## Soil Organic Matter & Available Water Capacity

un/oc  
SEC  
IN THE  
SO

Percent SOM	Sand	Silt Loam	Silty Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

**Sandy Soil without Cover**



Inches of Water/One Foot of Soil  
1 acre inch = 27,150 gallons of water

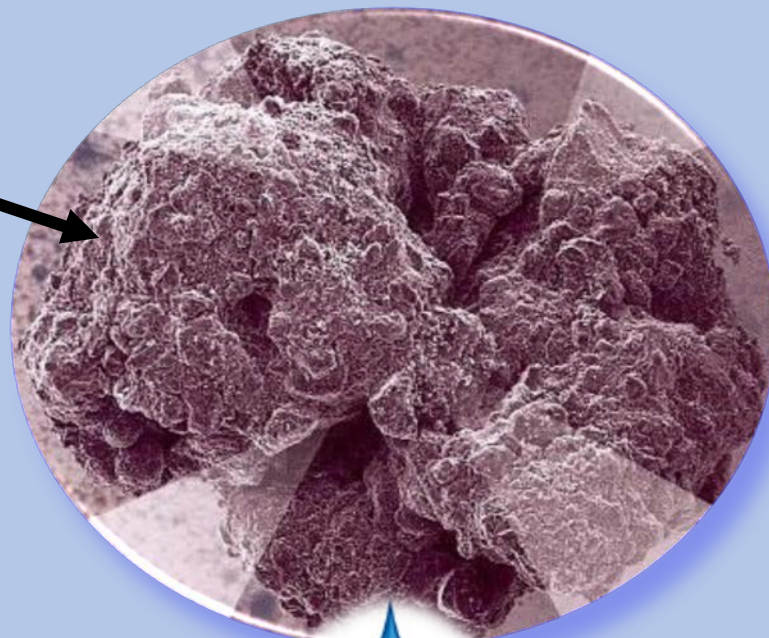
# Soil Aggregate

(Porous & holds soil moisture)

# Sea Sponge

(Porous & holds water)

An electron micrograph of Soil Aggregate, held together by carbon. Soil aggregates are a storage place for water, nutrients and soil micro-organism



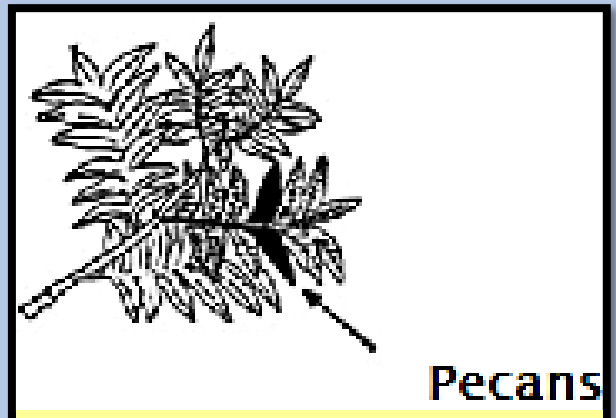
Healthy soil is like a Sponge: It can hold a lot of water.

For every 1% that you increase SOM  
Waterholding capacity increases 20,000-25,000 gallons per acre



Questions?

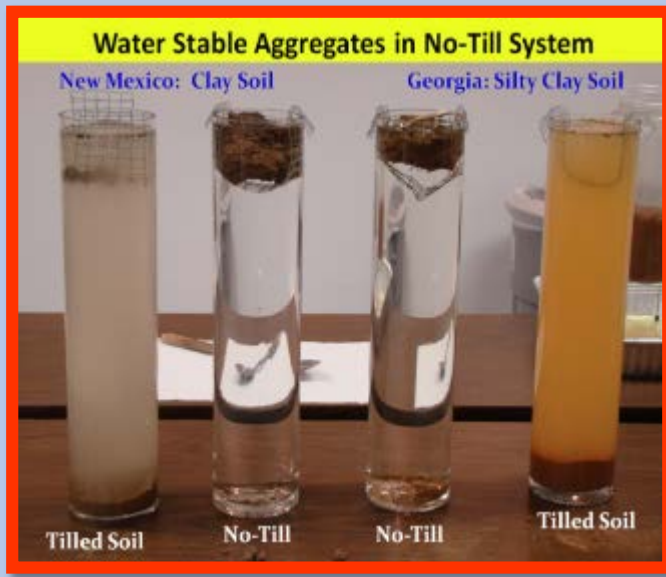
**Integrated Nutrient Management:**  
evaluated through the lens of a Soil Health Mgt. System.



Collecting Leaf Samples for Nutrient Analysis



Evaluating Pecan Yield & Quality

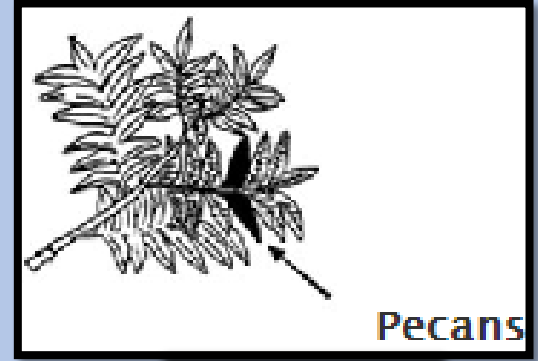






### Pecan Plant Tissue Analysis:

- N = 2.66%    **Optimum:** Sufficiency Range: 2.49 – 2.8%
- P = 0.12%    **Optimum:** Sufficiency Range: 0.11 – 0.3%
- K = 0.95%    **Optimum:** Sufficiency Range: 0.74 - 1.25%
- S = 0.22%    **Optimum:** Sufficiency Range: 0.19 - 0.4%
- Ca = 1.21%    **Optimum:** Sufficiency Range: 0.89 – 1.5%
- Mg = 0.31%    **Optimum:** Sufficiency Range: 0.29 - 0.6%
- Zn = 58.22 ppm    **Optimum:** Sufficiency Range: 49 – 100 ppm
- Fe = 135 ppm    **Optimum:** Sufficiency Range: 49 – 300 ppm
- Mn = 58.1 ppm    **Low:** Sufficiency Range: 99 - 800 ppm
- Cu = 5.8 ppm    **Low:** Sufficiency Range: 9 – 30 ppm
- B = 105.4 ppm    **High:** Sufficiency Range: 29 – 45 ppm
- Na = 0.02%    **Optimum:** Sufficiency Range: 0 – 0.1%



- Sample at Midseason
- Sample midshoot leaflets/leaves
- Sample #: 25 – 60



### Soil Analysis:

- Organic Matter = 0.6% (**Low**)
- Nitrogen Mineralized = 12.0 lbs./ac.
- Nitrate-N = 8.55 lbs./ac. (**Low**)
- Phosphorus = 5.0 ppm (**Low**)
- Potassium = 122.0 ppm (**Low**)
- Sulfate-S = 20.7 ppm (Adequate)
- Calcium = 2,948.0 ppm (High)
- Magnesium = 187.0 ppm (**Low**)
- Zn = 0.4 ppm (**Low**)
- Iron = 4.6 ppm (**Low**)
- Mn = 4.2 ppm (**Low**)
- Cu = 0.6 ppm (Adequate)
- B = 0.4 ppm (**Low**)
- Sodium = 2.6% of total CEC (good)

Irrigation is by micro-sprinkler and subsurface drip (These fields were previously flood irrigated).



### Water Quality Analysis Pounds per Acre:

- Nitrate-N = 12.2
- Potassium = 89.5
- Sulfate-S = 490.0
- Calcium = 591.0
- Magnesium = 146.2
- Sodium = 592.0
- Chloride = 783.0
- Bicarbonate = 1,911.4
- Carbonate = 26.1
- Iron = 9.3
- Mn = 0.22
- B = 1.31

Total Salts = 5,640.2

## Saline Soils:

$EC_e > 4.0 \text{ dS/m}$

$ESP < 15$  (or  $SAR < 13$ )

$pH < 8.5$



Evaluate Salinity Effects on Soils and/or Plants. Precipitated Salts (e.g., Calcium Carbonate, Gypsum); Leaching Requirement, etc.

## Saline-Sodic Soils:

$EC_e > 4.0 \text{ dS/m}$

$ESP > 15$  (or  $SAR > 13$ )

$pH < 8.5$

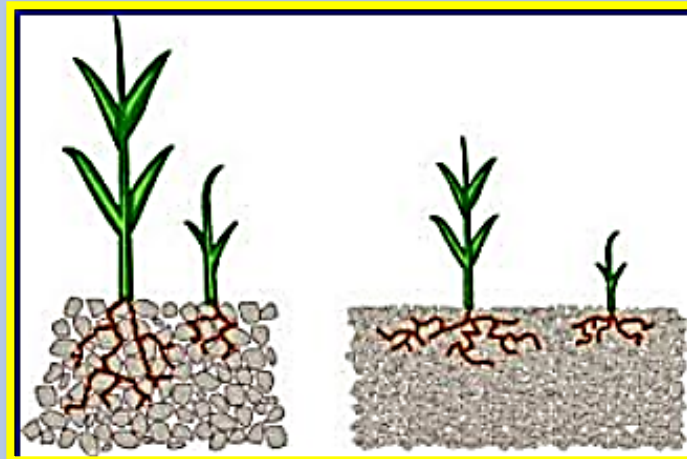


## Sodic Soils:

$EC_e < 4.0 \text{ dS/m}$

$ESP > 15$  (or  $SAR > 13$ )

$pH > 8.5$



(L) Soil with good structure (non-sodic soil); (R) Soil with poor and dense structure (sodic soil).

## Calcareous Soil



When acid is placed on a soil containing appreciable calcium carbonate, the soil fizzes in the form of carbon dioxide gas bubbles.

## Crop Salt Tolerance Table: EC (dS/m) = 640 mg/l of soluble salts

Crop (name)	Yield loss 0%		Yield loss 10%		Yield loss 25%		Yield loss 50%		Maximum ECe <sup>3</sup>
	ECe <sup>1</sup>	ECw <sup>2</sup>	ECe <sup>1</sup>	ECw <sup>2</sup>	ECe <sup>1</sup>	ECw <sup>2</sup>	ECe <sup>1</sup>	ECw <sup>2</sup>	
Alfalfa	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	15.5
Almond	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.7	7.0
Apple	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8.0
Apricot	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	6.0
Barley	8.0	5.3	10.0	6.7	13.0	8.7	18.0	12.0	28.0
Beans	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
Beets	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15.0
Bermuda Grass	6.9	4.6	8.5	5.7	10.8	7.2	14.7	9.8	22.5
Blackberry	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0
Boysenberry	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0
Broccoli	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	13.5
Cabbage	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12.0
Cantaloupe	2.2	1.5	3.6	2.4	5.7	3.8	9.1	6.1	16.0
Carrot	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.1	8.0
Clover	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	10.0
Corn, Grain & Silage	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Corn Silage	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15.5
Corn, Sweet	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Cotton	7.7	5.1	9.6	6.4	13.0	8.4	17.0	12.0	27.0
Cucumber	2.5	1.7	3.3	2.2	4.4	2.9	6.4	4.3	11.0
Fescue, Tall	3.9	2.6	5.8	3.9	8.6	5.7	13.0	8.7	21.0
Grape	1.5	1.0	2.5	1.7	4.1	2.7	6.4	4.3	11.0
Lettuce	1.3	0.9	2.1	1.4	3.2	2.1	5.0	3.3	9.0
Love Grass	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	13.0
Meadow Foxtail	1.5	1.0	2.5	1.7	4.1	2.7	6.4	4.3	11.0
Onion	1.2	0.8	1.8	1.2	2.8	1.8	4.4	2.9	8.0
Orchard Grass	1.5	1.0	3.1	2.1	5.5	3.7	9.0	6.0	15.0
Peach	1.7	1.0	2.2	1.4	2.9	1.9	4.4	2.9	8.0
Pear	1.7	1.0	2.3	1.6	3.3	2.2	5.0	3.3	9.0
Pecan <sup>+</sup>	1.9	1.3**	2.4*	1.6**	3.2*	2.4**	4.6	3.0**	8.0*

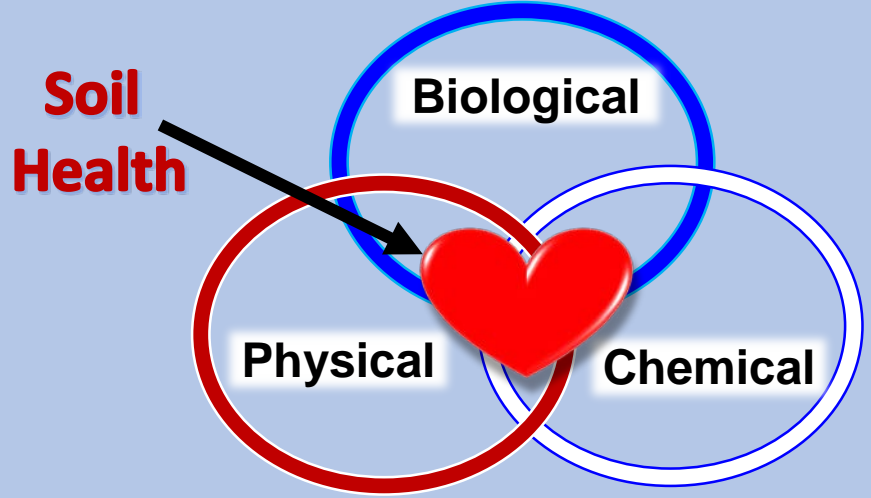
ECe = Electrical Conductivity of the soil saturation extract (Soluble Salts)

Soil Salinity will concentrate 1.5 – 3.0 times the irrigation water salinity in most cases

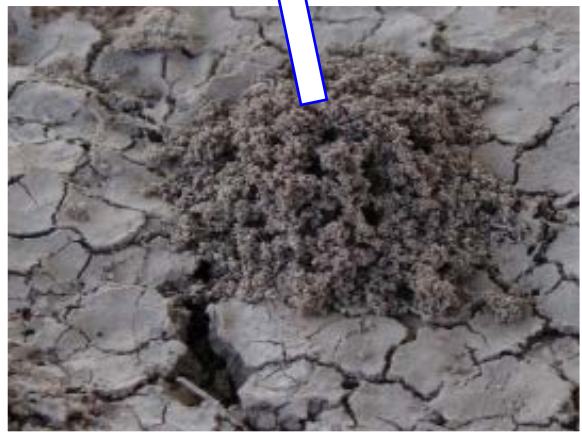
ECw = Electrical Conductivity of the Irrigation Water (Soluble Salts)

Comparison of the "crop salt tolerance" between Cotton & Pecans at 25% Yield loss.

# Soil Health Management System (Managing SOM)



(Orchard with a cover: soil has an "Optimal" Bio-Geo-Chemical Nutrient Cycle)



Bare Surface (poor nutrient cycling)

Grass is mowed several times during the growing season (residues are left on the surface to decompose & recycle back to the soil)

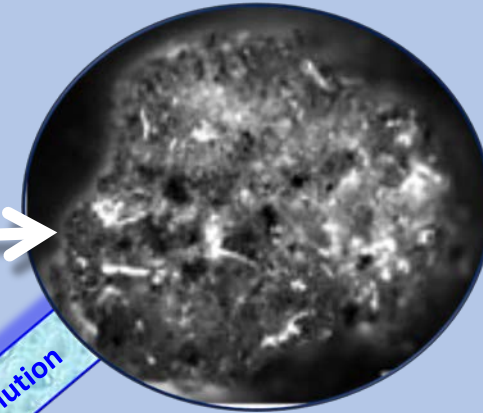


Grass Roots

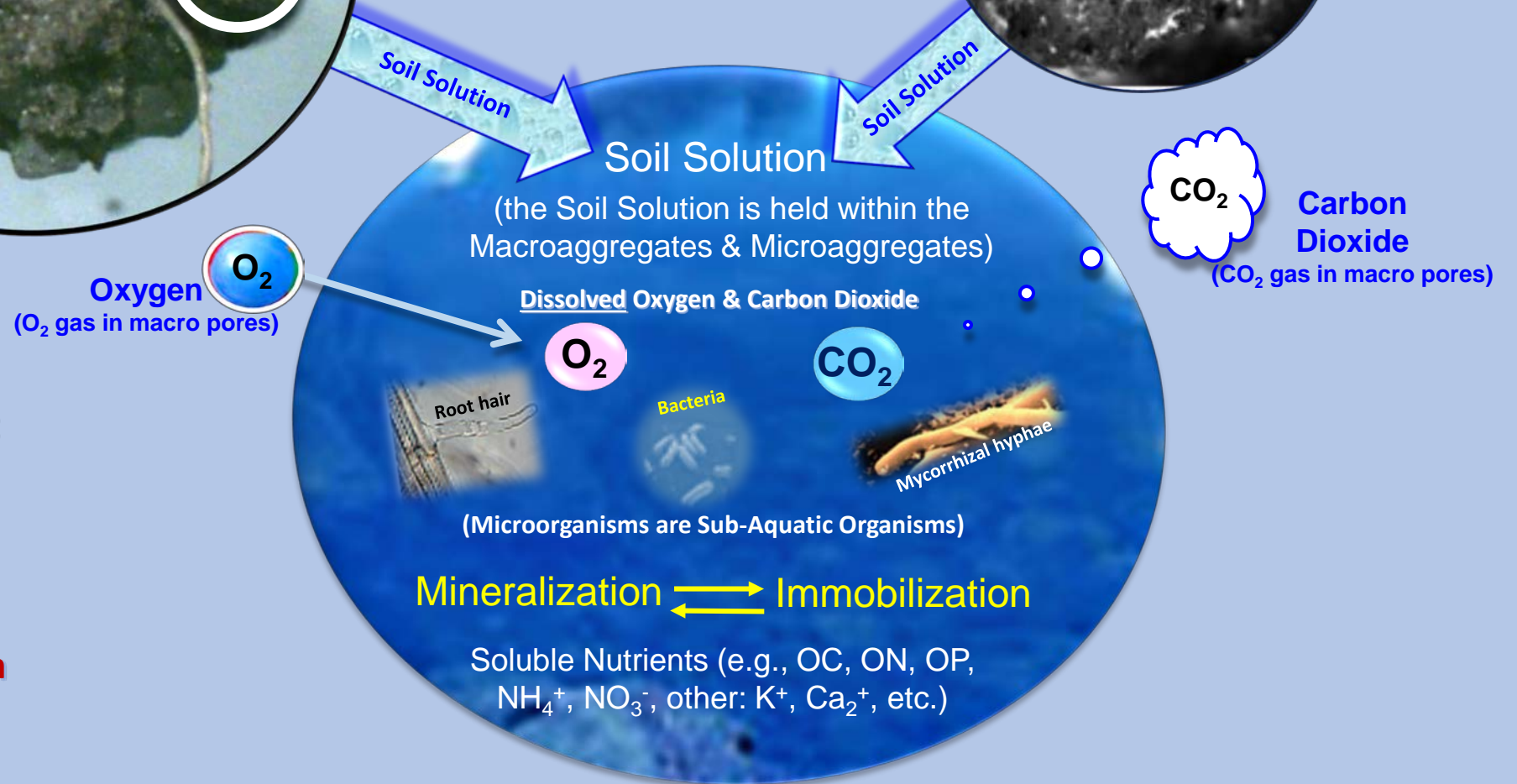
**Macroaggregate  
(2.0 – 5.0 mm dia.)**



**Microaggregate (< 0.3 mm dia.)  
Consisting of Clay, silt, humus, particulate  
organic matter, very fine sand.**



**White areas  
indicating presence  
of glomalin (Dr. Kris  
Nichols, USDA/ARS  
Mandan, ND)**



**Factors affecting Nutrient  
Cycling & Soil Health:**

- **Temperature**
- **Aeration**
- **Soil Moisture**
- **Soluble Organic Carbon**
- **C:N ratio**
- **Salinity**



**Soil Health improves Yield and Quality**

## **Soil Health & Salinity?**

**Will higher levels of Soluble Salts and higher Sodium Adsorption Ratio (SAR) affect Yield and Nut Quality, while using predominantly Well Water? Yes!**

**Can improving Soil Health help ameliorate Salt problems to both plants and soils? Yes!**

## Pecan Orchard irrigated with sub-surface drip



**This orchard yields about 3,200 lbs./acre. Soil type is a silty clay loam, which are some of the most productive soils.**

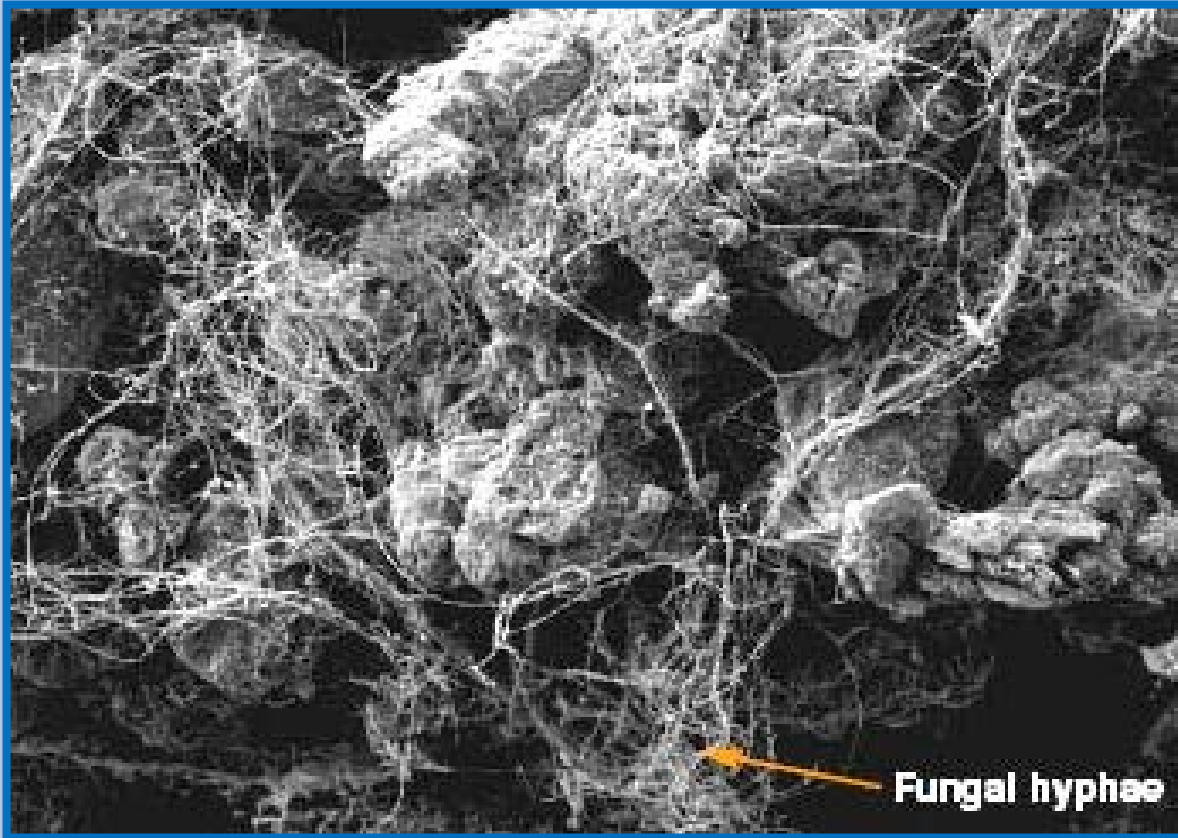
## Nut Quality



**Quality is at 59% nut & Shell is 41%  
(typical quality is at 56 – 57%)**

N inputs have been reduced from 200 units/ac to 125 units/ac on mature orchards. Phosphorus inputs have been reduced by up to 40% in some orchards. Zinc applications have been reduced from 5 to 3 foliar applications. Leaf samples are showing sufficient levels for all nutrients. And soil health is improving significantly (i.e., earthworms, water-stable aggregates, higher OM, healthier trees, consistent high yields, etc.)

Fungal hyphae binding soil particles together into aggregates.  
Arbuscular Mycorrhizal fungi produces Glomalin that glues soil particles together.



## Mycorrhizosphere (Glomalin)

### Soil Humus Formations:

- 1) Photosynthesis
- 2) Resynthesis
- 3) Exudation
- 4) Humification

Dr. Christine Jones



Crop Residues are needed to protect the soil surface and to feed the soil organisms.

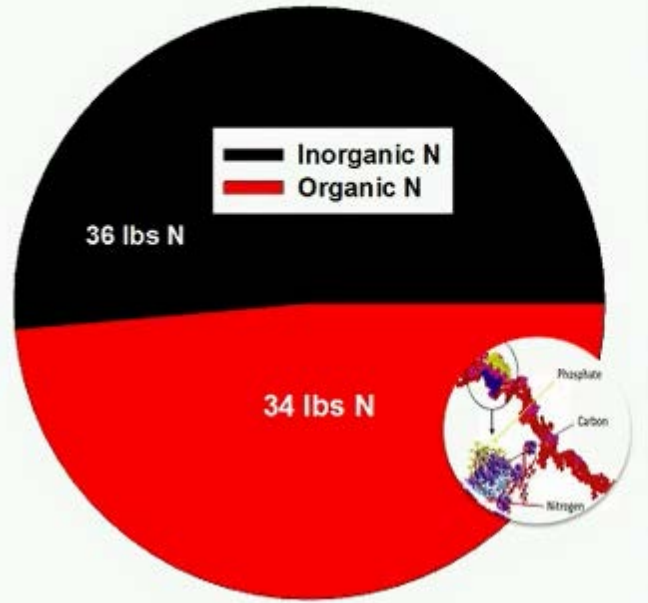
## Rhizosphere

- Narrow region of soil directly around roots.
- Living roots release many types of organic materials.
- These compounds attract Bacteria that feed on the proteins & sugars.



# We have been missing half of the N

Water Extractable Total Nitrogen  
Average of 6227 soil samples

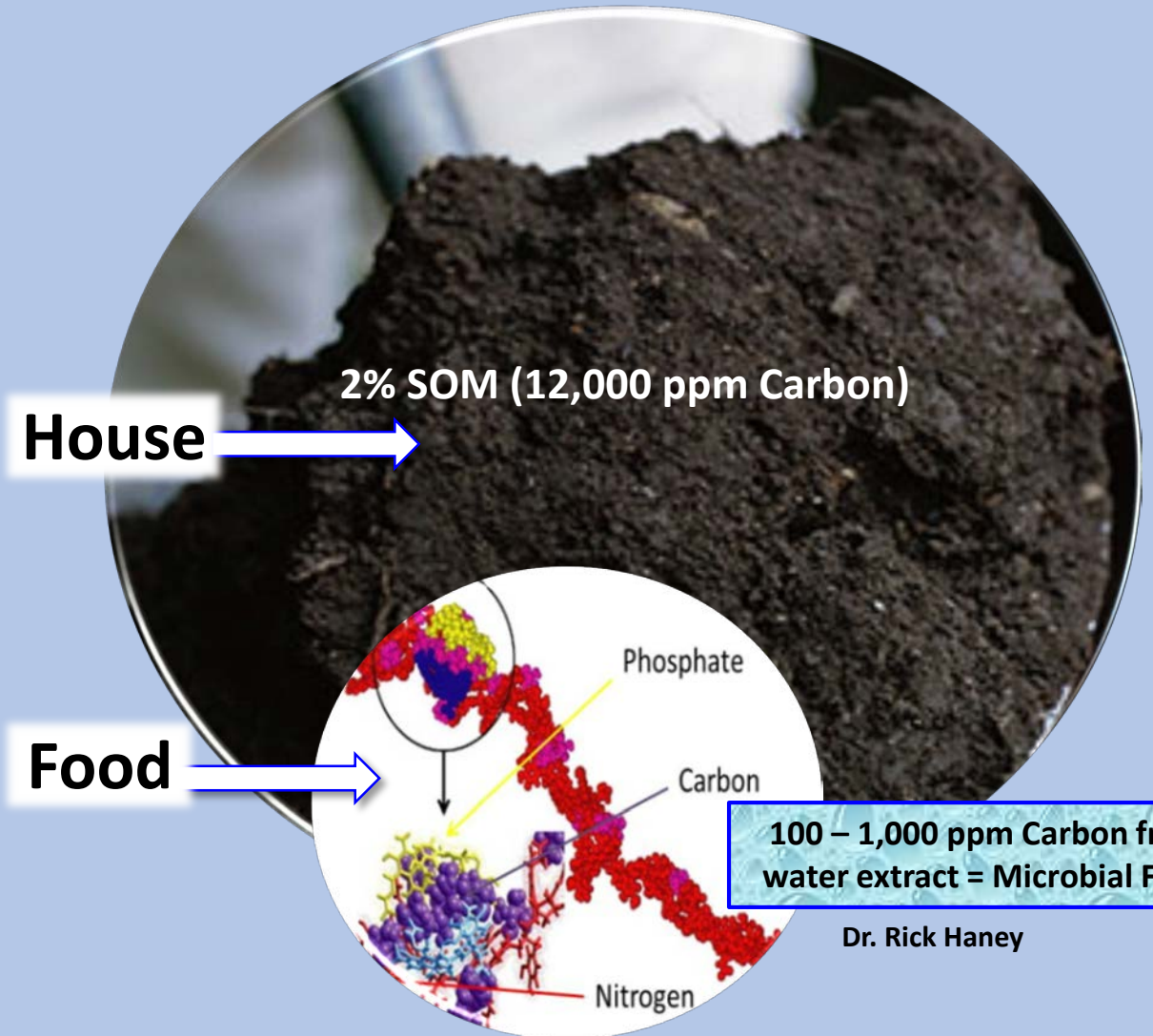


2M KCl 1965 Bremer

"If plants could not take up organic compounds herbicides would not work" Liz Haney 2013  
Plants eat: Inorganic N  
And Organic N from soil organic matter

**Standard Lab Soil Test do not measure Soluble Organic Nitrogen**

Soil Organic Matter is the House microbes live in, Water Extractable Organic Carbon is the Food they eat.



Dr. Rick Haney

# Questions?

- Where do we go from here?
- This is a work in progress; we have much more to learn and understand about how the soil health functions.
- Our learning curve is quite steep.

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