WASHINGTON STATE UNIVERSITY EXTENSION

Orchard Soil Health

Stephen Bramwell
WSU Extension
6/6/23

What is Healthy, High-Quality Soil

- Good soil tilth
- Sufficient depth
- Sufficient nutrient supply
- Small population of plant pathogens and insect pests
- Good soil drainage
- Large population of beneficial organisms
- Low weed pressure
- No chemicals or toxins that may harm crop
- Resilience to degradation and unfavorable conditions

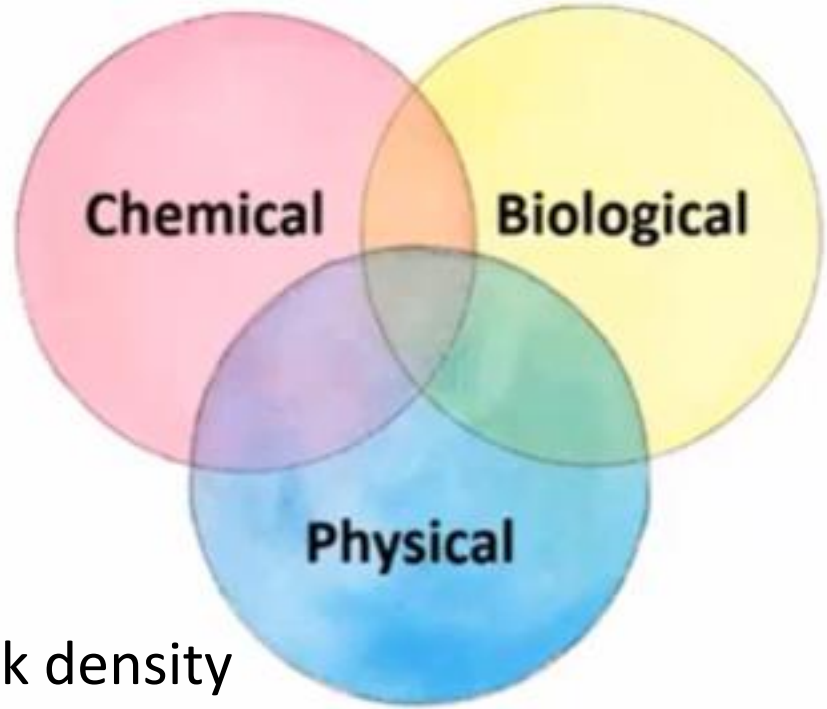
DuPont et. al, 2020

What are Functions of Healthy Soil

- Root health – aeration, access to nutrients, water holding capacity, drainage, water infiltration (antibiotics, predation, competition, paratization ie Trichoderma…replant dec.)
- Nutrient availability – OM release, cation exchange, microbial cycling (up to ¼ of available N from nematodes, mites, springtails)
- Water availability – storage and release (from 5-25% water capacity from 0.5 – 3% OM
- Disease resistance – Organisms responsible for suppressing root disease

Soil Health Indicators

- Cation exchange capacity
- N,P,K, Ca, Mg, S
- Micronutrients
- Toxins, pollutants
- Glomalin



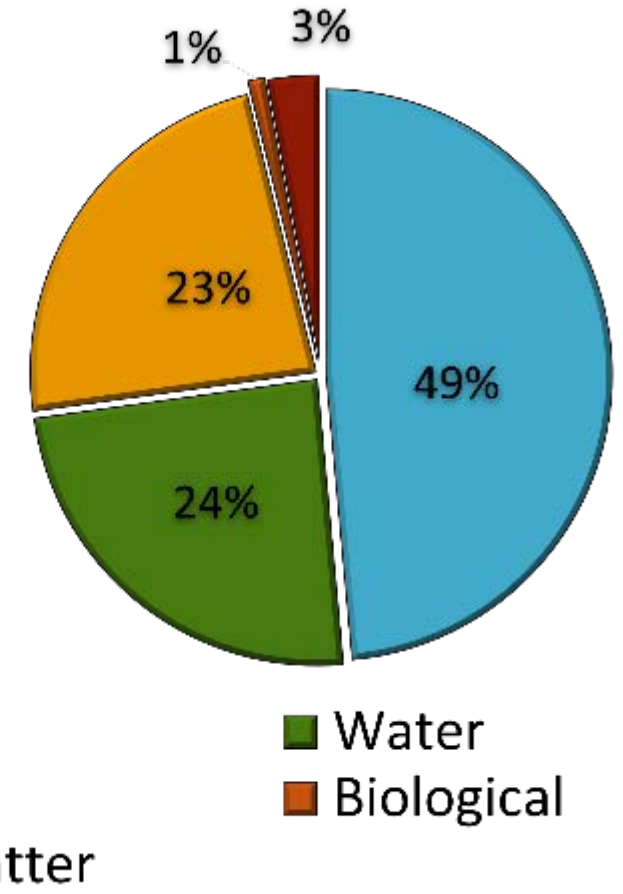
- % OM
- “Active” C, N in OM
- Soil disease suppressiveness
- N mineralization rate
- Decomposition rate
- Microbial biomass
- Earthworm counts
- Genetic diversity

- Bulk density
- Penetration resistance
- Aggregate stability
- Water infiltration rate
- Water holding capacity
- Pore size distribution

DuPont et. al, 2020

Manage for Soil Biota

- Compost
- Cover crops
- Leaves, prunings, manure, wood chips
- Reduced disturbance
- Reduce compaction
- Orchard floor management



Alley Vegetation

Legumes for N Fixation

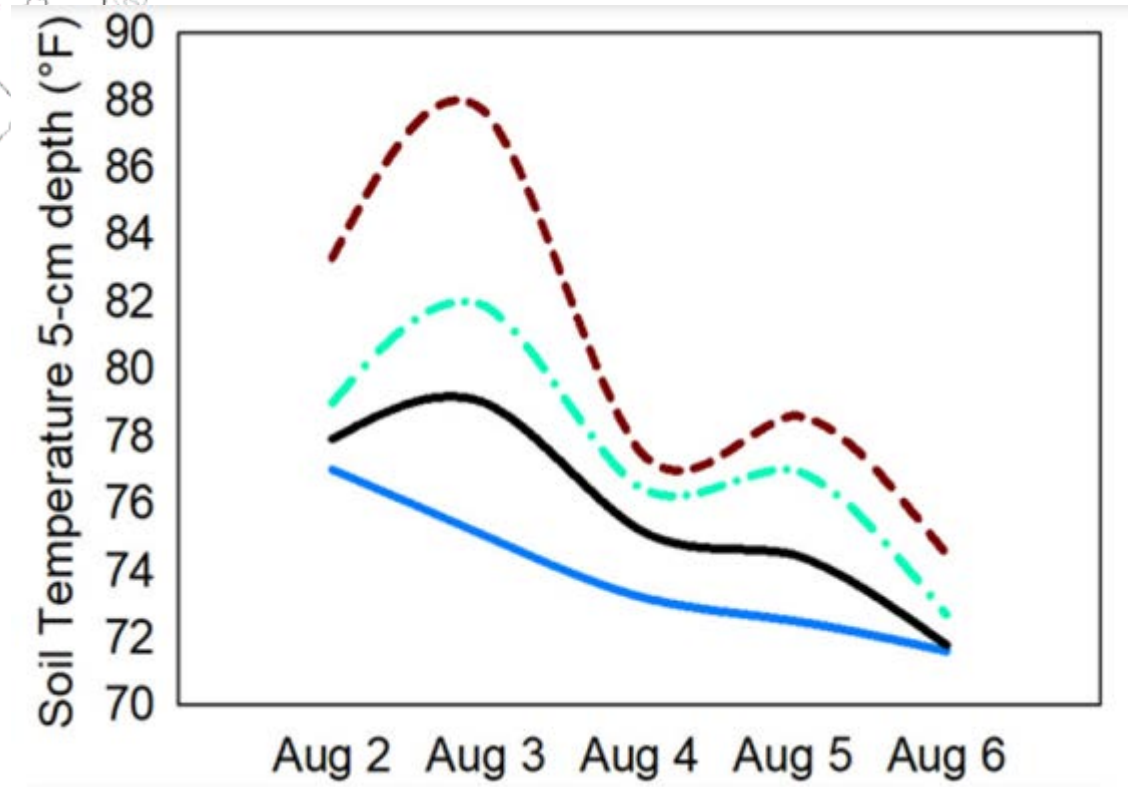
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

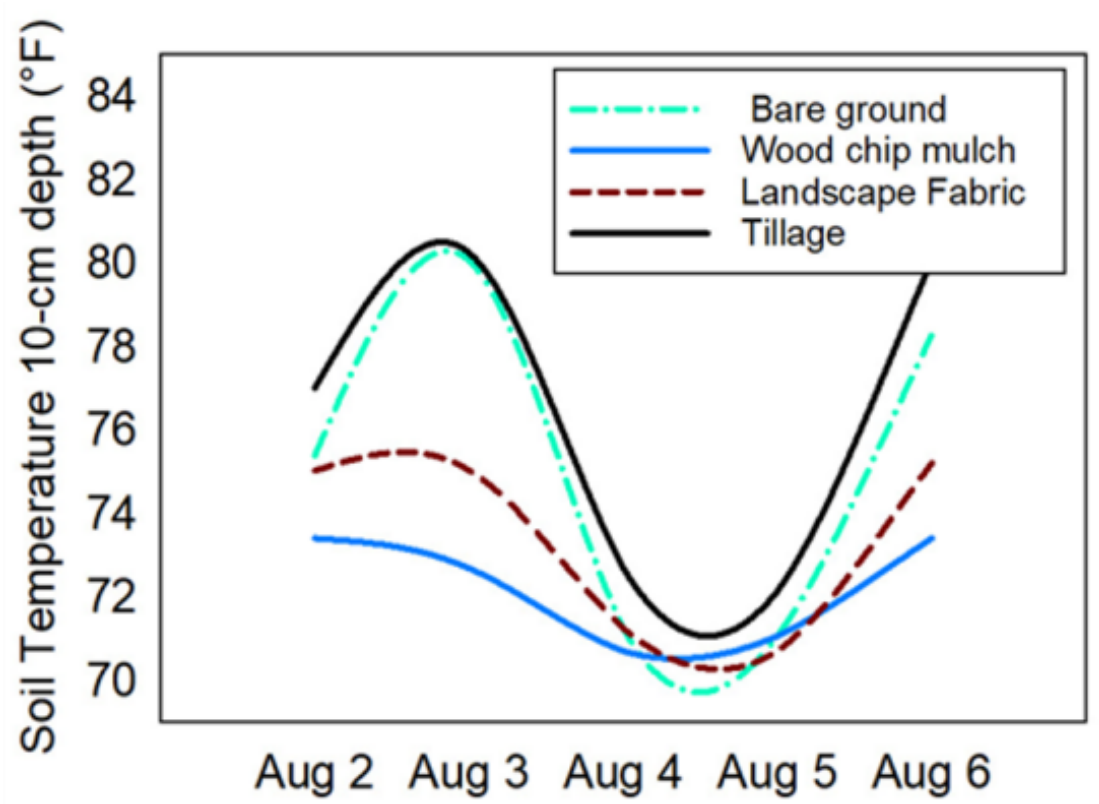
39 days after mowing; initially direct seeded

Add 30- 80 lb avail. N/ac/yr;
US$0.70/lb N

Granatstein, 2013

Orchard Floor Management





- DuPont & Granatstein, 2020: https://treefruit.wsu.edu/orchard-management/soils-nutrition/soil-health-in-orchards/
- https://www.goodfruit.com/what-lies-beneath/

Orchard Soil Organic Matter

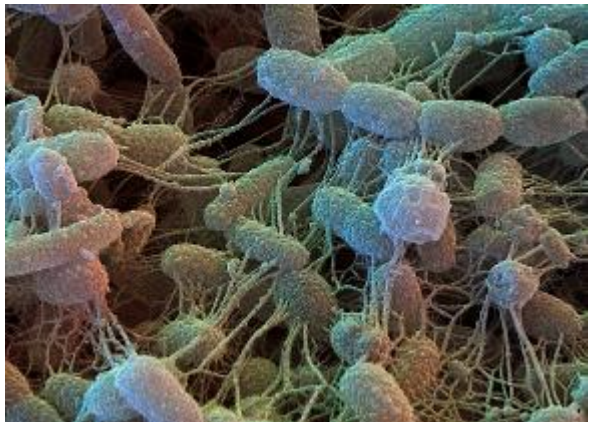
- Cover Crops
  - Pathways
  - In-row
- Mulch, wood chips
- Compost

- 5% OM: 20-24lbs N/% => 120 lbs N/ac

DuPont et. al, 2020

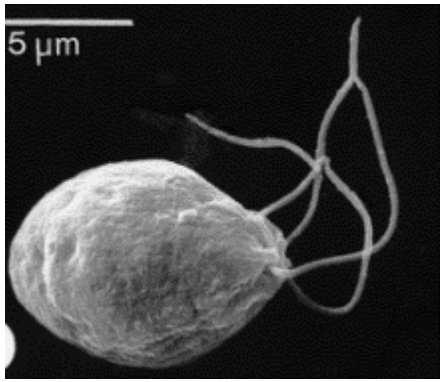
Orchard Soil Biota

BACTERIA
FUNGI



N

5-10x less N than bacteria



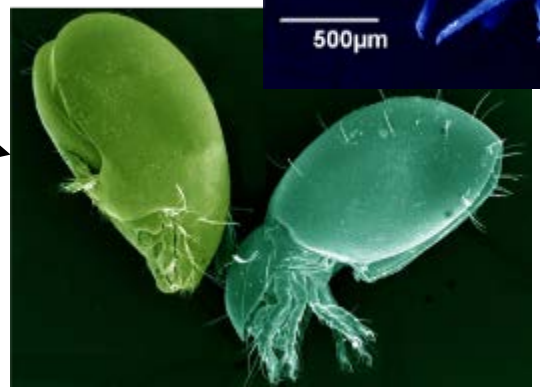
PROTOZOA

N

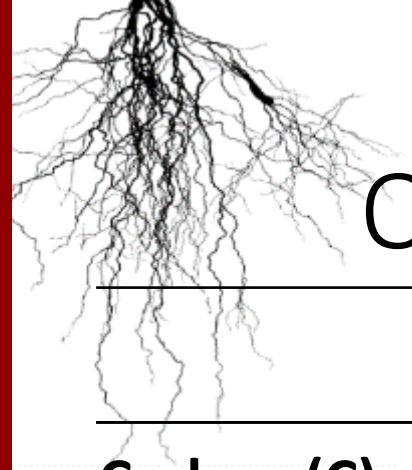
- 10-100x less N than bacteria
- 5-50x less than fungi

NEMATODES

N



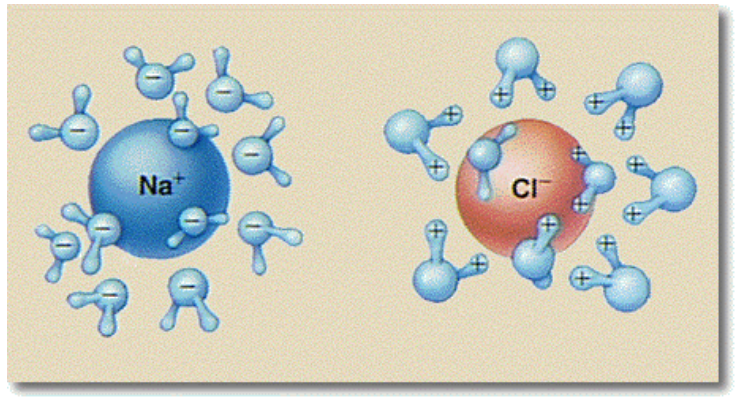
MICRO ARTHROPODS



Orchard Soil Fertility

Macronutrients		Micronutrients	
Carbon (C)	45.00%	Chlorine (Cl)	0.01 %
Oxygen (O)	45.00%	Iron (Fe)	0.01%
Hydrogen (H)	6.00%	Manganese (Mn)	0.005%
Nitrogen (N)	1.50%	Boron (B)	0.002%
Potassium (K)	1.00%	Zinc (Zn)	0.002%
Calcium (Ca)	0.50%	Copper (Cu)	0.0006%
Phosphorus (P)	0.20%	Molybdenum (Mo)	0.00001%
Magnesium (Mg)	0.20%	Nickel (Ni)	0.000001%
Sulphur (S)	0.20%		

Ions



Cat___ions (+)

Ammonium
NH_4^+

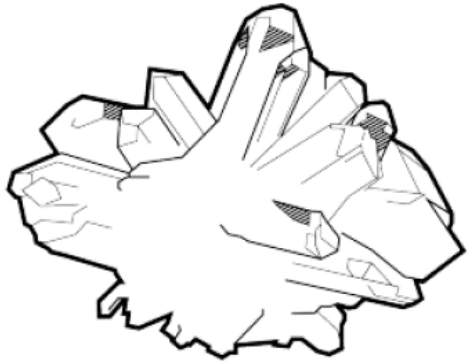
Potassium
K^+

An__ions (-)

Nitrate
NO_3^-

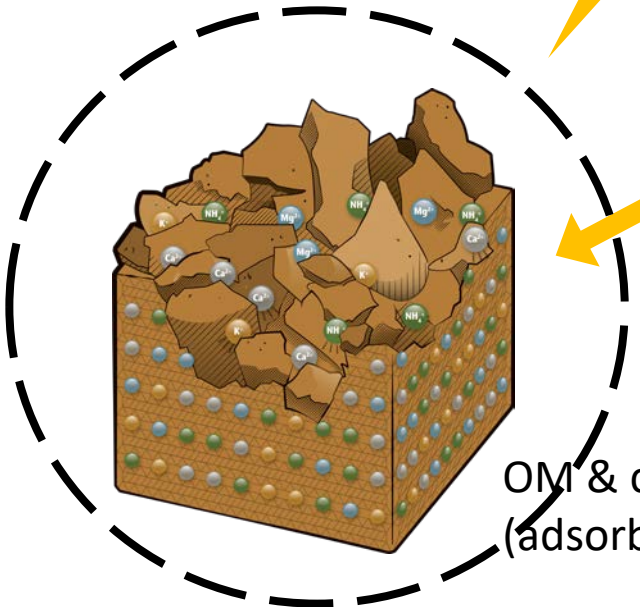
Phosphorus
$H_2PO_4^-$

Where do Nutrients Live



Rocks and Minerals

Organic Matter



OM & clay surfaces (adsorbed)

Soil solution (dissolved)

PO_4^-

K^+

Ca^{2+}

SO_4^{2-}

Fe^{2-}

Mg^{2+}

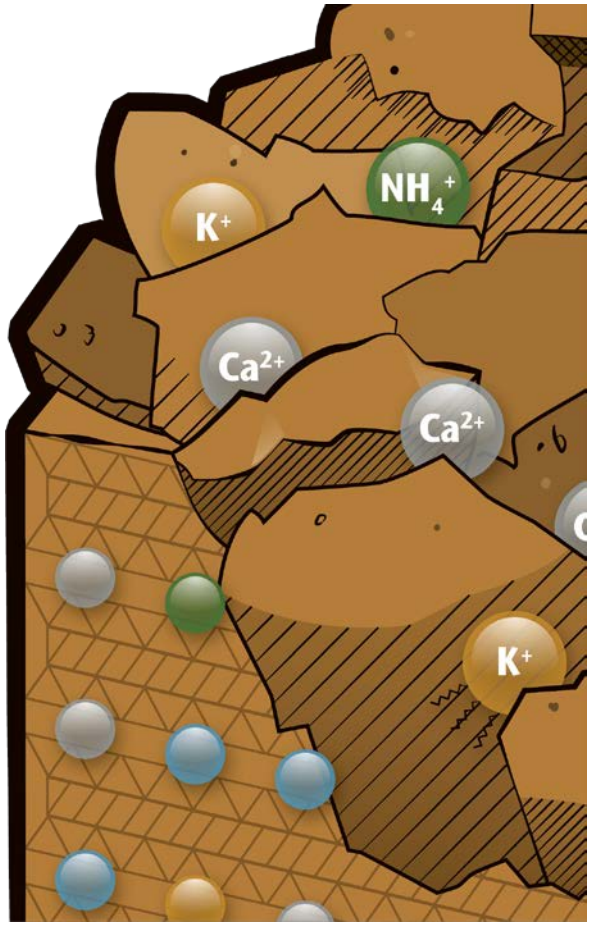
NH_4^+

NO_3^-

Soil Capacity to Hold Positive Nutrients (CEC)

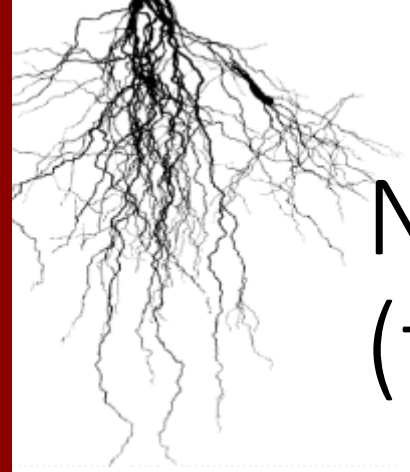
TYPICAL CEC VALUES FOR DIFFERENT SOIL TEXTURES

Soil Type	CEC meq/100g
Sands (light colored)	3 to 5
Sands (dark colored)	10 to 20
Loams	10 to 15
Silt Loams	15 to 25
Clay and clay loams	20 to 50
Organic soils	50 to 100



Orchard Soil Fertility Targets

Soil test	Unit	Low	Optimal
pH	-	< 5.0	6.0-7.5
P-Bray	ppm	< 30	35-50
Potassium (K)	ppm	< 120	150-250
Calcium (Ca)	ppm	< 600	820-4000
Magnesium (Mg)	ppm	< 60	60-300
Sodium (Na)	ppm		
Boron (B)	ppm	< 1.0	1.0-1.5
Sulfur (S)c	ppm	< 4.0	9-20
Zinc (Zn)	ppm	< 0.25	0.6-1.0
Copper (Cu)	ppm	< 0.1	0.6-1.0
Manganese (Mn)	ppm	–	1-5
Iron (Fe)d	ppm	> 4.5	20-50
Molybdenum (Mo)	ppm	–	0.11-0.20



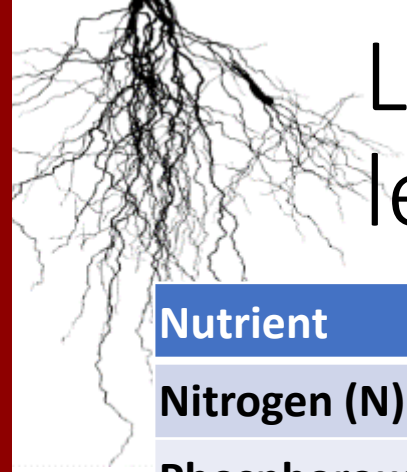
Nutrient Targets by Soil Type/CEC (for orchards)

Group	1	2	3	4	5
CEC	25	20	18	16	12
Ca	4450	3550	3200	2850	2150
Mg	550	425	390	350	250
K	260	225	215	200	165

Leaf Tissue Analysis

- non-bearing shoot or non-bearing spur, from mid-canopy, typically during July
- recent mature leaves, same cultivar
- 50-100 leaves for a sample (10-20/tree)
- store in a paper bag, keep cool until sent to laboratory
- submit within 24 hours
- N, P, K, Ca, Mg, S…
- Fe, Zn, Cu, Mn

https://treefruit.wsu.edu/orchard-management/soils-nutrition/leaf-tissue-analysis/



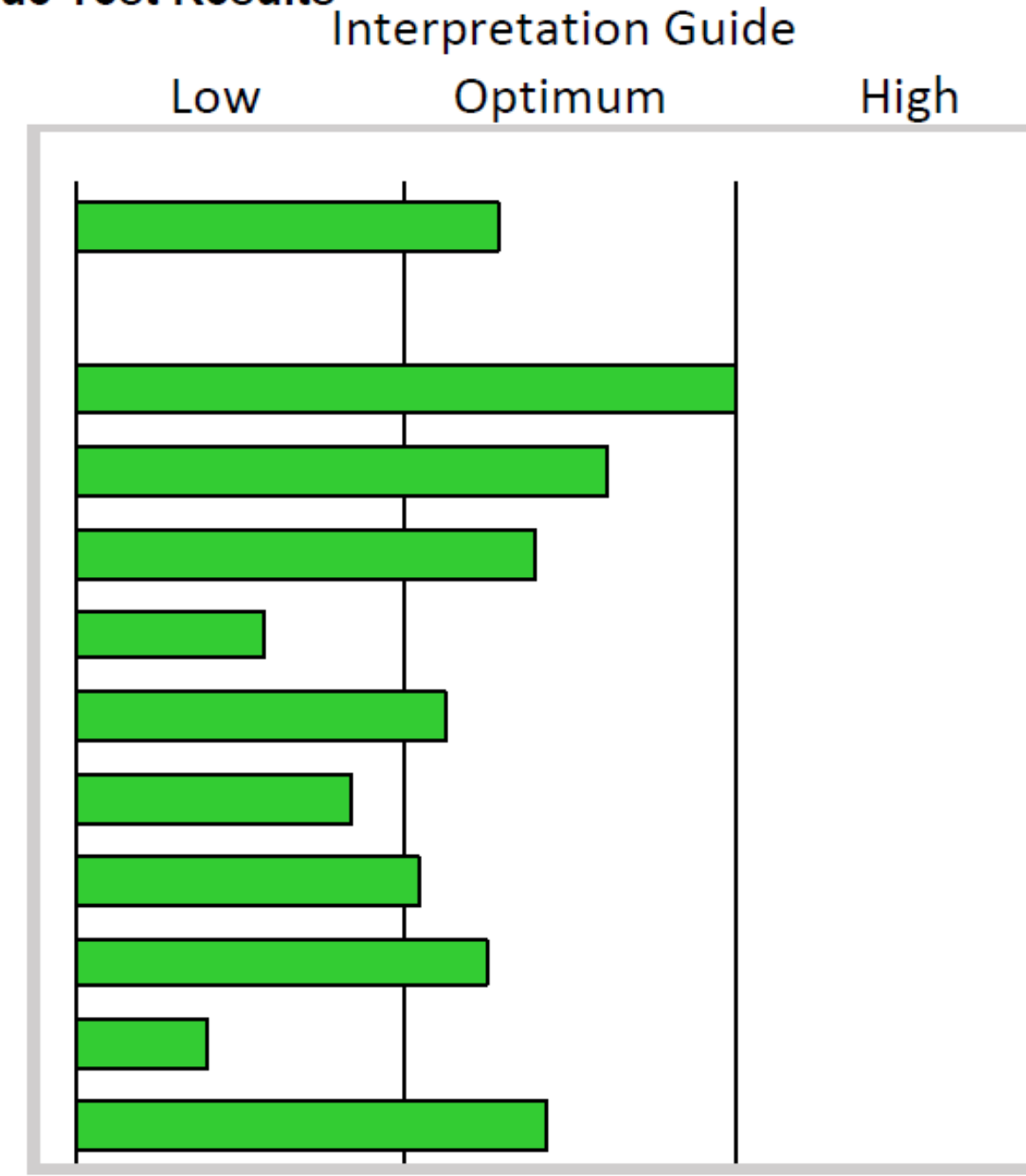
Leaf tissue standards for recently mature leaves in different tree fruit species

Nutrient	Unit DW	Apple[a,c,d,e]	Pear[a,c,d,e]	Cherry[b]	Peach[b]	Apricots[a,b]
Nitrogen (N)	%	1.7 – 2.5	1.8 – 2.6	2.00 – 3.03	2.7 – 3.5	2.4 – 3.3
Phosphorous (P)	%	0.15 – 0.3	0.12 – 0.25	0.10 – 0.27	0.1 – 0.30	0.1 – 0.3
Potassium (K)	%	1.2 – 1.9	1.0 – 2.0	1.20 – 3.3	1.2 – 3.0	2.0 – 3.5
Calcium (Ca)	%	1.5 – 2.0	1.0 – 3.7	1.20 – 2.37	1.0 – 2.5	1.10 – 4.00
Magnesium (Mg)	%	0.25 – 0.35	0.25 – 0.90	0.30 – 0.77	0.25 – 0.50	0.25 – 0.80
Sulfur (S)	%	0.01 – 0.10	0.01 – 0.03	0.20 – 0.40	0.2 – 0.4	0.20 – 0.40
Copper (Cu)	mg/Kg	5 – 12	6 – 20	0 – 16	4 – 16	4 – 16
Zinc (Zn)	mg/Kg	15 – 200	20 – 60	12 – 50	20 – 50	16 – 50
Manganese (Mn)	mg/Kg	25 – 150	20 – 170	17 – 160	20 – 200	20 – 160
Iron (Fe)	mg/Kg	60 – 120	100 – 800	57 – 250	120 – 200	60 – 250
Boron (B)	mg/Kg	20 – 60	20 – 60	17 – 60	20 – 80	20 – 70

Plant Tissue Test Results

Olympia orchard, sampled May 22nd, 2023

Element	Result
Total-N	2.28 %
Phosphorus	0.35 %
Potassium	1.62 %
Sulfur	0.14 %
Calcium	0.69 %
Magnesium	0.23 %
Boron	21 mg/kg
Zinc	16 mg/kg
Manganese	44 mg/kg
Copper	2 mg/kg
Iron	151 mg/kg
Sodium	0.00 %

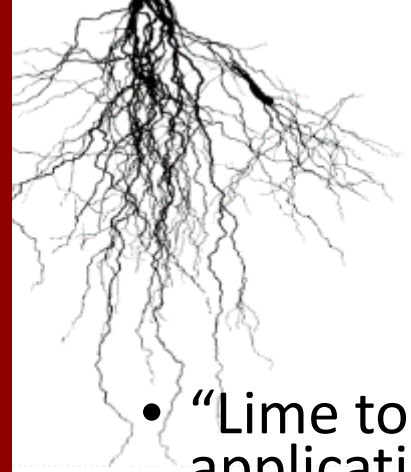


Fertility at Planting

	Soil test results 2014	Recomm. (ppm)	Soil test results 2020
pH	4.8	6-6.8	6.5
P	27	35-40	90VH
K	86	200-300	178M
Ca	493	Follow lime rec.	~
Mg	91	150	222M
S	13	20	9L
B	0.1	1-2	0.3VL
Zn	0.5	3.5-7	1.8
Fe	30	20-50	61VH
Cu	0.5	1-3	1.0

Fertility regime: Winter rye-vetch cover crop, and per 1,000 sf annually: 1-yd compost, 75 lbs Microna lime, 3-5 lbs N (100-160 lbs 3-2- stutzmans), and 5-10 lbs kelp meal

- Soil sample
- Follow liming recommendations (split app if > 140 lb/1,000 sf)
- 1-3 yrs cover crop in tree rows or field recommended
- Soil test will indicate lbs/ac application rates (Thurston CD) – surface applied after planting
- I like Bob Contisano's publication
- Phillips: 1 lbs rock phosphate, 1 lbs azomite, mycorrhizal root dip*
- Mound planting



Liming Rate (SMP Interpretation)

- "Lime to apply" values are based on application of 100-score lime and 6-inch soil sampling depth. For example, lime to apply = 78 lbs per 1,000 ft^2 when a desired soil pH is 5.6 and the lime requirement test (SMP) value is 6.0.

- ***If the value is greater than 140 lbs per 1,000 ft², consider splitting the application.***

- https://ir.library.oregonstate.edu/downloads/m613mx90d

	Desired soil pH		
	Lime to apply to attain desired soil pH (lbs per 1,000 ft²)		
SMP value	pH 5.6	pH 6	pH 6.4
6.7	0	0	0
6.6	0	0	46
6.5	0	46	78
6.4	0	51	101
6.3	0	69	124
6.2	46	92	147
6.1	64	110	170
6	78	133	193
5.9	96	152	216
5.8	115	170	243
5.7	129	193	266
5.6	147	211	289
5.5	165	234	312
5.4	179	253	335
5.3	197	275	358
5.2	216	294	381
5.1	230	317	409
5	248	335	432
4.9	266	354	455
4.8	285	381	478

Nutrient-accumulators

Deep-rooted perennials for soil minerals, less competitive ground cover (water, nutrients), and eventual chicken forage

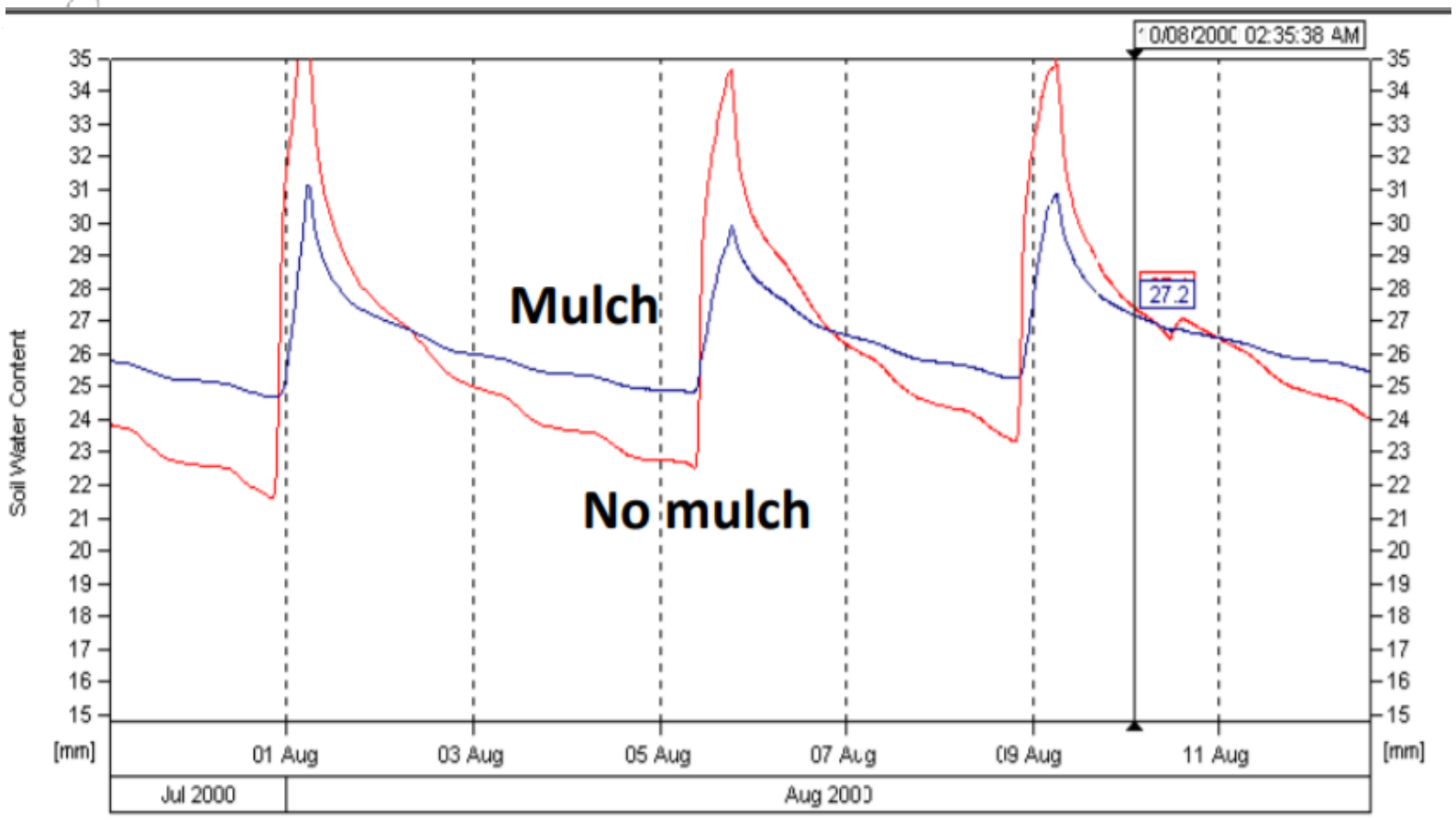
Comfrey

Orchard Soil Physical Health

- Apply wood chips
- “Mow and Blow” for larger operations
- Temp, moisture
- Orchard floor cover + compost = H_20 infiltration, H_20 storage, root channels, good structure, C inputs, less compaction
- “Ramial”

Phillips, Holistic Orchardist

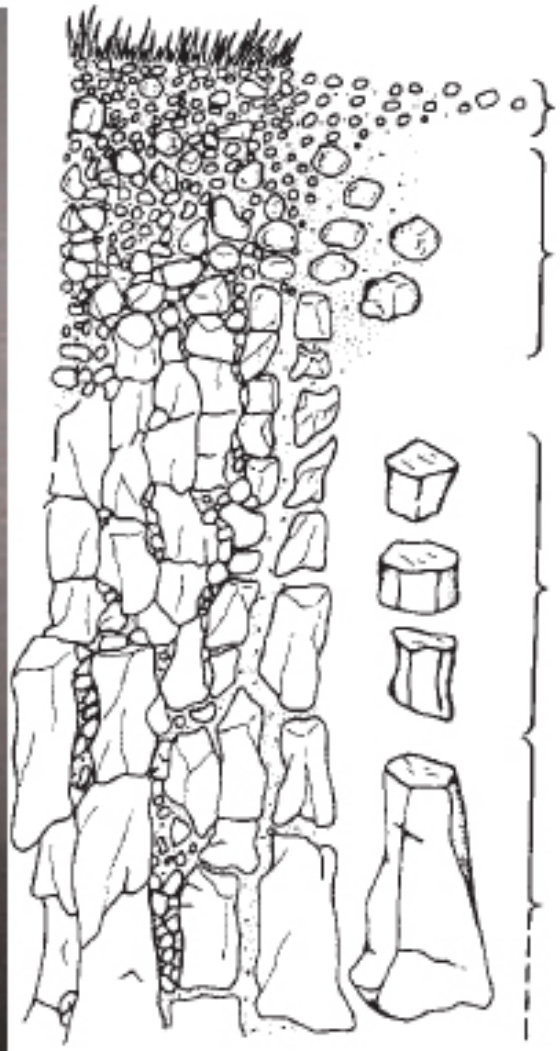
Mulching for Water Conservation

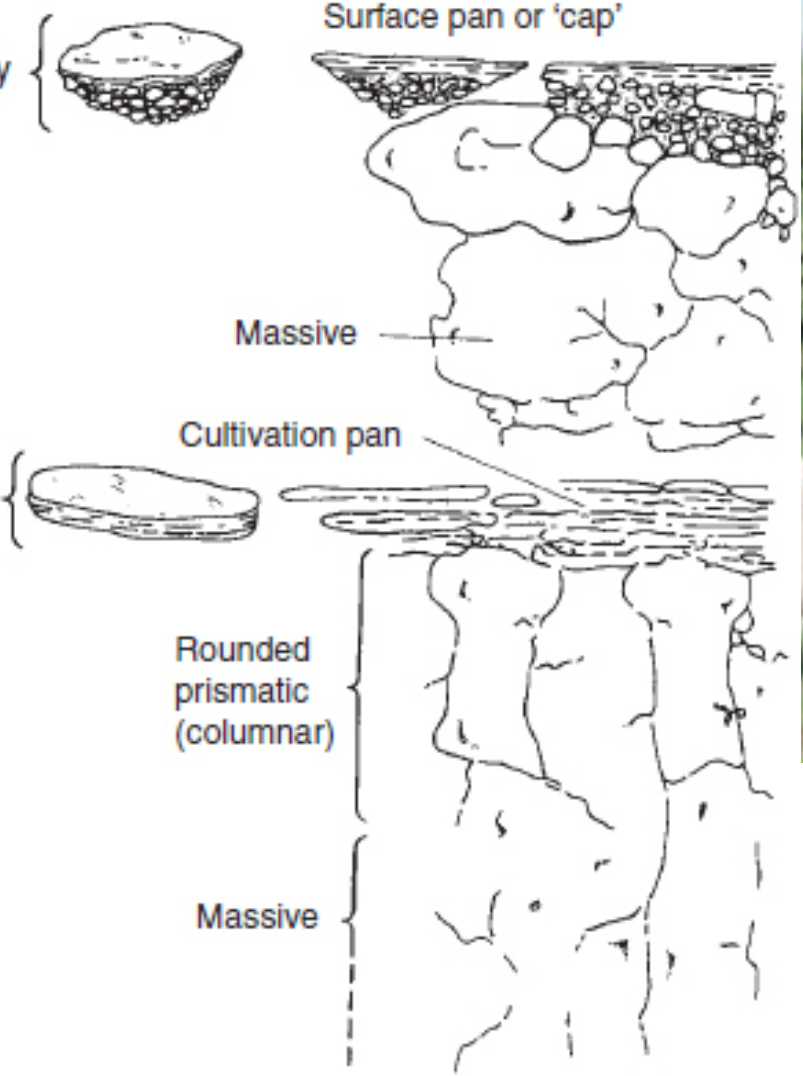


Woodchip mulch led to 20-25% less moisture depletion between irrigations

DuPont et. al, 2020

Soil Structure



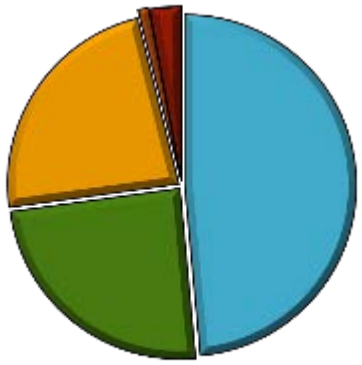


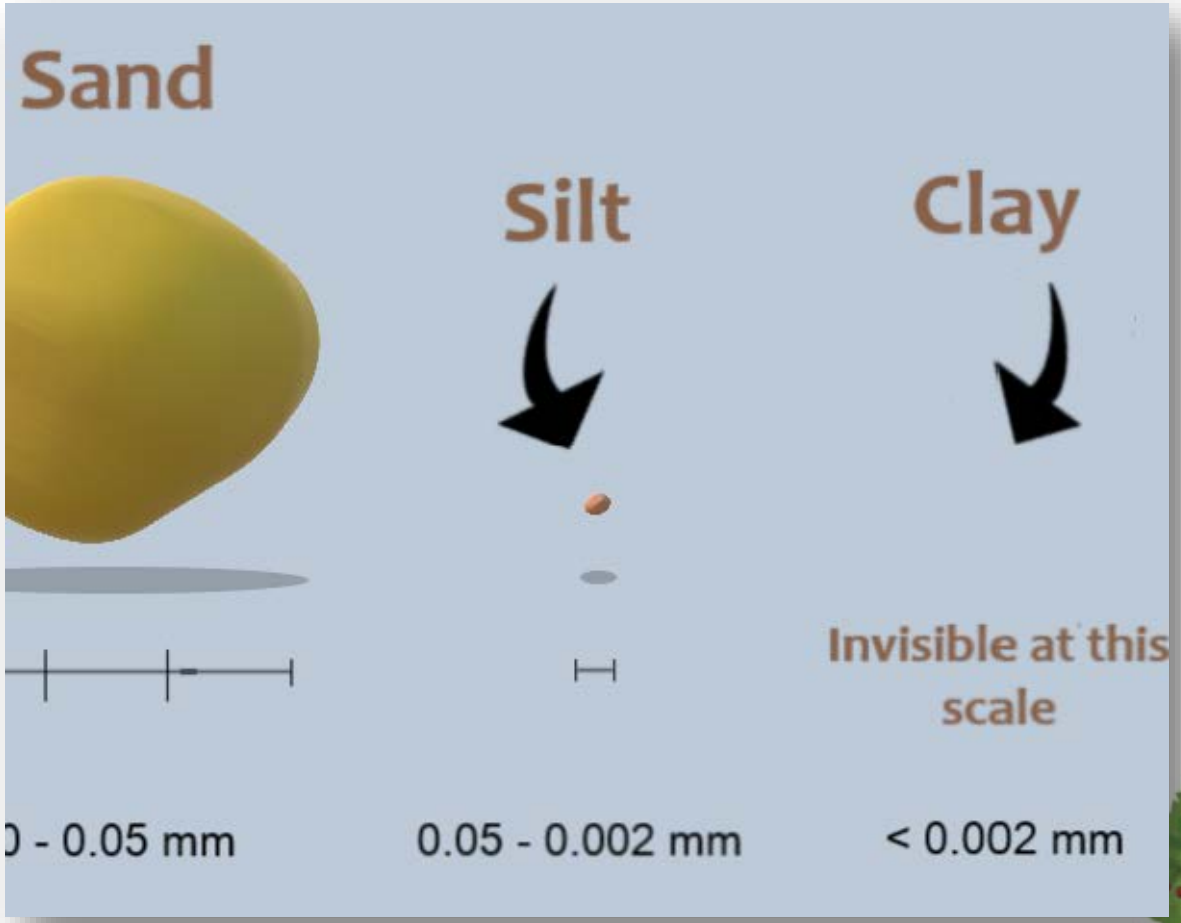
Living Mulches, In Row

- Often lowers yield, lowers growth
- No change on yield if mowed regularly

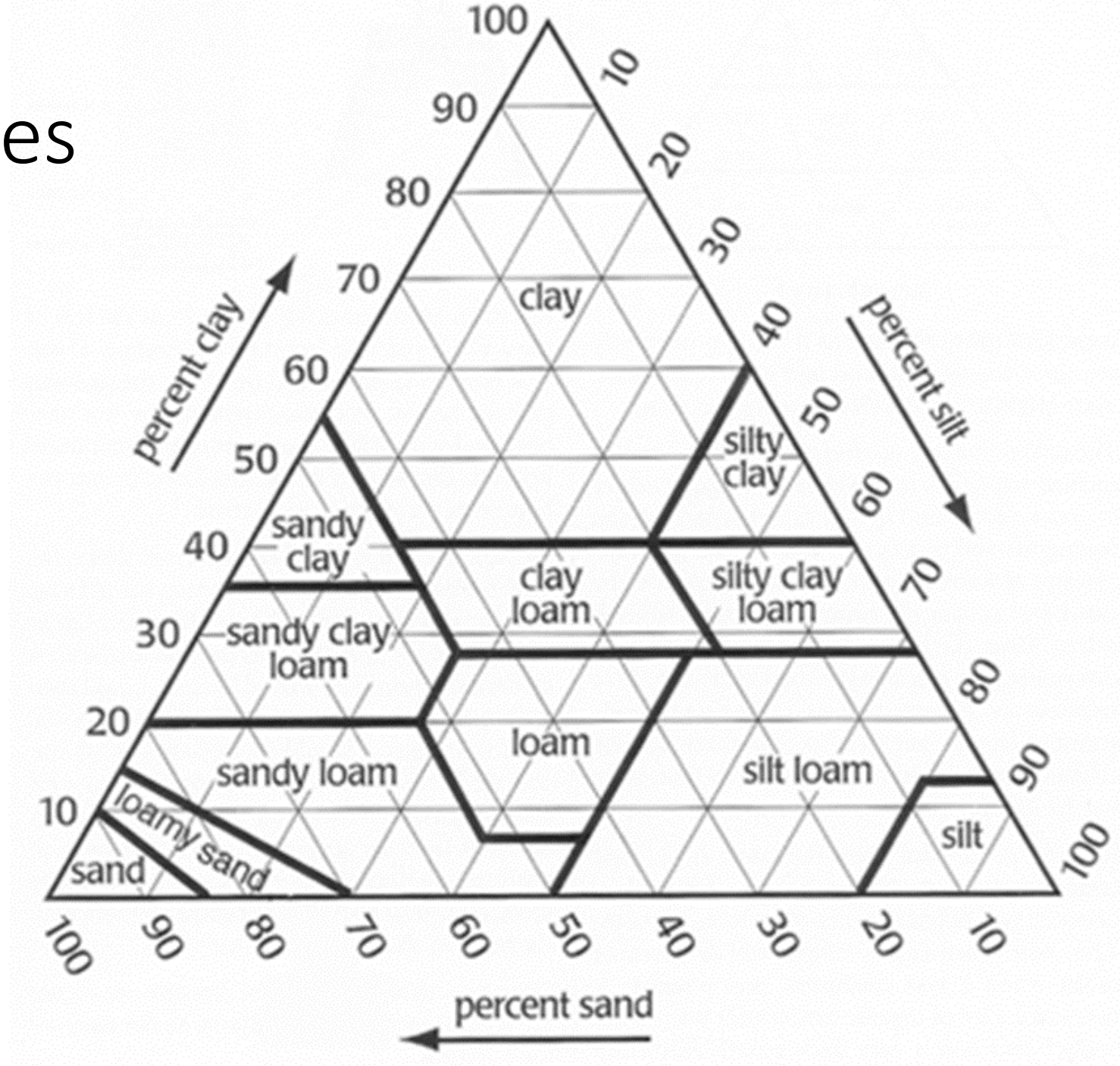
https://treefruit.wsu.edu/crop-protection/weed-control/organic-weed-control/

Soil Texture





Texture Classes



Soil Biota - Mycorrhizae

- Scavenge/solubilize phosphorus, nitrogen, micronutrients, and water
- Help with replant disease
- Extend root volume, explore smaller pore openings

Seedlings inoculated with isolate AMFS-2

Max increase in growth parameters i.e. height, stem, internodal length, leaf area, shoot/ root fresh and dry weight was observed in the. The % root colonization was also higher

Indian Journal of Agricultural Sciences **83** (11): 1173–8, November 2013/Article

Effect of indigenous arbuscular - mycorrhiza (*Glomus* spp) on apple (*Malus domestica*) seedlings grown in replant disease soil

PRAVEEN MEHTA[1] and NARENDER K BHARAT[2]

https://epubs.icar.org.in/index.php/IJAgS/article/view/34535/15296

Soil Biota – Bio-innoculants

- Vesicular arbuscular mycorrhizae (VAM)
  - P-solubilizing inoculant
- Azobacter, Azospirillum
  - N-fixing inoculants

VAM + Azobacter:

"…most effective and desirable treatment combination for higher yield and better quality of fruit."

Indian Journal of Agricultural Sciences **83** (11): 1159–64, November 2013/Article

Yield and quality of apple (*Malus domestica*) cv Red Delicious as affected by bio-inoculants

S R SINGH[1], A H DAR[2], A S SUNDOURI[3] and M K SHARMA[4]

https://epubs.icar.org.in/index.php/IJAgS/article/view/34533/15294

Soil Sampling

- Separate orchard into similar areas
- A soil core auger is best
- Obtain 15-20 cores from beneath trees in the sampling area (block) of interest
- Collect composite of 0-6” cores, and a composite of 6-18” cores
- Mix composite in clear plastic bucket (avoids zinc contamination)
- Place pint to 1-quart sub-sample in clean bag; follow lab instructions and complete paperwork

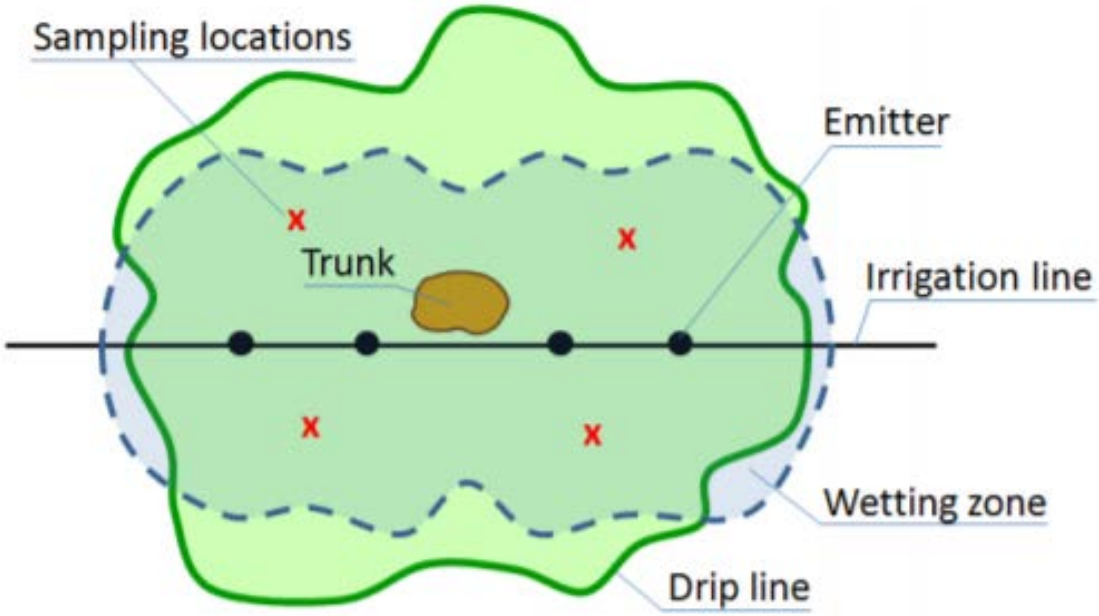
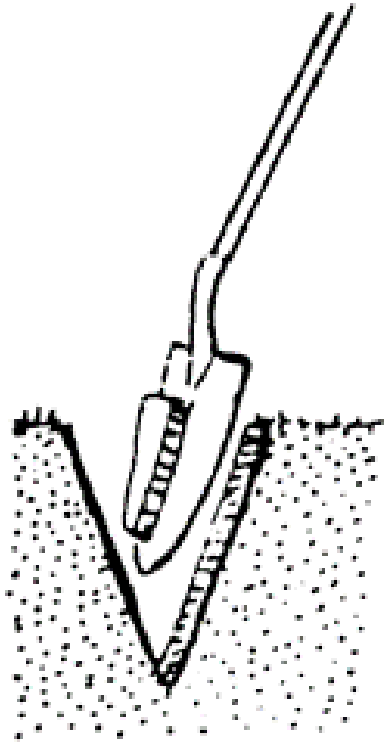


Figure 2: Bird’s view of the optimal sampling location under orchard trees. Soil samples are taken within the wetting zone halfway between the trunk and the drip line.

https://apps1.cdfa.ca.gov/fertilizerresearch/docs/Soil_Sampling_Orchards.pdf

Soil Sampling

- Keep moist samples cool during and after sampling
- Refrigerate, freeze, or bring directly to lab
- Same time year, same sampling depth
- Send about 1 pint to lab, carefully labeled



Resources

- WSU Wenatchee Tree Fruit Research and Extension. https://treefruit.wsu.edu/orchard-management/
- Strategies for managing soil fertility. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2903&context=extension_curall
- Tree Fruit, Horticulture. https://www.uvm.edu/~orchard/fruit/treefruit/tf_horticulture/VTAppleNutr/vtapplenutr030198.html

Resources

- Orchard tissue testing: https://extension.usu.edu/files/publications/publication/AG-FG-02.pdf
- Orchard Establishment: http://treefruit.wsu.edu/orchard-management/orchard-establishment/
- Orchard Soils and Nutrition: http://treefruit.wsu.edu/orchard-management/soils-nutrition/
- Below the Canopy: http://treefruit.wsu.edu/article/below-the-canopy/
- Fertilizing Fruit Trees: http://extension.colostate.edu/topic-areas/yard-garden/fertilizing-fruit-trees-7-612/
- OSU Tree Fruit and Vegetable Fertilizer Guide: https://catalog.extension.oregonstate.edu/ec1503

Soil Health

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes

NRCS Soil Health