The Latest Dirt: Research-Based Innovation in Soil Health

CLCA Landscape Industry Show
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http://ccag-eh.ucanr.edu

Topics to be Covered

- Physical Characteristics of Soil
  - ➢ Soil texture and its effects water & nutrient retention
  - ➢ Soil organic matter and soil aggregation
- Plant Roots and the Rhizosphere
  - ➢ Root structure and Rhizosphere
  - ➢ Mycorrhizae

➢ Soil Structure
  - ➢ Effects of tilling & compaction
  - ➢ Dealing with compaction

➢ Mulches

➢ Cover Cropping

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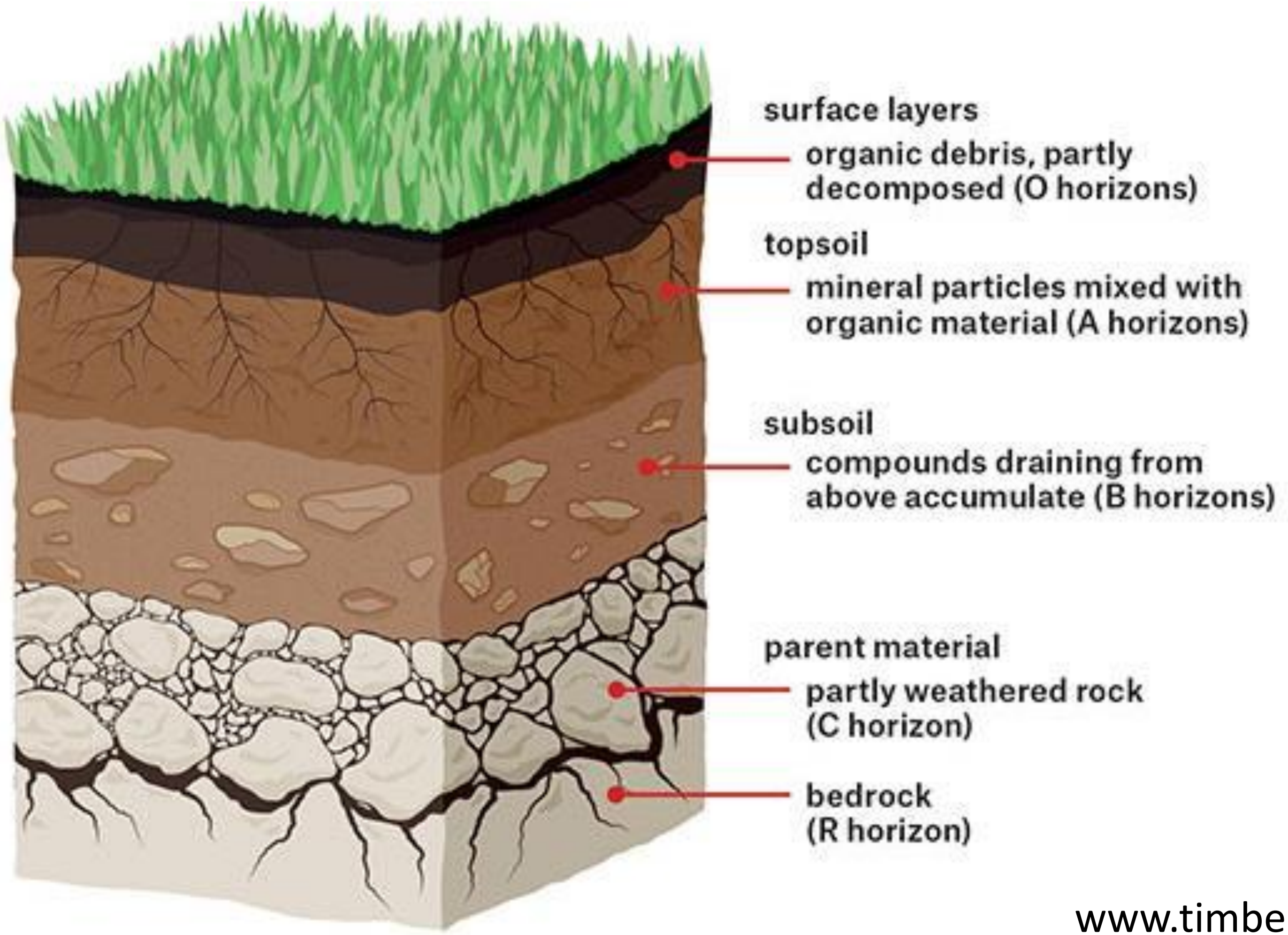
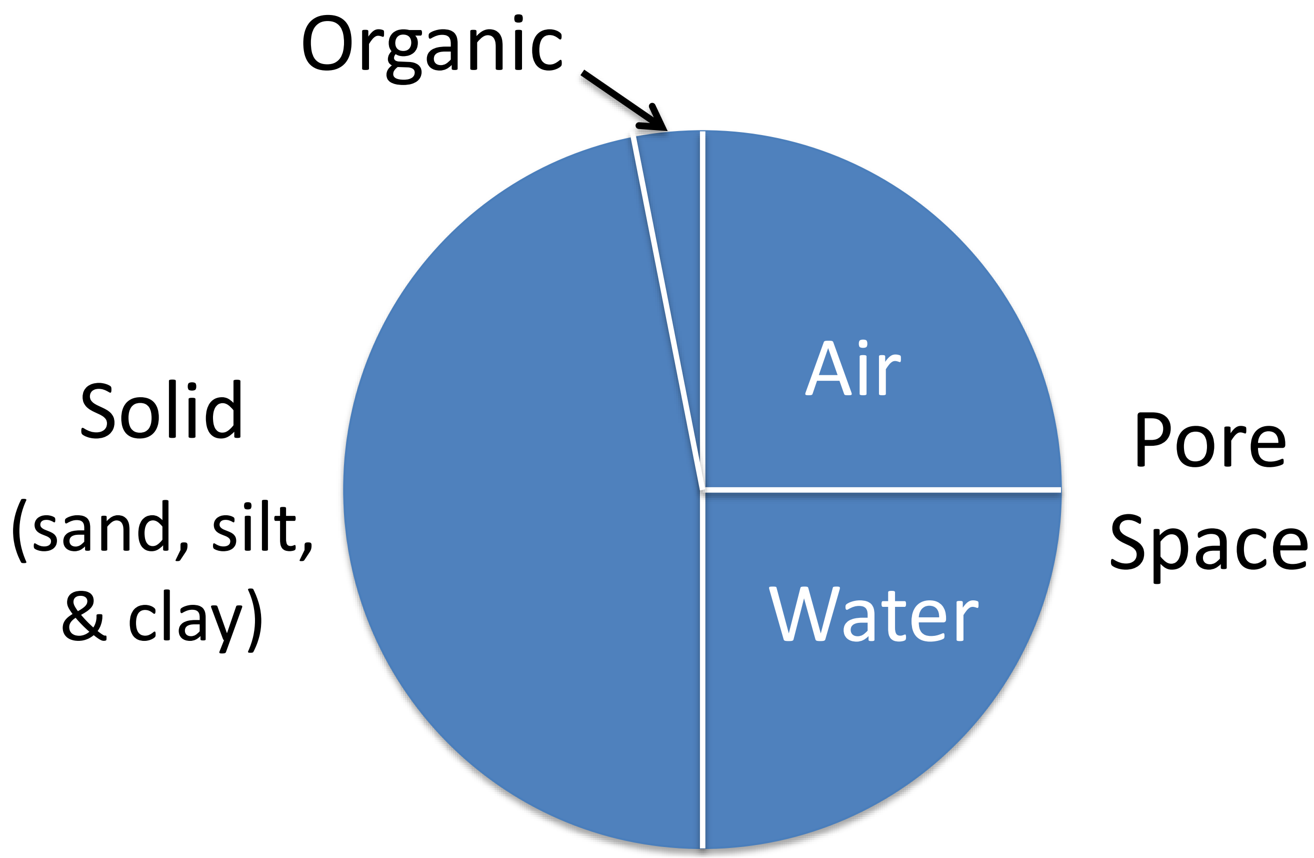
Typical Soil Profile



www.timberpress.com

Makeup of Soils



Physical Characteristics of Soil

Sandy loam

Clay loam

✓Texture

✓Structure

Soil Texture vs. Structure

<u>Texture:</u> Percent sand/silt/clay

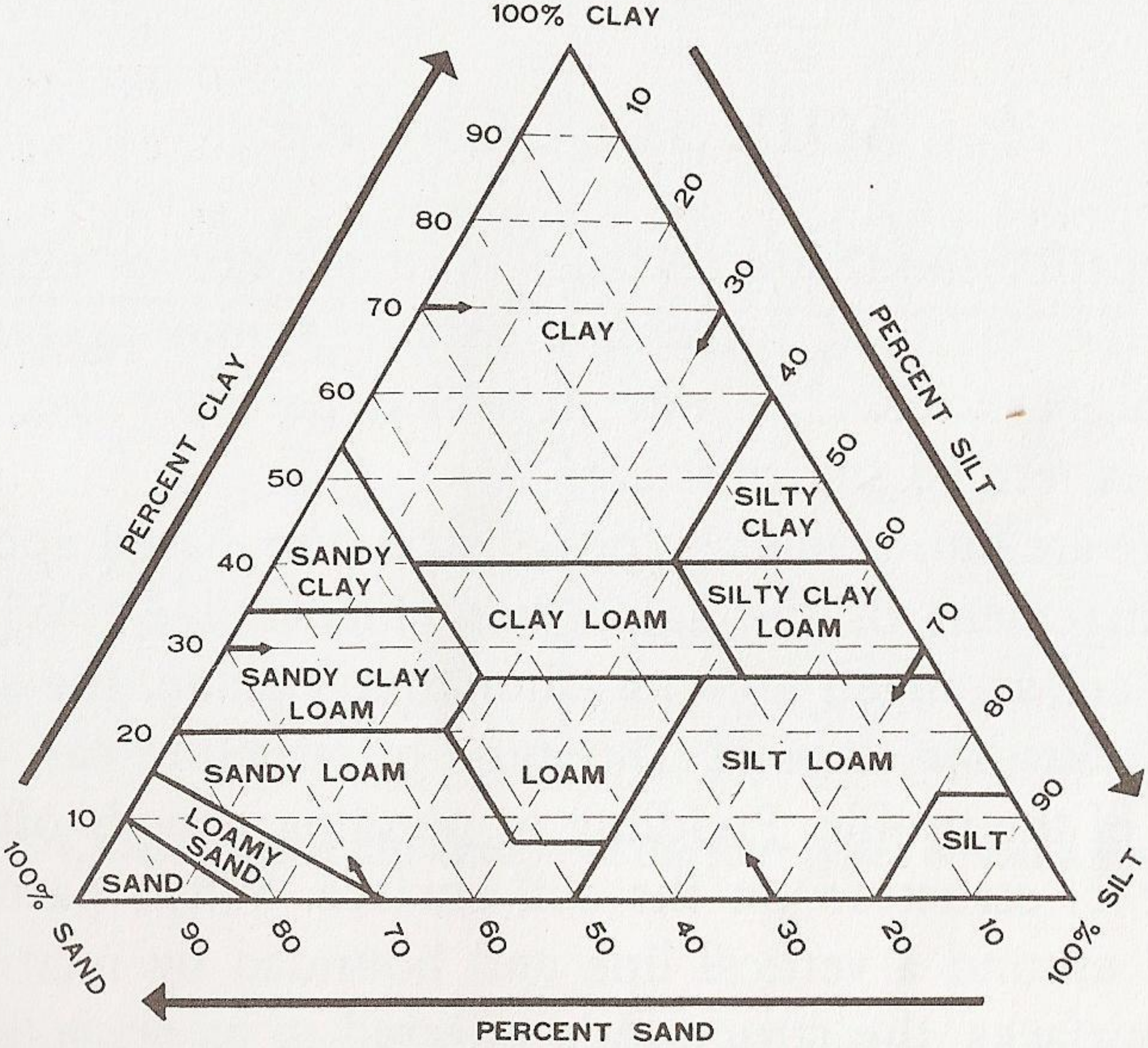
- Examples: sandy loam, clay loam

Impractical to change

<u>Structure:</u> Arrangement of particles into aggregates, clods, crusts, pans, etc.

- Affected by compaction

<u>Can</u> be changed – for better or worse



Soil Texture

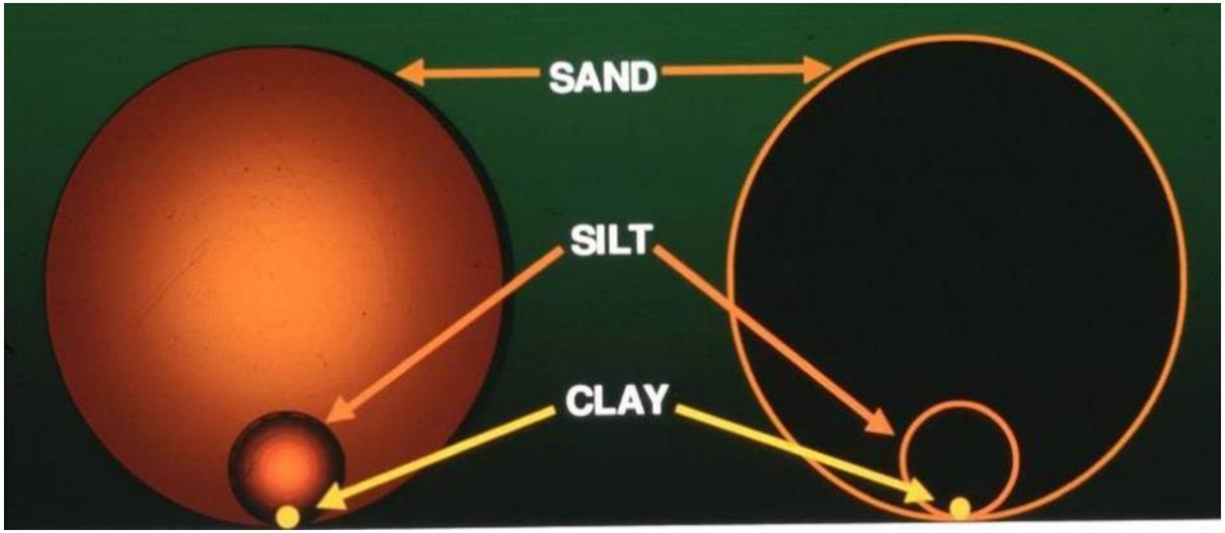
The Soil Triangle
(Based on lab analysis)

Soil Particle Sizes

Sand 2.00 to 0.05 mm

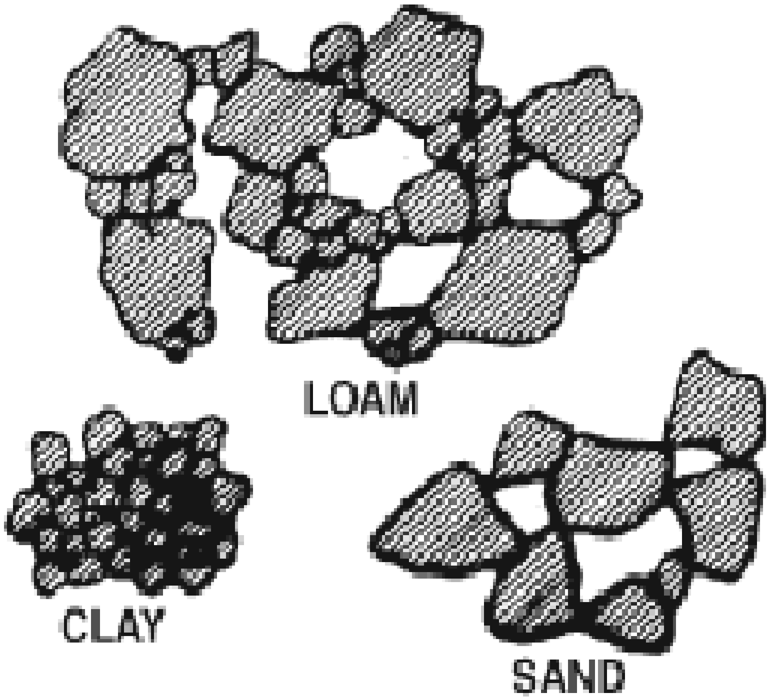
Silt 0.05 to 0.002 mm

Clay 0.002 to <0.0002 mm

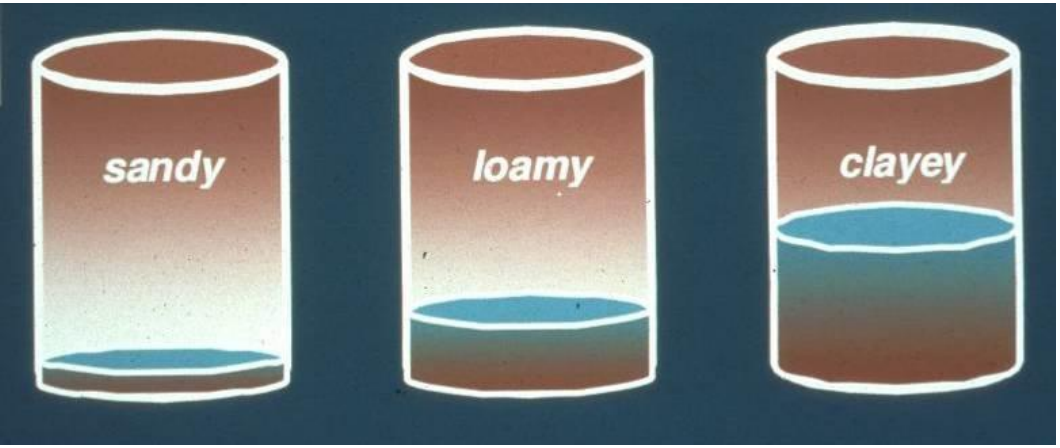


Soil Texture

Loamy sand — LIGHT
Sandy loam
Loam
Silty loam
Clay loam
Clay
Silty clay
Sandy clay — HEAVY

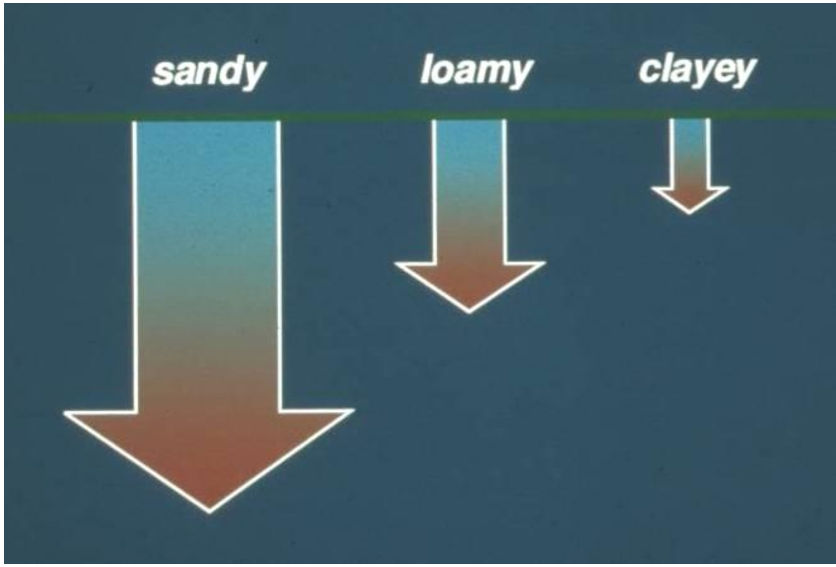


Soil Texture Affects Soil Moisture

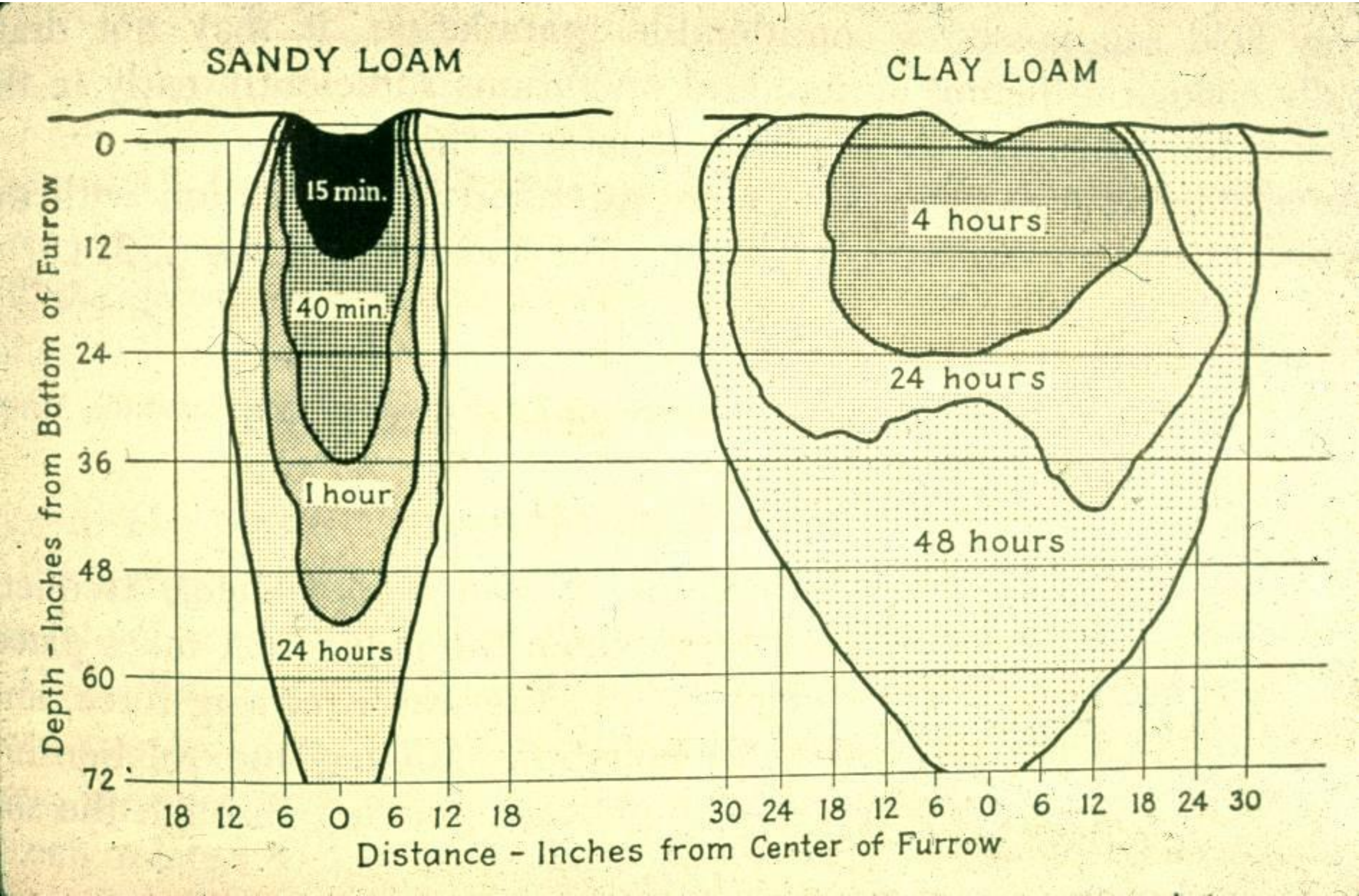


Water Holding Capacity

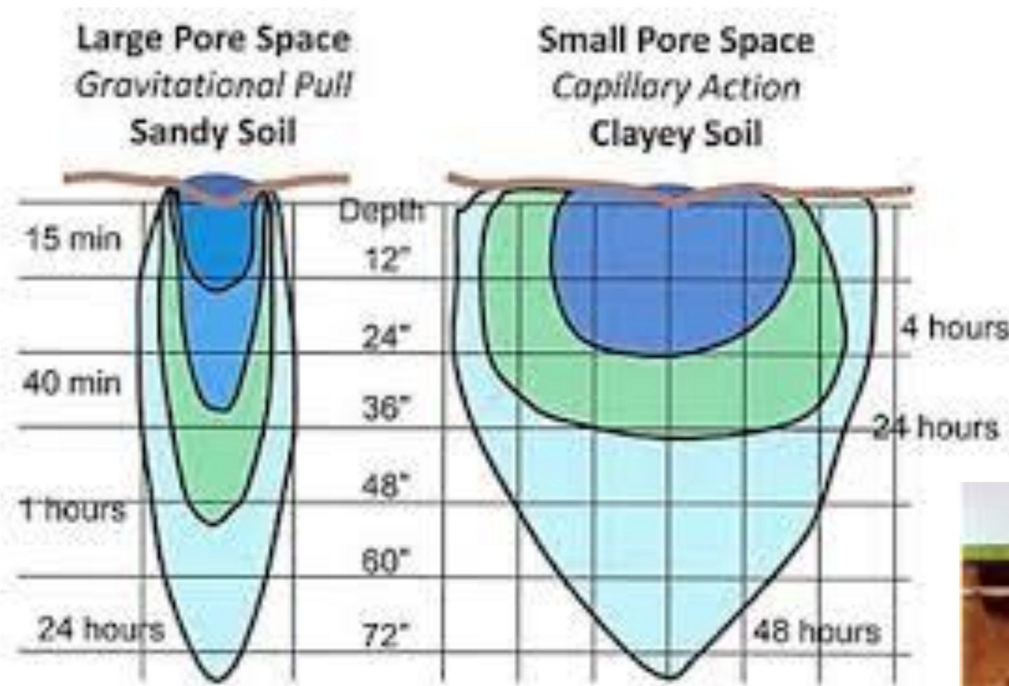
Permeability

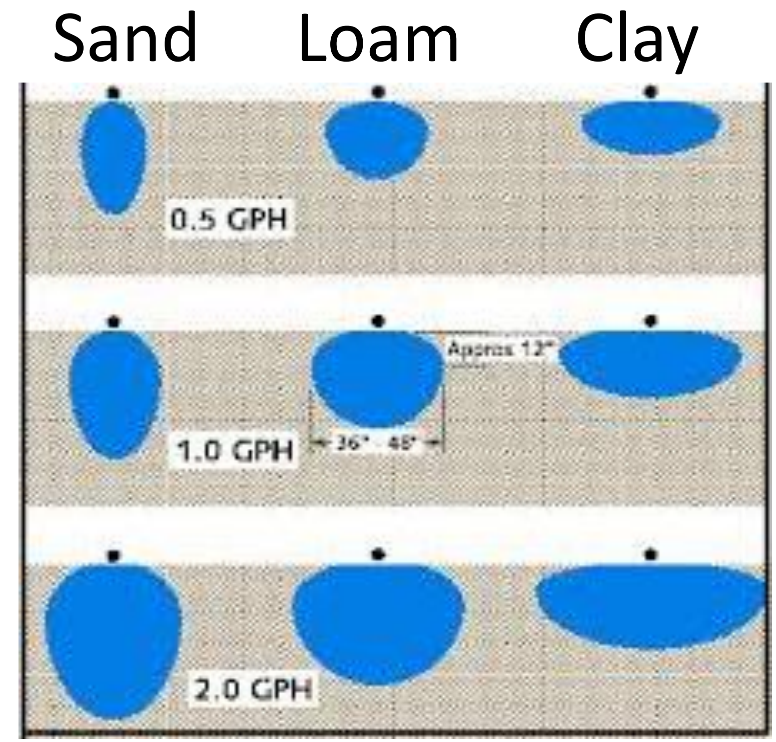


Water Infiltration through Soils



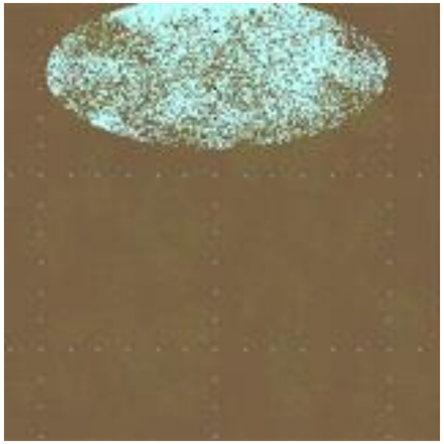
Water Movement in Soil



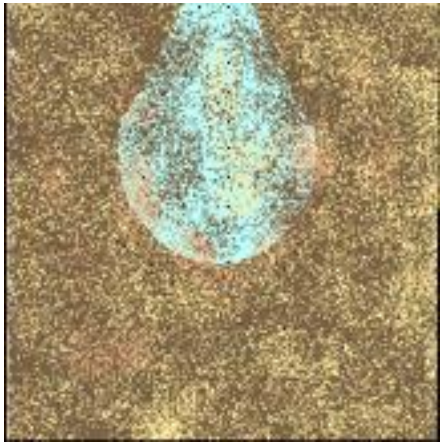


Wetted Pattern and Area

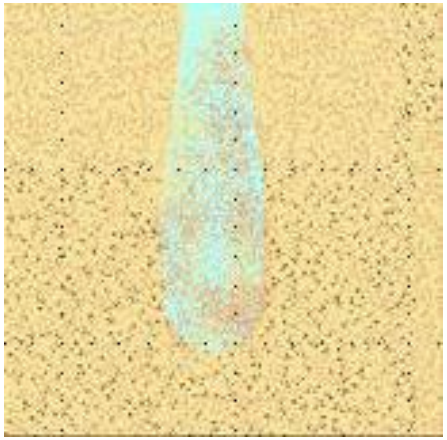
½ GPH Emitter



Clay
20-38 ft^2



Loam
7-20 ft^2



Sand
3-7 ft^2

Source: Ewing Irrigation

Soil Type	Emitter Flow Rate (gal/hr)	Soil Wetted Area	
		Diameter (ft)	Area (ft^2)
Sand	0.5	2 to 3	3 to 7
	1.0	3 to 3.5	7 to 10
	2.0	3.5 to 4	10 to 13
Sandy Loam	0.5	3 to 4.5	7 to 16
	1.0	4.5 to 5	16 to 20
	2.0	5 to 5.5	20 to 24
Loam	0.5	3 to 5	7 to 20
	1.0	5 to 6	20 to 28
	2.0	6 to 7	28 to 38
Clay Loam	0.5	4 to 6	13 to 28
	1.0	6 to 7	28 to 38
	2.0	7 to 8	38 to 50
Clay	**0.5**	5 to 7	20 to 38
	1.0	7 to 8	38 to 50
	2.0	8 to 9	50 to 64

Capillary Water Movement in Clay Loam Soil

University *of* California
Agriculture and Natural Resources | Cooperative Extension

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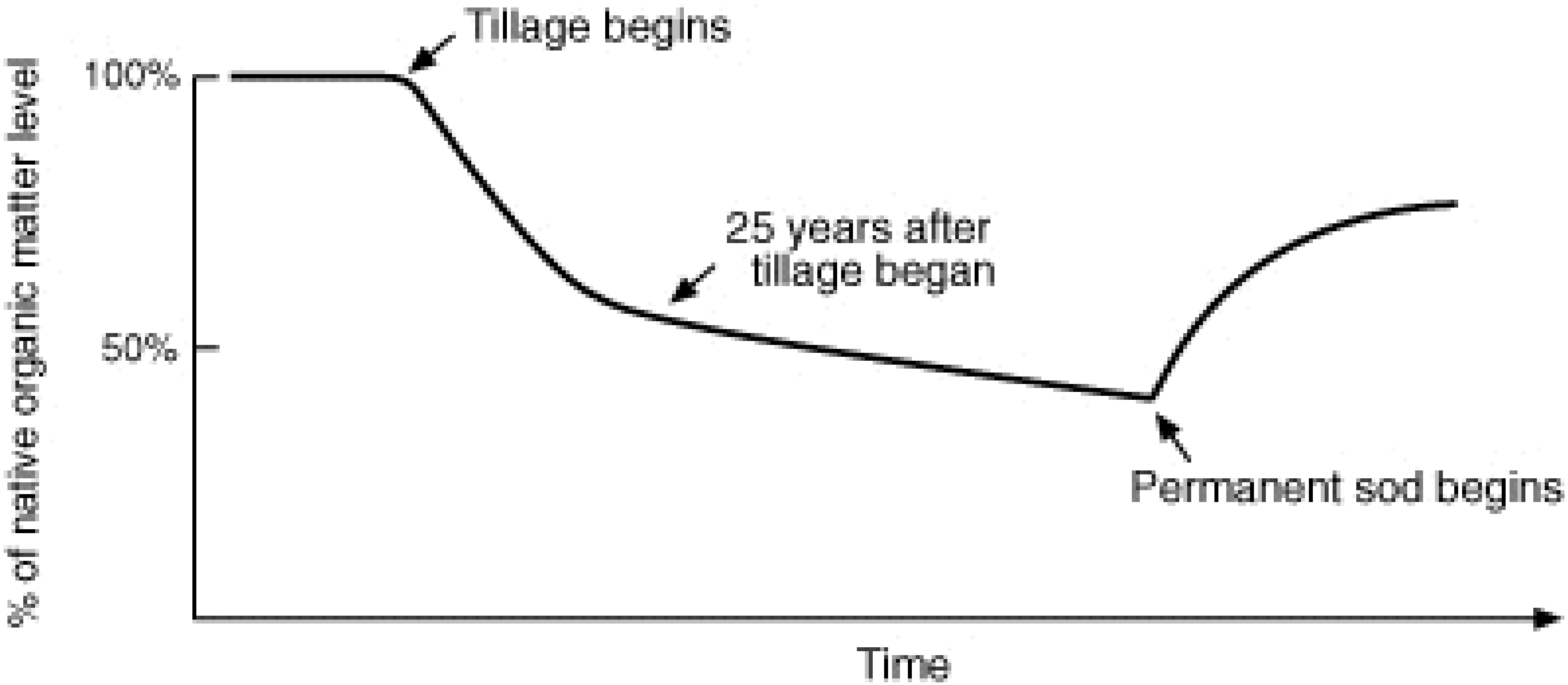
Soil Organic Matter

- Serves as energy source (food) for microbes, which promote aggregation
- Essential nutrients are obtained by plants as OM decomposes
- Enhanced by OM additions but destroyed by cultivation

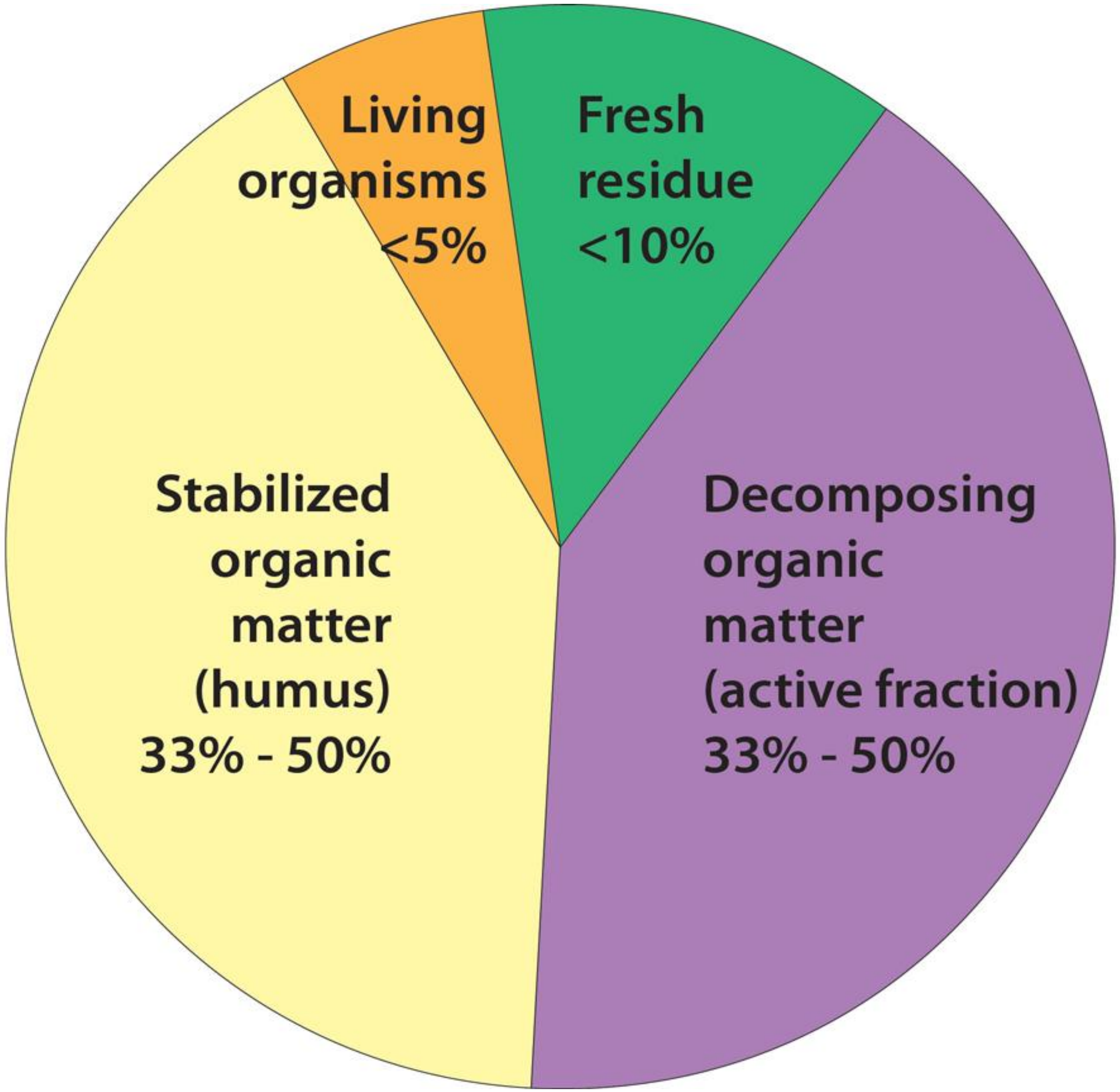
Soil Organic Matter Loss

Recent Research



Sources: Univ. of Minnesota,
Ohio State Univ.

Makeup of Soil Organic Matter



Humus

What We've Been Taught

- What's left over after organic matter decomposes
- Cannot be seen by naked eye
- Very reactive (CEC)
- In equilibrium with organic matter additions

A New Understanding of Humus

Background

- Many years ago soil scientists noticed that good agricultural soil was black
  - Devised a method to extract it from the soil
  - Treated soil with a strong alkaline solution (pH 13)
    - Pulled the organic component out of soil for study
  - Treatment with alkali produces humic acid and fulvic acid!

A New Understanding of Humus

“The Contentious Nature of Soil Organic Matter”

http://www.nature.com/nature/journal/v528/n7580/abs/nature16069.html

- Nature journal, Dec. 2015
- Humus is created during the pH 13 extraction process – the strong alkali creates humus
  - Molecules interact with soil - hiding from microbes
  - Microbes build large molecules making the process start all over again
- Humus does not exist! (This is largely academic)

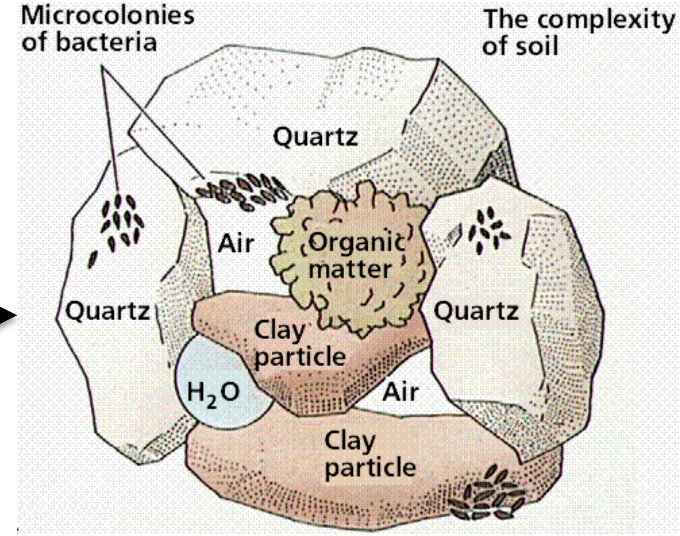
Source: http://www.gardenmyths.com/humus-does-not-exist-says-new-study/

Soil Aggregate Formation

Humus, OM, plant & microbial exudates, and earthworm castings act as "binding" agents

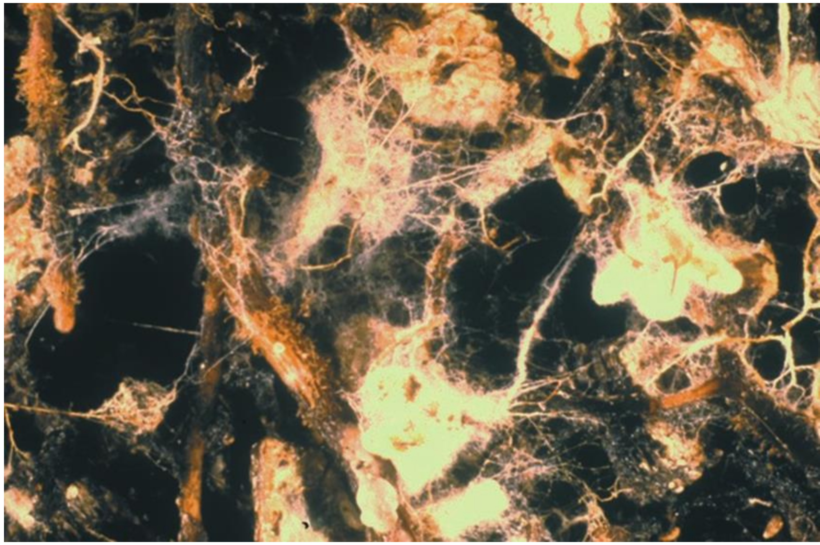
Soil Aggregation

- Bacteria, polysaccharides, etc. – micro-aggregate formation
- Fungal hyphae – enmeshing micro-aggregates into macro-aggregates

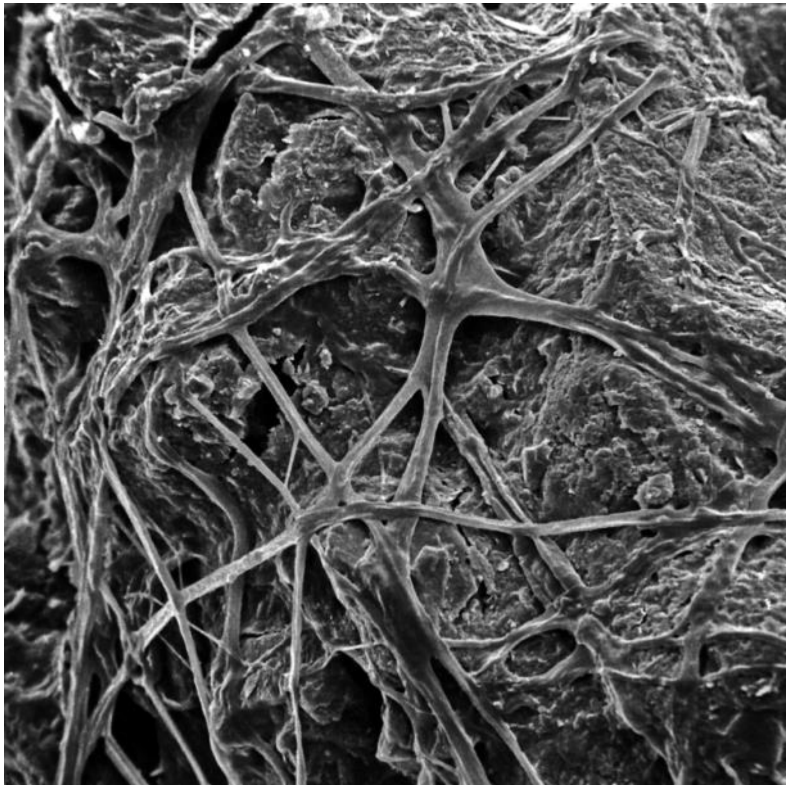


Fungi

- Fungi grow as long strands (hyphae) several thousandths of an inch in diameter
- They push their way between soil particles, roots, and rocks
- A single hyphae can span in length from a few cells to many yards.

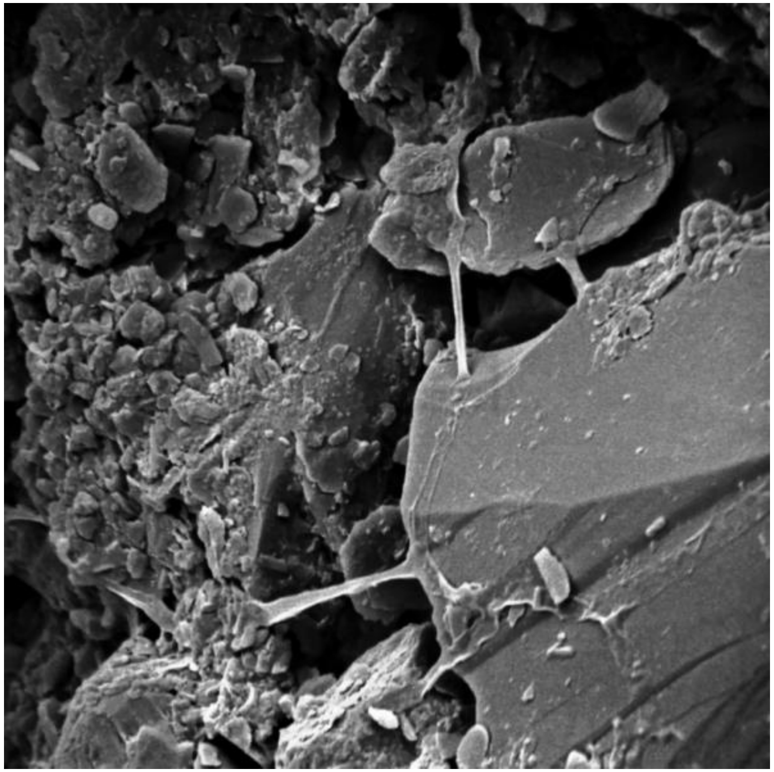


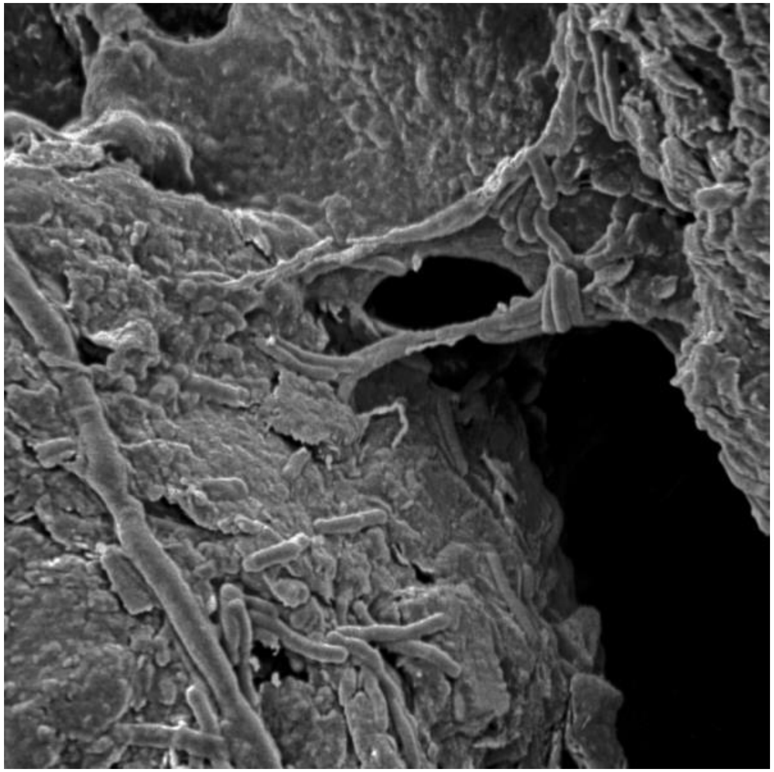
Netlike fungal mycelia can stabilize micro-aggregates



http://www.microped.uni-bremen.de/SEM_index.htm

Stabilization of Soil Structure by Actinomycete Filaments





http://www.microped.uni-bremen.de/SEM_index.htm

What Do Earthworms Do?

- Stimulate microbial activity
- Mix and aggregate soil
- Increase infiltration (burrows)
- Improve water-holding capacity by increasing aggregation and soil porosity
- Provide channels for root growth
- Bury and shred plant residue

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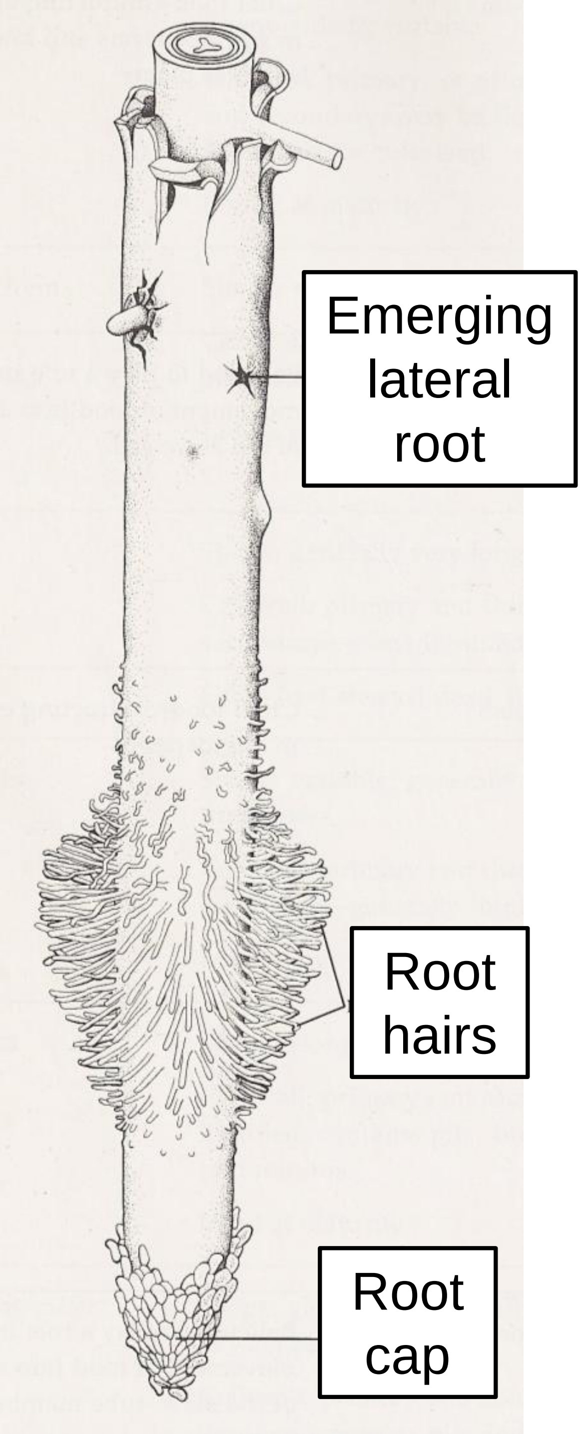
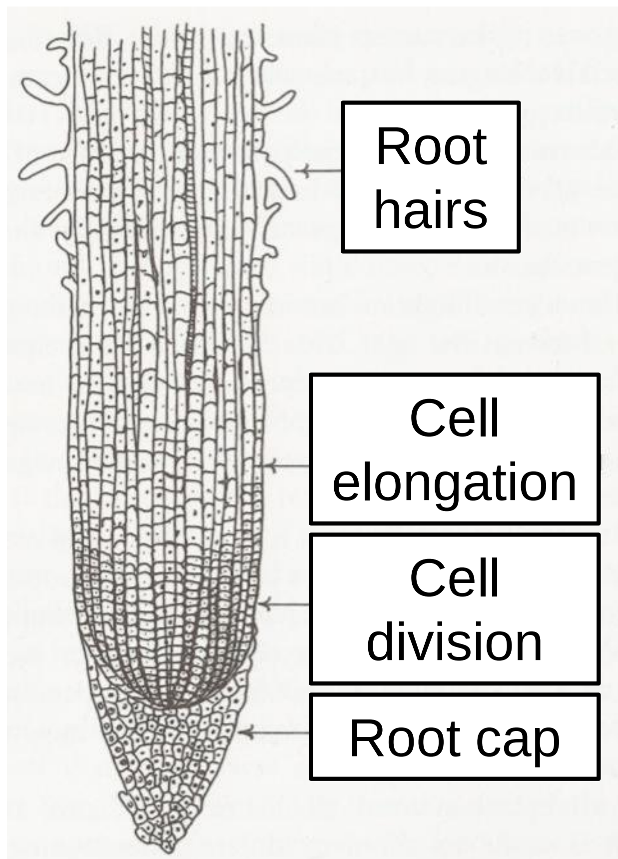
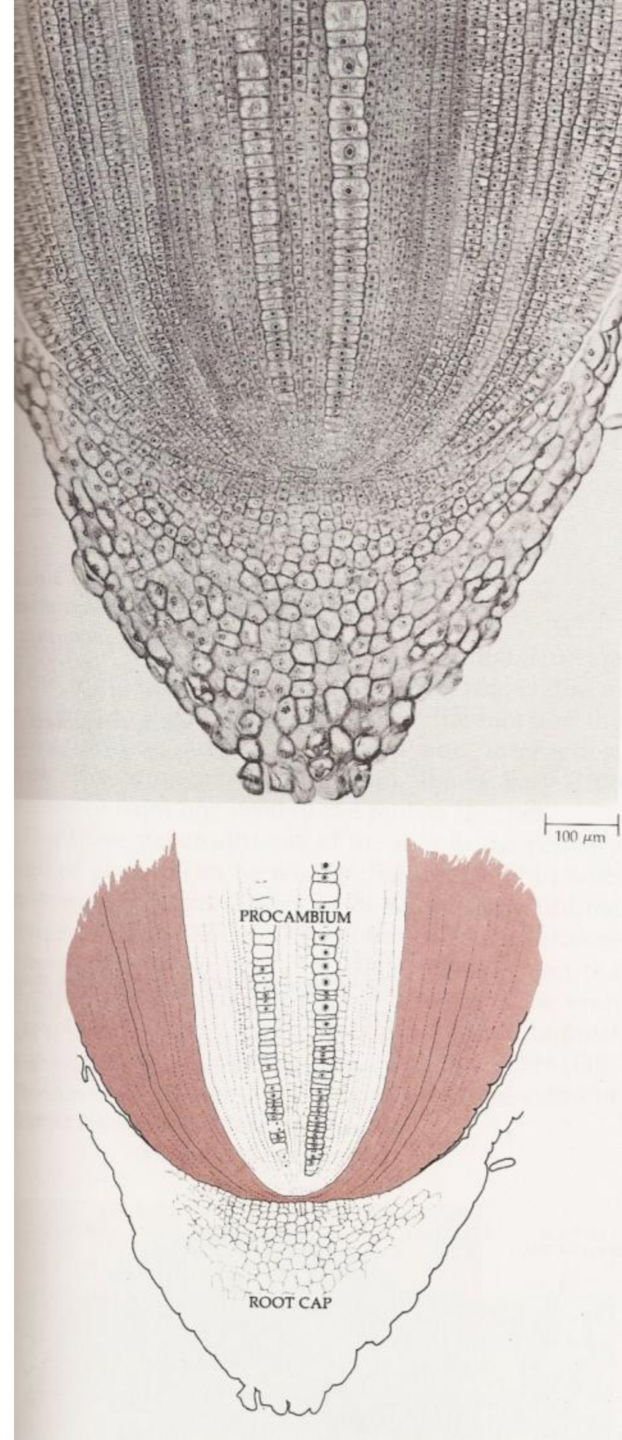
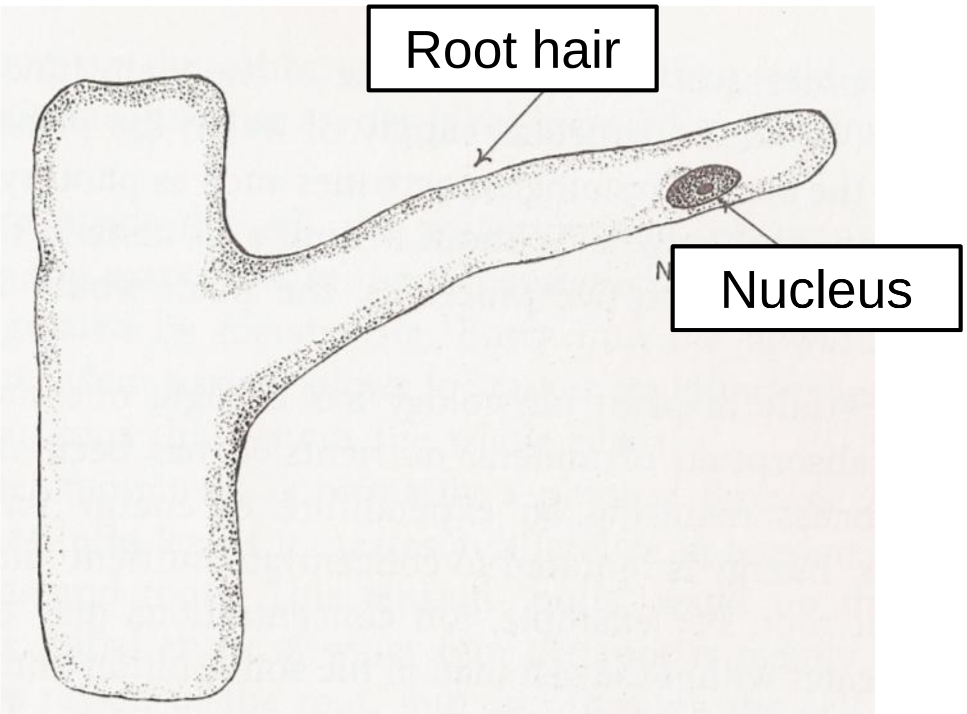
Anatomy of Young Roots





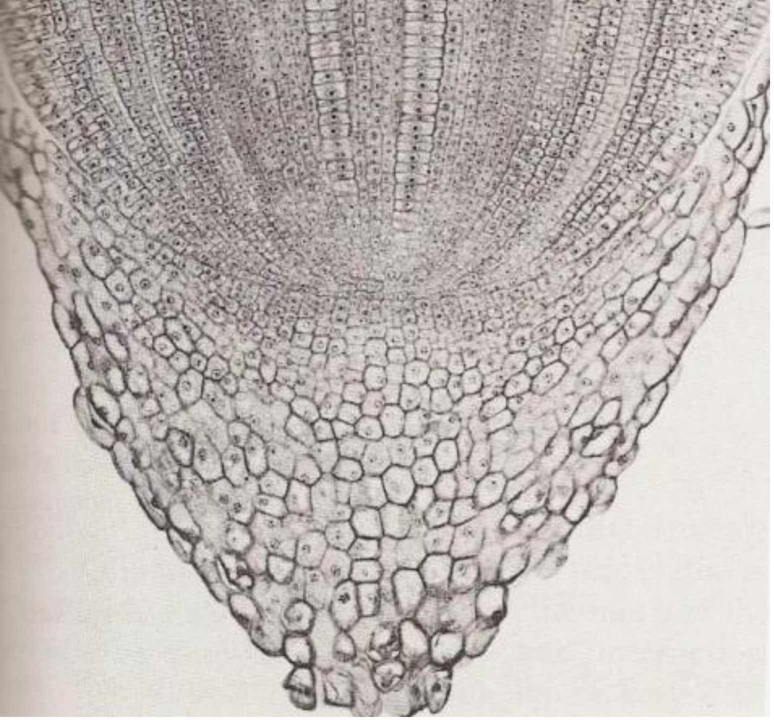


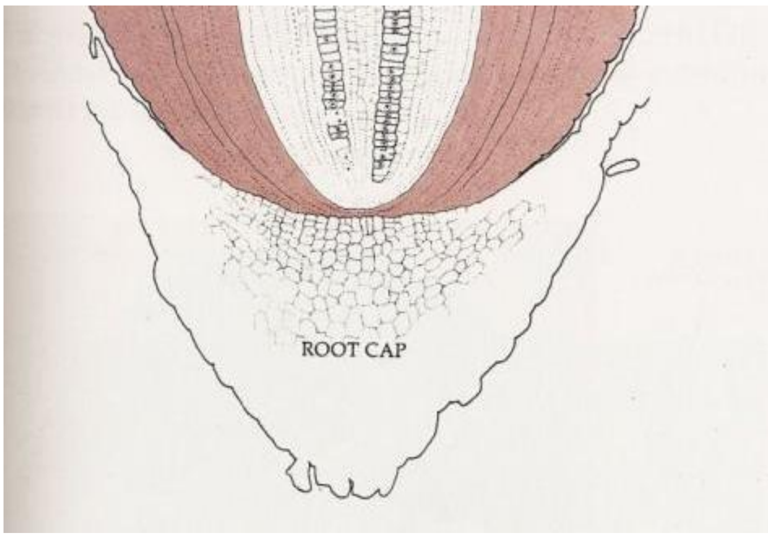
Root Hairs



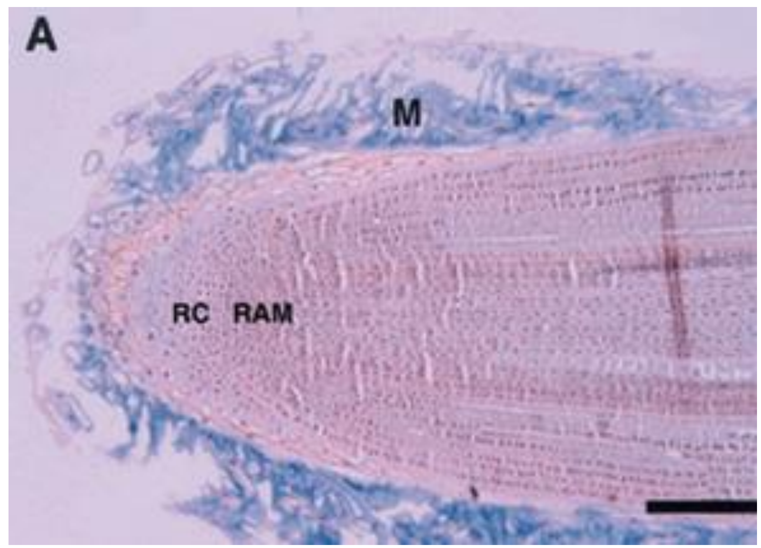
- Cells, not roots!
- Greatly increase root surface area
- Very short lived

Root Cap





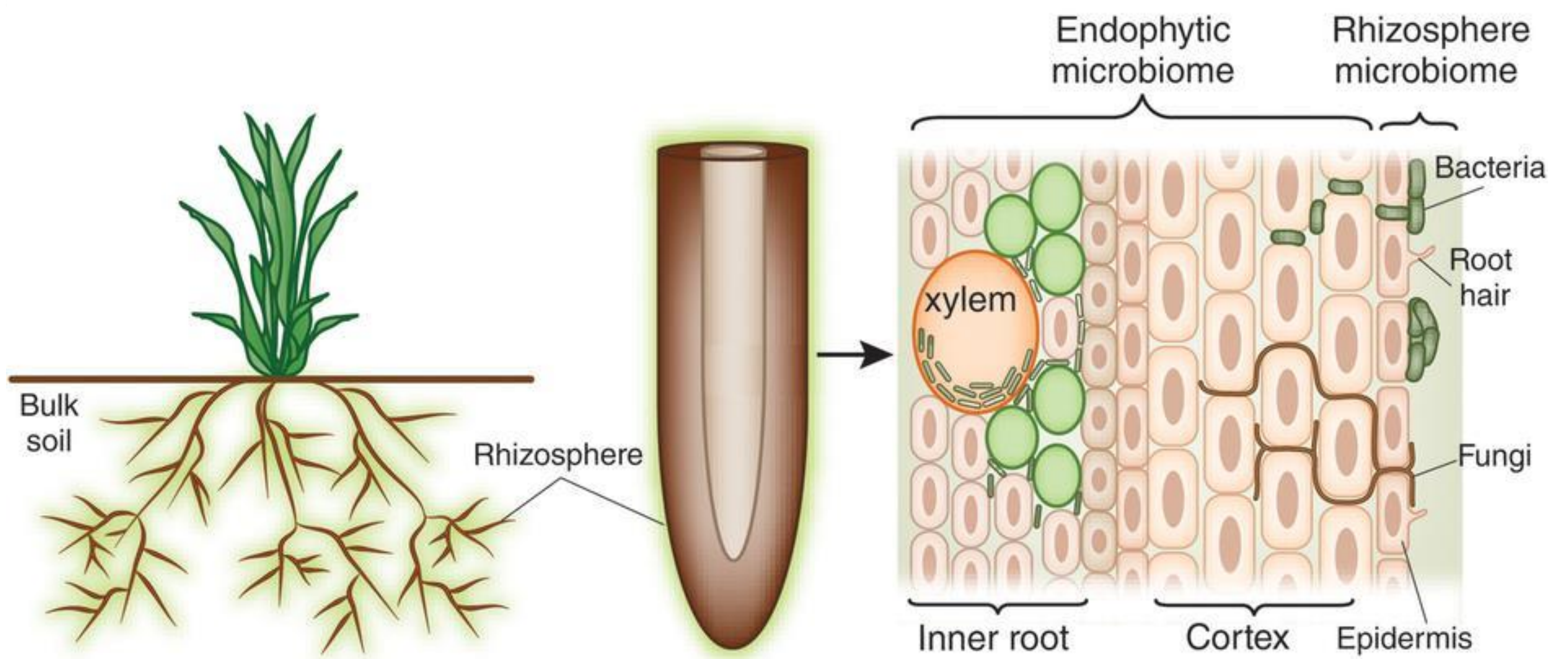
- Covers apical meristem
- Produces slimy "mucigel"
  - Sugars, enzymes, amino acids
  - Protects & lubricates root tip
  - Improves soil aggregate formation



Source: Laprotox (UFRGS)

Plant Roots Feed the Microbes!

- Use 25-40% of carbohydrate supplies to feed microbes
- Use hormones to attract and “farm” bacteria, fungi, and other organisms to help recycle soil nutrients & water



Sources:
1. J. Hoorman, Ohio State Univ.
2. www.nature.com

The Rhizosphere

- Thin region of soil that is directly influenced by root secretions (exudates) and soil microbes
- Roots release organic substances into the rhizosphere
- There are over 1000 times more microbes associated with a live root than in the bulk soil

Source: J. Hoorman, Ohio State Univ.

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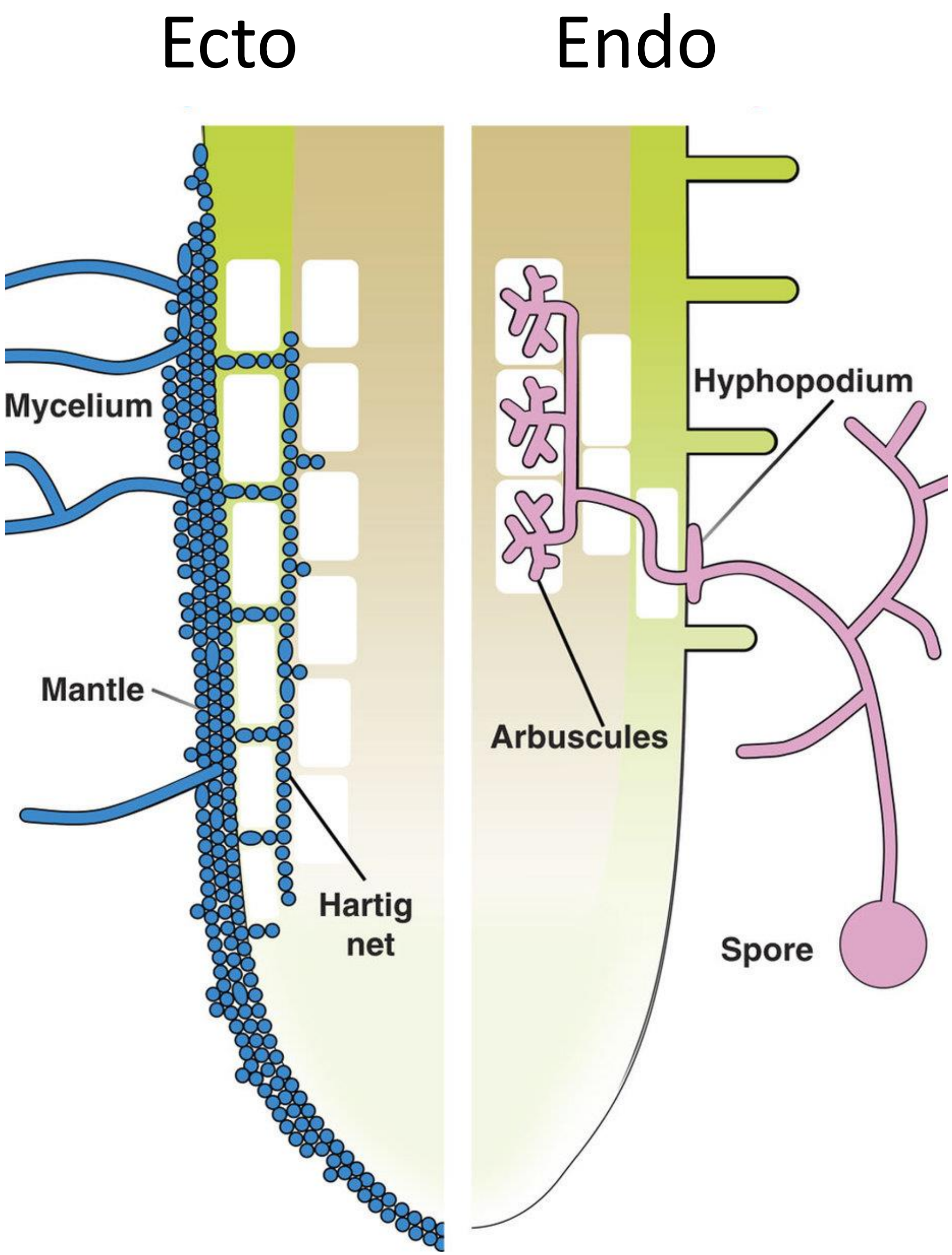
Mycorrhizae

(“Fungus-Roots”)

- Fungal infection of roots – symbiotic relationship
- Fungi – receive sugars; Plants – phosphorus & water
- Help roots explore up to 20x the volume of soil
  - Increases plant resistance to drought
- Lacking only in sedges & brassicas (cabbage fam.)
- Poor growth without myc. where nutrients limited
- Soil inoculation helpful only in poor/disturbed soils
- Two main types: Ecto- and endo-mycorrhizae

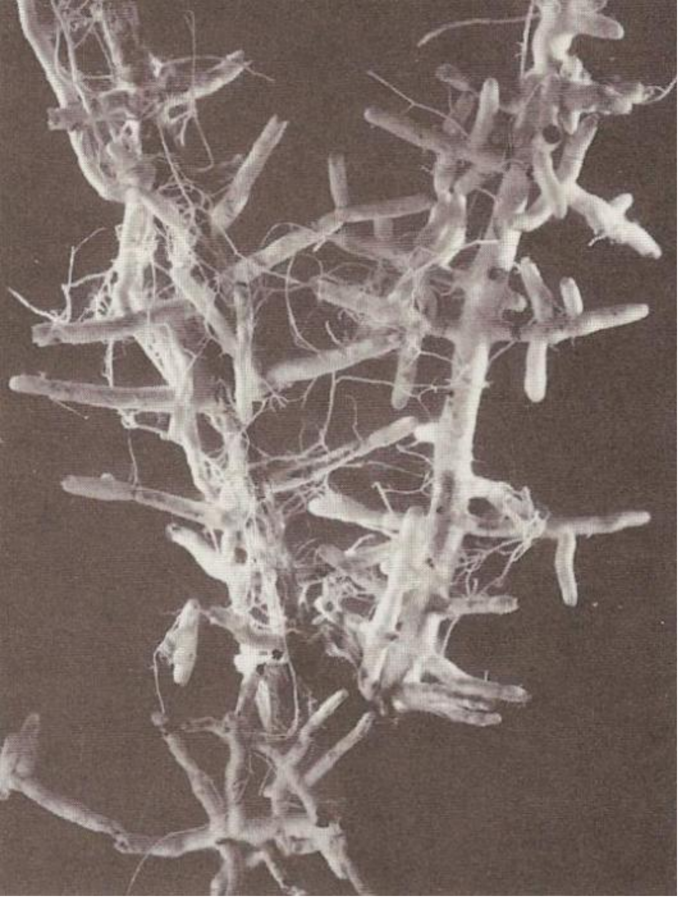
Mycorrhizal Fungus



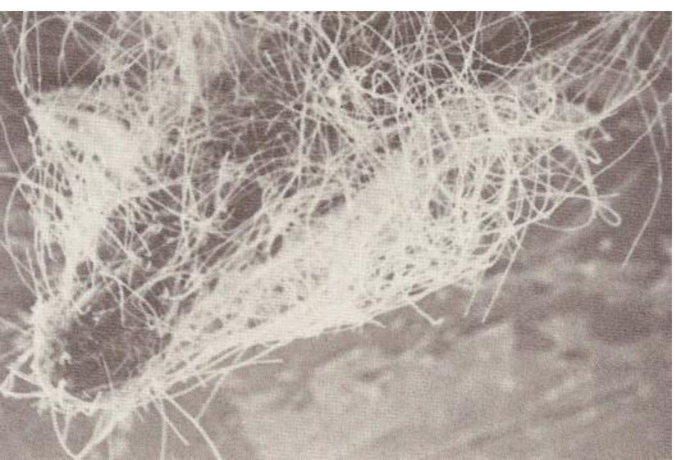
Sources: Bonfante & Genre 2010, Astrid Volder, UCD

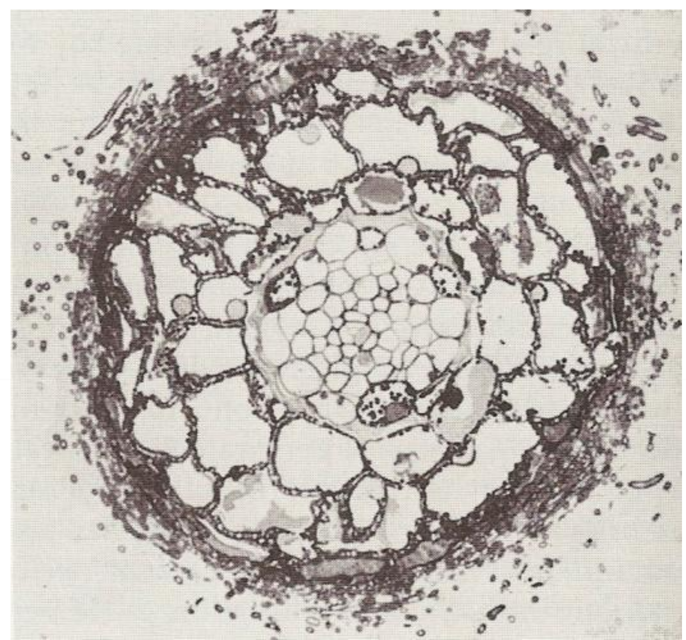
Mycorrhizal Fungi

Ecto-Mycorrhizae



- Grow on trees in pine, oak, beech, birch, and willow families
- Grow outside and between cells of young roots



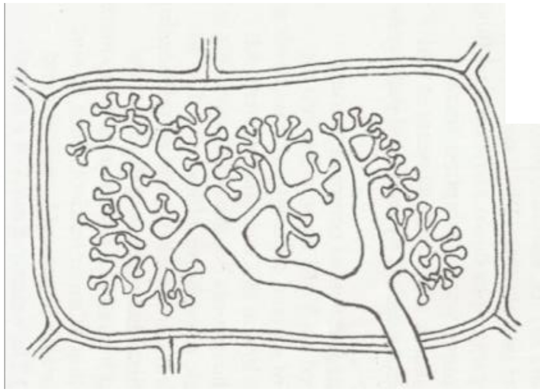


Mycorrhizal Fungi

Endo-Mycorrhizae

Infection directly into root cells

- Most important is vesicular-arbuscular myc. (AMF or VAM)
  - Vesicle = bladder-like structure
  - Arbuscule = branched structure
- 80% of plant species
- Most crops (monocots & dicots), hardwoods, non-pine conifers



Mycorrhizae

Poor growth of forest trees without mycorrhizae – <u>where nutrients are limited</u>

Add Mycorrhizal Inoculants?

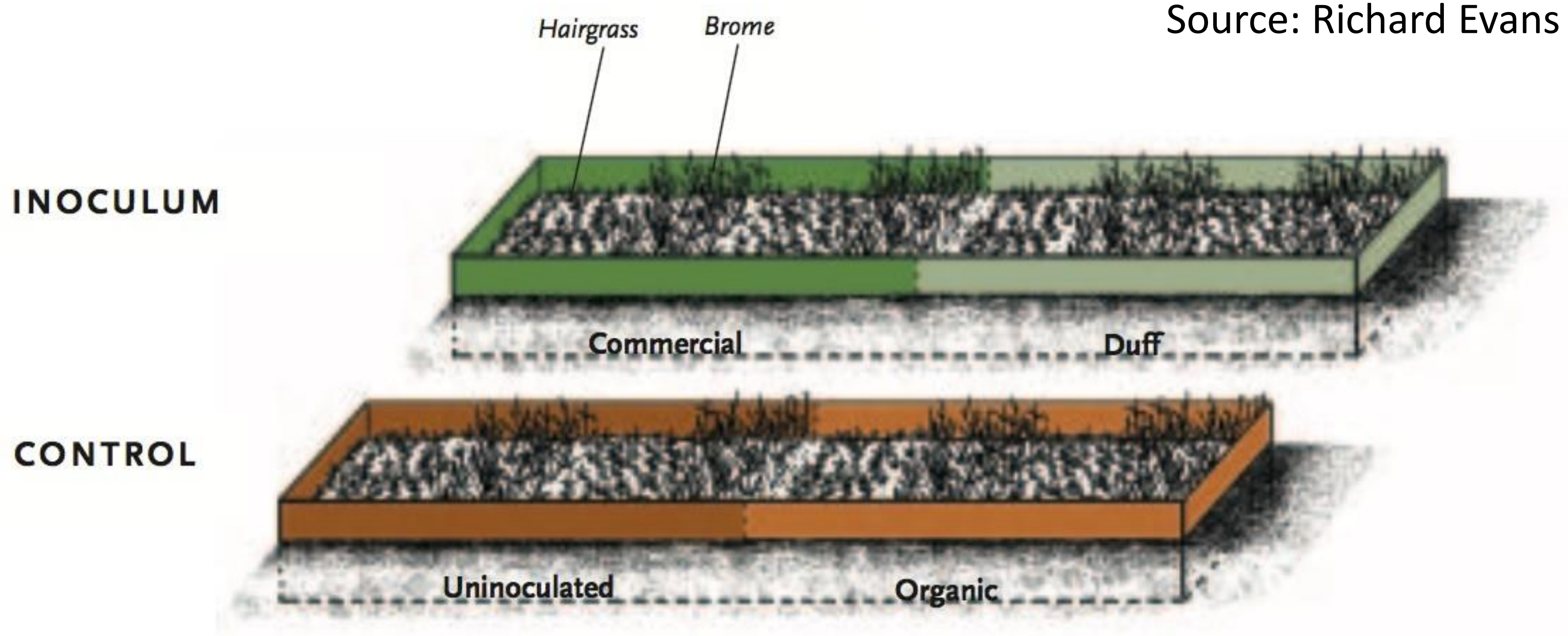
- Plants often choose fungi selectively
- Research shows that the wrong fungi, or wrong combination, can impair plant growth
- Adding purchased AMF not wise:
  - Often dead in the bag
  - May not be the correct species
  - Adding fungi has unknown effects on the growth of that plant, the soil organisms in your area, etc.

Research on Adding Mycorrhizae

Salyards et al., 2003

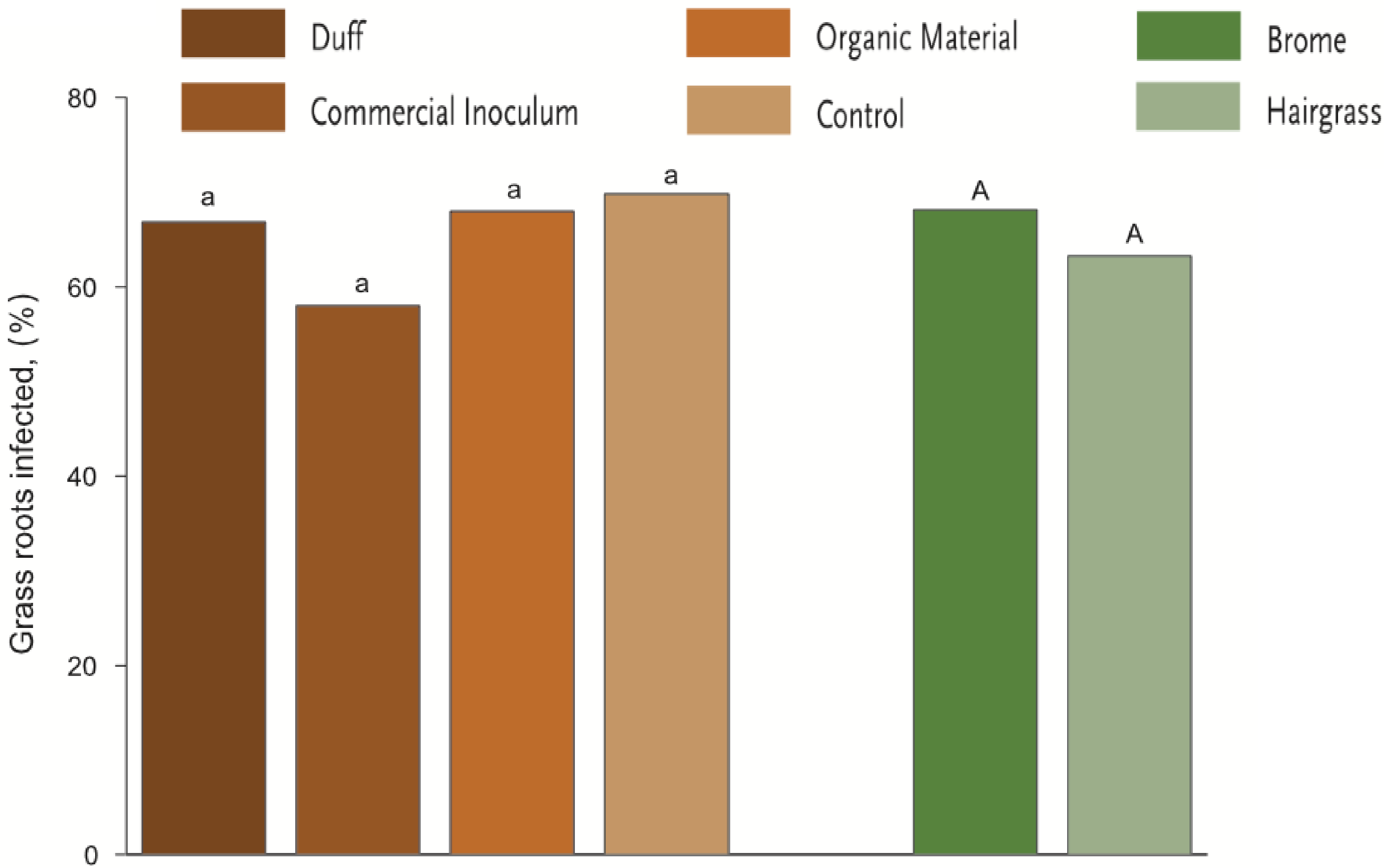
Sandy loam soil sterilized, then treated with a mycorrhizal inoculum (*Glomus intraradices*), forest duff, organic matter, or nothing. "Inoculation with AMF is unnecessary except in sites where early colonization is essential."

Source: Richard Evans



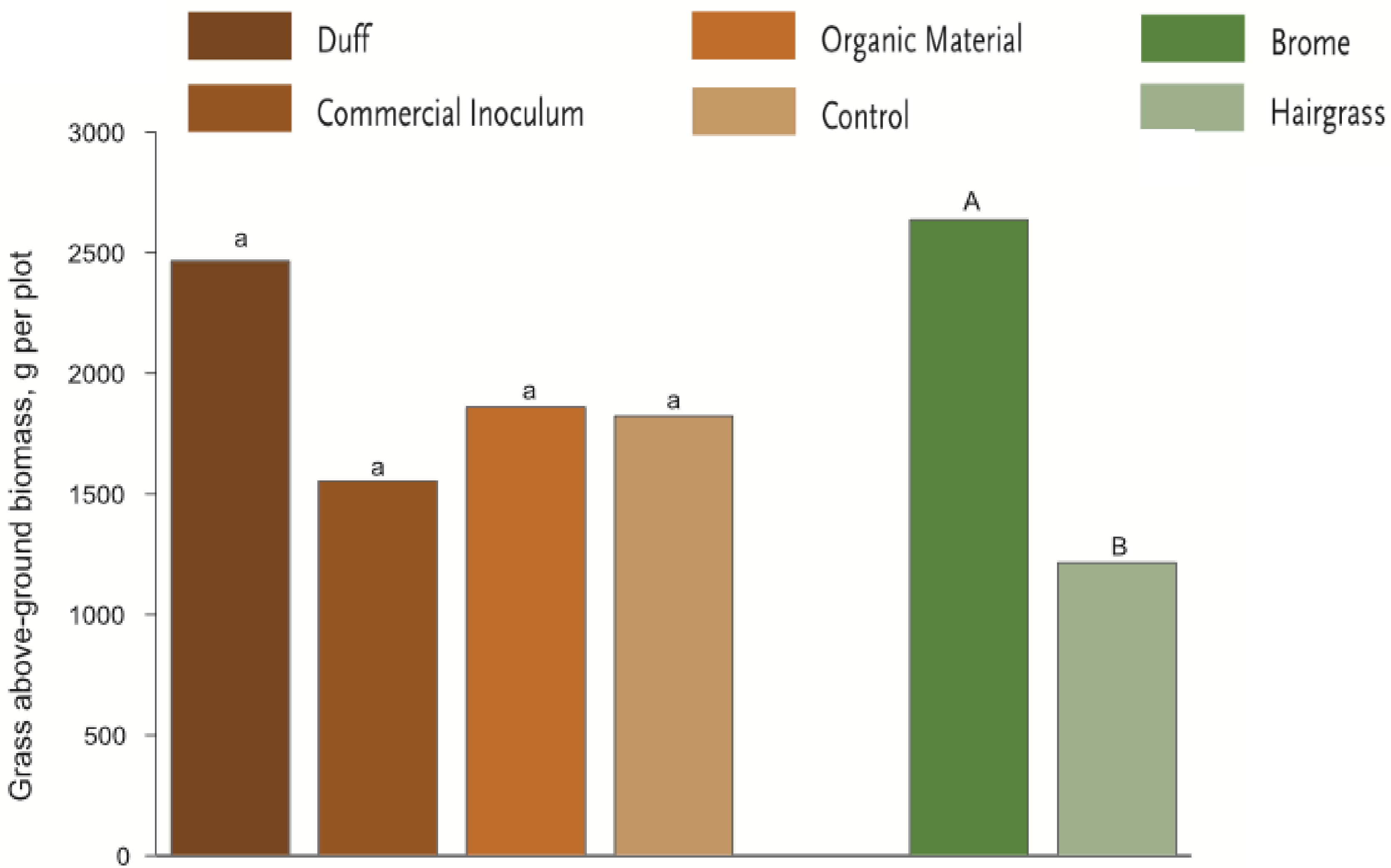
Salyards, J.E. Richard, and A. Berry. 2003. Mycorrhizal development and plant growth in inoculated and non-inoculated plots of California native grasses and shrubs. Native Plants. Fall issue pp. 143-149.

At 68 weeks: No effects on percentage of grass roots infected with mycorrhizae



Salyards et al. 2003

After 95 weeks there were no significant effects on biomass of the grasses



Salyards et al. 2003

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Tillage vs. No-Till

Effects on Soil Aggregation

No-till Tilled

Soil Structure

<u>Structure</u> - the arrangement of soil particles into aggregates

<u>Good structure:</u> holds water (micropore space) and has air space (macropore space)

<u>Poor structure:</u> lacks adequate macropore space

A Key Goal = Good Soil Tilth

Soil Stratification

Soil Structure May Vary Greatly

Soil structure & texture can be highly variable across small areas

Photos:
Larry Costello

Cemented Hardpan

Hardpan vs. Compaction

Compacted soil

Cemented hardpan

Cemented hardpan

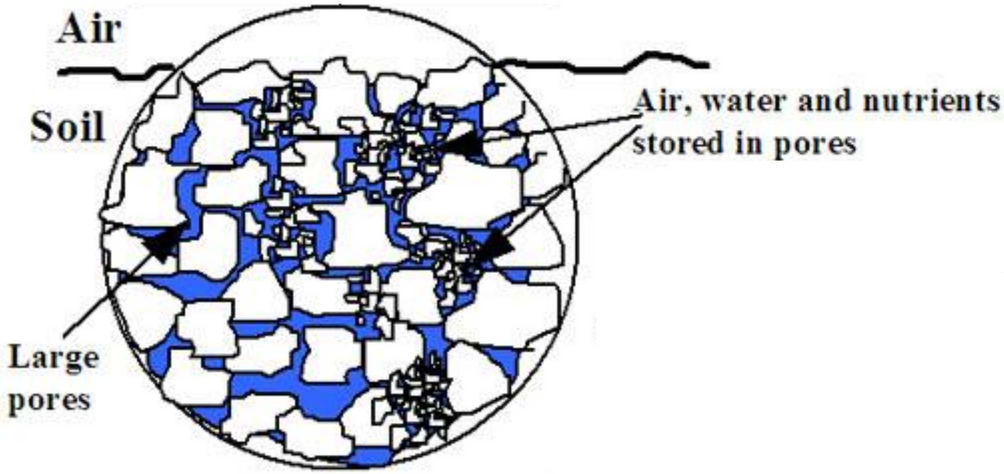
Compacted soil

Good vs. Poor Soil Structure

Effects of Compaction on Soil

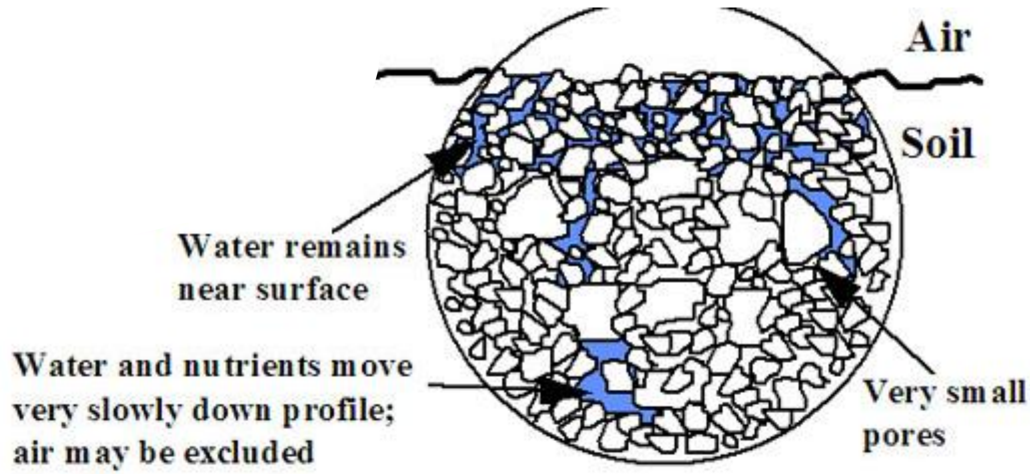
- Soil structure is destroyed – pore space is severely reduced
- Soil drains slowly and is prone to being anaerobic
- Compacted soil physically impedes root growth

Water Movement in Soils



Well
Structured Soil

Poorly Structured/
Compacted Soil



Results of Compacted Soils, Poor Drainage

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Some Soil Layers Restrict Air, Water, and Root Penetration

- Hardpan – cemented (by silica, iron, carbonates)
- Traffic or compaction pan – caused by vehicles, tillage implements, feet, hooves
- Crust – brittle, compact/hard when dry
- Claypan – higher clay than overlying layer

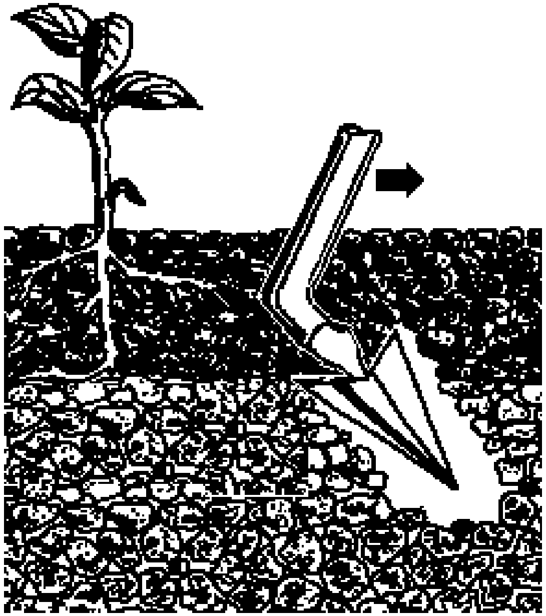
Tire Compaction

Avoid Traffic on Wet Soil

No compaction, good aggregation

Compaction, no aggregates

Plow Pan



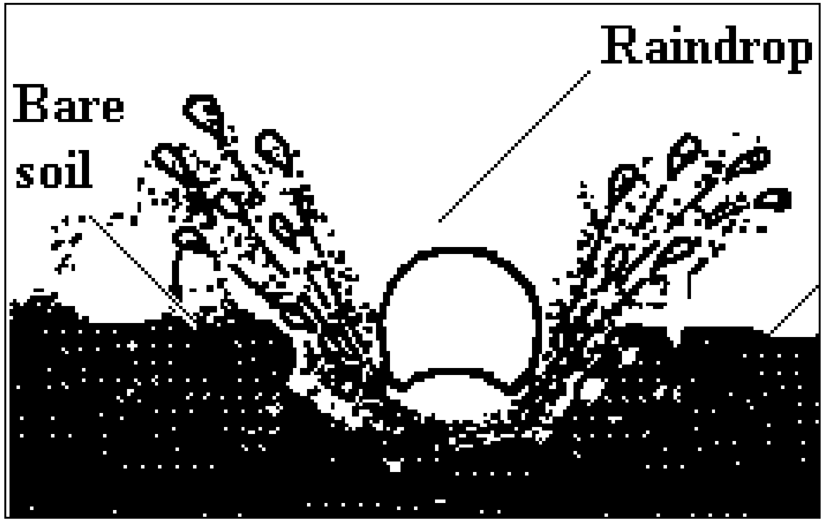
Plow Pan

Disked Soil (18 mo. Ago)

Ripping to break up plow pan

Crust Forms on Unprotected Soil

Rainfall or Sprinklers



Cemented Hardpan

Protect Soils

Avoid Compaction During Construction

– Create Temporary Walkways

Photo:
Marcia Braga

Protect Soils

Avoid Compaction During Construction

– Remove and store topsoil

Photos: Marcia Braga

Protect Soils

Prevent Erosion

Protect & Nurture Soils

Aerate Compacted Soils

De-Compacting Soils

Dealing with Compaction and Hardpan

- Break it up – down to good soil
  - ✓ Rip / Drill
  - ✓ Backhoe
  - ✓ Trencher
  - ✓ Jackhammer / clay spade / pick ax
  - Ø Dynamite
- Use raised planters
  - ✓ With walls or barriers
  - ✓ Without walls (raised mounds)
- Provide drainage
- Will gypsum or compost break it up? *NO*

Drainage systems need to be carefully designed and installed

Subsurface drainage can be improved with drain lines, but…

…maximize soil drainage to minimize runoff

Ripper

(maybe a little too big for landscapes)

Drill or Trench Soil

Backhoe or Excavate

Or Break it Up Manually

Jackhammer, clay spade attachment

Pick axe

Traditional approach

Use Raised Beds…

…Or Raised Planters

Evaluate Soils and Soil Moisture

Soil probe

Soil sampling tube

Soil auger

Organic Amendments

- Composts
- Manures

"Finished" Compost

- Thermophilic heating process with turning
- Temperature low, no ammonia smell
- Contains diverse microbial populations
- Contains most nutrients required by plants
- Should not contain weeds & plant pathogens
- N content usually 1-1.5%, very slow release
- Usually considered a soil amendment to add organic matter, not fertilizer

Earthworm Castings Better than Compost?

- Both add slow-release nutrients, improve soil structure, increase water & nutrient retention
- Earthworm castings may be better for:
  - Promoting beneficial microbial activity
  - Adding more humic acid to stimulate plant growth
  - Improving soil aggregation
- Using compost and some EW castings ideal

Topics to be Covered

- Physical Characteristics of Soil
  - ➢ Soil texture and its effects water & nutrient retention
  - ➢ Soil organic matter and soil aggregation
- Plant Roots and the Rhizosphere
  - ➢ Root structure and Rhizosphere
  - ➢ Mycorrhizae
- ➢ Soil Structure
  - ➢ Effects of tilling & compaction
  - ➢ Dealing with compaction
- ➢ **Mulches**
- ➢ Cover Cropping

Mulching with Wood Chips

Potential Benefits of Mulch

- Reduces weeds & erosion
- Reduces impact of raindrops
- Insulates roots from temp. extremes
- Conserves soil moisture → ↑ root growth
- Increases microbial activity
- Increases water penetration
- Improves plant establishment

Potential Problems with Mulch

- May prolong saturation in heavy soils
  - Favors root and crown rot
- May host plant diseases, insects, and nuisance fungi
- Some wood chips poor quality
- Can't see soil moisture
- Time consuming to spread

Mulch Basics (Wood Chips)

(LGtoM, CIWMB, 2002)

- Remove weeds, water before applying
- Replace grass with mulch under trees
- Keep 6-12 in. away from the base of trees & shrubs
- Application rate: Generally 2-4 in. deep
  - Fine = <2 in.   Coarse = 4-6 in.
- Keep mulch on top of soil to prevent N tie-up

More Mulch Basics

- Durability of wood chips increases with underlying fabric or plastic
  - But no contact of soil with organic matter
- Mulch has little or no effect on termites
- Softwood mulches (conifers) last longest
  - Less microbial feeding

Wood Chips

Weight and Coverage

- Weight per yard is highly variable
- Average (depends on moisture):
  - 500 to 700 lbs. per yard
  - 3 to 4 yards per ton
- 4 inch application:
  - 1 cubic yard covers 81 square feet
  - 538 cubic yards covers 1 acre

Do Wood Chips Affect Soil Nutrients?

- Tie-up of N?
  - N immobilization from high C:N mulch
  - Generally N tie-up at interface only
  - Avoid mulch in planting holes
- Soil pH (pine needles acidic) – little effect unless incorporated

Mulching and Weed Control

- Thickness to mulch depends on mulch type
- Various studies:
  - 3-in. layer: 85% weed control over 3-yrs.
  - 4-in. mulch gave better control than 3-in.
  - Phenols & tannins in coniferous bark improved weed control

Can Mulches Spread Diseases?

Some Potential Problems

- Pine pitch canker
- Sudden oak death
- Dutch elm disease
- Oak root fungus?
- Verticillium wilt?
- Fire blight?

- Don't transport these wood chips
- Keep mulch 6 in. away from trunks

Dog Vomit Fungus

(Slime Mold)

Other Mulch Fungi

Mushrooms

Bird’s nest fungus

Dyemaker's puffball

Stinkhorn

Synthetic Mulches

Polypropylene and Polyester

- Better weed control than chips alone
- Slower breakdown of wood chips
- Allow water & air movement
- Do not improve soil quality
- Most are effective 3-5 yrs. (under chips)
- Most are not recyclable (landfill!)

Plastic or Fabric Underneath?

Needs to be Held in Place on Slopes

Synthetic mulches will usually become exposed and shred, especially on slopes

Weed Control After 4 Years (UCD)

1 pre-emerg. applic.

1 wood chip applic.

Wood chips + woven polyprop.

Problems with Quality of Mulch from Tree Service Companies



Avoid turf or weeds by trunk

Mower blight

Avoid weedeating by trunk

Mulch alone won't keep soil in place on steep slopes

Conclusions - Mulches

- Avoid mulch in planting holes
- Control perennial weeds first
- Caution on clay soils; away from trunks
- Little or no N tie-up; add N or compost
- Little or no disease transmission
- Root growth improved
- Benefits outweigh disadvantages
- Fabric reduces weeds but it shreds

Topics to be Covered

- Physical Characteristics of Soil
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  - Mycorrhizae
- Soil Structure
  - Effects of tilling & compaction
  - Dealing with compaction
- Mulches
- **Cover Cropping**

Cover Crop Before Establishing Fair Oaks Horticulture Center

Cover Crops

Definitions

Cover crop

- A non-harvested crop planted to provide any of a number of benefits, such as improving soil quality, reducing erosion, adding N, and/or attracting beneficial insects

Green manure cover crop

- A crop grown & plowed under for its beneficial effects to the soil and subsequent crops

Cover Crops

Benefits

- Lowest fertilizer energy use: On-site production of N
  - May still need additional N
- Add organic matter
- Improve soil tilth and water penetration

Cover Crop Roots

Grass roots more beneficial to soil structure

Cover Crops

Potential Problems

- Competition with trees for water & nutrients
- Insect and vertebrate pests
- Increased costs and management
- Additional equipment required
- Requires chopping/disking in spring

Cover Crops

Nitrogen Fixation of Legumes

- Atmosphere = 78% N; only legumes can use
- Rhizobium bacteria in roots use N in soil air
  - Symbiotic relationship
  - Store N in nodules on roots
  - Nodules resemble root-knot nematodes
- Most N translocated to foliage

Nodules Created by Rhizobium Bacteria

Berseem clover

Cover Crops

C/N Ratio

- Low ratios (legumes) – rapid decomposition, net release of N
- High ratios (cereals/grasses) – slow decomposition, & net tie-up of N

Example of C/N Ratios

Oat straw	70:1	<u>Ideal microbial diet</u>	<u>24:1</u>
Wood chips	60:1	Rotten manure	20:1
Corn stubble	57:1	Legume	17:1
Rye (mature)	37:1	Young alfalfa hay	13:1
Rye (vegetative)	26:1	Hairy vetch	11:1
Mature alfalfa hay	25:1	Soil microbes (avg.)	8:1

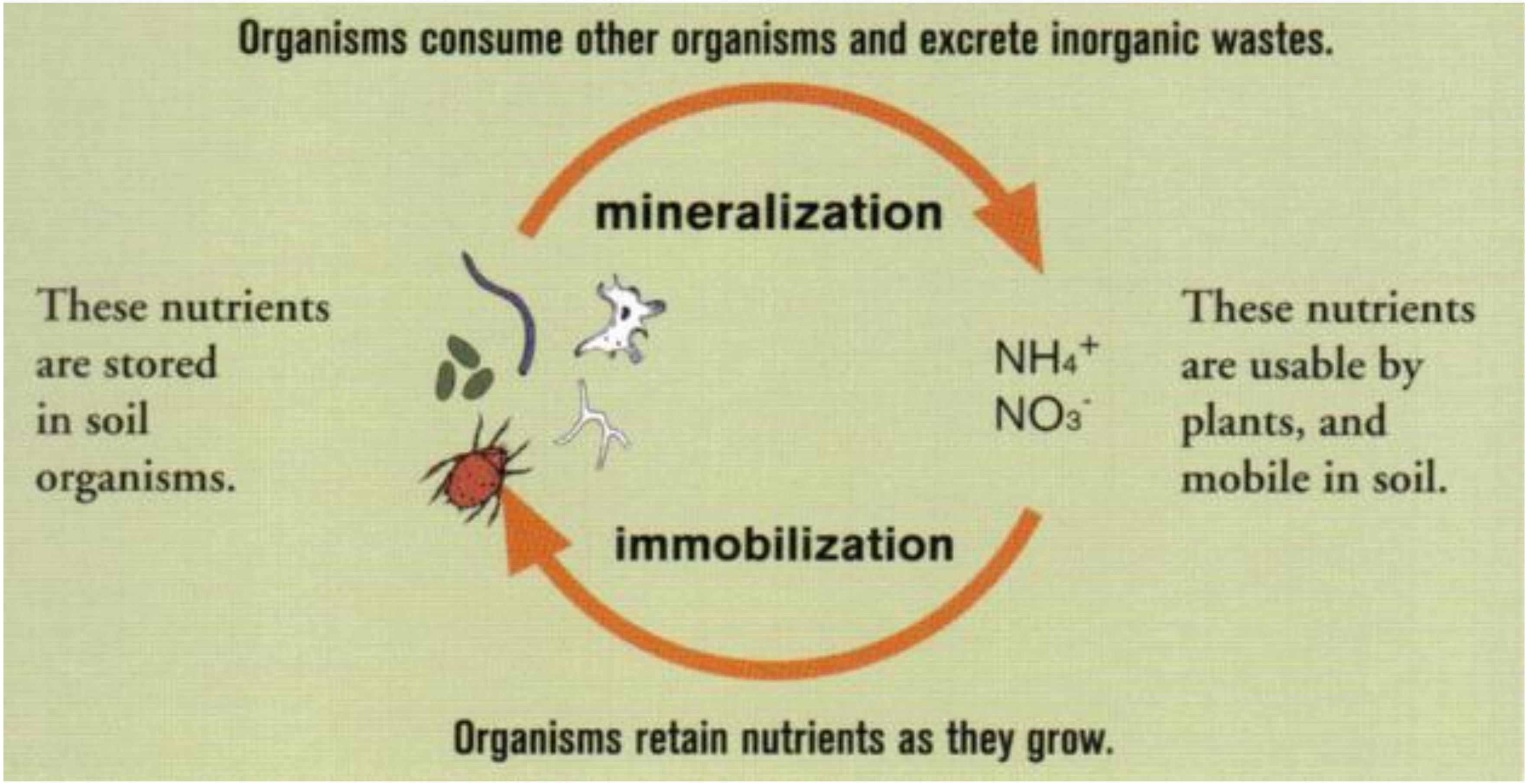
Source: J. Hoorman, Ohio State Univ.

Cover Crops

General C/N Ratios

RESIDUE	C/N RATIO
Legume	15:1 to 20:1
Brassica	20:1 to 30:1
Grass	40:1 to 80:1

Mineralization and Immobilization



C:N Ratio of Organic Matter

- As a rule of thumb:
- At C:N >20:1, NH_4^+ is immobilized (tied up)
- At C:N < 20:1, NH_4^+ is mineralized (released)

C:N < 20:1

N in organic matter and microbes → NH_4^+ (ammonium)

N in organic matter and microbes ← NH_4^+ (ammonium)

C:N > 20:1

Cover Crops

Species

- Standard winter green manure legume mix:
  - High N mix: Bell beans, vetch, and field peas
  - Add for soil tilth (or use alone): Oats or barley
- Annual reseeding mix (orchards & vineyards):
  - Crimson, rose, subclover + bur medic
- Summer:
  - Cowpeas, buckwheat

Vetch/Pea/Oat Mix →

Annual Clovers

- Self reseeding
- Mainly for orchards and vineyards

Cover Crops

Planting and Incorporation

- Good seedbed preparation; inoculate seed
- Scatter seed and rake in (or drill)
- Rototill 3-4 weeks before planting spring crop
  - Reduced soil-borne diseases
  - Reduced tie-up of soil N

Inoculating Legume Seeds

Background

- Specialized bacteria (Rhizobium sp.)
  - ➢ Not to be confused with Mycorrhizae
  - ➢ Creates nodules on roots
  - ➢ Captures N in plant, most moves into foliage
- Insures that N fixation will occur
- Not essential to inoculate for same soil in year 2
- Good to inoculate garden peas & beans too

Inoculating Legume Seeds

Methods

- Use at least 1 oz./10 lbs. of seed
- To help inoculant adhere to the seed:
    - Mix 9:1 hot water (non-chlor.) + corn syrup
    - Let cool, add a small amount to seeds
    - Rate effect (up to a point) – Use plenty!
- Pouring dry into hopper may work but would not provide uniform application

Cover Crops

Nutrition

- Grass alone may require N
- Avoid N fertilizers on legumes
  - High soil N → legumes fix little N
- Max. N contribution is at early flowering (incorporate in March)
- >80% of N is in above-ground parts; <20% in roots

Cover Crop, Tomatoes

FOHC

THANK YOU!

Questions?

http://ccag-eh.ucanr.edu

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