Understanding Roots

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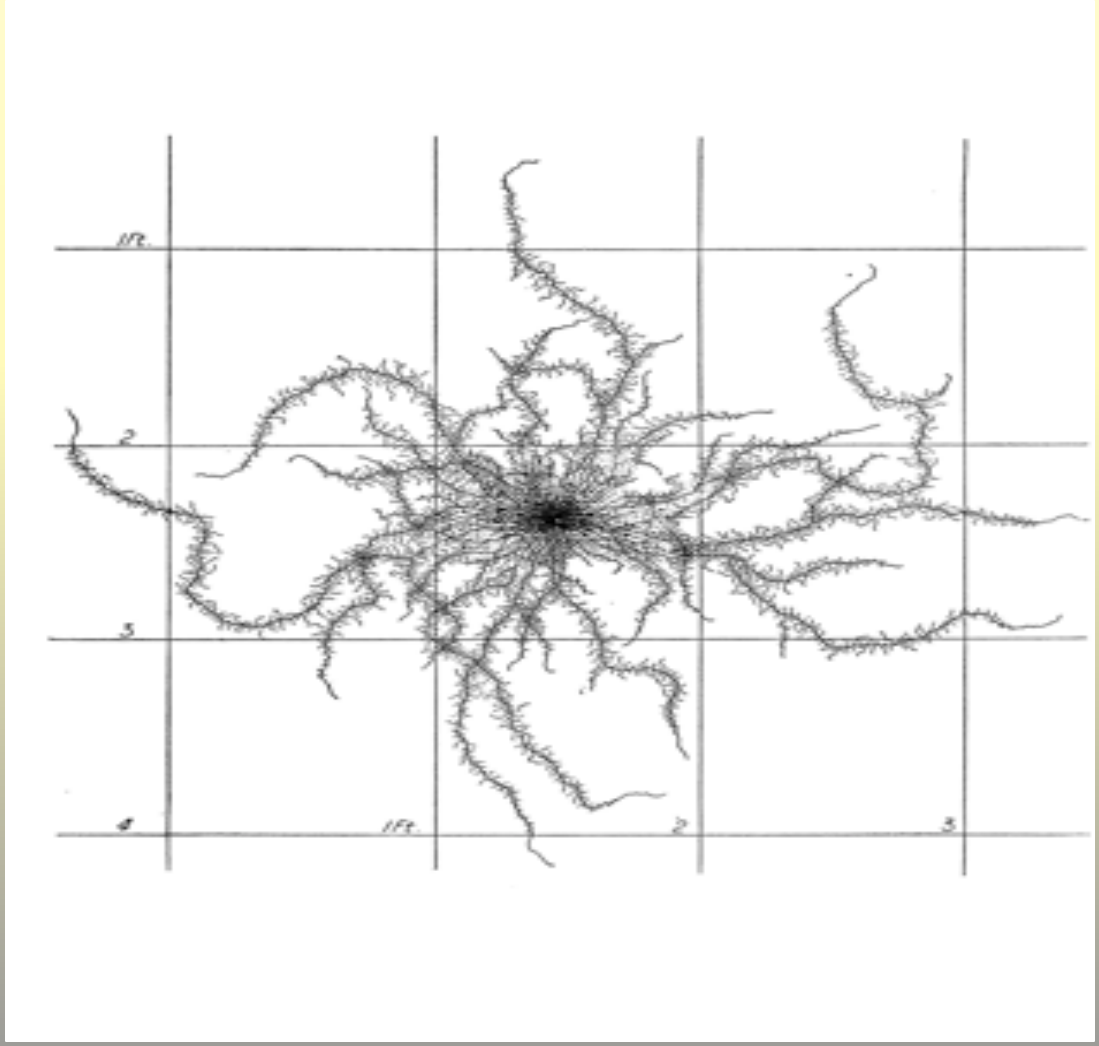
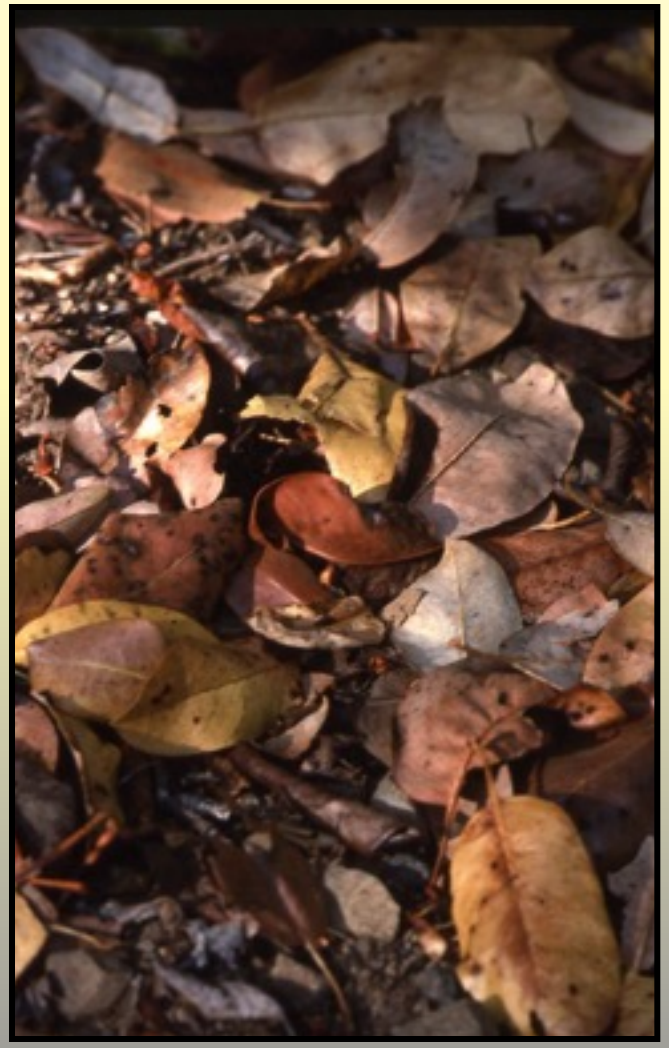
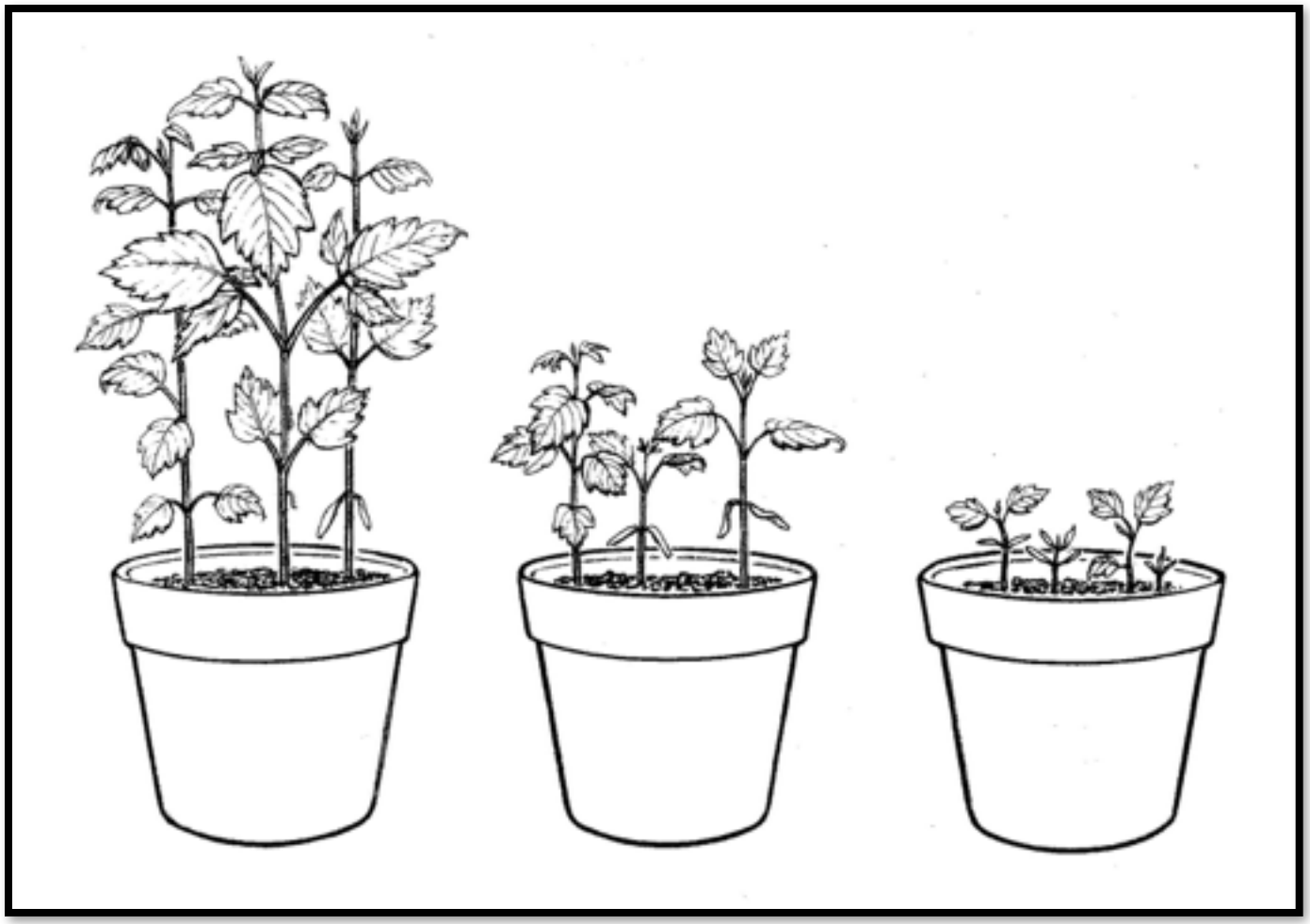
Kidney Bean, top 6 inches of root zone from above.



It all begins with the duff above the soil.



Then the first layers of humus and soil.

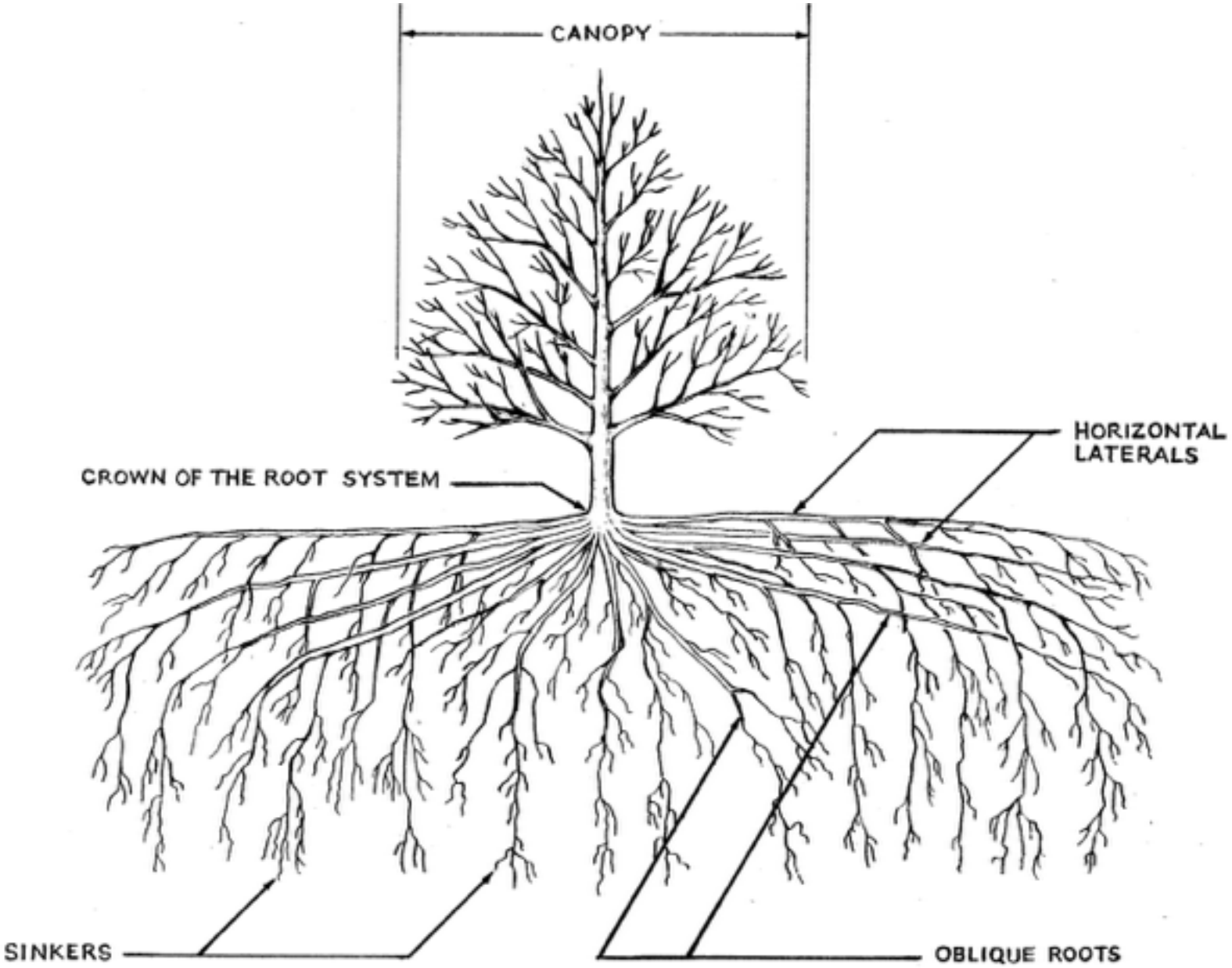


1-2” 2-4” Subsoil

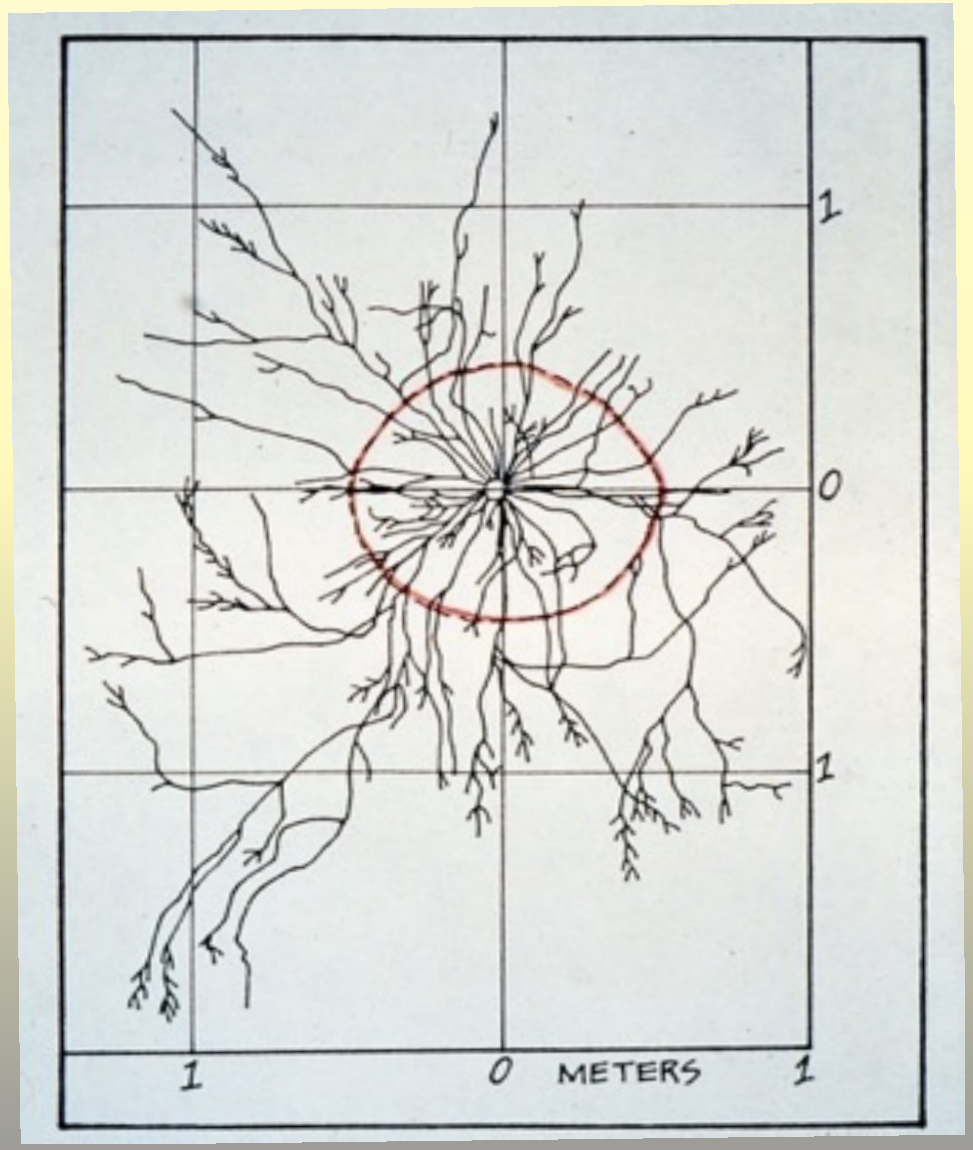
Myth versus Reality

Roots grow well beyond the dripline

- 1.5-3Xs the canopy
- Some 5Xs, or more
- Feed at or beyond the dripline
- Trees less able to tolerate stress beyond the dripline
- Protect trees and vegetables beyond their dripline


CANOPY
HORIZONTAL LATERALS
CROWN OF THE ROOT SYSTEM
SINKERS
OBLIQUE ROOTS

Apple tree with roots far beyond the dripline.



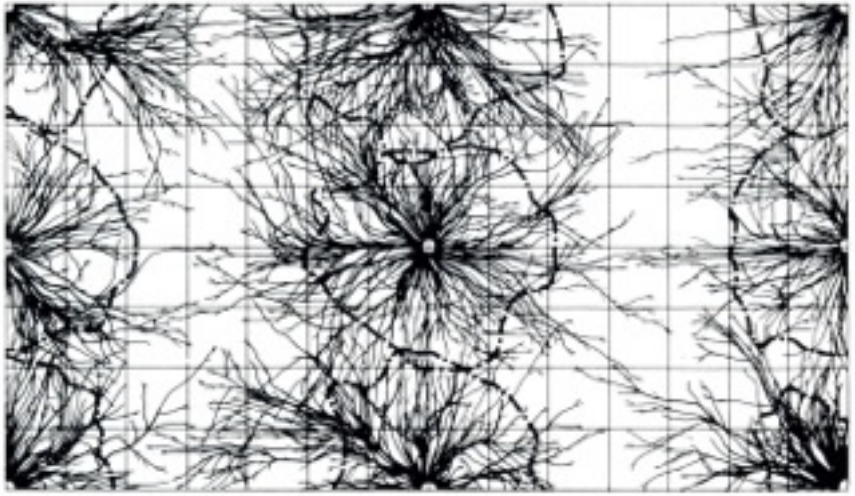


Fig. 37. Five-year-old spindle bush type Jonathan apple trees on M4 stock planted in sandy soil at a spacing of 7×4 m the root system occupied 29.1 m². (The sides of the squares are 1 m)

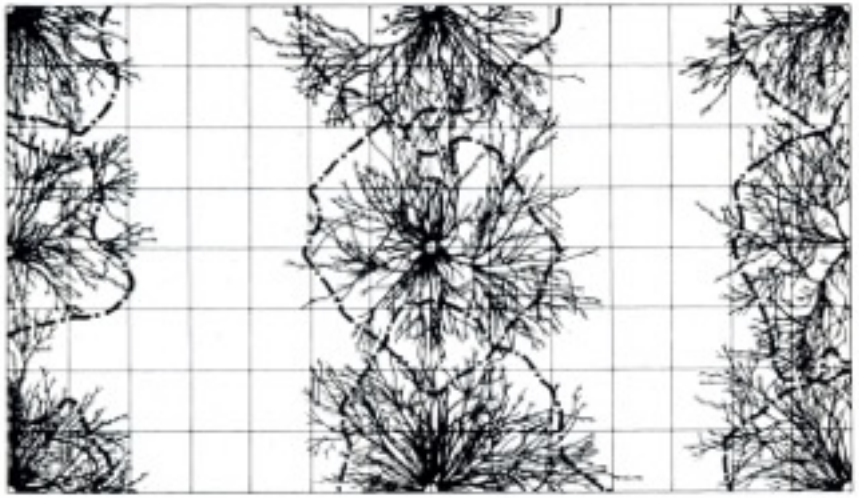


Fig. 38. Five-year-old spindle bush type Jonathan apple trees on M4 stock planted in loam at a spacing of 7×4 m. The root system only occupied 18.2 m². (The sides of the squares are 1 m)

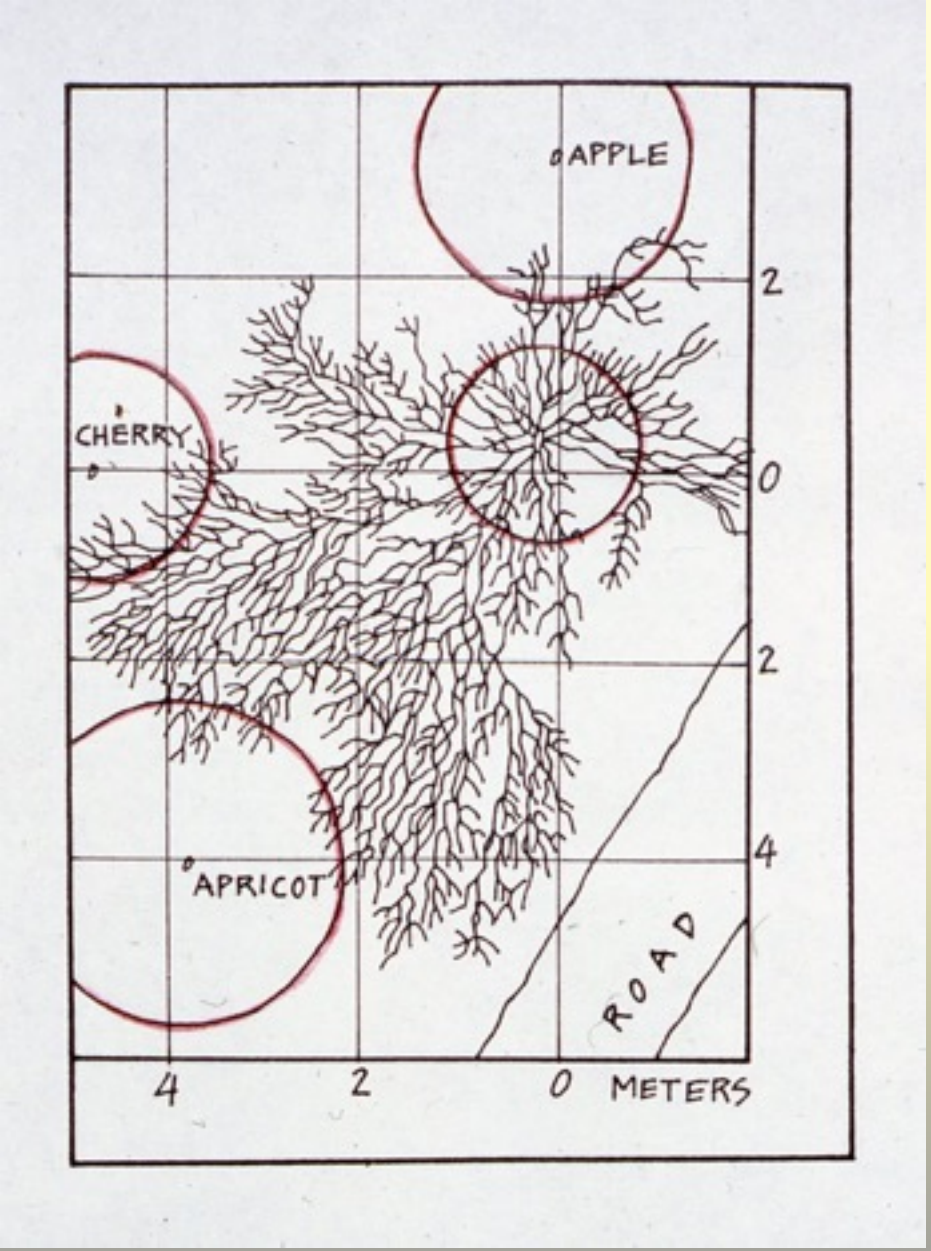
Roots Grow Well

Beyond the Dripline,

(in red circles)

and away from

compaction.



Soil horizons

Most plants don't send many roots into clay subsoil. Main roots are only as deep as the topsoil. Even in deep topsoil, most of a tree's feeding roots are found in the top 12-36 inches.

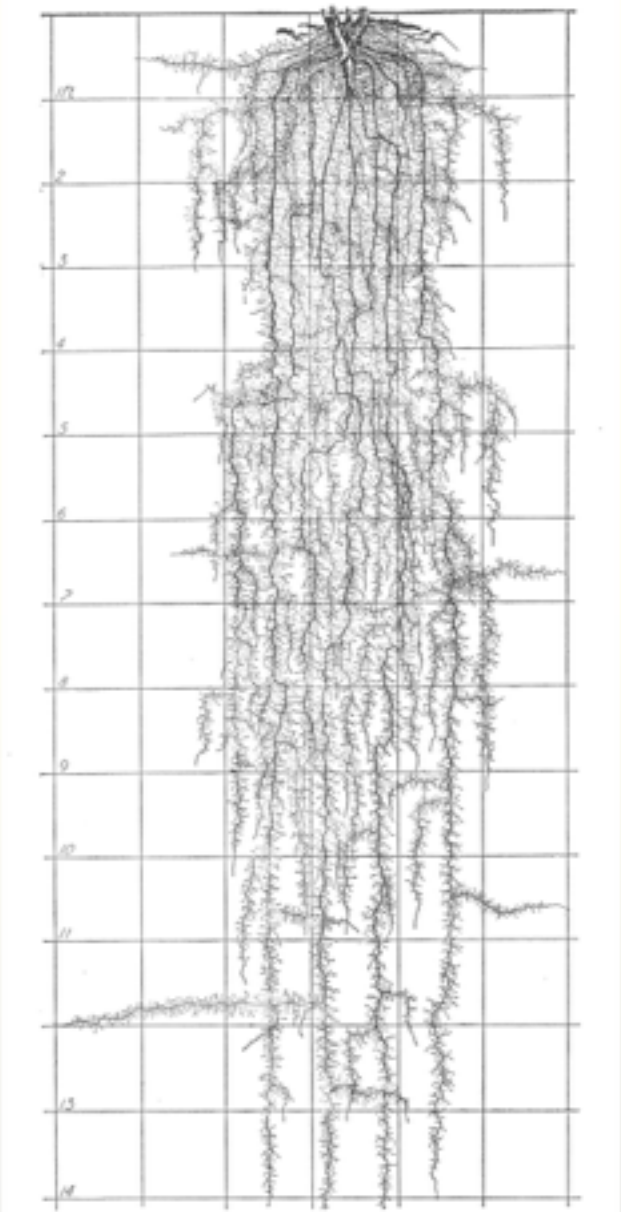
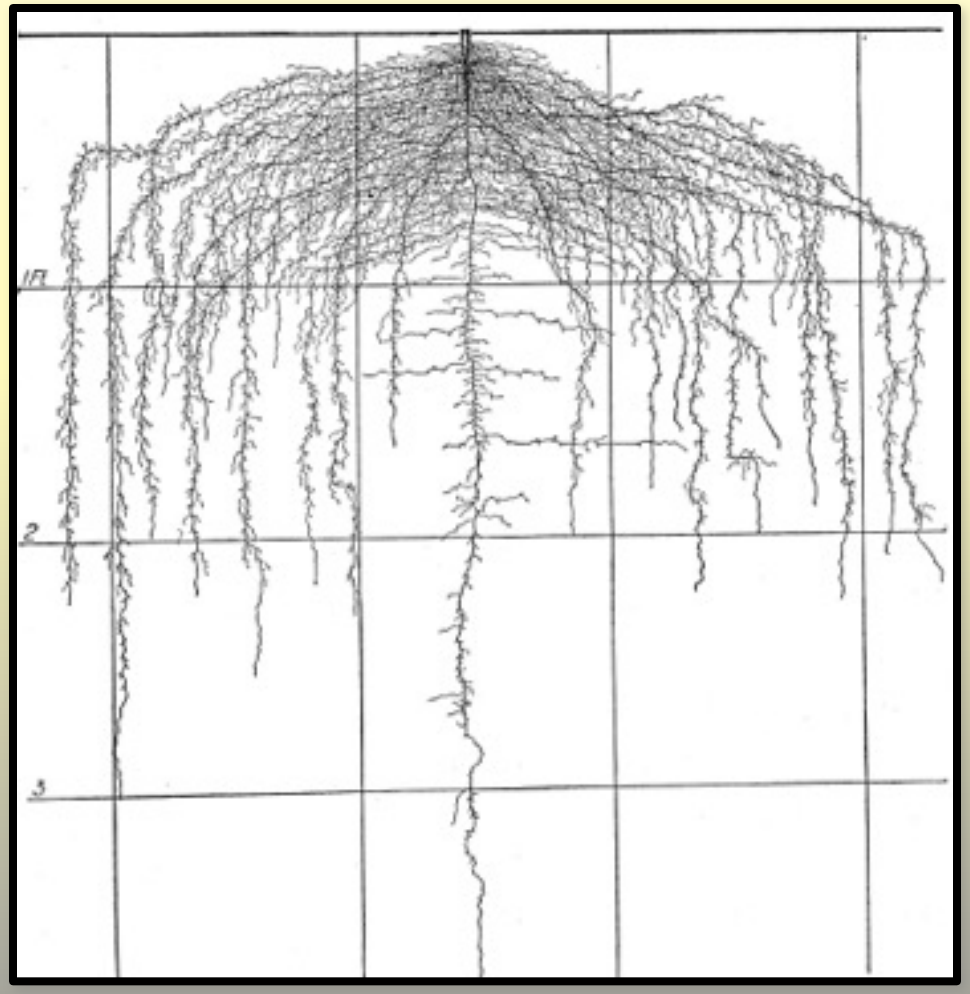


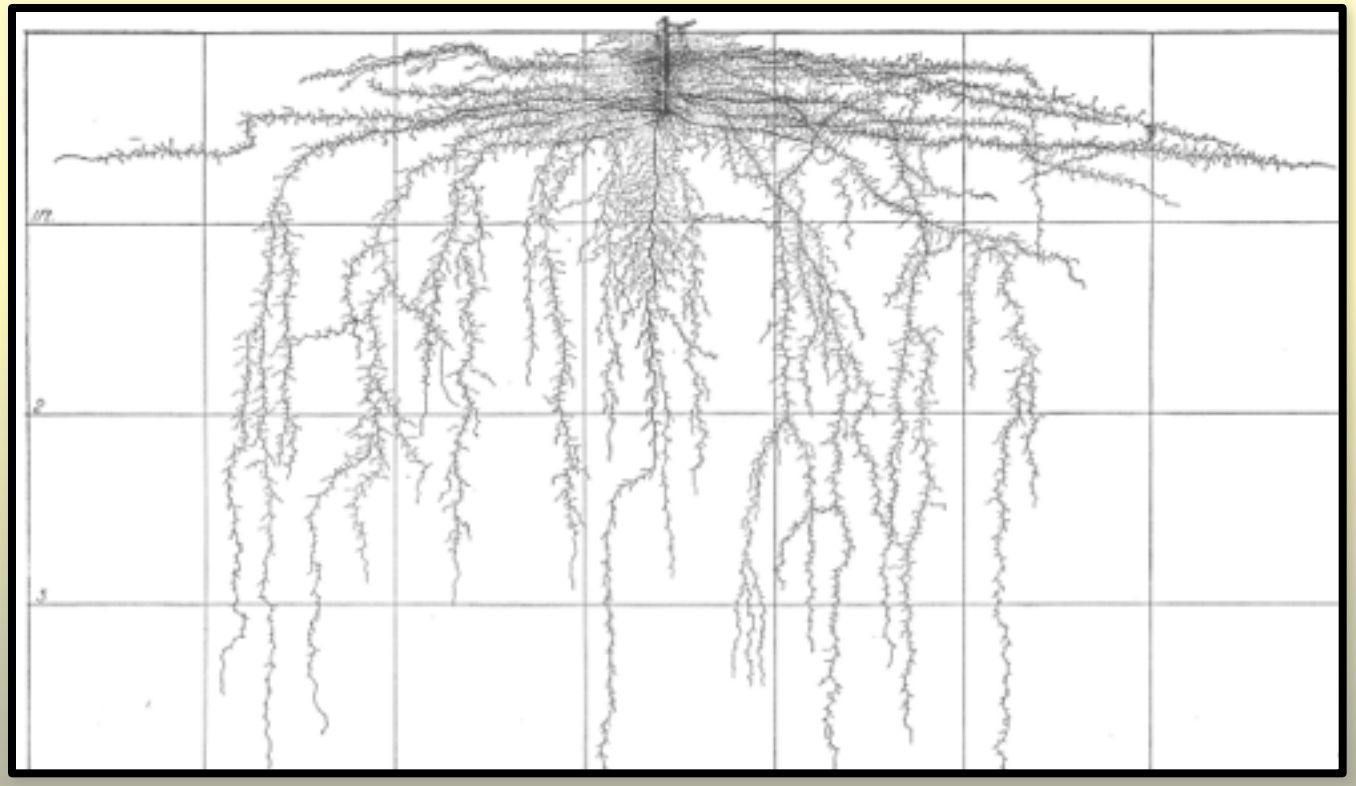
FIG. 45.—Mature root system of a 10-year-old plant of horse-radish.

10-year-old Horseradish

Lettuce



Tomato



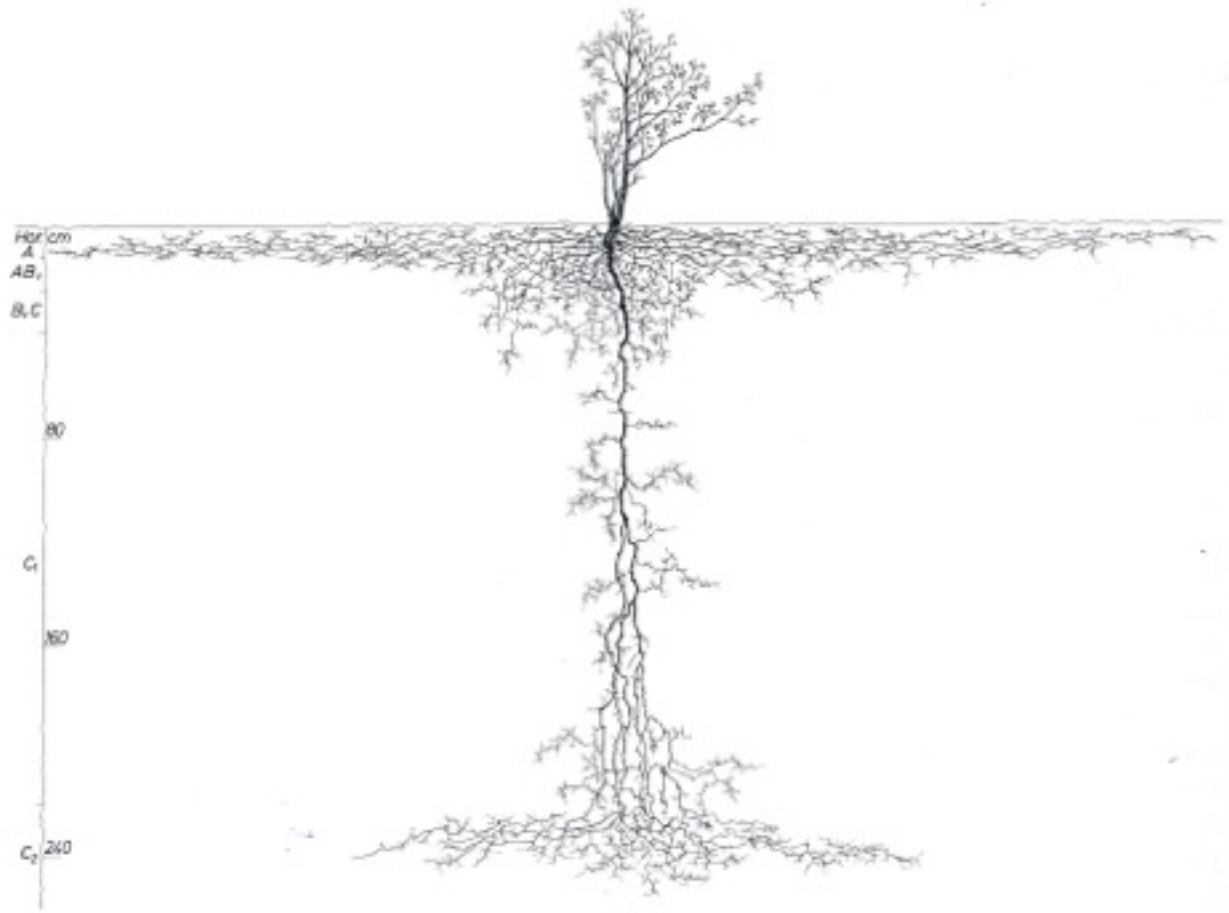


Abb. 111: Stiel-Eiche, *Quercus robur*, H–T–S = 82–253–445 cm, bei Grafenstein, Kärnten, Oberkante eines Südhanges mit einzelnen naturverjüngten Eichen, 460 m NN. Lockersediment-Braunerde über Niederterrasse. Bodenprofil Hor.: A 0–12 cm humoser, lehmiger Sand, feinkrümelig, locker, schwach steinig, stark durchwurzelt, AB_v 12–24 cm schwach humoser l S, steinig, locker, stark durchwurzelt, B_vC 24–40 cm l S, sehr steinig, locker, stark durchwurzelt, C_1 40–220 cm sandiger Schotter und Kies, sehr locker, Durchwurzelung abnehmend, C_2 Sand, Kies und Schotter, sehr locker, grundfrisch, Durchwurzelung gestaucht endend.

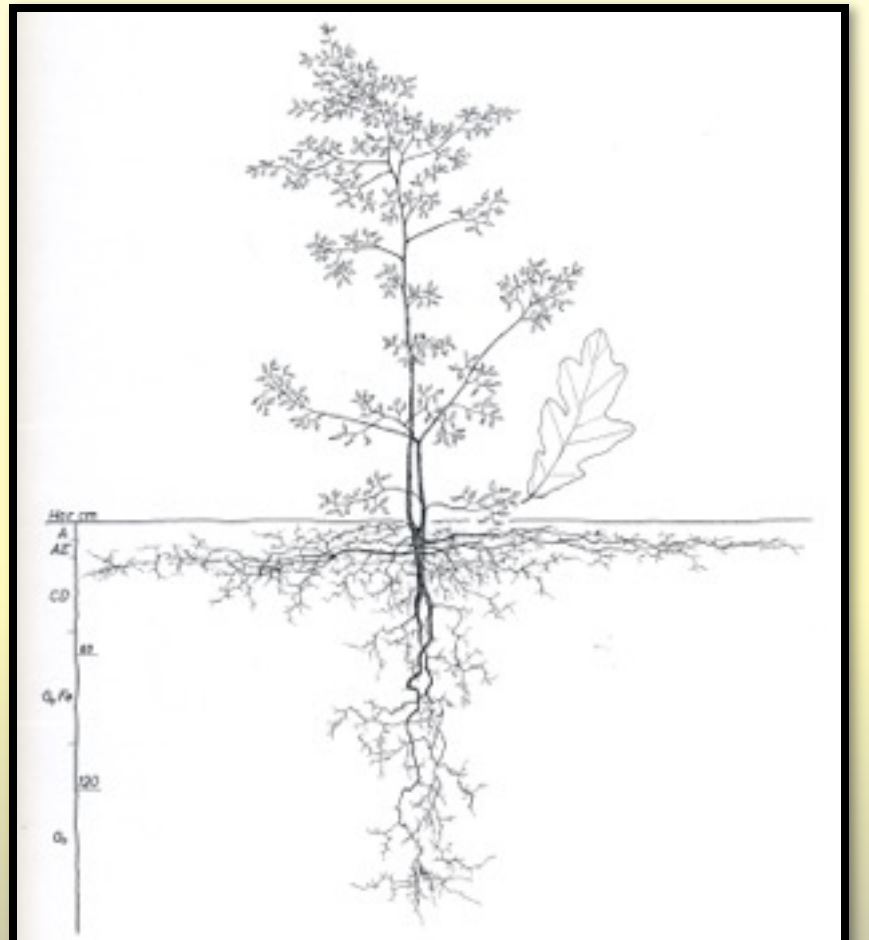


Abb. 117: Stiel-Eiche, *Quercus robur*, H-T-S = 222–173–324 cm, March-Au bei Drösing, Niederösterreich, Flußniederung, 158 m NN. Großer Wald-Kahlschlag mit einzelnen Stiel-Eichen, in der Krautschicht vorwiegend *Calamagrostis epigeios*. Vergleyter Semipodsol auf saurer Sandflur. Bodenprofil (Beschreibung nach Prof. Solar, verkürzt) Hor.: A 0–9 cm Grauwurzelfilz, dunkel braungrauer Sand, stark humos, puffiger Moder, undeutlich krümelig. AE 9–17 cm undeutlich gebleichter Krumenunterraum, brauner Sand, humos gefleckt, strukturlos, CD 17–32 cm Sand-Feinkies-Lage, G_{ox} rd Fe 50–70/100 cm trockengefallene Oberpartie des G_r-Hor. Wurzelsteck-Ortstein-Horizonte, Sand, Eisenhumus-Ortstein, verkittet, G_r temporär grundwasserführender Unterboden, Sand, rostfleckig, Durchwurzelung auslaufend, Grundwasserstand zur Zeit der Untersuchung 120 cm tief.

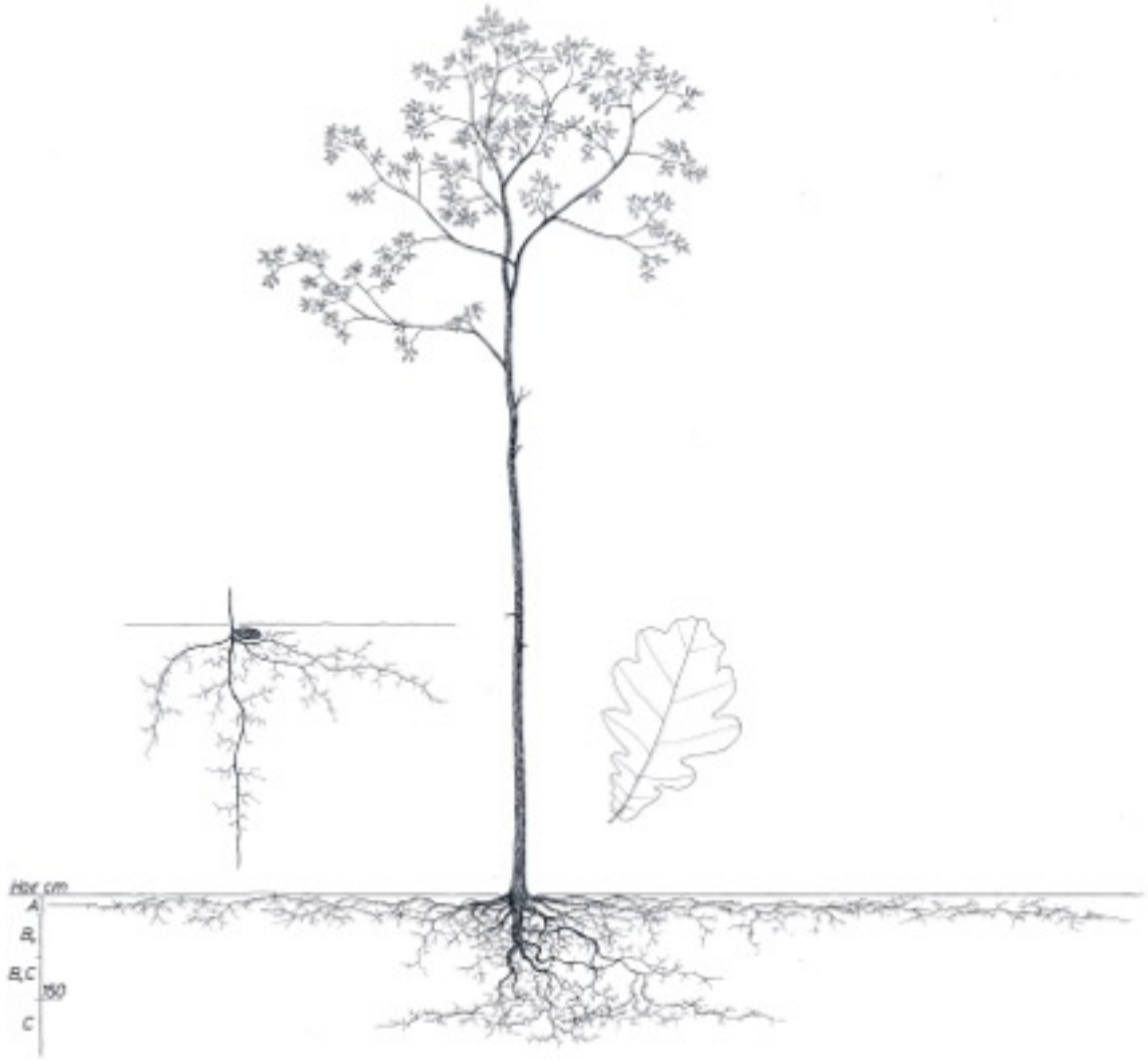


Abb. 113: Stiel-Eiche, *Quercus robur*, H–T–S = 1.290–222–1.569 cm, Umgebung Klagenfurt, eben, 450 m NN. Eichen-Hainbuchen-Wald mit *Pinus sylvestris*, im Unterwuchs vorwiegend *Rubus caesius* und *R. idaeus*. Lockersediment-Braunerde über Niederterrasse. Bodenprofil Hor.: A_1 0–8 cm Modermull, stark humoser, sandiger Lehm, sehr locker, schwach steinig, stark durchwurzelt, A_2 8–30 cm stark humoser s L, krümelig, locker, steinig, stark durchwurzelt, unterer Bereich der flachstreichenden Wurzeletage, B_v 30–90 cm lehmiger Sand, stark kiesig, schotterig, locker, mäßig stark durchwurzelt, Wurzeln vorwiegend abwärts gerichtet, B_vC 90–150 cm lehmiger Sand mit Kies und Schotter, sehr locker, schwach durchwurzelt, C Grobsand, Kies und Schotter, grundfrisch, Durchwurzelung gestaucht endend.

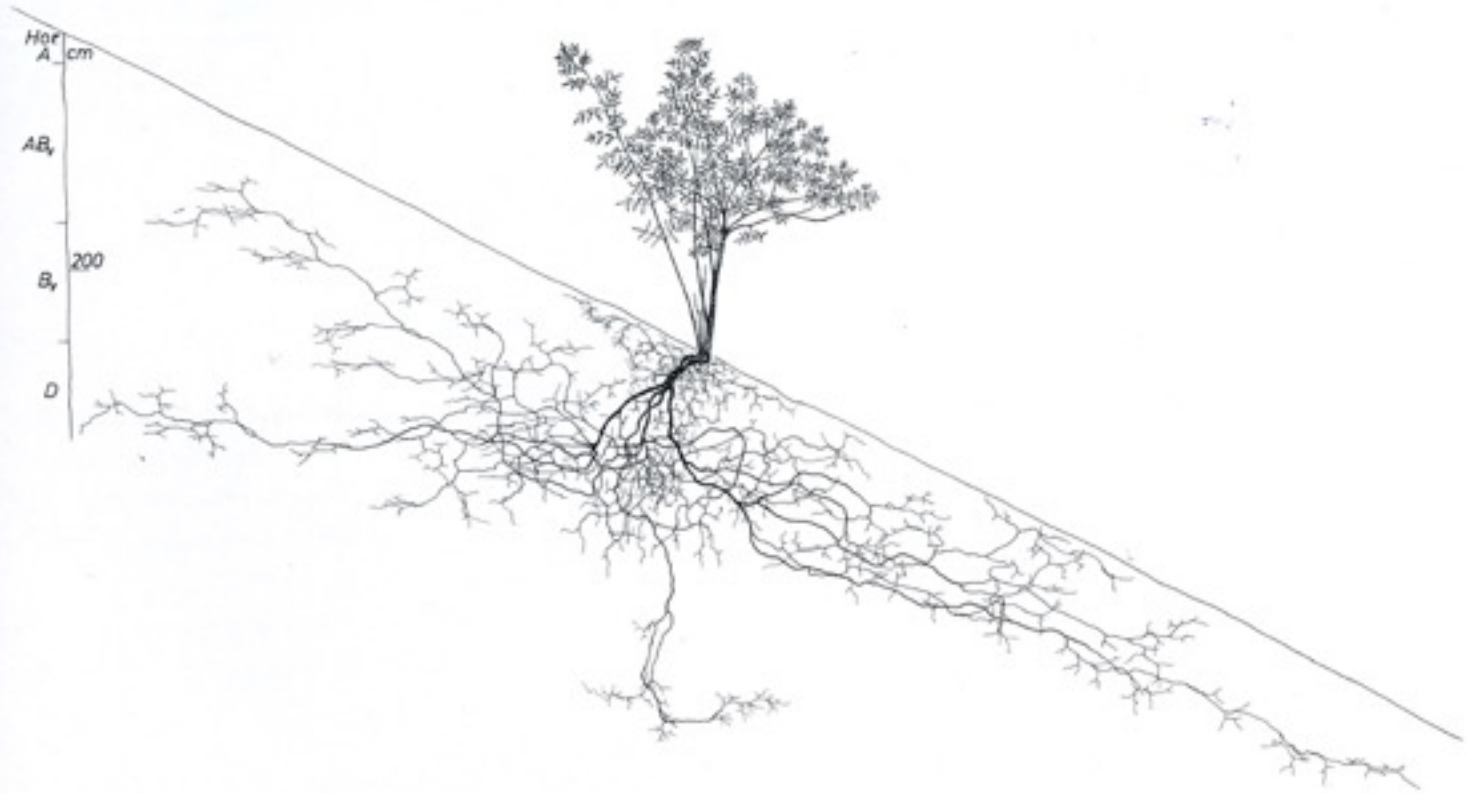


Abb. 182: Schwarzer Holunder, *Sambucus nigra*, H–T–S = 270–300–1.180 cm, Treffen bei Villach, Südhang, 515 m NN. Gebüsch mit *Salix alba, Alnus incana, Fraxinus excelsior* und *Sambucus nigra*. Lockersediment-Braunerde über Niederterrasse, Bodenprofil Hor.: A 0–25 cm humoser, lehmiger Sand, feinkrümelig, locker, schwach steinig, pH 6,9, mäßig stark durchwurzelt, AB$_v$ 25–160 cm schwach humoser l S, schwach durchsetzt mit Kies und Schotter, mäßig stark durchwurzelt, B$_v$ 160–260 cm l S, stärker kiesig-schotterig, mäßig stark durchwurzelt, D grauer, griffiger Sand, grundfrisch, pH 7,1, Durchwurzelung auslaufend.

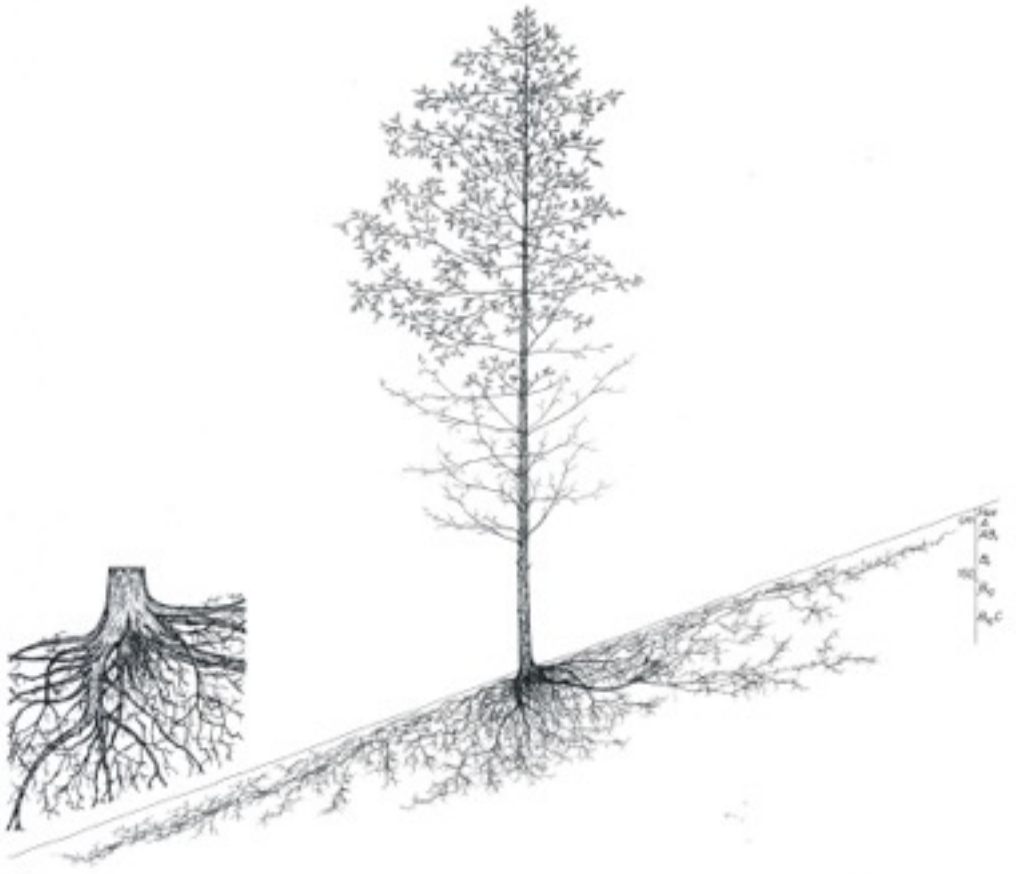


Abb. 51: Douglasie, *Pseudotsuga menziesii*, H–T–S = 1.395–240–2.025 cm, bei Treffen, Kärnten, Nordhang, 640 m NN. Buchen-Fichten-Wald mit eingeforsteter Douglasie, in der Strauchschicht vorwiegend *Sambucus racemosa*, in der Krautschicht vorwiegend *Atropa belladonna* und *Salvia glutinosa*. Tiefgründige Braunerde, Bodenprofil Hor.: O 5–0 cm Streuauflage, Grobmoder, A_1 0–21 cm stark humoser, lehmiger Sand, Modermull, dunkelbraun (10YR 3/2), sehr locker, pH 4,8, sehr stark durchwurzelt, A_2 21–45 cm Mull, humoser l S, dunkelbraun (10YR 3/3), sehr locker, sehr gut durchwurzelt, AB_v 45–65 cm schwach humoser l S, braun (10YR 4/3), locker, schwach steinig, gut durchwurzelt, B_v 65–150 cm sandiger Schluff, mehlig, gelblichbraun (10YR 4/4), mäßig dicht, schwach steinig, pH 5,6, gut durchwurzelt, B_{vg} 150–180 cm feinsandiger Schluff, rostfleckig, sehr hangsickerfeucht, steinig, $B_{vg}C$ schluffiger Sand, rostfleckig, stark durchsetzt mit Feinschutt aus Silikatschiefer, pH 6,3.

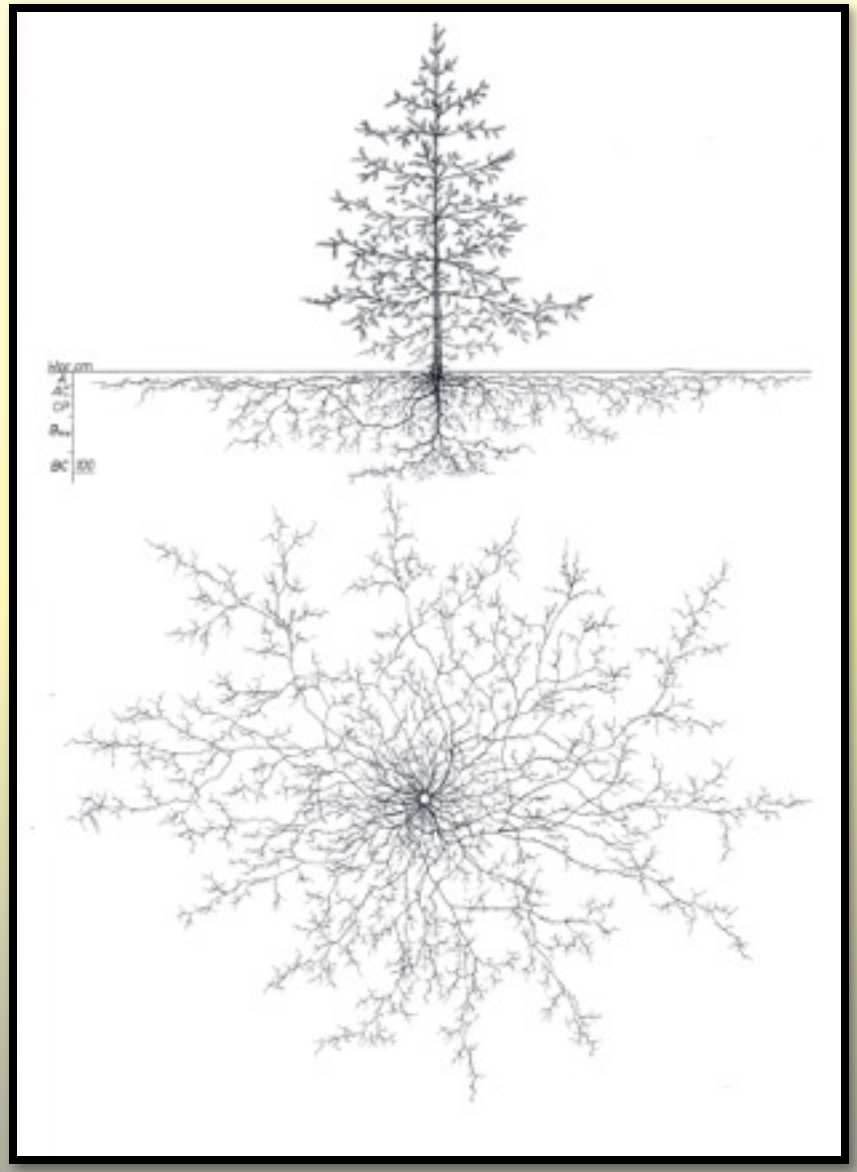
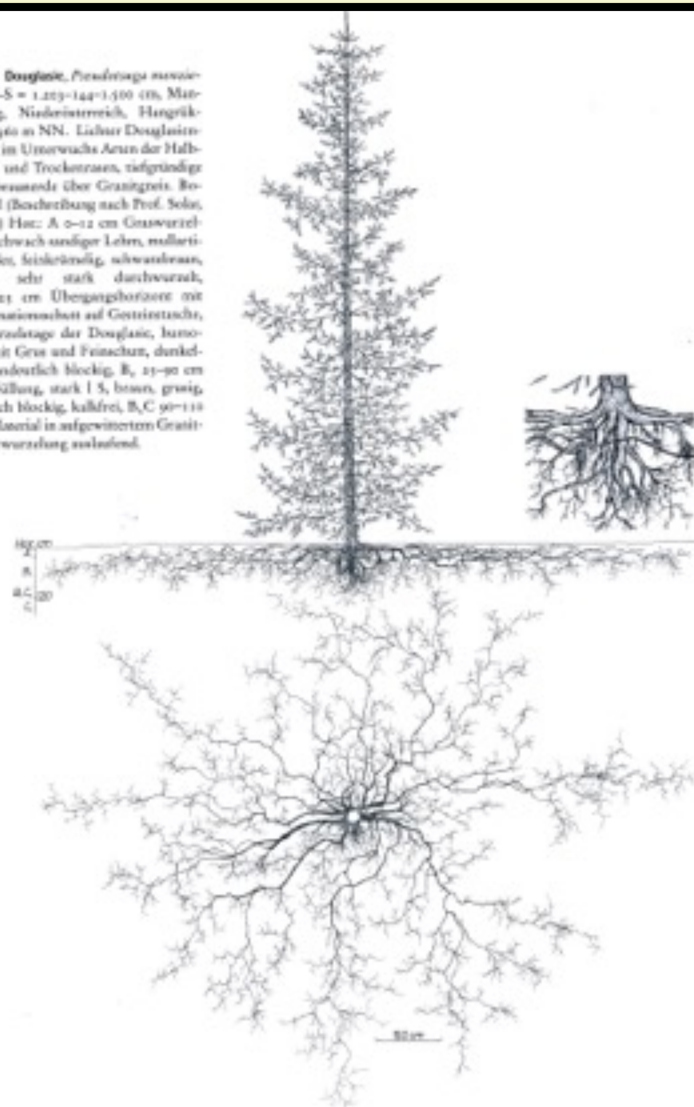


Abb. 50: Douglasie, *Pseudotsuga menziesii*, H–T–S = 1.213–144–1.500 cm, Manhartsberg, Niederösterreich, Hangrückenfläche, 360 m NN. Lichter Douglasien-Bestand, im Unterwuchs Arten der Halbtrocken- und Trockenrasen, tiefgründige Taschenbraunerde über Granitgneis. Bodenprofil (Beschreibung nach Prof. Solar, verkürzt) Hor.: A 0–12 cm Graswurzelkruste, schwach sandiger Lehm, mullartiger Moder, feinkrümelig, schwarzbraun, kalkfrei, sehr stark durchwurzelt, AB_v 12–23 cm Übergangshorizont mit Kryoplanationsschutt auf Gesteinstasche, Flachwurzeletage der Douglasie, humoser l S mit Grus und Feinschutt, dunkelbraun, undeutlich blockig, B_v 23–90 cm Taschenfüllung, stark l S, braun, grusig, undeutlich blockig, kalkfrei, B_vC 90–110 cm B_v-Material in aufgewittertem Granitgneis, Bewurzelung auslaufend.



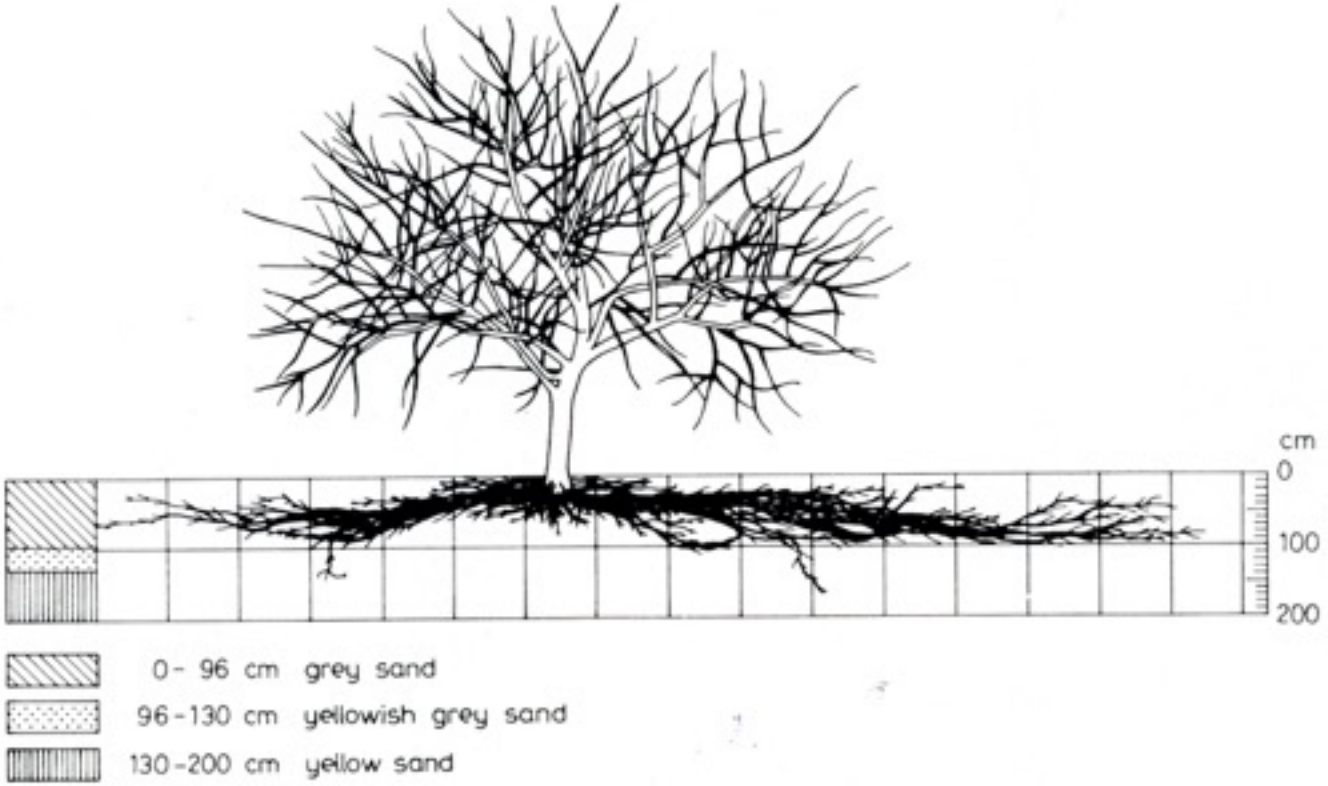


Fig. 113. The mass (76.02 per cent) of the root system of a 23-year-old apricot tree standing in drift sand on wild apricot stock was located in the 30–80 cm soil horizon. (The sides of the squares are 1 m)

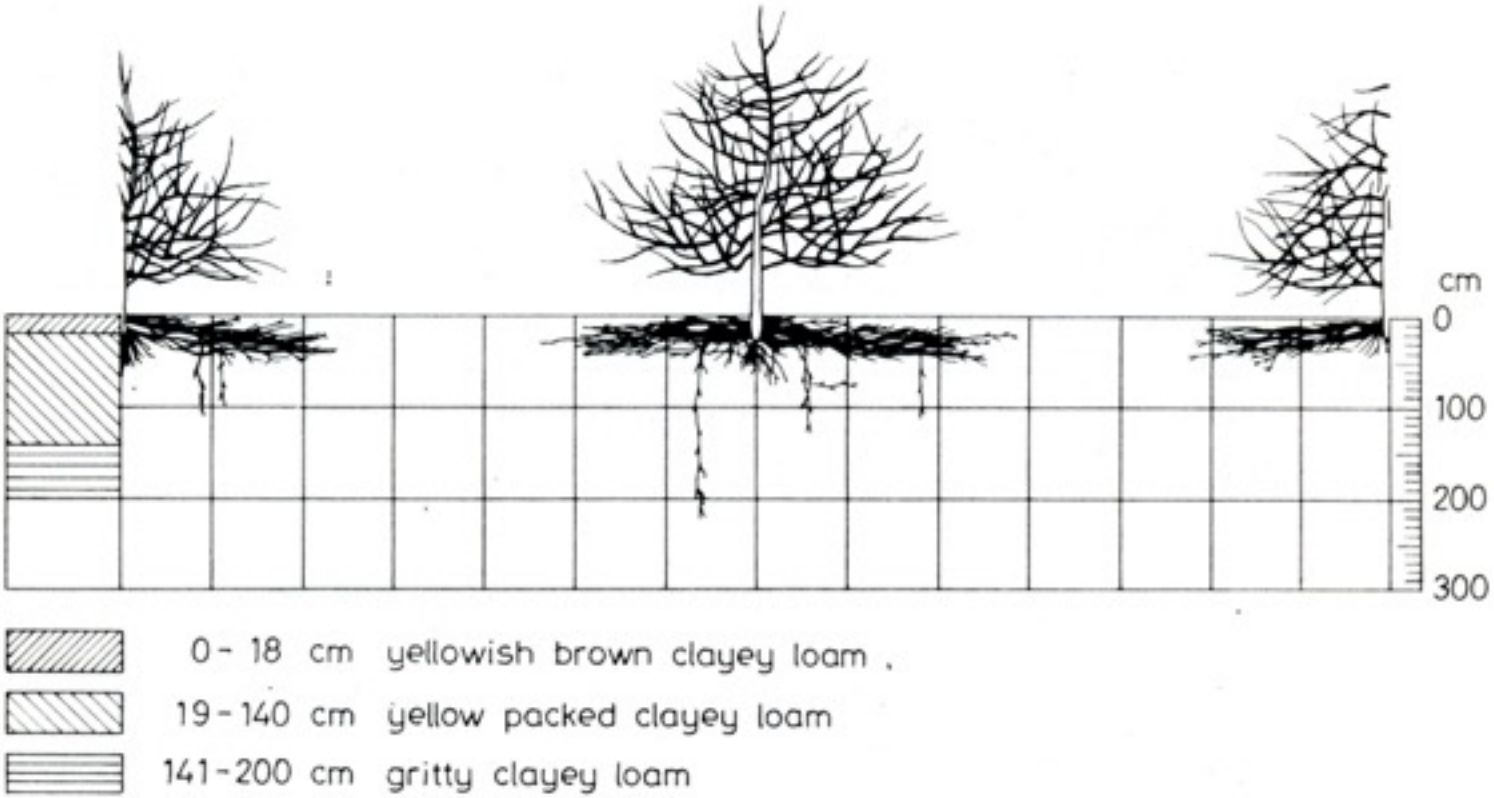


Fig. 44. Of the root system of 5-year-old spindle bush type Jonathan apple trees standing in loam on M4 stock 31.8 per cent was located in the upper 20 cm soil layer. (The sides of the squares are 1 m)

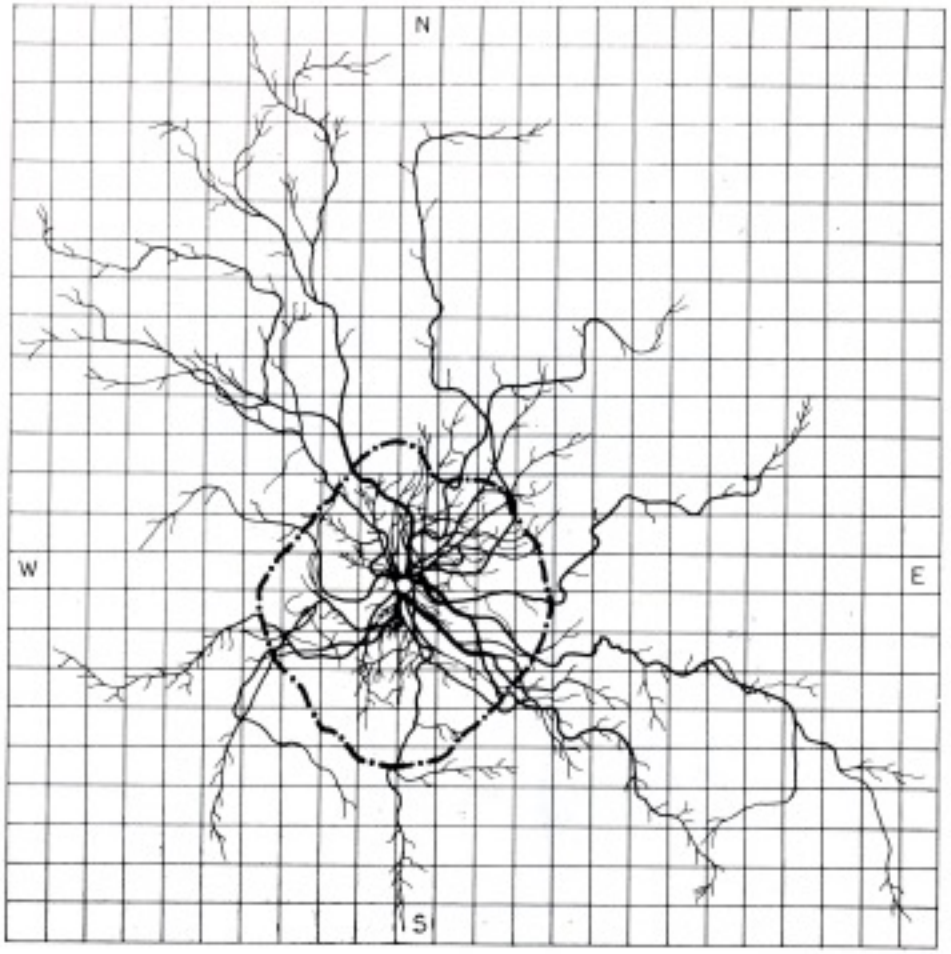
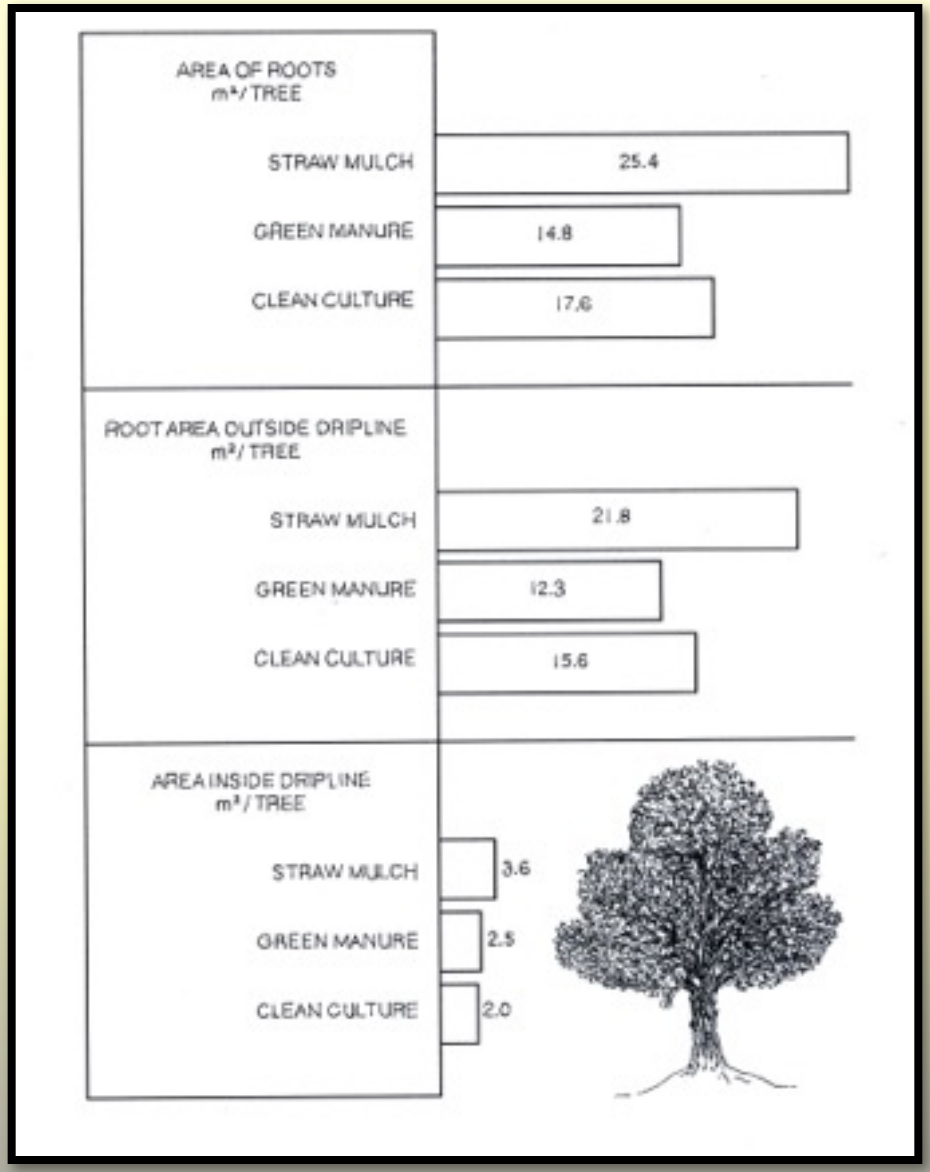
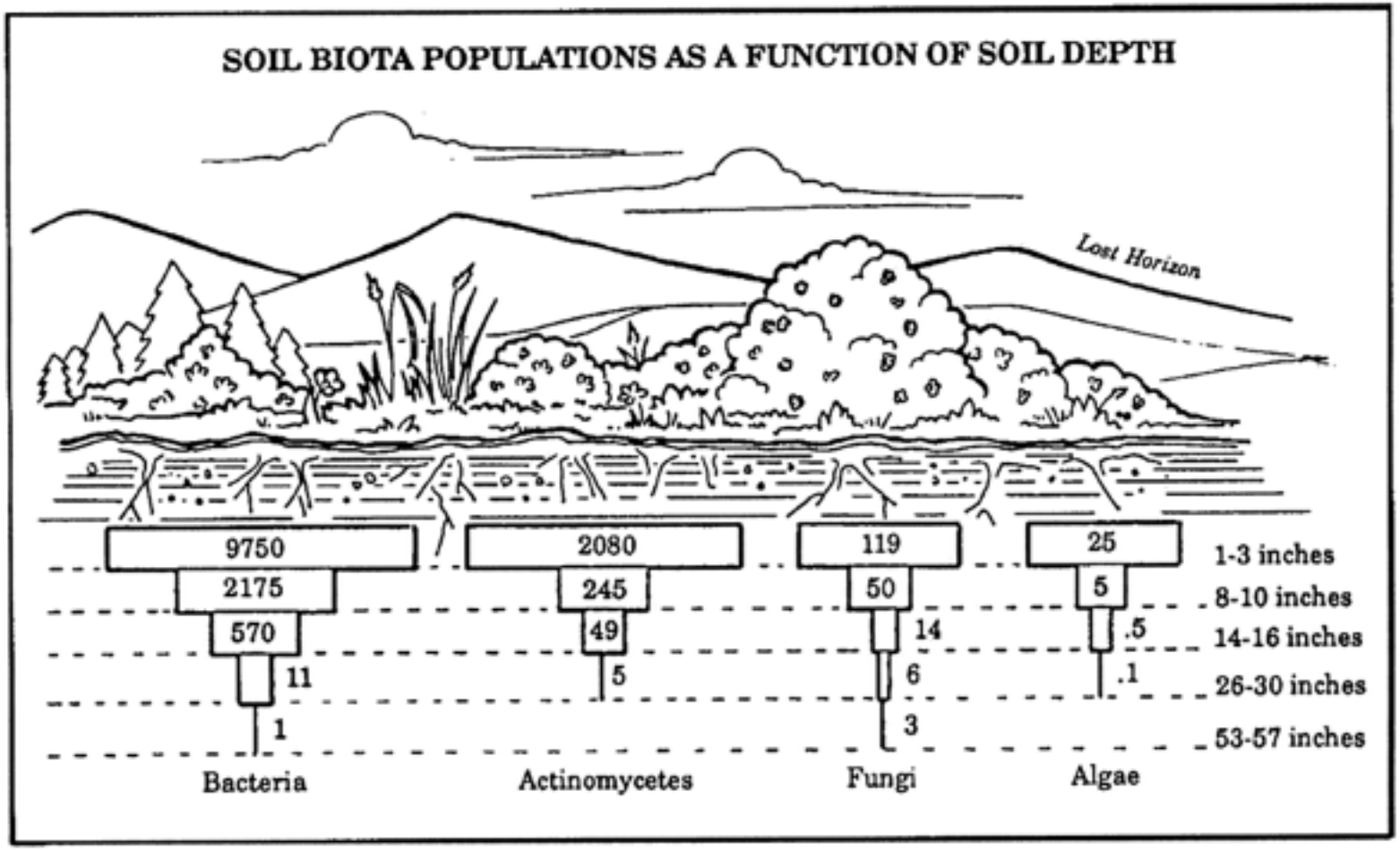
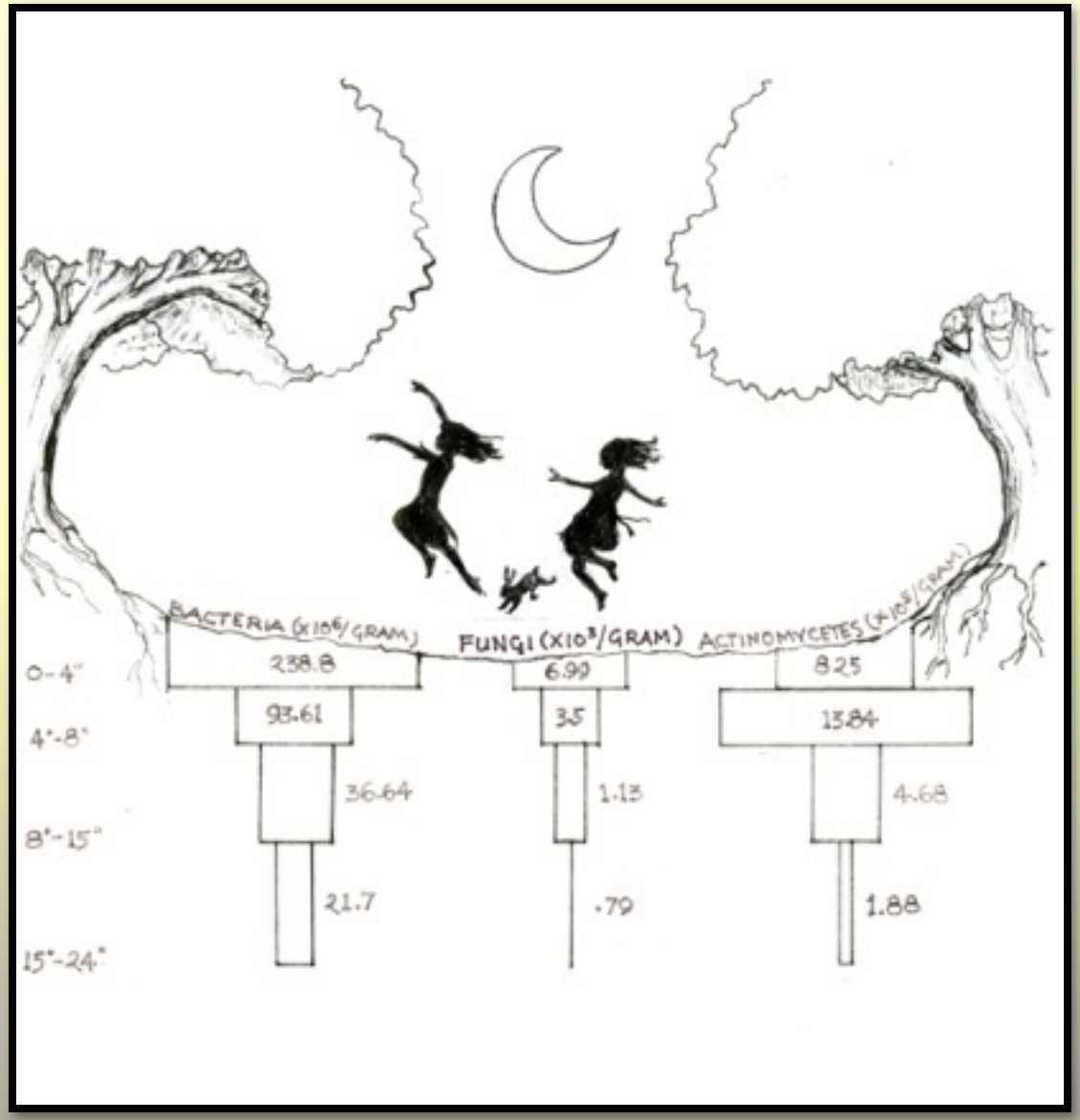
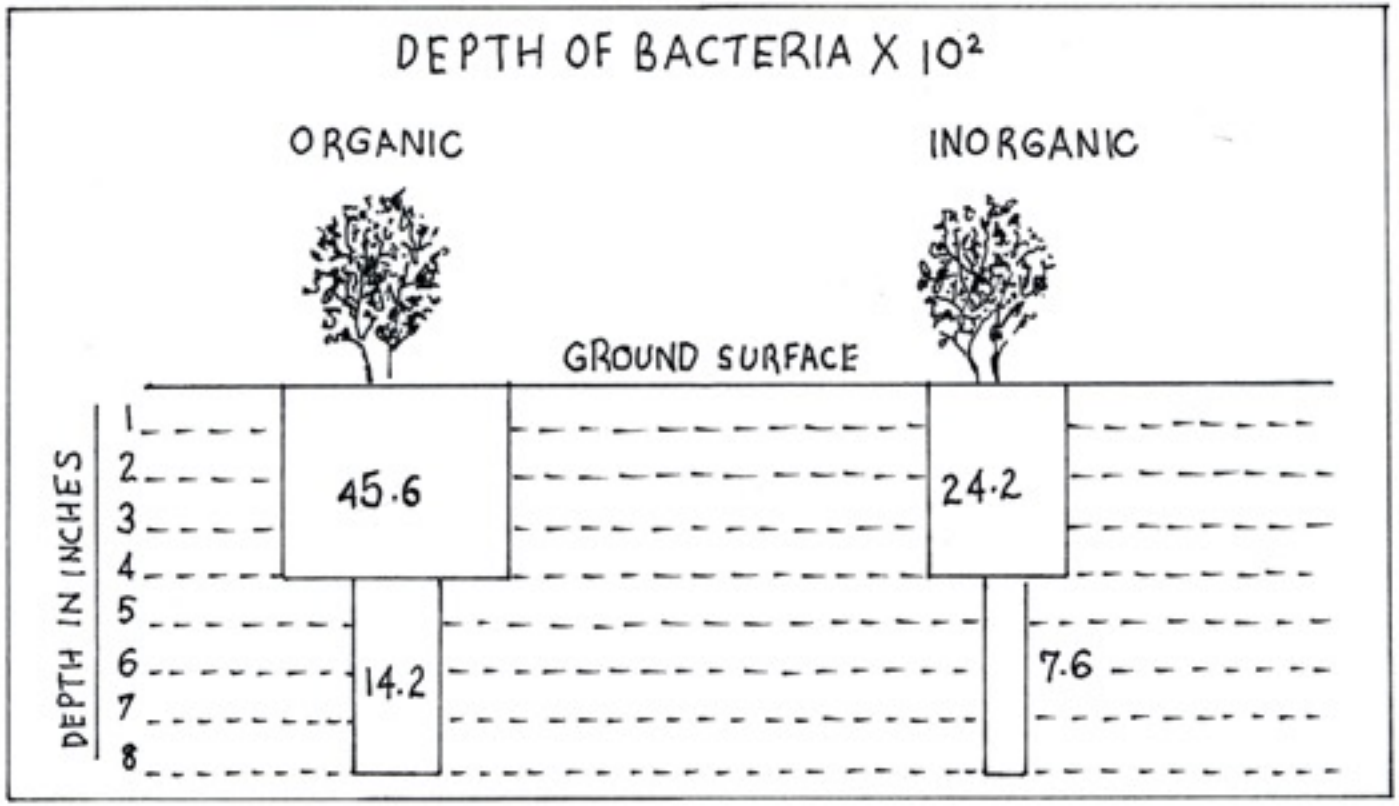


Fig. 131. The root system of a 24-year-old walnut tree raised from seed in sandy soil occupied an area of 199 m². The diameter of the root system was 3.5 times that of the branch system. The projection of the crown (drip-line) is marked by a dashed line. (The sides of the squares are 1 m)

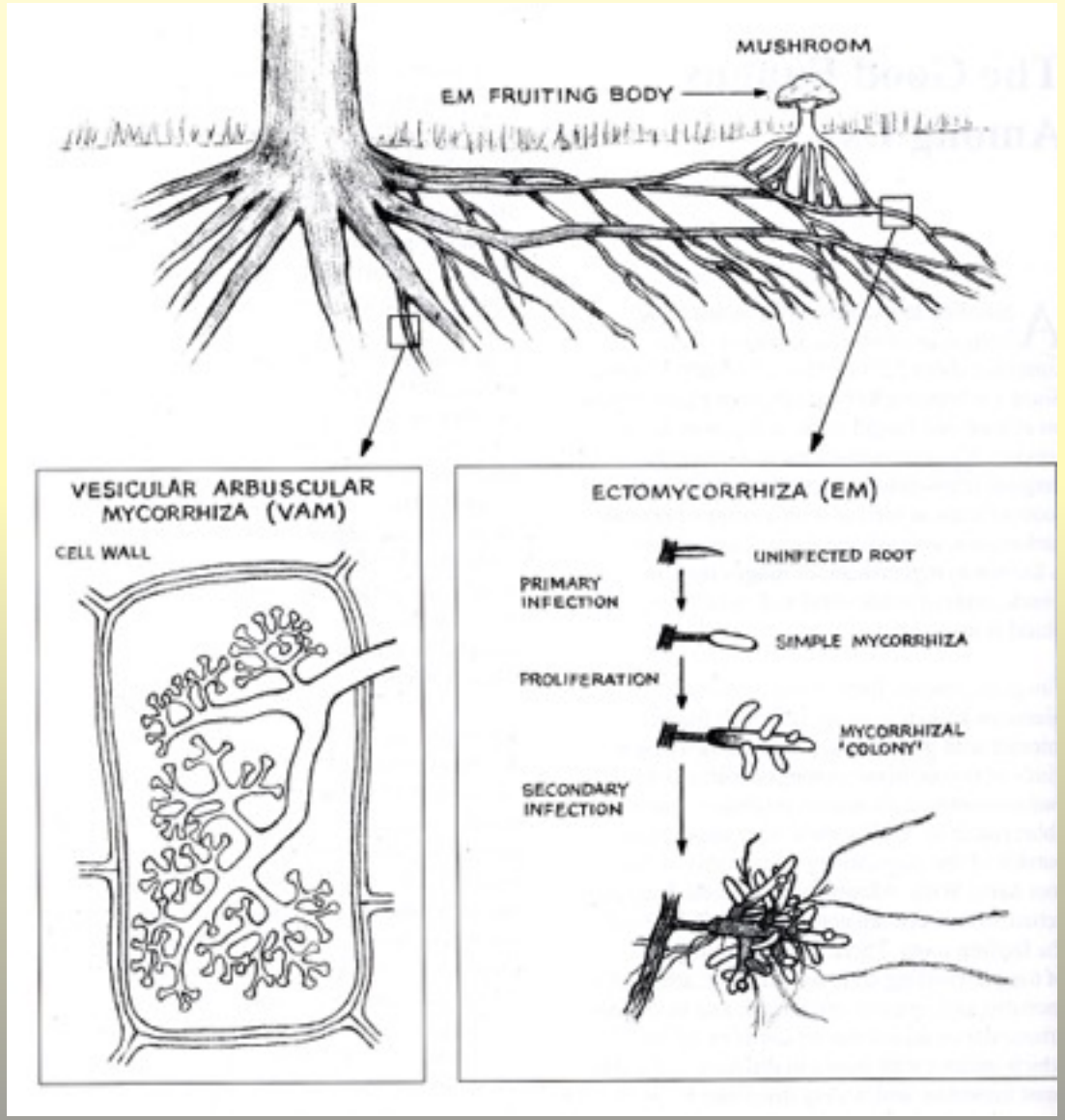

AREA OF ROOTS
m²/ TREE
STRAW MULCH
25.4
GREEN MANURE
14.8
CLEAN CULTURE
17.6
ROOT AREA OUTSIDE DRIPLINE
m²/ TREE
STRAW MULCH
21.8
GREEN MANURE
12.3
CLEAN CULTURE
15.6
AREA INSIDE DRIPLINE
m²/ TREE
STRAW MULCH
3.6
GREEN MANURE
2.5
CLEAN CULTURE
2.0


SOIL BIOTA POPULATIONS AS A FUNCTION OF SOIL DEPTH
Lost Horizon
9750
2175
570
11
1
2080
245
49
5
119
50
14
6
3
25
5
.5
.1
1-3 inches
8-10 inches
14-16 inches
26-30 inches
53-57 inches
Bacteria
Actinomycetes
Fungi
Algae


BACTERIA (X10⁶/GRAM)
FUNGI (X10³/GRAM)
ACTINOMYCETES (X10³/GRAM)
0-4"
4"-8"
8"-15"
15"-24"
238.8
93.61
36.64
21.7
6.90
35
1.13
.79
825
13.84
4.68
1.88

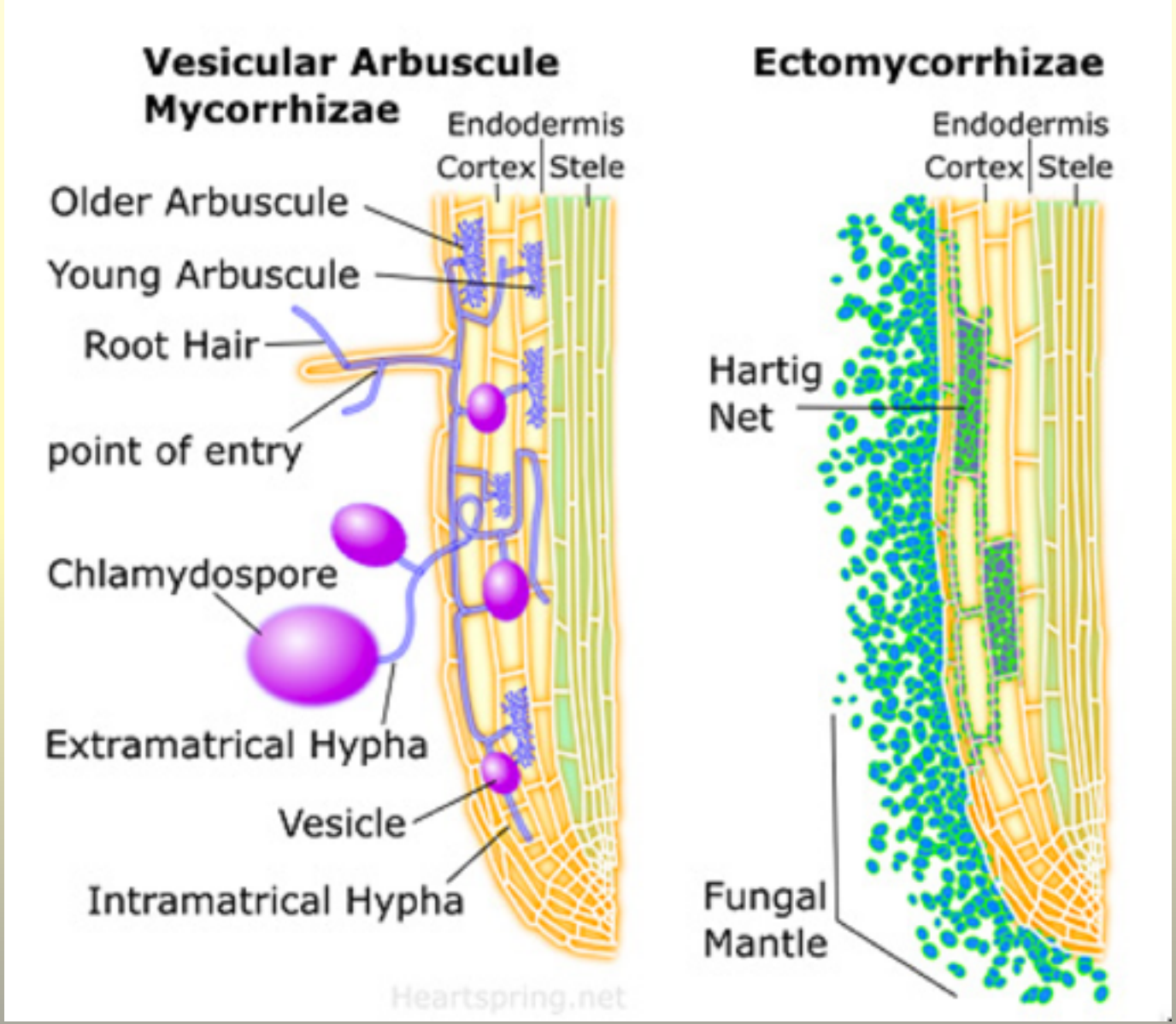

DEPTH OF BACTERIA X 10²
ORGANIC
INORGANIC
GROUND SURFACE
DEPTH IN INCHES
1
2
3
4
5
6
7
8
45.6
14.2
24.2
7.6

- Endo- & Ectomycorrhizae

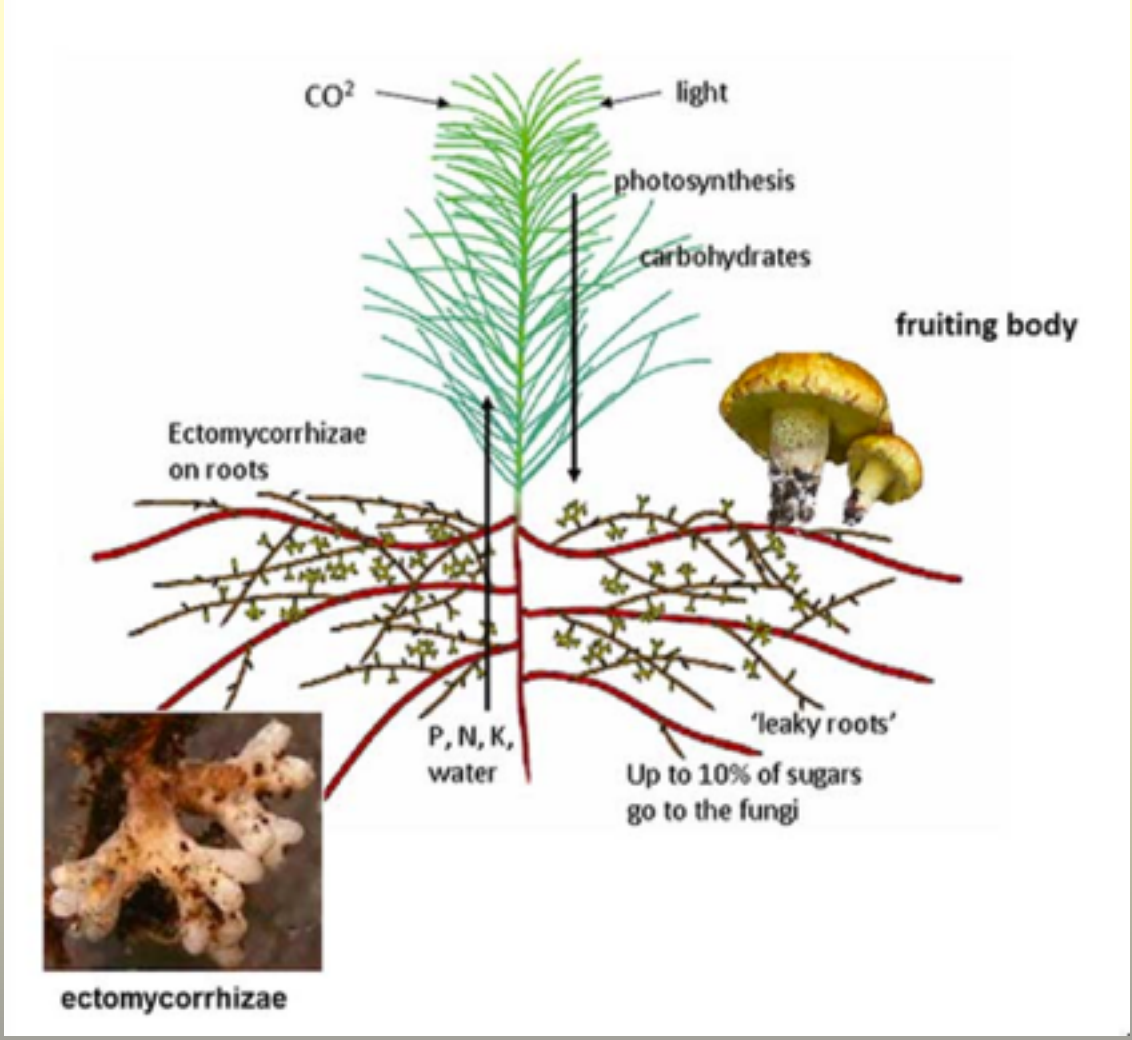


Plant groups that do not support mycorrhizae.

- Beets, *Beta vulgaris* spp.
- *Brassicaceae* (Cruciferae)
- *Chenopodiaceae* (lambs quarters)
- *Portulacaceae* (claytonia)
- *Amaranthaceae* (*Amaranthus* spp.)
- Orchid
- Protea
- Carnation
- Rush
- Sedge
- Heath
- Rhododendron
- Azalea


Vesicular Arbuscule Mycorrhizae
Endodermis
Cortex
Stele
Older Arbuscule
Young Arbuscule
Root Hair
point of entry
Chlamydospore
Extramatrical Hypha
Vesicle
Intramatrical Hypha
Heartspring.net
Ectomycorrhizae
Endodermis
Cortex
Stele
Hartig Net
Fungal Mantle

- Ectomycorrhizal Association



The Benefits of Mycorrhizae

- Increase the surface area and efficiency of the roots (up to 1000%)

- Promote water absorption and nutrient uptake of poorly mobile soil ions such as zinc, copper, molybdenum, and potassium

- Most importantly, the transfer of phosphorus that is hard for trees to absorb on their own

- Enhance the growth of stimulatory plant hormones

- Boost plant resistance to some pathogens, drought and high soil temperature

- Promote growth and yields, reducing the need for artificial fertilizers

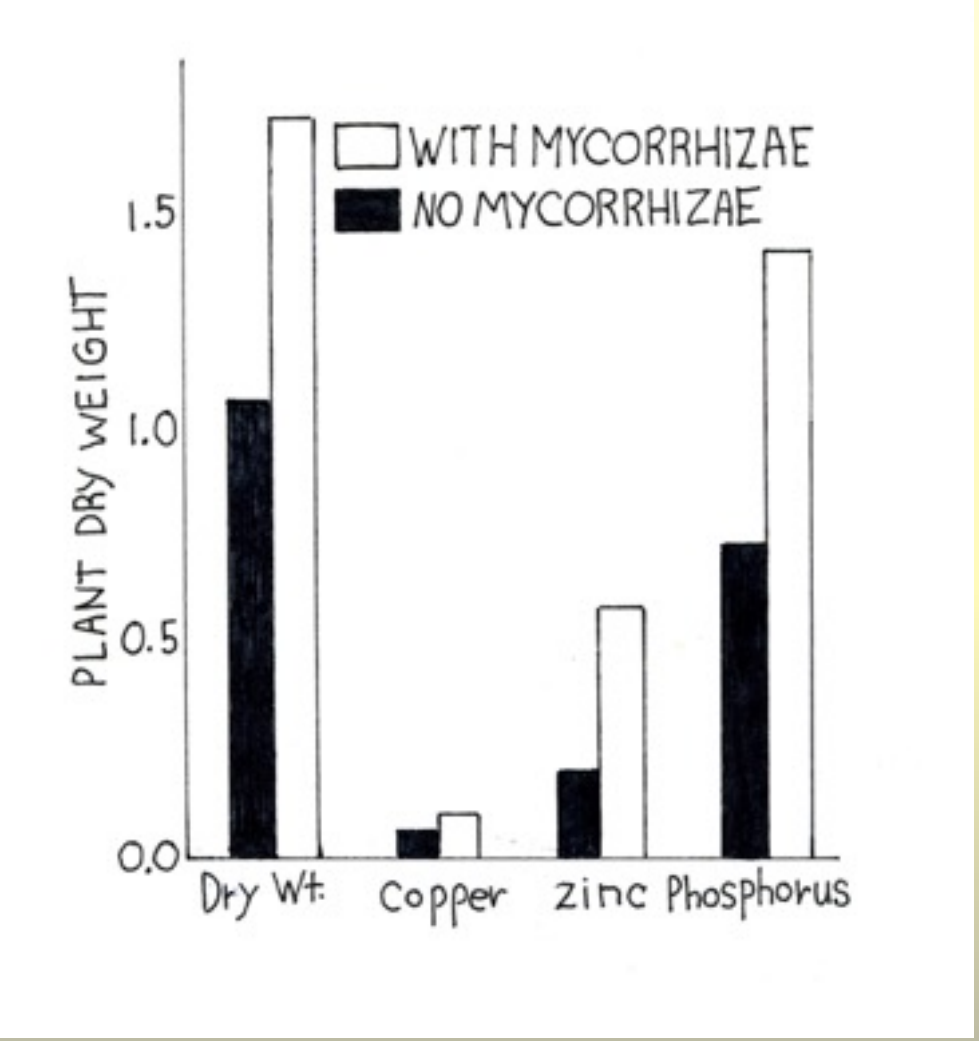

WITH MYCORRHIZAE
NO MYCORRHIZAE
PLANT DRY WEIGHT
1.5
1.0
0.5
0.0
Dry Wt.
Copper
Zinc
Phosphorus

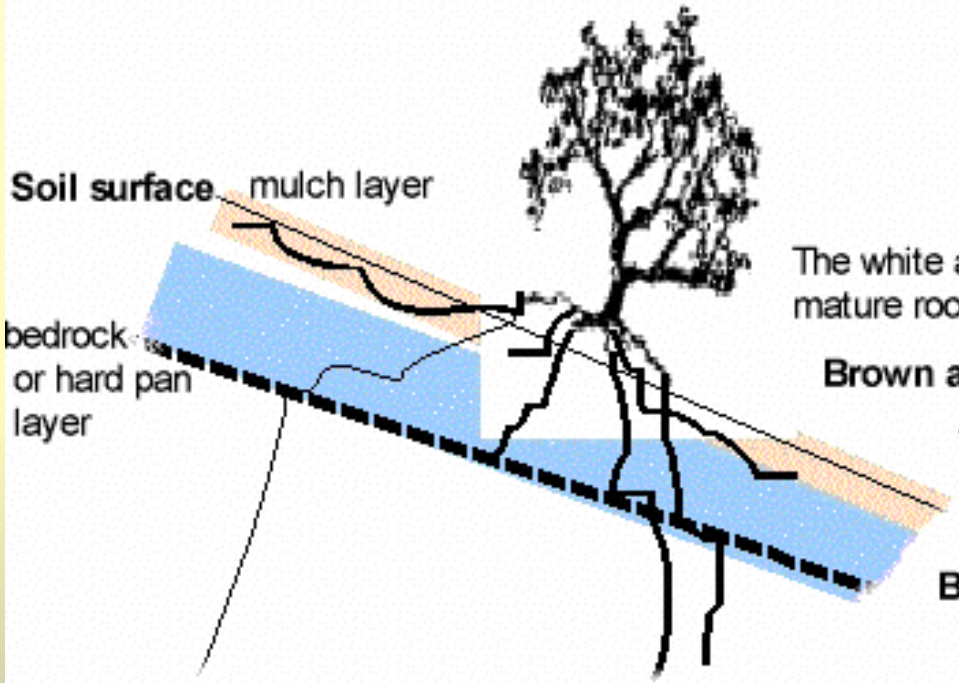
Table 87
Effect of mycorhizas on the growth of pine seedlings

Indexes of growth	With mycorhizas	Without mycrohizas
Length of shoots of seedlings, cm	35.5	17.5
Increase in length after 2 years, cm	18.0	3.0
Length of sprouts of 2nd order, cm	10.0	0.3
Weight of shoots part, gm	17.0	3.1
Weight of roots, gm	11.0	4.5
Number of leaves	42	12
Total area of leaves, cm^2	591.0	96.0

This chart, based on the growth of pine seedlings started in a sterile potting mix, provides a number of ways to look at the influence of sterile soil inoculated with beneficial fungi. (Note the 1958 Soviet Union spelling of mycorrhizae.) [3]

This could be a mature oak, manzanita or ceanothus.

The top 6 inches of soil under the drip line of the plant is the most sensitive to disturbance



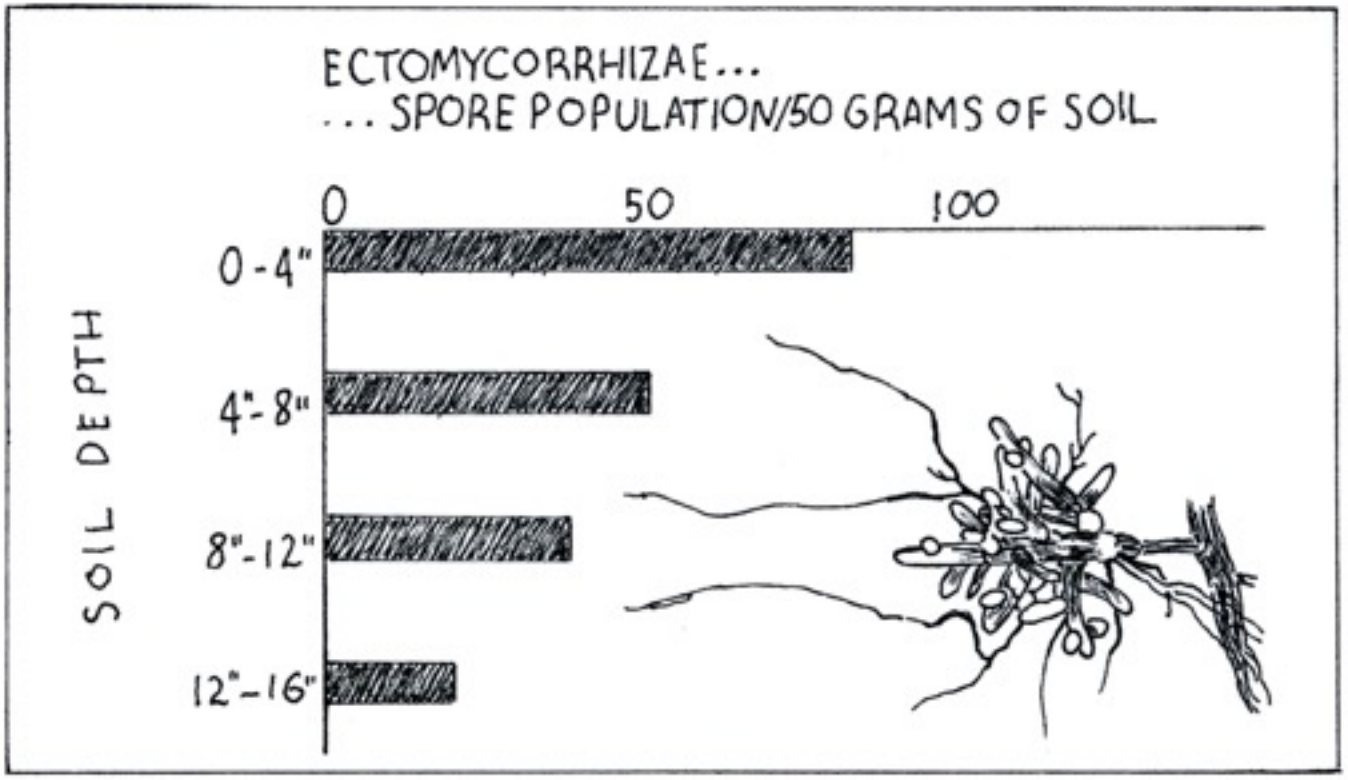
The white area, under the drip line, contains mature roots that are no longer absorbing.

Brown area = Strong Ectomycorrhiza

The Ectomycorrhiza helps absorb nutrients from the mulch layer

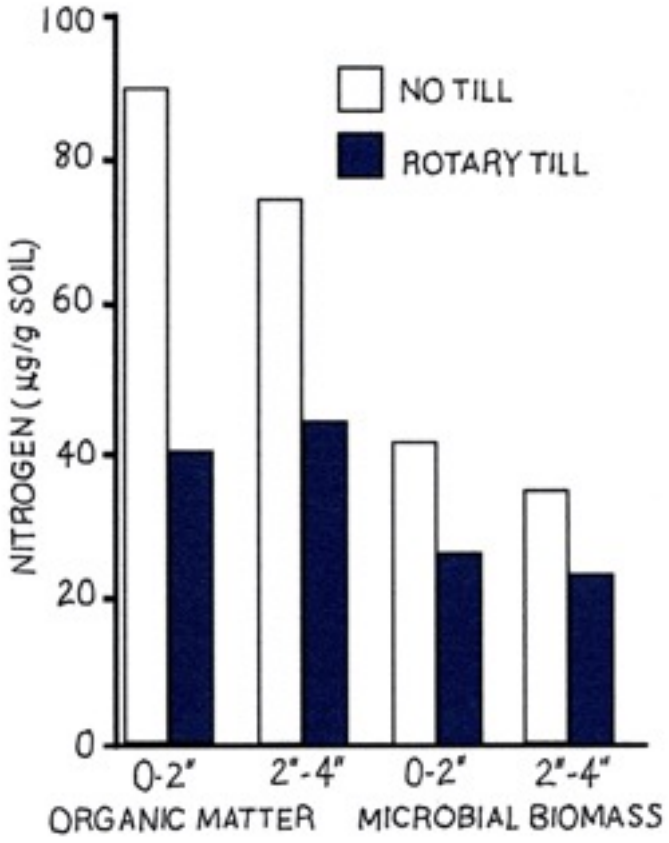
Blue area = Strong VA Mycorrhiza

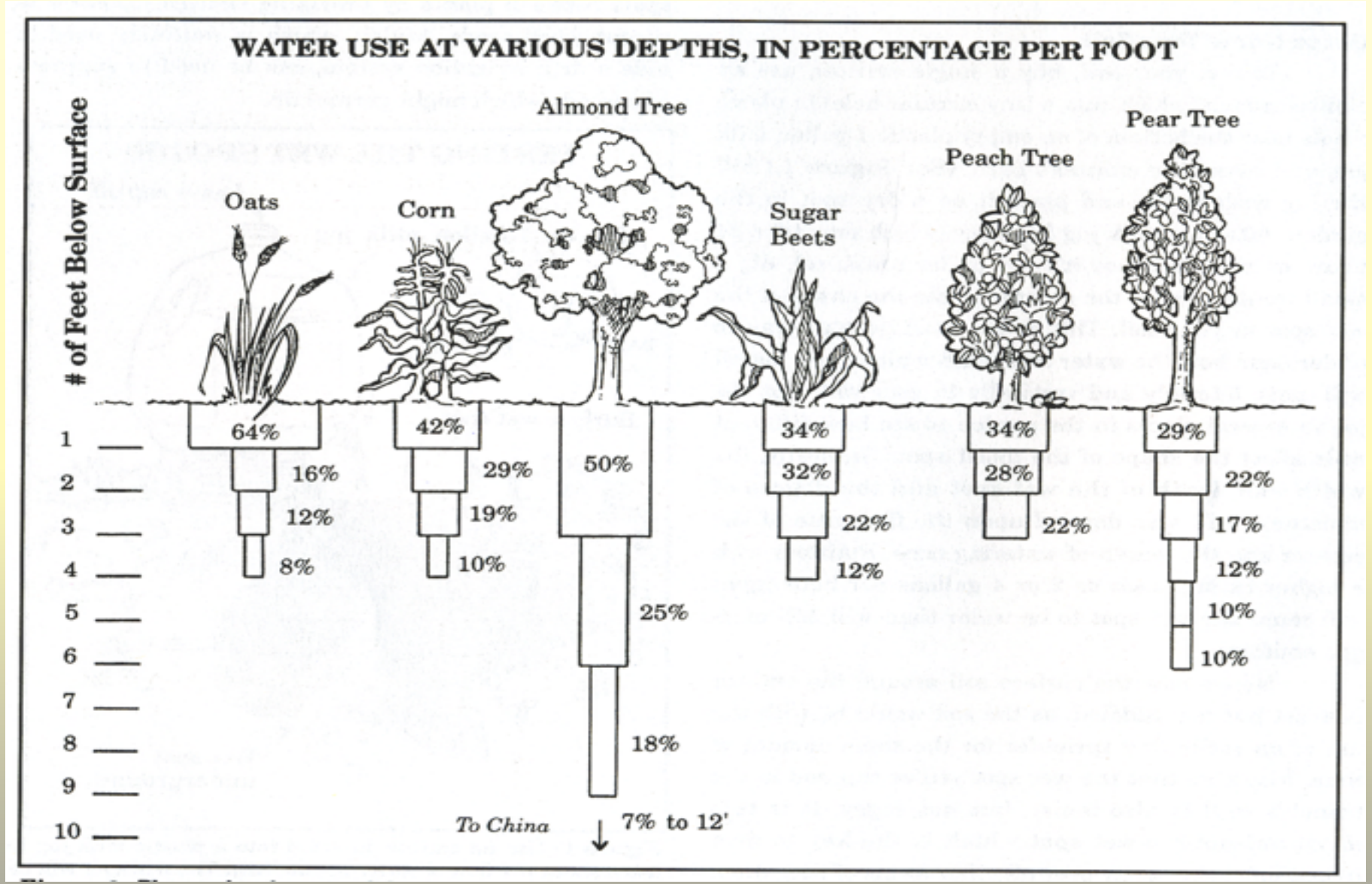
A few roots penetrate the hard pan and go deep to get water for the plant and its friends


ECTOMYCORRHIZAE...
... SPORE POPULATION/50 GRAMS OF SOIL
0
50
100
SOIL DEPTH
0-4"
4"-8"
8"-12"
12"-16"

- When to Apply Inoculants

- *In a container plant grown in a sterile potting mix.*
- *When a planting site site has been scraped to subsoil.*
- *In very sandy or beach properties.*
- *To amend soil that contains too much salt.*
- *On toxic tailings from mining. (I hope this doesn't apply to you!)*
- *When sterile topsoil has been added to the site.*
- *If certain fungicides have been used in the planting area. (See: http://mycorrhizae.com/faqs: What effect do fungicides have on mycorrhizal fungi?*)
- *After soil fumigants have been used.*


100
80
60
40
20
0
NITROGEN (µg/g SOIL)
NO TILL
ROTARY TILL
0-2"
2"-4"
0-2"
2"-4"
ORGANIC MATTER
MICROBIAL BIOMASS


WATER USE AT VARIOUS DEPTHS, IN PERCENTAGE PER FOOT
# of Feet Below Surface
1
2
3
4
5
6
7
8
9
10
Oats
64%
16%
12%
8%
Corn
42%
29%
19%
10%
Almond Tree
50%
25%
18%
To China
7% to 12'
Sugar Beets
34%
32%
22%
12%
Peach Tree
34%
28%
22%
Pear Tree
29%
22%
17%
12%
10%
10%

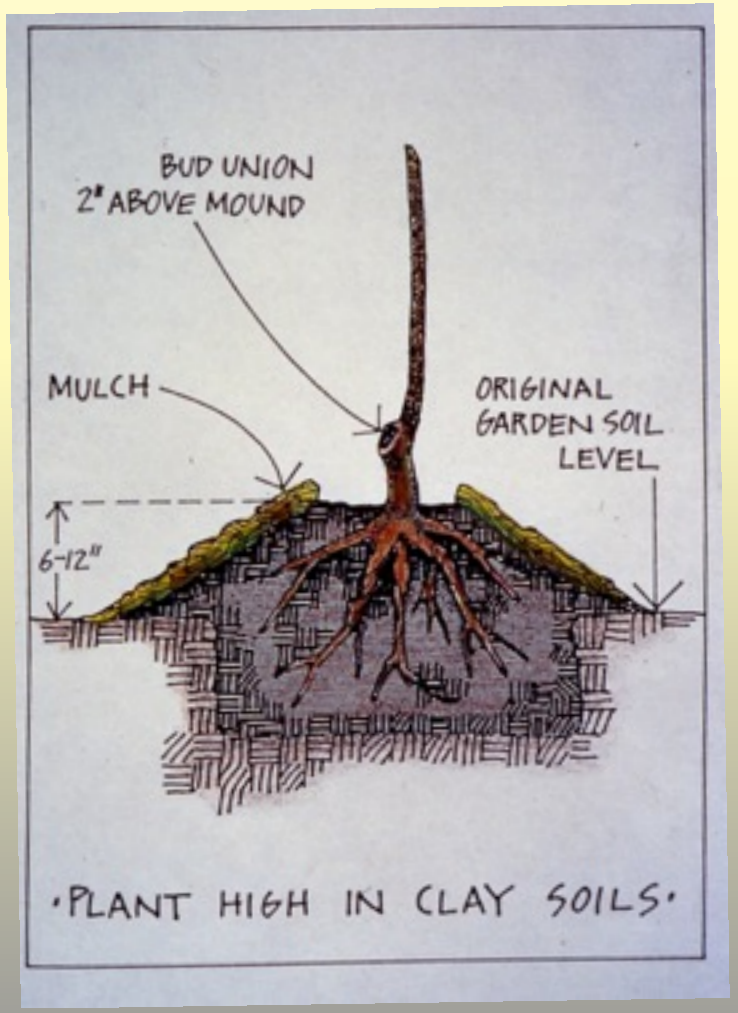
End the battle of doughnuts of death!

Mulch to dripline or beyond, not just near trunk

Some choices for mulching trees

Or, in a lawn with plenty of drainage and on a mound.

Plant on a mound in any soil, but especially clay soils.

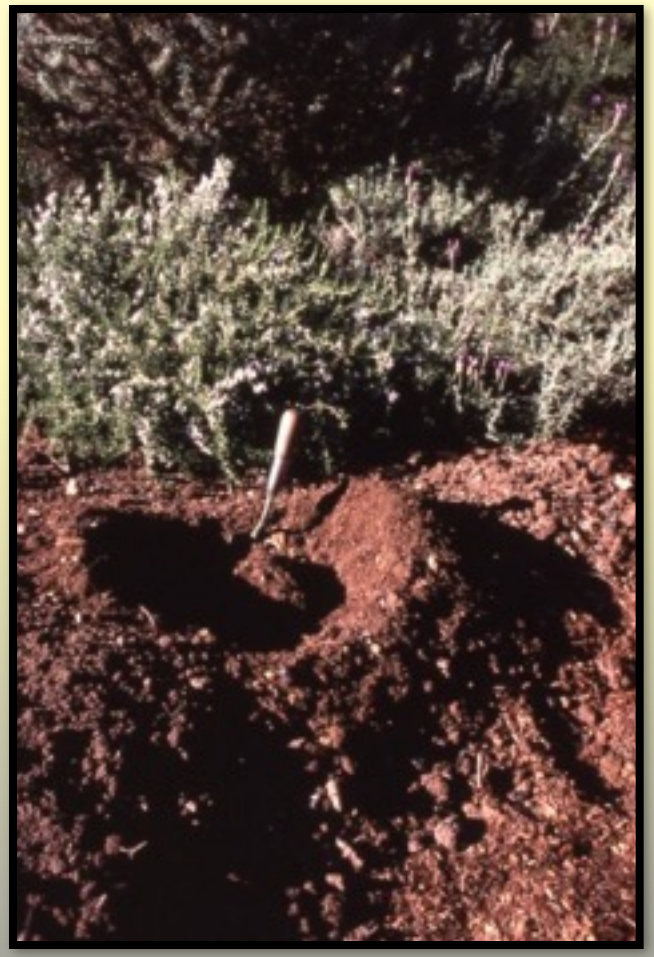


Planted on a mound,
not mulched too high.

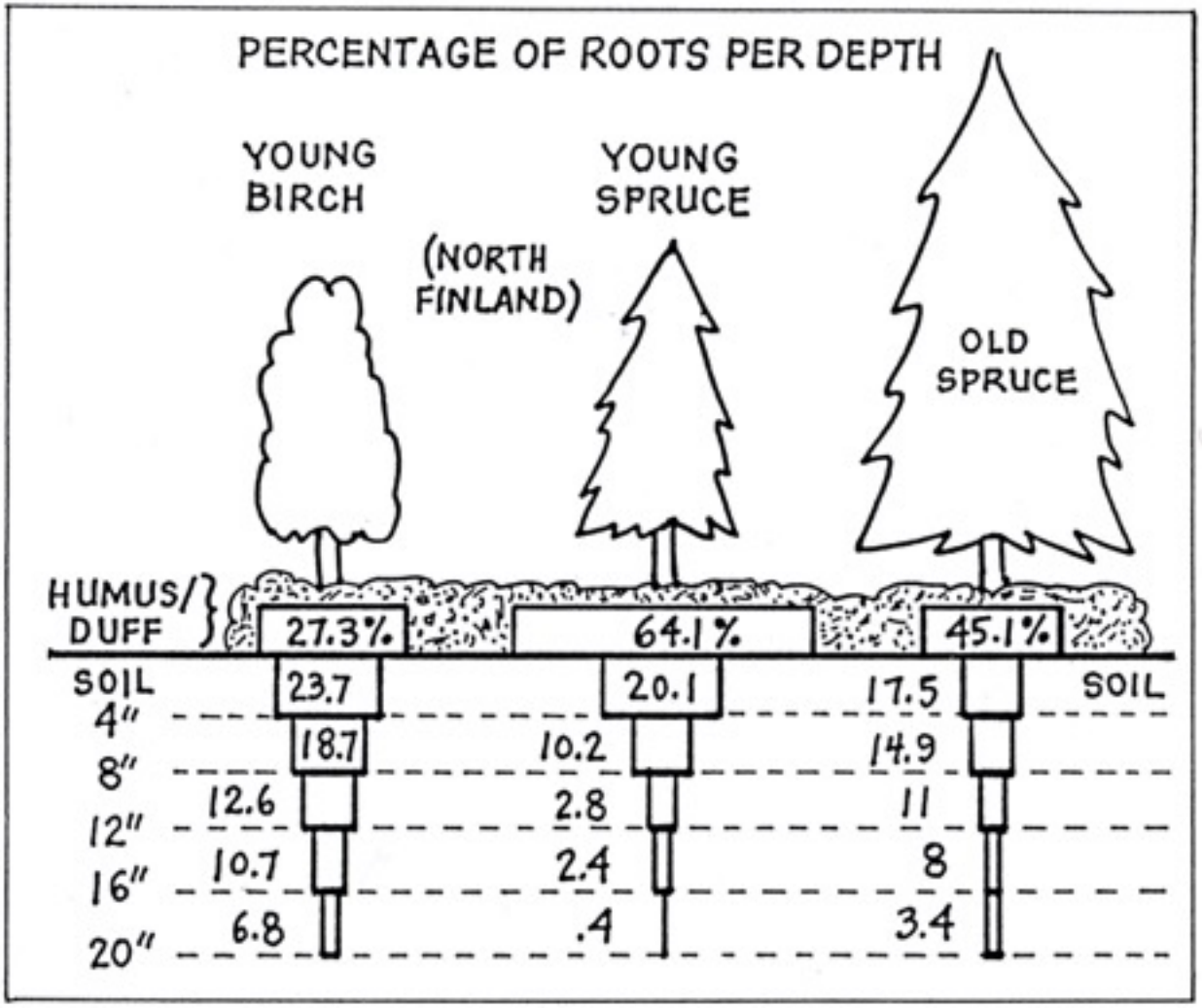
- **Plant high on a mound, will settle 20-50%**
- **Cover with newspaper (or old garden B&W catalogs!)**
- **Cover with attractive mulch**
- **Use only B & W newspaper, not color inserts on slick paper**

(Shameless product placement.)

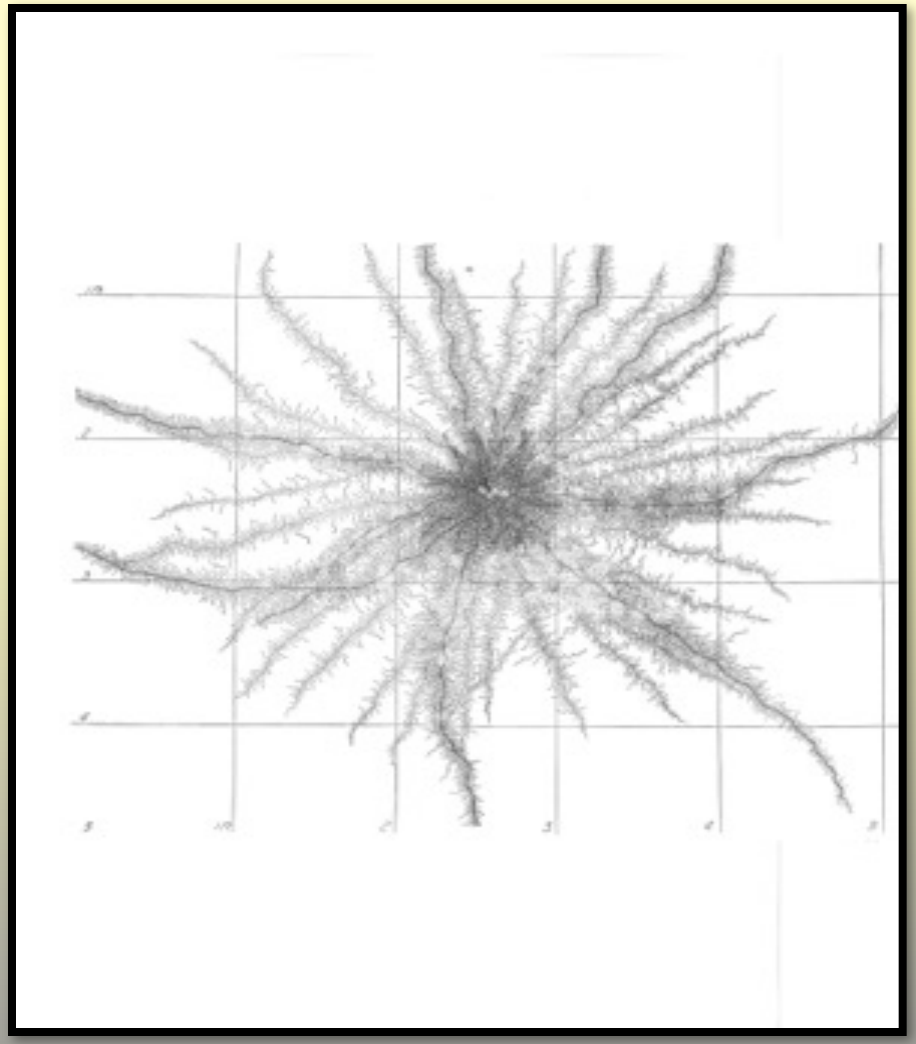
Step-by-step planting on a mound (Part 1)



Step-by-step planting on a mound (Part 2)

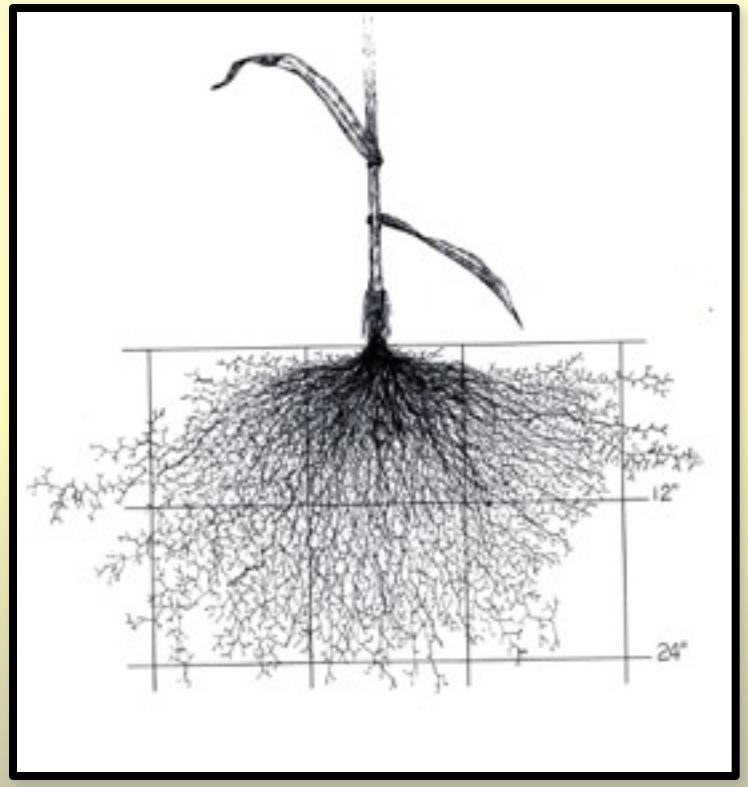

PERCENTAGE OF ROOTS PER DEPTH
YOUNG BIRCH
YOUNG SPRUCE
(NORTH FINLAND)
OLD SPRUCE
HUMUS/ DUFF
27.3%
64.1%
45.1%
SOIL
SOIL
4"
8"
12"
16"
20"
23.7
18.7
12.6
10.7
6.8
20.1
10.2
2.8
2.4
.4
17.5
14.9
11
8
3.4

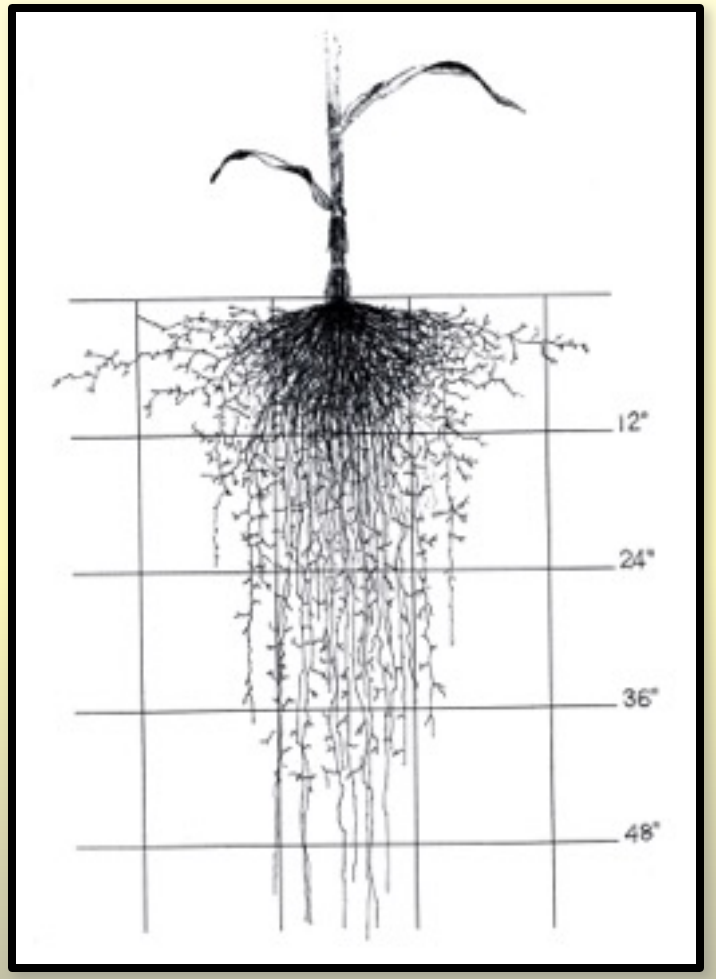
Many vegetables have roots wider than foliage.



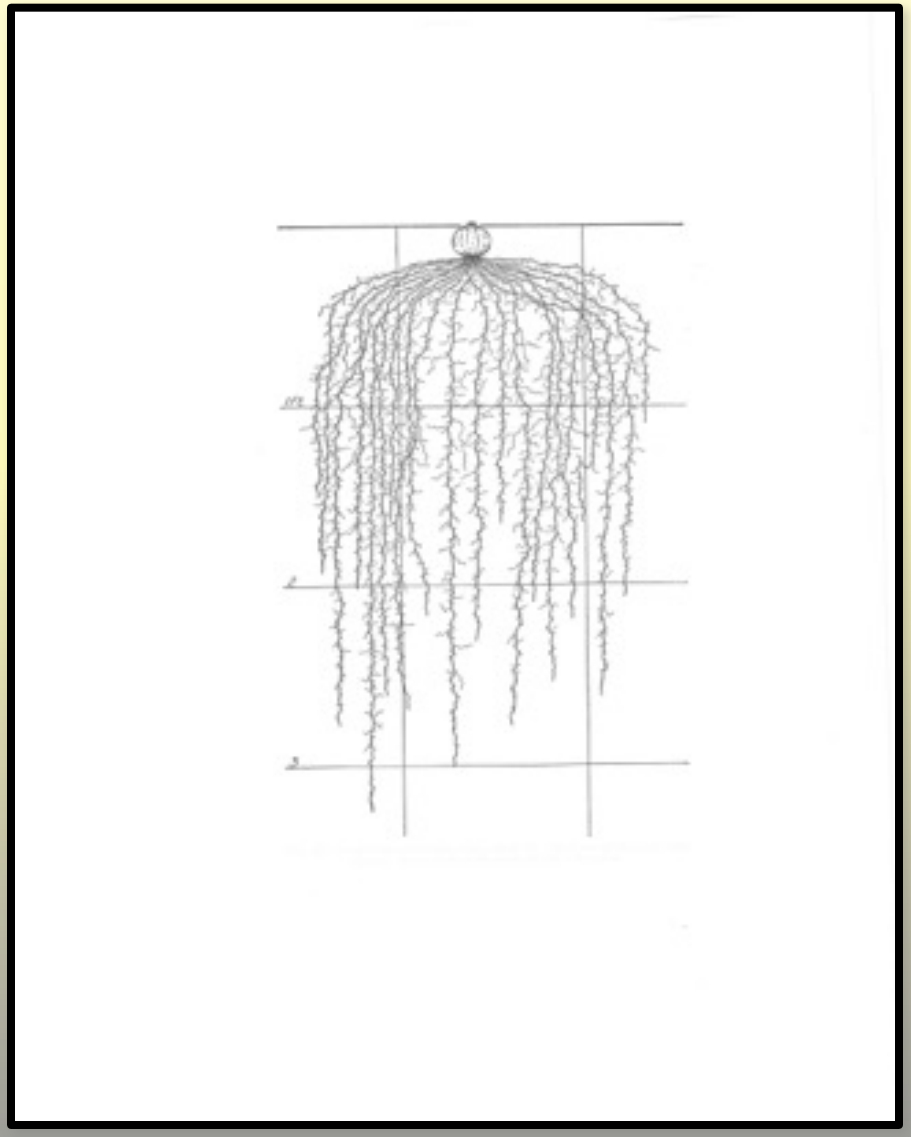
Corn plant seen from above (the top 6” of the root system) extends 2-3 feet beyond the corn’s stems.

Corn

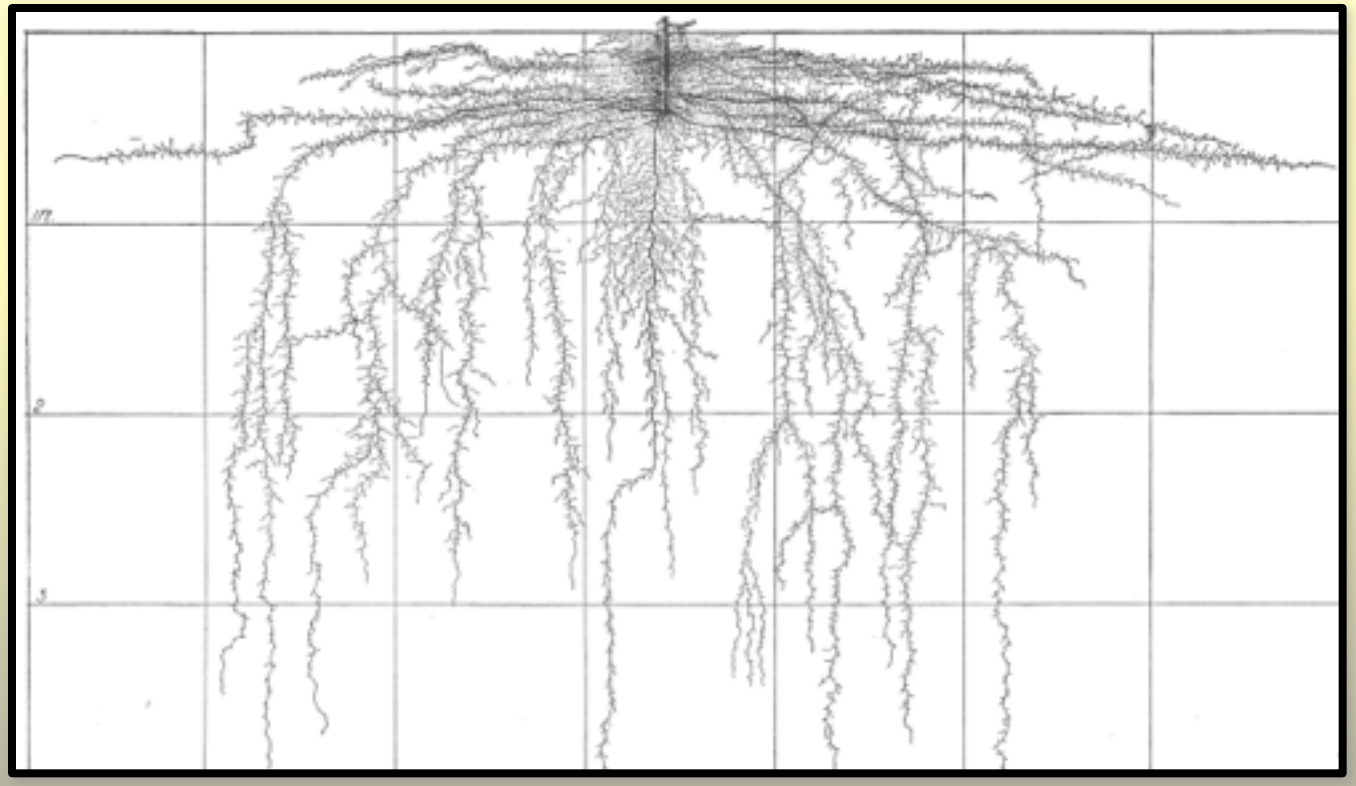




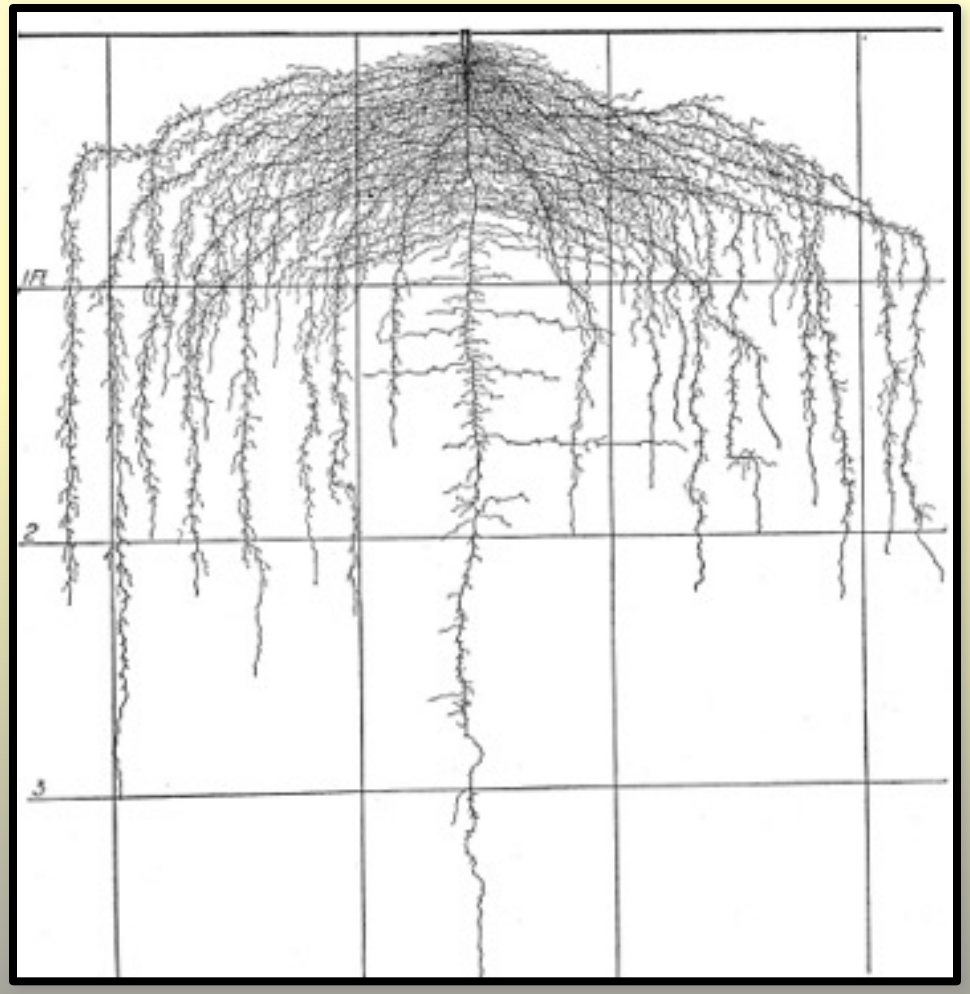
Onion



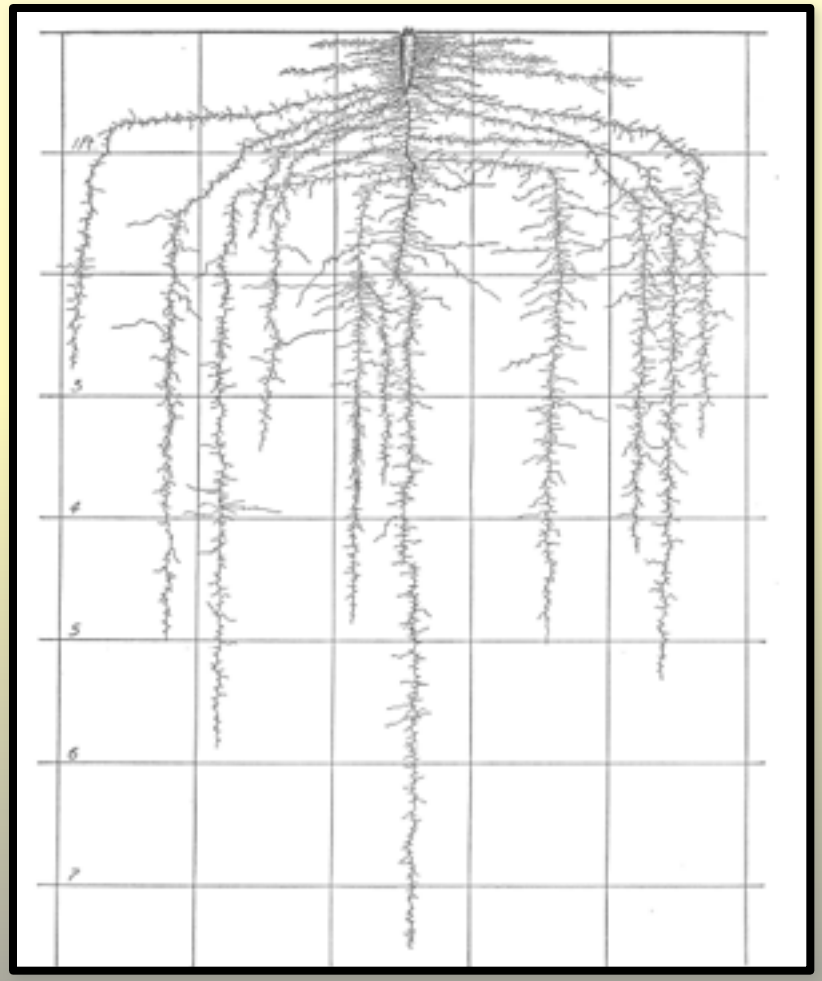
Tomato

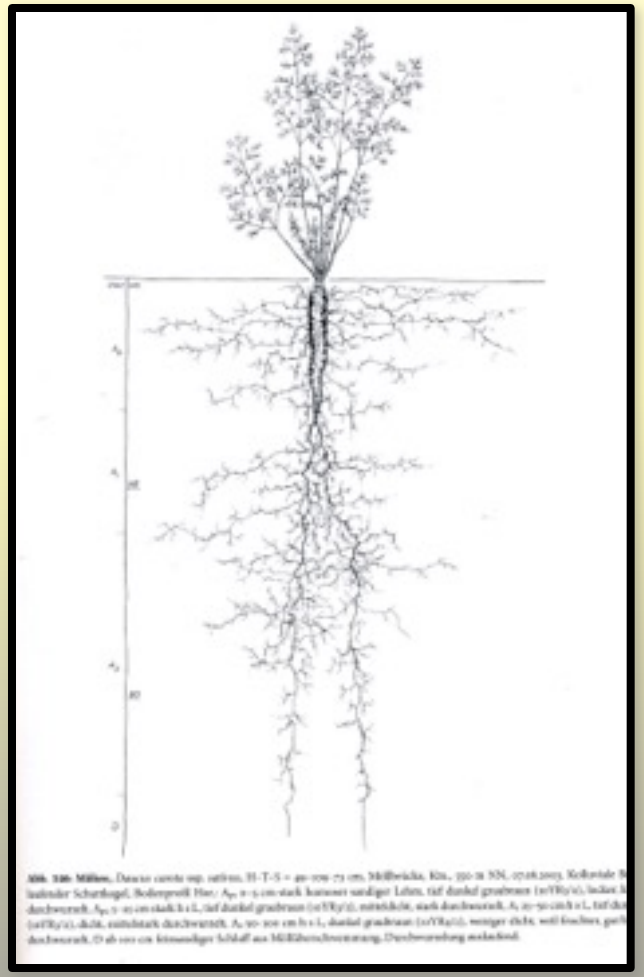


Lettuce

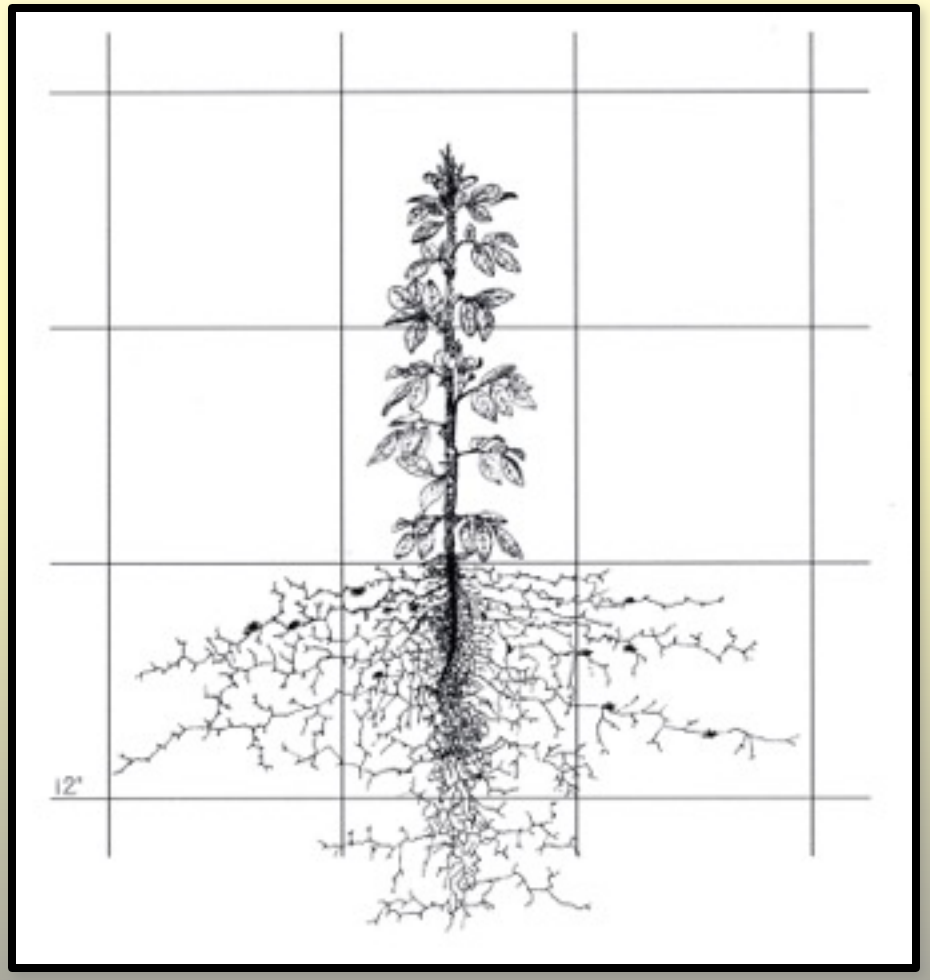


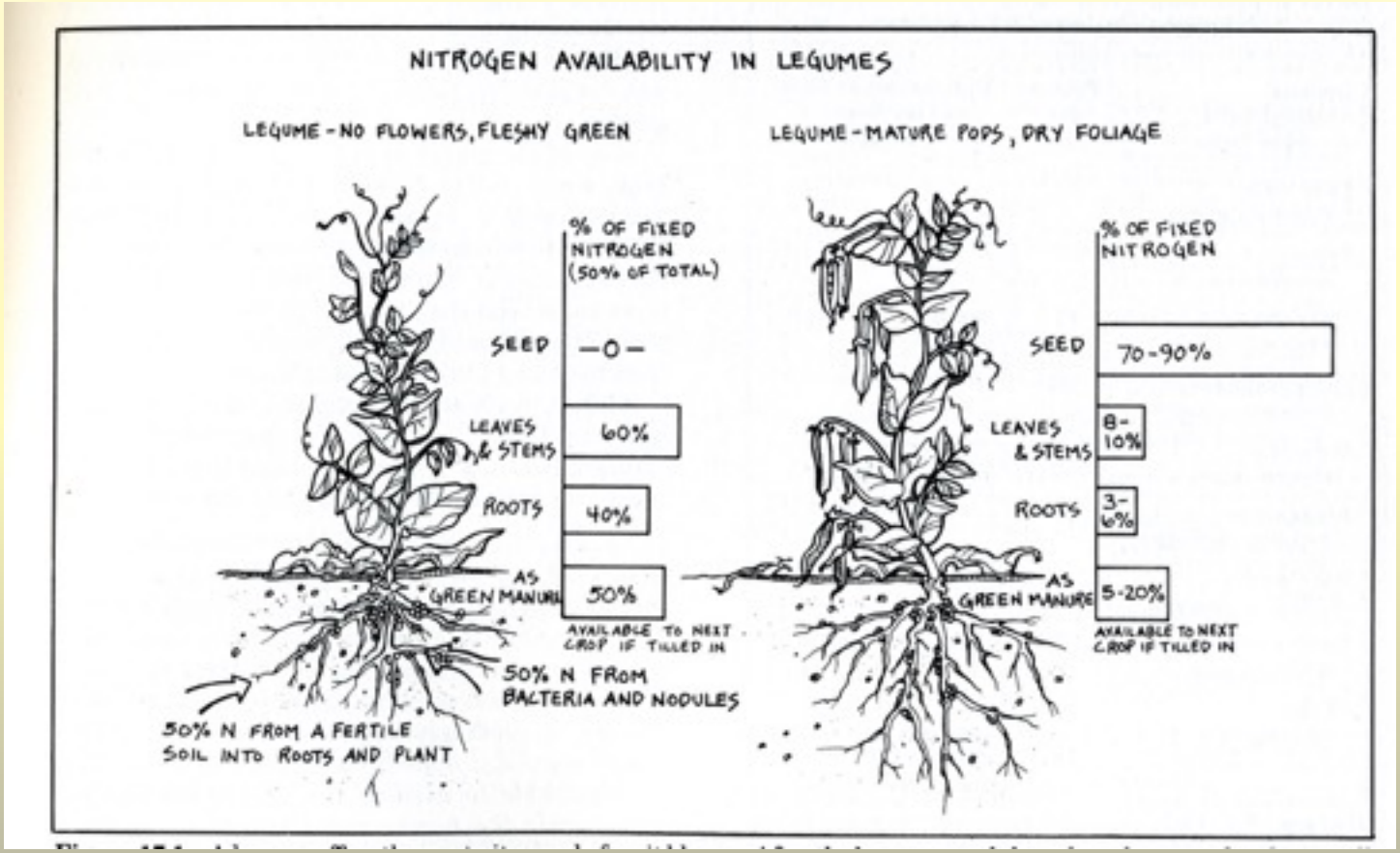
Carrot

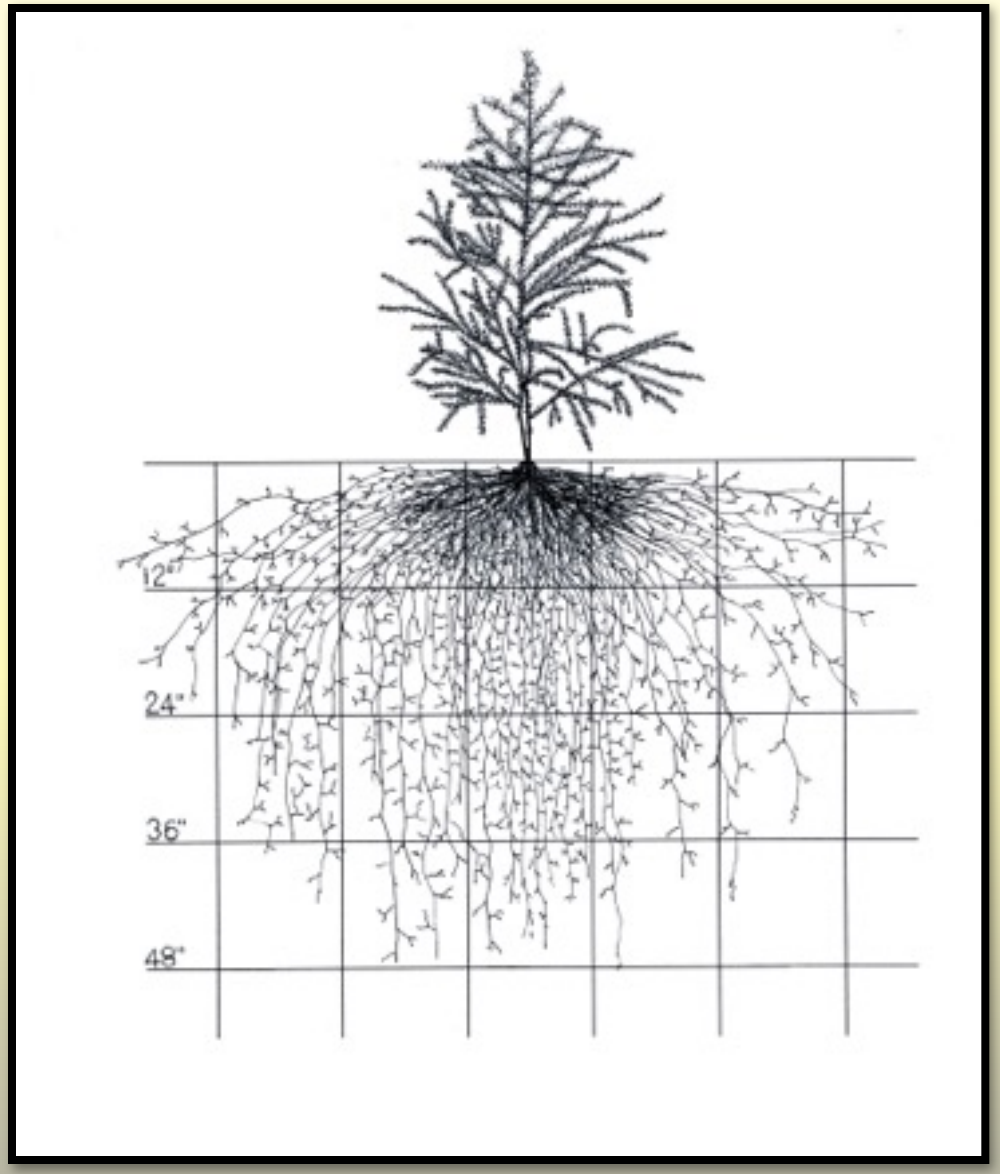




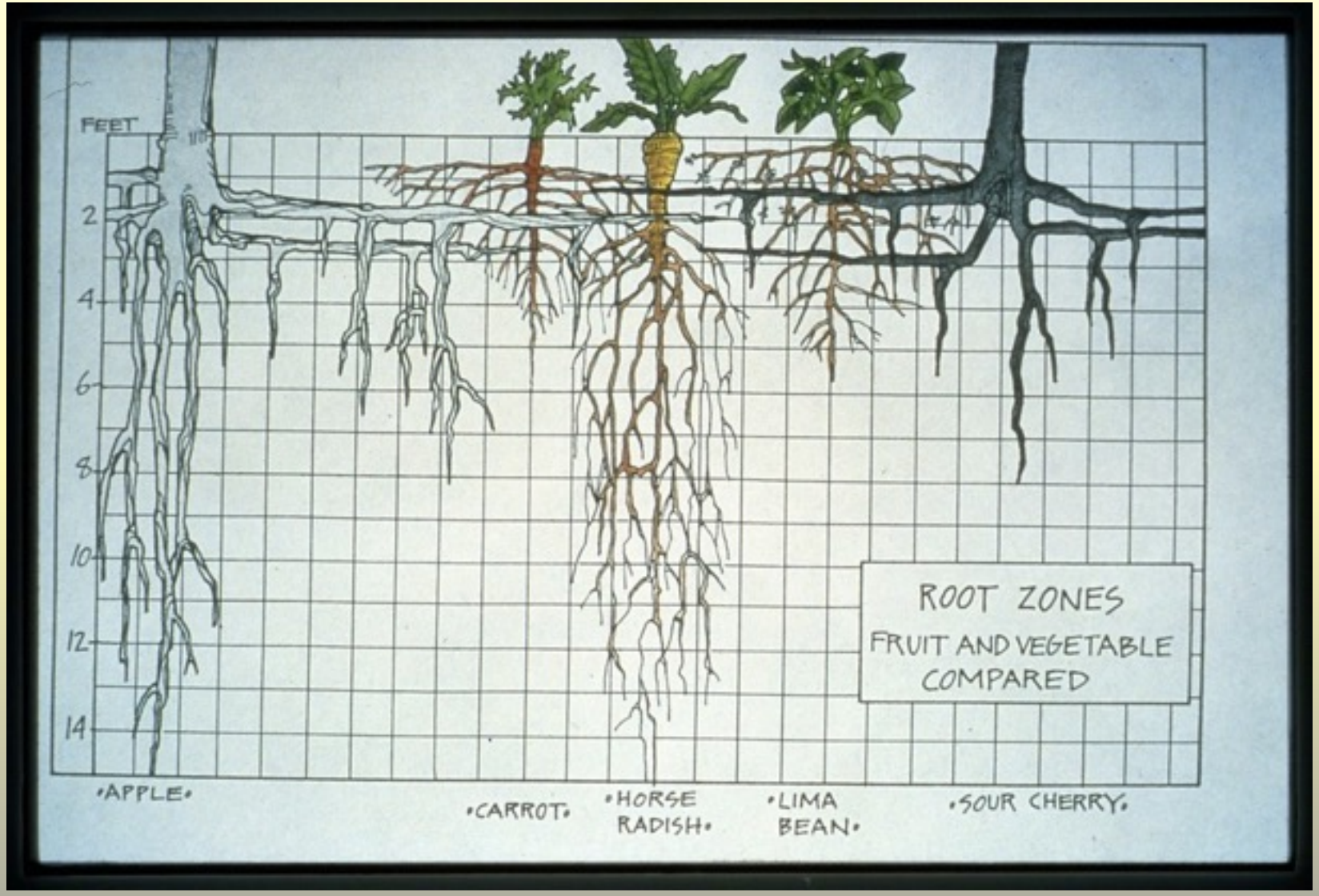
Fava Bean



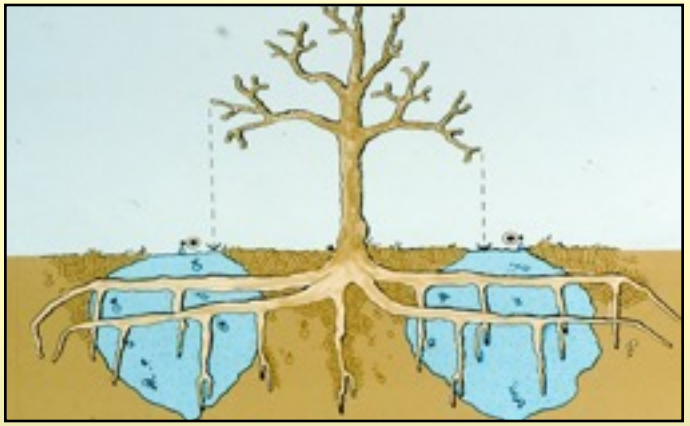

NITROGEN AVAILABILITY IN LEGUMES
LEGUME - NO FLOWERS, FLESHY GREEN
% OF FIXED NITROGEN (50% OF TOTAL)
SEED
—0—
LEAVES & STEMS
60%
ROOTS
40%
AS GREEN MANURE
50%
AVAILABLE TO NEXT CROP IF TILLED IN
50% N FROM BACTERIA AND NODULES
50% N FROM A FERTILE SOIL INTO ROOTS AND PLANT
LEGUME - MATURE PODS, DRY FOLIAGE
% OF FIXED NITROGEN
SEED
70-90%
LEAVES & STEMS
8-10%
ROOTS
3-6%
AS GREEN MANURE
5-20%
AVAILABLE TO NEXT CROP IF TILLED IN

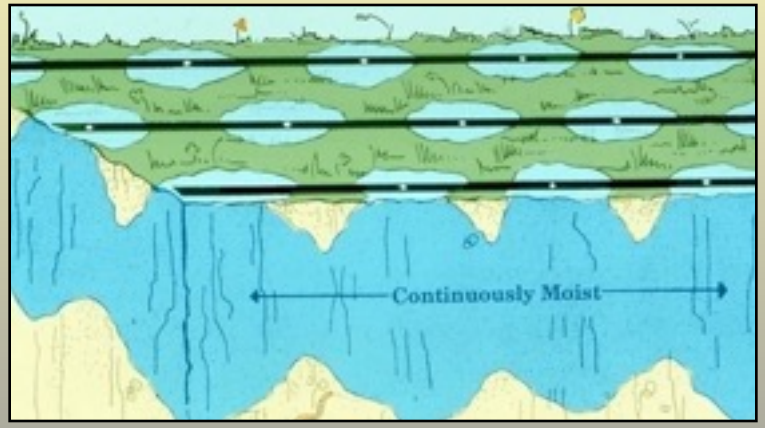


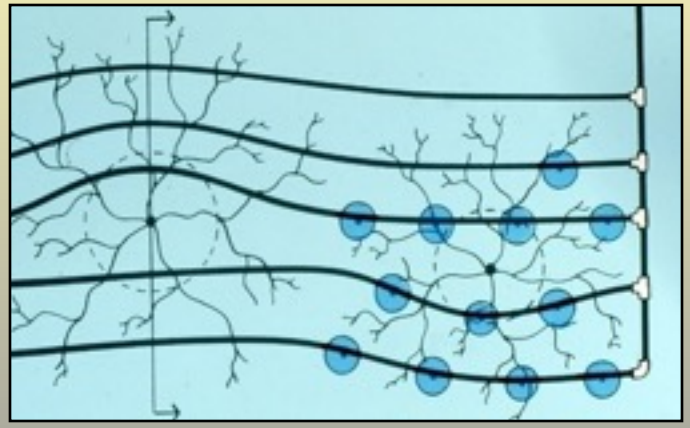
Asparagus


FEET
2
4
6
8
10
12
14
ROOT ZONES
FRUIT AND VEGETABLE
COMPARED
•APPLE•
•CARROT•
•HORSE
RADISH•
•LIMA
BEAN•
•SOUR CHERRY•

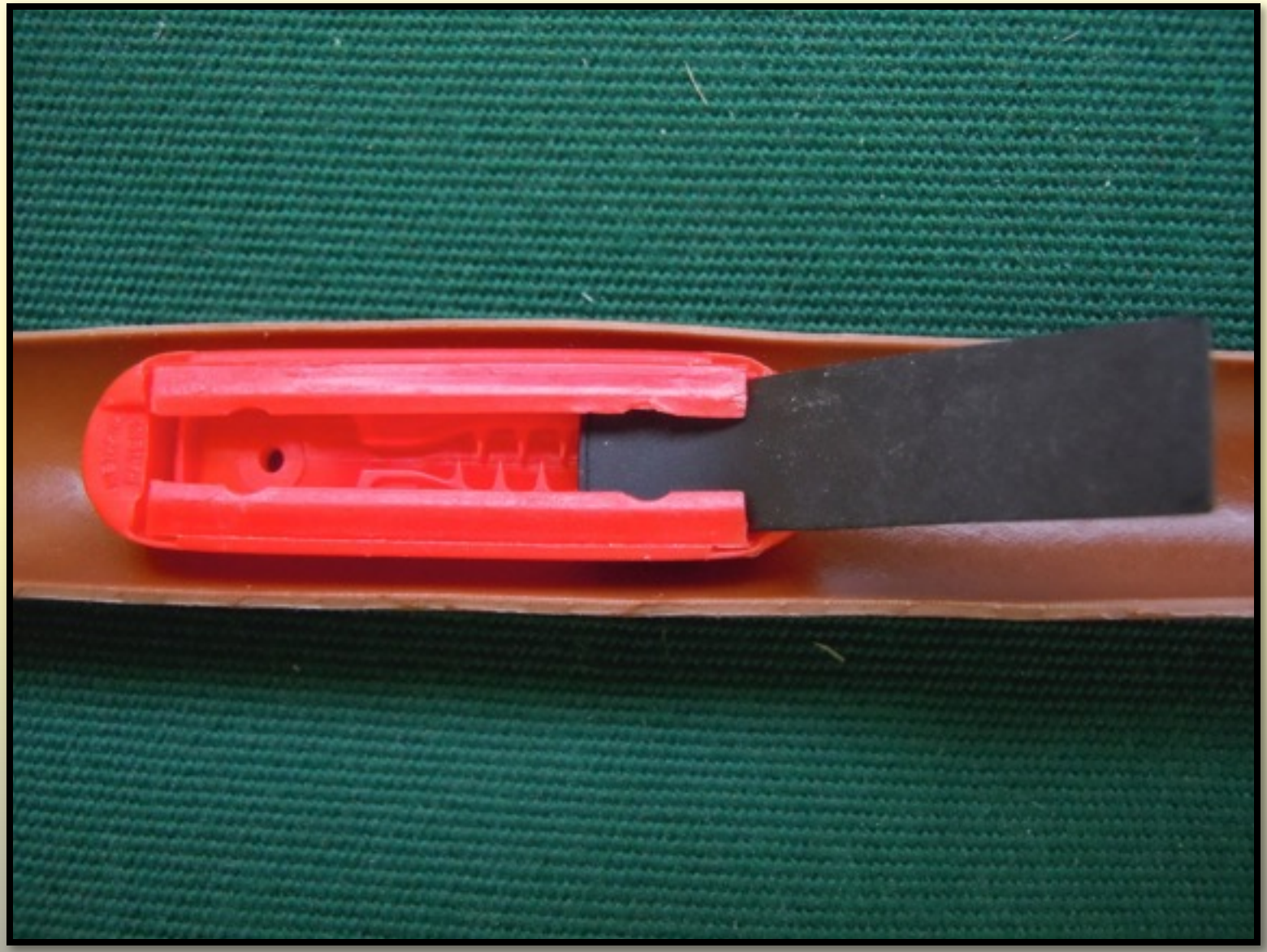
Drip irrigation for healthier root zones.







Plant *Between* the Wet Spots



Surface cultivation uses Scrapper (also called onion hoe) to skim the roots 1-3” below the soil.

Surface cultivation protects upper roots where most water and nutrient exchange happens.

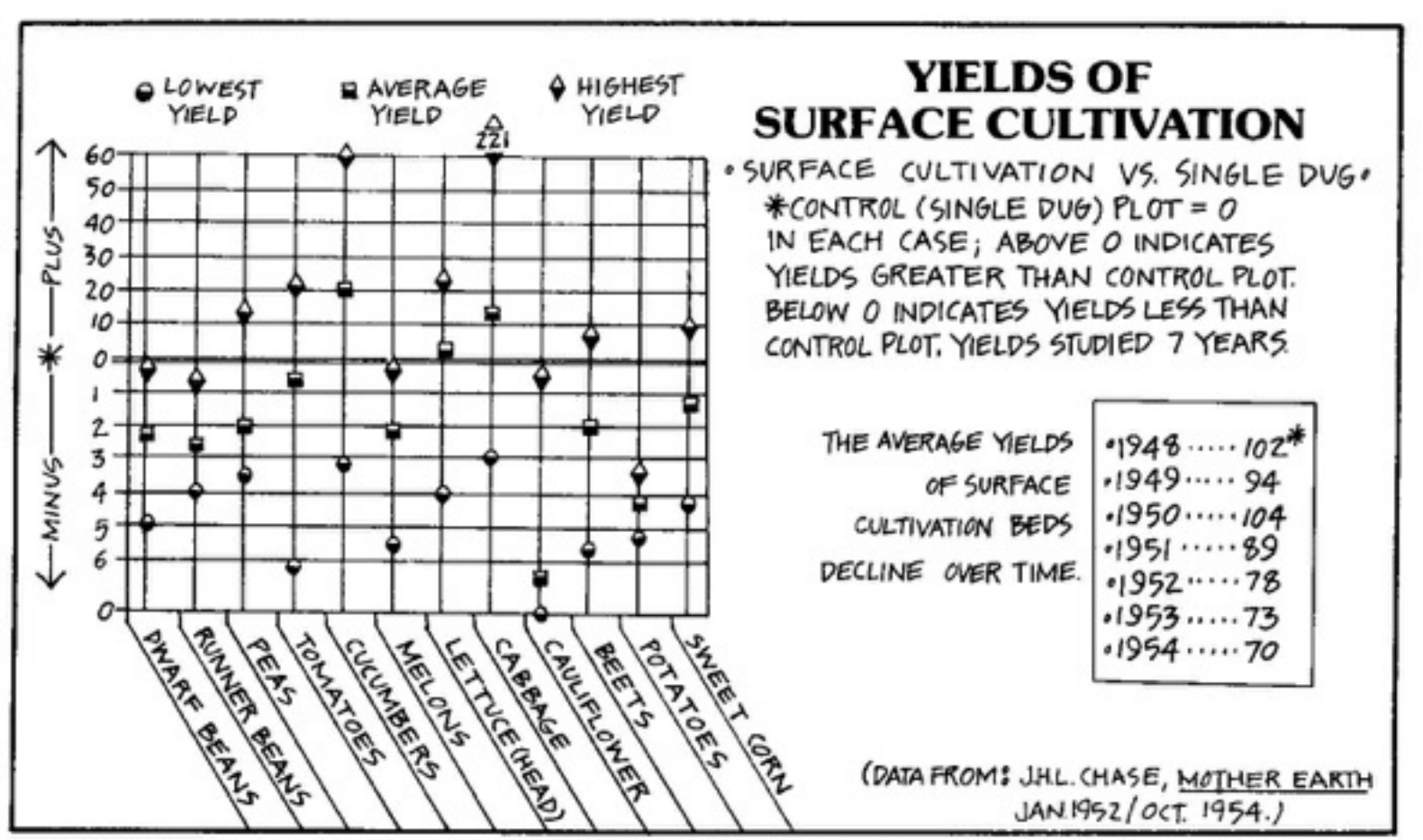
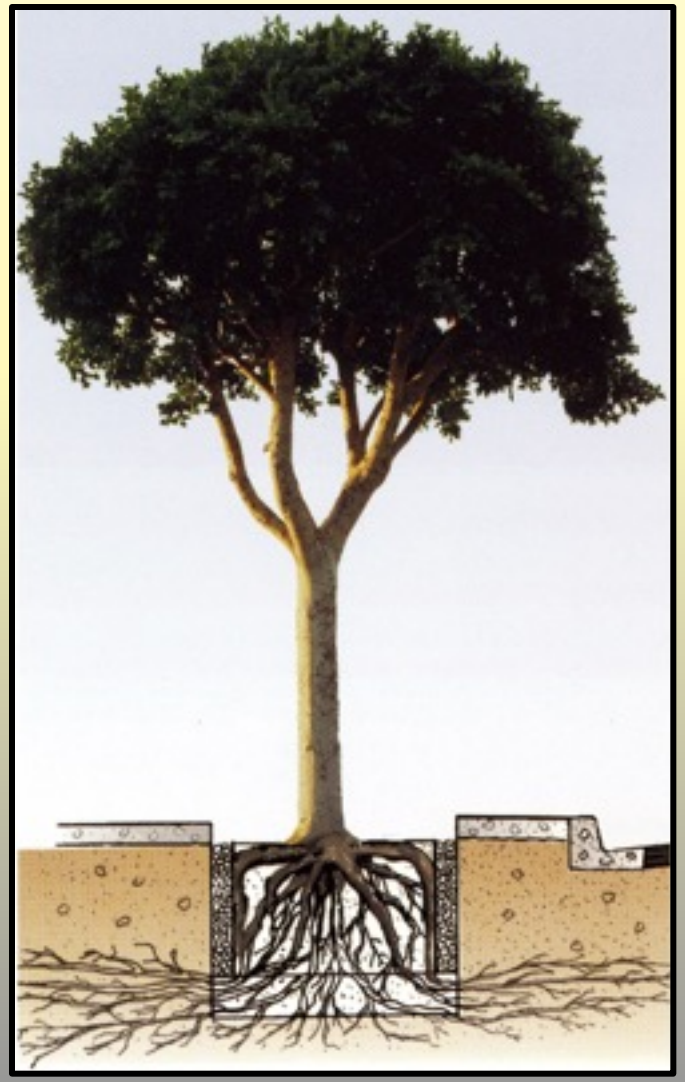


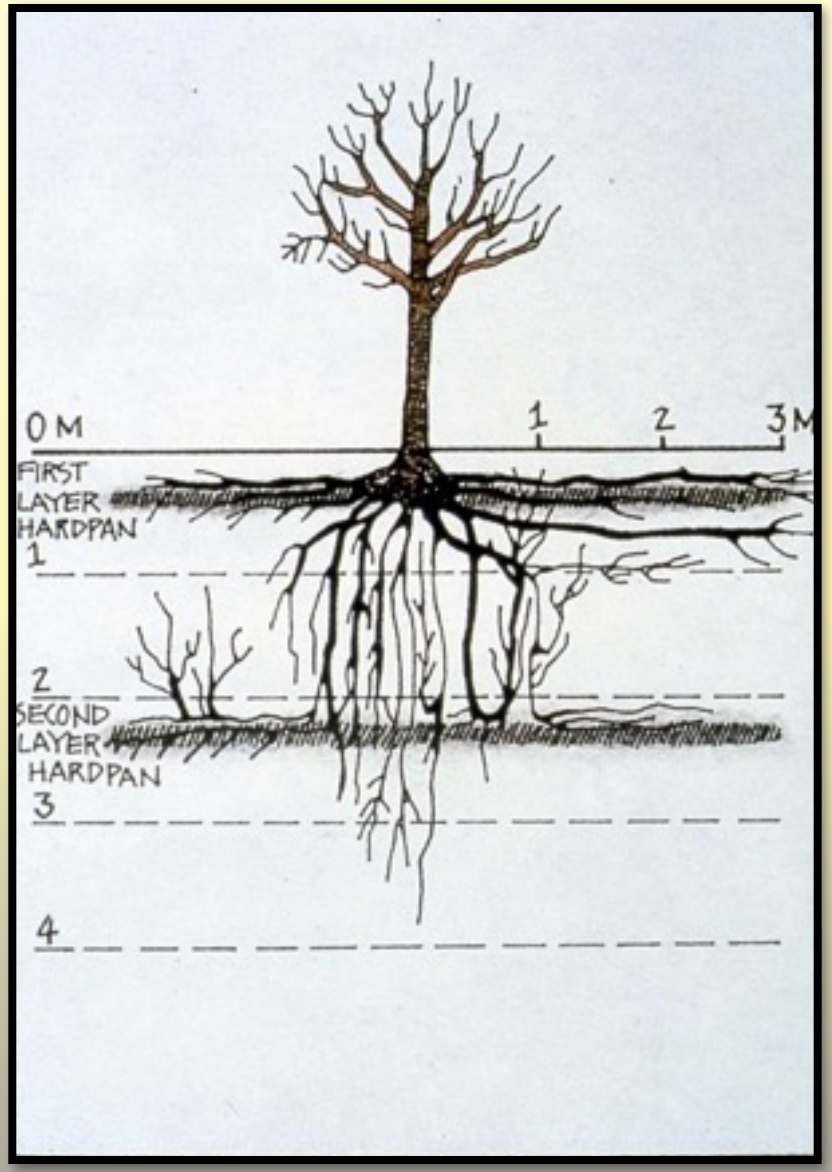
Figure 7.13 The average yields of a surface-cultivated garden were very close to the yields of a single-dug garden, in this study from England. Some surface-cultivated vegetables out-produced the single-dug vegetables.

Ruth Stout - the great champion of no-till gardening

- Deep mulch
- No cultivation

Ideal concept of root barriers.




0 M
1
2
3 M
FIRST
LAYER
HARDPAN
1
2
SECOND
LAYER
HARDPAN
3
4

Realities of root barriers.

Roots are ambitious enough to grow right over the root barrier in pursuit of aerobic surface soil.

Promote good drainage and “breathing.”

Permeable Landscapes

- Air
- Water absorption
- Less compaction
- Healthier roots
- Lower runoff

Room to move.

Give the poor roots space to grow!

Chico, CA best list for spacing of trees.

- CA Sycamore 'Yardwood‘ 70´h X 50´w. Optimal spacing 35´-40´
- The minimum planter width at least 7 feet.
- Best along riparian habitats or where roots can spread at least in one direction.

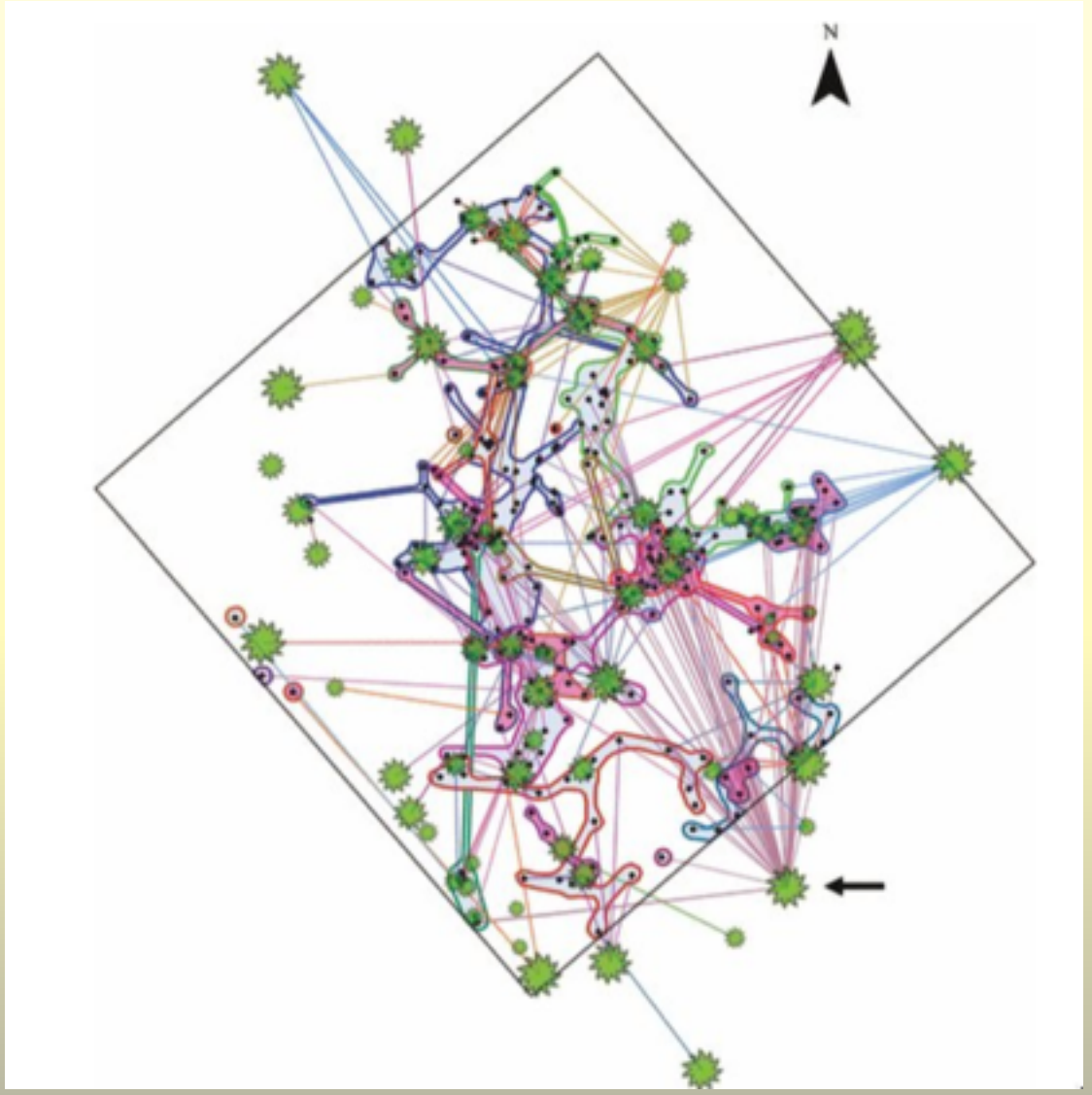
Troubles with wire gopher baskets.

- Tube-grown trees are air-pruned by the “egress” at the bottom of each tube.
- Causes more laterals for less transplant shock and faster growth.
- The top-to-root ratio about equal to six- and seven-inch tube seedlings.
- The smaller the top foliage, the better.

Very windy location!

- “Nurse” shrubs shelter young coastal cypress
- After four years, 12” trees are 10+ feet and require no staking
- The more a tree is buffeted by the wind, the bigger its trunk and the healthier its roots

The tree with the black arrow next to it was by far the most well-connected tree; it was linked to 47 other trees through eight individuals of one *Rhizopogon* species and three individuals of another. Suzanne Simard



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