Plant Growth and Rhizosphere

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"Root" is a contact point between plant and soil

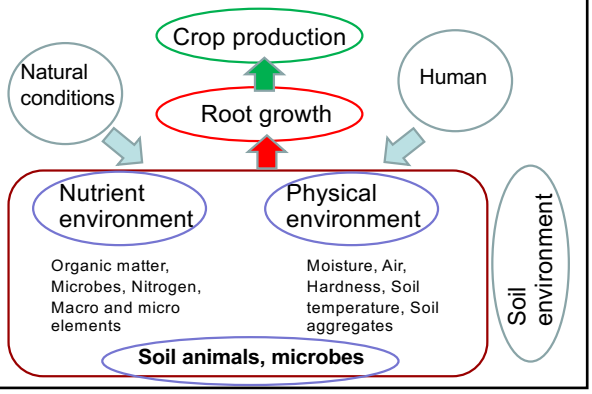
- What gives root to soil?
- What gives soil to plant through root?

- Root improves soil.
- Soil supports the growth of plant through the root.

"Ishiwari-zakura" in Morioka, Iwate.

Cherry root breaking the big stone.

Soil factors related to crop production



History of earth and soil formation

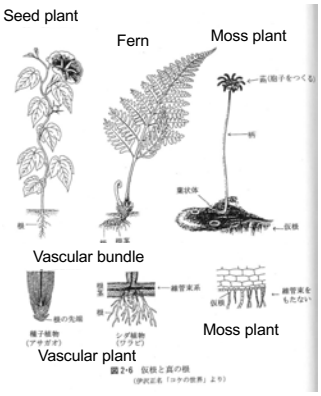
Years b. present	Important Events	Atmosphere	Soil
4.6×10^9	Birth of Earth		
4.0×10^9	Ocean of HCl	CO_2 97 %	
	Rock solubilization → Neutral Ocean		
	Precipitation of $CaCO_3$		
3.8×10^9	Evolution of aquatic anaerobic microbes.		
$3.5 - 2.7 \times 10^9$	Evolution of stromalite. Origin of photo-synthesis.		
2.0×10^9	Evolution of sea algae.	O_2 0.2 %	
0.6×10^9	Evolution of lichen and terrestrial organisms.	O_2 2 %	Start of root and
0.4×10^9	Evolution of early terrestrial plants.	O_2 21 %	Early soil formation
0.3×10^9	Evolution of fern and cycad.		Soil formation
200,000	Evolution of humankind		
10,000	Homo sapiens sapiens		
6,000	Start of agriculture		

Fossil of stromalite

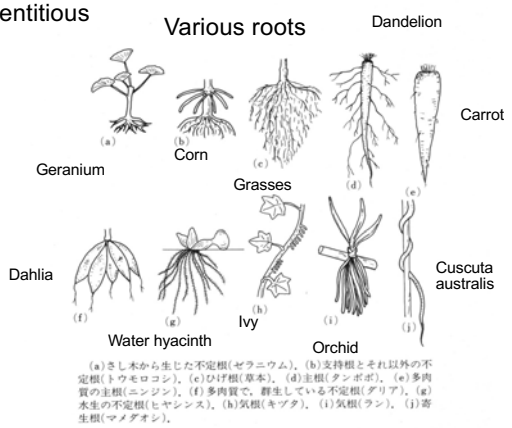
First photosynthetic bacteria, producing oxygen.

Bridged the change from the worlds of anaerobic to aerobic organisms.

Rhizoid and True root

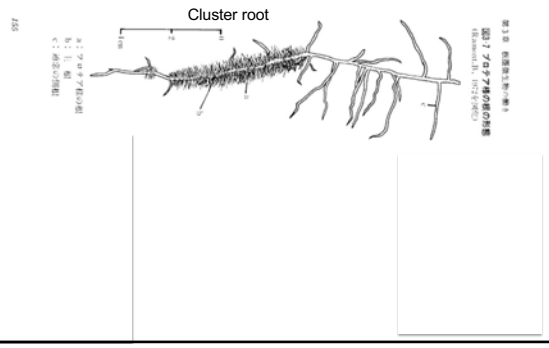


Adventitious root



(a)さし木から生じた不定根(ゼラニウム)。(b)支持根とそれ以外の不定根(トウモロコシ)。(c)ひげ根(草本)。(d)主根(タンポポ)。(e)多肉質の主根(ニンジン)。(f)多肉質で、群生している不定根(ダリア)。(g)水生の不定根(ヒヤシンス)。(h)気根(キヅタ)。(i)気根(ラン)。(j)寄生根(マメダオシ)。

Root of protea and lupin



Rows of *Taxodium distichum* (swamp cedar) in Saga University

Aerobic roots of swamp cedar

Aerobic roots of aquatic trees Sarawak river, Malaysia

Organic matter distribution

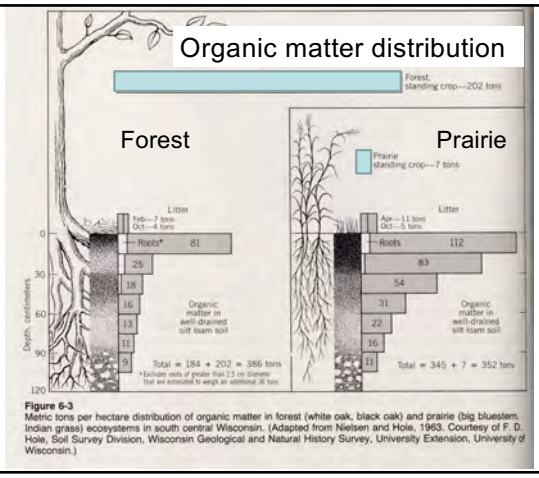


Figure 6-3
Metric tons per hectare distribution of organic matter in forest (white oak, black oak) and prairie (big bluestem, Indian grass) ecosystems in south central Wisconsin. (Adapted from Nielsen and Hole, 1963. Courtesy of F. D. Hole, Soil Survey Division, Wisconsin Geological and Natural History Survey, University Extension, University of Wisconsin.)

Annual dry matter production in root and above ground parts

	Plants	Root (t/ha)	Above (t/ha)	Total (t/ha)	Root/ Above
Grasses	barley	1.3-3.0	7.2-12	8.5-15	0.18-0.26
	wheat	1.4-2.5	4.5-9.2	6.5-11.7	0.21-0.44
	clover	1.8-4.5	5.0-6.7	7.5-11.2	0.28-0.67
	corn	4.4-4.5	8.3-9.0	12.8-13.5	0.50-0.54
	potato	3.9-4.0	2.4-2.8	6.4-6.7	1.39-1.67
	Sugar beet	6.6-13	1.2-5.0	7.8-18.0	2.6-5.5
Woods	pine	1.8-1.9	7.4-10.5	8.6-12.4	0.16-0.18
	oak	1.3-1.8	6.5-10.0	7.8-11.8	0.18-0.20
	Tropical f.	2.6-2.8	21.7-28.7	24.3-31.6	0.10-0.12
	German f.				0.15-0.33

Proportion of root to whole plant :

Grasses 13-84%
Woods 9-24%

Root residue remained in soil after harvest :

Some hundreds kg/10a,
Some t / ha

Root length

- **Total root length / unit area**
  - Grasses 50-90 km/m^2
  - Soy bean 25-40 km/m^2
  - Potato 20 km/m^2
- **Total root length / unit mass**
  - Grasses 300-400 km/m^3
  - Potato 100 km/m^3

Generally large in surface layer and decrease with depth. Large at 10 – 20 cm depth for corns and soy bean.

Factors influencing root development

- Crops with long growth period have longer roots.
  → winter wheat
  No difference between C3 and C4 plants.
- Water shortage, high or low temperature, nutrients deficiency enhance the root growth. Shortage of sunshine retards the root growth.

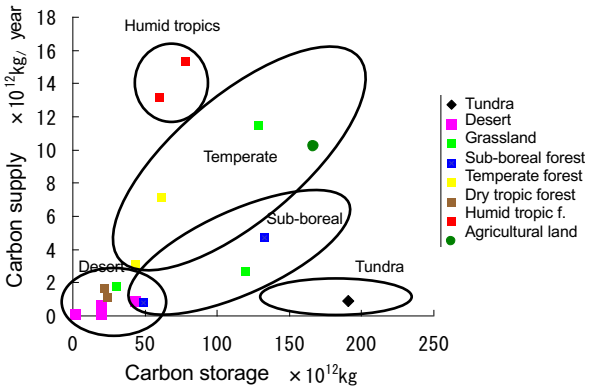
Maximum and frequent root depth of various crops.

Plants	Maximum (cm)	Frequent (cm)
Rice	60	55
Winter wheat	190	130
Spring wheat	145	90
Barley	135	80
Corn	240	180
Soy bean	60	40
Sugar beet	170	160
Sweet potato	100	80

Maximum and frequent root depth of various crops.

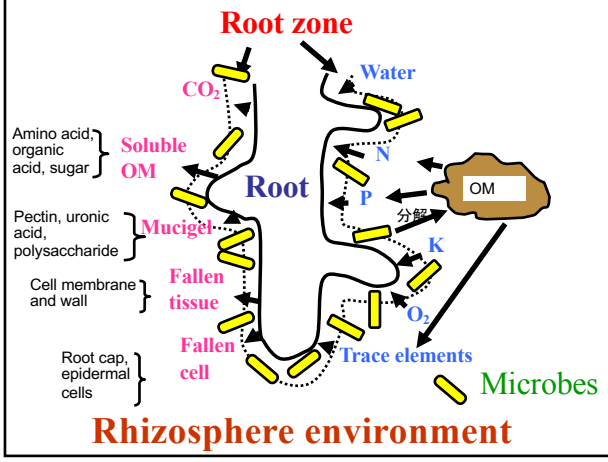
Plants	Maximum (cm)	Frequent (cm)
Tomato	150	90
Cabbage	145	80
Cucumber	110	30
Onion	100	80
Asparagus（6th year）	310	180
Sunflower	200	70
Alfalfa（2nd year）	300	160
Red clover	280	100

Supply and storage of carbon to soil



Turn over rate of soil carbon in 3 climate zones.

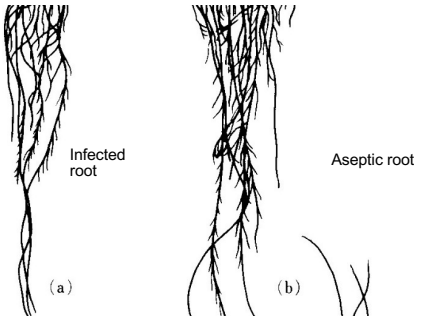
	England	West Canada	Brasil
Climate zone	Temperate	Cool temperate	Tropics
Soil types	Luvisol	Mollisol	Spodosol
Crop	Wheat	Wheat - fallow	Sugar cane
Soil weight (Mg/ha)	2200	2700	2400
Organic carbon (Mg/ha)	26	65	26
Annual carbon input (Mg/ha)	1.2	1.6	13
Turn over rate of C (years)	22	40	2



Microbial numbers ratio between rhizosphere and non rhisosphere

Plants	Rhizo／Non-rhizo
Wheat	7. 6
Oat	5. 2
Flax	6. 5
Timothy	10. 8
Alfalfa	10. 8
Red clover	10. 1

Change in the root system of corn after the infection by microbes



Functions of rhizosphere microbes

Decompose organic matter and hand nutrients to root.

Protect root from disease germs.

Symbiosis with mycorrhizal fungi enhance the absorption of hardly soluble phosphate and water far from root.

Symbiosis with rhizobium bacteria enables nitrogen fixation.

What root system does to soil : 1

Formation of soil aggregate.

Secretion of amino acid and sugar.

Old root hair and root cap cell are fell.

→ Stimulation of rhizosphere microbes

Increase soil organic matter.

What root system does to soil : 2

Solubilize hardly soluble nutrients such as phosphates in Ca, Fe and Al salt form.

Mugineic acid for wheat.

Piscidic acid for pegion pea.

Oxalic acid, citric acid, malic acid are very common in various plants.

Secretion of organic acids from root

Lupin	Citric acid	Ca phosphate
Alfalfa	Citric acid	Ca phosphate
Rapeseed	Malic acid and citric acid	Ca phosphate
Pigeon pea	Piscidic, malonic, oxalic acids	Fe phosphate
Chick pea	Citric acid and succinic acid	Ca phosphate Fe phosphate
Buckwheat Brassica napus	Hydrogen ion	Ca phosphate

Chickpea

The bean adapted to Vertisol in India.

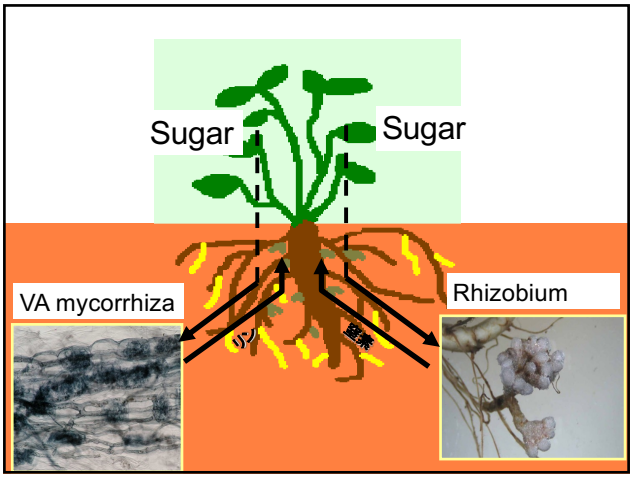
Grow well on high pH, high Ca, and dry soil. Secretes citric acid.

Pigeonpea

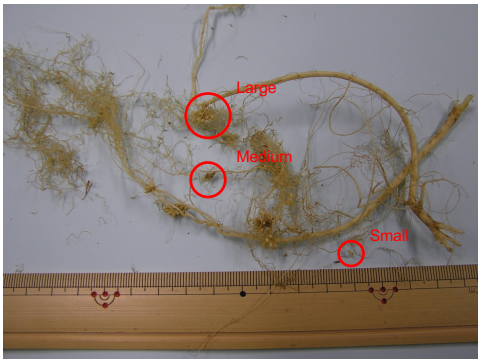
The bean adapted to red soil (Alfisol) in southern India.

Absorbs iron phosphate.

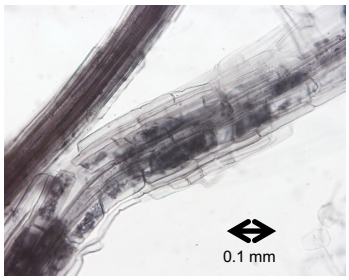
Secretes piscidic acid.



Root nodules of alfalfa



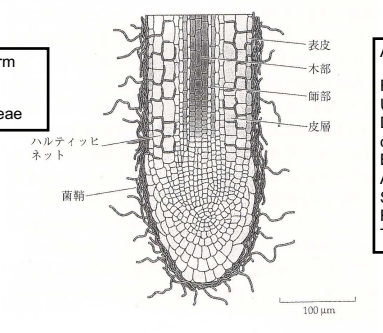
Mycorrhiza in the root of timothy



Ectomycorrhiza

Gymnosperm

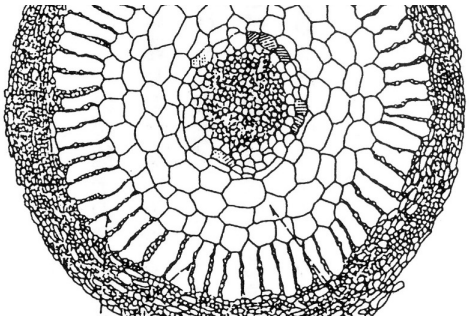
Pinaceae,
Cupressaceae



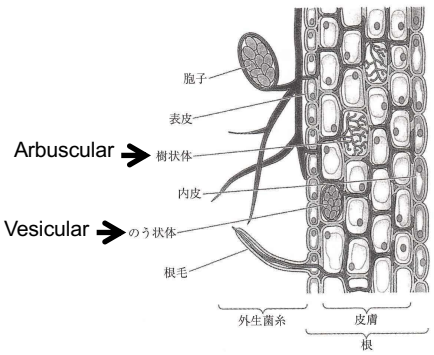
Angiosperm

Fagaceae,
Ulmaceae,
Dipterocarpaceae,
Betulaceae,
Aceraceae,
Salicaceae,
Rosaceae,
Tiliaceae, etc.

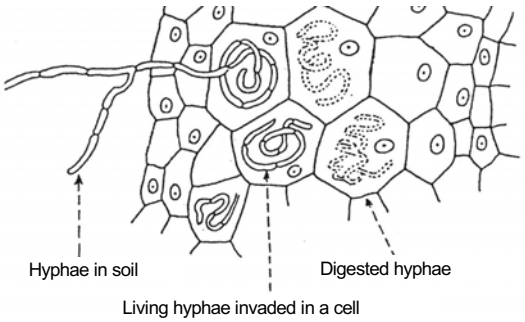
Beech root coated by exo-arbuscular fungi



VA mycorrhiza



endo-type arbuscular fungi in orchid

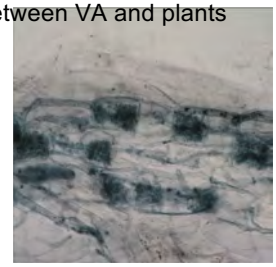


What is VA mycorrhiza?

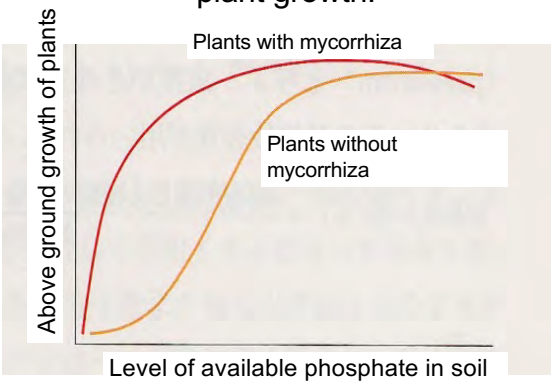
- Symbiotic microbes with plant root.
- Symbiotic relationships between VA and plants

Absorption of phosphate and water in plants is promoted by VA.

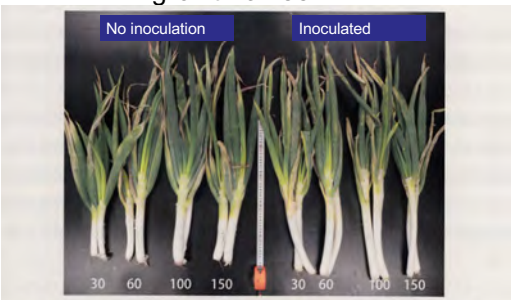
VA accepts photosynthetic products from plant.



Effect of mycorrhizal formation on the plant growth.



Effect of mycorrhizal inoculation on the growth of leek.

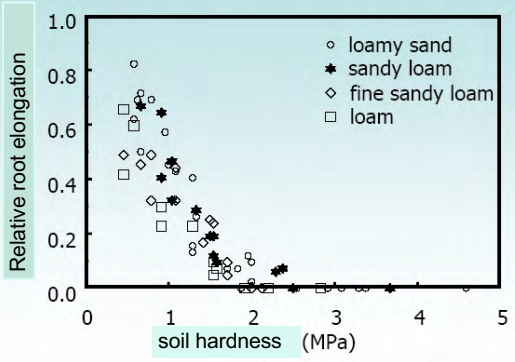


Effect of mycorrhizal inoculation on the growth of leek.

Available phosphate (mg/100g) in horizontal axis.

Relationship between soil hardness and root elongation

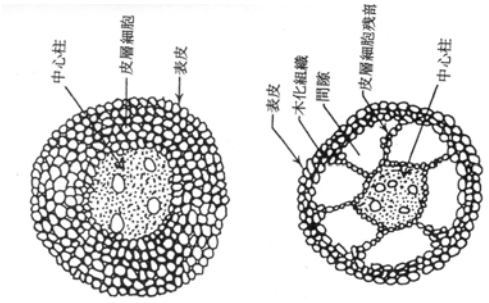
(Taylor, H. M. et al., 1966)



Physical properties of soil influencing the root growth

- Penetration resistance value
  Inverse proportion
- Moisture content
  Inverse proportion
- Air space volume
  Direct proportion
- Bulk density
  Optimum range around 1.0

Comparison of root sections between barley and rice



Barley Rice

Non rhizosphere soils in upland and paddy fields

	Redox state	Major microbes	States of various substances
Upland	Oxidative	Aerobic microbes	NO_3^-, Fe^{3+}, MnO_2, SO_4^{2-}
Paddy	Reductive	Anaerobic microbes	NH_4^+, Fe^{2+}, Mn^{2+}, S^{2-}

Rhizosphere soils in upland and paddy fields

	Nitrogen absorption	pH	Redox state
Upland	Nitrate (absorbtion) CO_2 (secretion)	Increase compared with non rhizosphere	Decrease compared with non rhizosphere
Paddy	NH_4^+ (absorbtion) H^+ (secretion)	Decrease compared with non rhizosphere	Increase compared with non rhizosphere

What is good soil for the root growth?

- Root can develop deep, wide, and healthy, and can supply enough amounts of nutrient and water to above ground part.
- For this purpose ・・・・・・

What is good soil for the root growth?

① Good soil aeration, drainage, and water retention, and soft.

← Aggregate structure formation
← Application of organic matter

What is good soil for the root growth?

② Have a good balance in nutrients.
Have a proper pH value.

← Soil diagnosis is carried out.
← Improvement of soil acidity
(Application of lime)

What is good soil for the root growth?

③ Contains organic matter,
food for soil microbes and organisms.
Soil organisms are abundant.

← Application of compost
and green manure.