



RHIZOTERRA
Healthy Soil for a Healthy World

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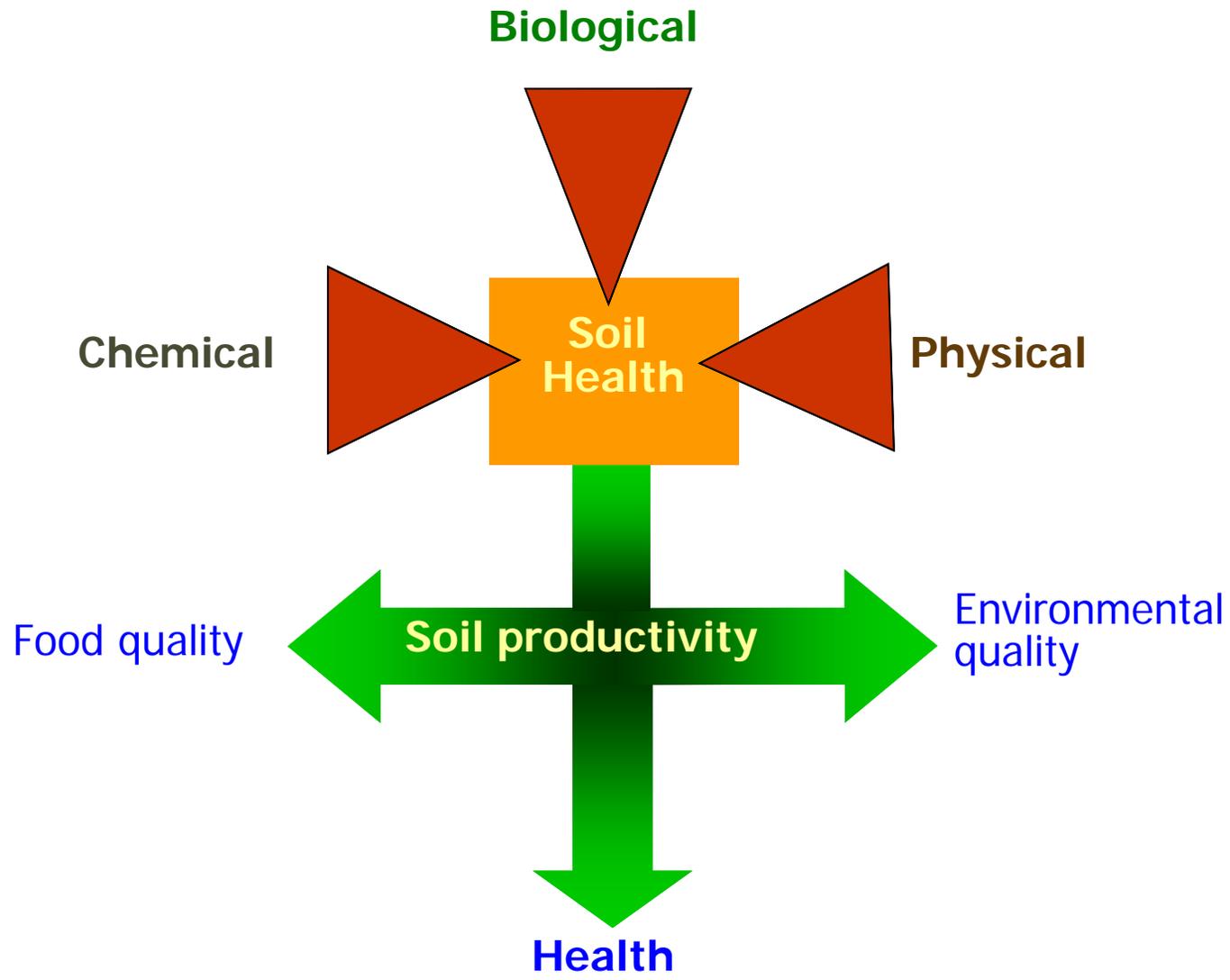
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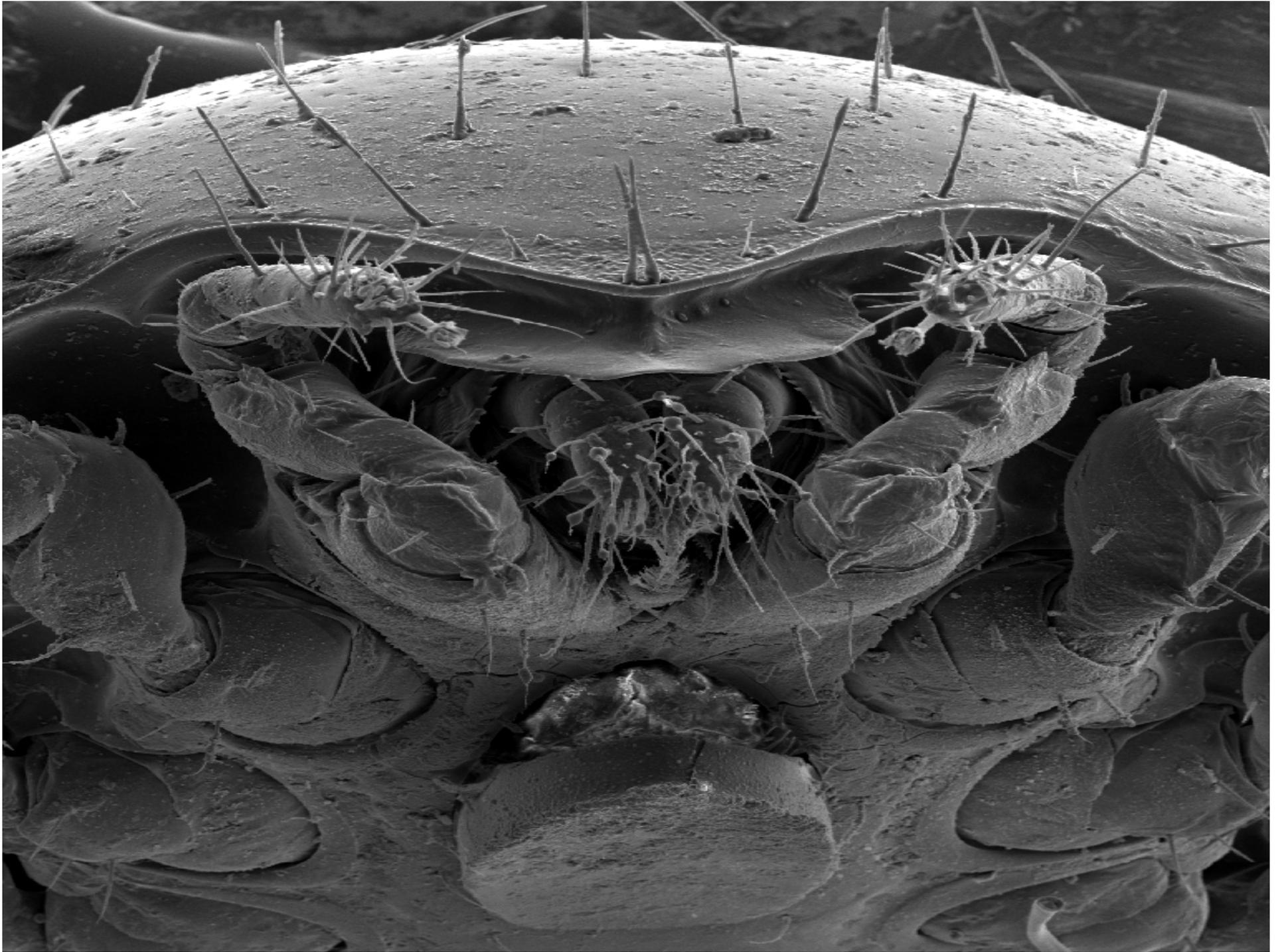
Gaia Theory

In 1979- James Lovelock PhD published the book: A New Look at Life on Earth.

He proposed an idea that he hoped would facilitate the task of converting destructive human activities into constructive and cooperative human behaviour.

The idea that both the living (biotic) and non-living (abiotic) parts of the Earth are interconnected in intricate ways, so all ecosystems can function together harmoniously.





If you build it.....



And build it the best you can.....





Photo by V. Behan-Pelletier AAFC



Tardigrade



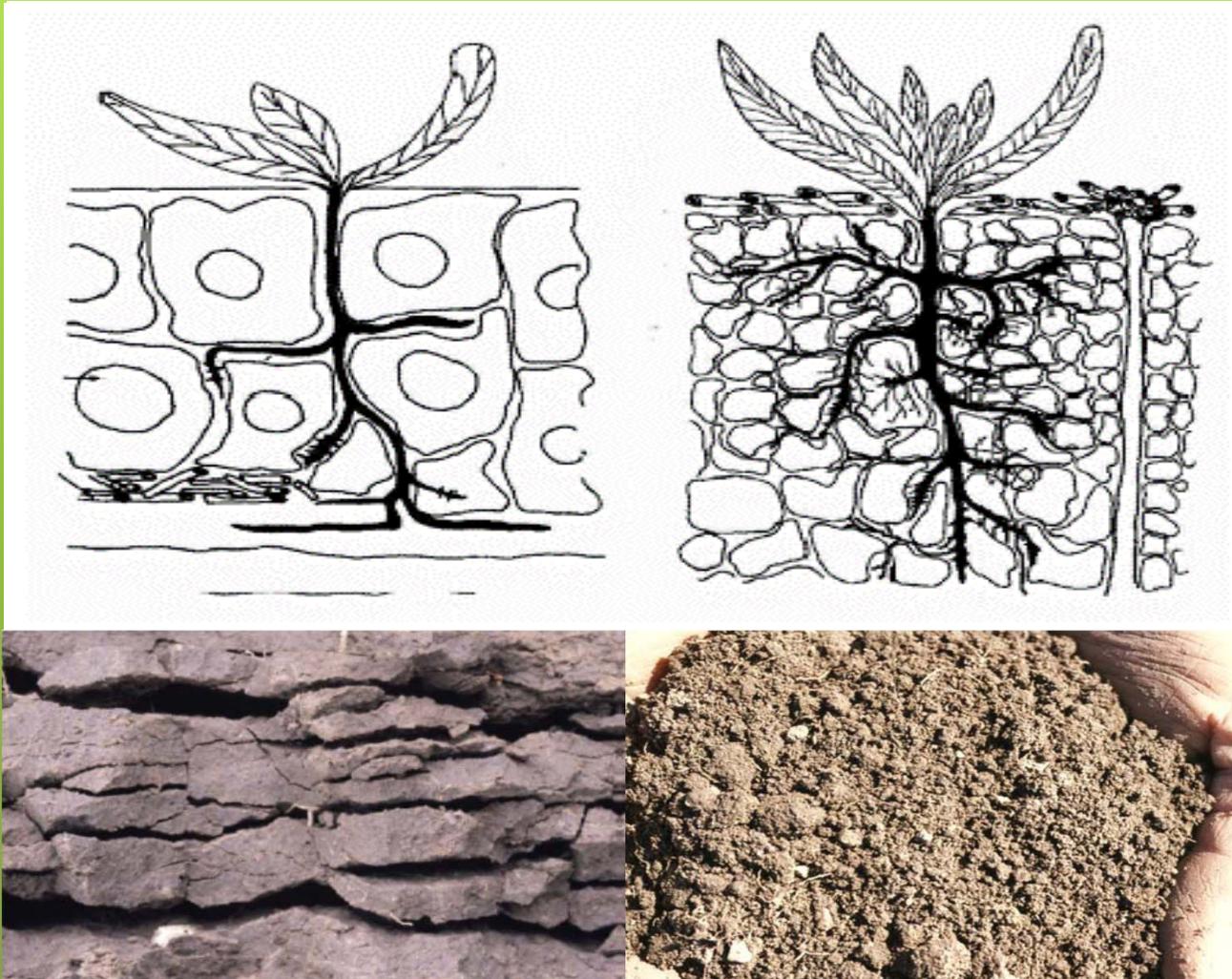
.....but it will take time and good management



Building Soil Structure= building the habitat

- No Tillage and/or pasture and forages allow the soil biota to build soil infrastructure- homes linked by a huge soil pore network.
- Diverse crop rotation- feeds the diversity belowground maintaining soil ecosystem functions and services. That means we have improved infrastructure, info exchange and a carbon trading network (mycorrhizae).
- More quality SOM combined with improved infrastructure means more water holding and exchange capacity, and improved water use efficiency – Better and more efficient soil ecosystem services

Soil structure determines root depth and architecture and predator/prey relationships. In turn, roots modify the soil structure improving predator/prey relationships and nutrient availability to the plants. Roots can also create nutrient depleted zones very quickly in poorly structured soil.



From: Bayerische Landesanstalt für Landwirtschaft (LfL)



Predators are responsible for up to 45% of the N mineralisation in well structured soil. Amoebae can engulf bacteria, fungal spores and protozoa in the tiniest soil pore. These effective predators concentrate N in the rhizosphere.

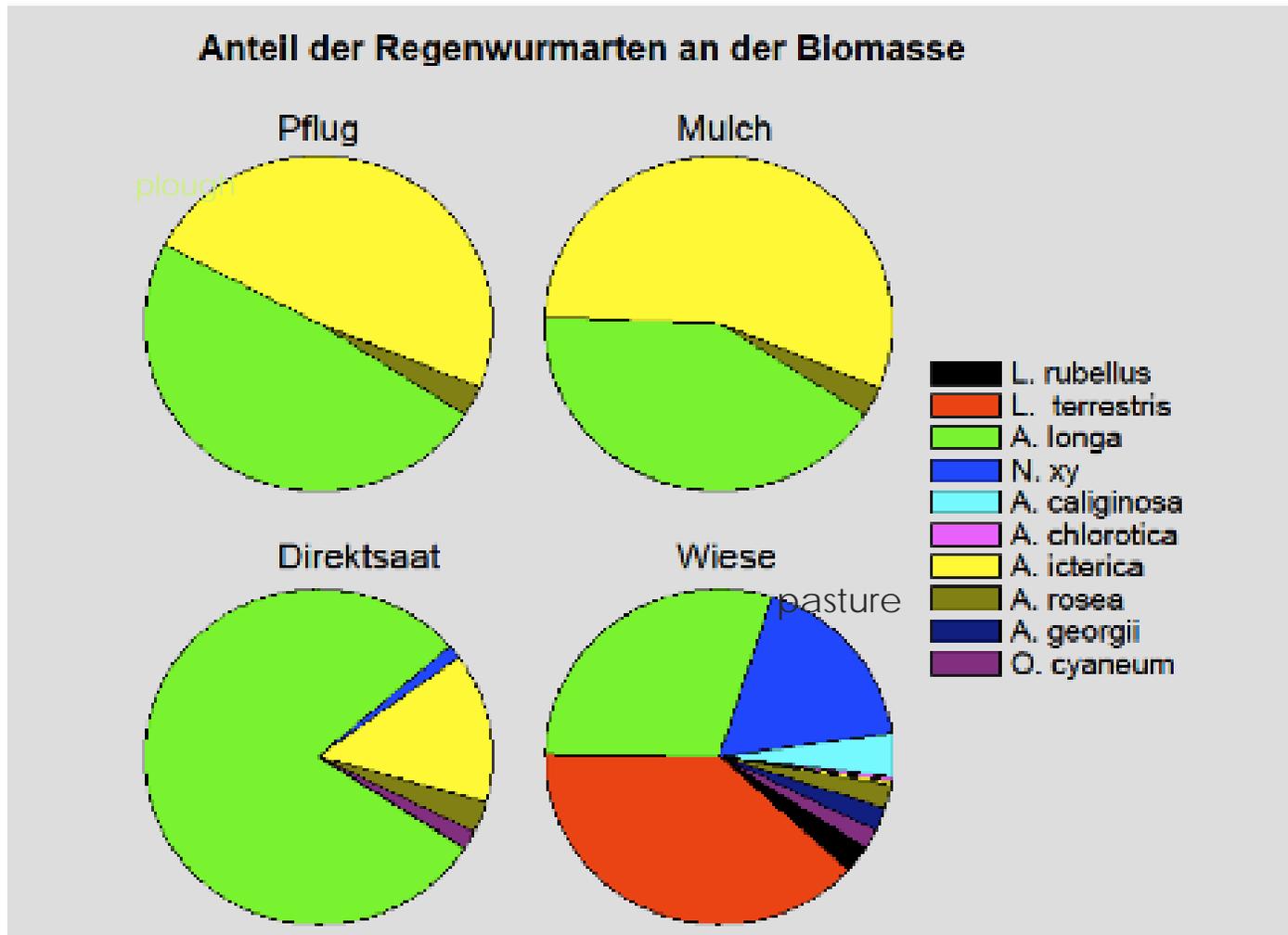


Old root channels and earthworms



- Accessing nutrients in the subsoil is easier with better soil structure
- Between 20 and 40% of roots in field grown crops access subsoil on the earthworm and old root channel freeways.
- Deep roots capture leached nutrients- as much as 30% of their N for growth

Earthworms prefer a stable habitat with a diverse food supply



Quelle: Dr. Ehrmann

Winkler, LRA Lörrach, Fachbereich Landwirtschaft



Creating a Root Canopy

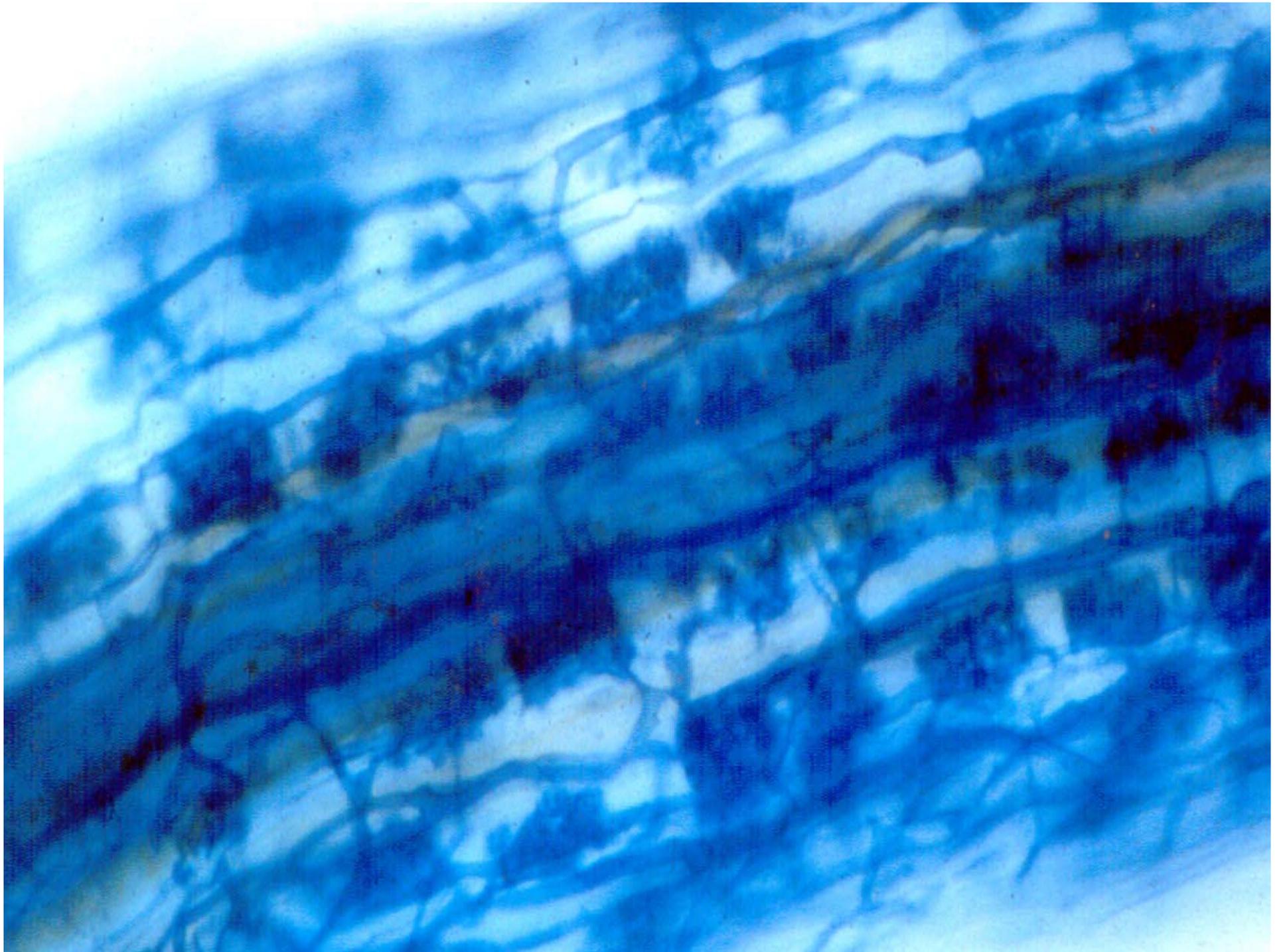




Aboveground diversity is a mirror for belowground diversity

Intermingling of roots





Sunflower rooting depth reached 1.88 m (6.2 ft) at the beginning of disk flowering and 2.02 m (6.6 ft) m at the completion of disk flowering (Jaffar et al., 1993). Use sunflowers in the mix to tap the subsoil, and they will feed and water the neighbors.

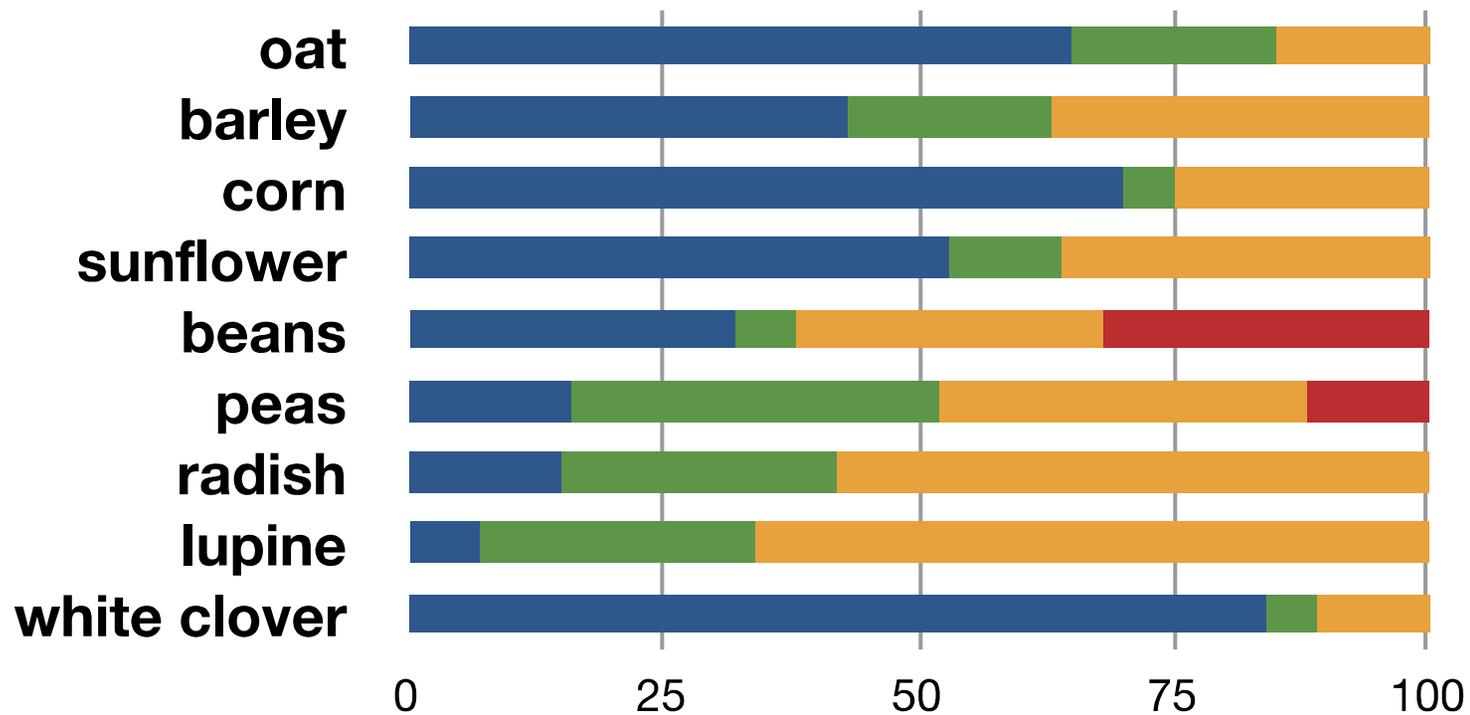


- Human-driven ecosystem simplification has highlighted questions about how the number of species in an ecosystem influences its function (Tilman et al. 2006), this includes crop and forage systems.
- The diversity in root systems alone will stabilize an ecosystem and insure that there is always something for the soil biota to feed on.

Soil Food Webs

- Soil food webs are mainly based on three primary carbon (C) sources: root exudates, litter or residues, and soil organic matter (SOM). These C sources vary in their availability and accessibility to soil organisms, and can thus, increase the C flow and biodiversity within the food web.

The percentage of N in the roots as nitrate (blue), amino acids (green), amides (yellow) and ureides (red). These compounds leak from the roots as exudates and are part of the plant's signature to create a unique rhizosphere.



Soil Food Webs

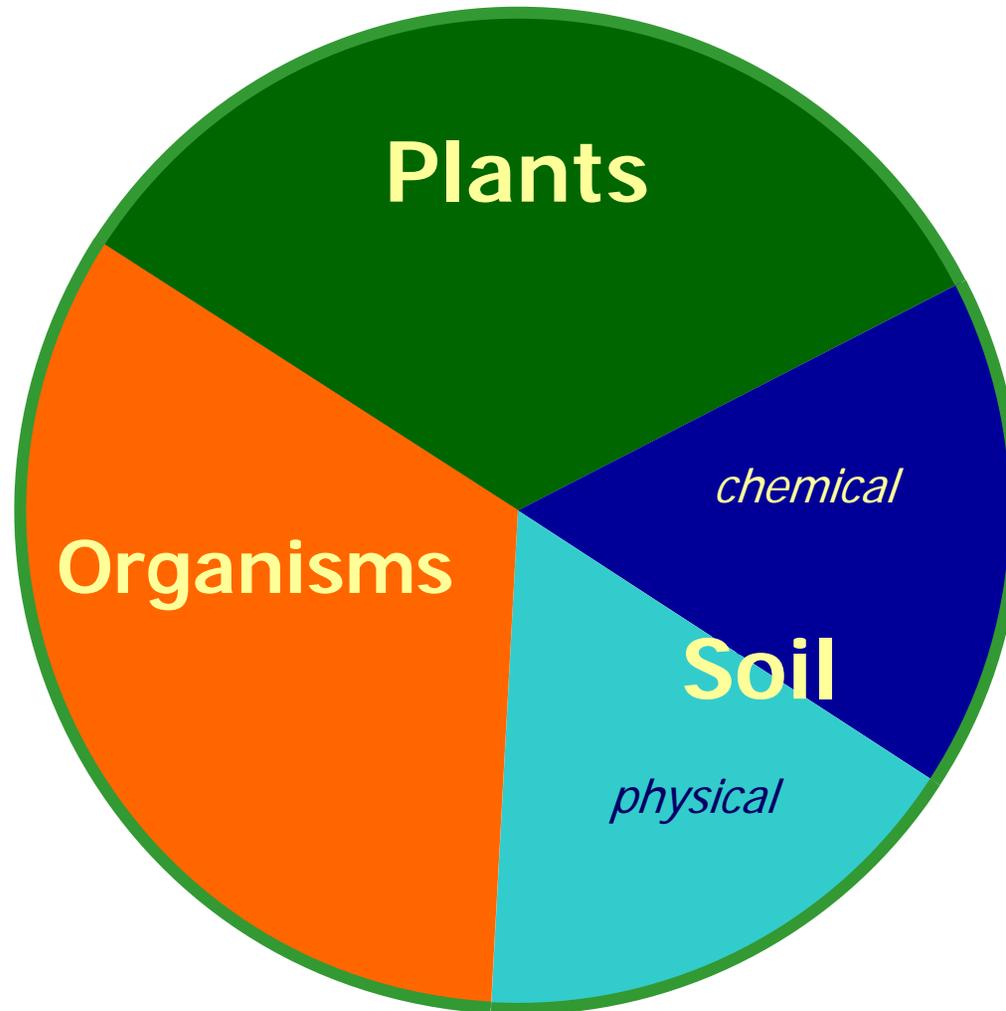
- Soil Carbon from roots is retained and forms more stable soil aggregates than shoot derived C (Gale et al. 2000)
- Roots normally account for only 10-20% of the total plant weight
- Contribute 12% of soil organic C, 31% soluble organic C, and 52% of the microbial biomass C (Liang et al. 2002)



Soil Food Webs

- The amount of carbon from corn roots and corn root exudates can be as much as 1.5-3.5 times higher than the organic C contribution from corn stover (Allmaras et al. 2004; Wilts et al. 2004)

Rhizosphere

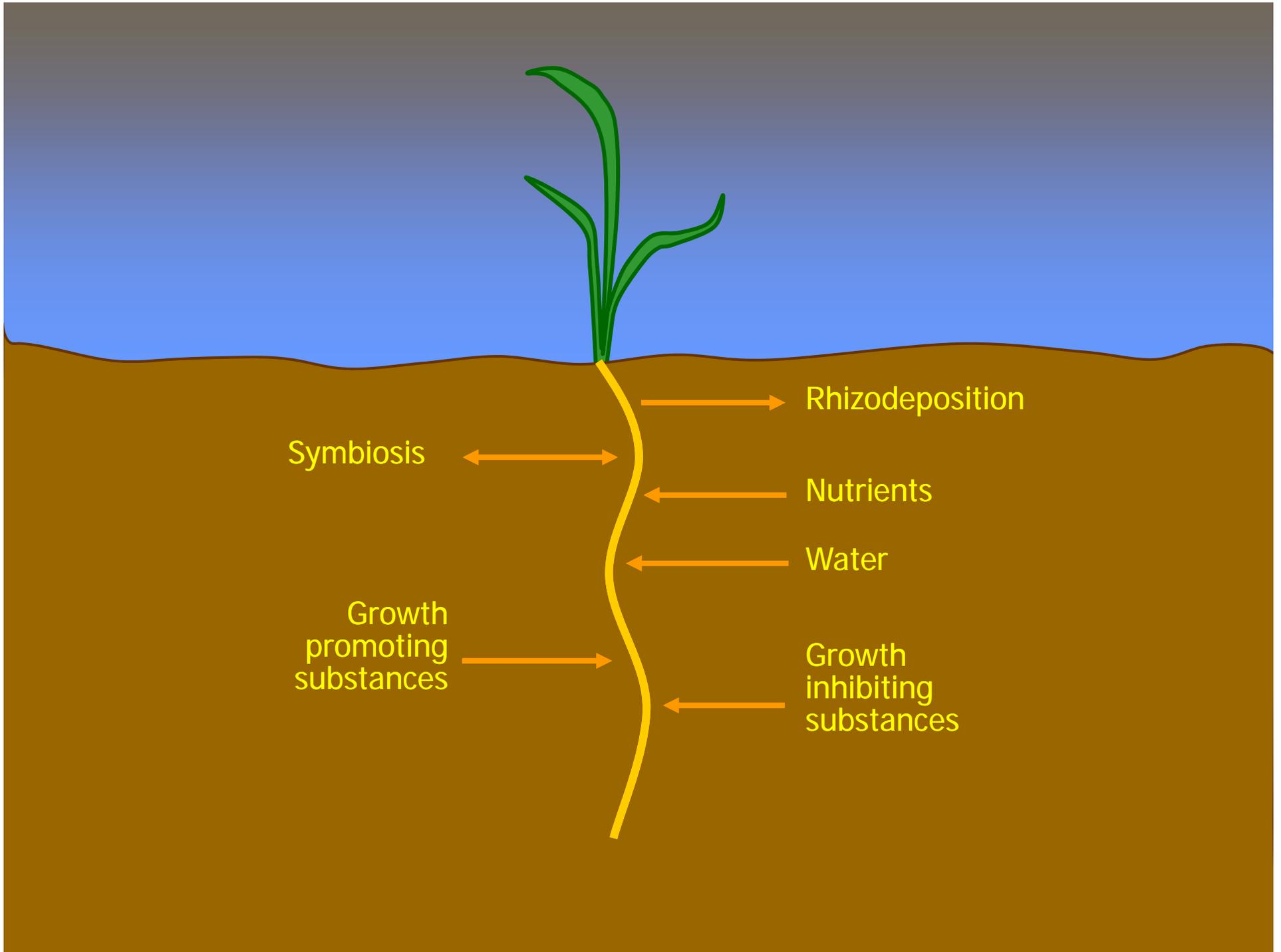


Plants Soil and Soil Organisms

Each plant species or crop species modifies the soil and soil organisms in ways that can benefit, inhibit or have no affect on the establishment and growth of the subsequent crop.

We can use these processes to manage crops, weeds, diseases to increase soil and plant health and productivity, and animal and human wellness.

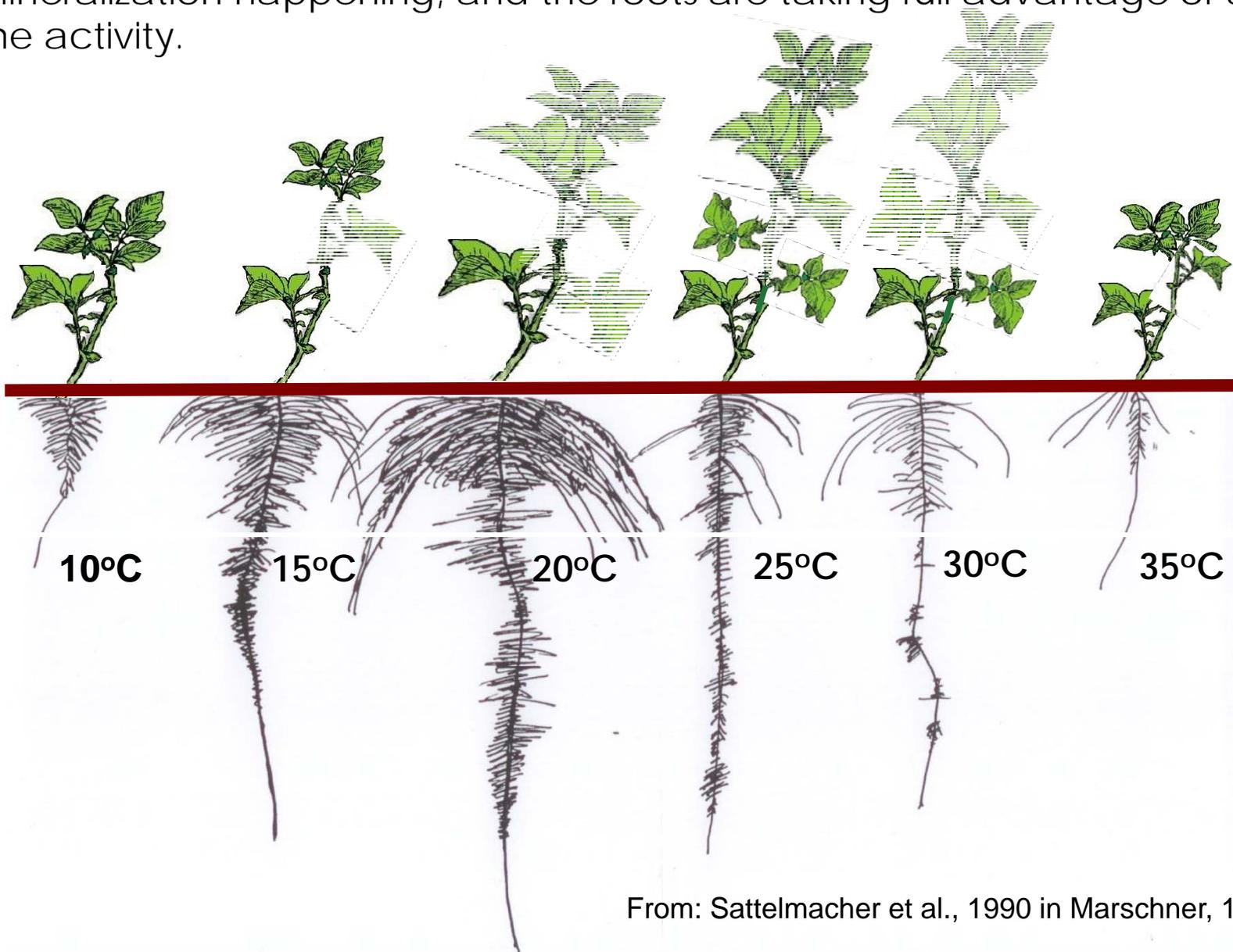
The Rhizosphere Effect.....



Getting to the roots of soil health

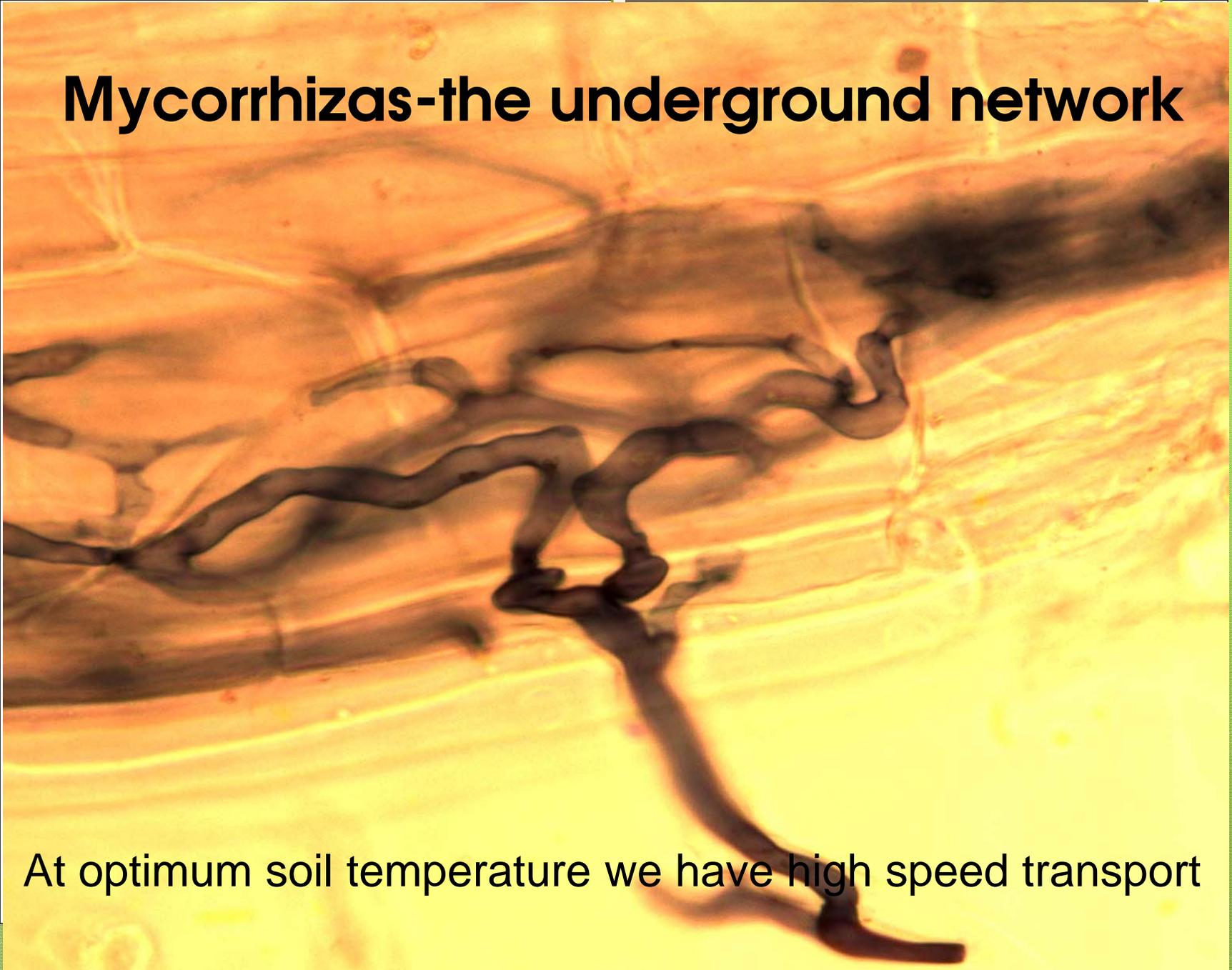


At a soil temperature of 20°C or 68°F most organisms have fully functional populations and may be actively reproducing, which means there is a lot of mineralization happening, and the roots are taking full advantage of all the activity.



From: Sattelmacher et al., 1990 in Marschner, 1995

Mycorrhizas-the underground network



At optimum soil temperature we have high speed transport

- Increasing the amount of carbon exuded from the roots drove the microbes to release more extracellular enzymes to breakdown the organic N accelerating the turn over of organic N (Phillips et al. 2011, Ecol. Lett. 14:187-194).

Plants and nutrient uptake

- Plants species differ in abilities to acquire nutrients, each may have a different strategy
 - Exudation of P mobilizing carboxylates
 - Fe- and other micronutrient (Zn)- chelating phytosiderphores (may depend on pH).
 - Mycorrhizas or other symbionts
 - A combination of all of the above

- So why is biodiversity important?

Rhizosphere interactions and processes

Beneficial

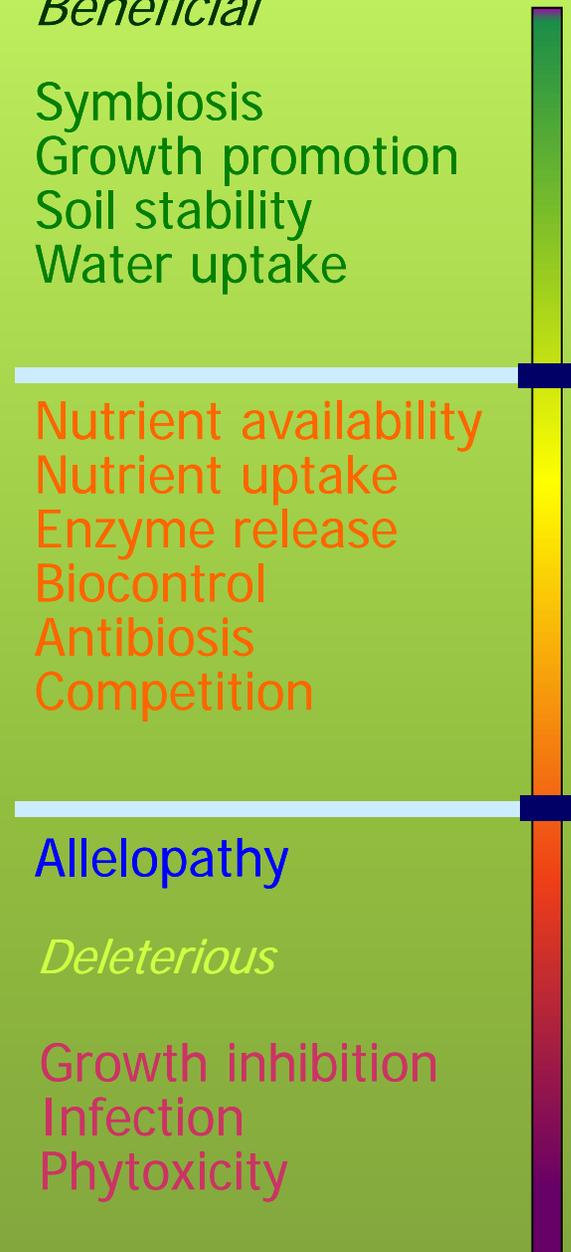
Symbiosis
Growth promotion
Soil stability
Water uptake

Nutrient availability
Nutrient uptake
Enzyme release
Biocontrol
Antibiosis
Competition

Allelopathy

Deleterious

Growth inhibition
Infection
Phytoxicity



Beneficial rhizosphere interactions

- Maiz or corn when attacked by insect larvae will release 2 chemicals (sesquiterpene and beta- carboxyphyllene) to attract insect pathogenic nematodes. These chemicals help the nematode locate a host and at the same time helps the plant get rid of a pest. There are a number of plant species that do this.
- Lupins have cluster roots instead of mycorrhizas. The cluster roots release a burst organic acids (carboxylates) when the P concentration gets too low. The burst is strong enough to so that the plant gets the P before the microbes.

Weeds vs Natives

- Cheat grass or Downy Brome (*Bromus tectorum*), Japanese Brome (*Bromus japonicus*), and dandelion (*Taraxacum officinale*) all produce root exudates that inhibit bacterial nitrification (stop the conversion of NH_4 to NO_3).
- Native grasses such as *Stipa comata* (Needle and thread grass) have exudates that promote nitrification.
- John Neal, Can J Bot. 1976



Mix 6 Faba Bean, pea, oats



Mix 5 Lentil and Phacelia

Another soil ecosystem service

- In a model grassland system it was recently shown that increasing plant diversity enhances CO₂ assimilation by surrounding plants. This in turn increased the amount of C allocated to the roots and mycorrhizal fungi, which is a key mechanism driving carbon sequestration in soil.
- These effects, however, were due to the presence of legumes in high-diversity mixtures, rather than to diversity per se (Gerlinde De Deyn et al. 2009, *Journal of Ecology* 97: 864-75).

What about food quality?

Agriculture has not held nutrient output as an explicit goal of its production systems.

The mean nutrient content of wheat grain (mg/kg) from organic and low-input rotations, analysed by ICP, n = 4, \pm s.e., p<0.05.

Rotation	P	Ca	Zn	Cu	Mg	K
1 Organic	267 \pm 24	2730 \pm 240	43.2 \pm 4	3.9 \pm 1.0	1080 \pm 60	2040 \pm 90
2 Low input	198 \pm 17	2400 \pm 270	29.7 \pm 3	1.89 \pm 0.48	990 \pm 60	1830 \pm 90
3 Organic	246 \pm 20	2520 \pm 180	38.1 \pm 1	2.91 \pm 0.69	1110 \pm 30	1920 \pm 90
4 Low input	237 \pm 20	2520 \pm 120	37.2 \pm 2	2.67 \pm 0.36	1110 \pm 14	1980 \pm 90
5 Organic	270 \pm 17	3330 \pm 180	44.7 \pm 2	2.73 \pm 0.60	1020 \pm 30	2310 \pm 60
6 Low input	264 \pm 20	3540 \pm 270	42.9 \pm 4	2.76 \pm 0.27	1020 \pm 30	2340 \pm 150
7 Wheat	249 \pm 16	3060 \pm 210	40.2 \pm 3	2.94 \pm 0.36	1020 \pm 30	2160 \pm 60

Talking about N and wheat

- The more N available to wheat.....
 - More protein in the grain
 - Fewer essential amino acids such as Lysine
 - Fewer carbohydrates that can be used in the conversion to Vitamin C
- Use of ammonia sulphate increases the Thiamine content

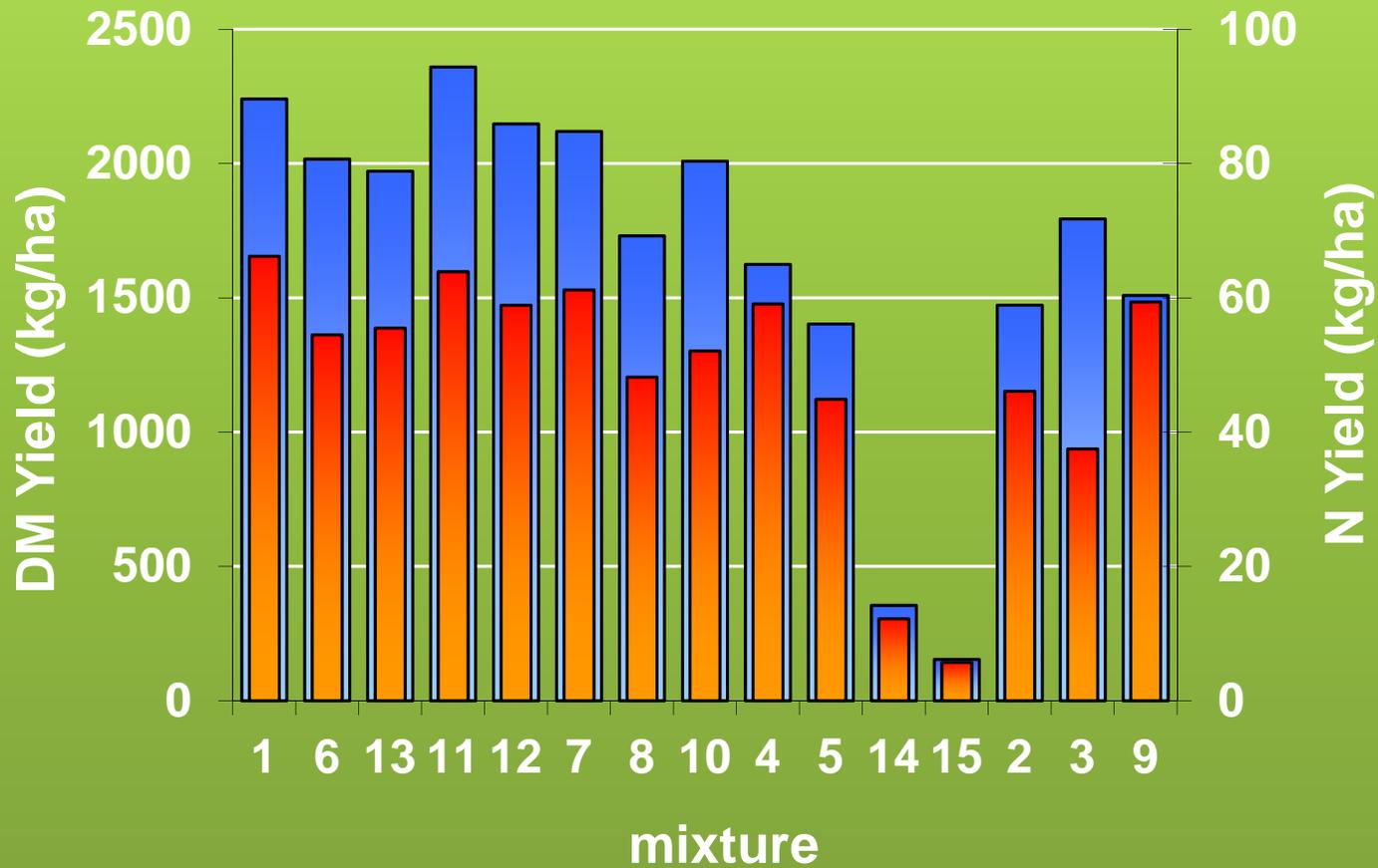
The economics

- On average 49 k N/ha (44 lbs N/acre) are mineralised with every 1 % organic matter.

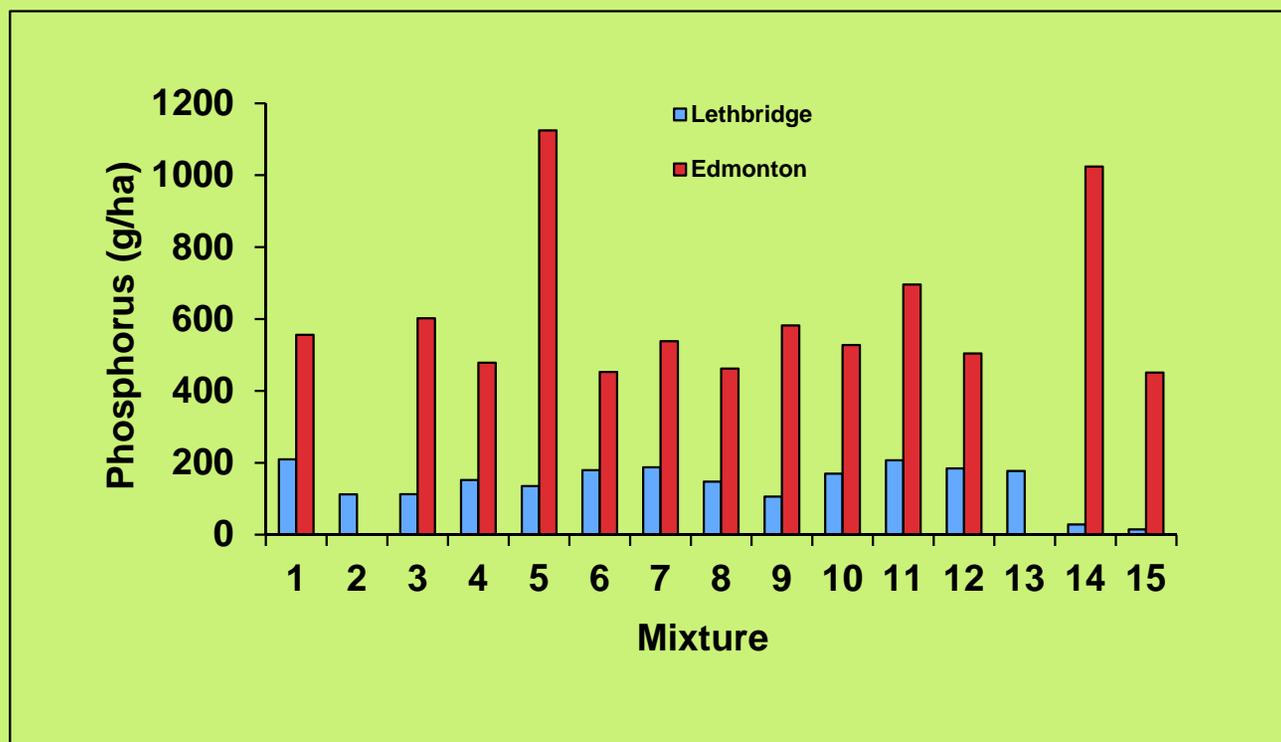
Vigil et al 2002.

- 1 Pea, Hairy Vetch, Oat
- 2 Sun Hemp (*Crotalaria juncea* L.), Sorghum-sudan grass (*Sorghum bicolor* xs Sudanese), Buckwheat (*Fagopyrum esculentum*)
- 3 Cowpea, Sorghum-sudan grass
- 4 Lentil, Buckwheat
- 5 Lentil, Phacelia
- 6 Faba bean, Pea, Oat
- 7 Crimson clover, Oat
- 8 Persian clover, Oat
- 9 Subterranean clover, Sorghum-sudan grass, Buckwheat
- 10 Woollypod Vetch, Oat
- 11 Chickling Vetch, Oilseed Radish, Oat
- 12 Crimson clover, Chicory, Oat
- 13 White Lupin, Pea, Oat
- 14 Oilseed Radish, Hairy Vetch
- 15 Chicory, Hairy Vetch

Dry Matter and Nitrogen Yield



The concentration of Phosphorus in the various annual forage mixtures



1 Pea/hairy vetch/oat, 3 cowpea/sorghum sudan, 5 Lentil/phacelia, 9 subclover/sorghum sudan/buckwheat, 11 Chickling vetch/oat, 14 oilseed radish/hairyvetch

Dryland wheat yield (bu/acre) CDC Teal HRSW the year after a fallow replacement Cover

Cover Crop Mix	Yield (bu/ac)	Grain minerals
1 Pea, Hairy Vetch, Oat	65.5	High (Mn, P, Zn, Mg, S)
2 Sunn hemp, SSG, BkWt	61.9	
3 Cowpea, SSG	61.9	
4 Lentil BkWt	65.9	
5 Lentil Phacelia	61.5	Highest Fe content
6 Faba Pea Oat	67.6	Highest, except Fe
7 Crimson Clover Oat	65.0	High (K, S, Mg)
8 Persian Clover Oat	57.3	
9 Sub clover, SSG, BkWT	60.2	
10 Woollypod, Oat	57.9	
11 ACGfix, OSR, Oat	61.4	
12 Crimson, Chicory, Oat	59.5	High (P, Mg, K)
13 Lupin, Pea, Oat	59.9	High (P, S, Ca)
14 OSR, H vetch	65.1	High S
15 Chickory, H Vetch	36.9	



Generally speaking plants that have more roots also have greater productivity and yield better, and more surface area means more nutrient uptaks.

Rooting trials at DSV seed in Asendorf, Germany.



Historically speaking

- When yield became a critical factor cereals became the dominant crop.....
- When cereals were made a staple food there was a decrease in the nutritional quality of the diet
- Major cereal grains lack the essential vitamins and minerals, and have lower protein quality compared with pulses (food legumes).

Daily Express UK . 14th. Feb 2005.

Healthy bread that could save your life

Loaf fights cancer and helps heart

By Sarah Westcott

THE first "superbread" that could help beat cancer and protect the heart hits the shelves today.

The new loaf is enriched with the mineral selenium following claims that British consumption of the essential micro-nutrient has fallen to "worryingly" low levels.

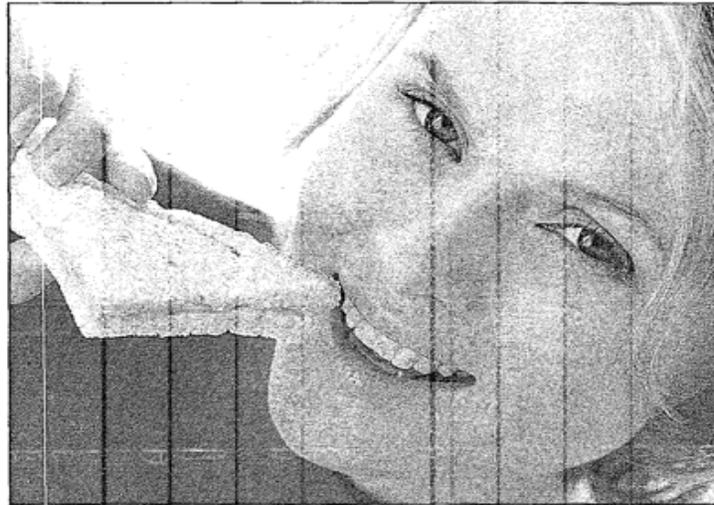
Scientists have proved that selenium can reduce breast cancer by up to 80 per cent and regulate blood pressure, yet it is one of the human nutrients in greatest shortage.

Now Waitrose is launching the selenium-enriched bread, the latest in a growing breed of pharmaceutical foods to be offered to health-conscious consumers. Britons can already buy Intelligent Eating eggs, which contain healthy fatty acid and even crisps containing the natural anti-depressant St John's Wort.

Other "pharma-foods" available in supermarkets are Tropicana orange juice enriched with calcium, probiotic drinks which claim to maintain a healthy gut and spreads containing plant substances which inhibit cholesterol.

A Waitrose spokeswoman said: "Selenium is crucial to our diet for the function of a strong immune system but our current consumption is relatively poor due to the lack of it in British soil.

"Our bread suppliers have worked very closely with farmers to develop a natural way of putting this trace element back into the soil just as mother nature intended. As a result, the wheat from this reinvigorated soil is then harvested and used to bake naturally-enriched sele-



CRUMBS! A loaf enriched with the mineral selenium could bring many health benefits

mium loaves. British consumption of selenium is at a worryingly low level. However, consuming two to four slices of selenium-enriched bread each day would ensure a good intake of this essential micro-nutrient as part of a healthier diet."

The Food Standards Agency has warned the average dietary

intake of selenium has plummeted to half of what it was 20 years ago in the UK due to a steady depletion of the mineral in British soil.

Scientists at the University of Liverpool last year discovered that an increase in selenium intake improves immune function while many studies since

the 1970s have shown that there is an inverse relationship between selenium intake and cancer mortality.

Studies have indicated that selenium can also fight the development of advanced prostate cancer.

A trial in the US found those receiving selenium showed 50 per cent lower total cancer mortality and 37 per cent lower total cancer incidence, with 63 per cent fewer cancers of the prostate and 58 per cent fewer cancers of the colon.

Food agency researcher John Arthur said: "The low concentration of selenium in an enriched loaf gives a lot of safety to consumers as toxic consumption of pill supplements could be achieved with just 20 pills, while the equivalent intake could only be achieved by eating nearly 13 loaves in a day."



UPPER CRUST: Two to four slices daily could ensure the right intake of the micro-nutrient, Waitrose claim, and scientists agree

Male motorists are | Ladies desperate

