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The *Ideal Soil* — a Possible Dream

by Ehrenfried E Pfeiffer, Ph.D

[This article is reprinted from Number 40 of the journal Bio-Dynamics.*]*

What makes the ideal, fertile soil? Many have thought it is fertilizer that makes crops grow. They came to this idea because the nutrients (mineral or other) are what is available to plant roots. Some look upon the soil as only a carrier of nutrients, natural or added. This idea becomes increasingly reasonable if one considers hydroponics, the use of water cultures to which all major and trace minerals have been added. One can top the result of even a well-balanced mineral solution in these cultures, by adding humus to the solution. Humus in a soil is looked upon as a major, indeed a decisive, factor. A soil definitely remains fertile only if and as long as humus is present, the more of it the better.

Recently, in our soil testing and research laboratory we came across two samples of soils, one was from Holland, the other from Illinois. We found that their contents as regards the major, available minerals was about the same: potash, phosphates, nitrates — there was a slight difference in lime and organic matter, the Dutch soil being a few points better.

But the differences were not enough to explain why the Dutch soil had yielded 135 bushels of oats per acre last year (unbelievable, but well confirmed by witnesses), while the other soil had produced a very poor yield. The latter farmer explained that in spite of applying lots of manure, compost, and other necessary fertilization he had difficulties in obtaining adequate yields. Both samples were taken in wintertime, both were equally moist. One can give the Dutch sample the benefit of better climactic, better weather conditions. But then, this soil had received its most recent gift of manure 5 years ago, and had grown good yields throughout the observation period of 20 years.

This Illinois soil has been treated with biological methods for several years, and shows remarkably strong granular structure and tilth ... the "ideal soil" that would please any farmer in any nation.

We had to go deeper (literally) to explain the differences, and we investigated the subsoil in each case. The Dutch sample of topsoil was from zero to 10" in depth. A sample of the subsoil under it, from a depth of 10" to 20", was analyzed. It showed almost the same available mineral findings as the topsoil, but the organic matter of the subsoil was 1.5% while that of the topsoil was 2.5%. The other, poorly-yielding soil had a topsoil of 10" in depth, and was sitting on a hardpan. Deep-growing roots were able to profit from the subsoil in the

See Compost Brings Soil, page 2

What Has Boosted Yields Most?

Hybrid Cultivars Have Had the Biggest Impact

By Paul W. Syltie, Ph.D.

A host of effects, both environmental and genetic, have conspired to boost average crop yields considerably during the past several decades. Not the least of these beneficial effects has been good overall weather across much of the breadbasket of America for many years, but other effects are also highly important.

In 1982, V.B. Cardwell at the University of Minnesota published a paper in *Agronomy Journal* (Vol. 74, No. 6, pages 984-990) which partitioned the causes of yield increases for corn over the 50-year period of 1929 to 1979. During this time, average corn yields rose from 2,010 kg/ha (32.0 bu/acre) to 6,290 kg/ha (100 bu/acre), an amazing leap of 213% ... or about 1.3 bushels per year.

According to Cardwell, this increased yield can be attributed to a series of technological, cultural and management practices adopted by farmers over this period. These increases were offset to some degree by negative influences on yield.

These increases in grain yield do not reveal decreases in crop quality that have accompanied the large rise in bulk yield. In general, mineral, vitamin, and protein composition of the grain have fall-

See Nutritional Quality Still, page 6

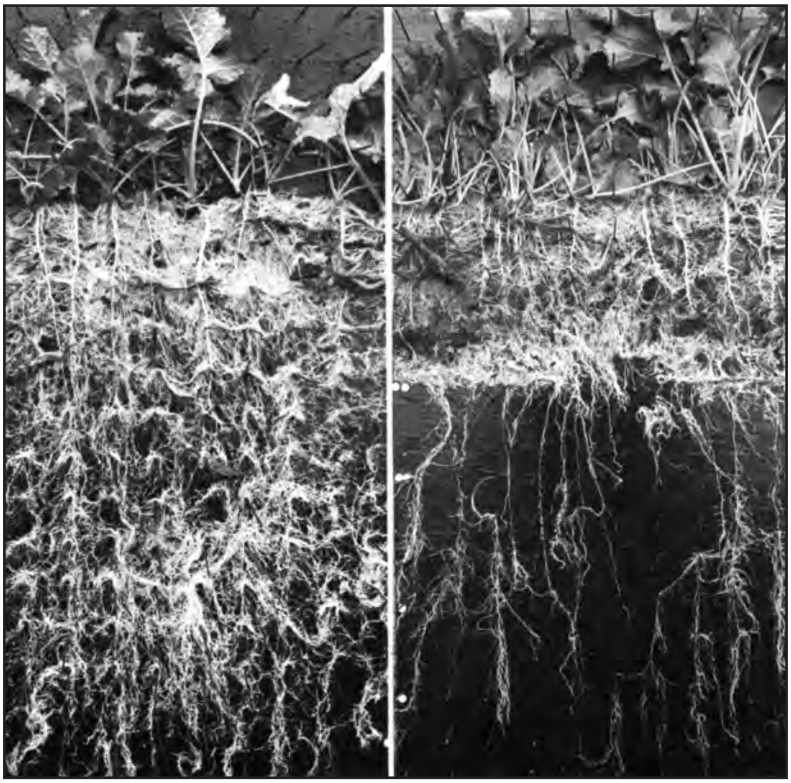
A Hardpan Destroys Productivity

Continued from page 1

Dutch sample, while nothing could grow deep in the Illinois sample. The Dutch soil showed an ideal humus formation to a great depth. Physically there was an ideal, crumbly structure, with good aeration and soil life, and no hardpan, to a depth of 20", while in the poor soil — of quite similar findings with respect to available minerals — there was no depth, due to the various layers of hardpan.

We have investigated many soil profiles recently, and found most roots do not penetrate hardpan, and stop growing, even begin to move away, horizontally instead of downward, in such cases. These hardpans become an especial handicap if the soil is acid and produces strata of acid humus compacted in the deeper layers.

It came to our mind that in 1933 we had seen an interesting experimental field at the Missouri Experimental Station. It had been kept in several plots for decades, in the following manner: one group of plots was left as it had been originally, as virgin prairie, not troubled by man. This area had a deep soil and showed no structural change, no hardpan, was crumbly all the way through. It was deep. The good Dutch soil with the top yield resembled it.



Notice how growthy and dense the roots are in the left-hand soil, which has good fertility and no hardpan. In contrast, equally good fertility but a restricting hardpan on the right greatly reduce root growth below the hardpan, limiting nutrient uptake severely and reducing yields. Inherent productivity of both soils is about equal.

Other plots were treated in various ways — corn grown right after corn, a corn-wheat, corn-wheat rotation, i.e. one-sided rotation and cultivation; others had a sound crop rotation, etc. We were shown that the more one-sided the rotation and cultivation was, the more the virgin, ideal structure had vanished and deficiency symptoms as well as hardpan and crust showed up.

From these comparisons, we learn the important lesson that the ideal soil is deep and has no hardpan and other structural disadvantages. It is well aerated and the humus formation as well as microlife can go to great depths. It should be noted in this connection that the Dutch sample came from a field under cultivation for several hundred years, but with sound management and proper rotations.

"... the ideal soil is deep and has no hardpan and other structural disadvantages. It is well aerated and the humus formation as well as microlife can go to great depths."

It is the kind of cultivation, plowing, etc., that creates a hardpan and compacting process which transforms a good soil into a poor one. This includes not only mechanical errors but also mistakes in fertilizing. The poor soil is poor because it does not offer enough area for root growth; it remains superficial, shallow. Wherever man has caused hardpans, he has ruined the original capacity of his soil. Any plowsole which influences roots to grow away from it, or to stop penetrating the soil entirely, is a detriment. No fertilizer, not even organic matter, can help when the soil becomes shallow. We say "becomes shallow" because many a soil had the capacity to remain deep.

The ideal soil therefore is one which is not ruined by cultivation and fertilizer. A good farmer is one who is able to maintain or even increase the depth of his soil. The more a soil has been ruined structurally, the more it *seems* necessary to correct with fertilizer, without ever getting at the bottom of the trouble, that is without ever correcting the original sin against fertility. Farmers spend a lot of money and effort but actually render the best fertilization program ineffective as long as they don't know how to grow their soils deeper. For that reason we thought it worthwhile to tell of the two samples which were chemically almost alike, in fact according to the standards of soil testing both perfectly alright, but which varied so widely in their production. The one standing way at the top of international yields, the other yielding poorly. ❒

Be kind, for everyone you meet is fighting a hard battle

Plato (427-347 B.C.)
Bits and Pieces

Big Farms Dominate U.S. Agriculture

It should come as no surprise that the size of American farms continues to grow. The latest figures of the U.S. Department of Agriculture reveal that the 70,600 farms with annual sales of more than $500,000 produced about 62% of the nation's agricultural products in 2002. The last previous survey showed that proportion to be 56.6%.

U.S. farms produced $200.6 billion in products in 2002, an average of about $94,200 per farm, which was a gain of about $3,400 from 1997. The number of very small farms, having fewer than 10 acres, declined by 26,000 over the five-year period to 179,000. Middle-sized farming operations — those having 500 to 1,000 acres — also declined by 18,000, but the number of large farms with 3,500 acres or more grew by 18,000 over the five years to 78,000 in 2002.

This information indicates that economies of size are dominating the decisions of farmers in America today. Bigger equipment to cover more acres in less time is replacing the smaller operations, which are having difficulty competing as machinery prices have continued to escalate. Grain, livestock, and other farm product prices continue to be depressed, in many cases returning the farmer less than the total input costs.

Especially distressed is the middle group of farmers having 500 to 1,000 acres. These producers, especially if they are grain farmers, are at the margins of economies of size and find that investments in larger machinery tax the budget to the limit.

The number of farms and farmland in production continues to shrink. There were 2.1 million farms in 2002, 87,000 fewer than in 1997. Land devoted to farming and ranching in 2002 totaled 302.7 million acres, about 16 million fewer acres than five years earlier.

The average farm grew by 10 acres since 1997, to 441 acres. It produced $97,320 in sales and government payments in 2002, and earned a net cash income of about $19,000.

The average age of farmers continued to increase. Of the 1.2 million people who considered themselves full-time farmers in 2002 — an increase of 180,000 over 1997 — the average age was a bit over 55. This was more than a year older than the average age of farmers in 1997. Only 6% of farmers were less than 35 years of age, a very serious fact considering how critical the occupation of farming is to the welfare and prosperity of the entire nation. A young and thriving owner-operator base for the farm economy is critical for sustained economic health.

There was a wide variation between poor and rich farms. The poorest farms, those with sales of less than $1,000 in 2002, had an average loss of more than $7,100. One must question whether these small farms included many non-farmers who were using the operation as a tax write-off. On the other hand, the richest farms, those with sales of more than $1 million, averaged more than $698,000 in net farm income.

The American farm is no longer the ideal picture that our founding fathers envisioned when the nation was young ... when the vast majority of the population was rural and directly involved in food production. Low prices for produce, and high prices for inputs, have forced millions of farmers from the land into cities. The elimination of the owner-operator farmer has progressed further, and farmers that remain are often tied to creditors.

Changes need to be made on the land. May we soon see the return of the owner-operator in large numbers, and may his tenure on the soil be secure and prosperous as the coming decades unfold. ❐

Precocious Puberty: a Modern-Day Bane

[Condensed from an article in Acres U.S.A., 1/05, *by Sherrill Sellman, N.D.]*

Something strange is happening to many of our children: they are developing secondary sexual characteristics far ahead of the normal schedule. In America, by the time girls turn age 8, 15% of Caucasian girls and 50% of African American girls will be starting puberty. Even more startling, 1% of Caucasian girls and 3% of African American girls will show these characteristics by age 3!

What is the cause of such a disturbing trend? A Canadian study related childhood obesity with precocious puberty, and many more children are overweight today than even a few years ago. Research in Puerto Rico, where the highest rate of premature puberty exists, revealed that soy-based infant formulas and high levels of chemical plasticizers — mainly phthalates, which mimic estrogen in the body — were related closely to the problem. These children had 13,000 to 22,000 times the level of estrogen normally found in the blood!

The culprit in this outbreak of premature child development is chemical hormone disruptors. The children's highly sensitive endocrine systems are being assaulted by the estrogen mimicers in car exhaust, room fresheners, artificial fragrances, baby shampoo, dry cleaning, furniture polish, fire retardant-infused clothing, plastic water bottles, fly spray, and on and on the list goes. Even *in utero* the children are being exposed.

The consequences of this assault is leading to cancer, multiple allergies, learning disabilities, behavior problems, and infertility for starters. It behooves us to shield our children from these harmful chemicals, and feed them natural, fresh foods raised on fertile, organic-rich soils so they can have every chance possible in a polluted world to live normal, healthy, abundant, and useful lives. ❐

WHAT SUCCESSFUL PEOPLE SAY ABOUT THEIR WORK

- I love to create, and use my imagination to build up others.
- I like to trust others.
- I like people to tell me all about themselves.
- I like knowing that I can do more than is expected of me, and then *do it*.
- I like working at something where the sky is the limit.
- I like knowing that when I make a dollar, the other person makes two dollars.
- I like the security that comes with doing my level best.
- I like to build things.

15-Minute Soils Course

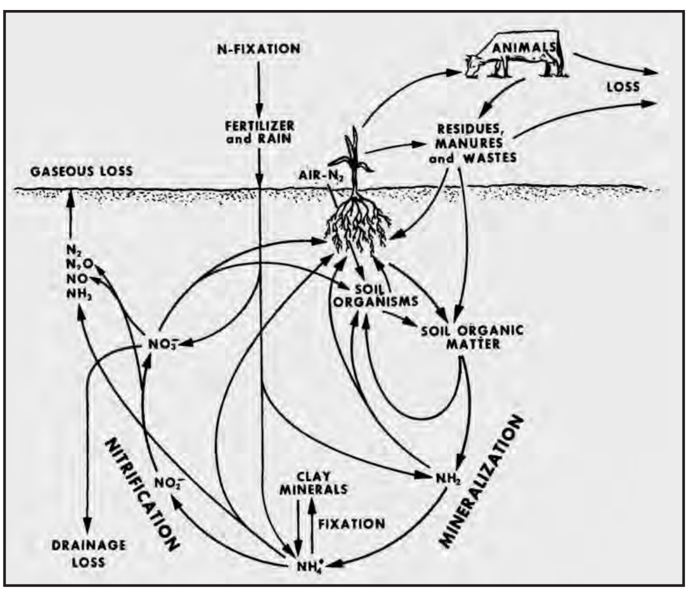
Lesson 20:

Nitrogen (N), That Elusive Essential Nutrient

Of all the elements essential for plant growth — and applied as fertilizer — nitrogen (N) is needed in the greatest quantity. A 150 bu/acre corn crop requires 310 lb of nitrogen, 52 lb of phosphorus, 205 lb of potassium, and 58 lb of calcium, but only 3 lb of iron and 0.1 lb of boron in the grain, stems, and roots.

It is an "elusive" element because, unlike the other essential nutrients, it comes from the gaseous N_2 state in the air and must be "fixed" in a form that the plant can use. The N_2 gas of the air (79%) cannot be used by the plant. The amount found in the soil is small, and it can be readily lost due to soil erosion, organic matter loss, leaching, and denitrification (gaseous loss to the air). For these reasons it is imperative to closely monitor it so that plants have enough.

Nitrogen tends to move fairly rapidly through the soil-plant system, and is retained only for relatively long times in stable organic matter fractions and as fixed ammonium (NH_4^+) ions within clay lattices. It is also stored within stable soil structural units for long periods of time. This cycling of N is pictured in the diagram shown below in the left column.



Explanation of Terms

Immobilization. The process of converting NH_4^+ and NO_3^- into organic combinations (the reverse of mineralization).

Nitrification. The conversion of reduced N forms ($-NH_2$, NH_4^+) into oxidized forms.

$$NH_4^+ \xrightarrow[\text{bacteria}]{\text{Nitrosomonas}} NO_2^- \xrightarrow[\text{bacteria}]{\text{Nitrobacter}} NO_3^-$$

Mineralization. The conversion of the N in organic matter to NH_4^+ (ammonium).

$$-NH_2 \xrightarrow{\text{Microbes}} NH_3 \xrightarrow{\text{Microbes}} NH_4^+$$

Immobilization

Making Nitrogen Usable

Nitrogen enters the plant-soil system primarily through the activity of N fixing microorganisms. These organisms "reduce" N from the air to the form needed by plant cells, and either deliver the N directly to the plant roots from N fixing nodules, or die, decompose, and allow the roots to take up N from the soil after they release it as NH_4^+ or NO_3^- ... the two forms most readily used by plants. When organisms utilize N and die, the "organically fixed" N is more-or-less stabilized in their organic remains as various N compounds. The N is made available as soil organisms break them down under favorable growing conditions. Only 2 or 3% of the total N pool in organic matter is made available during the growing season, so a soil low in organic matter will provide little N from the soil.

The Great Importance of N-fixing Organisms

Many different types of soil organisms are involved in fixing nitrogen (N_2) from the air to make it usable by plants. A few even live on plant leaves! (See the following page.)

The most commonly used N fixing organisms are the Rhizobium types, of which there are

Continued on the next page

15-Minute Soils Course

seven major groups, each somewhat specific to certain legume species such as alfalfa, clover, beans, and cowpeas. Amounts of N fixed per year can be great, about 250 lb/acre for alfalfa and 105 lb/acre for soybeans. Non-legume fixation, however, can yield over 100 lb/acre in some cases such as in hay fields, sod, and forests. Cyanobacteria and other bacteria and fungi play a major role in this fixation process.

Nitrogen-Fixing Organisms

Require a carbon energy source

Aerobic. Azotobacter, Rhizobium, Beijerinckia
Facultative anaerobic. Bacillus, Azospirillum, Klebsiella
Anaerobic. Clostridium

Free-living, need light

Cyanobacteria. Nostoc, Anabaena
Purple non-sulfur bacteria
Purple and green sulfur bacteria

Nodulating, symbiotic with roots

Legumes. Rhizobium
Non legumes. Rhizobium, Frankia

Symbiotic with other organisms, need light

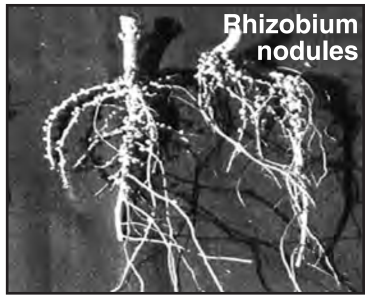
Lichens. Nostoc, Calothrix
Liverworts. Nostoc
Mosses. Halosiphon
Water ferns (Azolla). Anabaena

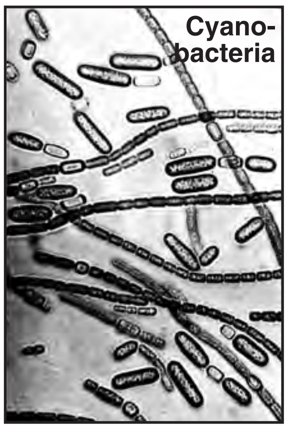
Some N is brought down by rainfall, but generally in small amounts (1 to 7 lb/acre/year). Conversely, significant N can be lost to the air as soil organisms convert nitrate into gaseous forms, especially when a lot of fertilizer N is applied under wet (anaerobic) conditions. Urea also can lose significant N when applied to soils.

Managing Nitrogen

It is important for the farmer to encourage natural N fixation for his crop to limit the amount of expensive fertilizer N he applies. Crop rotations with legumes will add considerable N to the system, and also disrupt pathogen buildups from year to year. Reduced or zero tillage help preserve and build soil organic matter stores, and thus promote future N release for crops.

More frequent N applications are preferable to only one or two during the cropping season, since more will be used by the crop and less lost due to denitrification and leaching. Crop residues should be returned whenever possible, and livestock manures or compost added along with biostimulants — such as Vitazyme — to encourage the production of organic fractions resistant to decomposition, like glomalin (synthesized in the hyphae of mycorrhizae). A properly managed soil, especially under organic cropping systems, will produce crop yields as high as those produced under conventional high fertilizer inputs.





See How Much You Learned

1. Nitrogen moves rather quickly through soils and plants in a system called the nitrogen ________,
2. Which of the following are good nitrogen fixing organisms for agriculture?
a. Cyanobacteria
b. Rhizobium c. Penicillium d. Azotobacter
3. A good crop of alfalfa can fix 250 lb/acre of nitrogen per year. T or F
4. ________________ are essential in converting nitrogen to its various forms in the process of immobilization and mineralization.
5. Organic matter is vitally important as a storehouse of nitrogen in the soil. T or F
6. A 150 bu/acre corn crop requires _______ lb of nitrogen in its grain, stover, and roots.
7. Super bonus question: In a few words, define "nitrification".

Answers: 1. cycle; 2. a, b, d; 3. T; 4. Microorganisms (or microbes, or bacteria); 5. T; 6. 310; 7. the conversion of reduced N forms into oxidized forms.

Nutritional Quality Still a Problem

Continued from page 1

en as starch content has increased, the so-called "dilution effect."

Current yields of corn in Minnesota are now pushing 150 bu/acre. If such yield levels are sustained, the increase would represent another 50% increase in yield over 25 years — 2.0 bushels/year — probably due mainly to further refinements in plant breeding and high levels of fertilization. Other crops besides corn have seen strong yield increases over the past decades, but few like corn.

FACTORS INCREASING YIELD		FACTORS REDUCING YIELD	
• Adoption of hybrid cultivars	58%	• Corn following corn:	
		Rootworm damage	3%
		Interference effect	7%
• Use of herbicides	23%	• Corn borers	5%
• Increased planting density	21%	• Earlier planting	8%
• Drilling versus hill dropping	8%	• Soil erosion	8%
• Fall plowing	5%	• Other negative and unaccounted factors	23%
• Closer row spacing	4%	Total	– 46%
• Use of commercial N fertilizer	19%		
Total	+146%		

While it has been the primary motive of modern agri-business to push crop yields to their limit, little attention has been paid to the nutritional value of that increased yield. Usually the effects have been negative, showing how there needs to be a change in the focus of agriculture's future: food crops of optimum quality, commensurate with high yields, to promote maximum health and longevity of man and animal, and the highest possible fertility of our precious soil resources.

Those Brilliant, Helpful Mycorrhizae!

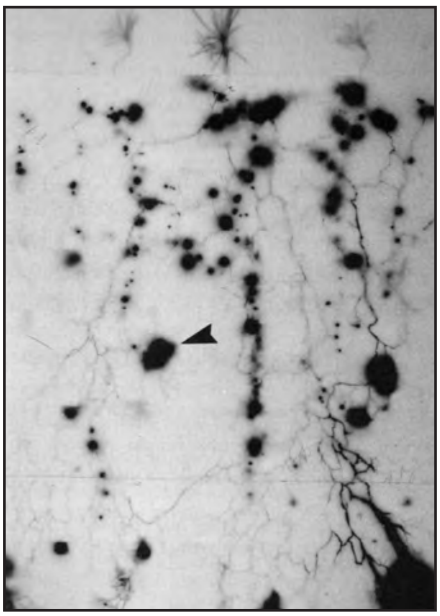
by Paul W. Syltie, Ph.D.

News from soil fungal ecologists continues to confirm that mycorrhizae are indeed some of the most prized organisms on earth. While a single handful of fertile garden soil contains more individual organisms than the total number of human beings that have ever lived (10^{12} bacteria, 10^4 protozoa, 25 km of fungal mycelia, and countless other species[1]), amongst this vast array of microbes the mycorrhizae stand head and shoulders above the rest in importance to plant growth and development.

The mycorrhizae, existing as several types, but especially as the vesicular arbuscular (VAM) and ecto (EM) types, can send out extensive networks of threadlike mycelia that may total 20,000 km (12,500 miles) in a cubic meter of soil. These threads grow out from the roots, effectively multiplying the feeding volume of the root system multiple times ... and because their very small size (one-60th the diameter of fine roots) they can get into tight spaces and retrieve hard-to-get nutrients.

Utilizing the plant's energy fed to them by leaf-generating photosynthate, they proliferate out into the soil to pick up immobile phosphorus, copper, zinc, and other nutrients — and transfer them back to the root for uptake.

Early experiments on sterilized soil revealed that good plant growth was impossible in such a medium; only natural soil gave vigorous growth responses of plants[2]. During these early investigations the discovery of mycorrhizae began to show their widespread presence over the earth ... from boreal forests to temperate grasslands, and from alpine meadows to tropical forests. The only exceptions were lava fields, strip mines, exposed subsoil, and heavily fertilized farmland. This last category should draw the attention of farmers, since heavy chemical use can shut down the function of these highly chemical-sensitive workhorses that provide so many benefits for crops.



Radioactive PO_4, fed into the mycorrhizal mycelium from the lower right-hand corner, has moved quickly throughout the fungal network, even to other nearby pine seedlings ... illustrating the ability of mycorrhizae to share nutrients in a community.

Biologists have found that about 80% of plants on earth have roots entwined with mycorrhizal fungi. According to John Klironomos, a soil ecologist at the University of Guelph in Ontario, Canada, "It would be hard to go outside anywhere and pick up any handful of soil and not have mycorrhizae". These hard-working microbes have made it possible for plants to survive in diverse soil niches, and they even play an integral part in plant succession ... helping certain climax species prosper to replace the first invaders of a landscape[3]. To explain this phenomenon, one ecologist noted that some fungi are more active than others in extracting energy-rich carbon from a particular plant. If this uptake translates to a greater nutrient flow back to the plant, then the plant has a competitive advantage over its neighbors.

On soil sites where stress levels are high, such as strip mines, heavily fertilized land, and polluted land, mycorrhizae are especially effective.

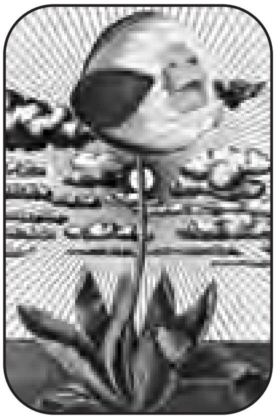
Continued on the next page

Plants Talk to Each Other!

by Paul W. Syltie, Ph.D.

It may seem rather bold to suggest that plants communicate with one another in direct ways, but take a look at the evidence ... mostly from tree studies. Physicist Ed Wagner in Oregon found that trees talk to each other in a language he calls W-waves. If you chop into a tree, adjacent trees put out an electrical pulse. Chemical communication has been understood for years, but this communication is much quicker and more dramatic. Wagner calculated that the W-waves traveled about 3 feet per second, and they do not seem to be electromagnetic. He has also detected electrical standing waves in trees.

Woulter Van Hoven in South Africa has discovered that acaia trees that are nibbled on by antelope produce elevated levels of tannins in their leaves, which are lethal if consumed in large enough quantities. The trees emit ethylene into the air, that can travel in high enough concentrations for up to 50 yards to warn other trees of impending danger; these other trees then step up their own tannin production within just 5 to 10 minutes to discourage further grazing. If the antelope are forced to graze on restricted areas, especially during drought periods, whole herds can be forced to eat the high tannin leaves and can die.



What other amazing qualities of plants will soon be discovered? Read *The Secret Life of Plants* by Tompkins and Bird for more exciting information, such as how plants respond to a lie detector, and how they react to remote thoughts. ❐

Mycorrhizae Form Communities

Continued from page 6

According to one researcher, "Many plants are dependent on mycorrhizal fungi, especially when grown under stress conditions, such as an excess of heavy metals in soils[4]". A disturbed site is often first populated by weeds that do not require mycorrhizae, but once the fungi move in the diversity of plants expands. The mycelia can make toxic elements like cadmium unavailable, and aid in the formation of a strong and stable soil structure. Recall the article on glomalin from the summer, 2003, issue of *The Vital Earth News (Ag)*. Glomalin is a hyphal wall constituent that contributes greatly to more persistent stores of soil organic matter, and thus helps build strong soil structure that is so critical to air and water movement in soils.

Not to be slighted is the ability of mycorrhizae to form a vast network of fungal mycelia throughout the rhizosphere of entire communities of plants. For instance, a giant oak tree through its maze of mycorrhizae can connect with neighboring plants and feed them some of its own photosynthate. Simard and others in Canada recently showed how trees share energy through the ectomycorrhizae maze in the soil, the strong individuals in some cases supporting the weak[5]. Many plants, including germinating seeds, can tap into this life-giving pipeline for instant access to food reserves. Orchid seeds, which carry no reserves at all, are totally dependent on such a pipeline for survival, and some opportunistic plants tap into the supply and reduce their energy production at the expense of others on the pipeline.

As research continues, the tremendous importance of mychorrhizae for the livelihood of plants will be revealed more lucidly each year. It behooves growers to support the development of these friendly fungi, and all of the wonderful things they do for plants, by practicing natural, sustainable methods in the field or nursery. ❐

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3, 4. See 2.
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Statement of Purpose

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Vitazyme increased corn yields in replicated university and independent trials in Iowa and North Carolina by 14.3 to 20.3 bu/acre. Even with depressed farm prices, economic returns with these increases are excellent, bringing from $4 to $6 for every dollar invested!

Vitazyme applied to corn produces more aggressive and larger plants, having more roots — especially fine root hairs — which absorb more nutrients for higher yields.

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Once again we return to the subject of soil structure, continuing from Lessons 7 and 8. Why? Because soil structure is so critical to permit the movement of air and water throughout the root system, enabling roots, and thus the stems and leaves they support, to grow at maximum rates.

Roots build soil structure for rather "selfish" reasons: to enable them to more easily penetrate the soil, and to improve air and water movement to insure better oxygen delivery. Both reasons improve the health of both root cells and of microorganisms that live on and near root surfaces. They strive to develop a granular structure such as shown above that has many strong subunits, and a high percentage of macropores.

The series of figures on the next page illustrates root strategies to create better soil structure. These three methods are ...

(1) mycorrhizal sac formation
(2) root cap and root hair extension, and
(3) polysaccharide "glue" production by microbes.

There is a fourth method as well, which also involves the mycorrhizae. This method is the production of a special cell wall constituent of the mycorrhizae called *glomalin* ... a subject featured in the Summer, 2003, issue of *The Vital Earth News, Agricultural Edition*. Glomalin is notorious for its persistence in the organic fraction of the soil, and for its great benefits to structure.

How the System Works

Mycorrhizal fungi feed on plant energy stores fed to it by root cortex cells. In fact, the energy that feeds a teeming array of trillions of microbes along root surfaces comes from energy rich compounds moved down the stem into the root zone, and excreted into the soil. The fungi grow out from the roots into the surrounding soil and form sac-like structures that bind smaller structural units and sand grains together. Actinomycetes further assist in the binding process.

Polysaccharides – sticky compounds – produced by bacteria, fungi, and algae abounding near the root surface stick together silt and clay particles to form "peds" ... small structural units. Tiny amounts of these polymer sugars are highly effect: only 0.02% of added microbial carbohydrate can markedly stabilize clay aggregates. Roots form channels as they extend through the soil — provided compaction is not too severe — and root hairs assist in the process.

The construction of a strongly aggregated soil may be likened to building a brick house. Note the box below.

See How Much You Learned

1. Why do roots build soil structure?
   a. Enable roots to more easily penetrate soils.
   b. Improve oxygen and water movement.
   c. Increase plant health.
   d. All of the above.

2. An important assist to soil structure, derived from mycorrhizal hyphae walls, is ________________.

3. Polysaccharide "glues" are important in binding small soil particles together. T or F

4. Which of these items helps to build strong soil structure?
   a. Polysaccharide "glue"
   b. Glomalin
   c. Mycorrhizal sac formation
   d. Argon in the soil

5. The energy powering the structure building process comes from the leaves aboveground. T or F

6. The "bricks" of the soil structure fabric are the ______________, formed by bacteria binding sand, silt, and clay.

7. Huge amounts of polysaccharide glue and certain other mucilages are needed in the soil to affect soil structure. T or F