The Vital Earth News

Agricultural Edition

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Soil Compaction - The Hidden Enemy

Nearly All Fields Have It, and It's More Serious Than You Think

by Paul W. Syltie, Ph.D.

We tend to believe only what we see, hear, and feel... but, when applied to soils, such a limited view can be dangerous. What we don't see beneath the soil surface is every bit as vital to plant growth as what we actually see growing above ground level. One of these unseen influences on growth is soil compaction, a hidden and growing nemesis to crop production that is operating in virtually all parts of the country.

How serious a problem is soil compaction? Because of our heavy machinery, tillage, and chemical usage compaction is **very** serious. Hardly a field in commercial production today is not affected to some degree, with consequential reductions in yields, profits, and quality of our environment.

First of all, what **is** soil compaction? Compaction is an increase in the bulk density (weight per unit volume) of the soil in one or more of the horizons, which creates a somewhat impermeable barrier to root extension and gas and water exchange within the soil. Soil structure is broken down from a crumb or blocky to a massive type. The causes for this change can be several and varied, but in all cases the percentage of all-important **macropores** becomes greatly reduced, while the smaller **micropores** increase. The larger macropores readily permit the movement of air and water, whereas micropores greatly impede air and water movement through the mass, largely restricting water movement solely to capillary action. Thus, a sandy soil, though low in total porosity, allows rapid water movement because of a predominance of macropores. A clayey soil, conversely, has few

$$\text{Bulk Density} = \frac{\text{Weight of Soil}}{\text{Volume of Soil}}$$

Note how the compacted layers of soil in this field have been created by tractor wheels, cultivators, and even planter shoes to allow only a small partion of the soil volume to be explored by the corn roots.

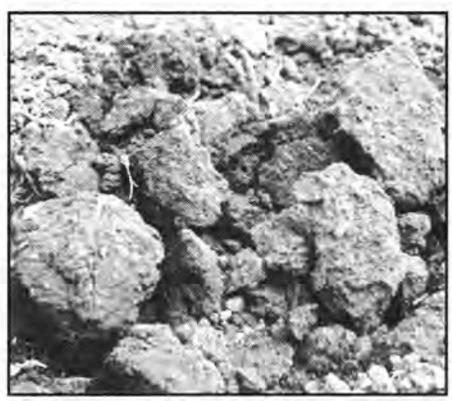
See Do Not Minimize, page 2

Dealing With Magnesium in the Soil

by Neal Kinsey
Kinsey's Agricultural Services, Charleston, Missouri

Magnesium (Mg) is an important plant nutrient and provides a very critical part of the fertility level in a soil. It is necessary for use by the plant in chlorophyll production. Without the correct amount of magnesium, a plant cannot properly utilize nitrogen to provide that good green color. But magnesium has far more to do with soil fertility than just helping keep plants green.

Compared to the primary nutrients, N-P-K-S (considering S as expressed in the plant-usable sulfate form), magnesium is not needed in such great amounts. It requires around 30 lb per acre to grow 150 bushels of corn. Since most soils contain several hundred pounds of magnesium, it is regarded as less important than the big four as a nutrient to be supplied for growth, thus its classification as a secondary element. Even so, if it is deficient in the soil, it can reduce corn yields by 10 to 20 bushels per acre. Legumes decline in yield as well when there is not enough magnesium in the soil. Fruits and vegetables also suffer when magnesium is defi-



High magnesium soils, resulting oftentimes from continual applications of dolomitic limestone, can produce a cloddy structure such as this.

See Avoid Excessive, page 3

OUR SOIL PROBLEM

by Eric Eweson

Deep concern about declining soil fertility and danger of world starvation is evident on many sides. Books by Fairfield Osborn, William Vogt and J. I. Rodale have focused attention on the subject. The United Nations and numerous other political and economic bodies have discussed the problem. Statistics from the U. S. Department of Agriculture showing that more than two-thirds of the American farming area is completely or partly worn out confirm the view that the situation is extremely grave. Opinions are sharply divided, however, on how to solve the problem. One extreme group favors having more people work the land and fewer living in cities, reducing also the number of industries which draw on an arable land for raw materials, and replacing farm machinery with animals in order to increase the supply of manure. Some even propose limiting the world's population, as already advocated by Malthus at the beginning of the last century.

Another group, the most numerous one, made up of most of our agricultural experts, agronomists and chemists, contends that chemistry and modern techniques can solve the problem. This group therefore recommends more chemical fertilizers, more farm machinery, more effective pest sprays and weed controls and, of course, extensive soil rehabilitation and erosion control. Growing vegetables in chemical solutions is another proposal to increase our food supply.

A third group, disagreeing with most of this, advocates various forms of composting by farmers and gardeners for better utilization of their vegetable and animal wastes, supplemented with wastes from nearby cities. With this I agree in principle, but doubt its general practicability with present high labor costs, rural labor shortages, general lack of knowledge of the art of making compost, etc. My specific proposal is therefore large scale industrial manufacture of compost by a new process utilizing the vast abundance of municipal and industrial organic waste materials—making rich compost available in sufficient quantities to restore our topsoil to its oldtime fertility, and thereby also solve our increasingly serious problems of air and water pollution from improper disposal of city wastes.

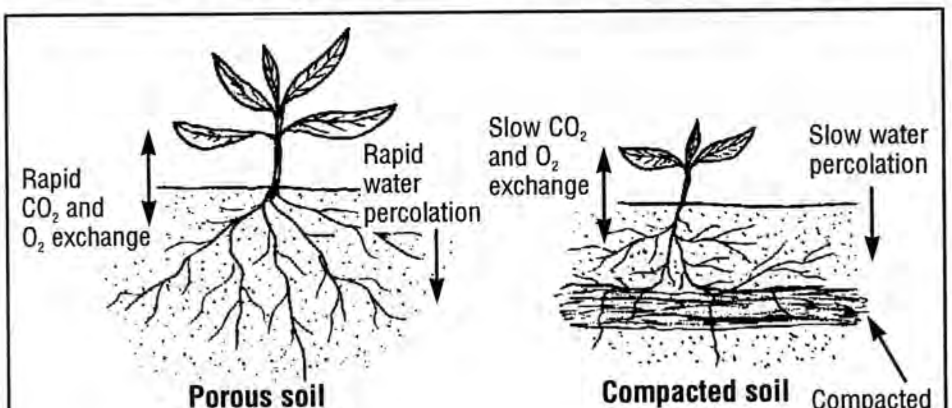
It is possible to turn around our present course of land degradation by practicing soil conservation and returning "wastes" back to the soil from which they come.

IMPORTANCE OF TOPSOIL

Fertile topsoil, by far our most valuable and indispensable national resource, is a mixture of disintegrated rock in the form of sand or clay, organic residue and humus, the latter being a mass of microor-

See Protect Our Soils, page 5

Do Not Minimize the Seriousness of Compaction!



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macropores.

Why is soil compaction so serious?

1. The percolation of water through the soil is restricted.

2. Air movement (O_2+CO_2) into and out of the soil is reduced.

3. Consequently, water storage and availability throughout the growing season, and oxygen levels in the root zone become restricted, and CO_2 levels rise to high levels.

4. Root growth becomes difficult due to the tight physical barrier and low oxygen levels in the root zone.

5. Water and nutrient uptake are limited, and consequently plant growth is also limited.

6. Runoff and erosion are increased due to a slower infiltration of rainwater into the soil. Untrafficked soil may drink in nearly all rainfall, but a conventionally trafficked soil soon sheds as much as 90% of rainfall.[1]

7. Due to a breakdown of structural units, nutrients stored in them are lost more quickly.[2]

8. Soil nitrate nitrogen is quickly lost due to accelerated dentrification within an anaerobic (low-oxygen) soil environment (up to 95% lost within 10 days!).[3]

Reductions in corn uptake due to compaction

Potassium	70%
Nitrogen	30%
Magnesium	20%
Calcium	10%

9. Plant diseases can increase.[4]

As if these facts about compaction are

See To Limit, page 5

Avoid Excessive Magnesium in Soils

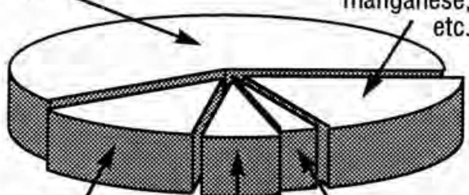
Continued from page 1

cient. For example, carrots have tops that die prematurely when there is a lack of sufficient magnesium. Without adequate magnesium, crop yields will always suffer, and so will crop quality. But keep in mind, soils are very sensitive to magnesium, and there is a fine line between too little and too much.

When deficient, magnesium can be supplied to the soil from several possible sources. Usually, the most economical source is dolomitic limestone. But this is only advisable when there is also a need for the calcium which it supplies. A standard dolomite lime will supply twice as much calcium as magnesium. When the calcium is not needed, another possible source is sulfate of potash-magnesia or potassium-magnesium sulfate (K-Mag or Sul-Po-Mag), since dolomite should not be used in such cases. Again, this is only suitable when the soil can tolerate both the potassium and sulfur, as well as the magnesium. The next most likely choice is magnesium sulfate or Epsom salts. It is generally the most expensive solution for supplying the needed magnesium. Another possible source on farms using sprinkler irrigation is the water. If the water is high in magnesium, the levels will normally rise accordingly in the soil. With furrow or flood irrigation, where the water keeps moving, irrigation water does not appear to be such a significant source of magnesium for the soil.

There are those who feel growers never need to apply magnesium to the soil as dolomite, and that doing so is detrimental. This concept has probably come about because there are certain soils which, when limed with calcitic lime, will show an increase in available magnesium. Such soils have free magnesium ions trapped between the clay plates which are released when the calcium is added. This has happened on certain soils we have helped to bring back to better production. It is most common on soils with adequate calcium levels (60+%) where gypsum or calcium sulfate is applied. It is not unusual to have a farmer call about his concerns when he has spent money on gypsum to reduce magnesium in his fields, and instead it rose the first year. From our experience, this is not a long-term effect. But it has perhaps helped encourage the concept that magnesium should never be supplied using dolomite. Again our experience shows, if the magnesium is truly deficient, the crops will never reach their greatest potential without adding it back to the soil. This is most evident on sandy soils, but generally holds true for all soils which are lacking in magnesium. And when magnesium is needed, dolomite is usually the most economical source to apply if soil conditions allow its use.

> "...the wise man stays at home, but when his necessities, his duties, on any occasion call him from his house, or into foreign lands, he is at home still and shall make men sensible by the expression of his countenance that he goes the missionary of wisdom and virtue."
>
> *Ralph Waldo Emerson*



A properly mineralized soil should have a reasonable balance among the many cations (positively-charged ions) on the exchange complex. With magnesium in the 12 to 15% range, soil properties will tend to be optimized provided other elements, especially calcium, are within their appropriate ranges.

Just as soils can be too low in magnesium and cause yield losses, levels can also be too high in the soil and reduce yields. Too much magnesium can cut corn yields by 10-15 bushels per acre, even when everything else is present in the proper amounts. When excessive, it reduces cotton yields by 3/4 bale per acre and soybeans by 10 bushels per acre. In fact, legumes such as soybeans and alfalfa are more sensitive to high magnesium levels than corn or cotton. As pointed out in chapter four of *Hands On Agronomy*, red clover seed production doubled when magnesium was sufficiently reduced in the soil.

In agriculture today, magnesium is more likely to cause yield losses in soils due to excessive levels than a decline in yield from too little contained in the soil. There are probably several reasons why this is so. One is the belief that there is no such thing as too much lime. The greatest damage caused by the grower from the use of too much magnesium is generally an overuse of dolomite or high-magnesium lime. This damage is partly due to the fact that too much magnesium in the soil can tie up potassium and calcium. The problem is, too few remember the worst reaction will be three years after the application is made, because it takes that long for the magnesium to break down and become completely available. By then many have forgotten they applied magnesium lime, let alone that it may be hurting the yields. But this is to be expected, since most sources of information available to growers insist there is no problem with too much magnesium in the soil anyway.

Indeed, many individuals involved in agriculture today refuse to accept that magnesium can be too high in the soil—so high it causes crops to decline in yield. In answer to this, perhaps there is only one sure way to find out if it is actually true. Use your own soil for a test. Just begin to analyze your soil for magnesium and compare the areas with the best yields to those that do not produce as well. On the test we use, the soils that measure between 10 and 12% base saturation of magnesium will do the best, provided the other nutrients are adequately supplied. As the magnesium levels increase or decrease from there, the yields will begin to suffer. (Please remember, all soils tests will not measure magnesium in the same way as the testing we do. For some, the ideal may be 15% or more, while others may be at 7 or 8%. For most labs, we do not know what their ideal levels are.) The point is, start comparing magnesium levels of various soils to determine where the best response occurs. Then, note what happens to yields as the magnesium level begins to go significantly up or down from there, when other nutrient levels remain comparatively even in the soils. One after another, clients tell how their own land provides all the proof they need.

Every grower should be taught, the higher the magnesium level in the soil, the more nitrogen it requires to achieve the same yield. Magnesium makes the soil tighter as its content increases in the soil. The tighter the soil, the less aeration there

See Excessive, page 4

Excessive Magnesium Replaces Calcium

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will be, and the harder it is for the plant to take up nitrogen. Then there is a greater need for increasing the nitrogen, or the yields will drop. More nitrogen in the soil does not mean the extra will be taken up by the crop. Actually, this is not the case. What does happen is that more nitrogen is free to leach and drive off the calcium, which is why the pH drops. When calcium is driven out of the soil, magnesium previously controlled by the calcium is now freed up, and becomes available on the soil colloid in place of the calcium.

Furthermore, magnesium has a greater influence on pH than calcium does. So as the calcium drops and the magnesium is released that was previously tied up by that calcium, the pH does not drop enough to accurately reflect how much calcium has been lost. Then if a farmer or gardener limes according to pH, even if dolomite lime is used, he will have more magnesium and less calcium than before at the pH previously considered to be ideal.

Thus, it is actually not the same soil as it was before at the very same pH. There will be more magnesium and less calcium than before. Because there is more magnesium available, the soil is tighter than before. And every time the soil test shows the pH is low enough to need lime, if that is how you determine when to lime, this same thing happens all over again. Only each time it happens the magnesium level increases and the calcium level drops.

High soil magnesium levels with a compact soil structure more often than not can lead to scenes like this, where rainfall infiltration is restricted and erosion is serious.

This makes the soil tighter, which calls for more nitrogen, which drives out more calcium, which releases more magnesium, and on it goes. And the farmer wonders why it takes a larger tractor to pull the same plow in his fields. If magnesium is not measured as a regular part of the soil test, the answer will probably never become apparent.

The more magnesium a soil contains, the more potassium in that soil remains unavailable. Thus, as with nitrogen, more potassium is needed to attain the best possible yields on high magnesium soils. Excessive magnesium ties up potassium, and excessive potassium ties up magnesium. On farms we consult for, we work with potassium levels which have been measured to increase by as much as 100 lbs. per acre on soils as magnesium levels were reduced, even though no potassium was applied for the crop based on soil tests. On soil low in potassium, do not

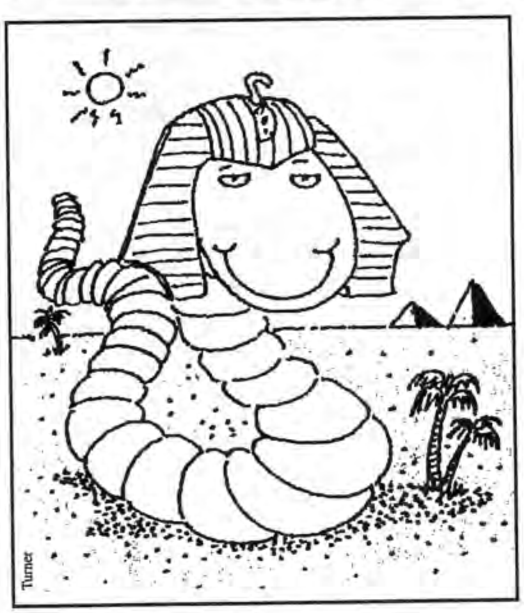
See Correct, page 11

Phertilizer of the Pharaohs

Cleopatra wasn't a very good judge of male suitors. But the ancient Egyptian queen must have known plenty about farming. She's said to be the only ruler in history who decreed the earthworm a sacred animal to be revered and protected by all her subjects.

And with good reason. Earthworms each year add an estimated 120 tons of castings per acre to farmland in the Nile River Valley, according to a 1949 USDA report. How much fertilizer is that? About five times the available nitrogen, seven times the phosphorus, and eleven times the potassium that you'd find naturally in the soil where worms produced the castings, research shows.

One thing Cleopatra didn't know is that earthworms add more than just NPK to the soil. They may also contribute signifi-



cant amounts of plant growth-promoting substances, according to a March '88 article in *The IPM Practicioner.*

Scientists in India have found that soil rich in earthworms contains larger amounts of auxins and cytokinins than does soil where worm populations are low. Depending on the worm species, earthworm-rich soil also was from 17 percent to 55 percent lower in phenols, which indicates it was breaking down into humus more quickly.

Imagine that. The sphinx may be nothing more than an overgrown night crawler.

***The New Farm*, Vol. 10, No. 6, 1988**

To Limit Compaction, Limit Wheel Traffic!

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not serious enough, it has been shown at Iowa State University that the uptake of nutrients by corn plants is greatly reduced by soil compaction:[5]

Al Trouse of the National Tillage Machinery Laboratory in Auburn, Alabama, who has conducted extensive studies on the affects of tillage on compaction, has stated, "...since soil compaction can alter the ability of the soil to supply the current needs of the roots of plants and the ability of roots to absorb these current needs from the soil, soil compaction can effectively restrict plant development.... Soil compaction can be extremely detrimental to crop yields."[6]

Implement tires collapse the soil structure with each pass over the field, especially when the soil is wet. Try to avoid tilling wet soils.

Field studies with cotton have shown greatly reduced production with compacted soil, yields being only 46% of the uncompacted soil, while corn yields have been reduced to only 45% of the control.[7] It is no wonder yields are reduced with compaction, since under ideal conditions each dominant root can grow from 2 to 2.5 inches a day, reaching to depths of 6 feet or more and spreading laterally more than 4 feet in less than 30 days.[8]

A larger root system can possess 50,000 roots and rootlets at peak growth. However, when oxygen levels are low in compacted layers the root extension will be only a fraction of the values given. Not only that, the leaf stomata—openings on leaf surfaces for critical gas exchange during photosynthesis— are closed a goodly portion of the time when the plant is experiencing compaction stress.[9]

In addition, herbicide carryover is usually exacerbated by compaction because aerobic microorganisms cannot work as aggressively to break down these biocides in a low-oxygen environment. Plant emergence can also be impeded if compaction extends to the upper soil surface, and if crusting occurs.

Causes of Compaction

While in some cases soils can have a compacted horizon due to genetic (soil formation) processes, by far the most common causes of compaction are cultural. They can be conveniently classified into two major headings: machine and implement traffic and tillage, and reduced

See Microbial, page 8

Protect Our Soils at All Costs!

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ganisms and decayed organic matter. In temperate climates, under favorable conditions and no cropping, such topsoil may accumulate at about one inch in 100 to 300 years.

Mesopotamia, Persia, Greece, Italy and North Africa, sites of ancient civilizations, once enjoyed great accumulations of fertile topsoil but are now barren deserts. Central Europe's soil resources began to show severe deterioration during the 18th century. In America, in less than a century, the process of soil exhaustion has now reached even our so called "inexhaustible" Middle West, as the inevitable consequence, dust storms, droughts and floods, cause destruction of increasing intensity and frightening regularity. Modern agricultural methods are, unfortunately, using up topsoil very much faster than the old ways.

The failure to return what is removed from the soil is typified in this overgrazed sheep pasture in south Texas. Protection of grazing lands is critical.

The significant characteristic of fertile soil is its content of humus, which word is here used in the restricted sense to indicate only the rich, complex, living mass of end products from the microorganic process of decay—nature's composting process. True humus is not synonymous with organic matter in organic soil residue, and above all it must not be confused with peat or peat humus, which are the results from an entirely different process of decomposition, taking place when the supply of air is cut off, usually by water. The actual content of true humus even in relatively fertile topsoils is amazingly small; one percent is adequate for many types of soil, provided that the

See Humus, page 11

Why Is Healthy Soil Vital to Your Health?

Part 2 - *How the Soil Under Your Feet Affects the Survival of Our Society*

Continued from the last issue of *The Vital Earth News, Agricultural Edition*

By Harold Willis, Ph.D.

The Fertilizer Numbers Game

Another way the system creates problems is by the over-use of synthetic commercial fertilizers, especially certain ones that are harmful to the soil. It sounds strange that something sold as a fertilizer could harm the soil, but it's true.

Most commercial fertilizers are very pure and are composed of chemical compounds of three major elements — nitrogen (N), phosphorus (P), and potassium (K). But a plant needs at least 16 elements for normal growth, and all but three come from soil minerals and humus. The elements needed in lesser amounts (secondary and trace elements) used to be supplied by rock fertilizers, lime, and recycled manures. As the use of synthetic, pure fertilizers increased (since World War II), use of more natural fertilizers decreased.

Standard university recommendations generally over-emphasize nitrogen and potassium (which produce lush growth but poor quality) and under-emphasize phosphorus and calcium (which help produce high quality crops). This, plus the reduction in trace elements noted previously, has led to soil nutrient imbalances.

Then, the cheapest, "most economical" fertilizer materials used to supply nitrogen (anhydrous ammonia and urea) and potassium (potassium chloride, or muriate of potash) are harmful to the soil. The high ammonia content of these nitrogen sources can injure or kill seedlings and soil life, plus it makes humus soluble, allowing this valuable substance to leach away. Reduced humus leads to harder, compacted soil (poor tilth). Potassium chloride is the worst of the high salt fertilizers, which can injure plant roots and kill soil life.

The fertilizer industry leads us to believe that those fertilizers with the highest amounts of N, P, and K are the "best buy." Anhydrous ammonia is therefore the "most economical" source of nitrogen — but we have seen that it is no bargain.

The most promoted sources of phosphorus are those with a high number on the label. This means that there is a high percentage of phosphate that is water soluble (that's the way fertilizer laws are written). But university research (and soil chemistry textbooks) tell is that nearly all this water soluble phosphorus becomes insoluble (unavailable to plants) within hours after its application to the soil. It won't do your crops any good (until after soil bacteria and fungi work on it to make it available), but it sure sells fertilizer!

Synthetic fertilizers with their few elements cannot replace the natural nutrient-supply system of adequate humus and beneficial soil organisms. (Some synthetic fertilizer materials are not harmful when used in the proper way; they can provide a needed boost to a crop if the natural system isn't working well.)

Large equipment makes short work of spreading fertilizers and pesticides in today's modern agriculture, but is this a case of going nowhere at an even faster rate?

Pesticides

We are told that the use of toxic herbicides and insecticides is essential to maintain an adequate food supply and our high standard of living. But what results has over 35 years of heavy use of highly toxic pesticides brought us?

1 About 400 species of insect and mite pests have developed pesticide resistance, as have many species of weeds.

2 Pesticides kill many organisms in the environment, not just the "target" species, upsetting the balance of nature. The elimination of natural enemies insures that pest problems will increase.

3 Pesticides are absorbed by plants and can be passed on to the animals (and people) that eat them. Some pesticides (DDT and DDE, for example) are found in the body fat of virtually every person on earth (as indicated by autopsy studies).

4 Some pesticides are very stable and persist in the environment for many years (others break down rapidly). Little is known about the possible effects of combinations of two or more toxic chemicals. Some combinations are much more toxic, or carcinogenic, than the separate materials.

5 Most of the ground water (and thus much drinking water) in agricultural areas is polluted by several pesticides, along with nitrates from excessive fertilization.

A Better Way

The need for these dangerously toxic chemicals can be greatly reduced or eliminated by following different farming methods than are currently being promoted by "the system." These methods promote soil life and humus, which automatically improve soil tilth, detoxify abused soil, and help crops grow healthfully. A healthy plant has built-in resistance to diseases and pests. For example, healthy corn plants release a substance called DIMBOA when their tissues are injured. DIMBOA repels young European corn borer larvae as well as inhibiting the growth of the fungi involved in northern corn leaf blight and gibberella stalk and ear rots.

The reason for pests and diseases in nature is to eliminate the unhealthy and unfit. They are attracted to or selectively attack sick or stressed plants, as recent research has shown. They tell us there is a problem we need to correct. Similarly,

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A Healthy Soil Builds a Healthy Society!

Continued from the previous page

weeds tell us there is something wrong in the soil. Most of them grow best in out-of-balance, compacted, or oxygen-starved soil. Are we listening to their message?

Why not farm a better way? And it pays off in the bank account, too. After the soil has begun to improve, the farmer will spend less for pesticides and even fuel (good loose soil is easier to plow). His yields should not fall off much if at all, while the quality, nutritional value, and market value of the crops will increase. If he feeds his crops to his livestock or poultry, the farmer will be pleasantly surprised by higher meat, milk, or egg production and fewer health and reproductive problems — meaning lower veterinarian and drug bills. And of course his and his family's health will improve from less exposure to toxic chemicals and from eating better food.

Making the Switch

Many farmers are so used to farming the "modern" way that they are hesitant to try changing to more natural methods. That's understandable. After all, they have to get a crop every year to pay the bills.

It may take several years to complete the change-over. On abused and heavy clay soils it takes longer, while lighter, less abused soils can respond in only a year or two. But if the farmer does nothing, nothing will get done.

If the farmer is not convinced natural methods work, he can begin with a small field or a test plot. Or he can begin the change on a larger acreage and only use pesticides when necessary. Often the rate of application of pesticides can be reduced by 1/3 or 1/2 with effective results. As the soil improves, the amount needed should lessen each year.

To be successful, one must know what he is doing or seek the advice of someone who does. Good soil testing methods, proper fertilizers and soil conditioners, and suitable tillage and waste recycling methods are of utmost importance.

The most important change that needs to be made is a change in attitude. We need to realize the vital importance of healthy soil and want or do whatever is necessary to obtain it. We need the attitude of building back the soil instead of taking from it. The natural created systems are designed to grow abundant, nutritious crops if we will just let them. Humus and soil life in well aerated soil can supply just the right balance of nutrients at just the right time to produce healthy crops.

Seeing the Light

More and more farmers are realizing that the system's agricultural methods are leading us into a quicksand-filled swamp. They see the problems first-hand — and they're getting worse. Farmers are looking for alternatives — a better way. There are precious few people expounding the better way, but their number is increasing.

More and more farmers are finding for themselves that they can get along without toxic herbicides and insecticides. Not only get along, but do much better than they were with them. They are growing better crops and healthier animals with less dollar input and more profits.

Toxic pest control in orchards is costly and risky. Biological alternatives are much safer and are effective.

It won't necessarily be easy. Soil that has been abused for decades may take a few years to recover. But once the farmer stops bad practices and begins good ones, recovery begins. Progress can usually be seen the first year if corrective measures are above a certain level.

Change is possible, and necessary for the survival of humankind. Will we change while there is time to prevent catastrophe? ■

Where You Lead....

SOMEBODY is following you.

Somebody is catching a glimpse of you as you thread your way through life and unconsciously going your way, perhaps merely because he knows no better direction to take.

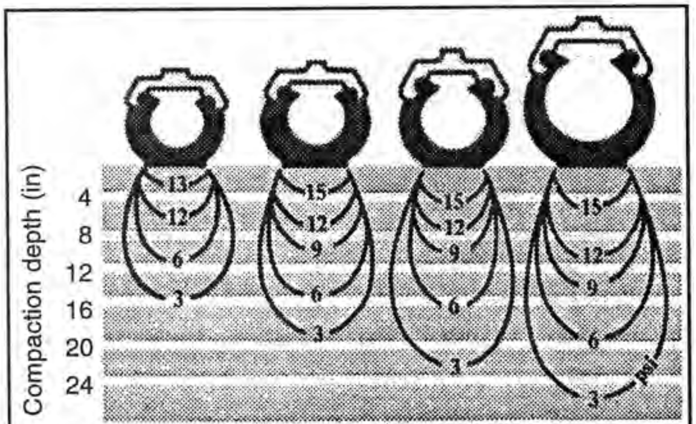
The fatal power of leading others is inescapable. And nobody is so insignificant and commonplace that he does not determine by his example the life of someone else. People do things because others do, more than for any other reason. This is the strange force of crowds, where we are swept along by the cumulative power of example to do what in our sober judgement we never would have done.

A little of this pulling power rests in every one of us. No matter how small and inconsiderable a person you seem to yourself to be, someone is being led by you. Unconsciously, even more than consciously, you are making this world a better or worse place, you are adding to its pile of happiness or its heap of misery, you are shedding light or spreading gloom.

Your "little nameless unremembered acts" are the ones that will weigh the most when the final books are balanced.

It's up to YOU what SOMEBODY will be!

Microbial Activity Reverses Compaction!



Tire size	7 x 24	9 x 24	11 x 24	13 x 24
Load	660 lb	1,100 lb	1,650 lb	2,200 lb
Pressure	12 psi	12 psi	12 psi	12 psi

Larger tires and heavier tractors exert the same pressure per square inch (psi) as smaller ones, but compact a wider, deeper area of soil.

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microbial activity.

Tractors and implements are major culprits in compacting the soil and creating horizons—such as plowpans and diskpans—that are highly impermeable to water, air, and root penetration. Not only do tractor, combine, sprayer, and implement tires apply great pressures to the soil, compressing and collapsing macropores and aggregates, but tillage tools such as plows, dishes, and cultivators routinely disturb the soil mass and apply forces that break up structural units while compressing the soil at the depth of tillage. Wheel traffic is no respecter of tractor or implement size either. Note the accompanying figure that shows how a wider tire will compact as much as, or more than, a narrow tire.[10] Only one pass of a tractor wheel is needed to cause dramatic increases in soil density, enough to severely inhibit good root development and deny the plant proper nutrients and moisture for proper growth.[11] The compacting effect is greatly magnified when the soil is tilled wet, for the plastic limits of the clay and organic matter complex will be breached much easier to allow a breakdown of aggregates.

The other major contributor to compaction is **reduced soil biological activity.** This factor works hand-in-hand with machine traffic, since a soil replete with an abundance of organic matter and well-balanced minerals will be less susceptible to initial tire and cultivation effects, and will recover faster after the structure and macropores have collapsed. Since soil fungi, bacteria, cyanobacteria, algae, and other life forms synthesize the polysaccharides, mucilages, and humates that glue together clay platelets, any reduction in earthworm and microbe activity will by reflected in reduced structural integrity. What, then, are the factors that affect soil organism activity?

Microbe Activity Factors

1. *Levels of organic matter addition to the soil*: crop residues, manures, and compost. These substances feed microbes and earthworms.

2. *Pesticide use.* Herbicides and pesticides kill not only the target weed or pest, but also beneficial organisms that aid in organic matter breakdown and structural development.

3. *Soil mineral levels and balance.* Insufficient or excessive soil minerals, or imbalances among them, will retard fungi, bacteria, algae, earthworms, and other soil organisms that build structural units and create channels through hardpans... much like a diet deficient in vitamins and minerals will stunt the growth of a person or animal. As regards soil structure, this is especially true for magnesium, since though it is a required nutrient for plants and microbes it can be detrimental to a sound soil structure if present in excessive amounts. Magnesium ions possess a higher hydration number than calcium ions (about 50% higher). Thus, according to Kerens, when magnesium is present in relatively high amounts its wide hydration shell would mean that "...less energy would be required to break down [high] Mg soil aggregates than to break down Ca soil aggregates. Thus, it is expected that [high] Mg soil would disintegrate more easily that Ca soil when subjected to rainfall...."[12]

4. *Acid-forming fertilizers.* The use of anhydrous ammonia and other nitrogen fertilizers acidifies the soil, causing the leaching of various cations from the soil, especially calcium which is so critical for the flocculation of clay and organic matter during structure formation. Sulfur, phosphoric acid, and ammonium phosphate fertilizers also acidify the soil, requiring lime (calcium and magnesium) additions over time, but anhydrous ammonia is the worst culprit. For every ton of anhydrous ammonia applied to the soil, 2,960 lb of calcium carbonate are needed to counteract its affects.[13] This highly acidifying effect is due largely to the dissolving of organic matter near the injection band in the soil, directly liberating carbon, nitrogen, and other elements (especially Ca and Mg) in the soil biomass.[14] Since anhydrous ammonia is injected into the soil to create concrete-hard military airport runways in tropical areas, it is easy to imagine the destructive effect it has on soil structure. Silica is also solubilized by the acidification process and is leached to lower soil levels where it is absorbed on soil particle surfaces. When combined with machinery traffic a true cementation occurs.[15]

5. *Tillage.* Initial tillage produces a flurry of microbial activity due to enhanced oxygen levels and the crushing of structural units, thus releasing organic compounds and minerals for microbial feeding. According to Trouse, "Forces from

See Avoid Tilling, page 9

Large machinery can get the job done quickly, but the payback in terms of soil compaction is highly deleterious to subsequent production.

Try to Avoid Tilling Wet Soils

Continued from page 8

such implements [tractors and farm implements] can compact tilled soil sufficiently to reduce root activity to 25% of its capability and reduce water insoak to where up to 90% of an intense rain can wash from soil surfaces, taking with it applied chemicals, fertilizers, and irreplaceable topsoil."[16]

Minimizing Compaction

While the goal of eliminating compaction while using agrichemicals and machinery may not be realistic, the best one can hope to accomplish is to limit compaction to the point that root development will not be seriously impeded. Yet, there is a lot one can do to manage one's cropping system to reduce—and in some cases eliminate—compaction. The forces of nature such as wetting and drying, freezing and thawing, and earthworm and microorganism activity all favor the development of a well-structured, non-compacted soil profile, so however well one conforms to the laws of nature that prescribe such favorable soil conditions will determine the success of an approach.

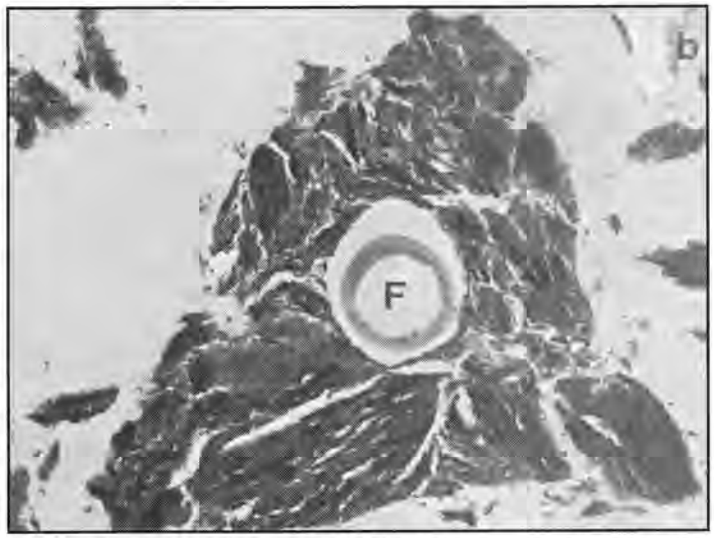
• **Reduce tractor and implement traffic over the field.** Each pass with a wheel or tillage tool adds additional pressure over aggregates to collapse their internal support and create layers of compacted soil which are impermeable to water and air, and are highly resistant to root penetration. To reduce traffic one can consider the following:

a) *Double up on field operations* (such as cultivating and fertilizing in the same operation). This makes good sense in terms of cost savings as well.

b) *Use controlled traffic lanes.* Run the tractor wheels in the same place each pass, which is common in ridge tillage and certain other systems.

c) *Practice minimum or zero tillage.* These management systems, however, have a negative side to them in that herbicides use—which works in favor of compaction—is usually integral to their adoption.

• **Do not till the soil when it is wet.** It is usually possible to exercise patience and wait to prepare the seedbed and plant in the spring when moisture conditions are proper. In a few cases it may not be possible to wait, in which case one must suffer the consequences, which will usually be noted as chlorotic, stunted growth in the wheel tracks of the previous year's crop.



***Note how the dark clay platelets are held together by the polysaccharides produced by a fungus (F). The nutrients held internally are thus protected from immediate loss, and compaction is prevented unless tillage breaks the unit.*[22]**

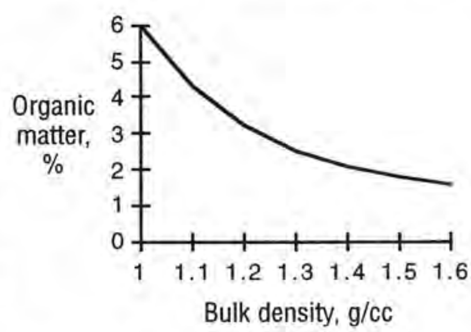
Despite the fact that Extension Service advice may be to plant corn in April in the Corn Belt or face yield losses for every day of delay, the 1996 cropping year in Iowa proved that a season delayed by three weeks can still give bumper yields of both corn and soybeans. Besides, weed control can be enhanced by allowing warm-season weeds to germinate before a final cultivation prior to planting.

• **Rotate crops, including a perennial legume.** The legume crop, such as alfalfa, serves a multiple function by (1) eliminating tillage for two to four years and thus allowing time for a strong structure to form, (2) breaking through compacted layers with the leguminous tap root system, (3) removing the need to apply microbe-destroying herbicides, (4) giving the soil support to counteract compacting effects of wheel traffic, and (5) maintaining a continuous soil cover to eliminate raindrop splash action and enhance rainfall infiltration and percolation, while reducing erosion to near zero. According to Dr. L. S. Robertson,[17] "Generally speaking, continuous cropping is a soil compacting process because plows are frequently used each year to bury crop residues. Both disks and mouldboard plows excessively pack the soil below the plow layer if the soil happens to be wet."

On the other hand, the closer one approaches a native plant ecosystem—which includes primarily deep-rooting perennials—the less will be a compaction problem.[18] See the accompanying table.[19]

Soil parameter	Cash crop	Continuous bluegrass
Total pore space, %	41.80	59.80
Air pore space, %	10.50	26.00
Water pore space, %	31.30	33.80
Bulk density, g/cc	1.48	1.11
Percolation rate, min/100cc	40.20	0.80

• **Restore vigorous soil biological activity.** This can be accomplished in a number of ways, the object being to build a predominance of macropores in the soil and strong structural units. Recall that stable aggregates will store and slowly release essential crop nutrients from their anaerobic internal environment. Strive to increase organic matter levels, since high organic matter means lower bulk density and reduced compaction (see the accompanying chart).[20]



a) *Return abundant crop residues and manures to the soil,* ideally to the surface as in natural ecospheres.

b) *Balance the minerals in the soil.* Maintain calcium at around 60 to 70% of the base saturation, and magnesium around 10 to 15%.

c) *Encourage a prolific earthworm population.* Research conducted by Zachmann and Linden has proven that earthworms substantially increase infiltration rates even in continuously cropped corn fields, and especially where crop

See Follow, page 10

Follow Nature's Laws to End Compaction

Continued from page 9

residues are present.[21]

d) *Apply a soil biostimulant to the soil in the cropping program.* One of the best of these is Vital Earth's Vitazyme. This material will encourage the proliferation of soil microbiota in the rhizosphere, especially mycorrhizae, and can help diminish compaction over a period of several months.

e) *Reduce agrichemical use to the bare minimum.* Better yet, eliminate the use of herbicides altogether.

f) *At last resort, subsoil.* However, this practice is very expensive and is only a temporary fix. The channels opened through compacted layers will soon close again unless the cause for compaction is first corrected.

Build Structural Units

The objectives of rebuilding a strong soil structure within compacted soil layers is achieved by promoting aggressive microbial action that results in an increased level of polysacharides and mucilages in the soil. These compounds serve as "glues" to hold mineral and organic particles together. As little as 0.02 % of added microbial carbohydrate can markedly stabilize clay aggregates. Earthworms and prolific root activity create additional channels to help open up compacted soils,[24] and mycorrhizal fungi, which can expand the feeding volume of the root by ten times or more, produce sac-like structures that encapsulate soil particles.

Soil compaction is one of the true archenemies of agriculture, and results from our modern methods that employ heavy tillage tools, agrichemicals, biocides, and an economic paradigm that discourages the recycling of minerals and organic matter back to the soil ... a one-way stream from farm to city. Nearly all fields are compacted to some degree. While total elimination of compaction may not be practical, one can reduce its severity substantially by harmonizing with natural laws as closely as possible, in particular by encouraging soil life.

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2. According to research by F. Norstadt, B. Payne, and C. Cole at Colorado State University, soil organic matter, N, P, and other plant nutrients are cycled slowly into available forms because they are bound within the confines of water-stable soil aggregates. The oxygen levels within these aggregates is low, creating insoluble forms that are stored until roots, tillage, water percolation, and microbes gradually break down the protective coating of the aggregates and release the nutrients. (*Agrichemical Age*, August/September, 1985).

3. For waterlogged soil, nitrate nitrogen can be lost at 15% in two days, 50% in five days, and 95% in ten days; this can translate to a 25 bu/acre corn yield loss in two days (Iowa State University data, in *Solutions*, July/August, 1984).

4. L. Gray and R. Pope at the University of Illinios showed that Corsoy soybeans suffered significantly more plant loss due to *Phytophthora* root rot in compacted soils. (*Crops and Soil Magazine*, Vol. 38, No. 4, January, 1986, American Society of Agronomy, Madison, Wisconsin).

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19. Same as 17.

20. Same as 17.

21. J. Zachmann and D. Linden. 1985. Infiltration as affected by two species of earthworms in tilled and untilled continuous corn. In *Agronomy Abstracts,* 1985 Annual Agronomy Society Meetings, Chicago, Illinios.

22. R. Foster, A. Rovira, and T. Cock. 1983. *Ultrastructure of the Root-Soil Interface.* The American Phytopathological Society, St. Paul, Minnesota.

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24. According to Trouse (reference 16), roots and rootlets may penetrate a soil area the size of a postage stamp 20 times.

What's in a Bushel of Corn?

A bushel of corn weighs 56 pounds and contains approximately 72,800 kernels. The average kernel is 61.0% starch, 19.2% feed, 3.8% oil, and 16.0% water. In processing, a bushel of corn will yield 32 pounds of starch...or 33 pounds of sweetener...or 2.5 gallons of ethanol plus 11.4 pounds of gluten meal and 1.6 pounds of corn oil. In 1995, aproximately 519.5 million bushels were used for ethanol, 398.8 million bushels were used for beverages, 183.5 million bushels were used for industrial starch, 118 million bushels for dry milled products, and 400 million bushels for nearly a dozen other general uses. Over 1,500.8 million gallons of ethanol were produced in 1995 of which Illinois had the lion's share with 583.5 million gallons; Iowa was second with 375.5 million, and Nebraska third with 283 million. No other state produced as much as 100 million gallons. In world production, the U.S. accounted for 38% of corn produced and no other nation comes close to 10% of the total. The U.S. exported 2,150 million bushels with Japan as the major customer at 634 million bushels. Since the passage of the North American Trade Agreement, U.S. exports have increased by over 840 million bushels.

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Correct Magnesium Levels Pay Dividends

Continued from page 4

wait for the potassium to be released by the reduction of magnesium. We recommend supplying any needed potassium for the crop at hand and then rely on a reputable soil test to show when extra is no longer needed.

Have you ever noticed the way some fields just seem to hold water and stay wet, while other fields nearby seem to have little or no problem at all? On those problem fields, even when subsoiled under the best of conditions, subsoiling does not achieve the desired results. Because magnesium helps to hold the soil together, the higher it is in the soil the tighter the soil becomes, and consequently the more water it holds. At worst, the water seems to stand in the field forever. Just keep in mind, the higher the soil's magnesium level the stickier it is when wet, and the harder it is when dry. The amount of magnesium in your soil helps to determine how much or how little it will be affected by excessive rainfall.

The ideal soil is shown in textbooks as 50% minerals and humus, 25% water, and 25% air. But it seems there is never an explanation as to what has to be done if your soil is not like that. The answer is tied to the amount of magnesium in the soil. In order to have the proper amount of pore space in the soil, a certain level of magnesium is required. This level must actually be measured in the percent of saturation, not the number of pounds per acre. It is the base saturation percentage which enables us to evaluate the soil's ability to produce in terms of yield. The number of pounds of material we need shows us what it takes to achieve the desired results. Even if a soil has a proper level of calcium but has low magnesium, it will not have the correct amount of porosity. There will be too much air in the soil. Yet, with the proper amount of calcium and too much magnesium the soil will not have enough air in it (too little porosity).

To achieve a beautiful, well-structured soil such as this, balance soil nutrients and be sure magnesium levels are not too high or low compared to calcium and potassium.

"When a soil has too much magnesium, the plants are not able to take it up adequately."

When a soil has too much magnesium, the plants are not able to take it up adequately. In fact, whether there is too little or too much in the soil, the plants growing there have trouble getting enough. We have measured this in crops as diverse as corn, strawberries, wine grapes, citrus, and pasture grasses. But when the levels are in the 10-15% range, with adequate calcium according to the leaf analysis, there appears to be no problem at all. Again, this helps to illustrate there is an ideal range for calcium and magnesium in the soil: with too little the crops will suffer, and with too much the crops will suffer. In order to assure that crops have the correct amount of magnesium, the soil must be neither deficient nor excessive, which is easily ascertained by the soil analysis we use.

What if a grower has too much magnesium in the soil? Some believe all you need to do is apply gypsum. However, gypsum will not work unless the calcium is already above the minimum range. First, check to see that there is adequate calcium present (60+% on the test we use, but this can vary from lab to lab). Then, so

See Magnesium, page 12

Humus, the Soil's Lifeblood

Continued from page 5

total amount of organic residue (from which humus will renew itself) is about three to four times that much.

Loss of soil fertility is nothing but loss of humus, normally from over-cropping. The growth of plants consumes humus which must, in turn, be replaced by the formation of new humus to prevent exhaustion of the soil's fertility. Chemical fertilizers can neither add to the humus content nor replace it; instead, they speed up the process of humus impoverishment, which is the main reason why we are using up our soil fertility so much faster than other nations have before us.

Why is humus such an important soil component? Humus has great moisture absorbing capacity, compensating for droughts and reducing to a minimum the peril of floods; it protects the soil from overheating during the day and overcooling during the nights; it acts as a soil binder to prevent erosion; it is essential for maintaining a thriving earthworm population; but above all it contains plant nutrients and billions of soil microbes in every ounce, which decompose and convert organic matter such as leaves, withered plants and roots, animal droppings and particles of rock into plant food. Some soil bacteria have also the ability to absorb nitrogen from the air to meet the requirement for this important element.

The common statement that most of our soils are now deficient in calcium, phosphorus and potassium is incorrect. Except in rare cases our soils have abundant resources of these plant nutrients, but they are locked up in

See Microbes Make, page 12

This sequence of peach shoots shows increasing zinc deficiency going left to right. While adding zinc fertilizers can alleviate the problem, oftentimes fresh organic residues which increase soil life will make tied-up zinc in the soil more available.

Microbes Make Nutrients Available

Continued from page 11

the rock materials and therefore not immediately available for plant growth. Relatively poor soil normally contains the equivalent of some 6,000 lb of calcium, 2,000 lb of phosphorus, and 30,000 lb of potash per acre in the top six inch layer, and many times as much as the seasonal requirements for most crops. Breakdown of the rock particles, liberation of the nutrients and their conversion into available plant food is all that is necessary, and such are exactly the functions of the humus and the microbial activities in fertile soil.

"Even fertile soil normally lacks enough nutrients in available form for vigorous plant growth ...."

Lately there has been so much talk about deficiencies in the soil of so-called "trace" minerals—such as boron, iron, copper, nickel, fluorine, manganese, iodine, etc.—and the adverse effect of such deficiencies on crops, domestic animals and national health. While the supply of these minerals in the soil is also normally more than adequate, they too are in non-water-soluble rock combinations and cannot be utilized by plants unless humus, microoganisms and other soil inhabitants are present in sufficient quantities to break down the rock materials into the kinds of compounds plants can assimilate. Mineral deficiencies are therefore common characteristics of humus-deficient soil, not of soil with enough humus.

It is of the most profound significance that the activating forces for these complex biological activities relate to the actual needs of the growing crops and primary shortages of available nutrients. This fact is recognized in one particular respect by all agronomists, who invariably recommend chemical fertilizers with little or no nitrogen in order to stimulate maximum nitrogen fixation in the nodules of leguminous crops; if sufficient nitrogen is added to the soil the microbes simply don't bother fixing any more. However, the same experts generally ignore that exactly the same principle holds true not only for other and more important forms of atmospheric nitrogen fixation, which are stimulated by plant growth in general, but also for the mineral requirements for plants. Even fertile soil normally lacks enough nutrients in available form for vigorous plant growth, and a good thing this is as otherwise a great deal would be lost by leaching, but fertile soil has instead the dynamic power to provide them as needed. Such has been, since the beginning of time, nature's efficient way to provide plant food in the required quantities and varieties.

THE USE OF CHEMICALS

Even if we possessed sufficient knowledge and it were practical to provide chemical fertilizers containing come 20 to 30 elements in the infinitely varying proportions required by plants—instead of only nitrogen, phosphorus and potassium as is now general practice—this would offer no solution to our soil problem. Forcing upon the plants immediately available food in the form of water-soluble chemicals, which they cannot reject but must absorb, constitutes a by-passing of the soil's extremely important functions in relation to plant life and all other life, in the same manner as intravenous injections of sugar or protein by-pass the digestive system of the human body. Neither can contribute to normal, vigorous life.

To be continued in the next issue of *The Vital Earth News, Agricultural Edition.*

Magnesium

Continued from page 11

long as there are sufficient water and sulfur or sulfate fertilizers used, and the soil is open enough for water to move through, magnesium can be leached from the soil. But if calcium is below 60% by the test we use, the magnesium will not be lowered, whatever amount of gypsum and/or other sulfate materials are used.

"Magnesium is a necessary part of high quality and high yielding crops ... but it can and must be controlled for best results."

Magnesium is a necessary part of high quality and high yielding crops. But it can and must be controlled for best results. And like about everything else on the farm, to do so requires understanding, time, and patience. ■

CORNFORMATION

The average American consumes 3 pounds of corn every day in the form of meat, butter, milk, and cheese. Figuring 230 million people, more or less, that's 690 million pounds or approximately 12.3 million bushels per day. Which comes to nearly 4.5 billion bushels of corn per year for human consumption. And that's a lot of corn, folks!

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Much of our unhappiness comes from comparing ourselves with other people.

Statement of Purpose

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