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JOHN'S CORNER

TO TILL OR NOT TO TILL

by John Ferguson

I've heard we should NOT till garden beds, that it disturbs the microbes, soil bacteria, whatever. Back in my boyhood we used to disk and harrow the fields to break up the soil every year, and I've carried that same practice over to my garden beds today. If I have to pack away my beloved Mantis Tiller I will, but I'd like a fuller explanation as to why it's beneficial.

Thanks!
Jere

Tillage is a root cause of agricultural land degradation, one of the most serious environmental problems worldwide. Over the years as a member of the Soil Science Society of America, the American Agronomy Society and the Crop Science Society and numerous others, I have read hundreds of articles related to tillage or no-till methods. However, I have never looked at the history of tillage so I thought a brief overview would be interesting.

Tillage has been around since 8000 B.C. when a sharp stick was pulled through the ground to make a trough to plant seeds. By 6,000 B.C. draft animals (oxen) were used to pull the simple plow. Around 1100 A.D. the moldboard plow was developed with a curved blade to invert the soil, burying the weeds and crop residue. In 1837 John Deere developed the steel moldboard plow that allowed farmers to break up the tough prairie sod. In the early 1900's tractors could pull multiple plows at once and finally roto-tillers were developed to pulverize the soil and we thought all was well. Then the "dust bowl" era of 1930-1939 occurred. This environmental (and financial) disaster exposed the dangers of tillage.

In 1943 an agronomist named Edward Faulkner wrote a book called "Plowman's Folly" that questioned the need for tillage and the no-till era had begun. In his first paragraph he stated, "The truth is that no one has ever advanced a scientific reason for plowing".

In the 1950's the Soil Conservation Service (now National Resources Conservation Service) began measuring soil erosion and loss. Research on modern no-till methods began in earnest during the 1960's, triggering counter-publicity from plow, tiller and tractors manufacturers.

Over the years many types of tillers (plows) and methods have been developed but that is beyond the scope of this article. In general, conventional tillage uses a moldboard plow which turns and covers 90% of the crop residue (primary tillage). Another pass through the fields with a disk tiller to smooth the ground surface and finally a third pass with a cultivator to prepare the seed bed is required (secondary tillage). In gardening our gas powered roto-tillers do both types in one pass.

In the 1990's researchers from Cornell University estimated that the cost of undoing damage from tillage was costing the USA $44 billion per year. In 1993 a study by researchers at the University of Kentucky found that no-till methods decreased soil erosion by 98%! Other research found that for every dollar invested in soil conservation would save society $5. Additionally, no till methods saved farmers the cost of buying expensive equipment and the fuel and labor costs of multiple trips through their fields.

The 1985 Farm Bill gave farmers incentives to switch to no-till methods along with the much higher fuel prices. As a result the USDA developed a program called conservation tillage as a first step toward no-till and to help farmers make the transition.

It is estimated that no-till methods have helped the USA avoid 241 million metric tons of carbon dioxide emissions which is equivalent to the annual emissions of 50 million cars.

So, what is No-till?

By definition a no-till system allows no operations that disturb the soil other than planting or drilling.

So, why did we till (plow) in the first place?

The assumption was that tilling the soil would loosen it so that more air and water could reach the root zone. It seemed logical that friable, loose earth would allow roots to grow and spread. However this was not the case. Plowing and disking results in a soil with a broken structure lying on top of a heavily compressed plow pan layer that forms beneath the plow depth. The broken soil structure clogged the pathways (channels) between soil particle that allowed air and water to freely enter the soil. With reduced airflow in and out of the soil they becomes more anaerobic or low in oxygen. The low oxygen conditions reduce root growth and encourages soil pathogens to grow. This same sealing prevents water from easily entering the soil which causes water to pile up on the surface of the soil and run-off which then leads to massive erosion. The loss of soil structure returns the soil to its original very tiny components that are light and can blow (e.g. wind erosion that created the dust bowl).

Healthy soil is composed of *peds*. These are the basic units of soil structure formed by microbes gluing the individual soil particles together, whether it be clay, silt or sand. They have distinct boundaries and well-defined planes of weakness between the aggregates. Peds consist of primary particles bound together by cementing agents like organic matter, clay, and hydrous oxides of iron and aluminum. Peds can take many shapes and creates the channels that air and water use (See figure below).

Many microbes help build or create the ped structure found in healthy productive soil (sometimes referred to as soil tilth). The glomulus fungus produces a glue called glomalin that helps form the peds. The fecal material from this fungus is food for a bacteria that produce chemicals called polysaccharides a type of complex sugar that also glues small particles together or as shell around the bacteria to prevent it from being eaten by protozoa forming a micro-aggregate. Other fungal species tie these micro-aggregates together forming the ped.

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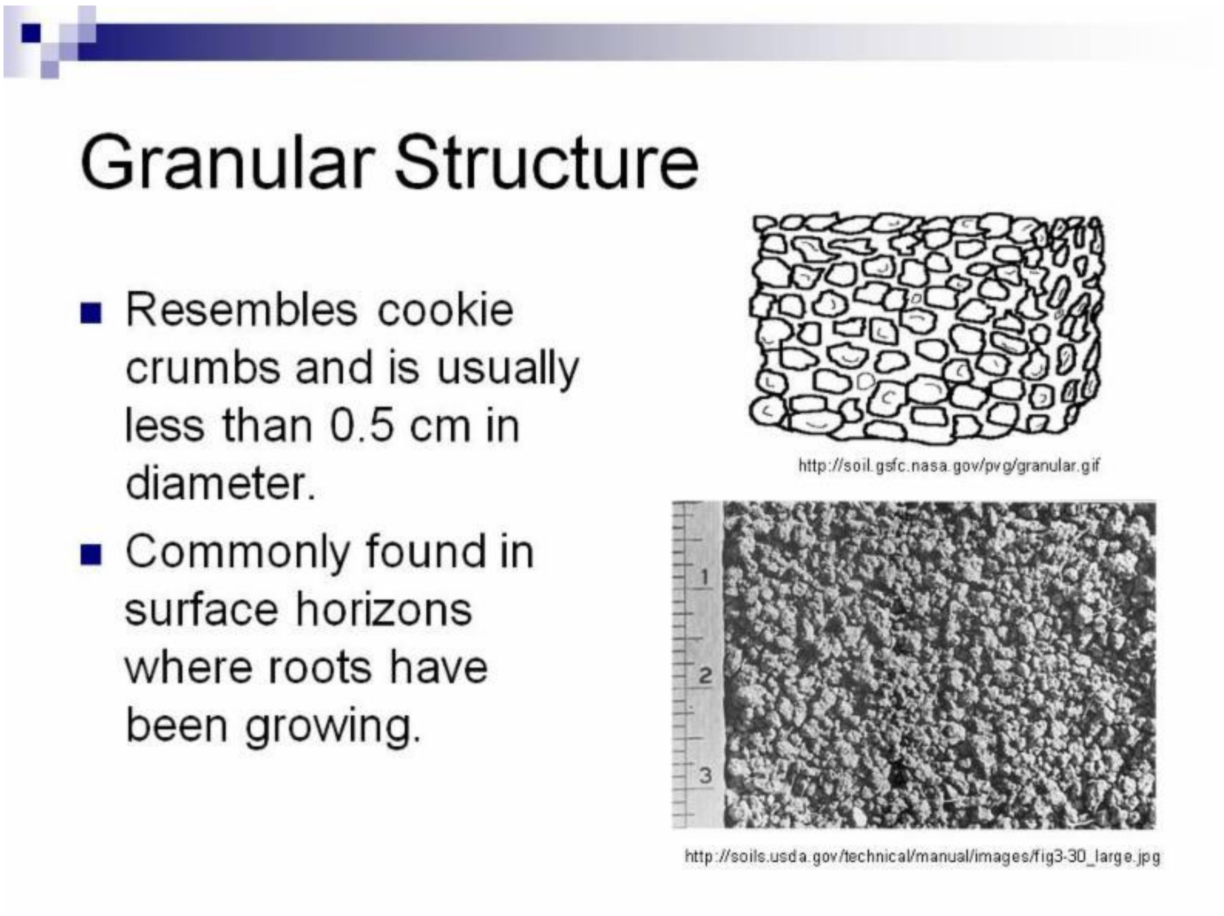

When we till the soil we rip apart the fungal hyphae in the soil which kills the good fungus. Without the fungus we do not have the populations of the correct bacteria to form peds. Without the creation of new glues, the existing ones are biodegraded over a couple years and the soil structure collapses. Additionally, tillage kills earthworms, microanthropods and other soil life that also contributes to good soil structure.

Every gardener should have read the following book by now and will help one understand the biological processes better.

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Teaming with Microbes. 2nd edition, A Gardener's Guide to the Soil Food Web, by Jeff Lowenfels & Wayne Lewis, Timber Press, 2013, *ISBN-13:* 9781604691139, *Highly Recommended*
This book is a great non-technical explanation of soil biology and why organic gardening methods work so well.

SUMMARY:
The only time we should till is in preparing a new bed for the very first time. In this case tilling can help kill weeds and grass, mix soil amendments into the soil, and help level the bed area.

PROS:

- aerates soil (temporary)
- reduces compaction (temporary)
- accelerates the conversion of organic N into plant available mineral N
- mixes amendments into soil (gypsum to break up high salt crusts and evenly spread throughout mix zone)), incorporate fertilizers for better utilization
- break up soil aggregates, creates a temporary loose porous condition conducive to young roots and emergence tender seedlings (long term it weakens soil aggregates)
- mechanically destroys weeds
- dries out soil before seeding
- if tilling in the fall then the exposed clods with repeated wetting/drying, freezing/thawing tend to flake and crumble making a smooth bed for seeding in spring
- lower cost than some herbicides for weed control

CONS:

- dries soil before seeding
- soil looses a lot of nutrients
- soil loses its ability to store water
- decreases the rate at which water soaks into the soil which results in more runoff and erosion
- tilling dislodges the cohesiveness of the soil leading to more erosion
- increases chemical runoff
- reduces organic matter in soils

- reduces all life in soil (fungus, earthworms, microanthropods, etc.
- destroys soil aggregates
- creates soil compaction
- causes eutrophication (dead zones) of nearby waterways
- attracts slugs, cutworms, army worms and other harmful insects
- crop diseases can be harbored in crop residues as reduced beneficial microbes to control them
- greatly accelerates soil erosion
- sediment downstream clogs waterways
- the aeration provided in the short term usually declines after a few years
- sub-surface hardpans formed by conventional tillage
- increase decomposition rate of organic matter previously protected (destroys humus)
- leads to crusting and additional compaction by rainfall
- changes soil properties erodibility, hydraulic conductivity, increase soil bulk density over time (less air space, less organic matter (humus)
- dust bowl caused by tillage (1930's)
- if soil is too wet, tillage smears soils destroys macro porosity (puddled conditions)
- reduces CEC (cation exchange capacity - the ability to hold and store nutrients)
- destroys soil ped structure
- reduces water holding capacity of soils
- destroys pores and worm tunnels that allow deep drainage recharge water table
- destroys fungus allowing soil to become highly bacterial - conditions which are preferred by many weedy species of plants
- forms many types of hard-pans (silt pans, iron or aluminum pans, clay pans or simple compaction pans
- heavy equipment created plow pans (traffic pans) that became worse each year as multiple passes of equipment
- kills many microanthropods that eat pest nematodes
- destroy fungus species hyphae that stores calcium in the soil
- lack of organic N leads to increased N fertilization requirements which increases a plants susceptibility to fungal diseases
- makes some nutrients unavailable leading to nutrient imbalances in plants (more susceptible to insects and disease)

- increases weeds (weed seeds need light to germinate, hence tilling exposes buried seeds to light causing them to germinate)
- increases nitrous oxide (NO_2) emissions from soil (NO_2 is 200X worse than CO_2 to global warming)
- increases carbon dioxide (CO_2) emissions from soil increasing the contribution to global warming

PROS of NO-Till:

- soybeans had more nodules, more biomass (8%), and fixed more N (74kg/ha)
- plants roots, worms, arthropods, other life forms are much higher
- after 7 years work root density was 36X higher
- reduces methane (CH_4) emissions from soil (methane is 23X worse than CO_2 to global warming)
- erosion control, water conservation, cleaner environment, greater crop yields, greater water infiltration
- increase mean residence time of carbon in soil (increase humus or stored CO_2)
- after decades of tillage (destroying the soil) in may take many years to see benefits (must undo the damage) versus virgin ground that shows benefits immediately
- increases all forms of organic matter in soils
- dark color of organic matter enhances soil warming in spring which promotes growth
- 98-100% less erosion

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