Soil Quality team

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Dr. Jeff Novak discusses Soil Quality with visitors at the Florence, SC Research Station .

Soil organic carbon contents increase in long-term tillage plots

By J.M. Novak, USDA-ARS, Florence SC

At the USDA-ARS-Coastal Plains Soil, Water and Plant Research Center, in Florence, SC, scientists continue to determine the effects of long-term crop and tillage management on soil organic carbon (SOC) levels in a Norfolk loamy sand soil. The plot study, located at the Clemson University Pee Dee Research and Education Center in Florence, SC, was initially set up in 1979 with a continuous corn rotation. The purpose of the study was to examine the interaction of tillage effect on crop biomass production and the effect of plant residue removal on crop yields, and soil chemical and physical properties. These initial crop management conditions were modified in the 1980s and 1990s to include a 2 yr rotation of corn, winter wheat, and a summer crop (soybeans or cotton). In 2003, cereal rye was planted instead of wheat to serve as a winter cover crop. The plots were managed over 24 yrs using either conventional (disking and non-inversion deep tillage), or conservation tillage (deep tillage only). Annually, soil samples were collected from the top 6 inches of the plots, divided up into 2 inch increments, and SOC levels were determined.

In the early 1990s, Dr. Patrick Hunt and colleagues at the Florence location examined SOC contents after 14 yrs of tillage and crop management. They divided the data into two pools representing soil conditions before the experiment started (0 yrs, 1979) and after 9-14 yrs (1987- 1992). They reported a significant SOC increase after 9 yrs of conservation tillage management. These SOC content increases were, however, limited to the top 0-2 inch soil depth. There were no significant SOC increases between tillage's in two lower topsoil depths (2-4 and 4-6 inch).

Increasing the SOC content in a sandy Norfolk soil using conservation tillage with typical crop rotations was a major accomplishment. Prior to this finding, it was questionable whether this could be accomplished in a sandy soil because of Carolina's climatic conditions that favors organic matter decomposition.

Dr. Jeff Novak and colleagues continue to monitor SOC contents in the two tillage systems. They separated the data pools into time periods to represent 16-18 and 19-24 yrs after the study commenced. They found that within a tillage system the mean SOC contents remained similar between 16-18 and 19-24 yrs. In other words, **under this crop rotation and tillage management scheme**, SOC levels did not increase further after 16 yrs. Additionally, it is possible that the droughts over the past few years have confounded predictable relationships between crop residue production, decomposition and the ability of soils to retain organic matter.

Although the SOC levels under conservation and conventional tillage leveled out, the long-term increase in SOC levels compared to initial conditions is impressive. For instance, the mean SOC contents in the Norfolk 0-5 cm deep soil increased 300% (from 0.53 to 1.59%) after 24 yrs of conservation tillage management. Likewise, the mean SOC contents in the Norfolk 0-2 inch deep soil under conventional tillage also increased, but only by 150% (from 0.63 to 0.93%).

Currently, there is a great deal of interest in how much C can be sequestered in soils. This interest is due to the fact that atmospheric CO_2 concentrations are rising and are thought to be responsible for global warming. We have shown that increasing SOC levels in a sandy soil using conservation tillage is possible under Carolinas climatic conditions. This finding shows the benefit of our regional soils serving as a C sink to off-set CO_2 atmospheric emissions.

GLOMALIN – THE SCUMMY SOIL BUILDER

By K.A. Nichols Soil Microbiologist, Northern Great Plains Research Laboratory, USDA-ARS, Mandan, ND

Why Build Soils?

First take a medium sized apple and imagine that it represents earth. Now, slice the apple into four pieces and remove all but one piece. This piece represents all of the land, since earth is ¾ water. Next, slice that piece in half. Keep one of these halves or an eighth of your apple.

This eighth represents the land people can live on while the other eighth is inhospitable (i.e. under polar ice caps, on top of mountains, etc.). Now, slice this in half leaving one sixteenth that is too cold, wet, rocky, or dry to grow food and one sixteenth that could be used for food production.

However, people need places to live, highways to drive on, shopping malls, and manufacturing facilities which take up about half of that sixteenth. Finally, take the other half of the sixteenth or one thirty second and look at it carefully. Only the surface of the earth can be used to grow food, right? So, remove the peel. This thin peeling is what is used to grow enough food to feed the over 6 billion people on earth. To be able to continue to feed these people and even more people, we need to look at our soils as a precious resource.

Therefore, I want you to begin thinking about yourselves as not just food or commodity producers but as soil builders who will provide the resources to feed the world now and in the future. This is good for the rest of the world but what does this mean for you. Soils are living, dynamic

Mean SOC contents (as %) in long-term tillage plots at Clemson University, PDREC

		Years in tillage/crop management			
Tillage	Soil depth (inch)	0 (1979)†	9-14 (1988-1993)†	16-18 (1995 -1997)	19-24 (1998-2003)
Conventional	0-2	0.63	0.72	0.92	0.93
Conservation	0-2	0.53	1.20	1.60	1.59
Conventional	2-4	0.52	0.56	0.79	0.75
Conservation	2-4	0.46	0.63	0.86	0.75
Conventional	4-6	0.39	0.45	0.50	0.52
Conservation	4-6	0.45	0.48	0.66	0.48

†Data from Hunt et al. (1996).

systems. If you build your soils, you will increase the resiliency of your production system by improving nutrient cycling and water and air

infiltration which will reduce input costs and increase production.

How do we build soils and what tools are needed? To build soils, just like when building a house, supplies (i.e. wood, cement, nails, etc.) and people (i.e. laborers, electricians, plumbers, etc.) are needed. In the soil, the supplies are sand, silt, clay, carbon, nitrogen, and other nutrients.

However, without the builders, no matter how many supplies you have you will never have a house. Who are these builders? They are soil biota. Billions of soil organisms – earthworms, insects, mites, bacteria, fungi, etc. – are living beneath our feet. In fact, more organisms may be present in a teaspoon of soil than there are people on Earth. These organisms come in all shapes and sizes and use different supplies to build different parts of the 'house' (i.e. soil). Each organism has a role just like each of the people involved in building a house in converting nutrients into forms available to plants by processes such as organic matter decomposition and nitrogen fixation. These organisms are related in a complex food web where one organism can't build the soil alone (Fig. 1). If you remove a group of organisms, then the whole web may collapse.

What is Glomalin (i.e. Soil Scum)?

One group of microorganisms that is important in nutrient

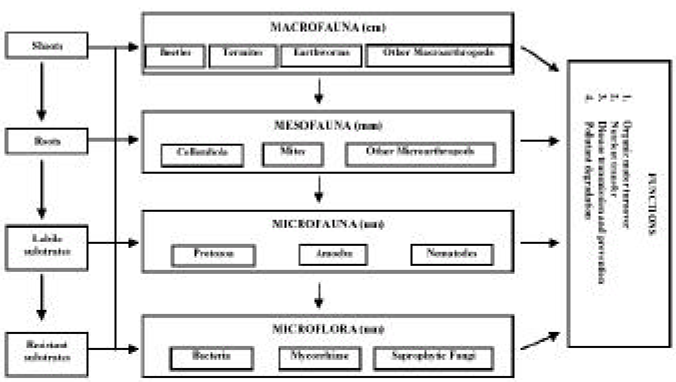

Figure 1. A complex food web exists in the conversion of plant debris and other substrates into plant available nutrients by a number of soil organisms. This diagram illustrates how different groups of organisms impact each other in this process.

cycling and adding structure to soil is arbuscular mycorrhizal (AM) fungi. Arbuscular mycorrhizal fungi form a mutually beneficial relationship with most (about 80%) plants (including many crop plants). The body of AM fungi consists of hyphae (which look like fine thread in the soil or long strands of hair coming out of plant roots) (Fig. 2).

Hyphae will grow out of roots and several centimeters (or 1-2 inches) into the soil. The structure of a plant's root only allows it to remove nutrients in the immediate area

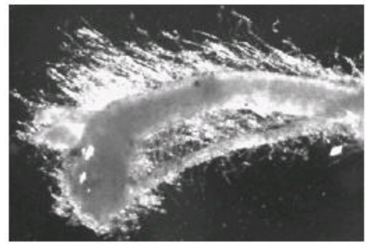

Figure 2. Long, thin thread-like strands of hyphae stick out of plant roots and grow into the soil to collect nutrients that the plant needs.

around the root. To obtain all the nutrients a plant needs, AM fungal hyphae extend beyond the nutrient depleted area around plant roots to deliver more nutrients to the root from the soil, especially immobile nutrients like phosphorus. These nutrients are carried back to the plant by the hyphal 'pipeline'. In exchange, the plant provides the fungus with carbon in the form of simple sugars that the plant produces in abundance by photosynthesis.

Numerous strands of AM hyphae (Fig. 3) form a net that entraps organic matter, clay, sand, silt, and other soil debris to form soil aggregates.

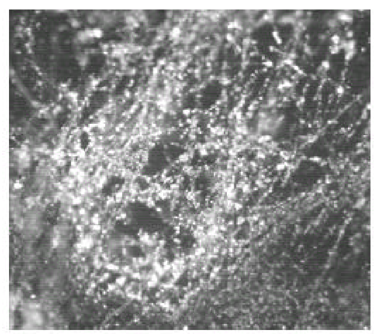

Figure 3. Strands of AM hyphae coated with glomalin physically entrap debris to initiate aggregate formation. After a laboratory procedure, bright spots indicate the location of glomalin.

Aggregates are glued together and 'protected' or stabilized by biomolecules, such as **glomalin**. **Glomalin** which was identified in the early 1990's is produced by AM fungi to protect the hyphal 'pipeline' from nutrient loss. In other words, glomalin acts to transform hyphae that are normally like paper tubes in the soil into stable PVC pipe. **Glomalin** is a sugar protein that is both sticky and water-insoluble which will slough off hyphae and become scum (Fig. 4).

Figure 4. Water-insoluble glomalin sloughs from fungal hyphae and aggregates together to form a foamy scum on the water surface..

When released from hyphae, individual **glomalin** molecules will stick together to form a scum on the surface of the water. This scum will attach to any nearby surface, especially aggregates that are formed around fungal hyphae. The sticky part of the **glomalin** molecule helps to glue aggregates together while the water-insoluble part forms a protective PVC-like lattice on the surface of soil aggregates (Fig. 5). So aggregates are important for many reasons including:

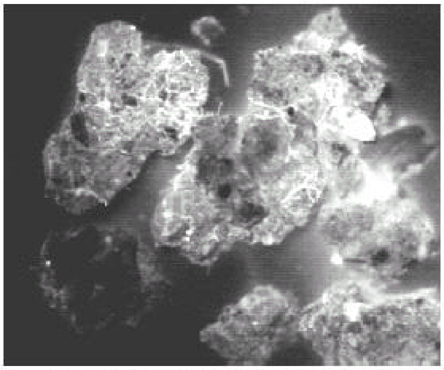

Figure 5. Glomalin is sloughed from hyphae onto a 1 to 2 mm aggregates to form a protective, insoluble coat that keeps aggregates water-stable. After a laboratory procedure, bright spots indicate the location of glomalin on the aggregate.

- Increasing the soil's stability against wind and water erosion.
- Maintaining soil pores, which provide air and water infiltration rates favorable for plant growth.
- Improving soil fertility by holding nutrients in protected microsites near the plant roots.
- Increasing organic matter concentrations by protecting plant and root biomass from decomposition.

Management influences aggregate stability and **glomalin** concentration (Fig. 6). In a never tilled, moderately grazed pasture, the water-insoluble **glomalin** coating encases aggregates so well that they will float on the surface water.

Without **glomalin**, water rushes into air-filled pores within aggregates. Because water diffuses more rapidly than the air can escape, air pressure in these pores increases and the aggregate bursts. When this occurs, as in the conventional till (CT) and no-till (NT) soils, aggregates are disrupted into smaller conglomerations, called micro aggregates) or fine particles which may be easily transported by wind or rain (Fig. 6B). With **glomalin**, a water insoluble barrier is formed on the aggregate, which allows water to seep in slowly and prevents aggregates from bursting. The more **glomalin**, the more water-insoluble the aggregates become.

How can YOU be a SOIL BUILDER?

To be a soil builder, you must manage your system appropriately. The management system that are most successful to increasing AM fungi, **glomalin**, soil biota, and organic matter (i.e. building soils) are those that include:

- Reduced or no tillage,
- Continuous cropping,
- Diverse rotations,

(Continued on page 5)

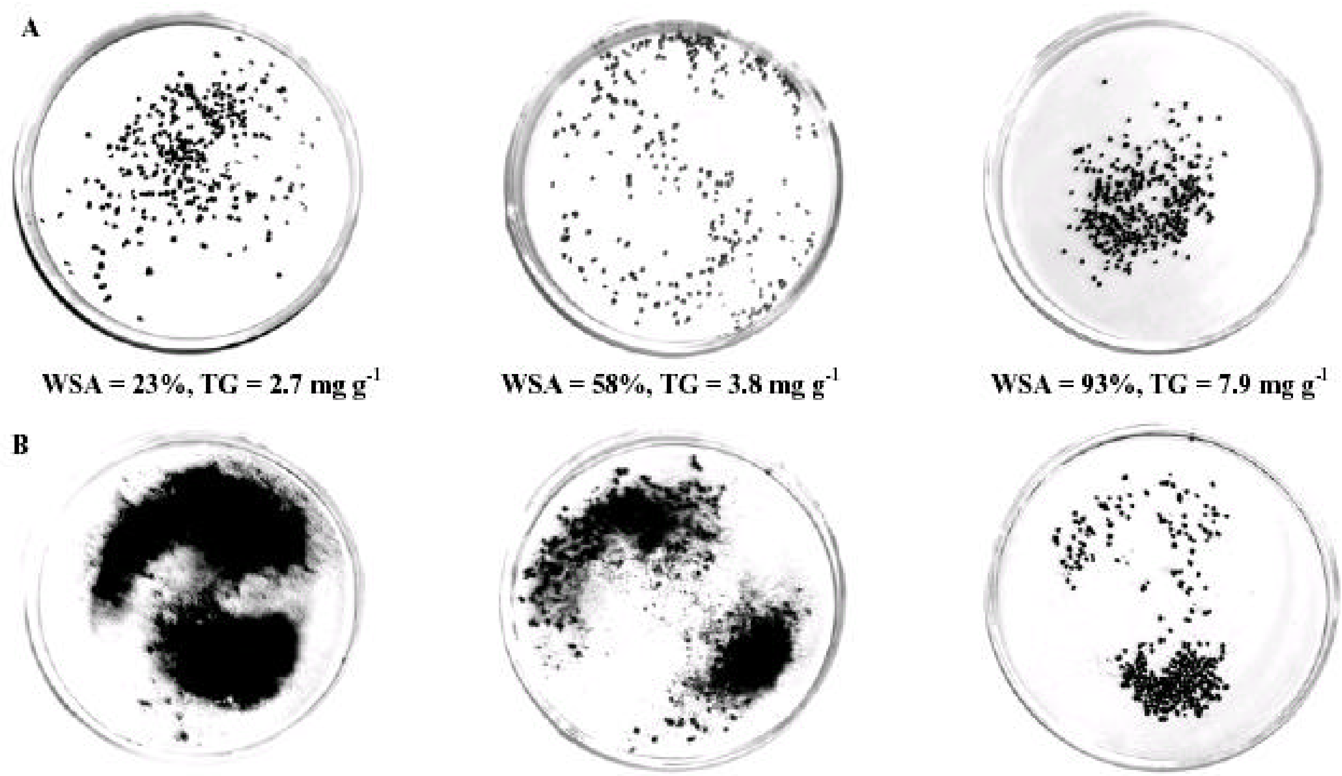

Figure 6. Dry-sieved soil aggregates (1-2 mm) (A) look about the same, but after the addition of water (such as during a rainfall event) (B), these aggregates do not act the same. Concentrations of water-stable aggregates (WSA) and glomalin (TG) in three soils at the Northern Great Plains Research Laboratory change with management (from left to right): spring wheat (SW)-fallow, conventional till; SW-winter wheat-safflower, no-till; and never tilled, moderately grazed pasture.

Reduced fertility inputs (especially P fertilizers), and
Minimum use of nonmycorrhizal crops such as canola, crambe, cabbage, broccoli, and cauliflower).

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employer."

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2005 Southern Conservation Tillage Systems Conference

The Science of Conservation Tillage: Continuing the Discoveries

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Dear Bobby Brock,

While going through a box of old books, looking for stuff to throw or give away, I came across the 1903 USDA yearbook. I don't really have the time go through it carefully, but I found the following during quick glance at an article by F.H. King, then Chief of Division of Soil Management, Bureau of Soils:

More Frequent and Deeper Plowing Needed
There can be little doubt that deeper plowing will not only lessen the tendency of Southern soils to wash, but that it will increase their general productive capacity. The deeper general plowing at frequent intervals, quite likely as often as once a year, will not only increase the effective openness of the soil, but it will greatly aid in developing a stronger and better granulation, and both conditions are necessary to reduce the tendency to wash.

Dr. Fred Magdoff

(I'll bet I can hear Will Mann hootin' and slappin' his knees all the way to Raleigh!!) BGB

Farmer Riggin'

By Teresa Hice, Wake SWCD

Jeff Deen, a Champion of Conservation (Partners May/June 2004), shared his adaptation to his no-till planter that helps prevents the cover crop from hanging up. Jeff took over the 650-acre farm after the death of his father in 1980. He grows peanuts and cotton. Six years ago, Jeff and his wife, Michelle, started no-tilling the cotton. In 2004, Jeff planted no-till peanuts for the first time so their farm is now a "No-Plow Zone". Michelle says, "No-till is good in every way I can think of".

Jeff uses a 1970 KMC unit with rubber tires that rips and plants in one trip. He bought the rig cheap since it had been sitting in another farmer's bushes for 20 years. Jeff plants in a heavy rye cover, 6 to 7 feet tall. Jeff says, "I believe if your not using a heavy cover crop, you're not really trying". The cover is not rolled, and will hang-up on the leading edges of the planter, the "H" shanks and the ripper. These edges were covered with Teflon but the covers don't come cheap. When they wore out, Jeff decided to do some farmer rigging. He cuts 2", 4", and 6" black plastic pipe long ways and clamps the pieces to the metal of the planter and shanks.

This picture shows how Jeff uses black plastic pipe and pvc pipe to keep residue from hanging on the tool bar and coulter in no-till planting.

Jeff Deen is dedicated to the use of heavy ground cover and continuous no-till.

Pictures by: Joey A. Futch, District Conservationist, Baxley GA., USDA-NRCS,

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