

TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE
PORTLAND, OREGON

NATURAL RESOURCES CONSERVATION SERVICE
OCTOBER 2009

OREGON SOIL QUALITY TECHNICAL NOTE NO. 3

Submitted by Dr. Stewart Wuest, USDA Agricultural Research Service, Pendleton, Oregon

How Tillage Affects Water Infiltration

Experience with no-till systems has proven that farming with little or no tillage results in better water infiltration, less runoff, and less soil erosion. Changing from tilled cropping systems to no-till systems results in many changes in the soil and in the position and fate of crop residues. No-till systems usually have continuous surface cover by residue of various ages, along with shallower and less extensive soil disturbance. This results in the preservation of crop root channels and a more attractive environment for earthworms and other soil animals. At the same time, no-till systems often have higher soil bulk density near the surface and less surface roughness than conventionally tilled soils.

It is important to understand the factors controlling water infiltration so we can design systems which maximize infiltration while at the same time maintain flexibility to solve other agronomic problems. As it turns out, the properties of a thin layer of soil on the surface control the maximum infiltration rate. Tillage affects infiltration by altering both the strength of soil aggregates at the surface and the amount of protection of aggregates by surface residue.

For a discussion on the concepts of infiltration, go to the Soil Quality Information Sheet, *Soil Quality Indicators: INFILTRATION* (<http://soils.usda.gov/sqi/publications/files/Infiltration.pdf>).

Factors Controlling Water Infiltration

The most important factor determining whether water will run off is the ability of the soil surface to resist slaking and reconsolidation, also known as crusting. Slaking is when wet soil aggregates (tiny clusters or clumps of soil) break apart into smaller aggregates or separate soil particles. When very small aggregates or individual sand, silt, and clay particles are free to move with the movement of water, they settle into a very compact layer. When this layer dries, we recognize it as a crust, but even when it is wet this layer is nearly impermeable.

Root channels, pores and cracks that develop over time in an untilled soil are not nearly as important as the prevention of surface crusting. Continuous soil pores only play a role in water infiltration if they happen to open at the surface in a place where water has accumulated.

In a soil where crusts are forming, these pores are quickly sealed by slaked soil. In a soil where aggregates are protected and strong enough to resist slaking, there is little surface water accumulation.

Surface residue helps protect aggregates from slaking. It reduces the action of rain, snow, freezing, thawing, wetting and drying that tends to break soil aggregates apart. This is why erosion prediction models give significant credit for the amount of surface residue cover. Surface residue improves water infiltration and reduces runoff and erosion even on intensively tilled soils. Its role as a source of organic matter, however, is even more important to long-term improvement in infiltration.

The Role of Soil Organic Matter

The soils of many dryland regions of the United States, including the Columbia Plateau, form very fragile aggregates (Pierson and Mulla 1990). This is partly because these loess soils have low clay content, and the warm, semi-arid environment does not allow much organic matter to accumulate. Clay helps bind aggregates together. Organic matter is even more important than clay in creating and binding soil particles into strong aggregates resistant to slaking.

The amount of organic matter in a soil is the most important factor determining the strength of soil aggregation. The effect of soil organic matter on aggregation and infiltration can be illustrated with data from long-term plots maintained by Oregon State University and the USDA Agricultural Research Service at Pendleton, Oregon (Machado et al. 2005). The Crop Residue experiment was established in 1931 to test the effect of residue management and manure applications on soil and crop production. These plots are in a winter wheat-summer fallow crop rotation with different residue management and fertility treatments. These treatments result in various amounts of residue being returned to the soil. After winter wheat harvest, residue is treated in several ways: one plot is burned in the fall and three others are burned in the spring. One plot receives 10 tons (wet weight) of barnyard manure, and another receives one ton of pea-vine hay collected after fresh pea harvest. All plots are plowed in the spring, followed by cultivation and rodweeding through the summer-fallow period. This leaves the soil surface completely bare in all treatments, so these data demonstrate the effect of soil organic matter alone without any surface residue protection.

FIGURE 1. Treatments of the Crop Residue experiment, Pendleton, Oregon, arranged in order of decreasing soil organic matter in the surface four inches (bar chart on left). All three charts have the bottom axis scaled so that the fourth treatment (80 lb N/acre—no burn) is 100 percent.

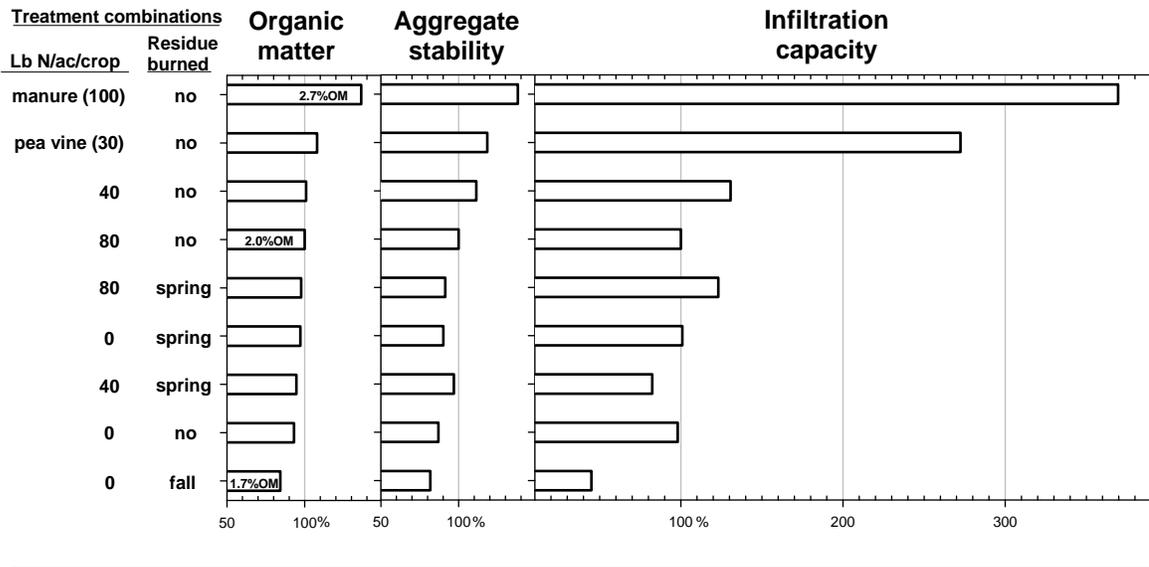


Figure 1 shows treatment combinations and nitrogen (N) fertilizer rates, arranged in decreasing order of soil organic matter measured in the top 4 inches after 70 years (Wuest et al. 2005). Aggregate stability, shown in the middle chart, mimics organic matter very closely because soil organic matter holds aggregates together. A ton of pea vines applied in the spring every other year for 70 years (35 tons total) increased organic matter relative to the 80 lb N/acre—no burn treatment by 10 percent. It increased aggregate stability by about 20 percent.

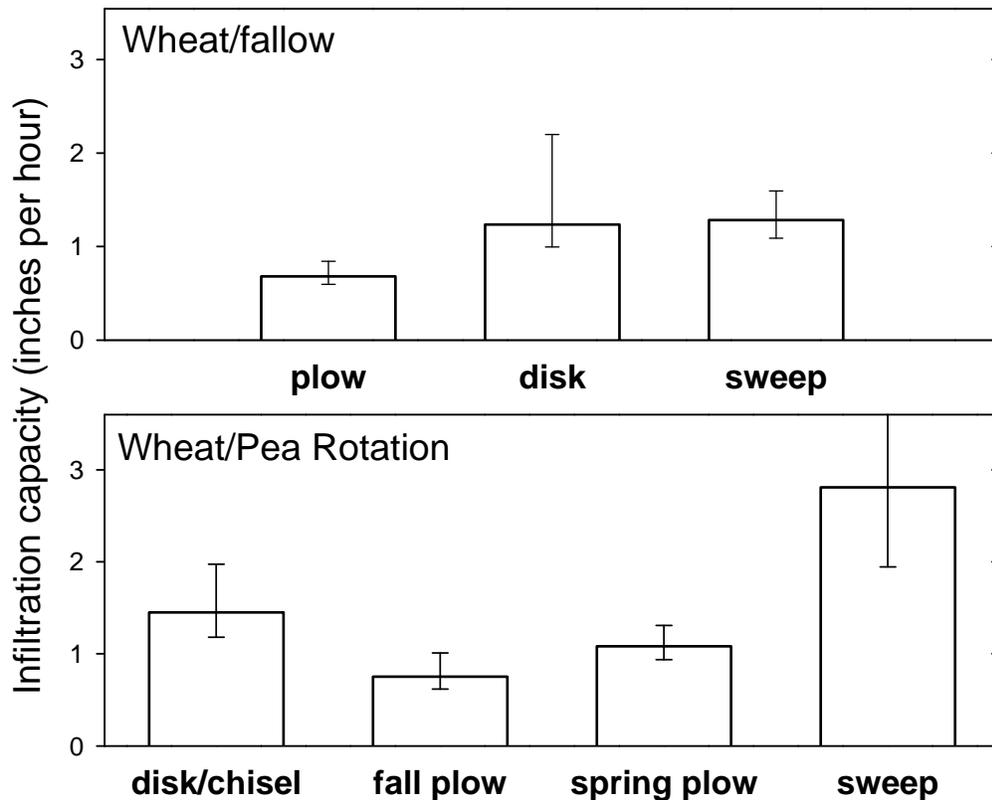
The third chart in Figure 1 shows ponded infiltration rates measured in the late winter after crust formation. The pea vine treatment increased infiltration capacity by about 170 percent, compared to the 80 lb N/acre—no burn treatment. This shows that a small increase in soil organic matter can have a substantial effect on soil aggregation and a very important effect on water infiltration, even in a highly tilled cropping system where increased organic matter levels are very difficult to achieve or maintain near the soil surface. In this experiment, higher organic matter levels were achieved by addition of manure and pea vine.

Tillage Redistributes Soil Organic Matter

Significant improvements in infiltration capacity can also be achieved by reducing depth of tillage and the amount of mixing done by tillage. Figure 2 shows infiltration capacity measurements made on two other long-term experiments located at Pendleton. The upper graph is from the Tillage Fertility experiment. This experiment compares three primary tillage methods for establishing summer fallow in the spring: 1) moldboard plow, 2) tandem disk, and 3) sweep plow. The moldboard plow incorporates almost all residue into the tillage layer. The

disk leaves intermediate residue levels on the soil surface and residue mixing is more shallow; the sweep plow, operated at about 4 to 6 inches, leaves the most residue at the surface and has the shallowest incorporation. All secondary operations (cultivating and rodweeding) are the same in all plots. The upper graph shows that, after 45 years, the disk and sweep plots have about twice the infiltration rate of plowed plots.

FIGURE 2. Ponded infiltration measured in two long-term experiments. The upper graph is the 45-year Tillage Fertility experiment where three initial spring tillage tools are compared, with all other summer-fallow tillage being the same. The lower graph is the 40-year Wheat/Pea Rotation experiment comparing disk/chisel, Noble sweep at 4- to 6-inch depth, and timing of moldboard plowing. Error bars are ± 10 percent UMVUE Confidence Limits, method of Land.

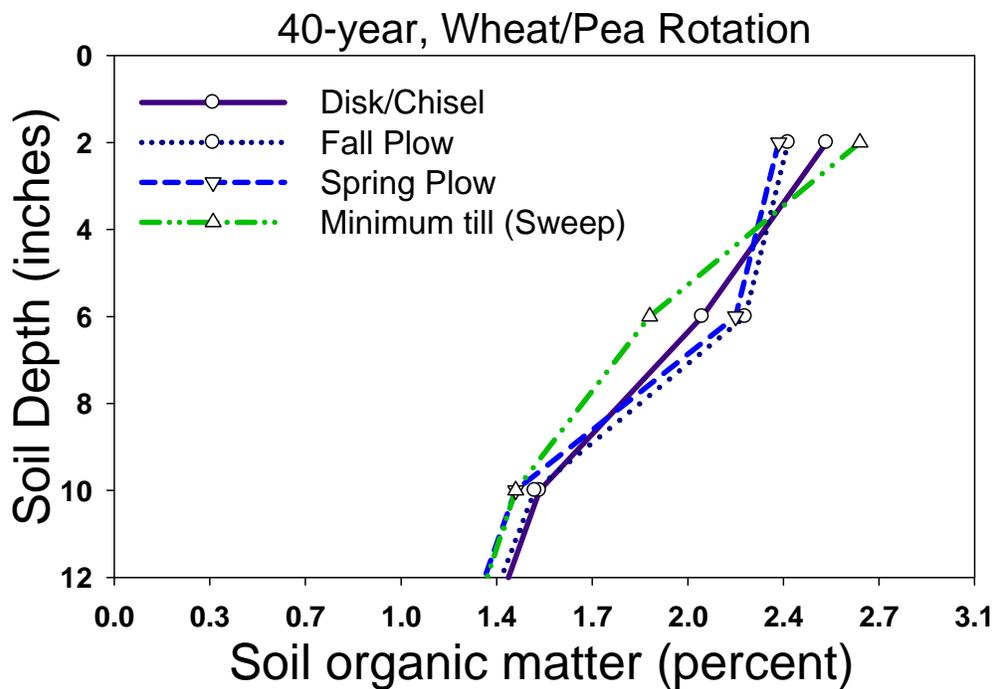


The lower graph in *Figure 2* shows infiltration measurements from the Wheat/Pea Rotation experiment (Wuest 2001). After 40 years, the disk/chisel (wheat stubble is disked in the fall, pea stubble is chiseled before planting winter wheat) and especially Noble sweep systems have much greater infiltration capacity compared to fall or spring plowing. The sweep system involves the 80-inch-wide Noble sweep at a depth of 4 to 6 inches as the only preparation of wheat stubble and pea vine before planting.

How is it that reduced tillage is improving infiltration? *Figure 3* shows soil organic matter content distribution with depth in the Wheat/Pea Rotation long-term plots. In the 0- to 4-inch soil increment, organic matter is greater in the disk/chisel and Noble sweep treatments. At a 4-

to 8-inch depth, the Noble sweep has less organic matter because it produces much shallower mixing of surface soil with deeper soil. In the moldboard-plowed plots, the organic matter levels are almost the same throughout the plow layer (0 to 8 inches). The disk/chisel mixes soil more than the Noble sweep and less than plowing. Mixing surface soil with deeper soil dilutes the soil organic matter that would otherwise build up at the soil surface. Since development of a surface crust is a major impediment to rapid water infiltration, maximizing soil organic matter in the top inch of soil is foremost to maximizing water infiltration capacity.

FIGURE 3. Soil organic matter in the Wheat/Pea Rotation experiment. Soil samples were taken from depths of 0-4, 4-8, and 8-12 inches. Moldboard plowing mixes surface residues into the plow layer, which lowers organic matter levels near the surface and increases them at lower depths. Sweeping allows organic matter to accumulate near the surface, and decreases subsurface organic matter.



Summary

No-till or direct-seed systems provide maximum soil protection and maximum water infiltration. After tillage stops on a formerly tilled soil, the surface develops stronger aggregation through the accumulation of soil organic matter. Untilled soils also tend to develop better internal drainage, meaning that water is redistributed to lower depths more quickly.

Where tillage is necessary, soil mixing should be as shallow as possible and residue retained on or very near the soil surface. The goal is to avoid diluting high organic matter soil at the surface by mixing it with low organic matter soil from deeper depths. Mimicking nature by maintaining

the highest possible levels of soil organic matter near the surface and providing continuous residue cover are the keys to minimizing water runoff and developing more sustainable agricultural production.

References

- Machado, S., K. Rhinhart, S. Petrie, S. Wuest, R. Correa, and T. Johlke. 2005. Long-term experiments at CBARC-Pendleton, 2004. Pages 73-86 in S. Petrie and D. Long, Eds., Agricultural Experiment Station, Oregon State University, Special Report 1061, June 2005. <http://cbarc.aes.oregonstate.edu>.
- Pierson, F.B., and D.J. Mulla. 1990. Aggregate stability in the Palouse Region of Washington: effect of landscape position. *Soil Sci. Soc. Am. J.* 54:1407-1412.
- Wuest, S.B. 2001. Earthworm, infiltration, and tillage relationships in a dryland pea-wheat rotation. *Appl. Soil Ecol.* 18:187-192.
- Wuest, S.B., T.C. Caesar-TonThat, S.F. Wright, and J.D. Williams. 2005. Organic matter addition, N, and residue burning effects on infiltration, biological, and physical properties of an intensively tilled silt-loam soil. *Soil Till. Res.* 84:154-167.



<http://www.or.nrcs.usda.gov/>

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.