SOIL COMPACTION

R.E. Sojka

WORKSHOP OUTLINE

1. What is Soil Compaction?
2. Is Soil Compaction good or bad?
3. What does Soil Compaction do to soils and plants?
4. How do I know if I have a Soil Compaction problem?
5. Does Soil Compaction occur or go away naturally? Or is it strictly a manmade phenomenon?
6. How can I manage Soil Compaction on my Farm? Creation, Prevention, Cure.
7. Has there been much Pacific Northwest Soil Compaction research?... Reading list on compaction-related potato research.
8. A summary of anti-compaction tips.

WHAT IS SOIL COMPACTION?

Strictly speaking, Soil Compaction is a REDUCTION IN SOIL PORE SPACE. When pore space is reduced the bulk density (weight of a given volume of dry soil) increases. Soil Compaction is often recognized and even defined (although improperly) as an increase in the "hardness" of soil. An increase in soil strength is only one of a number of changes that occur in soil when pore space is reduced. Ordinary soil is usually about half solid material and half pore space. At optimal field wetness, about half the pore space is filled with water. So, the soil as it rests in your field, is about half solid material, one fourth water, and one fourth soil-air. Some soils have more organic matter than others. In "typical" Pacific Northwest Soils not more than one or two percent of the solid material is composed of stable organic matter.

When Soil compaction occurs, the soil components simply get rearranged. Since the same amount of solid material and water are present, they account for a larger fraction of the soil on a volume basis. That makes a given volume of soil weigh more (the bulk density goes up). Since there is less pore space there is less room to store water. In addition to the amount of pore space being reduced, the geometry of the pores changes. There are fewer large pores, and usually fewer interconnected pores. These basic changes in soil properties bring about all the other changes that result from Soil Compaction.

IS SOIL COMPACTION GOOD OR BAD?

Soil Compaction can be either good or bad, depending on what we want from the soil, on what the soil texture and organic matter composition is, on what the environmental limitations are, and on soil chemistry. Various field crops have been shown to grow better under certain circumstances at specific bulk densities. Certain plant processes are impaired if bulk density is too low or too high.

Presented at Idaho Potato School on January 20, 1993

If bulk density is too high it can increase the energy and fuel required to draw tillage implements through the soil by increasing resistance on the implements. If bulk density is too low it can increase the energy and fuel required to draw tillage implements through the soil by reducing traction.

If bulk density is too high the reduction in water storage can result in runoff, erosion, or inefficient intake of irrigation. If bulk density is too low furrow irrigation water advance can be impeded because of excessive infiltration at furrow inlets.

The optimal bulk density for individual soil uses changes in a given field with soil water content. Determining whether soil compaction is good or bad depends on where you are on the scale of conditions at a given moment and what process you are evaluating. Good management prevents creating soil conditions that are too compact or too loose at specific times in the growing season when specific plant growth or farm management needs exist.

Note: In modern farm management, because of the use of larger equipment and implements, and because of the urgency to perform certain operations in a "timely" fashion, there are usually more problems brought on by creating excessively high bulk densities than with maintaining excessively low bulk densities.

WHAT DOES SOIL COMPACTION DO TO SOILS AND PLANTS?

"Light" surface compaction (e.g. from a press wheel in a seed bed) improves seed-soil contact, and root-soil contact. This improves water availability for germination and plant establishment.

Compaction increases availability of some nutrients (e.g. Phosphorous or Potassium) which move to plant roots primarily by diffusion, rather than mass-flow. It is generally a better strategy, however, to increase "availability" of these elements by promoting more robust root growth than by trying to change soil diffusive properties.

In a drought (where irrigation is not an option) compaction can sometimes increase availability of deep-profile water by reducing average pore size (thereby increasing "capillarity" and water availability over part of the desorption range).

Compaction reduces porosity and pore continuity. Once wet this reduction in pore space can cause more sever soil aeration problems than at comparable water contents in less compacted soils. Poor aeration can directly impede plant growth, because oxygen is needed for root respiration. Low soil oxygen also promotes denitrification (conversion of available soil nitrates to unavailable gaseous dinitrogen). Some plant pathogens are favored both by increased moisture in the soil environment and by absence of oxygen.

Compacting soil packs more particles into voids and increases their contact with one another. This makes soil more rigid (harder). More particle surface contacts allow greater cementation upon drying (creates conditions conducive to crusting and clod formation).

Harder soil supports traffic and machinery better and reduces infiltration (e.g. roadbeds), but it also impedes root growth and root penetration (roots explore less soil for water and nutrients, providing less buffer against deficiencies and stresses) and increases runoff (which can lead to erosion). Plants tend to "see" soil strength (hardness) more easily than bulk density. A large range of crop plants show growth and yield decline at about the same level of soil strength. This corresponds to a root "penetration resistance" of between 2 and 3 mega Pascals (about 280-420 PSI) of penetration resistance (measured on a standard 1 square centimeter cross section x 30 degree conical probe).

Soil strength (hardness) changes in response to texture, bulk density, soil water content, and soil organic matter content. Texture and organic matter content are (essentially) unchangeable soil properties. Therefore, soil strength changes in the short term as a result of changes in soil bulk density or soil water content. Because soil particle aggregation differences affect soil properties in much the same manner as texture differences, soil structure changes can override some of these relationships.

Compacted soils generally transfer heat more easily than loose soils, but because of the usual confounding of compaction with an altered soil water status, the effect of compaction on soil temperature will largely be determined by whether the compaction results in an increase in water content or a reduction in water content at the site of temperature measurement. Wetter soils are usually cooler soils.

HOW DO I KNOW IF I HAVE A SOIL COMPACTION PROBLEM?

Some soil compaction indicators include: Significant cloddiness after primary tillage or during potato harvesting (generally indicates compaction from early season or previous season operations); Sudden reduction in infiltration (or increased runoff) on a large area basis; traffic or tillage pans near the bottom of the normal tillage depth; wet soil streaks in the field or, streaks of accelerated or retarded germination or growth which correspond to earlier operation or traffic patterns; the harvester has difficulty digging to the bottom of the potato beds; need to slow down or gear down to perform deep tillage (common at field heads and roadways); increased bulk density in the absence of texture changes; high penetration resistance in wet soil; shallow rooting or (in tap rooted crops) abrupt horizontal root growth; shallow tuber set; high percentage of tubers malformed to conform to surrounding soil surfaces.

IS SOIL COMPACTION NATURAL OR ONLY MANMADE? WILL IT GO AWAY?

All soils will achieve a range of natural "resting" bulk density. This is determined by soil mineralogy, texture, organic matter level, structure, and the amount and intensity of rainfall, frost, and degree of vegetative cover. Sandy soils have higher bulk densities than loams or clay soils. In soils with a lot of shrinking and swelling clays, or with large numbers of winter freeze-thaw cycles, some compaction will dissipate naturally over time. You don't have the time to wait as long as it will take Mother Nature to cure a serious compaction problem. Furthermore, the natural processes that tend to reduce bulk density are usually only effective close to the soil surface. Compaction below the normal depth of tillage becomes essentially permanent. High levels of compaction occur primarily in response to traffic, tillage or high animal stocking rates. In some soils moderately high bulk densities can occur naturally in subsoils with migration of suspended or dissolved materials in soil water.

HOW CAN I MANAGE SOIL COMPACTION ON MY FARM?

Soil is much easier to compact when wet than when dry. Where possible take advantage of systematic compaction without creating additional compaction. For example use wheel track furrows to irrigate long runs. Keep track of wheel tracks and match up all implement and axle configurations to run down existing wheel track furrows. In no till keep track of wheel tracks from season to season for the same reason.

To prevent excessive soil compaction avoid unnecessary field operations. Keep axle loads to a minimum. Avoid mismatching of tractor size, horsepower, and wheel configurations with improper implement size, draft requirement etc. Preserve and incorporate as much organic matter as feasible (this takes several seasons to show lasting results). If necessary, consider a program of deep tillage to get back on the road to soil structure management. Be aware that deep loosening will not always show a response if compaction is marginal or where precision irrigation is available. If you deep-till try to do it at a medium soil moisture. Deep-tilling too dry or too wet will both cause problems on most soils. If you find you are having to deep till every year for every crop, you may need to examine your overall management scheme to see if you are systematically neglecting one of the above cautions.

COMPACTION RESEARCH IN POTATOES

A list of compaction-related publications is provided below: Your local farm advisor and or extension agent can help you obtain these if you need the information, and can help you interpret them with regard to your specific farming operation:

Bishop, J. C., and D. W. Grimes. 1978. Precision tillage effects on potato root and tuber production. Am. Pot. J. 55:65-72.

Boone, F. R., J. Bouma and L. A. H. de Smet. 1978. A case study on the effect of soil compaction on potato growth in a loamy sandy soil. Neth. J. agric. Sci. 26:405-420.

Campbell, R. B. and R. A. Moreau. 1979. Ethylene in a compacted field soil and its effect on growth, tuber quality, and yield of potatoes. Am. Pot. J. 56:199-210.Ibrahim, B. A., and D. E. Miller. 1989. Effect of subsoiling on yield and quality of corn and potato at two irrigation frequencies. Soil Sci. Soc. Am. J. 53:247-251.

Miller, D. E., and M. W. Martin. 1987. The effect of irrigation regime and subsoiling on yield and quality of three potato cultivars. Am. Pot. J. 64:17-25.

Miller, D. E., and M. W. Martin. 1990. Responses of three potato cultivars to subsoiling and irrigation regime on a sandy soil. Am. Pot. J. 67:769-777.

Parker, C. J., M. K. V. Carr, N. J. Jarvis, M. T. B. Evans, and V. H. Lee. 1989. Effects of subsoil loosening and irrigation on soil physical properties, root distribution and water uptake of potatoes (Solanum tuberosum). Soil Tillage Res. 13:267-285.

Ross, C. W. 1986. The effect of subsoiling and irrigation on potato production. Soil Tillage Res. 7:315-325.

Sojka, R. E., D. T. Westermann, M. J. Brown, D. C. Kincaid, B. D. Meek, I McCann, J. Halderson, and M. Thornton. 1991. Deep tillage effects on potato yield and quality. Proceedings of the 30th Annual Washington State Potato Conference and Trade Fair. Feb. 5-7, 1991. Moses Lake, WA. Washington State Potato Commission.

Sojka, R. E., D. T. Westermann, M. J. Brown, and B. D. Meek. 1992. Zone-subsoiling effects on infiltration, runoff, erosion, and yields of furrow-irrigated potatoes. Soil Tillage Res. (In press)

Sojka, R. E., D. T. Westermann, D. C. Kincaid, I. R. McCann, J. L. Halderson, and M. Thornton. 1993. Zone-subsoiling effects on potato yield and grade. Am. Pot. J. (In Press)

van Loon, C. D., and J. Bouma. 1978. A case study on the effect of soil compaction on potato growth in a loamy sand soil. Neth. J. agric. Sci. 26:421-429.