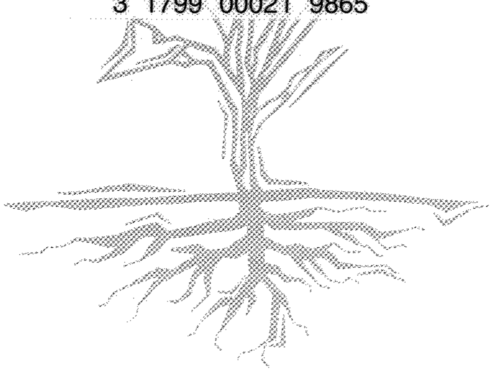

SOIL

Managing soil compaction no. 0.519

by M. Petersen, P. Ayers [1]

Quick Facts...

Soil compaction can reduce crop yields.

Tractor traffic in wet soils is a major cause of soil compaction.

Higher axle weights produce deep soil compaction.

Subsoiling in the fall can alleviate soil compaction, but avoid recompaction.

Soil compaction in cultivated fields may have an adverse effect on crop production in Colorado.

In intensively cropped irrigated cropland, soils that are frequently moist throughout the year often show the effects of extensive surface traffic causing soil compaction.

Introduction

Soil compaction is the movement of soil particles (sand, silt, and clay) into closer proximity due to an external force. The soil becomes more dense and soil pores become smaller. Increased soil density results in higher strength and lower hydraulic conductivity. In cultivated soils, excessive soil compaction results in poor internal drainage, the potential for increased runoff, inhibition of root development, and decreased yields. Growing roots do not penetrate high-strength soils and poor root development in the subsoil results. Consequently, the stressed plant is not able to take full advantage of subsoil moisture and nutrients. The plant becomes more susceptible to other stresses resulting from adverse environmental conditions. Soil compaction may not reduce yields every year. It is most likely to decrease yields in years when other stresses such as excessive heat, insect infestations and diseases are present.

All soils are compacted to some degree. Some amount of soil compaction is necessary to support the plant, avoid over-drying (desiccation of the soil) and provide seed/soil contact required for germination.

Visible Symptoms

In extreme cases, the plants reflect poor aeration and nutrient deficiencies caused by the compaction. In other cases, the plant may not exhibit symptoms even though somewhat stressed. A close look at a compacted soil zone will reveal fewer visible holes or pores in the soil matrix. Breaking a compact soil open will show elongated pores broken into small segments and irregularly (deformed) shapes. This is better viewed with a 10X magnification power hand lens. Soil bulk density, a measurement of soil weight per unit volume, may increase 10 to 20 percent due to soil compaction. Another more visible sign is soil structure altered from granular to platy. The platy structure appears as sheets of paper stacked one on top of the other. Surface crusting may be apparent after rain soaked soils dry and is accentuated by over-preparation prior to planting which deteriorates soil structure.

Symptoms in Crops

Crops grown in compacted soil exhibit a variety of symptoms. Small grains appear stunted, emergence is delayed, leaf structures are narrow, and grain heads are small. Small grains may lodge and go down in high winds. Root crops, such as potatoes, carrots, and sugar beets may lag behind those unaffected by compaction. Leaf edges may curl and appear to be bacterial wilt or chlorosis (yellowing).

During the summer, leaves roll more quickly and remain rolled longer when the air temperature is above 90F. Roots and tubers are shorter, deformed and rot more readily. Carrots and sugar beets may exhibit forked tips and thick, rough

Colorado State University Cooperative Extension walls. In early growth stages, corn may have purple tinged leaf edges such as appear with a phosphorus deficiency, plants may be stunted, chlorotic, and have narrower leaves. Dry edible beans may have younger trifoliate leaves with curled edges, yellow, stunted, small pods, and shorter climbing tendrils. Both corn and beans lodge easier due to shallow root systems. Many vegetables may be stunted, less erect, chlorotic, and have smaller heads (cabbage, lettuce and broccoli). All crops struggle for water uptake during heat stress and have a limited recovery.

Identification

There are several ways to identify soil compaction. The ease of identification depends on the soil moisture and the time of the year. Fall is the easiest time to detect compaction while the soil is relatively dry and has a high degree of strength. The knife blade penetration method involves digging a hole approximately 18 inches in diameter and 2-feet deep. One side of the hole should be free of shovel marks to avoid compaction caused by the spade. Working from the soil surface downward, push a knife blade into the unmarked side of the hole at 1-inch intervals. If it is more difficult to insert the knife into one zone than the one below it, you may have found a compacted layer. Confirm the results of this test with a soil scientist or other trained personnel.

Using a soil cone penetrometer and pushing it into the soil at a steady rate determines mechanical impedance to a desired depth in the soil profile. This is the most popular method to identify compaction; however, it is not always the most readily available method.

Using a soil-sampling tube or hand probe is another method. This method measures compaction by the resistance encountered while pushing the tube down into the soil. The tubes are easier to push in soils with less compaction. It is a quick and easy method that can be conveniently used by farmers doing their own soil sampling--this method is subjective, however.

The effect of soil compaction on the resistance to penetration is highly dependent on the soil moisture when the testing takes place. Under low soil-moisture conditions, the probe will resist insertion even though soil compaction may not be a problem. Conversely, under high soil-moisture conditions, the probe may penetrate easily when a soil compaction problem exists. Conduct probing throughout the year to correctly identify the presence of soil compaction. An important time to probe is when the crop's roots are moving into the subsoil. This is a time when the mechanical resistance due to soil compaction could reduce root penetration and distribution.

Alleviation

Once the presence of compaction is verified, implement a plan to alleviate or reduce compaction from the tillage zone. Compacted zones usually are a result of a mechanical means and they can be removed or reduced by mechanical means. The effectiveness of subsoiling depends on the type of tool used, available horsepower, soil moisture, and time of the year. Subsoiling may be the most effective way to counteract soil compaction.

Fall is the best time to subsoil in Colorado. Crops are removed, the soil usually is dry, and evaporation rates are fairly low. Subsoiling dry soils, although requiring more energy, provides better fracturing and heaving of the soil to break up compacted zones. Subsoiling during wet soil conditions may only leave slots in the soil profile and provide minimal soil disturbance between the shanks. Other considerations include the need of a cover crop for wind erosion control or other tillage operations for next year's crop.

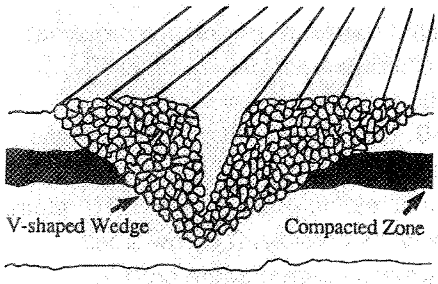

Figure 1: Subsoiling in dry soil fracture v-shaped wedge (Cooperative Extension, University of Nebraska).

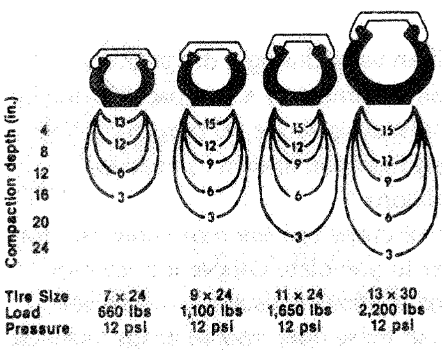

Figure 2: Heavier axle weight produces deep soil compaction (Soehne, 1958).

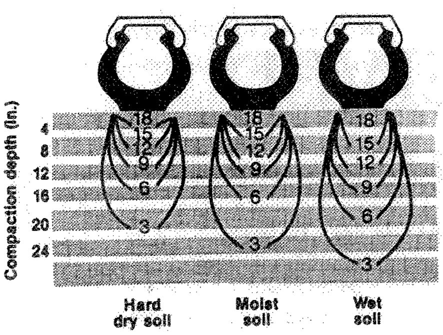

Figure 3: Soil compacts deeper in wet soils (American Farm Bureau Federation).

Subsoiling, when performed at the proper depth displaces a V-shaped section of soil upward, forward, and sideways to the surface (Figure 1). The depth of the operation varies with soil type, moisture, bulk density, and shape of the subsoiling shank.

Research shows that the ripping operation be carried out at 1.5 times the depth of the bottom of the compaction zone. For example, if the depth to the bottom of the compacted zone is 10 inches, set the depth of the subsoiler at 15 inches. Other research shows that tilling 1.5 to 2 inches below the bottom of the zone of compaction also fractures and disrupts the zone sufficiently. Available horsepower, speed of operation, shape of the subsoiler shank, and soil moisture conditions will modify your choices.

The amount of horsepower per subsoiler shank and speed at which the operation is accomplished are as important as the depth placement of the subsoiler. The minimum horsepower per subsoiler shank for most soils is 20 to 35 horsepower (hp). Keep tractor speed under 4 mph, which requires less draft than at higher speeds. Slower speeds minimize large clod displacement on the surface, need for secondary heavy tillage, severe surface heaving, and excessive soil drying.

To ensure the compacted zone is properly shattered, dig a hole and look for the V-shaped wedge of soil that should be loose. Secondary tillage in the spring may be needed to level the field and break the clods prior to seeding.

Frequency of deep subsoiling depends on how quickly the pan returns following the producer's tillage and harvest management routines. Positive effects from deep subsoiling have been observed as long as eight to nine years following the subsoiling operation. However, if the soil is exposed to heavy tractor traffic under wet conditions, recompaction occurs and the effect of subsoiling may not last one year. Since deep tillage is expensive, it should only be done when needed.

Minimizing Soil Compaction

Reduce tractor traffic (especially under wet conditions). Tractor traffic is the major cause of excessive soil compaction. The more frequently a tractor travels across a field, the greater the opportunity for detrimental soil compaction. Reduce the number of passes using a reduced tillage system.

Reduce tractor weight (to reduce deep compaction). Deep or subsurface soil compaction is caused by tractors with high axle weights. As tractors become heavier, compaction stresses go deeper into the soil (Figure 2) and deep soil compaction problems become more prevalent. This deep soil compaction is difficult to alleviate with subsoiling or freeze-thaw activity. Deep compaction cannot be reduced by utilizing dual wheels or decreasing tire pressure; it is solely a function of the axle weight.

Reduce tire pressure (to reduce surface compaction). While reduced tire pressure will not reduce sub-surface compaction, it will reduce the degree of surface compaction. Utilizing low pressure tires or dual wheels will reduce the degree of surface soil compaction, but may increase the area compacted. The soil must support the weight of the tractor. Using duals or low pressure tires simply spreads out the weight.

Reduce traffic under wet conditions. Soil is more compressible when wet. Traffic during high moisture conditions may compact soil, whereas the same traffic under dry conditions will not cause compaction. As the soil drys, it has a higher soil strength making it less susceptible to compaction. A dry soil supports traffic more readily than a wet soil. In addition, compaction stresses generated from the same wheel will be transmitted deeper in wet soils (Figure 3).

Control traffic. Whenever possible, restrict all equipment to specific tracks or traffic lanes through the field, while leaving the rest of the field essentially uncompacted. This requires some equipment management but may be well worth the effort. Mismatched equipment may be the cause of 80 percent of a field becoming tracked at least once. In furrow irrigated cropland, tracks are somewhat controlled by the size of the implements used. Utilizing a permanent ridge-till system is an excellent form of a controlled traffic scheme.

Maintain organic matter in the soil. Decomposition of crop residues promotes stable soil structure. This material acts as a gluing agent to hold soil aggregates together. There are several methods of adding organic matter: (1) retain previous crop residues on the soil surface as much as possible, (2) grow small grains that have grass-like rooting systems, (3) grow a green manure crop in rotation, or (4) apply animal manures, sludge, or other waste products. This strengthens soil structure, adds nutrients and organic carbon.

Reduce secondary tillage. Over-tilling destroys the natural soil structure while continuing to decrease soil pore size. Each tillage operation, in preparing the seed bed, breaks down soil aggregates and decreases the pore space necessary for good air and water flow. As a result, the soil becomes more susceptible to implement compaction and crusting. By decreasing the number of secondary tillage trips, the soil aggregates are preserved and susceptibility to compaction is decreased.

Altering plow depth. Plow deeper than usual during a dry year. In subsequent years, vary the depth to minimize development of a compacted zone by the implement. Avoid plowing when the soil moisture is above 60 percent of field capacity. Continuous sweeping in dryland wheat has been known to produce compaction pans, especially in wet spring conditions.

Cropping alternatives. Deep, tap root crops provide more channels for subsequent crop roots to follow and allow water to percolate deeper into the soil profile. Rotation that includes alfalfa, clover, and sunflowers usually leaves a soil conditions that is less compact than fields without these deep rooted crops included in the rotation.

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