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Tillage and Wheel Traffic Affect Soil Compaction

In the past 20 years farm machines have become larger and heavier. In many cases crop rotations have decreased as specialization in crop production has increased. The increasing use of fertilizer, insecticides and herbicides and the need for special trips over the field to apply them and to work them into the soil have resulted in increased traffic and tillage of the soil. The demand for earlier seedbed preparation and planting of many crops has also meant that soils are often wetter under the surface at tillage time.

The potential for compaction and damage to soil structure has increased as a result of this evolution in soil management. Fortunately, in some locations the potential for compaction due to larger field equipment has been offset by increased use of reduced tillage practices.

Significance of Compaction

The value of the soil as a root zone is determined by how well it can supply plant roots with water, air and nutrients. Its value also depends on the soil's capacity to transmit heat and water. In an average cultivated soil about one-half the total soil volume is pore space, filled with water and air. The amount of pore space and its distribution in the soil profile is determined to a great extent by the distribution of various-sized pores between soil particles, the location of the water table, and the addition and removal of water. Compaction alters the size and distribution of pores, the rate of rainfall infiltration and the rate and extent of water evaporation at the soil surface. In addition, compaction can affect seedling emergence, crusting, root growth, runoff and erosion. Tillage, in turn, affects compaction.

The primary effect of compaction on the soil is to decrease the total pore volume. Coarse or large pores are the first to be affected by compaction. They are the first to drain after wetting, and thus they represent the portion of the pore space filled with air most of the time. Consequently, tillage-induced compaction usually has the immediate effect of reducing the percent of the soil volume filled with air and increasing the percent filled with water. There is a sluggishness in the internal drainage of water; the soil stays wetter for a longer period of time after each rain. Often the result is a deficiency in the amount of air available to growing plant roots. Several studies have shown that root growth is significantly restricted when the total soil volume filled with air drops below 10 percent. Reduction in large-pore space also reduces the rate at which water can enter the soil and drain from the soil.

Another change in soil properties resulting from compaction is an increase in the soil density. Generally with increased compaction and increased bulk density, root growth decreases.

Tillage Affects Compaction

It is well recognized that the depth of compaction increases as the moisture content of the soil at the time of tillage increases. Figure 1 shows that if the soil is relatively wet when tilled, compaction will be excessive and deep. Conversely, til-

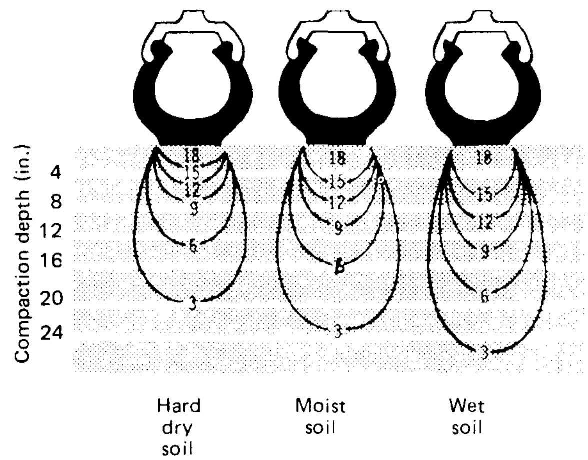

Figure 1. How soil moisture affects soil compaction. The lines in the soil under the tire represent curves of equal pressure. In all three situations the tire size was 11 x 28, the load was 1,650 pounds and the pressure 12 psi. On wet soil, pressures were transmitted to depths of more than 24 inches. (Source—Soehne, Jour. of Agr. Eng., May 1958.)

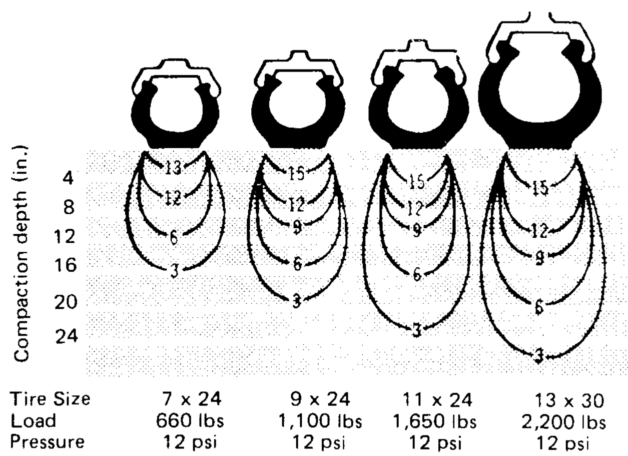

Figure 2. How tractor loads affect soil compaction. The lines in the soil under the tire represent curves of equal pressure. In this diagram pressure per unit area is a constant 12 psi. The size and total weight increase with tractor size as does depth and width of transmitted pressure. (Source—Soehne, Jour. of Agr. Eng., May 1958.)

lage on dry soils has a lesser tendency to compact the soil. Other research has shown that larger and heavier tractors cause compaction to a greater depth than smaller tractors. Such compaction, shown in Figure 2, is not always readily noticeable in the field.

Field experiments, conducted for five years on silty clay loam at Lamberton and three years on clay loam at Morris, showed that wheel traffic associated with spring field operations caused compaction to a depth of at least 12 inches in the soil. Freezing and thawing did not completely alleviate this compaction. However, fall moldboard plowing alleviated most of the compaction in the tilled layer.

In another study at Lamberton on Nicollet clay loam, persistence of subsoil compaction was studied during nine years of corn and alfalfa cropping. Soil density below the plow layer did not change over the nine-year period. Neither crop, overwinter soil water content, nor freezing and thawing affected the packed subsoil. Compaction reduced alfalfa rooting by as much as 36 percent in the 16- to 30-inch depth.

Seventy to 90 percent of the total plow layer compaction occurs on the first trip across the field. By using the same roadbed and controlling traffic, ruts in the field will be slightly deeper, but the soil between ruts will not be compacted. Dual wheels will reduce the depth of compaction, but they spread the compacted zone over wider areas. If compaction with dual wheels is excessive, such as sometimes occurs in the spring when farmers use dual wheels to keep from getting stuck in a wet field, soil structure and compaction problems can be more evident than where only single wheels are used on drier soil.

Compaction Affects Crop Yields

Compaction usually depresses crop yields, particularly in imperfectly drained soils or in wet years. Some crops are more severely affected than others. Deliberate soil packing caused an average decrease of 7.5 percent for corn yields, 10 percent for wheat, 13 percent for sugarbeets and 54 percent for potatoes. Yield of well-managed pasture in Wisconsin dropped 20 percent from packing by grazing animals.

Researchers have emphasized reduced tillage for seedbed preparation in recent years. Provided one gets seed germination, yields are little affected by cutting out some seedbed tillage. But this depends on the nature of the seed. Sugarbeets generally require a fine, firm seedbed in order to insure an even stand. Potatoes do just as well when planted in loose seedbeds or even with no tillage in wheat stubble. Corn is intermediate, but requires firming of the soil over the seed.

Seedbeds can be too loose for some crops, especially when it is dry at seeding time. Firming the soil then causes better seed-soil contact and water is held for a longer period around the seed.

During a five-year study at Lamberton, average soybean and corn yields were increased by about 18 percent and 14 percent, respectively, with wheel traffic on both sides of the row compared to no wheel traffic. Yield responses to firming the soil were greater during dry years and when soil P levels were low. At Morris, average soybean yields increased 18 percent due to wheel traffic, corn yield varied from year to year, and potato yields decreased 28 percent due to wheel-induced compaction.

In these studies, wheel traffic was always between rows rather than in the rows. Effect of compaction on wheat yields depended on the soil moisture content at planting time. In relatively dry soil, yields were increased 50 percent by wheel traffic between the rows, while in wet years yields were decreased 28 percent.

Secondary Tillage—Its Purpose

The need for secondary tillage depends on several factors, including crop to be grown, soil characteristics after plowing, erosion control considerations and available time. Generally, if there are no weeds, large clods or crust and if the surface of the field is sufficiently smooth for planting, there is little need or justification for secondary tillage. In some instances, excessive secondary tillage may result in surface compaction or erosion susceptibility.

Summary

Research has shown that there are no easy answers or solutions to the problems of soil compaction. The effects of compaction depend on the soil, crop, annual rainfall pattern and subsequent tillage operations. Information available to date has shown the following:

- Compaction usually causes yield reductions for root crops such as sugarbeets and potatoes and, to a lesser extent, corn and wheat.
- During wet years and on poorly drained soils, compaction may decrease yields by reducing the soil aeration porosity and slowing soil warming.
- During dry years and where moisture is limited, crop yields may be increased by a firm seedbed and moderate amounts of compaction that increase temporary water storage and better seed-soil contact.
- Compaction within the plow layer can be partially alleviated with tillage practices, but subsoil compaction may persist for long periods.
- Wetting and drying and frost action do not completely alleviate subsoil compaction.
- Compaction due to wheel traffic prior to fall tillage can reduce erosion by causing soil to work up rougher during primary tillage.
- Compaction after planting can increase erosion by leaving smooth surfaces to channel runoff.
- Essentially all soil-tire contact pressure affects root growth.
- Dual wheels do not prevent compaction; they merely change its distribution.
- Seventy to 90 percent of the total compaction is caused by the first wheel pass on bare soil.
- Excess secondary tillage may destroy the porosity produced by primary tillage and cause as much or more compaction than primary tillage operations.

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