Curing Soil Compaction Means Knowing the Causes

By Phil Brown and Bert McCarty

Soil compaction is a potentially serious problem for turfgrass managers. The altered soil physical properties caused by compaction can adversely influence plant growth and irrigation management (O'Neil and Carrow, 1983).

Particularly troublesome areas of soil compaction have been sports fields, putting greens, areas adjacent to cart paths and other intensely trafficked areas (Swartz and Kardos, 1963).

Soil compaction is the pressing together of soil particles, resulting in a more dense soil mass with less pore space (Carrow and Petrovic, 1982). A number of physical changes to the soil may occur as a result of compaction including reduced aeration porosity, increased bulk density, increased soil strength and altered pore size distribution (O'Neil and Carrow, 1983). These physical changes can have detrimental effects on turfgrass growth such as decreased root growth, decreased shoot growth, reduced carbohydrate reserves and decline in overall quality (O'Neil and Carrow, 1983). Destruction of the soil structure also may occur (Murphy, Reike, and Erickson, 1993).

Areas such as putting greens and athletic fields are particularly susceptible to compaction because of near constant traffic. However foot traffic is not the only cause of compaction. Vehicular traffic can also contribute to this. Sports fields maintained by heavy machinery can be particularly susceptible to compaction.

Soil is particularly susceptible to compaction when it is wet, especially when heavily trafficked. Water acts as a lubricant in the soil, allowing the soil particles to move easier while they are pressing together (McCarty, 2001). As water surrounds the soil particles, they are able to press together due to the reduced friction created by the lubricating effect of the water. If heavy machinery is then allowed on the soil, the particles will move closer together and compaction will increase.

Measuring soil compaction

Bulk Density: Several methods of measuring soil compaction exist. The most common is bulk-density sampling. Bulk-density sampling involves taking core samples of a known volume of soil, drying it and using the bulk-density equation of:

$$\text{BD}^* = \frac{\text{Dry Weight of Soil Sample (grams)}}{\text{Volume of Soil Sample (cm}^3\text{)}}$$

***Bulk density is expressed as grams per cm^3 (g/cm^3).**

It is important to know what type of soil being sampled. Sandy soils may have a higher bulk density than clay soils, but may not necessarily be more compact. This is because of the relative weight of the soil fractions. Sand particles are heavier than clay particles so a sand-dominated soil will be heavier than a clay-dominated one (Table 1). Common bulk densities range from 1.2 to 1.6 g/cm^3.

Surface hardness: Surface hardness can also be used as a measure of compaction. Surface hardness in turf is most often determined using an instrument such as a Clegg Impact Soil Tester (CIST). The CIST is a weight dropped through a cylinder and upon impact with the ground, the peak deceleration of the weight is measured and displayed. The reading is expressed as a gmax. Typical gmax values for sports fields fall between 70 and 120.

Water infiltration: Water infiltration is another method of assessing compaction. Water infiltration measures the rate at which water can enter the soil. It is commonly determined using a double-ring infiltometer. Double-ring infiltrometers are two rings: a smaller diameter ring set inside a larger diameter ring.

The infiltrometer is forced into the ground, and both rings are filled with water. The time required for water to drop in the rings is measured and the infiltration rate determined. This is commonly expressed in centimeters or inches per hour.

Soiloil strength: Soil strength may also be used as a measure of compaction. Soil strength is measured using a penetrometer, which is a prong forced into the ground, providing readings of soil strength at certain depths. The more compact a soil the higher the soil strength, hence the higher the reading from the penetrometer.

Reducing soil compaction

There are several methods to reduce soil compactions, including soil profile modification, soil cultivation and control of traffic. Of these three methods, soil cultivation is the most common method used on existing turf installations.

Soil cultivation usually involves machinery, which alters the structure of the soil, especially the soil surface, without destroying the turf (Landry, 2003).

Soil cultivation can be split into several method including coring (hollow and solid tine, and drill), high-pressure water injection (or hydrojet), slicing, spiking, grooving, forking and subaerification (Carrow and Petrovic, 1992).

On putting greens, core cultivation is typically performed with Vertically Operating Hollow Tine (VOHT) units, which selectively remove soil cores from the turf (Murphy, Reike and Erickson, 1993). The primary objective of core cultivation is the alleviation of soil compaction (Murphy, Reike and Erickson, 1993), which is often concentrated in the upper 3 inches of soil (Carrow and Petrovic, 1992).

Cultivation with solid tines has gained popularity in recent years as it causes less turf surface disruption and has lower equipment and labor costs associated with soil core cleanup following cultivation (Murphy, Reike and Erickson, 1993).

Since soil is not removed, little soil compaction relief accompanies solid tine cultivation. Furthermore, this method is popular for short-term compaction relief with minimal disruption of the playing surface. To reduce soil compaction, bulk density must be reduced. This is performed in turf by removing cores following aerification. Since soil is not removed, a major criticism of solid-tine aerification is additional compaction at the bottom and sides of the cultivation zone (Murphy, Reike and Erickson, 1993).

Murphy, et al, (1993) compared hollow-tine and solid-tine cultivation on a Penneagle bentgrass putting green. Under wet soil conditions, hollow-tine cultivation yielded best turf quality. Cultivation, however, did not lower soil density compared to the control from 0 to 3 inches in depth. In addition, the effect of cultivation was dependent on the tine type.

TABLE 1

Soil textural class and their relative bulk densities (McCarty, 2001).

SOIL TEXTURAL CLASS	BULK DENSITY (G/CM3)	
Sands or Compacted Clay	1.4 - 1.8	more compacted
Loam	1.2 - 1.6	↓
Loose silt loams or clay	1.0 - 1.4	
Organic soils	0.2 - 1.0	less compacted

Hollow-tine cultivation produced 20 percent higher air porosity values compared to solid tine cultivation. In compacted soils, hollow-tine cultivation also increased porosity 30 percent more than solid tine cultivation over two years, and both cultivation techniques increased overall porosity compared to the control.

Solid-tine cultivation also provides only short-term benefits and requires repeated application (at least three times yearly) to be an effective tool in the management of soil compaction (Murphy et al, 1993). Furthermore, with repeat use, solid tines exhibit a great potential for the development of a cultivation (or hard) pan.

Weicko, et al (1993) compared hollow and solid tine cultivation techniques along with a number of other treatments. Both solid and hollow tine aerification cultivation decreased soil bulk density from 1.69 g/cm^3 in the top two inches of the untreated, compared to 1.58 and 1.59 g/cm^3 for the hollow and solid tines, respectively. They also noticed a pan layer began to form between 4 to 6 inches below the surfaces for both the hollow and solid-tine cultivations.

Deep-tine aerification operates in a similar way to both the hollow- and solid-tine devices. The difference is that the deep-tine aerifier penetrates to depths of 8 inches to 12 inches. Some deep-tine aerifiers will also heave the soil when they reach the lowest point, further breaking up the soil structure (Landry, 2003).

Of the other methods of alleviating soil

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compaction, soil slicing is popular. Slicing can be performed in several ways. Originally, blades with triangular teeth were used to create a non-continuous strip of sliced soil. More recently, a continuous type of slicing equipment, known as "verti-slicing," has been used where the blades are more rounded resulting in continuous furrows (Carrow and Petrovic, 1992). Both slicing techniques operate in a similar way to solid tine aerification, designed to break up the soil structure in the upper levels of the soil.

Hollow-tine cultivation produced 20 percent higher air porosity versus solid-tine cultivation.

For greens, this can be done by simply moving the pin regularly so play is not continuously focused on one area. Turf managers can do this by putting up rope fences or signs restricting the traffic use on the grass, especially when wet.

Another option is to alter or modify the soil (Carrow and Petrovic, 1992). Modifications can be performed using amendments such as sand, peat or chemical products that alter the soil. It is important to be careful when altering the soil as just one-eighth of an inch layer of an alternate texture soil on top of the existing soil can cause drainage problems and lead to further compaction problems. Although effective, soil modification is usually expensive and time consuming.

Research

Three studies were established at Clemson University in 2002 to investigate the most efficient and effective means of relieving soil compaction in a heavy soil. Studies were conducted on a heavily trafficked band practice field with a Cecil sandy clay loam soil. Treatments are being assessed by bulk-density analysis, infiltration, surface hardness (using a Clegg impact soil tester) and visual turfgrass quality.

The first study is designed to compare the effectiveness of deep- and shallow-tine aerification and incorporating or removing the plugs extracted by the aerifier. Two tine lengths are being used: 3-inch or shallow tines, and 7-inch or deep tines. Cores extracted from the aerification are either removed or incorporated back into the plot using a brush.

Study two compares the effectiveness of hollow-tine and solid-tine aerification with the addition of topdressing. Both the hollow tine and solid tine used are 3 inches in length. The effectiveness of two different topdressing materials are being compared: sand and a peanut-based biosolid provided by Naturize.

Study three is comparing effectiveness of solid and hollow tine aerification. Both the hollow tine and solid tine used are 3 inches in length.

All studies were being conducted through the end of last year, and results are being compiled. The goal of the studies is to determine the most effective means of relieving soil compaction with minimal disruption to the playing surface and minimum labor costs.

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