

# SOIL COMPACTION IN TURF

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*By Dr. Beth Guertal and Dr. Dave Han*

The effects of traffic and compaction in turf are usually easy to see: thin turf, worn paths, areas of bare ground that do not respond to applications of fertilizer or water. Turfgrass growing in compacted areas has shallow rooting, causing greater susceptibility to drought and other stress. The soils in compacted areas have low air porosity and reduced infiltration. Such compaction is most likely to occur in fine-textured soils (those with a higher clay content), but over time all soils are susceptible to compaction.

Turf managers know that one key to correcting soil compaction in turf is aerification. Aerification is performed using a wide range of equipment which drills, slices, spikes, punches or water-injects the turf and its underlying soil to various depths. Sometimes the equipment removes a plug of turf, and sometimes it only cuts a slit or punches a hole. With some equipment there is the additional benefit of a small amount of thatch control, as the slicing or core removal also removes some thatch. Regardless of the exact piece of equipment used, almost every turf manager has a piece of aerification equipment in their shed.

Factors affecting the effectiveness of aerification include soil wetness, tine size, depth of aerification, soil texture, aerification frequency, and equipment type. Turf aerification research is somewhat difficult to perform. Studying soil compaction requires large plots, uniform areas of compacted (and non-compacted) turf, and possibly many different pieces of equipment. Additionally, collecting the data required to show treatment differences requires intensive sampling and a lot of labor. Typical data collected from compaction studies may include soil bulk density, soil penetrometer resistance, surface hardness, water infiltration, shoot density, and root length or weight. The objectives of this article is to provide explanations of the type of data collected in turf compaction experiments, and to discuss some past and current turfgrass compaction research.

## Things we measure in turfgrass compaction experiments

### Soil Bulk Density

Bulk density is defined as the mass of a unit volume of dry soil. To collect a bulk density reading a sample of known depth and diameter (typically 6 inches deep and 3 inches in diameter) is removed from the soil. The soil sample is dried and weighed and the bulk density is expressed as the mass per volume (grams per cubic centimeter). As the soil is compacted the bulk density increases, because more soil particles are forced into a smaller volume and soil pore space is reduced. Sandy soils typically have a higher bulk density than soils high in clay or loam, because sandy soils have few of the very small pores associated with fine-textured soils that have clay and organic matter. Additionally, sandy soils that contain sand in a range of sizes (as is a typically sand-based putting green) are already tightly packed, as smaller sand grains fit in between larger.

Typical bulk densities for clay and silt loam soils may range from 1.0 to 1.5 g/cm<sup>3</sup>, while the bulk density of sand-based soils may range

from 1.3 to 1.8 g/cm<sup>3</sup>. At the upper end of these ranges the bulk density is great enough that root penetration may be inhibited. As comparison, the USGA recommendation for bulk density of putting green rootzone mix is 1.2 to 1.6 g/cm<sup>3</sup>. It's important to note that bulk density is highly variable from location to location. One sample will usually not be an indicator of the bulk density of an entire field or turf area.



*A Remik CP-20 cone penetrometer was used to measure the resistance of soil to the insertion of a probe.*

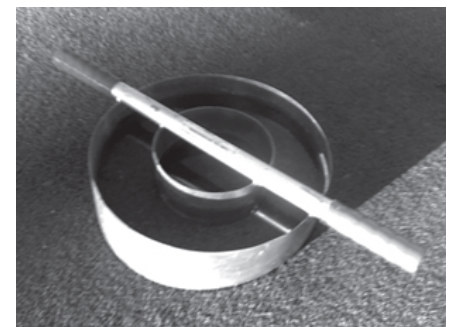
### Soil Penetrometer Readings

A soil penetrometer is a device used to measure the compaction of the soil. What is actually measured is the resistance, or amount of pressure needed to push a tipped rod through the soil. The rod tip is equipped with a load-sensing cell, and the soil strength is recorded as the tip is pushed down through the soil. Soil penetrometers used for research are very sensitive, and require some practice to use correctly to obtain accurate measurements. They are also very expensive (~\$6,000.00).

### Hydraulic Conductivity

Hydraulic conductivity is the ease with which soil transmits water. In turfgrass what we often measure is the saturated hydraulic conductivity, which occurs when all soil pores are filled with water.

Saturated hydraulic conductivity is typically measured using a double ring infiltrometer, which consists of two metal rings (one around 12 inches in diameter and the other around 18 inches), with the smaller placed inside the larger. Water is added to both rings until a height of water is maintained for a period of time, which indicates that the underlying soil has become saturated. The drop in the height of water inside the smaller ring during a given period of time is used to calculate the saturated hydraulic conductivity, which is reported in units such as inches per hour. Small-diameter (6 inches) infiltrometers can be purchased from many turf supply catalogs. The intended use of these units is to provide turf managers the ability to measure infiltration rates of their turf soils quickly, and directly in the field. Because research has shown that double-ring infiltrometers with an



*A double ring infiltrometer was used to measure infiltration rate of water into the surface of the soil on a putting green.*

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inside ring diameter of at least 12 inches produce the most accurate measurements of water infiltration, the accuracy of 6 inch diameter rings is a concern. A 1991 research study by D.H. Taylor compared single and double-ring infiltrometers with inner-ring diameters of 6, 8 and 12 inches on a variety of turf areas, from golf greens to football fields. They found that infiltration rates varied widely within each sampled turf area, even when the largest diameter rings were used. The conclusion from their work was that infiltration rates measured with ponded water should be used only as a rough estimate, and results should be used with caution (Taylor et al., 1991).

## Clegg Impact Readings

Typically used to measure the hardness of a turf surface, the Clegg hammer calculates the hardness of a surface based on its reaction to a weight dropped on the surface from a consistent height.

A diagnostic tool for discovering differences in surface hardness due to aerification treatments, work has also started on calibrating Clegg hammer readings to field hardness or softness. For example, a survey of 24 high school athletic fields had Clegg values that ranged from 33 to 167  $G_{max}$ . For comparison, a tiled concrete basement floor had a  $G_{max}$  reading of 1280, which was reduced to 260 when the floor was covered with a carpet pad (Rogers et al., 1988). In another study, compacted Kentucky bluegrass plots had a value of

206  $G_{max}$ , while plots that were not compacted had a value of 93 (Rogers and Waddington, 1992). A survey of college and professional soccer players compared their perceptions of soccer fields that had been used to collect Clegg data. Typically, fields with a hardness reading between 90 and 120  $G_{max}$  could not be differentiated by players (Miller, 1999).

## The Research

Our previous work at Auburn University found that aerification was less likely to have an effect in noncompact soils as compared compacted. We looked at the effects of using a deep, hollow tine aerifier (8 inch deep, 3/4 inch diameter) at two locations: a heavily trafficked and compacted marching band practice field, and a lightly trafficked field at the Auburn University Turfgrass Research Unit.

At the heavily-trafficked site, every additional core aerification in a given year decreased soil resistance. This was not the case at the lightly compacted site. Only one aerification was need in a given year to produce a significant reduction in soil resistance. At the heavily trafficked site, the effects of deep-tine aerification usually lasted about three weeks. This supports the conclusions of previous workers that frequent aerification might be needed on compacted sites. However we did not evaluate the effects of different equipment (e.g. tine depth, solid vs. hollow tine) on compaction in



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trafficked turf. We also wondered if continuous aerification would allow a compacted layer of soil to form at the bottom of the tine working depth. These "aerification pans" can form over time from the effect of tines pressing down on the soil below the level where they actually penetrate and remove soil.

This research examined three different pieces of equipment (a pull-behind aerifier, a GA-60 standard tine aerifier, and a Soil Reliever deep tine aerifier) using both solid and hollow tines. Plots were aerified four times per year and traffic was artificially applied with a heavy roller to induce compaction. Compaction was evaluated by measuring soil resistance to a soil penetrometer at depths down to 12 inches.

The equipment used has a large effect on the amount of compaction relief and where it occurs. The deep tine aerifier (eight inches deep) reduced soil resistance when either solid or hollow tines (5/8 inch diameter) were used. The standard tine aerifier (four inches deep) often produced a significant reduction in resistance when hollow tines (5/8 inch diameter) were used.

The deep tine aerifier reduced soil resistance from 3.5 to 7.6 inches, but did not reduce compaction in the top 3.5 inches. The standard tine unit did reduce resistance significantly in the top three inches, but had no effect deeper in the soil.

The long term effects of continued aerification with a standard tine unit fitted with solid tines (5/8 inch diameter) for three years in a row were assessed. At a depth of 2.3 to 5 inches, there was significantly more resistance compared to non-aerified plots. This indicates that a layer of compacted soil (known as a "pan" or "aerification pan") had developed near the bottom of the tine stroke. This illustrates the need for periodic deep tine aerification to avoid this problem.

The pan of compacted soil was less severe when hollow tines were used, but still could build up over time.

When the surface hardness of the turf was measured using a Clegg hammer, all forms of aerification produced a softer surface at least for one week after treatment. The standard tine aerifier with hollow tines tended to produce the softest surface.

### Conclusions

- Compaction of turfgrass soils lowers the percent macropores in the soil - a decrease in macropores limits soil aeration, which hurts root growth.
- Core aerification, especially solid tine, may not help eliminate thatch.
- Effects of aerification in heavily trafficked soils may be short-lived (~ 1 month).
- Diagnostic techniques for detecting compacted soils, such as infiltration measurements or soil penetrometer readings, are widely variable, even across supposedly uniform surfaces such as a putting green.
- Compacted "pans" develop over time at the bottom of the tine's penetration into the soil, especially when using solid tine equipment.
- Deep tine equipment is more effective at reducing soil compaction at depths below 2.5 inches.

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