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Comparing Hollow- and Solid-Tine Cultivation

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AS FAR AS golfers are concerned, cultivation (or aerification) is perhaps the least appreciated management practice used by golf course superintendents. Disruption of the playing surface and interruption of play are the main concerns of most golfers. On most golf courses, however, cultivation is necessary for the benefit of the turf. There are both short-term and long-term advantages to cultivation practices.

The objectives for using vertical-operating tine cultivation include: (1) relief of soil compaction, (2) improvement in rooting, (3) modification of thatch, (4) rejuvenation of turf by severing stolons and/or rhizomes, (5) renovation and overseeding, and (6) enhancement of fertilizer and lime penetration. The most frequently cited objective of cultivation is relief of soil compaction. By relieving soil compaction, cultivation improves water infiltration, soil aeration, surface resiliency, and turfgrass root growth in highly compacted soils.

Soil Porosity and Compaction

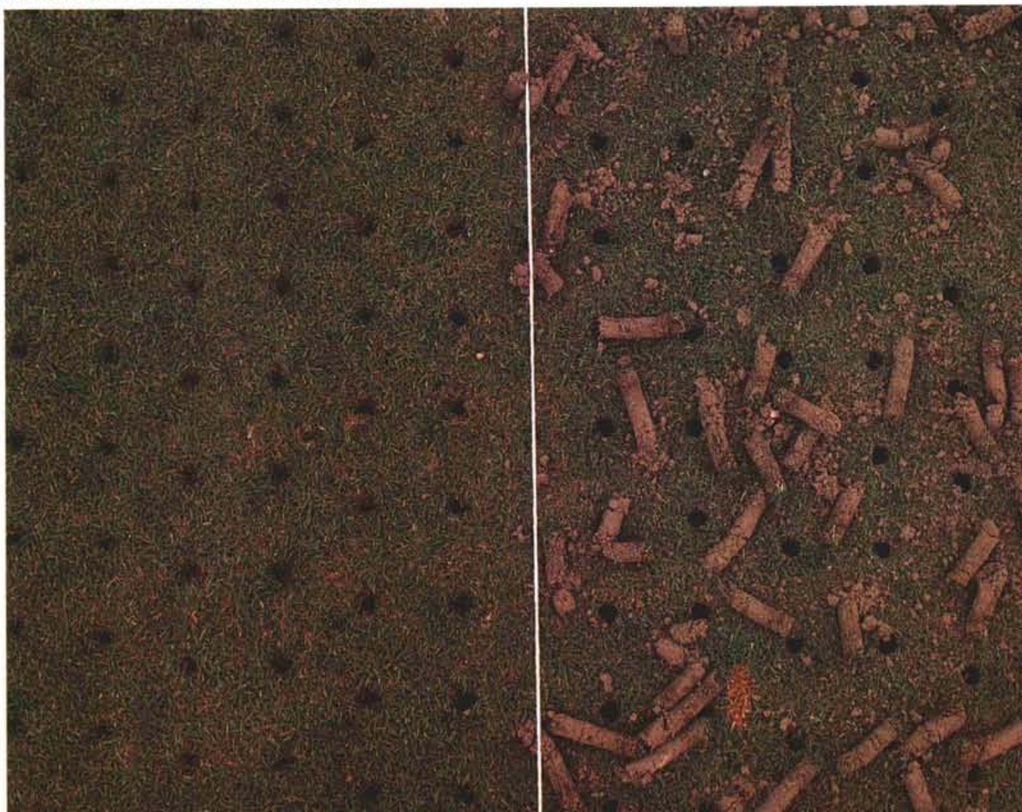
Macropores and micropores refer to the two general size classes of soil porosity. Macropores, the large soil pores, allow air and water movement into and through the soil. Macropores are also the passages through which roots grow and explore the soil. Micropores, on the other hand, are the small soil pores, and function mainly as water retention sites in the soil. Compaction of soil results when a compressive force (traffic) reduces the soil macroporosity while the microporosity remains unchanged or increases. When there are few macropores, air and water flow into and through the soil are limited, and root growth patterns are changed. The most important objective of core cultivation is to increase the amount of macroporosity in a compacted soil.

Solid-Tine Cultivation

While past cultivation practices have involved the use of hollow tines, solid-tine cultivation (STC) has recently received considerable attention as a means of reducing soil compaction. STC has been called shattercore cultivation or shattercoring. STC uses the conventional vertically operating tine units but replaces the hollow tines with solid tines. On dry, hard soils, considerable shattering of the soil mass is observed provided the equipment is heavy enough to permit adequate tine penetration. Less surface and soil disruption occurs on well-watered soils when using STC.

Among the advantages of STC are (1) reduced cleanup of putting surfaces, (2) reduced labor needs, (3) faster healing of the "coring" holes and improvement of putting surface playability, and (4) the ability to cultivate more frequently as a result of the other three benefits. Critics of STC are concerned that compaction at the lower end of the cultivation zone due to the cultivation treatment is more severe with STC compared to hollow-tine cultivation (HTC). The term "cultivation pan" refers to the compacted layer which can develop at the lower end of the cultivation zone.

The lack of soil cores is one advantage solid-tine cultivation (left) has compared to conventional hollow-tine cultivation.



Influence of recent solid-tine cultivation (center) on water infiltration compared to noncultivated turf (right) and turf cultivated one month previously (left).

This is similar to the plow pan commonly observed in agricultural soils when fields are plowed to the same depth each year. This plow pan is known to restrict air and water movement and limit rooting.

Research at Michigan State University has compared hollow- and solid-tine cultivation on a "Penneagle" creeping bentgrass green grown on a loamy sand soil (83.5% sand). Hollow- and solid-tine cultivation were performed on compacted and noncompacted plots over three seasons. Compaction was applied weekly with a Ryan Rollaire water-filled vibrating roller. Also, both cultivation methods were performed under dry and wet soil conditions. Cultivation treatments were applied once in 1984 and three times each in 1985 and 1986. This research was jointly funded by the USGA Green Section, the Michigan Turfgrass Foundation, and the Michigan Agricultural Experiment Station.

Soil Responses

Laboratory studies using computed axial tomography (CT) scanning showed HTC caused soil compaction along the sides and at the bottom of the coring hole (Petrovic, 1979). Compaction along the side of the coring hole is not considered a major concern with HTC, because compaction tends to dissipate with time as these sidewalls collapse into the coring hole. Soil compaction at the bottom of the coring hole does not dissipate quickly, and is considered to be of greater concern (Petrovic, 1979).

Our field studies have shown that HTC and STC result in different soil responses. STC did not reduce soil density because "coring" holes (very large macropores) were made without removing soil. As coring holes were created with STC, some of the macropores existing prior to treatment were destroyed. Overall, STC did not increase macroporosity under compacted soil conditions because the amount of macropores created (coring holes) did not exceed the macropores destroyed. Under noncompacted conditions, more macropores were lost than created with STC for an overall loss in macropores.

Since HTC removed soil, the adverse effect on existing macropores was minimal compared to STC. In noncompacted soil, the loss of existing macropores was smaller with HTC than with STC, with no net change in macroporosity. In compacted soil, HTC increased overall macroporosity compared to noncultivated soil. Therefore, the development of a cultivation pan is of greater concern with STC than HTC. In our research, cultivation pan development with HTC was only a problem in noncompacted soil.

As the cultivation pan developed with continued treatment, water movement to depths below the zone of cultivation slowed. Soil which was not compacted was affected by both HTC and STC, while compacted soils were negatively affectd only by STC. One way to reduce the tendency to form a cultivation pan is to allow the soil to dry prior to cultivation. Water infiltration rates remained high when cultivation (both HTC and STC) was done under dry soil conditions compared to when the soil was wet.

The shattering effect of STC can provide a significant loosening of the soil surface and allow for better surface infiltration of water and improved aeration. But this effect is short term compared to HTC. The loosening achieved with STC dissipates rapidly with continued traffic, and the soil quickly returns to a compacted condition. Conversely, HTC removes soil, providing space for soil to collapse into the holes when compressed, thus resisting a quick return to a more compacted condition. If a loosened soil condition is desired, routine STC will be required on turfgrass sites subjected to high levels of traffic. Unfortunately, this type of compaction management enhances the development of a cultivation pan. Varying the depth of cultivation, cultivating only under dry soil conditions, and using small diameter tines are ways to counteract cultivation pan development. Cultivation pan formation will vary with soil texture, compaction level, and soil moisture level at the time of cultivation.

Alternatives for Management of a Cultivation Pan

Several new tools which reach to a greater depth in the soil have come into use recently. Some units cause greater surface disruption than others, but all have been used on greens as well as other turf areas. The different techniques which cultivate to greater soil depths include (1) deep drill, (2) deep tine (hollow and solid), (3) subaerification, and (4) water injection aerification. Deep cultivators can break through cultivation pans which have formed. In our research with the Verti-Drain (deep tine), we noted significant loosening of the soil to a depth below six inches. Usually it is necessary to roll the greens after the use of solid tines to smooth the putting surface. Our studies with the Hydroject 3000 (water injection) showed surface disruption to be minimized while achieving deep soil cultivation.

Plant Response

Significant turf injury is a distinct possibility when cultivating under relatively dry soil conditions. Considerable soil disruption occurs when cultivating dry soil. As the soil shatters, roots are torn and severed. Also, HTC removes plant material and temporarily lowers turf density. This mechanical injury sets back the turf, slowing growth and recovery, and reducing the number of viable roots.

Midseason cultivation with either hollow or solid tines reduces the surface rooting of creeping bentgrass greens (Murphy and Rieke, 1987). Root growth in the coring holes is a slow process because the initiation of new roots is lowest in the summer months for creeping bentgrass (Koski, 1983). A significant increase in rooting following cultivation will occur during the early spring when new root formation is greatest, whereas root formation falls sharply in late spring. Although summer cultivation may not increase the number of roots, the functioning of the root system should improve due to the improved soil conditions, particularly on highly compacted soils.

Quality ratings on the compacted turf improved with both HTC and STC. However, when soil brought to the surface with HTC was worked back into the turf, HTC provided a superior quality turf compared to STC. Cultivation under wet soil conditions resulted in better turf quality than cultivating under dry soil conditions. Soil disruption is greater and the turf is under greater water stress when soils are dry during cultivation, resulting in greater root damage and lower turf recovery.

The ability to work soil into the thatch layer is a clear benefit of HTC over STC. A thatch modified with soil resists extreme changes in water content and temperature, thereby helping reduce the stresses imposed on a turf. Soil incorporated into the thatch also provides good conditions for rooting. In our research, coring three times a season was sufficient to maintain a well-mixed thatch/soil layer.

Soil profile after three years and seven treatment applications of cultivation; hollow tine (right) and check (left). Solid tine (not shown) is similar to check.

Recommendations for STC

STC with closely spaced, small diameter (¼ inch) tines can be used for temporary relief of compaction on heavily trafficked sites. Severely compacted soils will benefit from the temporary loosening achieved with STC, which can be used effectively on a monthly basis, if necessary. In our view, the potential for cultivation pan development is not a major concern when the site is already receiving severe compaction stress. In this situation, the problem in need of immediate attention is surface compaction. Additionally, STC may be effectively used when performed on a spot treatment basis. A regular program of STC with small diameter tines on high, dry areas susceptible to runoff and localized dry spots or on highly compacted traffic zones should improve water infiltration. By limiting STC to a spot treatment program, the potential for cultivation pan formation is isolated to known areas.

To counteract the development of a cultivation pan, it is best to cultivate when the soil is more dry and to vary the depth of cultivation, if possible. There must be sufficient soil water to allow tines to penetrate, of course. Also, small diameter tines should help limit the formation of cultivation pan, yet allow some loosening of the soil to improve water infiltration. Because no soil is removed with STC, the gain in improved water infiltration will be short-lived, and repeat treatment will likely be necessary.

STC can be an effective cultivation method when used in combination with HTC. The spring and fall seasons allow HTC to be used, while midseason cultivation can be accomplished with small diameter STC. On sites where soil compaction is not a severe problem, STC is not recommended. It is useful to review your overall management objectives and goals to determine which equipment and program are best for use in a particular situation.

Literature Cited

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Liability on the Golf Course

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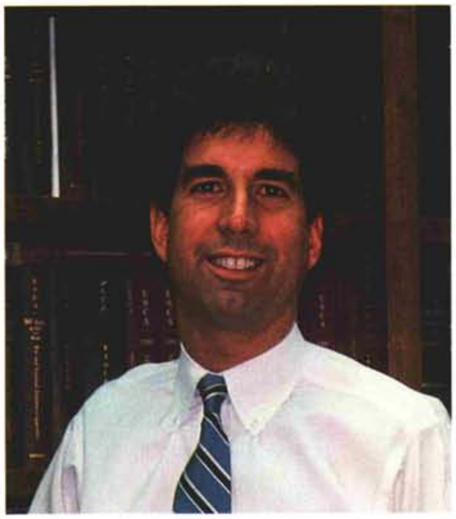
THE PAGES of this publication are normally devoted to responding to the numerous challenges that agronomic conditions pose to managers and superintendents of golf courses and clubs. However, in an increasingly litigious society, managers and superintendents are now becoming aware of the many ways in which their operations may invite litigation.

Liability on the golf course can conveniently be divided into three principal subjects. First, there is liability for injuries to employees, which generally involves the law of workers' compensation. Second, there is liability for injuries to golfers and others, which implicates the law of tort liability for personal injuries. Finally, of increasing prominence is the law governing liability for chemical damage to the course, which can best be described as tort liability for property damage.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Liability to Employees: The Law of Workers' Compensation

Anyone who suffers an injury is ordinarily entitled to recover damages for the injury if it was caused by the negligent conduct of another. Negligent conduct is that which falls below what we expect people to do in a given circumstance, such as to obey traffic signals to avoid automobile accidents. An individual injured because of someone else's negligence is entitled to recover full damages from them: all lost wages, future lost earnings, medical expenses, and pain and suffering. This is part of the law of tort, which is discussed more fully below.

An employee who is injured on the job as a result of the negligence of his employer or a fellow employee is ordinarily not allowed to sue them for damages. In other words, the employer and fellow employees are immune from damages under the law of tort. Instead, the employee is limited to recovering benefits provided by state statutes. These benefits are called workers' or workmen's compensation benefits. Typically, all medical expenses are paid by the compensation insurer, and an employee who misses work receives additional weekly benefits that approximate a fraction of his average weekly wage, usually either 2/3 or 3/4. He does not receive any damages for pain and suffering.

In return, the employee is not required to show that his injury was caused by the negligence of another. He is entitled to workers' compensation benefits simply by showing he was injured on the job, regardless of whether the accident was anyone's fault.

It is possible to have both legal remedies (tort and workers' compensation) apply to an accidental injury. For example, a grounds crew member may be seriously injured by the equipment he was operating. Because the injury occurred on the job, he would be entitled to workers' compensation benefits. However, he could not recover general damages from his employer, the club, or from any fellow employees