The original aeration device.

The latest concept, the Toro HydroJect.

Aeration Takes Root in Sports Turf

By Dr. John C. Harper

Sports fields, golf greens and park turf, as simple as they may appear, are complex communities of plants and organisms living in careful balance. While the vast majority of turf maintenance is directed at the foliage and thatch above ground, an equally important portion of the turfgrass community lies below the soil surface, completely out of sight. Failing to maintain the subsurface portion of turf over a period of time disrupts the balance of the turfgrass community and leads to its steady decline.

There are practical methods available today to maintain "the other half" of turf. They not only improve the overall quality of turf areas, they also increase the effectiveness of surface maintenance methods and provide the sports turf manager with greater control.

The most popular of these methods is mechanical aeration. This process makes a series of holes or slits in the soil. These openings relieve compaction, improve drainage, permit air and nutrients to penetrate the root zone, and provide channels through impermeable layers below the surface.

In the darkness of the soil, turfgrasses develop extensive root systems. Roots stabilize the foliage, they explore the pore spaces between soil particles for water, air and nutrients, and they store carbohydrates manufactured in the leaves above. Turf scientists have discovered turfgrass roots extending more than four feet into the soil. If you consider all the plant functions carried out by roots, you quickly realize they are every bit as important to the turfgrass plant as the leaves.

Leaves have one special task, to manufacture sugars and starches (carbohydrates) by a process called photosynthesis. Chlorophyll contained in the leaves captures the energy of the sun to convert water and carbon dioxide into sugars and starches. These carbohydrates are then utilized by the plant to fuel its growth. Excess carbohydrates are sent to the roots for storage.

The roots have the job of obtaining the water, nutrients and gases for photosynthesis, respiration, and growth. A turfgrass plant in full sun without a healthy root system will not perform up to its potential. Therefore, an equal amount of consideration should be given to turfgrass roots.

By applying quality fertilizers, sports turf managers provide most of the nutrients sought by the roots. Irrigation provides the necessary moisture. Even so, poor drainage, poor soil, heavy thatch or other barriers preventing nutrients and moisture from entering the root zone greatly reduce the effectiveness of standard turf maintenance practices.

These barriers preventing proper soil/atmosphere exchange are often caused by compaction of the surface soil. Thousands of impacts caused by foot and vehicle traffic tamp down the top inch or two of soil so tightly that neither air or water can pass through.

The negatives associated with compaction have been listed by Dr. J.R. Hall, extension agronomist at Virginia Tech, Blacksburg, VA. They include destruction of the soil structure, reduced soil drainage, and increased soil-eroding runoff, reduced protection of the root zone to heat or cold, pesticides are unable to reach and control insects in the soil, and there is less storage space within the soil for water, air, and nutrients, and results in higher maintenance costs. Root growth is also stunted by compacted soil. Shorter and smaller root systems render turfgrass more vulnerable to periods of stress.

Thatch, nondecomposed stems, leaves, and roots on the surface of soil, can be harmful to healthy turf if it becomes more than 1/2-inch thick. Heavy thatch reduces the effectiveness of some herbicides and insecticides, harbors insects and diseases and can disrupt uniform infiltration of irrigation or natural rainfall. Research has shown that periodic aeration helps mix soil into the thatch layer to aid in its decomposition. Some thatch is considered advantageous for sports turf since it provides a cushion that protects both the player and the turfgrass from damage upon impact.

Another barrier to healthy turf growth is soil incompatibility, a situation created when sod grown on highly-organic soil is installed over a sandy or clay soil. Heavy applications of organic materials to a turf growing in sandy or clay soils can have the same effect. The organic layer at the surface acts like a sponge, keeping the surface excessively damp and preventing surface water from draining through the soil as it should. This environment is destructive to

continued on page 18

Holland Aerway fractures subsurface layers of soil.

Aeration

continued from page 17

organisms living in the turf that assist in the decomposition of thatch.

Compaction, thatch, and soil incompatibility are often the real causes of turf failure blamed on poor irrigation practices, diseases, insects, or inadequate fertilization. There is enough evidence to support the use of aerators by sports turf managers to prevent and break up soil barriers.

The earliest documentation of aeration is in a book titled *Making A Lawn*, written in 1912 by L.J. Doogue of the Boston Parks Department. Doogue recognized the need to work fertilizer into compacted soils. He writes, "Take a round stick about one inch in diameter and three feet long and sharpen one end. At frequent intervals, drive the stick to a depth of two feet about the grounds. Make many such holes, and into these ram a mixture of finely-powdered manure, hardwood ashes and bone meal. In a short time the good effects of this treatment will manifest themselves and during subsequent seasons the treatment can be extended to parts not touched before. It practically means that the land will be as thoroughly renovated as if it had been plowed and harrowed."

However, in 1917, the need for aeration was not recognized in the first comprehensive U.S. publication on golf course management, *Turf for Golf Courses*, by Piper and Oakley. These early agronomists worked for the United States Department of Agriculture and assisted the United States Golf Association in establishing turf management practices for its members.

Dr. Fred V. Grau, the first extension turfgrass specialist for Pennsylvania State University, reported that he had no recollection of any type of equipment being used to improve soil-air relationships or to reduce soil compaction at the USDA's Arlington Turf Gardens in the early 1930s. Grau did remember golf course superintendents using potato forks and spading forks to loosen hard spots on putting greens that resisted water penetration.

In the mid-'30s, a Michigan concern offered for sale a three-gang, pull-behind spike disk fairway cultivator, a spike disk greens cultivator, and a 10-inch-wide home lawn spike disk cultivator. In its advertising, the company stated, "It is an accepted fact that turf requires aeration and cultivation especially upon turf that receives constant play." The tractor-drawn model on the market today is essentially the same as the 1930 version.

During the late '30s and early '40s, many turfgrass managers developed their own versions of aerating equipment, ranging from devices as simple as large spikes drive through planks to "Rube Goldberg-type" machines that required several men to push or pull. Soil aeration was a major topic of "Lawn Schools" given by agricultural agent Charles K. Hallowell in Philadelphia during the period.

In 1945, Grau, then director of the USGA Green Section, discussed developing a commercial aeration machine with Tom and Tony Mascaro, owners of West Point Products in West Point, PA. The Mascaro brothers decided to expand their topdressing business into equipment manufacturing and designed the West Point Aerifier. This development truly became the beginning of a new era for specialized turfgrass management equipment. Hahn purchased the manufacturing rights to the "West Point Aerifier" in 1970.

The West Point Aerifier had one drawback. Because the tines entered and exited the soil at an angle, they would lift up a lip of turf at the back of the core hole. Golf course superintendents were concerned that these lips would disrupt putting on golf greens. To provide superintendents with a neater surface following aeration, the Greensaire Aerification Co., of Hopkins, MN, (purchased by Ryan in 1950) invented an aerator that drove hollow, cylindrical tines vertically into the soil and pulled soil cores straight out. These machines were considerably slower than disc-type or West Point aerators.

The first walk-behind aerator for general lawn use was the Motoraire introduced in the '50s by Soilaire Industries (purchased by Ryan in 1960). Hollow tines pivoted on solid metal wheels as they turned. The tines entered and exited the soil in an almost vertical position providing a neat enough job for residential or commercial lawns. The unit was also as fast as a West Point aerifier.

The Dedoes Co. manufactures a drum aerator which traps the soil cores inside instead of depositing them on the turf. Screens on both ends of the drums trap the cores until they can be deposited in low spots or discarded. These are convenient for smaller jobs where cores could be a problem, but impractical for large areas where the aerator may remove 10 or more cubic yards of cores per acre.

In recent years, several new concepts have appeared in aerating equipment, including an oscillating or quaking tine effect. For the most part, the method of operation has basically been two-fold. The so-called punch-type aerators drive hollow or solid tines in and out of the soil vertically with very little tearing or raising of the sod around the hole. These machines were developed primarily for golf course greens, grass tennis courts, bowling greens or other closely-cut turf areas where minimum disruption of play is essential.

The second, or rolling-type, machines are equipped with solid spikes, hollow tines, open-spoon tines, or slitting-slicing tines of varying shapes and sizes. the tines are mounted on a drum, a series of discs, or directly on an axle that rolls forward with the machine. The tines enter and exit the soil at an angle. For this reason, some tines tend to tear and raise the soil around the lip of the hole.

As previously indicated, there are many different types of tines. Hollow tines and open-spoon tines remove soil cores while solid tines remove little or no soil. Most tines vary from 1/4 to 3/4 inches in diameter. Slicing tines are available in a variety of shapes, sizes and thicknesses. An early aerator known as the Nightcrawler designed for greens actually used augers (large drill bits) in place of tines.

The spacing of tines determines the number of holes or slices made in a given area. A machine equipped with hollow tines on two-inch centers will provide approximately 36,000 holes per 1,000 square feet. A random check of commercial literature reveals tine spacing of 2, 2.5, 2.75, 3, 3.5, 4, 4.5, 5.5, and 6 inches are currently available.

Tine mounting also varies on rolling-type aerators. Most rolling-type, core-removing machines have hollow or open-spoon tines mounted rigidly on the drum or axle. A few manufacturers of rolling-type machines have the tines mounted on hinges. The theory is the tine enters and leaves the soil in an almost straight vertical position causing less tearing of the sod around the hole. Generally, spiking, slicing and slitting tines are mounted rigidly.

Speed of operation has been a major consideration in the development of aeration equipment. Unfortunately, there has been a direct correlation between speed and the quality of the aeration results. Generally, the faster rolling-type machines do not have close tine spacing, the clean entry and exit, or the depth of vertical-core machines. The outcry for faster equipment is the result of greatly increased labor costs, down time of the turfgrass area and inconvenience to the player. Some golf courses, where cost is not a limiting factor, have begun using slow-moving punch-type greens aerators to cultivate their fairways. Classen, Cushman, Green Care International, Jacobsen, Terracare, and Toro have reengineered punch-type aerators for fairways and sports fields.

Depth of penetration also has been a concern. Most machines on the market today that pull soil cores penetrate approximately two to three inches. One U.S. manufacturer provides six inch hollow tines. Slicing or slitting machines may penetrate as deeply as six inches whereas spikers normally used to break up surface crusts only penetrate one to two inches.

Some manufacturers offer accessories for their equipment line. Attachments to windrow or pick up soil cores are on the market today. One manufacturer offers an attachment that picks up the plugs, shatters them and returns them to the turf as topdressing material. Weight trays and weights for maximum tine penetration are offered by many suppliers.

A major concern of many turfgrass managers is the development of a compacted soil layer at the point of maximum tine penetration following frequent aerification. It makes no difference whether the machine is a punch-type or rolling-type.

One possible means of reducing this problem may be the development of better depth control for existing machines so penetration depth can be varied from one aeration to the next. Unfortunately, the shallow maximum depth of many machines limits this approach. A possible alternative would be to follow a program using several machines having different depths of maximum penetration.

The development of the compacted layer is akin to the development of a fragipan or hard pan in a crops soil. Not only is drainage impeded but roots fail to penetrate the

continued on page 20

Aeration
continued from page 19

compacted layer. This layer in turf soils may be more serious than in some crop soils because it develops at such a shallow depth. The resulting shallow roots may lead to severe stress of the plants during drought periods.

Deep aeration devices have been developed in the past few years to break through subsurface compacted layers. The Verti-Drain is one example. Holland Co. of Ontario, Canada, has developed a spike-like tine that fractures the soil below the surface without damaging the turf above. Yeager Twose and Olathe have machines that aerate by cutting grooves in the soil. The Vertigroove by TurfTech removes thin, deep slices of soil instead of cores. The slices are removed or broken up like cores would be.

Obviously, tines have the potential to damage irrigation heads and shallow lines. Heads should be marked before aeration and the depth of aeration should be set to prevent tines from hitting irrigation lines or wires.

Tines glazing the sides of core holes or soil slits is also a concern. Glazed surfaces have a very thin compacted layer which reduces the movement of oxygen and water into the soil and carbon dioxide out of the soil. Some manufacturers claim that the action of their tines shatters the wall of the hole or slit and thus avoids the problem. This may be true for relatively dry soils, but moist soils do not shatter readily. Furthermore, some aerators will not penetrate dry soils well.

Aerator manufacturers have added devices to their machines that counteract some of the tearing and lifting of the sod. Springs attached to each tine compress the surface as the tine enters the soil and reduces lifting of sod when it exits. Even vertical core machines have spring-loaded guides that hold the soil around the points the tines enter. Toro has taken a different approach to this problem by introducing the Hydro-Ject which uses jets of water instead of tines to create channels in the soil.

As indicated earlier, speed of aeration is important in some turf operations. In situations where uninterrupted turf use is critical, especially from a financial standpoint, sports managers are forced to sacrifice some quality for speed. Where time is a limiting factor, slicing equipment can be operated at higher speeds than coring equipment although quality may be less. A.J. Turgeon gives a detailed discussion of the relative merits of coring as compared to slicing or spiking in his book *Turfgrass Management*.

Rapid drying out of the turf can be a problem if aeration timing is improper. During hot weather, especially under windy conditions, desiccation around the core or slit opening can occur quite rapidly. Drying out potential is greater with coring than slicing or spiking. During hot, windy weather, it is recommended that a slicing or spiking machine be used rather than a coring unit and that irrigation be available.

On the other hand, soils that are prone to remain wet for long periods benefit from coring just prior to expected periods of prolonged rainfall. When hurricane Agnes struck the Atlantic Coast in the spring of 1972, golf greens that had been core aerated that spring withstood flood waters and/or prolonged rainfall much better than those that had not been cored. Wet soils can also be dried out faster by coring providing the equipment used is capable of pulling cores from wet soil.

Opening up the soil for air, moisture, and nutrients, also opens it up for insects and weed seeds. Cutworms living in core holes and feeding near the surface will cause a brown, damaged ring of turf at the top of the hole. Aerated areas known to be infested with cutworms or insects of similar habit, should be treated with an insecticide at the first sign of insect damage.

Aeration can bring viable weed seeds to the surface that would be too deep to germinate otherwise. Crabgrass seed has the ability to lie dormant in the soil for many years and to germinate readily when brought to the soil surface. Annual bluegrass seed germination also can be increased by aeration.

It's important to note that aerators should not be used during the effective period of preemergence herbicides. These herbicides form a chemical barrier just below the surface of the soil which blocks germinating weeds. Mechanical aeration breaks through the chemical barrier and damages the effectiveness of these herbicides.

The benefits of aeration far outweigh the problems it creates. The most common benefits attributed to aeration are the improvement of gaseous exchange between the soil and the atmosphere and the reduction of compaction. By removing the cores, the bulk density or hardness of the soil decreases. This softer soil cushions the impact of players falling on it and a major factor in reducing sports injuries.

The effectiveness and efficiency of fertilizer and liming materials is increased when these materials are applied following aeration but prior to dragging to break up soil cores on the surface. Experimentally, it has been shown that the amount of phosphorus at the two and three-inch level is increased approximately 29 percent if aeration precedes phosphate application. This is especially important in phosphorus-deficient soils since surface-applied phosphate moves downward in the soil very slowly. The downward movement of lime is also slow and aeration offers a way to amend acid soils more quickly. Control of soil-inhabiting insects and other pests with pesticides is markedly improved through aeration.

Aeration increases water infiltration if soils have shallow layers of compacted or incompatible soil within the depth penetration range of the equipment. These layers may consist of sand, organic matter or soils of totally different composition. This problem most frequently occurs on golf greens or high-maintenance fields where topdressing with sand; sand and soil; or sand, soil and organic matter is a standard practice. The problem arises when the type of topdressing material is changed.

Coring is more effective than slicing when layering is a problem. Coring reopens a channel between soil layers, removes part of the problem soil and permits topdressing material is changed.

Thatch layers that develop in sports turf also impede water movement through the soil profile, especially if the thatch has dried out. Dry thatch, like dry peat, is highly hydrophobic (resists wetting). Thatch buildup also prevents lime, fertilizer and pesticides from moving downward in the soil. Many insecticides are readily bound by thatch, greatly reducing their efficacy in controlling insects such as white grubs.

Thatch that becomes saturated tends to remain wet for long periods. This is as much a problem as dry, hydrophobic thatch. When thatch remains soaked the oxygen supply available to the plant is greatly reduced and limits the activity of aerobic soil microorganisms necessary for nutrient conversion and decomposition of organic material. Aeration can increase microbial activity in the soil and assist in the breakdown of thatch. By improving oxygen relations in the thatch layer, aerobic decomposition is increased. Most thatch layers are highly acidic. The movement of lime into the thatch through aeration raises the Ph of the thatch and stimulates bacterial activity.

Examination of turf managed with a regular aeration program will show proliferation of new, white and healthy roots in the core holes or slits. This is the response of the plants to improved environmental growth conditions, especially oxygen relationships in the soil adjacent to the core hole.

Aeration also provides a means of overseeding into established turf without destroying the existing vegetation. Overseeding with a turf-type disk seeder is the most effective method of overseeding. But thorough aeration (six to 10 passes) can be quite effective as a means of introducing seed to the soil when a disk-type seeder is not available. Apply the seed after aeration but before dragging. Some sports turf managers prefer to apply one third to one half the seed prior to aeration and the remainder after aeration but prior to dragging.

It is impossible to properly maintain any sports turf facility, especially those with heavy use, without a regular aeration program in combination with other sound agronomic practices.

There is a noticeable difference in appearance between turf that has been aerated and turf that hasn't. In some cases resodding can be replaced with aeration and overseeding. But, most importantly, both halves of the turfgrass community will be properly maintained.

Dr. Harper retired last year as extension agronomist at Pennsylvania State University. This article was updated from the original version which appeared in the March 1987 issue.