Nutrient runoff from bermudagrass fairways after aerification

Will aerification decrease nutrient runoff from fairways?

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Nitrogen and phosphorus are two of the most important nutrients used for the establishment and maintenance of golf course turf (1), including fairways, which often border lakes, streams and other water features. Bermudagrass (*Cynodon* species) is commonly used for fairways and is fertilized with nitrogen and phosphorus, which both have the potential for off-site movement in surface runoff.

High nutrient-concentration levels of nitrate and phosphate in surface water encourage eutrophication, the undesirable growth of algae and aquatic plants that can deplete oxygen and affect plants and animals in the area. Nitrogen is transported in water runoff from turfgrass, primarily as nitrate-nitrogen and ammonium-nitrogen, and may contribute to eutrophication at concentrations as low as 3.8 milligrams/gallon (1 milligram/liter) (10). Phosphorus in surface runoff from golf course turf areas is primarily transported as HPO_4^{2-} and $H_2PO_4^-$, which is also called dissolved reactive phosphorus, and can contribute to eutrophication at concentrations as low as 0.09 milligram/gallon (25 micrograms/liter) (10). Because many blue-green algae can assimilate atmospheric nitrogen, phosphorus, rather than nitrogen, is typically the more important contributing factor for eutrophication of surface water (8).

Turfgrass is effective at reducing nutrient runoff (4,5), especially if the fertilizer is watered-in (9) after application. However, nutrient concentrations in runoff from turf were high enough to contribute to eutrophication in previous studies (3). Research has demonstrated that vegetative filter strips, commonly called buffers, may reduce nutrient runoff from fairways (2,6), but in both studies nutrient concentrations were high enough to contribute to the degradation of surface-water quality. Additional research is required to determine which management practices further reduce nutrient runoff from turf.

Aerification

Researchers have found that aerifying buffer strips (rough) does not affect nutrient runoff from simulated fairways (2), but little is known about the effects of aerifying the fairway itself. Hollow-tine aerification transfers soil from beneath the turfgrass to above its surface. Whether the soil cores are dragged back into the core holes or left on the turfgrass surface, portions of the soil located on the turfgrass surface could potentially contribute to nutrient runoff. Alternatively, the aerification holes could increase water infiltration and decrease potential nutrient runoff.

The objective of this study was to investigate the influence of hollow-tine aerification on nutrient runoff from bermudagrass fairways under natural rainfall conditions. We hypothesized that aerification would reduce nutrient runoff from bermudagrass fairways under natural rainfall conditions by increasing water infiltration into the soil profile.

Site description

This research was conducted on the Okla-

The runoff experiments were conducted at the Oklahoma State University Turfgrass Runoff Research Site in Stillwater. **Photos by J. Moss**

homa State University Turfgrass Runoff Research Site, Stillwater. The soil at the site was Norge silt loam with a bulk density of 0.87 ounce/cubic inch (1.50 grams/cubic centimeter). The runoff site was divided into three large blocks. Each block consisted of two experimental units that measured 40.4 feet (12.3 meters) wide with a uniform 5% slope that measured 80.05 feet (24.4 meters) long. The site was graded and sodded with U-3 bermudagrass [*Cynodon dactylon* L. (Pers.)] in summer 1998. Plots were mowed three times a week at 0.5 inch (1.3 centimeters) during the growing season. Before this study, plots were fertilized with nitrogen at 43.7 pounds/acre (49 kilograms hectare) per month and phosphate at 21.4 pounds/acre (24 kilograms/hectare) per month during the growing seasons of 2000, 2001 and 2002.

Runoff measurements

Earthen berms that confined runoff to the area under investigation separated experimental units and blocks. Covered troughs collected runoff water from each experimental unit and channeled it through calibrated Parshall flumes by gravity flow. (A Parshall flume has a specially shaped open-channel flow section that may be installed in a ditch, canal or lateral to measure the flow rate.) Modules mounted over each flume used ultrasonic reflection to measure water level (6). Portable samplers were programmed to determine the rate of water flow from these water-level measurements, and a pump in each sampler provided runoff sample collection. A rapid transfer device enabled information transfer from samplers to a computer.

Irrigation and soil moisture

Time-domain-reflex probes were permanently buried along the slope in each experimental unit to assess soil moisture content and to help maintain antecedent soil moisture at uniform conditions before natural rainfall. An in-ground sprinkler-type irrigation system that delivered 2 inches (51 millimeters) per hour was located along the edges of each block. The experimental units were irrigated three times per week to field capacity determined by volumetric water content 24 hours after saturation. The runoff site was at or very near field capacity (1.8 square feet of water/cubic yard of soil [0.22 square meter/cubic meter]) immediately before each occurrence of natural rainfall.

Covered troughs collected the runoff and channeled it through Parshall flumes by gravity flow.

In-ground sprinklers were used to make sure the experimental area was at field capacity when natural rainfall occurred.

Runoff sampling

Treatments consisted of three plots (one plot per block) that were aerified using hollow tines and three plots that were not aerified. Data were collected for two months in 2003 and two months in 2004. Plots were aerified at the beginning of each of the four months of the study.

Aerification was done in a single direction using tines that were 0.6 inch (1.6 centimeters) in diameter and 3 inches (7.6 centimeters) long. Spacing between tines and aerification holes was 2.5 inches (6.4 centimeters). After aerification, cores were dragged within each plot with a wire rake pulled behind a utility vehicle; the remaining soil core pieces were further broken down by mowing each plot with a reel mower.

Following aerification, fertilizer was applied to all plots as urea at 43.7 pounds nitrogen/acre (49 kilograms/hectare) per month and as triple superphosphate at 21.4 pounds P_2O_5/acre (24 kilograms/hectare) per month.

Plots were irrigated lightly for 7 minutes at the rate of 2 inches (51 millimeters) per hour after fertilization to water-in the nutrient application. Time from the beginning of rainfall to the initiation of runoff was recorded for each rainfall, and runoff water samples were collected in 5-minute intervals for 60 minutes.

Analytical procedures

Water samples were analyzed for nitrate-nitrogen and ammonium-nitrogen using colorimetric methods by automated flow-injection analysis, and they were analyzed for dissolved reactive phosphorus using the phosphomolybdate colorimetric procedure (7). The detection limit was 0.01 milligram/liter for each nutrient in the runoff water samples. The average background levels of nutrients in the natural rainfall samples were 0.58 milligram/liter for nitrate-nitrogen, 0.29 milligram/liter for ammonium-nitrogen and 0.09 milligram/liter for dissolved reactive phosphorus. The nutrient mass and concentrations reported in this paper are the background nutrient levels plus fertilizer losses. The background nutrient levels were subtracted from the measured concentrations in collected runoff samples when the proportion of fertilizer loss from plots was determined.

Natural rainfall that produced measurable runoff was recorded on seven dates: 0.6 inch (15 millimeters) on May 14; 1.6 inches (41 millimeters) on May 16; 0.7 inch (19 millimeters) on June 10; 2.2 inches (55 millimeters) on June 25; and 0.7 inch (17 millimeters) on Aug. 30 in 2003; and 2.5 inches (64 millimeters) on March 4 and 1.3 inches (33 millimeters) on April 10 in 2004. Runoff water nutrient samples were collected following the first significant rainfall after aerification each month. Therefore, no water nutrient samples were collected on May 16 and June 25, 2003. Flow data were recorded for all events.

Nutrient losses following the beginning of runoff were calculated by multiplying the average nutrient concentration during each sampling interval by the total amount of runoff that passed through the Parshall flume during each 5-minute sample period. The total nutrient loss for each treatment following runoff initiation was computed by adding the total amount of nitrate-nitrogen, ammonium-nitrogen or dissolved reactive phosphorus that was calculated for each 5-minute sample period.

Flow rate

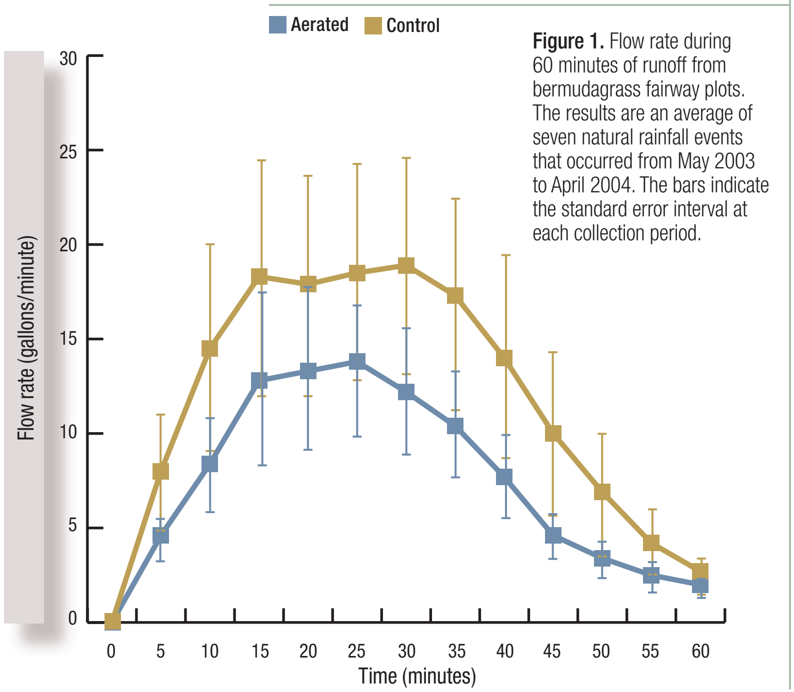

Figure 1. Flow rate during 60 minutes of runoff from bermudagrass fairway plots. The results are an average of seven natural rainfall events that occurred from May 2003 to April 2004. The bars indicate the standard error interval at each collection period.

Rainfall and runoff response

There was no interaction between collection date and treatment, so data were averaged over all collection dates. The minimum amount of rainfall required to produce runoff from fairway plots during the course of this study was 0.6 inch (15 millimeters).

Aerification had no significant effect on flow rate or nutrient concentration during 60 minutes of runoff (Figures 1,2,3). The peak runoff rates of aerified plots and control plots were not significantly different. Runoff from all plots reached an average maximum flow rate of 16.1 gallons (61.1 liters) per minute at 25 minutes after runoff began.

Nutrient concentrations in runoff samples from aerified and control plots also were not significantly different. The average nutrient concentrations in the 360 runoff samples were nitrate-nitrogen at 0.54 milligram/liter, ammonium-nitrogen at 0.44 milligram/liter, and dissolved reactive phosphorus at 1.20 milligrams/liter. Less than 1% of the urea and triple superphosphate applied were lost to runoff, probably because the fertilizer was watered-in immediately after application and because rainfall did not occur for an average of 13 days following treatment. These results concur with earlier research (9) demonstrating that nutrient losses from bermudagrass fertilization were reduced when fertilizer was watered-in immediately after application and as time between application and runoff increased.

The initiation of runoff in aerified plots was delayed significantly (by an average of 4.1 minutes) when compared to initiation of runoff in control plots. The average time to initiation of runoff was 47.9 minutes for control plots and 52.0 minutes for aerified plots. This delay may be attributed to an increase in water infiltration caused by aerification.

Aerification did not significantly reduce total nutrient loss or runoff volume (Table 1). Average nitrogen loss from plots was 0.28 ounce/acre (20.2 grams/hectare), and average dissolved reactive phosphorus loss was 0.36 ounce/acre (25.4 grams/hectare); average cumulative runoff volume from plots was 8,391.4 gallons/acre (78,493 liters/hectare). The maximum average nutrient concentrations for nitrogen and dissolved reactive phosphorus occurred at 5 minutes after runoff initiation and were 1.7 milligrams/liter for nitrogen (Figure 2) and 1.5 milligrams/liter for dissolved reactive phosphorus (Figure 3). There was no significant difference in nutrient concentrations at any sample time during this study. Although these nutrient concentrations were relatively low, they were above the minimum capable of enhancing eutrophication of surface waters (10). Although the treatment effects were not significant, the surface runoff from the aerified plots was consistently lower than surface runoff from the control plots (Figure 1). In addition, nutrient concentrations of nitrogen and dissolved reactive

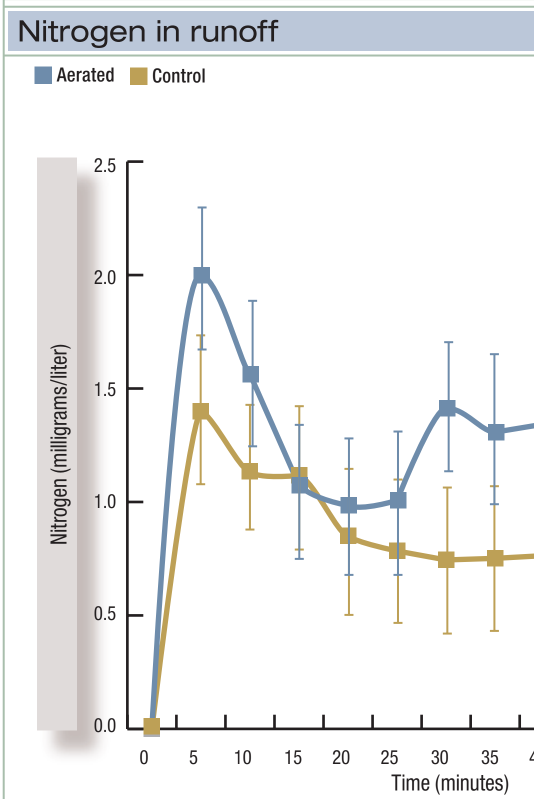

Figure 2. Concentration of nitrogen (nitrate-nitrogen + ammonium-nitrogen) in natural rainfall runoff from bermudagrass fairways for 60 minutes after runoff began. The results are an average of seven natural rainfall events that occurred from May 2003 to April 2004. The bars indicate the standard error interval at each collection period.

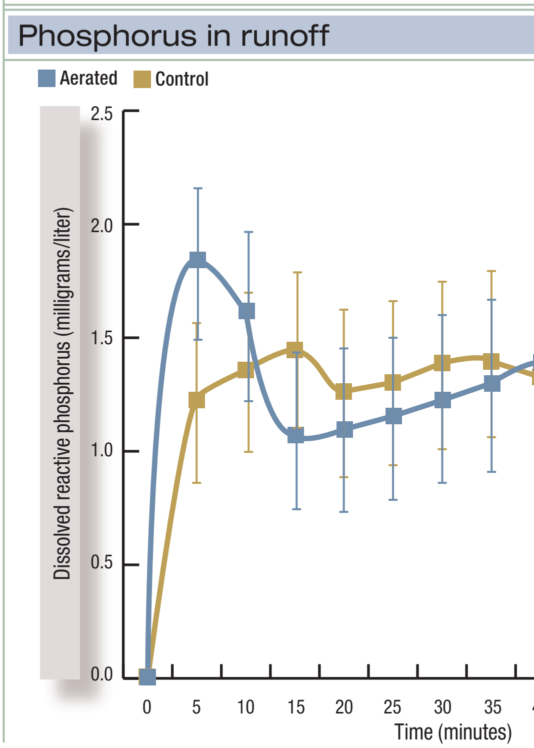

Figure 3. Concentration of dissolved reactive phosphorus in natural rainfall runoff from bermudagrass fairway plots for 60 minutes after runoff began. The results are an average of seven natural rainfall events that occurred from May 2003 to April 2004. The bars indicate the standard error interval at each collection period.

Nutrients in runoff

Treatment†	Cumulative volume	Nitrogen	Dissolved reactive phosphorus
	Mean ± standard error		
Control	10,267 ± 3,531 gallons/acre (96,034 ± 33,032 liters/hectare)	0.24 ± 0.06 ounce/acre (16.8 ± 4.1 grams/hectare)	0.33 ± 0.09 ounce/acre (22.8 ± 6.4 grams/hectare)
Aerification	6,516 ± 1,773 gallons/acre (60,951 ±16,583 liters/hectare)	0.34 ± 0.10 ounce/acre (23.6 ±7.2 grams/hectare)	0.40 ± 0.12 ounce/acre (27.9 ± 8.7 grams/hectare)

†In all cases, the values for the aerification treatments were not significantly different from the values for the controls.

Table 1. Cumulative volume of natural rainfall runoff from bermudagrass fairway plots for 60 minutes after runoff began and total mass of nitrogen (nitrate-nitrogen + ammonium-nitrogen) and dissolved reactive phosphorus in natural rainfall runoff from bermudagrass fairway plots for 60 minutes after runoff began. The results are the average of seven natural rainfalls.

phosphorus were consistently higher during the first 5 minutes of runoff from the aerified plots than from the control plots. With the high variability of natural precipitation and the use of only three replications for each treatment in this study, the large standard error values for surface runoff and nutrient concentrations could be expected. The construction of a larger turfgrass surface runoff study area than the one used here could be beneficial for future research by providing more replications and degrees of freedom.

Conclusions

Aerification is a common turf management practice that serves to alleviate compaction, promote new growth and increase soil oxygen content. According to the results of this study, aerification will neither increase or decrease surface water runoff and nutrient loss from bermudagrass fairways under natural rainfall conditions. Although aerified plots consistently produced less runoff volume under the parameters of this study, the difference in runoff volume between aerified and control plots was not statistically significant. Superintendents using management practices like the ones in this study may aerify their fairways one or more times during the growing season without affecting nutrient losses to surface runoff.

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The research says

➔ Three plots of fairway-height bermudagrass were aerified monthly with hollow tines; the aerified plots and three control plots were fertilized with 43.7 pounds nitrogen/acre and 21.4 pounds phosphate/acre at the beginning of each month of the study.

➔ Runoff samples were collected and tested after seven occurrences of natural rainfall.

➔ Aerification delayed runoff by 4 minutes but did not significantly reduce runoff volume or nutrient losses when compared to control plots.

➔ For both treatments, the total amount of applied fertilizer lost to surface runoff was extremely low (<1%); nutrient concentrations were not statistically different between treatments.

➔ Hollow-tine aerification neither reduced nor contributed to a loss of nutrients to natural rainfall runoff.