Mowing Roughs to Minimize Runoff

Scientists at Oklahoma State University demonstrate the environmental protection value of multiple-height roughs.

BY GREG BELL AND JUSTIN MOSS

Golf course fairways are fertilized to promote good turf cover, high turf density, and minimal weed encroachment. The higher-cut golf course rough acts as a vegetative filter strip or buffer that reduces runoff. Oklahoma State University researchers compared the use of multiple barriers with a single-buffer barrier in reducing nutrient runoff.

Golf course fairways tend to receive more fertilizer than most turfgrass areas to promote good turf cover, high turf density, and minimal weed encroachment. There is a slight but nonetheless possible likelihood that a small portion of the fertilizers applied to golf course fairways can dissolve in surface water runoff and contaminate lakes, streams, and other water features. Given this possibility, it is important that turf scientists pursue and investigate management methods that help superintendents develop environmentally sound practices that reduce the potential for nutrient runoff.

The higher-cut golf course rough that commonly surrounds fairways acts as a vegetative filter strip or buffer that reduces runoff.[2] Research suggests that the higher the buffer, the longer the period between rainfall initiation and runoff, and the more likely that runoff will be eliminated or reduced following a particular rainfall event.[1] The density of the turf on the fairway or in the rough also has an impact on runoff.[3,4] Golf course superintendents strive to maintain full turf cover and maximum turf density, thereby reducing the likelihood that runoff will occur.

Even under worst-case conditions where fertilizer was applied to turf but not watered in and a major storm event occurred within a few hours of application, the amount of fertilizer nitrogen (N) and phosphorus (P) lost to runoff was generally less than 10% of applied and, more often, only 2-4% of applied.[9] The levels of P that were found during studies of nutrient runoff from turf were often less than those found in natural rainfall.[6]

Based on previous research, we reasoned that it is difficult for water to flow through the dense system of shoots formed by closely mowed turf.[3,4] Consequently, because turf density tends to increase with decreasing mowing height, it may be reasoned that a low mowing height should be more effective than a higher one for providing resistance to flow. That may be the case for turfgrass stands of a single mowing height, but it did not prove correct for turfgrass stands that include vegetative buffers.[1] When runoff flows from a low-cut turf to a higher-cut turf, its passage is further restricted.[2] Based on the density principle, water flowing from a short mowing height to a taller mowing height should pass easily through the relatively low density of the higher height of cut. Research indicates, however, that this does not occur. Buffers of 1.5 inches did not restrict flow as effectively as buffers of 3.0 inches.[1]

When surface runoff from a golf course fairway encounters golf course rough, it tends to slow and puddle until sufficient energy builds to allow the water to flow through or over the higher height of cut. The higher-cut turf forms a barrier to gravitational flow that must be overcome before the surface runoff continues down the slope, providing more time for the runoff to infiltrate into the thatch and soil. Therefore, a graduated system of rough such as apron to first cut to primary rough would provide three heights of cut, resulting in three barriers. Since wider buffers do not seem to deter runoff with greater effectiveness than shorter ones[2] and since exceptionally high mowing heights could negatively affect playability, this multiple-barrier strategy could provide the best alternative for reducing nutrient runoff from fairways. The objective of this research was to effectively compare this multiple-barrier strategy with the single-buffer strategy that is already known to be effective.

THE RESEARCH SITE

The water runoff research site at Oklahoma State University consisted of three irrigation blocks with two 40 ft. × 80 ft. plots per block, for a total of six plots on 0.44 acre. The site was mature common bermudagrass (*Cynodon dactylon*) on compacted silt loam soil with a surface infiltration rate of less than 0.5 inch per hour. The turf irrigation system delivers a precipitation rate

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of 2 inches per hour. A series of 18 time domain reflectometer probes served to monitor soil moisture so that the site could be consistently maintained at field capacity. The turf was mowed at 0.5 inch across the upper sections of each plot three times per week to simulate golf course fairways.

The fairway sections were 40 ft. wide by 62 ft. long and were bordered by rough that was 40 ft. wide by 18 ft. long at the bottom of the slope. The single-barrier rough was mowed at 2 inches for the full 18 ft. length from fairway to collection trough, and the multiple-barrier rough was mowed at increasingly higher heights every 6 ft. down the slope. The mowing heights for the multiple-barrier rough increased from 1.0 inch at the highest surface elevation to 1.5 inches at the intermediate location to 2.0 inches at the lowest elevation. The buffers were mowed once per week.

Researchers at Oklahoma State University found that using vegetative buffers maintained at multiple mowing heights improved the ability to limit both nitrogen and phosphorus runoff compared to buffers maintained at a single height of cut.

FERTILIZER, PRECIPITATION, AND SAMPLE COLLECTION

To test nutrient runoff, urea and triple super phosphate fertilizer were applied at 1 lb. nitrogen (N) per 1,000 sq. ft. and 0.5 lb. phosphorus (P) per 1,000 sq. ft. four hours before irrigating and again following irrigation events to await natural rainfall. The fertilizers were applied as granules and were not watered-in so that the study represented worst-case conditions. Fertilizers were

Table 1

The mean runoff flow rate, amount of N and P, and N and P concentrations (conc.) during 5-minute intervals in runoff produced by six irrigation events and four natural rainfall events.

Time	Flow Rate		N Lost to Runoff		P Lost to Runoff		N Conc.		P Conc.	
	Multiple	Single	Multiple	Single	Multiple	Single	Multiple	Single	Multiple	Single
min	gal/ac/min		lb/ac/min				ppm			
Irrigation Runoff										
5	62	73	0.0005	0.0005	0.0015	0.0010	1.0	0.7	2.9	*1.7
10	151	182	0.0018	0.0015	0.0050	0.0043	1.4	*1.0	4.0	*2.8
15	234	*286	0.0046	0.0042	0.0120	0.0122	2.3	*1.7	6.2	5.1
20	285	*345	0.0075	0.0081	0.0185	0.0204	3.2	2.8	7.8	7.1
25	313	*381	0.0093	0.0112	0.0215	0.0254	3.5	3.5	8.2	8.0
30	334	*398	0.0102	*0.0126	0.0221	*0.0260	3.6	3.8	7.9	7.8
35	347	*412	0.0102	*0.0128	0.0207	*0.0243	3.5	3.7	7.1	7.1
40	348	*422	0.0097	*0.0126	0.0180	*0.0220	3.4	3.6	6.2	6.3
45	363	*423	0.0096	*0.0122	0.0164	*0.0197	3.2	3.5	5.4	5.6
50	365	*412	0.0090	*0.0113	0.0144	*0.0172	3.0	3.3	4.7	5.0
55	354	*406	0.0082	*0.0105	0.0125	*0.0150	2.8	3.1	4.2	4.4
60	341	*406	0.0074	*0.0102	0.0104	*0.0135	2.6	*3.0	3.6	4.0
Natural Rainfall Runoff										
5	284	277	0.0037	0.0034	0.0090	0.0061	1.6	1.5	3.8	*2.6
10	512	508	0.0073	0.0066	0.0205	0.0145	1.7	1.6	4.8	*3.4
15	349	409	0.0057	0.0057	0.0188	0.0183	2.0	1.7	6.5	5.3
20	191	*266	0.0034	0.0041	0.0124	0.0160	2.1	1.8	7.8	7.2
25	153	*195	0.0027	0.0033	0.0104	0.0127	2.1	2.0	8.1	7.8
30	170	*198	0.0029	0.0035	0.0107	0.0127	2.0	2.1	7.6	7.7
35	157	*218	0.0026	*0.0039	0.0091	*0.0130	2.0	2.1	6.9	7.1
40	126	*194	0.0019	*0.0033	0.0064	*0.0102	1.8	2.1	6.2	6.3
45	82	*143	0.0012	*0.0023	0.0037	*0.0066	1.7	2.0	5.3	5.5
50	45	* 93	0.0006	*0.0015	0.0017	*0.0038	1.6	1.9	4.6	4.9
55	18	* 55	0.0002	*0.0008	0.0006	*0.0020	1.5	1.8	4.0	4.4
60	11	* 33	0.0001	*0.0005	0.0003	*0.0011	1.4	1.8	3.4	3.9

*Indicates a significant difference between the multiple-barrier and single-barrier rough ($P < 0.05$)

applied to the simulated golf course fairway area six times in 2001 and six times in 2002. Fertilizer was not applied to the rough.

Covered troughs collected runoff water from each plot and channeled it through calibrated Parshall flumes by gravity flow. Ultrasonic modules (Isco 710) mounted over each Parshall flume used ultrasonic reflection to measure water level. Isco 6700 portable samplers (Isco, Lincoln, Nebraska) were secured to concrete platforms located between each experimental block. The samplers were programmed to determine water flow rate and collect runoff samples every five minutes for 60 minutes. Samples were tested to determine the amount of N and P in the runoff. The time from the beginning of precipitation to the beginning of runoff also was measured for each plot during each event.

Runoff caused by irrigation was collected three times in 2001 and three times in 2002. Natural rainfall runoff was collected once in 2001 and three times in 2002. Each time precipitation occurred, multiple samples of the irrigation or rainfall were collected and the concentrations of N and P in the samples were determined. Background concentrations were subtracted from the nutrient concentrations in the runoff to determine the actual amount of N and P removed from the turf.

RESULTS — RUNOFF RATE AND TIMING

During irrigation, the multiple-barrier rough reduced the peak runoff rate by 14% compared with the single-barrier rough and reduced the total runoff at 60 minutes by 16%. In contrast, peak runoff occurred more rapidly during the natural rainfall events, producing an average of 510 gallons per acre per minute at 10 minutes after runoff began (Table 1). The multiple-barrier rough did not significantly affect the peak natural rainfall runoff rate, but it did significantly reduce the cumulative runoff volume by 19% during 60 minutes of runoff.

The multiple-barrier rough significantly delayed the time from the beginning of precipitation to the beginning of runoff compared with the single-barrier rough during both irrigation and natural rainfall. The multiple-barrier rough delayed runoff initiation by approximately four minutes during irrigation and by two minutes during natural rainfall. The average time to initiation of runoff during irrigation events was 20 minutes for the multiple-barrier rough and 16 minutes for the single-barrier rough. Time to runoff for natural rainfall events was 39 minutes for the multiple-barrier rough and 37 minutes for the single-barrier rough.

NUTRIENT LOSSES

The fertilizer application methods that were applied to the irrigation experiments in this study were established to provide worst-case conditions. Golf course superintendents generally do not apply fertilizer within 48 hours prior to predicted rainfall and nearly always water-in the fertilizer immediately following application to minimize possible runoff losses. The nutrient losses in this study are representative of a worst-case scenario and are likely to be more severe than what typically occurs.

Fertilizer losses in runoff were small compared with fertilizer applied. On average, 1.5% of the N applied was lost to irrigation runoff and 0.5% to natural rainfall runoff during 60 minutes of runoff. Irrigation runoff caused a 5.5% loss of applied P and natural rainfall runoff caused a 3.3% loss of applied P during 60 minutes of runoff. These results are comparable with the results of other researchers and further support the contention that turf has a positive influence on the reduction of nutrient losses from runoff.[3,7]

The reduced runoff volume resulting from the use of the multiple-barrier rough compared to the single-barrier rough caused a significant reduction in the amount of N and P lost to both irrigation and natural runoff (Table 1). The multiple-barrier rough reduced the amount of N lost with 60 minutes of irrigation runoff by 18% and the amount of N lost with 60 minutes of natural rainfall runoff by 17%. The multiple-barrier rough reduced the amount of P lost to irrigation runoff by 14% and the amount of P lost to natural rainfall runoff by 11% during 60 minutes of runoff.

The concentration of NO_3-N never exceeded the recommended EPA limit for drinking water of 10 ppm,[8] but both dissolved N (NO_3-N + NH_4-N) and dissolved P consistently exceeded 1 ppm and 25 ppb, respectively, the commonly recommended allowances for reducing the likelihood of eutrophication.[9] The N concentrations in both irrigation and natural rainfall accelerated rapidly from 5 to 25 minutes and were highest between approximately 25 to 35 minutes (Table 1). The P concentrations also accelerated rapidly and were highest in both forms of precipitation at approximately 20 to 35 minutes (Table 1).

The rapidly accelerating nutrient losses during the beginning of runoff offset the delay in time to runoff between treatments and effectively neutralized the beneficial effects of the multiple-barrier rough during the initial stages of runoff. After 20 to 25 minutes of runoff, nutrient losses were nearly equal among treatments in spite of the average four- or two-minute delay in time to runoff caused by the multiple-barrier rough and the greater volume of irrigation runoff from the single-barrier rough (Table 1). Consequently, the multiple-barrier rough did not affect nutrient runoff significantly for the first 30 to 35 minutes of runoff, but maintained an advantage following 35 minutes until at least 60 minutes of runoff during both irrigation and natural rainfall.

RUNOFF REDUCTION

Based on 55 years of precipitation data collected at Stillwater, Oklahoma, an average of 81 rainfall events occurred each year.[5] Most of those events did not produce adequate precipitation to force runoff, but seven events per year produced at least 0.5 inch of rainfall (the amount required to produce runoff at the research site) at an average precipitation rate greater than 0.5 inch (the surface infiltration rate) for at least one hour, and lasted longer than 72 minutes (the average time of precipitation required to produce significant differences in nutrient losses between buffer treatments). Consequently, the use of multiple-barrier roughs could make a meaningful difference in the amount of nutrients lost in runoff during those seven runoff-producing rainfall events that are likely to occur each year in Stillwater, Oklahoma. The average annual rainfall in Stillwater is 37 inches, a relatively dry climate compared with many regions of the world. The multiple-barrier rough may well make a greater difference in regions where rainfall is more plentiful.

A simple observation of turf following a severe rainstorm indicates that runoff not only occurs through the shoots but also occurs over the leaves. Areas of severe runoff are identified by the prostrate appearance of the turf. When runoff water from bare soil encounters a grass barrier, the runoff slows due to shoot resistance until sufficient volume accumulates to provide the force necessary to bend the shoots and the lower leaves, allowing the runoff to flow over or around the plants. We hypothesize that when water encounters a second mowing height, a similar resistance occurs and sufficient volume must be accumulated to overcome this second barrier.

During this study, a puddle of water formed each time the runoff encountered a buffer. The puddling was most noticeable at the interface of the fairway and initial buffer but also occurred at the interface of each height increase in the multiple-height buffers. Although turf density can be expected to increase with lower mowing height and have an inhibitory effect on runoff,[3,4] the work of Baird et al.[1] indicated that when a buffer strategy is employed, the shoot height of the buffer vegetation had a greater effect on runoff than turf density. Baird et al.[1] reported that a 3.0-inch buffer height was more effective for reducing water runoff than a 1.5-inch buffer. Accordingly, multiple mowing heights result in multiple barriers that slow runoff and reduce runoff volume.

Editor's Note: A more detailed research report originally appeared in *USGA Turfgrass and Environmental Research Online* (http://usgatero.msu.edu). Readers may visit this Web site for this and many other articles reporting the results of USGA's Turfgrass and Environmental Research Program.

LITERATURE CITED

1. Baird, J. H., N. T. Basta, R. L. Huhnke, G. V. Johnson, M. E. Payton, D. E. Storm, C. A. Wilson, M. D. Smolen, D. L. Martin, and J. T. Cole. 2000. Best management practices to reduce pesticide and nutrient runoff from turf. *In* J. M. Clark and M. P. Kenna (eds.) Fate and management of turfgrass chemicals. American Chemical Society. Washington, D.C.

2. Cole, J. T., J. H. Baird, N. T. Basta, R. L. Huhnke, D. E. Storm, G. V. Johnson, M. E. Payton, M. D. Smolen, D. L. Martin, and J. C. Cole. 1997. Influence of buffers on pesticide and nutrient runoff from bermudagrass turf. *J. Environ. Qual.* 26:1589-1598.

3. Easton, Z. M., and A. M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. *J. Environ. Qual.* 33:645-655.

4. Linde, D. T., T. L. Watschke, and J. A. Borger. 1994. Nutrient transport in runoff from two turfgrass species. Pages 268-293. *In* A. J. Cochran and M. R. Farrally (ed.) Science and Golf II: Proceedings of the World Scientific Congress of Golf. E & FN Spon, London.

5. NCDC Data Online. 2005. TD3240 hourly precipitation data [online]. National Climatic Data Center, Asheville, N.C. Available at: http://www.ncdc.noaa.gov/oa/climate/stationlocator.html (verified February 2, 2005).

6. Sharpley, A., B. Foy, and P. Withers. 2000. Practical and innovative measures for the control of agricultural phosphorus losses to water: an overview. *J. Environ. Qual.* 29:1-9.

7. Shuman, L. M. 2002. Phosphorus and nitrate nitrogen in runoff following fertilizer application to turfgrass. *J. Environ. Qual.* 31:1710-1715.

8. USEPA. 1976. Quality criteria for water. U.S. Gov. Print. Office, Washington, D.C.

9. Walker, W. J., and B. Branham. 1992. Environmental impacts of turfgrass fertilization. p. 105-219. *In* J. C. Balogh and W. J. Walker (eds.) Golf course management and construction: environmental issues. Lewis Publ., Chelsea, Mich.

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