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University of Wisconsin scientists initiated research at Wisconsin River Golf Club (WRGC) in Stevens Point, WI to compare the relative amount of nutrient loading in runoff and leachate when prairie and fine fescues were used as buffer strips alongside golf course fairways. They also wanted to determine the effect of three different ratios of buffer strips relative to the fairway area draining into the buffer strips. The information will be useful for predicting effectiveness of different vegetation types and buffer strip sizes on golf courses to limit runoff losses.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 350 projects at a cost of $27 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Impact of Prairie and Turf Buffer Strips on Golf Course Fairway Runoff and Leachate

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SUMMARY

University of Wisconsin scientists initiated research at Wisconsin River Golf Club (WRGC) in Stevens Point, WI to compare the relative amount of nutrient loading in runoff and leachate when prairie and fine fescues were used as buffer strips alongside golf course fairways. They also wanted to determine the effect of three different ratios of buffer strips relative to the fairway area draining into the buffer strips. The study's findings include:

- Golf course fairways infiltrated > 95% of rainfall.
- Buffer strips of fine fescues provided runoff and leachate results similar to prairie plantings.
- Buffer strips, regardless of size, did not affect water volumes or phosphorus runoff from fairways and represented a natural background level of phosphorus in surface water.
- Nitrogen in water leached from buffer strips of fine fescue or prairie was similar to that obtained under fertilized golf course fairways.

Federal mandates to decrease nutrient pollution of water supplies are resulting in various local and state regulations aimed at reducing phosphorus movement into surface waters and nitrogen movement into groundwater. Some regulations aim to reduce nutrient and sediment loading into surface waters based on the idea that "native", or prairie, vegetation should be used as buffer strips between mowed turf and natural areas or surface water.

While research on water runoff and leaching has been ongoing for over 30 years, efforts have been aimed largely at agricultural areas with much less activity in prairie and turf situations. Some research indicates that dense turf vegetation is more effective at reducing runoff and nutrient leaching than other strategies including mulched landscaped beds (5, 7, 8, 16). Data are just starting to be published which report on the effectiveness of prairie buffer strips to reduce nutrient loading in water runoff and leachate relative to turf (22). Also unknown is the size requirement of buffer strips relative to the area they are to be buffering.

Turf is often used as a ground cover throughout society, including golf course roughs, because it is relatively easy to establish and maintain, provides contiguous ground cover throughout the year under traffic and mowing, and the low mowing height facilitates human activity while discouraging vermin and insect pests. The various turf species allow some type of turf to be established across a diversity of situations, including moist or dry soils, and moderately shaded to full-sun conditions.

Prairie plantings are being increasingly promoted as a low-cost alternative to managed turf. They are also seen as "native" while most

Figure 1. Early establishment phase of fairway buffer plots on the 8th fairway at Wisconsin River Golf Course, Stevens Point, WI, April 2004

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Vegetation type	Ratio	Mean Area (m^2)
No buffer, fairway only (annual bluegrass)	Not applicable	12.45
Fairway: prairie (narrow buffer strip)	8:1	14.01
Fairway: fine fescue (narrow buffer strip)	8:1	14.01
Fairway: prairie (medium buffer strip)	4:1	15.58
Fairway: fine fescue (medium buffer strip)	4:1	15.58
Fairway: prairie (wide buffer strip)	2:1	18.68
Fairway: fine fescue (wide buffer strip)	2:1	18.68

Table 1. Vegetative buffer strip treatments at Wisconsin River Golf Course, Stevens Point, WI

cool-season turf species were introduced from Eurasia (3). While management is usually much less intensive than turf, establishment of prairie vegetation is not necessarily less expensive than turf as prairie seed may cost considerably more. Prairie establishment may take years during which time weeds, especially noxious weeds, must be regularly controlled. Lastly, prairie plantings are not necessarily suited for many habitats such as wooded golf courses. A number of golf courses utilize fine fescues as a low maintenance roughs which receive almost as little attention as prairie areas, yet establish quickly and easily. Generic regulations that require the installation of prairie buffer strips can be costly, reduce valuable golf turf areas, and promote the assumption that turf has inherently negative environmental consequences.

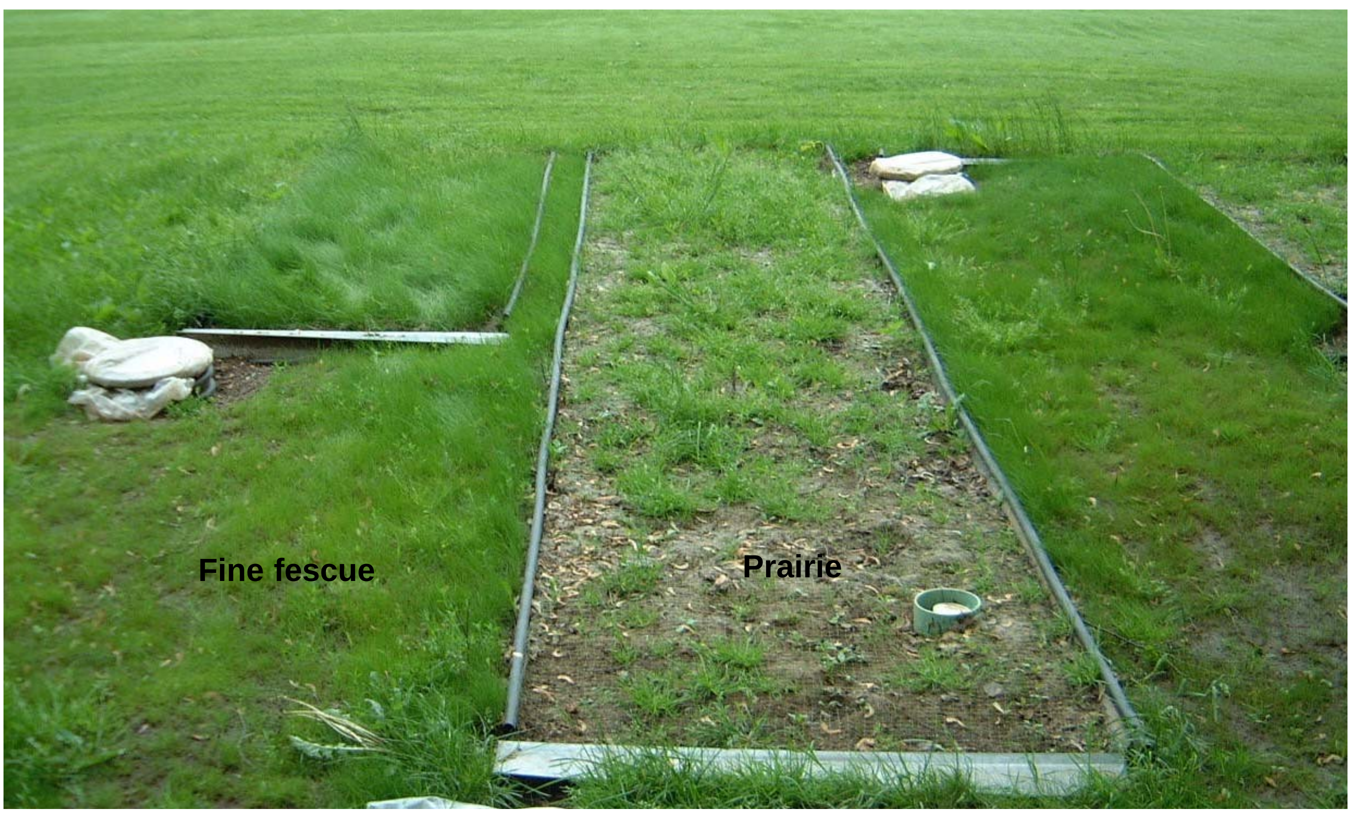

Figure 2. Rapid establishment of fine fescue in buffer strip plots (left) compared to slower establishment of prairie vegetation which allowed annual weeds and grasses to dominate (right)

Figure 3. Fairway and buffer strip runoff was collected in Nalgene® containers as water exited from a collection flume at the downslope end of the buffer strips.

Data culled from various projects suggest annual nutrient loading from mowed turf may be similar to that from prairies as most of the nutrient loss occurs when nutrients are leached from dead foliage (9, 15, 21). When we began the study in 2003, there were no data that directly compared the efficiency of turf to prairie vegetation for its ability to minimize runoff and leachate pollution, particularly during the establishment phase which can last for two to three years.

The goals of our project were to compare the relative amount of nutrient loading in runoff and leachate when prairie and fine fescues were used as buffer strips alongside golf course fairways. We also wanted to determine the effect of three different ratios of buffer strips relative to the fairway area draining into the buffer strips. The information will be useful for predicting effectiveness of different vegetation types and buffer strip sizes on golf courses.

Growing Buffer Strips and Installing Water Samplers

Research plots were constructed in 2003 at the Wisconsin River Golf Club (WRGC) in Stevens Point, WI. The golf course is adjacent to and drains into the Wisconsin River. Two large natural areas exist within the course and the course is surrounded primarily by forest with a small amount of agricultural land. The project provides a good role model for lower budget courses as WRGC has a management budget of less than $100,000 excluding the superintendent's salary.

The plots were developed in the roughs which drain fairways 4, 8, and 9. Fairways were approximately 85 feet wide and crowned in the middle with 1-2% slopes. Fairway turf was predominantly annual bluegrass (*Poa annua* L.). The sites had about 12 inches of silt to sandy loam over a sandy soil. Soil pH ranged from 4.8 to 5.5; lime was incorporated into the buffer strip sites one year prior to planting to raise the pH to 6.0 over a two- to three-year period. Buffer strip plots were installed at the edge of the fairways and had slopes ranging from approximately 1 to 4%. Plots on fairway 9 were in full sun, plots on fairway 8 were in slight shade from nearby maple trees, while plots on fairway 4 were moderately shaded and almost directly under a grove of maple and pine trees. Treatments included 2:1, 4:1, and 8:1 fairway to buffer strip ratios, with one ratio each of prairie or fine fescue mixtures (Table 1; Figures 1 and 2). A seventh treatment in each replicate was a no-buffer strip plot.

Galvanized steel runoff collection flumes (1-meter width) were installed at the lower end of each buffer strip plot. Each collection flume had a cover to prevent debris from falling into the flume while a screen-covered slit at the soil surface allowed runoff water to enter. Runoff water was collected in plastic Nalgene™ jugs, installed in covered pits, which were connected to each collection flume by a pipe (Figure 3). Plots were separated by 0.3-meter border areas. Plastic landscape edging was installed on both sides of each plot to prevent surface water from flowing between plots. Leachate was collected in each buffer strip using a low-tension lysimeter installed just upslope of the runoff-collection weir (14).

Plots were dormant-seeded in October as recommended for prairie plantings and covered with a biodegradable wood fiber erosion control blanket. Prairie plots were planted to a commercial prairie seed mixture which included flowers and grasses (Prairie Nursery Inc., Westfield, WI; Table 2). Fine fescue plots were seeded to a commercial seed mix containing Chewings, creeping red, blue, and hard fescues ("Care-free Mix", L.L. Olds Seed Co., Madison, WI).

None of the plots were irrigated, treated with pesticide, or fertilized during the study. Plots were mowed (clippings returned) at 7.6 cm height in early spring 2004 and 2005 to encourage new growth in accordance with recommendations for

Perennial flowers

Species†	Blooms Color	Blooms Month‡
Asclepia incarnata (Red milkweed)	Pink/red	6-7
Eupatorium purpureum (Woodland Joe Pye Weed)	Pink	7-8
Aster novae-angliae (New England Aster)	Purple	8-10
Monarda fistulosa (Bergamot)	Purple	7-9
Iris shrevei (Wild iris)	Blue	5-8
Rudbeckia subtomentosa (Sweet Black-eyed Susan)	Yellow	7-10
Liatris pycnostachya (Dense blazingstar)	Purple	8-9
Verbena hastate (Vervain)	Purple	7-10
Lobelia siphilitica (Great Blue Lobelia)	Blue	8-9
Vernonia fasciculate (Ironweed)		
Lobelia cardinalis (Cardinal flower)	Scarlet	7-8
Zizia aurea (Divided Leaf Golden Alexander)	Yellow	5-6

Grasses and sedges

Species†	Species†
Andropogon gerardi (Big bluestem)	*Elymus canadensis* (Canada wild rye)
Carex vulpinoidea (Fox sedge)	*Glyceria striata* (Fowl manna grass)

Fine fescue mixture

Species/cultivar	Scientific name	% in mix (wt.)
Creeping red fescue 'SR5210'	*Festuca rubra ssp. rubra*	19.6
Slender creeping red fescue 'Dawson'	*F. rubra ssp. litoralis*	19.6
Blue fescue 'SR3210'	*F. glauca*	14.7
Chewings fescue 'SR5100'	*F. rubra spp. commutata*	14.7
Chewings fescue 'Sandpiper'	*F. rubra spp. commutata*	9.8
Hard fescue 'SR3150'	*F. longifolia*	9.8
Hard fescue 'Scaldis'	*F. longifolia*	9.8

† Quantity of species varies depending upon that year's seed production and harvest. Mix was supposed to include at least 12 perennial flower species. Due to the nature of prairie seed production and collection, certified seed is unavailable.

‡ Number corresponds to month of year, e.g., 7 = July, 8 = August, etc.

Table 2. Species and cultivars used for vegetative buffer strips at Wisconsin River Golf Course, Stevens Point, WI

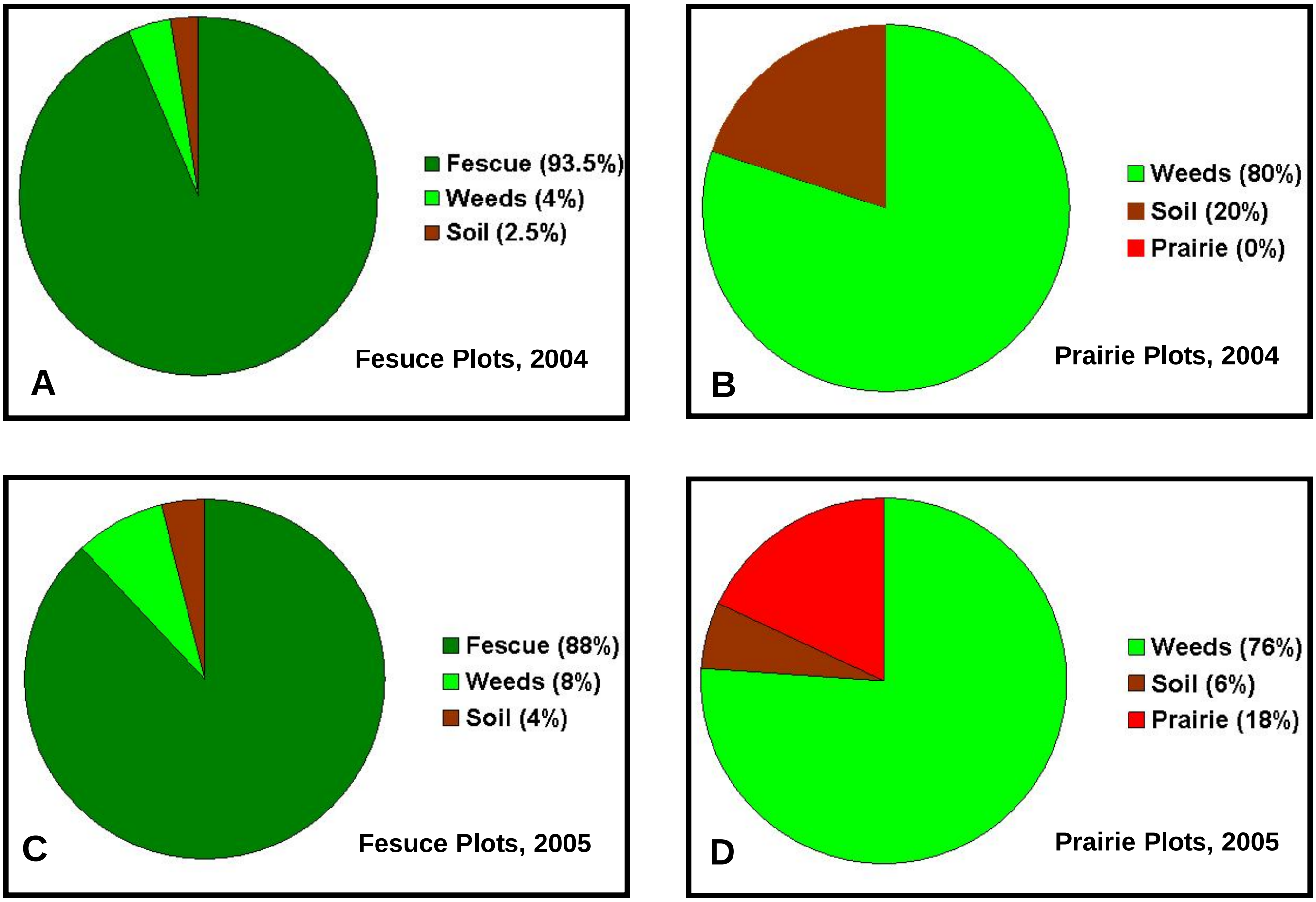

Figure 4. Type and amount of vegetative cover in fine fescue and prairie buffer strips following seeding in October 2003, Wisconsin River Golf Course, Stevens Point, WI. A and D show ground cover in fine fescue and prairie plots, respectively, in August 2004. C and D show ground cover in fine fescue and prairie plots, respectively, in June 2005.

prairie establishment. Fairways received 49 to 98 kg N ha^{-1} annually in one or two applications (spring and fall), with approximately 2.5 to 5 kg P ha^{-1} each year. Fairways received little to no irrigation, so snow melt and rainfall provide the source of runoff water. The 9th fairway remained flooded from excessive rainfall throughout most of 2004 and part of 2005. Re-seeding attempts in autumn 2004 were unsuccessful so this fairway was dropped from the study.

Analyzing Water Quality and Vegetation

Runoff samples were collected each time snow melt or rainfall occurred that caused runoff in any one of the plots. Leachate samples were collected once each month when the ground wasn't frozen. All water samples were stored in a freezer until they could be analyzed for nitrogen, phosphorus, and sediments. The leachate water samples were analyzed for nitrate- and ammoniacal-N (2) and soluble phosphorus. Runoff samples were analyzed for three P types: soluble P, biologically active phosphorus (BAP), and total phosphorus (TP) which were extracted from both sediment in the water as well as the water itself (13, 17). Sediment in runoff was collected by filtering water samples through 45-micron filters and drying and weighing the sediment. Turfgrass and prairie plant stands were analyzed two to three times each year by determining the percentage of desirable plants (turf or prairie), weeds, and bare soil.

Results and Discussion

Fine fescues covered nearly 40% of the ground by early May 2004 while weed seedlings

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
	Month								
	--------------------				mm				--------------------
2004	32.3	222.0	171.7	148.8	121.7	30.2	132.8	48.3	907.8
2005	92.5	73.9	167.1	33.3	151.9	188.0	32.3	83.1	822.1

Table 3. Monthly rainfall (mm) during runoff sampling periods at Wisconsin River Golf Course, Stevens Point, WI.

were the only vegetation on the prairie plots. Fescue cover was excellent by August while annual weeds covered 80% of the ground in prairie plantings (Figures 4A, 4B). A few prairie plants were present but comprised less than 1% of the ground cover. By June 2005, fescue cover remained dense and prairie vegetation had increased to 18% though weeds still covered over three quarters of the plot area (Figures 4C, 4D). Several of the prairie flower species were evident by summer 2005 though few bloomed that year. None of the prairie grasses were ever observed, consistent with several of our other establishment projects using similar prairie seed mixtures.

Buffer treatment†	Water runoff	Total P	Bioavailable P
	(mm)	(kg ha^{-1})	(kg ha^{-1})
2004‡			
No buffer	36.6	0.12	0.04
Short, Prairie	42.9	0.17	0.03
Short, Fescue	45.6	0.19	0.04
Medium, Prairie	50.1	0.17	0.04
Medium, Fescue	38.1	0.16	0.04
Long, Prairie	36.6	0.12	0.03
Long, Fescue	50.2	0.22	0.02
Statistical significance (P=0.05)	ns	ns	ns
2005§			
No buffer	3.5	0.04	0.01
Short, Prairie	4.2	0.03	0.02
Short, Fescue	4.6	0.04	0.03
Medium, Prairie	5.5	0.04	0.02
Medium, Fescue	5.5	0.05	0.02
Long, Prairie	3.5	0.03	0.02
Long, Fescue	4.1	0.02	0.02
Statistical significance (P=0.05)	ns	ns	ns

ns = not significant at P=0.05.

† Short buffer = 8:1 fairway:buffer length, medium = 4:1 fairway:buffer, long = 2:1 fairway:buffer

‡ May through October

§ April through November

Table 4. Total annual runoff volumes and phosphorus (P) losses from *Poa annua* fairways with or without various buffer strips of either prairie or fine fescue, Stevens Point, WI.

Buffer treatment†	Soluble P	Total N
2004‡	(mg L^{-1})	(mg L^{-1})
No buffer	0.33	2.89
Short, Prairie	0.32	7.60
Short, Fescue	0.12	32.08
Medium, Prairie	0.24	7.05
Medium, Fescue	0.05	30.15
Long, Prairie	0.13	6.28
Long, Fescue	0.07	25.66
Statistical significance (P=0.05)	ns	ns
2005§		
No buffer	0.58	3.91
Short, Prairie	0.56	4.15
Short, Fescue	0.36	5.02
Medium, Prairie	0.20	2.33
Medium, Fescue	0.36	4.00
Long, Prairie	0.26	3.61
Long, Fescue	0.49	3.72
Statistical significance (P=0.05)	ns	ns

ns = not significant at P=0.05

† Short buffer = 8:1 fairway:buffer length, medium = 4:1 fairway:buffer, long = 2:1 fairway:buffer

‡ May through October

§ April through November

Table 5. Mean monthly soluble phosphorus and total nitrogen (mg L^{-1}) in leachate under *Poa annua* fairway and prairie or fine fescue buffer strips, Wisconsin River Golf Course, Stevens Point, WI.

Prairie plots on fairway 4 had more weeds, especially *P. annua*, than plots on fairway 8 which were less shaded. Regulations requiring "native" vegetation for buffer strips in situations where climatic conditions are not favorable are likely to result in unwanted vegetation and/or exposed soil which will not necessarily decrease nutrients in runoff or leachate.

Real-world data are important because many controlled experiments simulate worse-case conditions, e.g., application of water-soluble fertilizers preceded and followed by intense, high-volume simulated rainfall events (5, 20). Such data are helpful for determining best management practices to reduce nutrient loading of ground and surface waters (e.g., not applying fertilizer to saturated soil prior to anticipated rain).

In our study, less than 5% of the total rainfall during the sampling period in 2004 ran off fairway and buffer strip surfaces, while less than 1% of rainfall ran off during 2005 (Tables 3 and 4). The minimal slopes of the fairways (1-2%) likely helped infiltration to occur by reducing speed of runoff despite periods of heavy rains. The nearly complete ground cover was likely just as, if not more, important for reducing runoff by slowing its rate and allowing it to infiltrate into soil (16).

None of the buffer strips changed runoff or phosphorus loading compared to the fairway alone, indicating fertilizer was not an important source of phosphorus (Table 4). Total phosphorus losses on a land area basis were similar, or less than, the annual 0.1 kg P ha^{-1} loss reported for native prairie in Minnesota when rainfall-induced runoff averaged 6 mm per year (23), and similar, or less, than the 0.18 to 7.04 kg P ha^{-1} in surface runoff from a variety of grazing lands in Oklahoma (21).

Phosphorus runoff in our study was more than 20 times less than that reported for wheat production (19), probably due to greater vegetative cover in the golf course system. Phosphorus sources in our study likely included natural sources such as vegetation, soil, and precipitation (4, 10, 18). We've found similar results when comparing Kentucky bluegrass (*Poa pratensis*) and prairie buffer strips for controlling urban runoff (22).

A growing body of evidence is indicating that when ground is well covered by vegetation (e.g., 70%), total P losses may be much reduced compared to predominatly exposed soil (11). In exposed soil situations, sediment-bound P is often the primary type of P. Vegetation greatly reduces total P runoff by reducing both runoff volume and sediment, though soluble P may increase as it leaches from vegetation and organic P-containing particles move in runoff (19). Prairie plants may be especially prone to P loss from vegetation as they are predominantly C_4 plants with foliage that dies in early autumn, while C_3 turf foliage may survive the winter and has a steady but low turnover rate coupled with less abundant aboveground biomass than prairie vegetation (22).

In our study, about 25-50% of the total P in runoff was bioavailable P (BAP). This is the type which stimulates algae blooms in ponds, lakes, and rivers. Values in our study were at least 20 times less than BAP in wheat field runoff and similar to BAP runoff from native grassland (19). Our data are important because they represent natural background levels of phosphorus. Consequently, regulations to limit phosphorus fertilization would in this case be ineffective at reducing phosphorus loading. Ultimately it is impossible to achieve zero P runoff.

Buffer strips did not affect phosphorus or nitrogen leaching below the soil surface (Table 5). Nitrogen is the most important nutrient contaminant in leachate water because excessive levels in drinking water may have adverse human health effects such as "blue baby syndrome". The U.S. Environmental Protection Agency sets the drinking water limit at 10 parts per million (ppm) nitrate-nitrogen. In our study, this level was exceeded in 2004 under the fine fescue plots, but the results were not statistically different than leachate under prairie plots or fairway alone. The higher concentrations in 2004 were likely due to soil disturbance effects from the establishment process and lack of vegetative cover until May 2004. In 2005, all nitrogen concentrations were below 10 ppm and were likely lower than 2004 because more vegetation existed in the second year.

Phosphorus has generally been regarded as having little movement in soil and so most leaching studies do not measure phosphorus. However, increasing awareness of ties between ground and surface water may soon require additional knowledge of phosphorus leaching (12). Easton and Petrovic (6) reported over 50% of P applied to turf from swine compost leached below the surface while synthetic fertilizer sources had significantly lower leachate losses. Our study indicates an unfertilized prairie stand has similar levels of P leachate compared to unfertilized fine fescue turf and fertilized *P. annua* fairways.

Conclusions

Our study is important because it shows that in real-world situations, at least where slope is minimal, runoff from golf course fairways was less than 5% of the rainfall over a two-year period of abundant rainfall. Phosphorus and nitrogen contamination of runoff and leachate water from golf course fairways was similar to natural background levels reported for non-fertilized native prairies and was not affected by buffer strip type or size.

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