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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 450 projects at a cost of $29 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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Optimizing Vegetative Filter Strips Treating Runoff from Turf

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SUMMARY

Joint greenhouse and field studies are currently underway to evaluate selected plants for their effectiveness in removing pesticides and nutrients from turfgrass runoff waters that enter vegetative filter strips (VFS).

Ten plant species were evaluated in a greenhouse pot study to determine which species most effectively remove six pesticides (2 fungicides, 2 herbicides, and 2 insecticides) from a silt loam soil. Five species (big blue stem, blue flag iris, eastern gama grass, prairie cord grass, and woolgrass) were determined to be most effective.

A run-on plot, consisting of 12 VFS, was established. Each VFS had a 5% slope and was lined with an impermeable liner. A manifold was placed on the front (top) edge of each VFS to evenly apply run-on water. At the bottom of each VFS, runoff water was collected. Lysimeters near the bottom of each strip sampled subsurface water.

Several storm/run-on scenarios using a rainfall equivalent to an average 1-year rain event were evaluated. The selected storm scenario produced runoff that was 1) measurable, 2) manageable, and 3) roughly equivalent to that used by Bell and Moss (3). A bromide tracer study determined any hydraulic differences between VFS prior to planting. VFS were then established in replicates of three (unvegetated, random mixture of plants, succession of plants, and turfgrass cut to three heights). The study found:

- Five plant species (blue flag iris, woolgrass, prairie cord grass, big blue stem and eastern gama grass, given in increasing heights) removed turfgrass pesticides from contaminated soil and have been selected for planting into the VFS.
- A run-on plot consisting of twelve identical VFS has been constructed at the UMASS Turfgrass Research Center.
- An initial bromide tracer study determined hydraulic characteristics and runoff flows of the 12 VFS prior to planting.
- A pump-driven delivery system has been fabricated for the precise delivery of run-on water to the VFS.
- Nine VFS have been planted (3 VFS will remain unvegetated) with either turfgrass or the five plant species selected from the greenhouse study.
- A pesticide run-on experiment will be conducted at the end of the 2008 growing season.

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A joint greenhouse and field project is currently underway at the University of Massachusetts to evaluate selected plant species for their effectiveness in removing pesticides and nutrients from turfgrass runoff waters that enter the rhizospheres of plants in vegetated filter strips (VFS) acting as buffer zones. Initially, a greenhouse study screened plant species for their abilities to remove pesticides from soil. The best arrangement of selected plants within VFS to optimize their ability to remove pesticides is currently being evaluated.

Vegetative filter strips will be compared to turfgrass buffer strips to determine the relative effectiveness of each and will consider how these two systems would work in conjunction with each other. The fate of contaminants entering the VFS will be evaluated by analyzing soil, plant tissue, soil water, and runoff for parent pesticides and their major breakdown products.

Greenhouse Study

A greenhouse study was carried out to identify the most effective plant species for placement in a field run-on plot (11). A silt loam was amended with six pesticides (Table 1) at 5% of their respective application rates. While this is an overestimation of the amount of the pesticides likely being lost, it will provide sufficient residues for screening plants for their ability to remove pesticides from soil at an amount that exceeds the detection limits for these pesticides.

The study objective was to screen ten aesthetically acceptable plant species for their ability to remove four commonly used and degradable pesticides: chlorpyrifos, chlorothalonil, pendimethalin, and propiconazole from soil in a greenhouse setting, thus providing invaluable information as to the species composition that would be most effective for use in VFS. Plant treatments

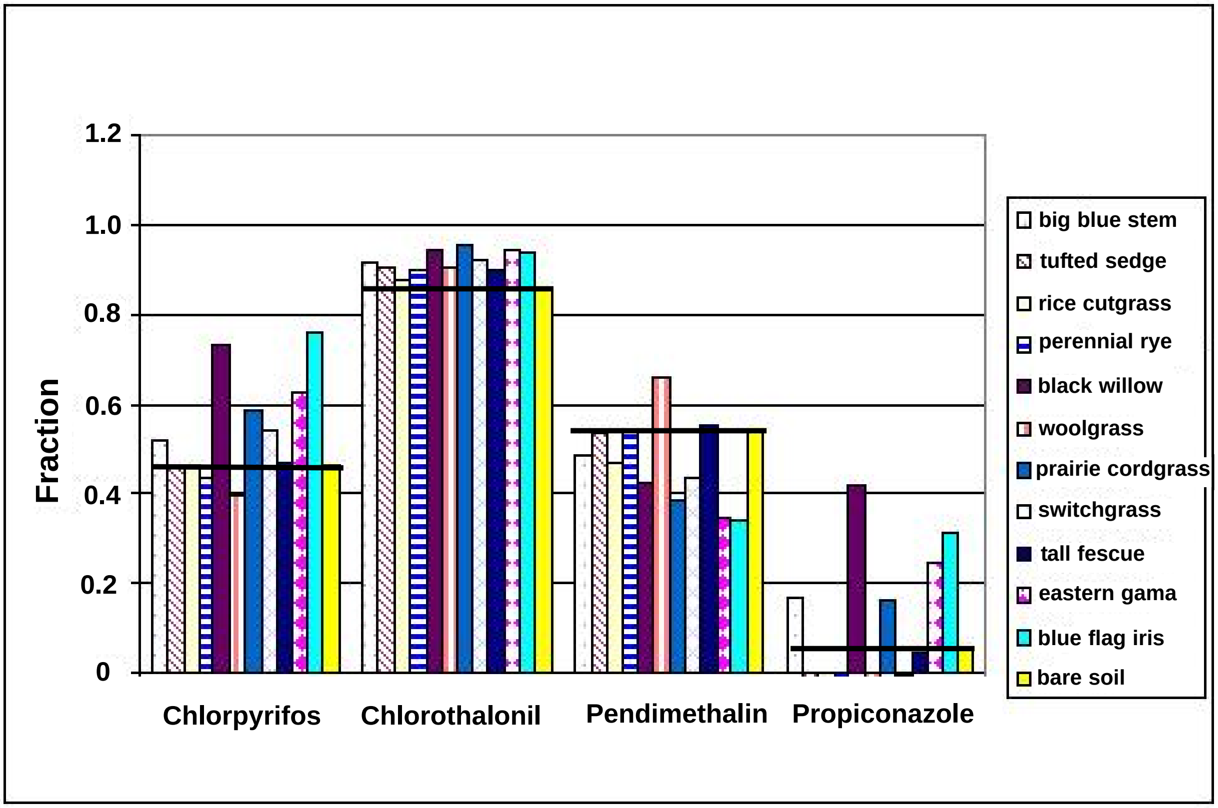

Figure 1. Fraction of applied pesticide lost from greenhouse soil for chlorpyrifos, chlorothalonil, pendimethalin, and propiconazole. Horizontal lines represent unvegetated controls (bare soil).

examined were; big blue stem (*Andropogon gerardii*), black willow (*Salix nigra*), blue flag iris (*Iris versicolor*), eastern gama grass (*Tripsacum dactyloides*), perennial ryegrass (*Lolium perenne*), prairie cord grass (*Spartina pectinata*), rice cutgrass (*Leersia oryzoides*), tall fescue (*Festuca arundinacea*), tufted sedge (*Carex stricta*), woolgrass (*Scirpus cyperinus*), and an unvegetated control. Many of these plant species have been effective in previous buffer strips studies or have some other quality that makes them good candidates (e.g., salt tolerance, dense growth, increase soil infiltration) (1, 2, 4, 5, 8, 9, 10, 12, 13).

Blue flag iris, big blue stem, eastern gama grass, prairie cord grass, and woolgrass enhanced the loss of one or more pesticides from the greenhouse soil. Blue flag iris (76% chlorpyrifos, 94% chlorothalonil, 48% pendimethalin, and 33%

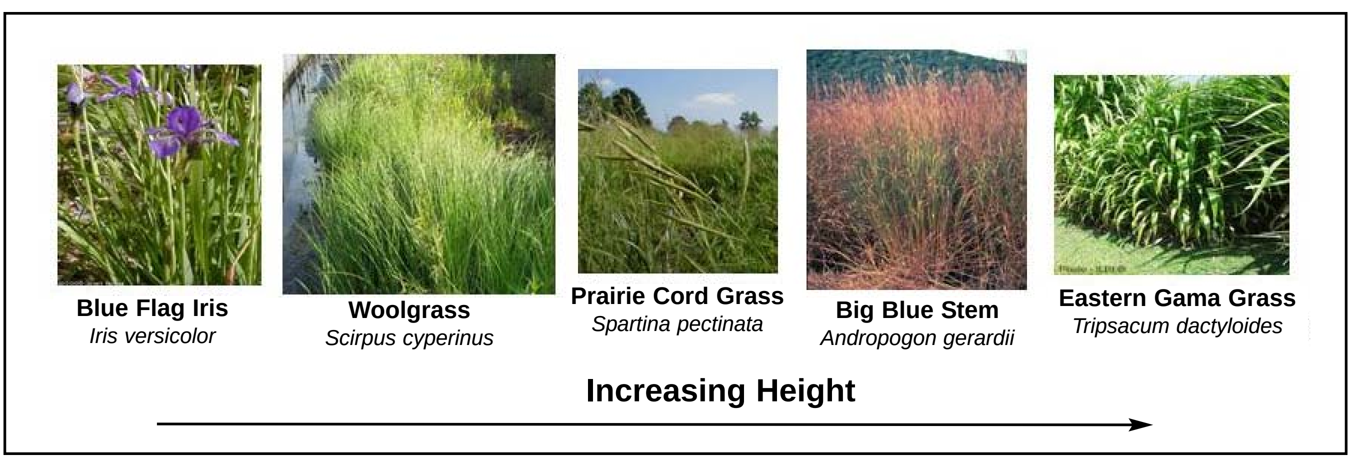

Figure 2. Plant species selected by the greenhouse study to be established in VFS

Figure 3. Each VFS in the run-on plot was 0.9 m x 4.6 m x 1.8 m, lined with an impermeable 36-mil polypropylene liner.

Figure 5. An aluminum manifold with holes drilled at 5-cm intervals allows runon water to flow evenly onto the top of the VFS

propiconazole were lost from soil after three months of plant growth), eastern gama grass (47% chlorpyrifos, 95% chlorothalonil, 17% pendimethalin, and 22% propiconazole were lost from soil after three months of plant growth), and big blue stem (52% chlorpyrifos, 91% chlorothalonil, 19% pendimethalin, and 30% propiconazole were lost from soil after three months of plant growth) were excellent candidates for the optimization of VFS (Figure 1). Blue flag iris was most effective at removing selected pesticides from soil and had the highest aesthetic value of the plants tested.

These five species were selected for use in the establishment of one of the two plant treatments (Figure 2). In the mixture treatment, each species will be evenly mixed throughout the plot. In the succession treatment, species will be arranged in order of increasing height from the front of the VFS (blue flag iris, woolgrass, prairie cord grass, big blue stem, and eastern gama grass).

Field Study

Twelve vegetative filter strips in a run-on plot will be used to evaluate the ability of four planting treatments (unvegetated, mixture of selected plant species, succession of selected plant

Figure 4. An aluminum sheet collector is located 7.62 cm below the surface of the soil until it exits the soil at the end of the strip and allows the collection of runoff water.

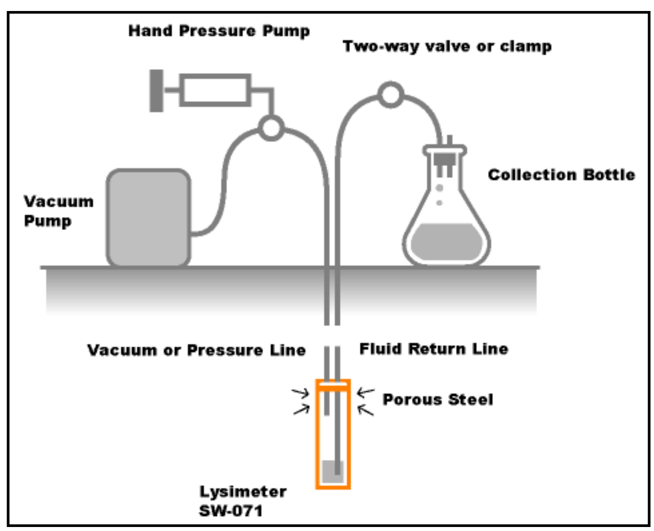

Figure 6. Stainless steel lysimeters placed 1.52 m below the soil surface and 4.27 m from the top of the VFS allows subsurface water to be collected.

Figure 7. Plastic liners were installed over the edging of each pre-planted VFS and the soil was graded to 5% slope.

Figure 9. Early plant establishment on the VFS

species, and succession of different heights of turf with each treatment replicated three times) to remove pesticides and nutrients from runoff water generated in two simulated rain events (1-year and 5-year). The first year of the study was primarily for site establishment; the second year was for plant establishment. The third year of the study and any subsequent years will have application of one of the pesticide groups in June with the other group applied in July.

Construction of VFS

A run-on plot for the field study was constructed at the University of Massachusetts Turfgrass Research Center in Deerfield, MA (summer 2006). Native sandy loam was used as the subsoil with a silt loam brought in from another location used for the surface horizon (0-15 cm). The 12 VFS in the run-on plot were 0.9 m x 4.6 m x 1.8 m each, lined with an impermeable 36-mil polypropylene liner, and graded to a 5% slope (Figure 3). At the end (bottom) of each strip, an aluminum sheet was placed under 7.6 cm of soil for the last 30 cm of the strip to collect runoff (Figure 4).

Figure 8. Researchers collect runoff water during a bromide tracer study on VFS prior to plant establishment.

Beneath the lip of the collector, a 5-gallon bucket was inserted to hold a 4-liter brown bottle used during the collection of runoff water from each VFS in the run-on plot. On the front (top) end of each VFS, an aluminum manifold with holes drilled at 5-cm intervals was placed to insure even water to flow onto the VFS (Figure 5). Stainless steel lysimeters were placed 1.5 m below the soil surface and 4.2 m from the top of the VFS to sample the subsurface water flow at the bottom of each VFS (Figure 6).

Storm/Run-on Scenarios and Bromide Tracer Study

Several storm/run-on scenarios on the bare (pre-planted) VFS were evaluated (Figure 7). The volume of runoff water applied as run-on to each VFS was based on a 1-year rain event. The runoff water generated during a 1-year rain event was calculated to be 25.4 gallons over the course of 24 hours from an turfgrass area 3 feet by 20 feet with a 5% slope (obtained by calculating the amount of water loss with these rain events using the SCS Curve Number Method, Climate System Research

Pesticide Class	Pesticide Name	Pesticide Mode	Maximum Application Rate (23.5%)	Active ingredient lost from 60ft^2 at 5% loss	Concentration in soil if all lost in first square foot on VFS*
Insecticides	Chlorpyrifos Imidacloprid	Non-systemic Systemic	1lb/acre 8.6 oz/acre (75% ai)	0.03 grams 0.01 grams	0.2 mg/kg 0.15 mg/kg
Herbicides	Pendimethalin 2,4-D	Non-systemic Systemic	3.6 oz/1000ft^2 (37.4%) or 5lbs/acre (60%) 1.1oz/1000ft^2 (48.99%)	0.11 grams 0.05 grams	0.81 mg/kg 0.37 mg/kg
Fungicides	Chlorothalonil Propiconazole	Non-systemic Systemic	20 lbs/acre (82.5%) or 16 2/3 pints/acre (54%) 176 oz/acre (14.3%)	0.52 grams 0.05 grams	3.85 mg/kg 0.37 mg/kg
* Calculation based on a bulk density of 1.6 g/cm^3.					

Table 1. Characterization and use of pesticides of interest

Center, University of Massachuseets-Amherst). This water volume is then applied to the top of the VFS as run-on water.

A storm scenario was selected which produced runoff that was 1) measurable, 2) manageable, and 3) roughly equivalent to that used by Bell and Moss (3) for similar runoff experiments conducted on turfgrass cut to three heights as a golf course rough. Early storm event trials were spread out over a 24-hr period. It was clear from these early trials that the 1-year rainfall event had to be condensed to 6 hours, and the soil needed to be pre-saturated to produce measurable runoff.

Soil pre-saturation was achieved by adding artificial rain for 10 hrs (~0.4 inches/hr), followed by a 12-hr drying period (6 p.m. - 6 a.m.) prior to the initiation of the storm event. The storm scenario selected for the 1-year rain event and the initial bromide tracer studies was as follows: artificial rain for 6 hours total (6 a.m. - 12 noon for approximately 2 inches total rainfall) and run-on for 2 hours (11 a.m. - 1 p.m. at a rate of 12.7 gal./hr).

A bromide tracer study was carried out to determine hydraulic characteristics and runoff flows on the 12 VFS prior to planting (Figure 8). This allowed us to evaluate the effects that the plants have on the flow of water through each VFS, and it will also allow us to know that any differences observed in runoff of the pesticides is due to the plant treatments and not differences in the hydrology between the plots. Artificial run-on containing the bromide tracer was applied to each VFS by using a scaled down version of previous run-on studies (1,7). Briefly, a holding tank was used to mix the water and bromide together and then run-on water was pumped to the manifold as previously described for a 1-year rain event (see above). Runoff water volume from the run-on event was measured by collecting in 4-liter amber bottles at the bottom of the VFS. Grab samples were collected every two minutes in 60-ml amber bottles for bromide analysis. Run-on was started at 11 a.m., and the first bromide grab sample was collected at 11 a.m.

Grab samples were collected until the 60-ml bottle was full, so collection duration varied depending on the runoff flow rate. Between grab samples the runoff was collected into the 4-liter amber bottles to ensure that the entire runoff volume was collected. The results from the initial pre-planting bromide tracer study are shown in

Strip	Runoff rate pre-run-on	Runoff rate with run-on	Rainfall	Total Volume	Run-on Stop*	Runoff Stop	Bromide				Planting
	(gal/hr)	(gal/hr)	(inches)	(liters)			(mg/L)** at				
							0 min	2 min	4 min	6min	
1	2.5	11.2	1.9 ± 0.60	58.4	1:16	1:25	0.27	600	2060	1900	Turf
2	0.9	7.6	2.0 ± 0.13	47.1	1:14	1:20	1.02	0.23	2690	1910	Succession
3	1.0	9.2	1.9 ± 0.19	49.2	1:18	1:42	0.7	95.1	1450	1890	Bare
4	1.0	9.2	2.2 ± 0.16	43.8	1:15	1:19	BDL	169	150	1920	Random
5	3.8	10.0	2.5 ± 0.13	50.0	1:06	1:51	BDL	480	1560	1610	Bare
6	0.4	4.4	2.2 ± 0.10	22.0	1:09	1:31	BDL	660	1820	1620	Random
7	0.4	4.3	1.9 ± 0.10	19.7	1:14	1:21	BDL	BDL	BDL	3	Turf
8	1.7	8.7	1.9 ± 0.10	40.5	1:11	1:49	0.75	70	1500	1680	Succession
9	2.5	13.0	2.0 ± 0.0	77.3	1:09	1:33	2	1360	2230	2430	Succession
10	1.9	9.0	2.2 ± 0.0	42.4	1:06	1:29	BDL	230	1560	1620	Turf
11	2.3	10.5	2.3 ± 0.11	54.5	1:05	1:37	BDL	140	1170	1360	Random
12	1.0	6.2	2.2 ± 0.22	26.5	1:05	1:36	0.12	0.11	0.1	470	Bare

* Time run-on delivery tank was empty.

**Bromide added at 4000 mg/l.

BDL = below detection limit

Table 2. Runoff rate, volume, and bromide tracer concentrations

Table 2. Only the first 6 minutes of bromide tracer data is shown as the bromide tracer had reached the end of the VFS by the 6-minute grab sample for all 12 VFS.

Plant Establishment

Individual VFS were planted in replicates of three (unvegetated, random mixture of plant species, succession of plant species, and turfgrass rough mix) (Figure 9). Greenhouse-reared plugs of blue flag iris, eastern gamma grass, prairie cord grass, and woolgrass were planted at a density of 25 plants per 9 sq. feet. Big blue stem was seeded at a similar rate, and was thinned in spring 2008. Three VFS were planted with a golf course rough mixture (80 % Kentucky blue, 20% Chewings fescue) at a rate of 4 pounds per 1000 sq. feet.

The rough mixture was maintained at three different heights (1.0, 1.5, and 2.0 inches, top to bottom) over the growing season. The results of the bromide tracer study were used to block the plantings in groups of three VFS (fast, intermediate, and slow flow rates). The individual VFS were planted as shown in Table 2.

Future Research Plans

The six pesticides in Table 1, plus cyfluthrin, will be used in the VFS run-on field trials. Pesticides will be applied with a water volume that would be generated for both a 1-year and a 5-year rain event, respectively. Bromide will also be added to the pesticide containing water at 4 g/L as a tracer. Prior to applying the pesticide-containing water, the entire VFS will receive a water volume that would occur in a 1-year or 5-year rain event (see Storm scenario above). In the case of the 5-year rain event, this would involve adding 3.8 inches of water as rain over 24 hours and 62.1 gallons of water as runoff over 24 hours (Climate System Research Center). The expected runoff water coming from a VFS is 0.24 gallons for the 1-year rain event and 36 gallons for the 5-year rain event.

The amount of pesticide lost will be evaluated using the concentration of the pesticide and the volume of water collected during runoff. In addition to pesticides, runoff water will be monitored for losses of nitrogen and phosphorus from fertilizer inputs. Soil, soil water, and plants within the VFS will also be analyzed to determine if the pesticides lost from the runoff water are sorbing to the soil, being degraded in the soil, taken up by the plants, or potentially lost to leaching or subsurface flow. These values will be compared against the bromide tracer, which will move freely with the run-on water. Soil sampling will be conducted at three different depths at three locations within the VFS (0.3 m, 1.83 m, and 3.35 m from the top of each strip).

The reason for sampling at multiple locations is because half of the pesticides of interest are water soluble, and it has been shown by many investigators that even chemicals that sorb tightly to the soil can be found deeper in the soil profile than would be expected based on the physical and chemical properties of those chemicals because of preferential flow pathways established by earthworms and old root channels (6).

Analyses will be conducted for parent compounds and expected metabolites based on existing literature. Soil water will be collected with lysimeters and should include water that has passed through all the rhizospheres and soil in the upstream part of the VFS and give some indication of whether or not pesticides that infiltrated into the VFS are being lost to leaching or subsurface flow.

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