Weed Control

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Section Editor

Environmental Fate of Glyphosate in Rain Garden Systems

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Significance to the Industry The aesthetic quality and health of ornamental plants in rain gardens is threatened by a lack of weed control. Glyphosate has the labeling potential for usage in rain gardens. After a series of lysimeter bioassays, glyphosate was shown not to leach through two substrates (sand and slate) after four simulated rain events and may provide effective weed control without damaging plants.

Nature of Work Rain gardens (commonly known as bioretention cells) are known for their stormwater control (1). A depression in the landscape is created by excavating the native soil then filling with an engineered, highly permeable substrate. The infiltration and retention of stormwater that permeates throughout the rain garden allows the microbial population, substrate, and plants to remove the pollutants (nutrients) before allowing them to reach the groundwater (2). The North Carolina Environment Quality Stormwater Rules and Regulation: 15A NCAC 02H.1052 states the substrate be composed of 75-85% medium to coarse washed sand, 8-10% silt and clay fines, and 5-10% organic matter (3).

With the addition of ornamental plants, rain gardens are functional in capturing the pollutants (nutrients), as well as being aesthetically pleasing. This necessitates the need for routine plant and pest maintenance, however, there are few recommendations for routine rain garden preservation. Kraus et al. (4) conducted a survey of 66 rain gardens that were at least seven years post-installation, located throughout the piedmont of North Carolina. Many of the rain gardens surveyed were found to be lacking proper weed management to the extent that the ornamental vegetation was completely covered by weeds. Mulches can be applied to rain gardens though they are not effective for long-term weed control (5). There are currently no herbicides labeled for use in rain gardens, however, in some sites it was apparent an herbicide had been applied (4).

Glyphosate has proven to be an effective weed control method for riparian areas. Using a spot-spray method with glyphosate allows for targeted weed control, saving time and money while achieving greater weed control (6, 7, 8). Glyphosate has a high sorption affinity to soil colloids, is degraded primarily by soil microbes, has little residual activity, and is approved for use near water making it a probable candidate for rain gardens (9, 10). Therefore, the objective of this study was to evaluate the potential use of glyphosate for weed control in rain gardens by testing two substrates for their leaching potential with simulated rainfall.

A bioassay lysimeter study was conducted in the summer of 2017 inside a polyethylene covered hoop house at the North Carolina State University Horticulture Field Lab. The efficacy and leaching potential of four herbicides in two substrates were analyzed (data shown only for glyphosate). The two substrates evaluated included: sand [80% washed sand, 15% clay and silt fines and 5% pine bark (by vol.)] and slate (100% expanded slate, MS 16) with no pine bark.

Lysimeters were constructed (Figure 1) with a PVC pipe 4 inches in diameter and 14 inches in length. After being cut to length, the pipe was cut lengthwise creating two halves. The halves were then secured with duct-tape along the seams and around the base of both ends. To ensure the seams were sealed, and to prevent preferential flow, the inside of each column was coated with contact cement (DAP Weldwood Original Contact Cement, DAP Products Inc.) and a thin application of each substrate of a particle size $\geq$ 1.4mm. An end cap (with five 1/8 inch drainage holes) was fastened to one end and the opposite end was fitted with a toilet flange and fastened with two ½ inch screws. Tables were constructed with 5 inch holes cut into the table face, allowing the lysimeter to pass through and be supported by the toilet flange holding them approximately 10 inches above the ground. The lysimeters were filled to a predetermined bulk density (sand = 1.3 g/cm^3 and slate = 0.9 g/cm^3) based on results reported by Turk et al. (11). After filling and placement in the tables, the lysimeters were irrigated (VibroNet Sprinkler, Netafim) until fully saturated.

Once saturated and allowed to drain for 24 hours, herbicides were applied at the highest labeled dosage, (glyphosate 4 lb ai/A). To simulate a “worst case scenario” a two-inch rain event was applied 5 minutes after the initial treatment [0 WAT (weeks after treatment)], with further rain events at 2, 4, and 8 WAT. On the weeks a full rain event did not occur, 1 inch of water was applied to each lysimeter to maintain saturation. After lysimeters drained for approximately 18 hours following the simulated rain event, each set of sample time lysimeters were carefully opened and each half was treated with a fungicide (SubdueMaxx; 1 oz/1000 ft^2) and sown with perennial ryegrass ‘Carly’ (*Lolium perenne* ‘Carly’) (20 lb/1000 ft^2) as a bioindicator species. After seeds germinated, they were fertilized at a rate of 100 ppm N (20N-4.4P-16.6K, Peters Professional, Everris, Dublin, OH) (Figure 2).

Approximately 21-28 days after sowing (DAS), the substrate in each lysimeter half was divided into seven increments: 0-1, 1-2, 2-3, 3-4.5, 4.5-6, 6-9, 9-12 inches. Roots and shoots were removed from each increment and roots were washed free of substrate. All root and shoot samples were oven dried at 105ºC for 48 hours before being weighed. Percent reduction from the control for root and shoot growth was calculated by the following equation: [(control dry weight – treatment dry weight)/control dry weight x 100].

The experiment was a factorial treatment arrangement of four herbicides, two substrates and four sample times (weeks 0-2-4-8) arranged in a randomized complete block design with six replications and untreated controls (N=240). All variables were subjected to analysis of variance (ANOVA) procedures using general linear models

(PROC GLM) where appropriate and means were separated by LSD in SAS version 9.4 and *P* was considered significant at $\leq$ 0.05 (12).

Results and Discussion The interaction terms [increment x herbicide x substrate x sample time, increment x herbicide x substrate (excluding 8 WAT for shoots), and increment x herbicide (excluding 4 WAT for roots in slate and 8 WAT for shoots)] for both root and shoot percent reduction of the control were not significant. At the eight week sample time, the lysimeters suffered a loss in irrigation causing the growth of the perennial ryegrass to be reduced across all treatments, potentially causing the data to be skewed at that time.

At each sample time, shoot and root growth was not reduced by glyphosate compared to the control in either substrate (data not shown). At 0, 2, and 4 WAT, shoot and root reduction was similar among all increments within each substrate except in sand at 4 WAT where root growth increased in the 0-1 inch increment (Tables 1 & 2). Additionally, leaching of glyphosate was not visually apparent as the perennial ryegrass was thriving in both substrates throughout the length of each lysimeter half. Glyphosate likely sorbed to the substrate components, even the slate which had no clay content. With a K_{oc} (soil adsorption coefficient) range of 2,600 to 4,900 glyphosate is expected to have a very low mobility (6,13). Although damage from the glyphosate was not apparent, the argument could be made that it was not bioavailable due to the binding by the substrate; however, the half-life can range from 45 – 60 days depending on pH, soil moisture, and soil type meaning it has moderate residual effects (13).

These results suggest glyphosate has the potential to be labeled for application in rain garden systems. Data from both substrates (sand and slate), paired with glyphosate's affinity to bind to substrate particles support weed suppression when using this compound (6, 7, 13) and its use in rain gardens. Research is continually adding to this field as herbicides are an attractive option for weed suppression in rain garden systems (6, 7, 8, 13, 14).

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Table 1. Percent reduction in shoot dry weight compared to the control by increment when glyphosate was applied to two substrates[z].

Increment	Sand			
	Week 0[y]	Week 2	Week 4	Week 8
	NSx	NS	NS	0.0028
0-1"[w]	-7.6	-37.7	-112.4b[v]	-73.5b
1-2"	-17.5	18.0a	-3.4a	17.1a
2-3"	3.6	-19.4ab	-48.4ab	7.6a
3-4.5"	-19.8	7.8a	-3.6a	5.4a
4.5-6"	8.3	13.2a	2.5a	30.6a
6-9"	-4.5	-14.9ab	10.3a	24.8a
9-12"	-19.7	-60.2b	15.7a	22.0a
Increment	**Slate**			
	Week 0	**Week 2**	**Week 4**	**Week 8**
	NS	NS	NS	NS
0-1"	-9.5	-47.6	-13.5a	17.4
1-2"	29.4	21.9	-56.6	-24.1
2-3"	25.4	-6.2	-8.5	7.7
3-4.5"	3.4	0.7	7.1	-19.5
4.5-6"	25.2	-130.0	-11.1	-12.8
6-9"	-32.8	3.5	-15.6	26.3
9-12"	-16.8	-90.1	-11.4	-44.9

[z]Substrates included: Sand ([80% washed sand, 15% clay and silt fines and 5% pine bark (by vol.)] and slate (100% expanded slate, MS 16) with no pine bark.

[y]Samples were collected at 0, 2, 4, and 8 weeks after treatment after a simulated 2 inch rain event.

[x]Analysis of variance (ANOVA). Not significant at P ≥ 0.05, P-value given otherwise.

[w]The lysimeters were divided into increments of 0-1, 1-2, 2-3, 3-4.5, 4.5-6, 6-9, 9-12 inches and shoots harvested, and oven dried at 105ºC for 48 hours.

[v]Means within a column with different letters are significantly different based on LSD mean separation procedures (P ≥ 0.05).

Table 2. Percent reduction in root dry weight compared to the control by increment when glyphosate was applied to two substrates[z].

Increment	Sand			
	Week 0[y]	Week 2	Week 4	Week 8
	NS[x]	NS	0.0086	NS
0-1"[w]	-163.8	-19.9	-161.5d[v]	-6.2ab
1-2"	-104.8	7.5	-89.7bcd	-48.5b
2-3"	6.2	8.0	-97.7cd	-41.6ab
3-4.5"	-17.7	1.8	-5.0abc	7.9ab
4.5-6"	-8.3	-13.7	-10.2abc	-10.5ab
6-9"	16.2	-136.0	15.2ab	-14.7ab
9-12"	-7.3	-24.8	30.3a	13.3a
Increment	Slate			
	Week 0	Week 2	Week 4	Week 8
	NS	NS	NS	NS
0-1"	-39.3ab	1.5	-37.1	-82.3
1-2"	-15.4ab	1.9	-59.7	-9.7
2-3"	26.0a	-47.7	12.9	-27.0
3-4.5"	25.1a	-53.6	-4.3	-20.0
4.5-6"	26.3a	-6.4	-56.5	-79.1
6-9"	-29.1ab	-45.0	-57.6	-13.0
9-12"	-126.7b	-23.2	-12.3	-55.5

[z]Substrates included: Sand ([80% washed sand, 15% clay and silt fines and 5% pine bark (by vol.)] and slate (100% expanded slate, MS 16) with no pine bark.

[y]Samples were collected at 0, 2, 4, and 8 weeks after treatment after a simulated 2 inch rain event.

[x]Analysis of variance (ANOVA). Not significant at $P \geq 0.05$, P-value given otherwise.

[w]The lysimeters were divided into increments of 0-1, 1-2, 2-3, 3-4.5, 4.5-6, 6-9, 9-12 inches and roots harvested, washed free of substrate, and oven dried at 105ºC for 48 hours.

[v]Means within a column with different letters are significantly different based on LSD mean separation procedures ($P \geq 0.05$).

Figure 1. A lysimeter constructed from 4 inch PVC and used to evaluate glyphosate leaching in two substrates.

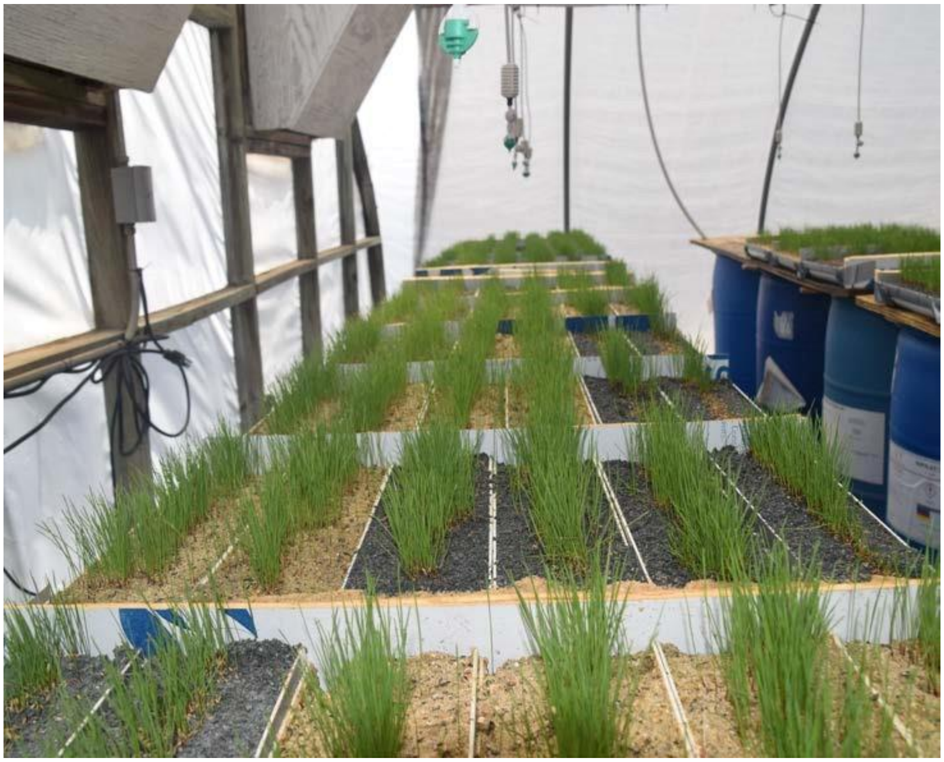

Figure 2. The lysimeters filled with sand or slate and sown with perennial ryegrass 'Carly' (*Lolium perenne* 'Carly') as an indicator species.