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Application factors affecting foliar spray loss for floating aquatic plants

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ABSTRACT

Mesocosm experiments were conducted in 2020 and 2021 in Louisiana and Florida to evaluate the effects of foliar spray application factors on spray deposition patterns for applications to floating aquatic plants using tracer dye. In the first experiment, spray trajectory and associated impact angles were investigated. A forward spray trajectory angle of 90° decreased spray loss by 22% to the water column when targeting waterhyacinth [*Eichhornia crassipes* (Mart.) Solms], compared to downward 90° and forward 45° spray angles. However, no difference in spray loss was detected for waterlettuce (*Pistia stratiotes* L.) among tested spray trajectory angles. The second experiment tested spray pattern (single-nozzle cone via spray-gun, single-nozzle straight stream via spray-gun, and multinozzle broadcast boom) effects on spray loss for applications to waterhyacinth, water lettuce, and giant salvinia (*Salvinia molesta* D.S. Mitchell). For waterhyacinth, spray loss was greatest with single-nozzle cone (51%), followed by single-nozzle straight stream (34%), followed by broadcast boom (25%). However, spray loss for waterlettuce was greatest using single-nozzle straight-stream applications (61%) and lowest with broadcast boom (40%) and single-nozzle cone (35%) applications. Spray loss for giant salvinia was greatest for single-nozzle cone applications (32%) and least for broadcast boom applications (19%). A third experiment tested spray loss between broadcast boom and spray-to-wet spray-gun application techniques; no differences were observed between techniques in applications to waterhyacinth or waterlettuce. These results suggest that foliar spray loss when targeting common floating aquatic plants can be minimized by manipulating application parameters and likely requires species-specific considerations. These results require verification under operational field conditions to develop best management practices to reduce spray loss for foliar-applied aquatic herbicide applications.

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INTRODUCTION

Foliar herbicide delivery techniques in agricultural systems have evolved significantly in the last four decades to accommodate application-driven efficacy and off-target movement requirements of herbicide chemistries and crop trait technologies (Combellack 1984; Baker and Mickelson 1994; Wolf et al. 2000; Power et al. 2013; Bish et al. 2020). Contrariwise, the foliar herbicide delivery techniques that are currently utilized in aquatic systems closely resemble those employed nearly 100 yr ago (Haller 2020). This lack of change in application technique is likely because of applicator familiarity and consistent success rates for aquatic vegetation management using traditional techniques. Likewise, until 15 to 20 yr ago, limited new aquatic herbicides were being registered for foliar use that may require alternative treatment approaches. In addition, most aquatic weed management operations are publicly funded, which unlike agricultural enterprises lack direct economic drivers for improving application efficiency. Though herbicide foliar application technologies differ among terrestrial and aquatic operations, most circumstances share the common goal of delivering and retaining product on the target pest plant while minimizing off-target spray loss to soil or water (Dorr et al. 2015).

Herbicide efficacy can be highly influenced by application technique in aquatic plant management operations. For example, reducing herbicide carrier volumes has been shown to increase control of waterhyacinth [*Eichhornia crassipes* (*Mart.*) Solms], phragmites [*Phragmites australis* (Cav.) Trin. ex Steud], and Brazillian peppertree (*Schinus terebinthifolia*) (Riemer 1976; Van et al. 1986; Sperry and Ferrell 2021; Sperry et al. 2021). Additionally, waterhyacinth control with 2,4-D was greater when cone-pattern nozzles were used compared to solid-stream nozzles (Sperry and Ferrell 2021). Optimized delivery of aquatic herbicides to target plants is of great importance to enhance efficacy, consistency, and limit treatment failure and the potential for off-target impacts. In Florida alone, more than 100,000 ha of floating plants received foliar herbicide treatments in 2019 (FFWCC 2019). Therefore, improvements to foliar application techniques that optimize efficacy and increase spray retention in aquatic systems should be identified and adopted to reduce off-target herbicide deposition.

The optimization of foliar application techniques is needed from a perceived environmental risk perspective. Although aquatic herbicides registered by the U.S. Environmental

Protection Agency undergo rigorous testing, and risk assessments are based on worst-case scenarios (100% deposition into the water column), spray loss to the water column has been a subject of concern to public stakeholders as well as natural resource management, regulatory, and permitting authorities. Until recently, minimal published data describing aquatic herbicide spray loss were available. In the 1980s, two field studies quantified foliar spray loss to the water column of 10 to 20% following applications to waterhyacinth (Rodriguez and Lebron 1982; Anderson et al. 1983). However, limited application technique information was described in these previous studies, and it is unknown whether the reported values reflect common application scenarios. More recently, Mudge et al. (2021) determined increases in floating plant density [waterhyacinth, water lettuce (*Pistia stratiotes* L.), giant salvinia decreased spray loss. Similarly, Sperry et al. (2022) observed reduced spray loss from lowering carrier volumes. These studies have demonstrated that floating plants intercept a considerable amount of the sprayed solution. Application parameters and target plant characteristics, such a leaf pubescence and plant architecture, and timing of applications based on plant growth stage are likely the main drivers of differential spray loss to the environment. Further studies are required to understand the suite of factors that influence foliar spray loss to develop best management practices for maximized spray retention and efficacy while minimizing off-target impacts.

For effective management of floating aquatic plants, a common goal is to maintain low plant populations through frequent, small-hectarage herbicide treatments. This is often referred to as "maintenance control" or "proactive management" (IFAS 2024; Joyce 1985). In this type of program, applicators routinely monitor sites and conduct herbicide applications to small mats or individual plants. In these scenarios when plants are scarce or scattered or at low vegetation cover, a spot-spray or spray-to-wet (where enough spray solution to "wet" the plants is applied before runoff) application technique is most common. However, larger hectarage rafts of free-floating plants (i.e., tussocks) that require broadcast applications are also commonplace if applicators are delayed or plants accumulate in areas constricted from wind and water currents. Broadcast applications may be accomplished quickly, and at large scales, by deploying aircraft-based applications or multiple boat-based crews that utilize wide swatch widths, faster travel speeds, and high-output nozzle arrangements to cover more hectares efficiently. Consequently, application parameters inherently change among these management scenarios because of differences in treatment goals and treatment area.

Many factors affect foliar spray retention including plant anatomy characteristics such as leaf angle, canopy structure, canopy density, target surface area; leaf microstructure that can contain trichomes, veins, and wax structures; variable droplet properties such as size, velocity, trajectories, and density; and variable formulation properties (e.g., surface tension and viscosity) (Furmidge 1962; Wirth et al. 1991; Zabkiewicz 2007; Journaux et al. 2011; Dorr et al. 2015). Furthermore, common aquatic application methods and equipment allow for spraying of targets close to the applicator and up to 15 m away, simply by adjusting the spray nozzle to produce a wider spray pattern or by arcing a solid spray stream, which allows spray droplets to fall onto target plants. Consequently, the droplet impact angle onto a plant or water surface can range from a direct side impact to an over-the-top impact, which is similar to traditional applications that utilize broadcast booms. Agricultural spray nozzles have also evolved from conventional downward angles to forward, rear, and dual-angled nozzle systems to maximize spray coverage on target plants (Foque and Nuyttens 2010).

Despite the widespread use of single-nozzle sprayers (i.e., spray-guns) for foliar aquatic herbicide applications, it is unknown if spray impact angle or spray nozzle pattern affects herbicide retention (i.e., spray loss to the water column) or if spray loss differs between application technique (i.e., broadcast boom vs. spray-to-wet). Therefore, experiments were conducted to evaluate the influence of spray angle, spray pattern type, and application technique on spray loss from foliar applications made to commonly targeted floating aquatic plants.

MATERIALS AND METHODS

Site description and plant establishment

In 2020 and 2021, outdoor mesocosm experiments were conducted at the Louisiana State University AgCenter Aquaculture Research Facility in Baton Rouge, LA (30.368055°N; 91.183333°W) and at the University of Florida Center for Aquatic and Invasive Plants in Gainesville, FL (29.721542°N; 82.417300°W). Three separate series of experiments were conducted for the influence of 1) spray angle, 2) spray pattern type, and 3) application technique on foliar spray loss to waterhyacinth, waterlettuce, and giant salvinia. All experiments were conducted similarly to Mudge et al. (2021) and Sperry et al. (2022), with all three trials established identically at both experiment locations. Floating plants were sourced from local cultures maintained at each facility and placed in 76 L high-density polyethylene (HDPE) containers (50 cm diameter) at Baton Rouge or in 96 L HDPE containers (61 cm diameter) at Gainesville. Containers at Baton Rouge designated for waterhyacinth or waterlettuce trials were filled with 72 to 74 L of unfiltered pond water (pH 7.0 to 7.5) and amended with water soluble fertilizer[1] (24-8-16) at 30 mg L^{-1}. Containers with giant salvinia were filled with 74 L of pond water, amended with sphagnum moss (100 mg L^{-1} dry material) to lower water pH < 7.0 and fertilizer (30 mg L^{-1}) (Cary and Weerts 1984; Owens et al. 2005). Giant salvinia was established and maintained as a single plant layer throughout the trials. Similarly, containers at Gainesville received well water (pH 7.8) and were amended with the same water-soluble fertilizer at 0.1 g L^{-1} plus 10% chelated iron[2] at 0.02 g L^{-1} for waterhyacinth and waterlettuce trials. Across experiments and locations, containers were maintained at the maximum water volume allowable (minus plant displacement) to ensure minimal spray deposition onto the container walls. Mesocosms were filled with plants and left to establish for 1 to 2 wk, to achieve maximum percent area covered by plant material. All plants were treated with zeta-cypermethrin[3] and imidacloprid[4] as needed to prevent insect damage at least 14 days prior to treatment.

All experiments utilized rhodamine WT[5] dye as an inert fluorescent tracer. RWT dye has been used for several years

Table 1. Experimental dates and locations for spray angle, spray equipment, and broadcast vs. spray-to-wet experiments evaluating effects on rhodamine WT dye spray deposition for three floating aquatic plant species in mesocosms following foliar applications. There were four replications (n = 4) per experimental run.

Experiment	Species	Location	Run	Treatment date	Average plant height (cm)	Dry biomass (kg ha^{-1})
Spray angle	Waterhyacinth	Baton Rouge	1	15 June 2020	26	2,846
			2	18 June 2021	26	2,674
		Gainesville	1	9 July 2020	29	3,886
			2	1 Sept. 2021	31	4,682
	Waterlettuce	Baton Rouge	1	11 June 2021	10	1,856
			2	16 June 2021	12	1,889
		Gainesville	1	9 July 2020	18	2,256
			2	1 Sept. 2021	15	1,908
Spray pattern	Waterhyacinth	Baton Rouge	1	30 June 2020	26	2,970
			2	1 July 2021	28	3,612
		Gainesville	1	21 June 2021	32	5,225
			2	9 July 2021	33	5,980
	Waterlettuce	Baton Rouge	1	11 June 2021	9	1,721
			2	16 July 2021	9	1,745
		Gainesville	1	21 June 2021	15	1,984
			2	9 July 2021	16	2,159
	Giant salvinia	Baton Rouge	1	30 June 2020	—	1,385
			2	1 July 2021	—	1,425
Application technique	Waterhyacinth	Baton Rouge	1	13 July 2021	28	3,847
			2	16 July 2021	27	3,751
		Gainesville	1	30 July 2021	31	4,208
			2	1 Sept. 2021	32	4,685
	Waterlettuce	Gainesville	1	30 July 2021	15	1,921
			2	1 Sept. 2021	16	2,074

in terrestrial pesticide application technology research as a suitable tracer of herbicide spray deposition in foliar- and soil-applied treatments (Everts and Kanwar 1994; Barber and Parkin 2003; Roten et al. 2013; Foster et al. 2018). Previous field research has also demonstrated RWT dye is compatible with, and has been correlated to, the dissipation of the aquatic herbicides diquat, endothall, fluridone, and triclopyr when tank mixed and applied subsurface to monitor water and herbicide movement and predict herbicide half-lives (Fox et al. 1991, 1993, 2002; Langeland et al. 1994; Turner et al. 1994). Consequently, RWT at 0.1% v v^{-1} plus a nonionic surfactant[6] (NIS) at 0.25% v v^{-1} was used in each treatment to trace spray loss to the water column and to simulate physicochemical properties of operational spray solutions, respectively (Hartzler and Foy 1983; Monaco et al. 2002; Sperry et al. 2021). Spray solution and mesocosm water pH at both sites were between 6.5 and 8, which is within the stable range for accurate RWT fluorescence readings (Feuerstein and Sellek 1963). At Baton Rouge, broadcast applications were made using a handheld boom attached to a CO_2-pressurized backpack sprayer equipped with XR11008 nozzles[7] calibrated to deliver 935 L ha^{-1} at 248 kPa, while Gainesville experiments utilized a CO_2-pressurized backpack sprayer equipped with XR11006 nozzles calibrated to deliver 935 L ha^{-1} at 345 kPa. This equipment was used for all broadcast applications across the three experiments. According to the nozzle manufacturer, both broadcast nozzle size and operating pressures produce medium spray qualities (TeeJet 2014). In addition, mesocosms without plants were treated to determine the maximum amount of spray solution that would reach the water column without plant interception.

Spray angle

Spray angle experiments were set up as a completely randomized design with four replications and repeated twice at each location (Table 1). Waterhyacinth and waterlettuce received foliar applications of the dye solution from the hand-held boom oriented directly downward 90°, forward 45°, or forward 90° spray angle trajectories. These spray angles were chosen to simulate potential spray droplet trajectory and impact angles possible in commercial operations.

Spray pattern

Spray pattern experiments were completely randomized with four replications per run (Table 1). Waterhyacinth and waterlettuce trials were conducted in Baton Rouge and Gainesville, whereas giant salvinia trials were conducted Baton Rouge only (Table 1). Mature plants received foliar applications of RWT and NIS with either 1) a hand-held boom with downward-pointed nozzles (90°), specified as treatment "multinozzle broadcast boom," 2) a single-nozzle spray-gun[8] equipped with a D8 disc on the straight-stream trigger setting at an upward ~45° spray angle (arc), specified as treatment "single-nozzle straight stream via spray-gun," or 3) a spray-gun[8] with a D8 disc on the wide-angle cone trigger setting at a forward spray angle, specified as treatment "single-nozzle cone via spray-gun." These equipment and application methods simulated three commonly used techniques deployed in the United States to manage floating species in operational field settings.

Application technique

Application technique experiments were completely randomized with four replications per run (Table 1). Waterhyacinth trials were conducted twice at each location, whereas waterlettuce trials were repeated at Gainesville only (Table 1). Mature waterhyacinth or waterlettuce plants received foliar applications of RWT and NIS solution using either 1) the previously described hand-held broadcast boom or 2) a single-nozzle sprayer equipped with an 800067 flat fan nozzle at 276 kPa. The single-nozzle equipment was utilized to make "spray-to-wet" applications and produced a very fine spray quality as specified by the manufacturer (TeeJet 2014).

Data collection and analysis

Background fluorescence of the source water was measured 15 cm below the surface in each mesocosm prior to RWT dye treatment using either a multiparameter sonde[9] (Baton Rouge) or a hand-held fluorometer[10] (Gainesville). For each experimental unit, in all waterhyacinth and waterlettuce experiments, the heights of five random petioles or leaves were measured from the water surface to the leaf tip (tallest point) prior to RWT application (Table 1).

All mesocosms remained undisturbed for at least 1 h following treatment to allow spray solution to dry on plant foliage, prior to water column mixing. A small submersible pump[11] was utilized to mix RWT in the water column, which was accomplished by carefully inserting the pump half-way into the water column (ensuring to not disturb vegetation) to allow the water to circulate for 1 min to ensure dye equilibrium. Dye concentrations were measured immediately after mixing as per previous background fluorescence measurements. Clean water was used to thoroughly rinse remnant dye from equipment and prevent cross-contamination between experimental units. Following RWT concentration readings, waterhyacinth, waterlettuce, and giant salvinia were placed in paper bags and dried in an oven at 65 C to a constant weight to determine biomass (Table 1).

Resultant RWT dye concentrations were adjusted for mesocosm volume and background fluorescence, and normalized to the control treatment (treated mesocosms without plants) yielding the percentage of applied dye found in the water column using the following equation:

$$Y = [(x - p)/(c - p)] \times 100, \qquad [1]$$

where Y is the percentage of applied dye deposited in the water column, x is the posttreatment dye concentration, p is the background fluorescence, and c is the posttreatment dye concentration in mesocosms without plant material.

Data were subjected to mixed-model analysis of variance (ANOVA) where treatment was considered a fixed effect, and experimental run and replicate (nested in experimental run) were considered random effects (Blouin et al. 2011). Where significant effects were detected, means were separated using Fisher's LSD test ($\alpha = 0.05$). All analyses were conducted in R (v. 3.6.1) under the LME4 and EMMEANS packages (Bates et al. 2015; Mendiburu 2019; R Core Team 2019; Lenth 2020). A paired t test was used to compare treatment means to the reference means from mesocosms that were sprayed and did not contain plants.

RESULTS AND DISCUSSION

Spray angle

Spray loss to the water column for waterhyacinth was similar for downward 90° and forward 45° spray angles, which were 33 and 29%, respectively (Table 2). When waterhyacinth was treated with a forward 90° spray angle, spray loss to the water column was minimized (11%). Conversely, spray loss for waterlettuce was similar among all tested spray angles ranging from 22 to 26%. There are two potential explanations for the observed reduction in spray loss for the forward spray angles made to waterhyacinth. First, waterhyacinth's growth form presents a greater vertical surface area for side-impacting spray deposition compared to downward deposition. Droplets traveling sideways toward the waterhyacinth canopy that either miss the first layers of foliage or bounce or disperse after initial impact have a greater chance to be intercepted and retained by background layers of foliage (Dorr et al. 2014). Conversely, downward sprays made to waterhyacinth canopies do not have a secondary canopy to be intercepted by and instead are deposited in the water. The second potential explanation is that droplets that did not make impact with plant tissue from the forward-facing spray angles were deposited outside of the sampled mesocosm. However, although deposition outside of mesocosms likely occurred to some extent, this observation was more likely anatomically and morphologically driven as the same result was not observed for waterlettuce. Waterlettuce canopies do not exhibit the secondary vertical growth that waterhyacinth canopies provide. Additionally, mature waterlettuce plants such as those tested, display upward leaf angles with a much shorter stature than waterhyacinth. This plant anatomy trait coupled with a hydrophobic leaf surface caused by the microstructure of the waterlettuce pubescent leaf surface likely caused significant spray droplet roll-off (Melo et al. 2015; Zheng et al. 2021).

Table 2. Spray loss to the water column (%) affected by spray trajectory angle for foliar applications to waterhyacinth and waterlettuce using a multinozzle broadcast boom in mesocosm experiments ($N = 16$ per species).

Spray trajectory angle	Waterhyacinth	Waterlettuce
	Spray loss to water column (%)[1]	
Downward (90°)	33 b (4.6)*	26 b (6.3)*
Forward (45°)	29 b (2.4)*	26 b (4.3)*
Forward (90°)	11 c (5.7)*	22 b (5.4)*

[1]Means within a column followed by the same letter are not significantly different based on Fisher's Protected LSD test ($\alpha = 0.05$). Means followed by an asterisk are different from reference treatments (mesocosms treated without plants) according to paired t test ($\alpha = 0.05$). Standard deviation in parentheses.

Spray pattern

Spray loss for waterhyacinth was greatest for the single-nozzle cone pattern (51%) followed by the single-nozzle straight-stream pattern (34%) followed by the broadcast boom pattern (25%) (Table 3). For waterlettuce, spray loss was minimized from single-nozzle cone (35%) and broadcast boom (40%) patterns. The single-nozzle straight-stream pattern resulted in the greatest spray loss to the water column of 61%. Spray loss for giant salvinia followed a similar trend to waterhyacinth across spray pattern types, which is interesting considering the large differences in plant anatomy and leaf morphology between these species. For giant salvinia, spray loss was greatest for the single-nozzle cone

Table 3. Influence of spray pattern on spray loss to the water column following foliar sprays to floating species in a mesocosm setting ($N = 16$ for waterhyacinth and waterlettuce; $N = 8$ for giant salvinia).

Application equipment	Waterhyacinth	Waterlettuce	Giant salvinia
	Spray loss to the water column (%)[1]		
Spray-gun (cone)	51 a (10.9)*	35 b (14.4)*	32 a (5.5)*
Spray-gun (straight stream)	34 b (7.8)*	61 a (16.1)*	27 ab (12.8)*
Boom (broadcast)	25 c (4.1)*	40 b (11.5)*	19 b (4.3)*

[1]Means within a column followed by the same letter are not significantly different based on Fisher's Protected LSD test ($\alpha = 0.05$). Means followed by an asterisk are different from reference treatments (mesocosms treated without plants) according to paired t test ($\alpha = 0.05$). Standard deviation in parentheses.

Table 4. Influence of application technique on spray loss to the water column following foliar spray using broadcast vs. spray-to-wet techniques to floating plant species in a mesocosm setting ($N = 16$ for waterhyacinth; $N = 8$ for waterlettuce).

Application technique	Waterhyacinth	Waterlettuce
	Spray loss to water column (%)[1]	
Broadcast	32 a (11.9)*	10 a (12.7)
Spray-to-wet	28 a (3.9)*	9 a (4.9)

[1]Means within a column followed by the same letter are not significantly different based on Fisher's Protected LSD test ($\alpha = 0.05$). Means followed by an asterisk are different from reference treatments (mesocosms treated without plants) according to paired t test ($\alpha = 0.05$). Standard deviation in parentheses.

pattern (32%), intermediate for the single-nozzle straight-stream pattern (27%), and least for the broadcast boom pattern (19%). For the species tested, the broadcast boom pattern generally resulted in the least spray loss to the water column, whereas the single-nozzle patterns shared similarities in some instances. Our qualitative observations suggest the broadcast boom pattern produced much finer droplets that appeared to have a lower terminal velocity than either of the single-nozzle patterns. Larger droplets coupled with high terminal velocity are known to result in reduced spray retention or adhesion (Lake 1977; Spillman 1984; Boukhalfa et al. 2014). The broadcast boom treatment for waterhyacinth and giant salvinia (smaller droplets and lower velocity) exhibited greater spray retention compared to the larger droplet and higher velocity single-nozzle straight-stream and cone treatments. Conversely, single-nozzle cone and broadcast boom treatments for waterlettuce performed similarly despite assumed differences in droplet size and velocity. Target surface orientation and texture of waterlettuce leaves could have influenced droplet adhesion characteristics (Massinon et al. 2014).

Application technique

No differences in spray loss to the water column were observed between broadcast and spray-to-wet treatments for waterhyacinth or waterlettuce (Table 4). However, we hypothesized that the spray-to-wet technique would result in lower spray loss compared to the broadcast technique because the broadcast technique delivers a constant carrier volume regardless of the target plant "wetness" level. The spray-to-wet technique is based on the applicator's visual queue or estimation of the target becoming adequately covered with the spray solution before droplet run off. Previously, lower spray volume has been correlated to reduced spray loss (Sperry et al. 2021). Although volume of solution was not quantified in spray-to-wet treatments, we suggest that these volumes would have been lower than the broadcast treatments, which were calibrated to deliver 935 L ha^{-1}. A possible explanation for the lack of spray loss difference between application techniques is due to droplet size spectrums and associated droplet velocities among techniques. According to the nozzle manufacturer, for the nozzles and operating pressures used for the broadcast and spray-to-wet treatments, these application techniques likely resulted in medium and very fine spray qualities, respectively (TeeJet 2014). Additionally, finer spray qualities or smaller spray droplets result in greater retention on target plants and dry quicker following deposition, which reduces the potential for secondary spray loss such as roll off (Spillman 1984; Feng et al. 2003; de Oliveira et al. 2019). However, finer spray qualities are more prone to off-target movement via particle drift (Foster et al. 2018). Future work should compare broadcast and spray-to-wet techniques utilizing the same nozzle type and sizes to reduce confounding factors, but understanding the impact of different nozzle types is also required.

CONCLUSIONS

A primary goal in foliar herbicide applications in aquatic environments is to maximize product retention on target vegetation above the water's surface to facilitate herbicide uptake and translocation and ultimately provide effective control of the target species. Here we evaluated the impact of multiple application factors on foliar spray loss to the water column and have identified several key findings: 1) target plant anatomy and leaf morphology heavily influence the amount of aqueous spray loss, 2) spray trajectories that result in side impact on the target plant decrease spray loss in species with complex canopy structures (e.g., waterhyacinth), and 3) application techniques that deliver smaller droplets traveling at lower velocities increase spray adhesion and reduce spray loss to the water column. In many operational settings, maximization of foliar spray retention and minimization of aqueous spray loss is critical for achieving effective control. However, many aquatic herbicides possess both foliar and in-water activity (Wersal and Madsen 2010; Mudge and Haller 2012; Glomski and Mudge 2013; Brown et al. 2022). Therefore, the aqueous spray loss fraction in certain foliar herbicide applications is likely absorbed by underwater stems, roots, and meristems and can contribute to efficacy outcomes in some species. Future research efforts to minimize foliar spray loss to the water column to minimize potential off-target impacts should 1) identify application parameters that can be manipulated to decrease foliar spray loss, 2) evaluate in-water activity components of selected herbicides on key target plant species, and 3) verify findings at operational field scales.

SOURCES OF MATERIALS

[1]Miracle-Gro® Lawn Fertilizer (24-8-16), The Scotts Company, P.O. Box 606, Marysville, OH 43040.

[2]Grow More Iron Chelate 10%, Grow More Inc., Gardena, CA 90248.

[3]GardenTech Sevin Insect Killer Concentrate, TechPac LLC, 2030 Powers Ferry Rd., Atlanta, GA 30339.

[4]BioAdvanced Complete Brand Insect Killer, SBM Life Science Corp. 1001 Winstead Dr., Suite 500, Cary, NC 27513.

[5]Rhodamine WT Liquid, Keystone Aniline Corp., 2501 W. Fulton St., Chicago, IL 60612.

[6]Surface™, Alligare, LLC, 13 N. 8th St., Opelika, AL 36801.

[7]TeeJet®, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60187.

[8]43-AL TeeJet GunJet® 22″, Spraying Systems Co., Wheaton, IL 60187.

[9]EXO1 Platform and Multiparameter Sonde, YSI Inc., 1700 Brannum Ln, Yellow Springs, OH 45387.

[10]Cyclops-7F, Turner Designs, Inc., 1995 N. 1st St., San Jose, CA 95112.

[11]MN404 MINI-Jet, Marineland, Spectrum Brands Pet LLC, 3001 Commerce St., Blacksburg, VA 24060.

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