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Note

Impact of herbicide retention time on the efficacy of foliar treatments for control of crested floating heart

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INTRODUCTION

Crested floating heart [*Nymphoides cristata* (Roxb.) Kuntzel], hereafter referred to as CFH, is a floating leaf plant native to Southeast Asia where it is considered a common weed in rice fields (Burks 2002). In the United States, CFH is found throughout Florida and has recently spread to Louisiana, North Carolina, South Carolina, and Texas (Willey 2012). Currently, there are no host-specific insect herbivores that feed on CFH, and grass carp are ineffective as a control agent (Singh et al. 1966, Willey and Langeland 2011). Mechanical harvesting and winter drawdowns have also proven ineffective at controlling CFH (Middleton 1990, Willey and Langeland 2011). Initial herbicide screening conducted by Willey et al. (2014) found that a subsurface application of endothall or diquat or a foliar application of imazamox or imazapyr are the most effective means to control CFH. Foliar applications of flumioxazin alone and in combination with glyphosate as well as foliar applications of carfentrazone-ethyl plus glyphosate were also effective at reducing CFH biomass in small-scale trials (Glomski et al. 2014). Although several herbicides have been identified as having activity against CFH in small-scale trials, ongoing management efforts in the field have been inconsistent. Some resource managers have suggested that for foliar-applied treatments, rapid loss of herbicide from the surface of the CFH leaf may be attributed to disturbances from boat wakes or wave action. In comparison with native floating-leaf plants such as nuphar (*Nuphar advena*), water lily (*Nymphaea odorata*), and American lotus (*Nelumbo lutea*), CFH has a much smaller leaf and grows from individual root crowns versus formation of extensive underground rhizomes. Although the native "lilies" can require management in some situations, they are typically considered valuable habitat and there is limited published work focusing on control of these plants.

Herbicides that rely on foliar absorption can be less effective when rainfall or irrigation occur before an adequate absorption time has passed (Gannon and Yelverton 2008) and many studies have been conducted to determine the rainfastness of various herbicides on agricultural weeds (Bryson 1987, 1988, Bariuan et al. 1999, Gannon and Yelverton 2008). For some emergent aquatic plants, however, herbicide wash-off from boat wakes or wind may be more problematic than rainfall or irrigation, as this wash-off may occur immediately after application or soon thereafter because of disturbances from passing boats or increased wave action due to higher winds. Recent observations in the field suggest that water disturbance from boat movement, wind, etc. can cause CFH surface leaves to momentarily dip below the water surface (Willey et al. 2014). When CFH leaves dip below the water surface, herbicide contact time is reduced, and efficacy of foliar applications is significantly affected; therefore, the objective of these trials was to determine the impact of foliar herbicide wash-off time on control of CFH.

MATERIALS AND METHODS

The trials were conducted in outdoor tanks at both the U.S. Army Engineer Research and Development Center's Lewisville Aquatic Ecosystem Research Facility in Lewisville, TX and the University of Florida's Center for Aquatic and Invasive Plants in Gainesville, FL. Plants utilized in these studies were from stock cultures of CFH originally obtained near Lake Okeechobee, FL. One CFH ramet was placed into the sediment (about ½ to ¾ of the propagule was below the sediment) into a 1-L pot filled with topsoil[1] amended with 3 g L^{-1} Osmocote®[2] (16–8–12) and 2.5 g L^{-1} sulfur[3]. One pot of CFH was placed into each 76-L tank (95-L tanks were used in Florida) and plants were allowed to establish for 8 wk. At that time, surface leaves covered 100% of the water surface of the tanks before treatment. Half of the tanks were treated with 0.43 kg ai ha^{-1} flumioxazin[4] + 5.67 kg ai ha^{-1} glyphosate[5] and the other half with 2.24 kg ai ha^{-1} imazapyr[6]. A nonionic surfactant (Thoroughbred[7] in Texas and Cygnet Plus[8] in Florida) was added to the flumioxazin + glyphosate combination at a rate of 0.5% v : v and a methylated seed oil (Inergy[9] in Texas and Sunwet[10] in

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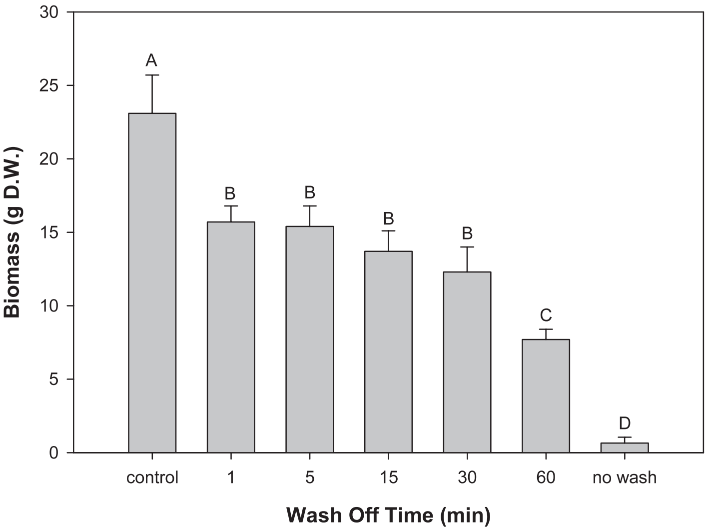

Figure 1. Effect of wash-off time on crested floating heart aboveground biomass (mean ± standard error) treated with a combination of flumioxazin and glyphosate. Tanks were harvested 4 wk after treatment. Bars sharing the same letter do not significantly differ from each other (Student–Newman–Keuls; $P \leq 0.001$).

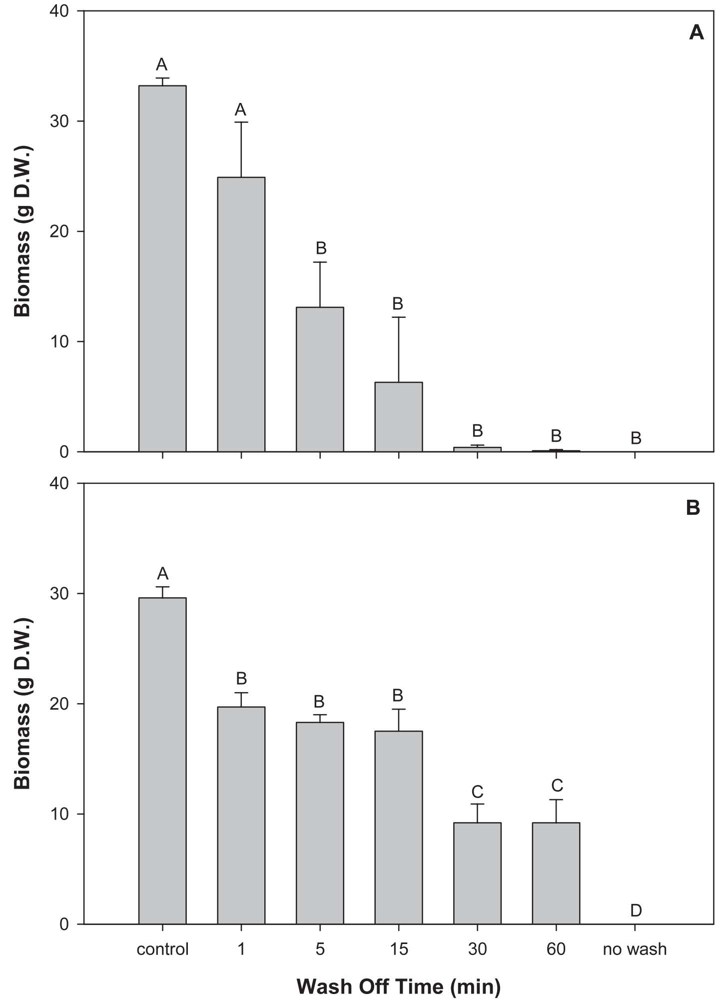

Figure 2. Effect of wash-off time on crested floating heart aboveground biomass (mean ± standard error) treated with imazapyr in A) Texas and B) Florida. Plants were harvested 4 wk after treatment. Bars sharing the same letter do not significantly differ from each other (Student–Newman–Keuls; $P \leq 0.001$).

Florida) was added to imazapyr at a rate of 1% v/v. Foliar treatments were applied using a CO_2-pressurized sprayer[11] equipped with a hand-held, single-nozzle spray header calibrated to deliver a spray volume of 934 L ha^{-1}. At 1, 5, 15, 30, and 60 min after treatment, plants were pushed under the water surface for several seconds to wash herbicide from the leaf surfaces and then transferred into tanks with herbicide-free water. We did not try to mimic multiple wash-off events that would be due to waves or boat wakes. The no-wash treatment plants were also moved to untreated tanks 1 d after treatment. Treatments were replicated three times and included an untreated control. At 4 wk after treatment, all viable aboveground biomass was harvested and dried at 65 C to a constant weight. Biomass data were subjected to a two-way ANOVA evaluating herbicide and wash-off time. If no significant differences were detected between trials (Texas and Florida), data were pooled. Means were separated via the Student–Newman–Keuls method ($P \leq 0.05$).

RESULTS AND DISCUSSION

Trials with flumioxazin + glyphosate in Texas and Florida were not significantly different and the data were pooled. All treatments, regardless of wash-off time, resulted in less aboveground biomass than the untreated control (Figure 1). As expected, the no-wash treatment provided the best outcome, with a 97% reduction in biomass compared with the untreated control. The lack of difference in control achieved between 1 and 30 min of exposure was not expected. The ability to achieve any control after just 1 min of exposure was surprising, and the lack of additional efficacy at 30 min suggests that the plants are subject to an extended period where wash-off can occur (e.g., wake from a passing boat). According to manufacturer labels, flumioxazin is rainfast in 1 h for the terrestrial product Chateua™ (Valent 2011), whereas glyphosate effectiveness is reduced if rainfall occurs within 6 h and retreatment may be required if heavy rainfall occurs within 2 h of application (Nufarm 2014a). There are multiple glyphosate formulations and the rainfast period can differ among these products, with some terrestrial formulations claiming rainfastness in 30 min. Results from the current trial indicated that the rainfastness of the flumioxazin + glyphosate combination is more than 1 h; however, more research is needed to refine rainfastness intervals. Reductions of plant biomass after only 1 min of herbicide retention suggest that some uptake of the herbicide occurred in a very short period of time, yet there was no evidence of increasing efficacy through the first 30 min of exposure. Despite reduced biomass of plants exposed from 1 to 30 min, recovery from new leaves was observed. In contrast, the plants that did not receive a wash-off showed no evidence of regrowth.

The Texas and Florida imazapyr trials yielded different results and therefore data were not pooled. In the Texas trial, CFH biomass was significantly reduced 61 to 100%

when wash-off occurred at 5 to 60 min after application or not at all (Figure 2A). However, Florida trial biomass was reduced 33 to 100% when wash-off occurred at 1 to 60 min or not at all (Figure 2B). The manufacturer label recommends avoiding wash-off of sprayed foliage for 1 h after application (Nufarm 2014b). There was a 99% reduction in biomass in the Texas trial when wash-off occurred at 30 and 60 min, but only a 69% reduction in the Florida trial. Although a methylated seed oil was used in both trials, different products were used and could account for the different outcomes. These initial results suggest that uptake of imazapyr may be enhanced compared with the flumioxazin and glyphosate mixture under these short retention scenarios. Given the similar results obtained on CFH with imazamox and imazapyr (Willey et al. 2014), additional rainfast evaluations of imazamox is suggested.

Adjuvants, diluents, carriers, volatilization, weed species and growth stage, and environmental conditions have an influence on herbicide penetration, retention, and wash-off (Bryson 1998). Reddy and Singh (1992) found that one organosilicone adjuvant could improve glyphosate efficacy when rainfall occurred 15 min after application to velvetleaf (*Abutilon theophrasti* Medik.), sicklepod (*Cassia obtusifolia* L.), and yellow foxtail [*Setaria glauca* (L.) Beauv.]. Efficacy was also improved when rainfall occurred 60 min after application to yellow nutsedge (*Cyperus esculentus* L.) and guineagrass (*Panicum maximum* Jacq.), but this particular organosilicone adjuvant failed to provide any rainfastness for barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.]. Although the current study was not designed to compare the impact of surfactant type on wash-off times, there is an indication that surfactant type may play a role in rainfastness on CFH. There is limited peer-review information available comparing the impact of different surfactants on efficacy of aquatic herbicides.

CFH presents a somewhat unique problem as the leaf size and plant morphology result in the surface leaves being prone to fairly rapid wash-off of foliar herbicides after boat-mounted applications or in areas where frequent disturbance from boat wakes is expected. The results demonstrate that when herbicides are retained on the leaf surface, foliar applications can be quite effective in providing control. For CFH, finding surfactants that can increase rainfastness may provide improved control for boat-mounted applications. In areas where CFH has become particularly dense, an aerial application via helicopter may be considered, as this could reduce potential wash-off disturbance compared with multiple boats treating the same area. Future work should focus on documenting rentention time in the field after various application strategies.

SOURCES OF MATERIALS

[1]Hapi-Gro topsoil, Hope Agri Products Inc, 2600-20 Old Highway 29 S., Hope, AR 71801.

[2]Osmocote®, The Scotts Company, P.O. Box 606, Marysville, OH 43040.

[3]Soil Acidifier, Bonide Products, Inc., 6301 Sutliff Road, Oriskany, NY 13424.

[4]Clipper®, Valent USA Corporation, P.O. Box 8025, Walnut Creek, CA 94596-8025.

[5]Aqua Neat®, Nufarm Americas Inc., Burr Ridge, IL 60527.

[6]Polaris®, Nufarm Americas Inc., Burr Ridge, IL 60527.

[7]Thoroughbred®, Winfield Solutions LLC, P.O. Box 64589, St. Paul, MN 55164-0589.

[8]Cygnet Plus, Cygnet Enterprises, Inc., 1860 Bagwell Street, Flint, MI 48503-4406.

[9]Inergy®, Winfield Solutions LLC, P.O. Box 64589, St. Paul, MN 55164.

[10]Sun Wet™, Brewer International, P.O. Box 690037, Vero Beach, FL 32969-0037.

[11]Bellspray Inc., 419 Highway 104, Opelousas, LA 70570.

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