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*Aquatic Plant Control Research Program*

# **Comparison of Generic and Proprietary Aquatic Herbicides for Control of Invasive Vegetation: Part 1. Floating Plants**

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# **Comparison of Generic and Proprietary Aquatic Herbicides for Control of Invasive Vegetation: Part 1. Floating Plants**

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## Abstract

Herbicides are one of the most effective and widespread ways to manage nuisance aquatic vegetation in the U.S. After the active ingredient is selected, often there are multiple proprietary and generic branded products to choose from. Limited research has been conducted to compare the efficacy of these herbicides head to head. Therefore, a series of mesocosm trials were conducted to evaluate 2,4-D, glyphosate, diquat, and triclopyr against the floating species giant salvinia, water hyacinth, and water lettuce. All active ingredients were applied to the foliage at broadcast rates commonly used in applications to public waters. Visual observations indicated that all herbicides within a particular active ingredient performed similarly with regard injury symptoms. There were no significant differences in product performance with regard to 2,4-D vs. water hyacinth, diquat vs. water lettuce, glyphosate vs. giant salvinia, and triclopyr vs. water hyacinth. Although statistical differences in performance of products were detected in the diquat vs. water lettuce (trial 3) and both glyphosate vs. water hyacinth trials, these differences were not consistent across initial and repeated trials. These results demonstrated that under outdoor mesocosm conditions, the majority of the generic and proprietary herbicides provided similar control, regardless of active ingredient or rate.

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## Preface

This study was conducted as part of the Aquatic Plant Control Research Program (APRCP). The APRCP is sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, MS. Funding for the APRCP was provided under the Department of the Army Appropriation Number 96x3122, Construction General.

The work was performed by the Aquatic Ecology and Invasive Species (EEA) of the Ecosystem Evaluation and Engineering Division (EE), U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Dr. Timothy Lewis was Chief, CEERD-EEA; Mr. Mark D. Farr was Chief, CEERD-EE; and Dr. Alfred Cofrancesco, CEERD-EZT was the Technical Director for the Civil Works Environmental Engineering and Sciences Office. The Deputy Director of ERDC-EL was Dr. Jack E. Davis and the Director was Dr. Ilker R. Adiguzel.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director.

## Acronyms and Abbreviations

<b>Acronym</b>	<b>Meaning</b>
AARF	AgCenter Aquaculture Research Facility
ANOVA	analysis of variance
APCRP	Aquatic Plant Control Research Program
DAT	Days After Treatment
DoD	Department of Defense
EL	Environmental Laboratory
ERDC	Engineer Research and Development Center
g	grams
km	kilometers
L	Liter
LSU	Louisiana State University
SON	Statement of Need
U.S.	United States
USACE	U.S. Army Corps of Engineers
USEPA	U.S Environmental Protection Agency
WAT	Weeks after treatment

# 1 Introduction

## 1.1 Background

Invasive submersed, floating, and emergent aquatic plants are continuously introduced into the United States (U.S.), negatively impacting U.S. Army Corps of Engineer (USACE), state, and private water bodies. Nuisance aquatic vegetation disrupts waterborne transportation, blocks potable water and irrigation intakes, degrades water quality, and displaces native plant and wildlife communities, including critical habitat for listed species (Getsinger et al. 2014). Chemical control, through the use of registered aquatic herbicides, is a technique that is widely employed by aquatic plant managers in the U.S. (Netherland 2014). Aquatic herbicides registered by the U.S. Environmental Protection Agency (USEPA) have been used to prevent further spread and provide control of existing populations of invasive plants. In general, herbicides are selected for a high-level of efficacy against the target species, possess relatively short aqueous half-lives, and have limited impacts on non-target/native plant species (Mudge 2007).

The standard herbicide registration has a 17-year patent for proprietary rights for brand name, formula, inert ingredients, and production of the proprietary brand-name or trademark product when it is initially registered (McFalls et al. 2015). After this period ends, other companies can synthesize/manufacture or distribute the herbicide under a different name (i.e., off-patent herbicide) (McFalls et al. 2015), commonly referred to as “generic” products (or “me-too” labels), using the original registration data. These generic products also have branded names, though different than the original, proprietary brand names. Although there are only 15 active ingredients registered for aquatic sites by the USEPA for Nation-wide use (Section 3 Registration) (Netherland and Jones 2012; University of Florida 2018), there are multiple registrants selling off-patent generic herbicides under a variety of branded names. In particular, end users have a large selection of available generic options when choosing some of the key legacy chemicals (e.g., 2,4-D, glyphosate, and diquat). However, many of the more recently registered proprietary aquatic herbicides do not have a generic counterpart because original patent life has not expired, or due to the cost or difficulty to manufacture the active ingredients.

There are advantages and disadvantages to using proprietary or generic aquatic herbicides. Often, proprietary herbicide manufacturers provide a wide range of customer/product support services and some level of product warranty to protect the end-user for rare cases of unacceptable performance. In addition, familiarity with proprietary products, well documented performance in the field, and/or manufacturer recognition are selling points to the end user. Conversely, proprietary herbicides may come with added expenses, even after patent expiration. Proprietary registrants must recover high costs associated with initial discovery, development, registration, and marketing expenses over an extended period due to the relatively minor market-share for aquatic herbicides. In addition, the USEPA requires a comprehensive registration review process every 15 years for all products seeking to maintain existing registrations (USEPA 2017). In most cases, the effort and costs associated with this process are heavily underwritten by the proprietary registrant.

Alternatively, generic products generally have a lower initial investment than their proprietary counterpart (McFalls et al. 2015), since the generic manufacturer does not pay the full cost of product development and/or registration. Lower initial investment costs allows these products to be offered at a lower market price. Moreover, some generic manufacturers provide little to no customer/product services, which also impacts market price. However, the generic product may carry a negative connotation/stigma of being an inferior product, even though it has the same active ingredient and percent composition as the proprietary herbicide. To be used as a viable alternative, most managers believe that a generic counterpart should deliver the same, or similar level of performance (i.e., efficacy) as the proprietary herbicide. Although active ingredient disclosure is required by the USEPA, non-pesticidal inert or inactive ingredients such as solvents, stabilizers, emulsifiers, surfactants and other additives can vary among products and are considered proprietary information. Inert active ingredients of products must be reported to the USEPA, and they are evaluated for potential impacts to human health and the environment.

Limited research has been conducted to evaluate the efficacy of generic herbicides alone, or direct comparisons of generic vs. proprietary aquatic herbicides. Previous research comparing generic vs. proprietary aquatic herbicides has focused on subsurface applications of fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) and copper

(Langeland et al. 2002; Koschnick et al. 2003; Poovey et al. 2004; Bultemeier et al. 2009; Turnage et al. 2015). Similarly, agriculture research has evaluated foliar applications of glyphosate, triclopyr, clopyralid (3,6-dichloro-2-pyridinecarboxylic acid), glufosinate (2-amino-4-(hydroxymethylphosphinyl)butanoic acid), and metsulfuron-methyl (2-[[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid) for efficacy against a variety of weed species (Hinklin et al. 2002; Cadenhead et al. 2007; Siekman and Sandell 2008; Latiff et al. 2009;). The limited data directly comparing herbicide performance in an aquatic setting has forced managers to rely on product name brand recognition, as well as anecdotal evidence when selecting an herbicide. Often, the resource manager or practitioner does not know if the chosen product is as effective as other available options, as well as if the product provides any added management values or benefits. In addition, there is considerable procurement pressure applied on, and by, public agencies to utilize the “lowest bid” for selection of herbicide brands that may ignore product performance and “valued-added” customer service by the registrant. Because of the sensitive nature of applying pesticides to surface waters, resource managers must ensure that products perform as advertised, and protection of the public and the environment is maintained.

Due to the limited amount of empirical evidence directly comparing performance of identical active ingredients, research is needed to fully understand the scope of generic herbicide utility. Over the past decade, these comparative evaluations have been requested by several USACE districts and state agencies searching for technical guidance for potential use of generic products in operational control programs in public waters. In FY16, the SAJ formally submitted a statement of need (SON) through the USACE’s Aquatic Plant Control Research Program (APCRP) to compare efficacy of generic vs. proprietary herbicides and determine their utility as a viable option for managing aquatic vegetation in public waterways. In the era of annual budget uncertainties and the proliferation of generic labels, key stakeholders need data on head-to-head efficacy comparisons in order to make informed and cost-effective management decisions. Once resource managers fully understand any differences between proprietary and generic products they can make more informed performance and procurement decisions in the best interests of the public, while adequately controlling invasive aquatic vegetation.

As the first of a three-part series, this document provides results on the efficacy of selected proprietary and generic products used to manage invasive floating emergent and submersed vegetation. Plant species, products, and application rates were selected based on extensive discussions with key UASCE District and state personnel responsible for managing invasive aquatic plants. Subsequent evaluations will compare proprietary and generic product performance on invasive submersed vegetation, and rooted emergent vegetation.

## **1.2 Objectives**

The objectives of this research were to (1) to evaluate the efficacy of commonly used herbicides, both generic and proprietary products, for controlling key floating aquatic plants found throughout the U.S. in a small-scale mesocosm setting, and (2) determine if differences exist between generic and proprietary product performance.

## 2 Materials and Methods

A series of outdoor, replicated mesocosm trials were conducted at the Louisiana State University (LSU) AgCenter Aquaculture Research Facility (AARF) in Baton Rouge, LA, to evaluate the efficacy of generic and proprietary 2,4-D, glyphosate, diquat, and triclopyr against giant salvinia, water hyacinth, and water lettuce. Both generic and proprietary herbicides commonly used by USACE districts and state agencies against problematic floating aquatic plants were evaluated. The trials were conducted from December 2016 through September 2017. All plants were collected from cultures maintained at LSU AARF or University Lake, Baton Rouge, LA. Within a given trial and plant species, equal amounts of fresh plant material were placed inside 76 Liter (L) plastic containers (49.5 cm diameter by 58.4 cm height). Containers were filled with water (pH 8.0–8.5) collected from ponds at LSU AARF and amended with Miracle-Gro® Lawn Fertilizer (The Scotts Company, Marysville, OH) (36-6-6, 41.6 mg L<sup>-1</sup>) initially and four weeks after herbicide treatment. Tanks with giant salvinia were amended with sphagnum moss (30 grams (g) dry material per tank) to lower the water pH to <7, to simulate favorable growth conditions for that species. Water level was maintained weekly at 60 L by the addition of pond water. Air temperature data were provided from the LSU AgCenter Central Research Station, 1.6 kilometers (km) to the east of the mesocosm location (LSU AgCenter 2017).

Plants were allowed to acclimate under experimental conditions for 1–2 weeks prior to herbicide application, and were in a healthy and active growing state at time of treatments. Herbicides were applied to foliage at broadcast rates commonly used in applications to public waters (Table 1 and Table 2). All herbicides within a given trial were applied at the same g acid equivalent (a.e.) or active ingredient (a.i.) ha<sup>-1</sup> regardless of g a.e. L<sup>-1</sup> or g a.i. L<sup>-1</sup> within each container. A non-ionic surfactant (Surf-AC® 910, Drexel Chemical Company, Memphis, TN) at the equivalent of 0.25% v/v was included with all treatments. An untreated control was also included with each trial to compare plant growth in the absence of herbicide. Treatments were randomly assigned and replicated five times and all trials were conducted 2 or 3 times. Herbicides were applied to plants using a forced air CO<sub>2</sub>-powered sprayer at an equivalent of 935 L ha<sup>-1</sup> diluent delivered through a single TeeJet® (Spraying Systems Company, Wheaton, IL) 80-0067 nozzle at 20 psi. This application technique provided even coverage of herbicides over the leaf and shoot surfaces.

At 1–8 weeks after treatment (WAT), all viable plant material was harvested, dried at 65 °C to a constant weight, and dry weight biomass was determined. Biomass data were analyzed using an analysis of variance (ANOVA) and if differences were detected, means were separated using Fisher's Protected LSD ( $p \leq 0.05$ ). If applicable, data were pooled across repeated trials if no differences between repetitions were detected ( $p \leq 0.05$ ).

**Table 1. Generic brand and proprietary brand aquatic herbicides trade name, active ingredient, and manufacturer of products evaluated against floating plants.**

Trade Name	Active Ingredient	Manufacturer	Address
2,4-D Amine	2,4-D	Alligare, LLC,	Opelika, AL
DMA® 4 IVM	2,4-D	Dow AgroSciences LLC	Indianapolis, IN
Shredder® Amine	2,4-D	Winfield Solutions, LLC	St. Paul, MN
WEEDestroy® AM-40	2,4-D	Nufarm Americas Inc	Burr Ridge, IL
Weedar® 64	2,4-D	Nufarm Americas Inc.	Burr Ridge, IL
Rodeo®	glyphosate	Dow AgroSciences LLC	Indianapolis, IN
Roundup Custom™	glyphosate	Monsanto Company	St. Louis, MO
AquaPro®	glyphosate	SePRO Corporation	Carmel, IN
AquaNeat®	glyphosate	Nufarm Americas Inc.	Burr Ridge, IL
Refuge™	glyphosate	Syngenta Crop Protection	Greensboro, NC
Glyphosate 5.4	glyphosate	Alligare LLC	Opelika, AL
Reward®	diquat	Syngenta Crop Protection	Greensboro, NC
Tribune™	diquat	Syngenta Crop Protection	Greensboro, NC
Littora®	diquat	SePRO Corporation	Carmel, IN
Diquat SPC 2L	diquat	Nufarm Americas Inc.	Burr Ridge, IL
Weedtrine® D	diquat	Applied Biochemists	Alpharetta, GA
Diquat	diquat	Alligare LLC	Opelika, AL
Tsunami DQ®	diquat	Sanco Industries, Inc.	Fort Wayne, IN
Harvester®	diquat	Applied Biochemists	Alpharetta, GA
Renovate® 3	triclopyr	SePRO Corporation	Carmel, IN
Garlon® 3A	triclopyr	Dow AgroSciences LLC	Indianapolis, IN
Triclopyr 3,	triclopyr	Alligare LLC	Opelika, AL
Trycera®	triclopyr	Helena Chemical Company	Collierville, TN

Table 2. Generic brand and proprietary brand aquatic herbicides evaluated against floating plants.

Active Ingredient	Products <sup>a,b</sup>	Rates (g a.e. <sup>c</sup> ha <sup>-1</sup> ) <sup>d</sup>	Plants Evaluated
2,4-D	Weedar 64, 2,4-D Amine, DMA 4 IVM, Shredder Amine, WEEDestroy AM-40	1598.0	Water Hyacinth
Glyphosate	Rodeo, Roundup Custom, AquaPro, AquaNeat, Refuge, Glyphosate 5.4	2242.8, 3364.1	Water Hyacinth, Giant Salvinia
Diquat	Reward, Tribune, Littora, Diquat SPC 2L, Weedtrine D, Diquat, Tsunami DQ, Harvester	841.0, 1682.1	Giant Salvinia, Water Lettuce
Triclopyr	Renovate 3, Garlon 3A, Triclopyr 3, Trycera	1682.1	Water Hyacinth

a Proprietary herbicides: Weedar 64, Rodeo, Reward, and Renovate 3.

b Consult state regulations concerning the use of these products for aquatic sites.

c Abbreviations: a.e., acid equivalent.

d Diquat was applied as g active ingredient (a.i.) ha<sup>-1</sup>.

### 3 Results and Discussion

Visual observations indicated that all generic and proprietary herbicides within a given trial and particular active ingredient performed similarly with regard to degree and progression of injury symptoms. Injury symptoms were observed at ca. <0.5, 1, 1, and 5 days after treatment (DAT) for plants treated with diquat, 2,4-D, triclopyr, and glyphosate, respectively. Most plants, except water lettuce treated with diquat (1682.1 g a.i. ha<sup>-1</sup>) and water hyacinth treated with triclopyr (1682.1 g a.e. ha<sup>-1</sup>), recovered from the herbicide treatments between 5 (water lettuce vs. diquat at 841.0 g a.i. ha<sup>-1</sup>) and 28 DAT (water hyacinth vs. 2,4-D at 1598.0 g a.e. ha<sup>-1</sup>). Plant recovery was expressed as the occurrence of healthy green tissue emerging as new leaves or stems in herbicide treated containers.

The generic 2,4-D products performed similarly with regard to injury symptoms and control provided compared to the proprietary product against water hyacinth in trials 1 and 2 (Table 3). Although the data could not be pooled between trials, product performance differences were not detected. Trial 1 provided 78–95% control, while trial 2 provided 81–96% control.

**Table 3. Efficacy (mean g dry weight,  $\pm$ SE) of generic and proprietary aquatic 2,4-D brands against water hyacinth 8 WAT<sup>a</sup>.**

Herbicide <sup>b</sup>	Trial 1	Trial 2
Control	382.4 $\pm$ 77.1 a <sup>c</sup>	163.1 $\pm$ 14.2 a
2,4-D Amine	83.6 $\pm$ 24.4 b	31.5 $\pm$ 15.3 b
DMA 4 IVM	47.3 $\pm$ 18.1 b	6.2 $\pm$ 5.6 b
Shredder Amine	51.9 $\pm$ 13.3 b	14.7 $\pm$ 8.1 b
WEEDestroy AM-40	23.1 $\pm$ 11.1 b	10.5 $\pm$ 5.6 b
Weedar 64	20.7 $\pm$ 10.6 b	18.1 $\pm$ 7.8 b

<sup>a</sup> Pre-treatment weights for trials 1 and 2 were 62.4 and 65.1 g, respectively.

<sup>b</sup> All herbicides applied at 1598.0 g acid equivalent (a.e. ha<sup>-1</sup>).

<sup>c</sup> Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at  $p \leq 0.05$ ; n = 5.

Diquat provided 98–100% giant salvinia control in trials 1 and 2 (Table 3). All products provided rapid injury (necrosis) and differences in speed of control were not detected among the eight diquat products evaluated in the mesocosm research. These trials were conducted in December when air temperatures were ca. 58 °C, which fell within the optimal temperature

range for maximizing diquat efficacy against giant salvinia (Mudge and Sartain 2018). All water lettuce treated with diquat at 1682.1 g a.i. ha<sup>-1</sup> was controlled 100% at 1 WAT (Table 3). The rapid plant death in the initial trial prompted a repeat of this trial at a lower application rate (841.0 g a.i. ha<sup>-1</sup>). The lower rate still resulted in 99% control, and this level of control was confirmed in the third trial at the evaluated rate which resulted in 68–99% reductions in biomass compared to the untreated reference. Efficacy differences in trial 3 could be the result of seasonal treatment timing, as this trial was conducted in mid-June (29°C) compared to trials 1 and 2 conducted in late-March and mid-April when average temperatures were 19 °C and 22 °C, respectively. The cooler temperatures at herbicide application may have resulted in consistently greater control of water lettuce, as plant tissue at that time was young, tender and more susceptible to herbicide uptake. In addition, only one herbicide (Weedtrine-D) provided less control in trial 3, but the product was similar to the others in trial 1 and trial 2 of diquat vs. water lettuce.

Similar to the other trials, there were no differences among the glyphosate products evaluated against giant salvinia as all products provided 85–95% and 94–99% in trials 1 and 2, respectively (Table 4). The efficacy of diquat (Reward, ≥1120 g a.i. ha<sup>-1</sup>) and glyphosate (Rodeo, ≥2240 g a.e. ha<sup>-1</sup>) vs. giant salvinia was previously investigated by Nelson et al. (2001), who documented diquat and glyphosate applied at rates similar and higher to those applied in the current trial, provided 99–100% control. The results of the current generic/proprietary research support those earlier findings.

Generic and proprietary glyphosate products did show differences when applied to water hyacinth (Table 4). All products were efficacious in the two trials and provided 82–99% control. In particular, Rodeo provided less control than Glyphosate 5.4 in trial 1, while AquaPro was more efficacious compared to AquaNeat in trial 2. In addition, less control was observed in the second glyphosate vs. water hyacinth trial and could be attributed to time of year trial 1 was treated ((7 April (18 °C), while trial 2 was treated 18 August (94 °C)). The maturity of plants and rate of growth following treatment could be responsible for decreased efficacy at the higher temperatures during treatments.

**Table 4. Efficacy (mean g dry weight,  $\pm$ SE) of generic and proprietary aquatic diquat brands against giant salvinia and water lettuce eight weeks after treatment<sup>a</sup>.**

	Giant Salvinia Trial 1 <sup>b</sup>	Giant Salvinia Trial 2	Water Lettuce Trial 1 <sup>c</sup>	Water Lettuce Trial 2	Water Lettuce Trial 3
	Rate (g a.i. ha <sup>-1</sup> )				
Herbicide	1682.1			841.0	
Control	32.4 $\pm$ 6.6 a <sup>d</sup>	26.0 $\pm$ 5.2 b	57.5 $\pm$ 2.5 a	105.0 $\pm$ 1.5 a	107.0 $\pm$ 4.2 a
Diquat	0.6 $\pm$ 0.3 b	0.3 $\pm$ 0.3 b	0.0 $\pm$ 0.0 b	0.8 $\pm$ 0.7 b	12.4 $\pm$ 9.2 c
Diquat SPC 2L	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.3 $\pm$ 0.3 b	17.6 $\pm$ 10.4 bc
Harvester	0.8 $\pm$ 0.6 b	0.2 $\pm$ 0.2 b	0.0 $\pm$ 0.0 b	0.4 $\pm$ 0.3 b	19.0 $\pm$ 11.2 bc
Littora	0.1 $\pm$ 0.1 b	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.2 $\pm$ 0.1 b	1.5 $\pm$ 1.1 c
Reward	0.1 $\pm$ 0.1 b	0.2 $\pm$ 0.1 b	0.0 $\pm$ 0.0 b	0.2 $\pm$ 0.0 b	10.5 $\pm$ 5.6 c
Tribune	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.1 $\pm$ 0.1 b	6.6 $\pm$ 2.6 c
Tsunami DQ	0.2 $\pm$ 0.2 b	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.6 $\pm$ 0.3 b	5.7 $\pm$ 4.3 c
Weedtrine-D	0.1 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b	0.7 $\pm$ 0.4 b	33.6 $\pm$ 8.1 b
<sup>d</sup> Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.05$ ; $n = 5$ .					

a Pre-treatment weights for giant salvinia trials 1 and 2 were 19.2, 20.2, and, respectively, while pre-treatment weights were 39.8, 52.1, and 48.3, for water lettuce trials 1, 2, and 3, respectively.

b Giant salvinia trials 1 and 2 were conducted during the winter, while giant salvinia trial 3 and the water lettuce trials were conducted during the growing season (spring or summer).

c Water lettuce trial 3 was harvested one week after treatment.

All triclopyr herbicides resulted in rapid leaf twisting (epinasty) of water hyacinth within 1 DAT and rapid plant control thereafter in the initial and repeat trials. All triclopyr products provided 100% control at three WAT (Table 5). Triclopyr was evaluated at a relatively high rate (1682.1 g a.e. ha<sup>-1</sup>) against water hyacinth in both trials. Direct comparison of products at lower rates ( $\leq 841$  g a.e. ha<sup>-1</sup>) should be evaluated in future studies to determine if efficacy differences can be quantified among the products.

**Table 5. Efficacy (mean g dry weight,  $\pm$ SE) of generic and proprietary aquatic glyphosate brands against giant salvinia and water hyacinth eight weeks after treatment<sup>a</sup>.**

	Giant Salvinia Trial 1	Giant Salvinia Trial 2	Water Hyacinth Trial 1	Water Hyacinth Trial 2
	Rate (g a.e. ha <sup>-1</sup> )			
Herbicide <sup>b</sup>	3364.1		2242.8	
Control	110.0 $\pm$ 5.9 a <sup>c</sup>	63.0 $\pm$ 6.7 a	235.8 $\pm$ 13.9 a	171.0 $\pm$ 18.3 a
Rodeo	10.5 $\pm$ 4.7 b	2.1 $\pm$ 1.6 b	13.2 $\pm$ 6.3 b	32.8 $\pm$ 5.0 bc
Roundup Custom	14.2 $\pm$ 2.9 b	2.1 $\pm$ 1.3 b	8.4 $\pm$ 3.6 bc	30.8 $\pm$ 2.7 bc
AquaNeat	8.9 $\pm$ 2.4 b	0.5 $\pm$ 0.4 b	3.9 $\pm$ 2.6 bc	43.3 $\pm$ 7.8 b
AquaPro	7.3 $\pm$ 2.1 b	0.7 $\pm$ 0.4 b	8.9 $\pm$ 3.8 bc	14.2 $\pm$ 4.2 c
Glyphosate 5.4	6.1 $\pm$ 2.5 b	3.8 $\pm$ 1.4 b	0.4 $\pm$ 0.4 c	22.7 $\pm$ 6.9 bc
Refuge	5.8 $\pm$ 1.6 b	5.8 $\pm$ 3.2 b	5.9 $\pm$ 1.7 bc	25.0 $\pm$ 6.5 bc

a Pre-treatment weights for giant salvinia trials 1 and 2 were 33.9 and 29.1 g, respectively, and pre-treatment weights were 40.7 and 96.9, for water hyacinth trials 1 and 2, respectively.

b All herbicides applied at 1598.0 g a.e. ha<sup>-1</sup>.

c Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at  $p \leq 0.05$ ;  $n = 5$ .

**Table 6. Efficacy (mean g dry weight,  $\pm$ SE) of generic and proprietary aquatic triclopyr brands against water hyacinth three weeks after treatment<sup>a</sup>.**

Herbicide <sup>b</sup>	Trial 1	Trial 2
Control	139.0 $\pm$ 5.9 a <sup>c</sup>	183.2 $\pm$ 14.1 a
Renovate 3	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b
Garlon 3A	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b
Triclopyr	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b
Trycera	0.0 $\pm$ 0.0 b	0.0 $\pm$ 0.0 b

a Pre-treatment weights for trials 1 and 2 were 72.3 and 72.2 g, respectively,

b All herbicides applied at 1682.1 g a.e. ha<sup>-1</sup>.

c Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at  $p \leq 0.05$ ;  $n = 5$ .

## 4 Conclusions

A total of 24 products were evaluated in these trials, and the results demonstrated that the majority of the herbicides provided similar control, regardless of active ingredient or foliar application rate. Previous aquatic (Koschnick et al. 2003; Bultemeier et al. 2009; Turnage et al. 2015), row crop (Cadenhead et al. 2007; Siekman and Sandell 2008;), and roadside (McFalls et al. 2015) research also found little to no differences in efficacy between generic and proprietary clopyralid, copper, glyphosate, metsulfuron-methyl, and triclopyr. The current small-scale trials and results are a necessary starting point for developing reliable operational guidance for direct comparisons among generic and proprietary products. Although these results did not indicate any appreciable differences among products, except for glyphosate vs. water hyacinth and giant salvinia, field verification of these small-scale evaluations will refine recommendations for use in large-scale operational settings.

## References

- Bultemeier, B. W., A. Puri, W. T. Haller, and V. V. Vandiver. 2009. Residue profile and efficacy comparisons between two liquid formulations of fluridone. *Journal of Aquatic Plant Management* 47:63–65.
- Cadenhead, J. F., C. R. Hart, R. K. Lyons, A. McGinty, B. Rector, T. Ball, E. Zimmerman, M. Palmer, R. Scott, T. Franke, and J. Hanselka. 2007. Generic herbicide efficacy for mesquite management 2007. Goldmine Applied Research Progress Report, Texas AgriLIFE Research and Extension Center. <http://agrilifecdn.tamu.edu/stephenville/files/2011/02/2007Mesquite-IPT-generic-Albaugh06.pdf>.
- Getsinger, K. D., E. Dibble, J. H. Rodgers Jr., and D. Spencer D. 2014. Benefits of controlling nuisance aquatic plants and algae in the United States. CAST Commentary QTA2014-1. Ames, IA: Council for Agricultural Science and Technology.
- Hinklin, B. A., J. A. Kendig, P. M. Ezell, and G. A. Ohmes. 2002. Chevrolet, ford, or dodge glyphosate. In *Proceedings, 54<sup>th</sup> annual meeting, Southern Weed Science Society*, Biloxi, MS.
- Koschnick, T. J., W. T. Haller, V. V. Vandiver, and U. Santra. 2003 Efficacy and residue comparisons between two slow-release formulations of fluridone. *Journal of Aquatic Plant Management* 41:25–27.
- Langeland, K. A., O. N. Hill, T. J. Koschnick, and W. T. Haller. 2002. Evaluation of a new formulation of reward landscape and aquatic herbicide for control of duckweed, waterhyacinth, waterlettuce, and hydrilla. *Journal Aquatic Plant Management* 40:51–53.
- Latiff, M. R., M. A. Arbain, and C. C. Tey CC. 2009. Efficacy of generic herbicides of glyphosate, glufosinate ammonium and metsulfuron methyl for weed control in oil palm. In *PIPOC International Palm Oil Congress*.
- LSU AgCenter. 2017. *Louisiana Agrilimatic Information System*. (Accessed on 13 June 2019). <http://weather.lsuagcenter.com/Default.aspx>.
- McFalls, J., Y. Yi, M. Li, S. Senseman, and B. Storey. 2015. *Evaluation of Generic and Branded Herbicides: Technical Report*. FHWA/TX-15/O-6733-1. College Station, TX: Texas A&M Transportation Institute.
- Mudge, C. R. 2007. *Characterization of Flumioxazin as an Aquatic Herbicide*. Ph.D. dissertation. Gainesville, FL: University of Florida.
- Mudge, C. R., A. J. Perret, and J. R. Winslow. 2016. Evaluation of foliar herbicide and surfactant combinations for control of giant salvinia at three application timings. *Journal of Aquatic Plant Management* 54:32–36.
- Mudge, C. R., and B. T. Sartain. 2018. Influence of winter on herbicide efficacy for control of giant salvinia (*Salvinia molesta*). *Journal of Aquatic Plant Management* 56:68–71.

- Nelson, L. S., J. G. Skogerboe, and K. D. Getsinger. 2001. Herbicide evaluation against giant salvinia. *Journal of Aquatic Plant Management*. 39:48–53.
- Netherland, M. D. 2014. Chemical control of aquatic weeds. In *Biology and Control of Aquatic Plants: A Best Management Practices Handbook*. 3<sup>rd</sup> ed. Marietta, GA: Aquatic Ecosystem Restoration Foundation.
- Netherland, M. D., and K. D. Getsinger. 2018. Scaling studies for submersed aquatic plant management research. *Journal of Aquatic Plant Management* 56s:10–16.
- Netherland MD, Jones KD. 2012. Registered herbicides and improving their efficacy on aquatic weeds. *Aquatics* 34(3):12-15.
- Poovey, A. G., J. G. Skogerboe, and K. D. Getsinger. 2004. *Efficacy of AVAST!<sup>®</sup> Fluridone Formulation Against Eurasian Watermilfoil and Nontarget Submersed Plants*. ERDC/EL TR-04-9. Vicksburg, MS: U. S. Army Engineer Research and Development Center.
- Siekman, D., and L. Sandell 2008. Comparing generic versus name brand herbicides. Lincoln, NE: University of Nebraska-Lincoln. (Accessed on 13 June 2019). <https://cropwatch.unl.edu/comparing-generic-versus-name-brand-herbicides>.
- Turnage, G., J. D. Madsen, and R. M. Wersal 2015. Comparative efficacy of chelated copper formulations alone and in combination with diquat against hydrilla and subsequent sensitivity of American lotus. *Journal of Aquatic Plant Management* 53:138–140.
- University of Florida. 2018. Plant management in Florida waters: an integrated approach. Details about the aquatic herbicides used in Florida. Gainesville, FL: University of Florida. (Accessed on 16 June 2019). <http://plants.ifas.ufl.edu/manage/control-methods/details-about-the-aquatic-herbicides-used-in-florida>.
- United State Environmental Protection Agency (USEPA). 2017. Registration review process. (Accessed on 16 June 2019). <https://www.epa.gov/pesticide-reevaluation/registration-review-process>.

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**14. ABSTRACT**  
Herbicides are one of the most effective and widespread ways to manage nuisance aquatic vegetation in the U.S. After the active ingredient is selected, often there are multiple proprietary and generic branded products to choose from. Limited research has been conducted to compare the efficacy of these herbicides head to head. Therefore, a series of mesocosm trials were conducted to evaluate 2,4-D, glyphosate, diquat, and triclopyr against the floating species giant salvinia, water hyacinth, and water lettuce. All active ingredients were applied to the foliage at broadcast rates commonly used in applications to public waters. Visual observations indicated that all herbicides within a particular active ingredient performed similarly with regard injury symptoms. There were no significant differences in product performance with regard to 2,4-D vs. water hyacinth, diquat vs. water lettuce, glyphosate vs. giant salvinia, and triclopyr vs. water hyacinth. Although statistical differences in performance of products were detected in the diquat vs. water lettuce (trial 3) and both glyphosate vs. water hyacinth trials, these differences were not consistent across initial and repeated trials. These results demonstrated that under outdoor mesocosm conditions, the majority of the generic and proprietary herbicides provided similar control, regardless of active ingredient or rate.

**15. SUBJECT TERMS**  
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