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Influence of shade on efficacy of aquatic herbicides for control of giant salvinia

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ABSTRACT

Giant salvinia (*Salvinia molesta*) can be found in open water under full sunlight as well as under the dense canopy of trees across the southern United States. To date, most herbicides have been evaluated for efficacy against giant salvinia under full sunlight. Because most herbicides interfere with light-dependent processes, the influence of shade where plant growth is slower and herbicide activity could be hindered should be evaluated. Therefore, a mesocosm trial was conducted to determine the impact of reduced light on the efficacy of carfentrazone, diquat, flumioxazin, glyphosate, metsulfuron, and penoxsulam when applied to the foliage of giant salvinia grown under 0, 30, and 60% shade levels. At 7 wk after treatment (WAT), all herbicides reduced giant salvinia biomass 87 to 100% of the control when plants were cultured under 0% shade. Diquat and glyphosate efficacy was not impacted by light intensity, with biomass reduced ≥97% regardless of light treatment. There were no differences in control for plants grown under the full sunlight or 30% shade treatments and exposed to a foliar application of flumioxazin. However, giant salvinia control decreased by 16 and 27% when treated with carfentrazone and grown under 30 and 60% shade levels, respectively. The greatest impact on efficacy occurred when penoxsulam and metsulfuron were applied to giant salvinia grown under the 30% light intensity and biomass was only decreased 20 and 23%, respectively, compared to 63 to 92% control by these slow-acting systemic herbicides when grown under 30 and 0% shade. These findings suggest that light availability plays a crucial role in herbicide performance and herbicide selection is critical for managing this species in shaded areas.

Key words: carfentrazone, chemical control, diquat, flumioxazin, foliar application, glyphosate, metsulfuron, penoxsulam.

INTRODUCTION

Giant salvinia (*Salvinia molesta* D.S. Mitchell) is a free-floating, aquatic fern native to Brazil. Since the late 1990s, the plant has become a major nuisance in various waterways throughout the southern United States (Jacono 1999). Although the majority of giant salvinia infestations occur within Louisiana and Texas (Jacono and Pitman 2001), populations continue to spread across the Gulf Coast region (Thayer et al. 2018). Giant salvinia is a troublesome weed because of rapid growth rates, as the plant can double biomass within 36 h under optimal conditions (Johnson et al. 2010) and a single plant frond can cover up to 103.6 km^2 within 3 mo (Creagh 1991/1992). Plant spread and vegetative reproduction occurs through rhizome and lateral bud growth, with broad dispersal typically resulting from frond fragmentation (Nelson 2014). Further, the plant can quickly form monocultures, inhibiting the growth of native aquatic plants that provide food and habitat for animals such as waterfowl (Mitchell 1978). As a result of dense surface mats, sunlight is shaded out and submersed vegetation growth is inhibited, and eventual plant death occurs (Prevost 2019). As giant salvinia continues to spread into waterways outside of Louisiana and Texas, natural resource agencies in neighboring states desire to eradicate the plant before long-term establishment occurs.

Although giant salvinia is typically found within open water systems (Owens et al. 2011), plants can thrive within isolated-backwater and shallow areas having heavy timber cover such as bald cypress [*Taxodium distichum* (L.) Rich.] (Sartain and Mudge 2018). Potgieter et al. (2023) evaluated the growth of giant salvinia under 0, 40, 60, 85, and 95% shade conditions and found the plants could survive and produced new fronds under all shade conditions, but the 60% shade regime resulted in the most optimal frond production. In a 3-wk study, Owens et al. (2011) investigated giant salvinia growth under various shade treatments and discovered plants had deeper green colors as shade level increased, which is likely a result of increased chlorophyll concentrations (Lambers et al. 1998). However, giant salvinia biomass was still the greatest under full sunlight (Owens et al. 2011). Another hindrance of the isolated plants in the low light and shaded areas is the limited access by boats or aircraft for the application of aquatic herbicides (Sartain and Mudge 2018, Cozad et al. 2019). Although chemical treatment of the target species is still possible under the shade of trees (if the site is accessible), there is a risk of reduced herbicidal activity, because plant growth is slower when light intensity is reduced.

Of the 16 active ingredients currently registered for aquatic use, carfentrazone-ethyl, diquat, flumioxazin, glyphosate, and penoxsulam (all Section 3 herbicides), as well as the Special Local Need [SLN, 24(c)] metsulfuron-methyl, have demonstrated high levels of efficacy against giant salvinia when applied to the foliage or as a subsurface injection (Nelson et al. 2001, Glomski and Getsinger 2006, Mudge et al. 2012, 2013, Mudge 2016, Prevost et al. 2021). The protoporphyrinogen oxidase (PPO)

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inhibitors carfentrazone and flumioxazin, along with diquat (Photosystem I inhibitor) interfere with photosynthesis in different ways (Duke et al. 1991, Hess 2000, Shaner 2014). Glyphosate is an enolpyruvylshikimate-3-phosphate synthase (EPSPS) inhibitor, whereas metsulfuron, and penoxsulam interfere with the activity of the acetolactate synthase (ALS) enzyme (Siehl 1997, Mateos-Naranjo et al. 2009, Shaner 2014). All of these plant processes are light dependent, and because of the variable light availability and intensity where giant salvinia is found, efficacy of these commonly used herbicides could be negatively impacted. Because sunlight can dictate herbicide performance, understanding the influence of shading on herbicides used for giant salvinia control is important for management.

To date, research evaluating herbicide efficacy to control giant salvinia has largely been conducted under full lighting conditions (Nelson et al. 2001, McFarland et al. 2004, Glomski and Getsinger 2006, Mudge et al. 2012, 2016). There is concern that the use of established treatment programs may fully provide expected control levels among shade-treated populations, which ultimately allows existing giant salvinia to persist or quickly reestablish following treatment activities. Additional data are required to determine how reduced sunlight (i.e., shading) impacts plant control with commonly applied herbicides to provide resource agencies with herbicide management guidance. Therefore, the contact herbicides carfentrazone, diquat, and flumioxazin and systemic herbicides glyphosate, metsulfuron, and penoxsulam were evaluated against giant salvinia under three light regimes to determine the impact of shade light quantity on herbicide efficacy.

MATERIALS AND METHODS

Repeated shade trials were conducted in outdoor mesocosms at the Louisiana State University (LSU) AgCenter Aquaculture Research Facility in Baton Rouge, LA in 2022. Giant salvinia culture and planting techniques were adapted from previous small-scale chemical control research conducted previously in Mississippi and Louisiana (Mudge et al. 2012, 2016). High-density polyethylene (HDPE) plastic mesocosms ($N = 120$; 76 L, 49.5-cm diam by 58.4-cm height) were filled with 60 L of locally sourced pond water (pH 8.5), sphagnum peat moss (15 g), and fertilizer[1] (2 g per container, 24–8–16). The peat moss was used to lower the water pH to ca. 6.5, and the addition of the fertilizer pretreatment and every 2 wk posttreatment promoted plant growth. Healthy, mature giant salvinia (tertiary growth stage) was collected from local stock tanks (1,325 L) at LSU Aquaculture and placed into the 76–L mesocosms. Each mesocosm received equal amounts of giant salvinia to cover 75% of the water's surface. Plants were cultured under one of the following shade regimes with or without black shade cloth (3.7 by 7.3 m): 1) 0% shade (no shade cloth and 100% sunlight, $n = 40$), 30% shade (70% sunlight, $n = 40$), or 60% shade (40% sunlight, $n = 40$). On sunny days throughout the course of the research, a light meter[2] was used to record light levels at the surface of the plant canopy (15 cm below shade cloth) and light averaged 1950, 1250, and 750 μmol m^{-2} s^{-1} for the 0, 30, and 60% shade regimes, respectively. The shade cloth was placed directly over the containers on the same day as plant establishment. Preliminary research (data not shown) indicated longer periods of time were required for plants to cover 100% of the water's surface when light intensity was reduced; therefore, plants that received the 30 and 60% shade treatments were established 1 and 2 wk prior to the 0% shade treatment plants, respectively, to obtain similar biomass at herbicide application. By staggering planting 1 or 2 wk, 100% plant coverage (single plant layer) occurred in all tanks prior to herbicide treatment.

Prior to herbicide application (1 May and 4 August 2022), all plant material was harvested from 12 containers (4 containers per light level) to assess pretreatment biomass. Harvested plants were placed in an oven (60°C) until dry and weighed to obtain dry-weight biomass. Once the acclimation period concluded (1 to 3 wk), plants were treated with the maximum foliar rates of carfentrazone[3] (224 g active ingredient [a.i.] ha^{-1}), diquat[4] (4,183 g a.i. ha^{-1}), flumioxazin[5] (429 g a.i. ha^{-1}), glyphosate[6] [4,205 g acid equivalent (a.e.) ha^{-1}], metsulfuron[7] (42 g a.i. ha^{-1}), or penoxsulam[8] (98 g a.i. ha^{-1}). The herbicides were applied to the foliage using a forced-air CO_2-powered sprayer calibrated to deliver 935 L ha^{-1} diluent through a single TeeJet® 80-0067 nozzle.[9] A nonionic surfactant[10] (0.25% v v^{-1}) was included with all treatments. For plants cultured under reduced light conditions, the shade cloth was temporarily removed, the plants were chemically treated, and the shade cloth was immediately returned until plant harvest. The experimental design was a randomized complete block and treatments were replicated five times. In addition, each light level included nontreated references to monitor plant growth in the absence of herbicide treatment.

Because of the slow activity of the ALS-inhibiting herbicides metsulfuron and penoxsulam, it was anticipated the trial would be conducted for a minimum of 8 wk (Mudge et al. 2012, Prevost et al. 2021). However, at 7 WAT, the health of the control plants grown under the 60% shade cloth declined (i.e., fungal pathogen) in the initial and repeated trials, and the trials were consequently harvested earlier than anticipated. All viable biomass was collected, placed in paper bags, and dried in an oven (60°C) for 1 wk. All biomass data were normalized to a percentage of the nontreated control within respective shade levels to account for inherent differences in plant growth to respective shade factor. Percent biomass data were subjected to a two-way analysis of variance (ANOVA) to determine if there was interaction between trials. Because there were no differences between trials, data were pooled and a *post hoc* test (Student's t test) was conducted to determine significant differences among treatments ($P < 0.05$).

RESULTS AND DISCUSSION

At 7 WAT, no differences were detected among the six herbicide treatments evaluated under full sunlight conditions, as all treatments reduced giant salvinia biomass 87 to 100% of the nontreated controls (Figure 1). Prior mesocosm research conducted under full sunlight conditions demonstrated diquat (1,120 g a.i. ha^{-1}), carfentrazone (112 g a.i. ha^{-1}), and metsulfuron (42 g a.i. ha^{-1}) provided 97 to 100% control of giant salvinia (Nelson et al. 2001, Glomski and Getsinger 2006, Richardson et al. 2008, Mudge et al. 2016, Prevost et al. 2021), whereas penoxsulam provided only 57% control under the same conditions. Under greenhouse conditions, flumioxazin (437 g a.i. ha^{-1}) provided 98% control (Richardson et al. 2008).

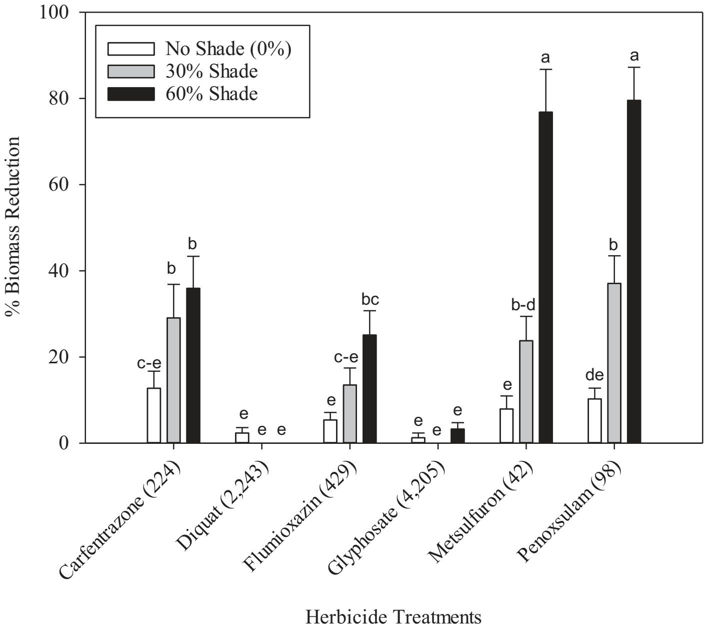

Figure 1. Influence of shade on the efficacy of six aquatic herbicides applied to the foliage of giant salvinia 7 wk after treatment in a mesocosm setting. Biomass data within each shade treatment were converted to % of control at each respective shade level. Numbers behind herbicide treatments represent rates as grams of active ingredient (a.i.) ha^{-1}, except glyphosate [g acid equivalent (a.e.) ha^{-1}]. Treatments with the same letter are not different based on Student's *t* test ($\alpha = 0.05$; $n = 10$).

There were no negative impacts of the 60% shade regime on the ability of glyphosate and diquat to control giant salvinia, as both treatments provided 97 and 100% control, respectively (Figure 1). These data show that neither diquat nor glyphosate efficacy was significantly influenced by shading; as no difference was detected among the shaded treatments, either herbicide could be used in aquatic systems that are heavily shaded. Previous research found that when glyphosate was used to manage the terrestrial weed purple bush-bean [*Macroptilium atropurpureum* (DC.) Urb] control was improved under shaded conditions compared to full sunlight (Costa et al. 2020). Similarly, Moosavi-Nia and Dore (1979) demonstrated increased glyphosate efficacy when cogon grass (*Imperata cylindrica* L.) and purple nutsedge (*Cyperus rotundus* L.) was grown under 50 and 75% shade.

Flumioxazin provided similar control when applied to plants growing under the 0 and 30% shade regimes, but control decreased under the 60% shade treatment. However, the activity of the other PPO-inhibitor carfentrazone was reduced by 16 and 24% (30 and 60% shade cloths, respectively) compared to the full-sunlight treatment. The reduced activity of flumioxazin and carfentrazone was not surprising, because PPO-inhibiting herbicides require full sunlight for optimal activity (Sherman et al. 1991, Wright et al. 1995). Growth-chamber research conducted by Mudge et al. (2012) demonstrated that as light intensity decreased from 400 to 20 $\mu mol\ m^{-2}\ s^{-1}$, the amount of time required by flumioxazin to reduce photosynthesis of hydrilla by 50% (ET_{50}) increased from 99 to 303 h (i.e., herbicide activity decreased). The average amount of light recorded under the 60% shade cloth was 750 $\mu mol\ m^{-2}\ s^{-1}$, which is almost double the amount of light that was tested in the hydrilla growth chamber trial (Mudge et al. 2012).

For plants exposed to metsulfuron under the various light regimes, there were negative impacts associated with reducing light levels with biomass reduction being 92, 76, and 23% for plants grown under 0, 30, and 60% shade levels, respectively (Figure 1). Similarly, penoxsulam- and metsulfuron-treated plants responded similarly with 90 to 20% biomass reductions at analogous light treatments. These data indicate slow-acting ALS-inhibiting herbicides like metsulfuron and penoxsulam do still maintain herbicidal activity under low light levels. The question remains if the metsulfuron and penoxsulam treated plants cultured under the 30 or 60% shade regime would have provided better control if the trial had been extended beyond 7 wk. Research by Mudge et al. (2012) and Prevost et al. (2021) demonstrated penoxsulam and metsulfuron required 8 and 11 WAT to provide control, respectively. Therefore, future research should consider evaluating these two ALS-inhibiting herbicides for longer periods of time under reduced light levels to determine if control could be improved beyond a 7-wk time frame. Further, this research should be conducted in field conditions where giant salvinia has been found thriving under dense vegetation producing similar shading levels evaluated in the present study. Another way to eliminate or decrease the impact of low light limitations is to apply herbicides during the late fall, winter, or early spring when tree leaves are absent and higher light levels can reach the water's surface. Prior mesocosm research demonstrated giant salvinia control can be achieved during the fall and winter by several herbicides (stand-alone and combination treatments) under full sunlight and when plant growth is slower (Mudge et al. 2016, Mudge and Sartain 2018, Sartain and Mudge 2019).

In conclusion, this research provides evidence that reduced light intensity can negatively influence herbicidal activity (particularly ALS and PPO inhibitors) on giant salvinia. Management of aquatic plants often occurs under conditions where light is limited by environmental (e.g., tree shading, cloudy days, and tropical storms) and artificial (e.g., bridge) shading conditions. Herbicide selection is key to overcoming these challenges when targeting giant salvinia in low-light management scenarios. Therefore, managers wishing to treat giant salvinia plant populations growing under heavy shade should consider herbicides that are less influenced by light quantity (e.g., glyphosate and diquat) over slow-acting, light-influenced herbicides (e.g., ALS and PPO inhibitors), or utilize higher rates and tank mixes.

SOURCES OF MATERIALS

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

[2]LI-250A, LI-COR, Inc., 4647 Superior St., Lincoln, NE 68504.

[3]Stingray®, SePRO Corporation, 11550 N. Meridian St., Suite 600, Carmel, IN 46032.

[4]Reward®, Syngenta Crop Protection LLC, P.O. Box 18300, Greensboro, NC 27419.

[5]Clipper®, Valent U.S.A. Corporation, P.O. Box 8025, Walnut Creek, CA 94596.

[6]Roundup Custom™, Bayer CropScience LP, P.O. Box 12014, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709.

[7]Cimarron® Max Part A Herbicide. FIFRA Section 24(c) Special Local Need Label. Bayer CropScience LP, P.O. Box 12014, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709.

[8]Galleon™ SC, SePRO Corporation, 11550 N. Meridian St., Suite 600, Carmel, IN 46032.

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

[10]Alligare Surface™, Alligare, LLC, 13 N. 8th Street, Opelika, AL 36801.

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LITERATURE CITED

Costa GA, Tuffi-Santos LD, dos Santos SA, da Cruz LR, Sant'Anna-Santos BF, dos Santos IT, Tanaka FAO. 2020. Efficiency of glyphosate and carfentrazone-ethyl in the control of *Macroptilium atropurpureum* (DC.) Urb. under different light intensities. S. Afr. J. Bot. 131:302–309.

Cozad LA, Mudge CR, Diaz R. 2019. Integrated management of giant salvinia using herbicides and the salvinia weevil. J. Aquat. Plant Manage. 57:62–68.

Creagh C. 1991/1992. A marauding weed in check. Ecos 70:26–29.

Duke SO, Lydon J, Becerril JM, Sherman TD, Lehnen Jr. LP, Matsumoto H. 1991. Protoporphyrinogen oxidase–inhibiting herbicides. Weed Sci. 39:465–473.

Glomski LM, Getsinger KD. 2006. Carfentrazone-ethyl for control of giant salvinia. J. Aquat. Plant Manage. 44:136–138.

Hess FD. 2000. Light-dependent herbicides: An overview. Weed Sci. 48:160–170.

Jacono C. 1999. *Salvinia molesta* (D.S. Mitchell) invades the United States. Aquatics 21(1):4–9.

Jacono C, Pitman B. 2001. *Salvinia molesta*: Around the world in 70 years. Aquat. Nuisance Species Dig. 4:14–16.

Johnson S, Sanders D, Eisenberg L, Whitehead K. 2010. Fighting the Blob: Efforts to control giant salvinia. La. Agric. 53(1):6–9.

Lambers H, Chapin FS III, Pons TL. 1998. Plant physiological ecology. Springer-Verlag, New York. pp. 317–320.

Mateos-Naranjo E, Redondo-Gómez S, Cox L, Cornejo J, Figueroa ME. 2009. Effectiveness of glyphosate and imazamox on the control of the invasive cordgrass *Spartina densiflora*. Ecotoxicol. Environ. Saf. 72(6):1694–1700.

McFarland DG, Nelson LS, Grodowitz MJ, Smart RM, Owens CS. 2004. *Salvinia molesta* DS Mitchell (giant salvinia) in the United States: A review of species ecology and approaches to management. ERDC/EL SR-04-2. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Mitchell DS. 1978. The distribution and spread of *Salvinia molesta* in Australia, pp. 321–326. In: Proceedings of the 1st Conf. Counc. Aust. Weed Sci. Soc., Melbourne, Australia.

Moosavi-Nia H, Dore J. 1979. Factors affecting glyphosate activity in *Imperata cylindrica* (L.) Beauv. and *Cyperus rotundus* L. II: Effect of shade. Weed Res. 19(5):321–327.

Mudge CR. 2016. Evaluation of topramezone and benzobicyclon for activity on giant salvinia. APCRP Technical Notes Collection. ERDC/TN APCRP-CC-21. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Mudge CR, Harms NE, Nachtrieb JG. 2013. Interactions of herbicides, surfactants, and the giant salvinia weevil (*Cyrtobagous salviniae*) for control of giant salvinia (*Salvinia molesta*). J. Aquat. Plant Manage. 51:77–83.

Mudge CR, Heilman MA, Theel HJ, Getsinger KD. 2012. Efficacy of subsurface and foliar penoxsulam and fluridone applications on giant salvinia. J. Aquat. Plant Manage. 50:116–124.

Mudge CR, Perret AJ, Winslow JR. 2016. Evaluation of foliar herbicide and surfactant combinations for control of giant salvinia at three application timings. J. Aquat. Plant Manage. 54:32–36.

Mudge CR, Sartain BT. 2018. Influence of winter on herbicide efficacy for control of giant salvinia (*Salvinia molesta*). J. Aquat. Plant Manage. 56:68–71.

Nelson LS. 2014. Giant and common salvinia, pp. 157–164. In: L. A. Gettys, W. T. Haller, M. Bellaud (eds.). Biology and control of aquatic plants: A best management practices handbook. 3rd ed. Aquatic Ecosystem Restoration Foundation, Marietta, GA.

Nelson LS, Skogerboe JG, Getsinger KD. 2001. Herbicide evaluation against giant salvinia. J. Aquat. Plant Manage. 39:48–53.

Owens C, Smart RM, Dick GO. 2011. Shade and depth effects on the growth of giant salvinia. APCRP Technical Notes Collection. ERDC/TN APCRP-EA-26. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Potgieter MJ, Vlok W, Mankga LT. 2023. The effect of different shade regimes on the growth of *Salvinia molesta*. https://www.researchgate.net/profile/Martin-Potgieter/publication/370890199_THE_EFFECT_OF_DIFFERENT_SHADE_REGIMES_ON_THE_GROWTH_OF_SALVINIA_MOLESTA/links/6467820f70202663165b448a/THE-EFFECT-OF-DIFFERENT-SHADE-REGIMES-ON-THE-GROWTH-OF-SALVINIA-MOLESTA.pdf. Accessed April 2, 2024.

Prevost W. 2019. Evaluation of metsulfuron-methyl for giant salvinia (*Salvinia molesta*) control and non-target species sensitivity. LSU master's thesis. https://digitalcommons.lsu.edu/gradschool_theses/5023. Accessed 13 April 2020.

Prevost WJ, Mudge CR, Fontenot KK, Strahan RE. 2021. Evaluation of foliar and subsurface applications of metsulfuron-methyl for control of giant salvinia. J. Aquat. Plant Manage. 59:14–19.

Richardson RJ, Roten RL, West AM, True SL, Gardner AP. 2008. Response of selected aquatic invasive weeds to flumioxazin and carfentrazone-ethyl. J. Aquat. Plant Manage. 46:154–158.

Sartain BT, Mudge CR. 2018. Effect of winter herbicide applications on bald cypress (*Taxodium distichum*) and giant salvinia (*Salvinia molesta*). Invasive Plant Sci. Manage. 11:136–142. DOI:10.1017/inp.2018.20.

Sartain BT, Mudge CR. 2019. The response of giant salvinia to foliar herbicide applications at three winter timings. J. Aquat. Plant Manage. 57:1–6.

Shaner DL 2014. Herbicide handbook. 10th ed. Weed Science Society of America, Lawrence, KS. 513 p.

Sherman TD, Becerril JM, Matsmoto H, Duke MV, Jacobs JM, Jacobs NJ, Duke SO. 1991. Physiological basis for differential sensitivities of plant species to protoporphyrinogen oxidase inhibitory herbicides. Plant Physiol. 97:280–287.

Siehl DL. 1997. Inhibitors of EPSP synthase, glutamine synthetase and histidine synthesis. Herbic. Act. Toxicol. Biochem. Mol. Biol. 1:37–68.

Thayer DD, Pfingsten IA, Jacono CC, Richerson MM, Howard V. 2018. *Salvinia molesta* Mitchell. Nonindigenous aquatic species database. U.S. Geological Survey, Gainesville, FL. https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=298. Accessed 16 November 2023.

Wright TR, Fuerst EP, Ogg AG, Handihall UB, Lee HJ. 1995. Herbicide activity of UCC-C4243 and acifluorfen is due to inhibition of protoporphyrinogen oxidase. Weed Sci. 43:47–54.