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Efficacy of Herbicide Active Ingredients against Aquatic Weeds[1]

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Weed control is a critical component of aquatic vegetation management in Florida waters. While physical, mechanical, and biological controls are utilized where they are feasible, herbicides are the primary tool used to control many troublesome species. This publication answers some common questions and provides efficacy information for all herbicide active ingredients labeled for aquatic use in Florida.

Do I need a license or permit to make an aquatic application?

Pesticide licenses and aquatic application permits are two separate issues. Regarding licensing, anyone who applies herbicides commercially or for a public agency should be licensed as a Restricted Use Pesticide (RUP) applicator. Information about RUP applicator training and licensing is available from your county Extension office or from the UF/IFAS Pesticide Information Office (https://pested.ifas.ufl.edu/). Individuals who choose to apply herbicides to their own ponds should learn about herbicide application and ecology through RUP certification training. However, in many instances, it is recommended that private pond owners employ a reputable aquatic plant management company to maintain their pond(s) through a service contract, especially if the pond has been neglected or is severely infested by difficult species.

Regarding permitting for aquatic applications, a permit from the Florida Fish and Wildlife Conservation Commission is required for control of weeds in public waters and waters with multiple ownership. Exemptions for some privately owned water bodies, allowances for specific shoreline weed control, and issues for Waters of Special Concern are described on the FWC aquatic plant permit website (https://myfwc.com/license/aquatic-plants/). The specific language provided in the Florida Administrative Code can be found at https://www.flrules.org/gateway/ChapterHome.asp?Chapter=68F-20.

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Are there any water use restrictions after an herbicide application?

Label instructions for aquatic applications may restrict the use of water for a given period for various purposes (e.g., irrigation, mixing agricultural sprays, domestic use, swimming, fishing, watering livestock, or consuming fish from treated water). Herbicide labels list these potential restrictions clearly; these should be consulted before the product is used.

Can I use an herbicide to control an aquatic plant not listed on the label?

It is legal to use an herbicide to attempt to control a plant species that is not listed on the label **as long as the product is labeled for use on the site**. Registrants, those companies responsible for the herbicide label, are not required to list all possible species on a label that are susceptible to a given herbicide. In many cases, they only list the most commonly managed plants. Registrants are not liable if an end user attempts to use a product to control a plant not on the label and the product does not work.

How is herbicide efficacy (weed control) defined in this publication?

Efficacy is not defined as a silver bullet (i.e., where one treatment completely eradicates the target weed). Efficacy is typically defined as a substantial reduction of the target plant that results in a diminishment of its negative effects on the system. There is also a time element involved. In aquatics, this is typically within the range of a few weeks to a few months for free-floating plants and algae, to a single growing season or entire year for many submersed and emergent plants. Tables 1 through 3 use the following codes: NR=Not recommended; F=Fair; G=Good; E=Excellent. Blank cells indicate insufficient data. The NR code is assigned where a given treatment will not provide any meaningful control of a target plant. The F code is assigned where some control occurs following treatment, but it may be inconsistent or short-lived. The G code is assigned where commercially acceptable control is generally achieved. The length of control may still vary by species. The E code is assigned where the target plant is highly sensitive to the herbicide and greater than 90% control is expected. An E code does not guarantee eradication, which is the elimination of all living parts of the plant that may include seeds, shoots, roots, rhizomes, stolons, and spores. Eradication is often exceedingly difficult, if not impossible, to achieve for many species.

Should I apply herbicide to the foliage of plants or just treat the water?

All herbicides are different, and the labels need to be reviewed before purchasing or applying a product. For example, glyphosate and imazapyr only control weeds by foliar applications and do not work if applied to the water. Several other herbicides may be applied to the water to control submersed weeds but need to be applied to the foliage to be effective on emergent, floating, or floating-leaved plants. Diquat is a good example of this. It is very effective against water lettuce when applied as a foliar spray, but it is not effective if applied to the water as a whole pond treatment. Several other herbicides can have both in-water and foliar uses, but effective control depends greatly on the application method and the target species. Typically, granular or pelleted formulations are not effective for free-floating or emergent plant control. Applicators must read the herbicide labels to select the most effective herbicide, the correct formulation, and the appropriate application strategy.

Where can I find herbicide labels online?

Herbicide product labels can be obtained from Crop Data Management Systems, Inc. (http://www.cdms.net), http://www.greenbook.net, manufacturer representatives, or manufacturer websites. Additionally, the Florida Department of Agriculture and Consumer Services (FDACS) Division of Agricultural Environmental Services maintains a reference list with the active ingredients of all pesticide products registered for use in Florida. Specific product information should be obtained from the product label. Label instructions must be followed for any herbicide application.

Which herbicides can be used in aquatic environments?

Only those herbicide products that are registered and labeled for application directly to water by the US Environmental Protection Agency (EPA) and FDACS may be used in Florida to control weeds growing in water. Active ingredients that are contained in aquatic herbicide products

may also be present in products that are not approved for aquatic uses. However, it is not legal to apply an herbicide directly to water unless the herbicide label has specific instructions for application to water. Tables 1 through 4 list all herbicide active ingredients labeled to date for use in Florida.

Tables 1, 2, and 3 show the effectiveness of herbicide active ingredients for control of common aquatic weeds. Table 3 is specific to troublesome aquatic grasses. Table 4 addresses algae control. The tables are a species by herbicide matrix of known efficacy. Tables 1 lists all herbicides classified as fast-acting, which are also generally referred to as contact herbicides. Tables 2a and 2b list all herbicides that are classified as slow-acting, systemic herbicides. The species are grouped according to growth form (free-floating, floating-leaved, submersed, emergent, and algae). The herbicides are grouped by mode of action according to the Weed Science Society of America's classification system and the Herbicide Resistance Action Committee codes.

Sensitivity of the target weed to the active ingredient is only one consideration in choosing the appropriate herbicide product. Other factors that may be important in such a decision include water uses, other plant species present, toxicity to fish and other organisms, and additives in individual products. These considerations and other important aspects of aquatic weed control are discussed more fully in the *Aquatic Pest Control Training Manual*, which is available from the UF/IFAS Extension Bookstore (http://ifasbooks.ifas.ufl.edu/).

Specific Notes on Free-Floating Plant Control

As the name implies, many free-floating plants move around with wind or water currents. One strategy is to treat after wind has consolidated plants in one area. This does not always work, however, as wind may push free-floating plants back into stands of emergent vegetation where treatment becomes more difficult. Many free-floating plants can also survive along the shoreline in muddy conditions for a short time. Another consideration is the incredible growth rate exhibited by many free-floating plants. Many plant populations can double in size in a few weeks. This warrants aggressive treatment when populations are small to prevent the species from covering the entire pond. Many fast-acting systemic herbicides are effective on free-floating plants. Additionally, surfactants often improve herbicide control of many free-floating plants.

Specific Notes on Floating-Leaved Plant Control

Floating-leaved plants, which anchor into the sediment and have leaves that remain at or near the water surface, can be difficult to control. Minimal wave action can easily wash foliar herbicide treatments off the leaf surface. Crested floating heart and watershield are good examples of this issue. Systemic herbicides are generally recommended for floating-leaved plant control. Surfactants often improve control of many floating-leaved plants.

Specific Notes on Submersed Plant Control

For submersed plants, the applicator treats the water column and not the plants directly. The herbicide is applied to the water and quickly spreads throughout the water column, where it reaches an equilibrium concentration. Submersed treatments are recommended on a concentration basis in parts per million (ppm) or parts per billion (ppb) by weight, or amount of product per acre-foot of water. Additionally, herbicides used in these applications require a specific minimum exposure time to be effective. Exposure time requirements can range from hours to months depending on the herbicide, target concentration, and target plant. Given the greater expense and potential for failure of submersed treatments, it is best to seek the advice of an aquatic specialist prior to implementing a treatment.

Specific Notes on Emergent Plant Control

Emergent plants root in the sediment, grow up through the water column, and emerge above the water surface. This strategy of "living in two worlds" often makes these plants more difficult to control. Most emergent plants are treated with a foliar treatment that targets growth above water. The ratio of the above-water to below-water biomass can greatly affect herbicide efficacy. Control is more difficult when below-water biomass is high. Cattail and Uruguayan water primrose are two examples of this issue, as most of their total biomass is often below water. Systemic herbicides are almost always recommended for emergent plant control. Many contact herbicides may only injure emergent plant foliage. The plants tend to recover quickly under good growing conditions. Surfactants almost always improve herbicide efficacy on emergent plants.

Specific Notes on Emergent Grass Control

Only three post-emergent foliar herbicides provide any meaningful emergent grass control. These include glyphosate, imazapyr, and sethoxydim (Table 3). Glyphosate is non-selective and has little to no in-water activity. It provides complete control of emergent growth with some below-water (stolon) and rhizome control. Length of control varies among species, but regrowth is common and retreatment is generally necessary. Imazapyr is also non-selective and has little to no in-water activity due to rapid degradation. However, imazapyr is highly soil active, and this can greatly improve long-term control when applied to species in seasonally dry areas. Imazapyr is slow to work but provides the most effective control of below-water stolons and rhizomes. Due to its soil activity, caution is needed when using imazapyr around desirable trees, shrubs, or forbs. Sethoxydim is a selective herbicide that only controls grasses. It provides some control and suppression of emergent grasses but is not as effective as glyphosate or imazapyr. Its selectivity confers a distinct advantage when desirable species are present. It has no in-water or soil activity. The most effective strategy for its use is to treat, and then apply a second treatment 14 days after the first but before the treated plants have senesced. The optimal timing for treatment is in the late spring (near the end of the dry season) when plants are actively growing but just before water levels increase with the summer rains. Treating just before water levels rise can improve control. However, this only works if treatments are made before water levels rise.

Specific Notes on Algae Control

It is best to implement algae control measures before problems become severe. This is especially true for filamentous algae, which break free from the sediment and form extensive surface mats. Algae often respond positively to high nutrient levels, especially phosphorus. Incorporating best management practices to prevent nutrient runoff into ponds is one of the best long-term strategies for algae management. Copper products are often used to control algae. However, copper toxicity to fish can be a serious issue and is driven by water alkalinity. Copper toxicity is a much greater threat to fish in low-alkaline waters than in high-alkaline waters. An additional option for many ponds is the use of a pond dye. Pond dyes have no algicidal activity. Instead, they reduce light penetration into the water column. They tend to work best in a preventative manner when used early in the season before algal growth becomes excessive. However, pond dyes may also reduce growth of desirable phytoplankton, which can in turn negatively influence pond productivity up the food chain.

Table 1. Effectiveness of fast-acting herbicides for aquatic weed control.[1,2] Contact: sfenloe@ufl.edu or learyj@ufl.edu. This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (https://sfyl.ifas.ufl.edu/find-your-local-office/).

	Carfentrazone	Copper	Diquat	Endothall (amine)	Endothall (dipotassium)	Flumioxazin
Free-Floating						
Duckweed(s) (*Lemna* sp., *Spirodela* sp.)	NR	NR	G–E	NR	NR	E
Frog's bit (*Limnobium spongia*)	NR	NR	E	NR	NR	G
Giant salvinia (*Salvinia molesta*)	G	NR	G	NR	NR	G
Mosquito fern (*Azolla filiculoides*)	E	NR	E	NR	NR	G
Water fern (*Salvinia minima*)	E	NR	E	NR	NR	E
Water hyacinth (*Eichhornia crassipes*)	F	F	E	NR	NR	NR
Water lettuce (*Pistia stratiotes*)	G	F	E	NR	NR	E
Watermeal (*Wolffia columbiana*)	F	NR	NR	NR	NR	G–E
Floating-Leaved						
Crested floating heart (*Nymphoides cristata*)	NR	NR	F	E	E	NR
Watershield (*Brasenia schreberi*)	NR	NR	NR	NR	NR	G
Spadderdock (*Nuphar advena*)	NR	NR	NR	NR	NR	F
American lotus (*Nelumbo lutea*)	NR	NR	NR	NR	NR	NR
Water lilies (*Nymphaea* sp.)	NR	NR	NR	NR	NR	F
Submersed						
Bladderwort (*Utricularia* sp.)	NR	NR	G	F	F	G
Coontail (*Ceratophyllum demersum*)	NR	NR	E	E	E	F
Fanwort (*Cabomba caroliniana*)	NR	NR	F	F	F	G
Hydrilla (*Hydrilla verticillata*)	NR	G	F–G[3]	E	E	G
East Indian hygrophila (*Hygrophila polysperma*)	NR	NR	NR	NR	F	G
Pondweed(s) (*Potamogeton* sp.)	NR	G	G	E	E	G
Proliferating spikerush (*Eleocharis baldwinii*)	NR	NR	NR	NR	NR	NR
Slender naiad (*Najas flexilis*)	NR	G	E	E	E	
Southern naiad (*Najas guadalupensis*)	NR	G	E	G	G	F
Tape grass (*Vallisneria americana*)				G		
Water milfoils (*Myriophyllum* sp.)	NR	NR	G	G	G	F

	Carfentrazone	Copper	Diquat	Endothall (amine)	Endothall (dipotassium)	Flumioxazin
Emergent						
Alligatorweed (*Alternanthera philoxeroides*)	NR	NR	NR	NR	NR	F
Cattail (*Typha* sp.)	NR	NR	F	NR	NR	NR
Dwarf rotala (*Rotala rotundifolia*)	NR	NR	G	NR	NR	NR
Elephant ear (*Xanthosoma sagittifolium*)	NR	NR	NR	NR	NR	NR
Parrotfeather (*Myriophyllum aquaticum*)	NR	NR	G	NR	NR	NR
Peruvian water primrose (*Ludwigia peruviana*)	NR	NR	NR	NR	NR	NR
Smartweed (*Polygonum* spp.)	NR	NR	F	NR	NR	NR
Soft rush (*Juncus effusus*)	NR	NR	NR	NR	NR	NR
Uruguayan water primrose (*Ludwigia hexapetala*)	NR	NR	NR	NR	NR	NR
Water pennywort (*Hydrocotyl* spp.)	NR	NR	F	NR	NR	F
Wild taro (*Colocasia esculenta*)	NR	NR	NR	NR	NR	NR
Willows (*Salix* sp.)	NR	NR	NR	NR	NR	NR

[1] In general, these herbicides kill plant tissue on contact, so coverage of the weed is important for foliar applications. These herbicides are often not effective for control of plants that have extensive vegetative reproduction from lateral roots, rhizomes, or stolons.
[2] NR=Not recommended; F=Fair; G=Good; E=Excellent. Blank cells indicate insufficient data.
[3] Hydrilla control with diquat alone is now somewhat more variable due to recently decreased maximum label use rates.

Table 2a. Effectiveness of slow-acting herbicides for aquatic weed control (synthetic auxin and pigment biosynthesis inhibitors).[1] Contact: sfenloe@ufl.edu or learyj@ufl.edu. This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (https://sfyl.ifas.ufl.edu/find-your-local-office/).

	2,4-D (granular)	2,4-D (liquid)	Florpyrauxifen-benzyl	Triclopyr	Fluridone	Topramezone
Free-Floating						
Duckweed(s) (*Lemna, Spirodela* spp.)	NR	F	NR	NR	E	NR
Frog's bit (*Limnobium spongia*)	NR	NR		F	NR	
Giant salvinia (*Salvinia molesta*)	NR	NR	NR	NR	E	F
Mosquito fern (*Azolla filiculoides*)	NR	NR	G	NR	E	
Water fern (*Salvinia minima*)	NR	NR	NR	NR	E	F
Water hyacinth (*Eichhornia crassipes*)	NR	E	G	E	NR	G
Water lettuce (*Pistia stratiotes*)	NR	NR	NR	NR	NR	G
Watermeal (*Wolffia columbiana*)	NR	NR	NR	NR	F	
Floating-Leaved						
Crested floating heart (*Nymphoides cristata*)	NR	NR	G	NR	NR	
Watershield (*Brasenia schreberi*)	NR	G	G	NR	F	
Spatterdock (*Nuphar advena*)	E	G–E	F	F	G	
American lotus (*Nelumbo lutea*)	G	G	E	E	NR	F
Water lilies (*Nymphaea* sp.)	E	G–E	E	G	G	
Submersed						
Bladderwort (*Utricularia* sp.)	F	F	F	NR	G	F
Coontail (*Ceratophyllum demersum*)	F	G	F	F	E	NR
Fanwort (*Cabomba caroliniana*)	NR	NR	F	NR	F	
Hydrilla (*Hydrilla verticillata*)	NR	NR	E	NR	E	G
East Indian hygrophila (*Hygrophila polysperma*)	NR	NR		NR	NR	NR
Pondweed(s) (*Potamogeton* sp.)	NR	NR	P–F	NR	F[3]	E

	2,4-D (granular)	2,4-D (liquid)	Florpyrauxifen-benzyl	Triclopyr	Fluridone	Topramezone
Proliferating spikerush (*Eleocharis baldwinii*)	NR	NR	G	NR	F	
Slender naiad (*Najas flexilis*)	NR	NR		NR	E	F
Southern naiad (*Najas guadalupensis*)	NR	NR		NR	G	F
Tape grass (*Vallisneria americana*)	NR	NR	NR	NR	F	
Water milfoils (*Myriophyllum* spp.)	E	E	E	E	E	F
Emergent						
Alligatorweed (*Alternanthera philoxeroides*)	NR	F	E	G	NR	
Cattail (*Typha* sp.)	NR	NR	NR	NR	F	
Dwarf rotala (*Rotala rotundifolia*)	E	E	E	E	NR	NR
Elephant ear (*Xanthosoma sagittifolium*)	NR	NR	E	G	NR	
Parrotfeather (*Myriophyllum aquaticum*)	F	E	G	G	F	
Peruvian water primrose (*Ludwigia peruviana*)	NR	F	NR	G	NR	
Smartweed(s) (*Polygonum* sp.)	NR	F	G	G		
Soft rush (*Juncus effusus*)	F	F	NR	NR	NR	
Uruguayan water primrose (*Ludwigia hexapetala*)	NR	F	G	F	NR	
Water pennywort (*Hydrocotyl* sp.)	G	G		G	NR	
Wild taro (*Colocasia esculenta*)	NR	NR		G	NR	
Willows (*Salix* sp.)	NR	NR		G	NR	

[1] NR=Not recommended; F=Fair; G=Good; E=Excellent. Blank cells indicate insufficient data.

Table 2b. Effectiveness of slow-acting herbicides for aquatic weed control (amino acid biosynthesis inhibitors).[1] Contact: sfenloe@ufl.edu or learyj@ufl.edu. This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (https://sfyl.ifas.ufl.edu/find-your-local-office/).

	Bispyribac	Glyphosate	Imazapyr	Imazamox	Penoxsulam
Free-Floating					
Duckweed(s) (*Lemna, Spirodela* spp.)	G	NR	NR	NR	E
Frog's bit (*Limnobium spongia*)		NR	E	E	E
Giant salvinia (*Salvinia molesta*)	F	E	NR	NR	E
Mosquito fern (*Azolla filiculoides*)	G	NR	NR	NR	E
Water fern (*Salvinia minima*)	G	NR	NR	NR	E
Water hyacinth (*Eichhornia crassipes*)	G	G	E	E	E
Water lettuce (*Pistia stratiotes*)	G	F	E	G	E
Watermeal (*Wolffia columbiana*)		NR	NR	NR	G
Floating-Leaved					
Crested floating heart (*Nymphoides cristata*)			NR	G	
Watershield (*Brasenia schreberi*)		G	E	G	NR
Spatterdock (*Nuphar advena*)		E	E	E	NR
American lotus (*Nelumbo lutea*)		G	E	E	NR
Water lilies (*Nymphaea* sp.)		E	E	E	NR
Submersed					
Bladderwort (*Utricularia* sp.)		NR	NR	NR	F
Coontail (*Ceratophyllum demersum*)		NR	NR	NR	NR
Fanwort (*Cabomba caroliniana*)		NR	NR		

	Bispyribac	Glyphosate	Imazapyr	Imazamox	Penoxsulam
Hydrilla (*Hydrilla verticillata*)	E	NR	NR	G	E
East Indian hygrophila (*Hygrophila polysperma*)	NR	NR	NR	NR	NR
Pondweed(s) (*Potamogeton* sp.)	G	NR	NR	G	E
Proliferating spikerush (*Eleocharis baldwinii*)		NR	NR	NR	F
Slender naiad (*Najas flexilis*)		NR	NR	NR	F
Southern naiad (*Najas guadalupensis*)		NR	NR	NR	E
Tape grass (*Vallisneria americana*)		NR	NR		
Water milfoils (*Myriophyllum* spp.)	G	NR	NR		
Emergent					
Alligatorweed (*Alternanthera philoxeroides*)	G	G	E	E	F
Cattail (*Typha* sp.)		E	E	E	NR
Dwarf rotala (*Rotala rotundifolia*)	NR	NR	NR	NR	NR
Elephant ear (*Xanthosoma sagittifolium*)			E	E	NR
Parrotfeather (*Myriophyllum aquaticum*)	G	NR	E	F	G
Peruvian water primrose (*Ludwigia peruviana*)		G	E	G	NR
Smartweed(s) (*Polygonum* sp.)		G	G	G	
Soft rush (*Juncus effusus*)		G	E	NR	NR
Uruguayan water primrose (*Ludwigia hexapetala*)		G	E	G	NR
Water pennywort (*Hydrocotyl* sp.)	G	E	E	E	E
Wild taro (*Colocasia esculenta*)			E	E	NR
Willows (*Salix* sp.)		G	E	G	NR

[1] NR=Not recommended; F=Fair; G=Good; E=Excellent. Blank cells indicate insufficient data.

Table 3. Efficacy of select herbicides for foliar treatment of emergent grasses.[1] Contact: sfenloe@ufl.edu or learyj@ufl.edu. This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (https://sfyl.ifas.ufl.edu/find-your-local-office/).

	Glyphosate	Imazapyr	Sethoxydim[2]
Paragrass (*Urochloa mutica*)	G	E	F
Common reed (*Phragmites australis*)	G	E	NR
Torpedograss (*Panicum repens*)	G	E	F
Tropical American watergrass (*Luziola subintegra*)	G	E	F
West Indian marsh grass (*Hymenachne amplexicaulis*)	G	E	G

[1] NR = Not recommended; F = Fair; G = Good; E = Excellent.
[2] Sequential applications 14 days after initial treatment generally provide better control of most emergent grasses.

Table 4. Effectiveness of contact herbicides for algae control.[1] Currently, there are no systemic herbicides labeled for algae control. Contact: sfenloe@ufl.edu or learyj@ufl.edu. This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (https://sfyl.ifas.ufl.edu/find-your-local-office/).

	Copper	Hydrogen Peroxide	Diquat	Copper + Diquat	Endothall (amine)	Flumioxazin
Algae						
Macrophytic	F	NR	NR	G	F	NR
Filamentous	G	NR	F	G	G	G
Planktonic	G	G	NR	G	NR	NR

[1] NR=Not recommended; F=Fair; G=Good; E=Excellent. Blank cells indicate insufficient data.