Circular 1408

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Aquatic Weed Management in Citrus Canals and Ditches[1]

Brian Boman, Chris Wilson, Vernon Vandiver, Jr., and Jack Hebb[2]

Introduction

Aquatic plants are necessary for maintaining the balance of nature and offering food, protection, oxygen, and shelter to aquatic species. One reality of growing citrus in Florida flatwoods areas is that nearly every citrus grower will sooner or later experience aquatic weed control problems (Fig. 1).

Figure 1. Aquatic weeds in drainage ditch. Credits: B. Boman

Maintaining a balance in the aquatic system while sustaining crop success and avoiding loss of income can be a challenge. For example, over the long-term, the inefficiency of a clogged intake system on an irrigation pump can result in excessive fuel consumption and diminished water delivery to the trees. The consequences can be especially severe if clogging occurs during a freeze event when irrigation is being used for cold protection.

Over-abundant aquatic weed growth can also lower drainage rates following heavy rains, resulting in severe root pruning, increased disease incidence, and fruit drop. Therefore management of aquatic vegetation species should be an essential component

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2. Brian Boman, Associate Professor, Department of Agricultural and Biological Engineering; Chris Wilson, Assistant Professor, Soil and Water Science Department; respectively, Indian River REC-Ft. Pierce; Vernon Vandiver, Jr., Associate Professor, Agronomy Department, Ft. Lauderdale REC; and Jack Hebb, Multi-County Citrus Agent, St. Lucie County Extension Office. Cooperative Extension Service, Institute of Food and Agricultural Sciences, Gainesville, FL 32611.

of the overall water management strategy for most Flatwoods citrus groves.

Effects of Weeds on Ditch Flow

Aquatic vegetation in ditches and canals not only reduce the cross-sectional area of the channel, they also reduce the velocity of water flow. As a result, aquatic vegetation in waterways may dramatically increase the time required to drain a specific storm compared to clean ditches that allow free-flow of runoff water.

Figure 2 demonstrates the effects of aquatic weeds on water flow. The data in the graph were calculated using the Manning Equation, the most commonly used equation for open channel flow calculations. The Manning Equation was developed for uniform steady state flow, and can be used for any type of cross-section (i.e. circular, trapezoidal, square, etc.). Uniform flow means that the channel has constant dimensions (including depth) along its length. Steady state means the flow rate and velocity are constant with time. In reality, no flow can be uniform and steady. However, for practical purposes the equation typically results in good estimates of water flow in canals and ditches. The Manning Equation can be written as:

$$v = K/n\ R^{2/3}\ S^{1/2}$$

where,

v = Velocity (ft/s)

K = 1.486 (for English units)

R = Hydraulic radius (ft) = A/P_w

A = Cross-sectional area of flow (ft^2)

P_w = Wetted perimeter (ft)

S = Channel slope

n = Manning's Roughness Coefficient

P_w is the length of the canal cross-sectional area that is in contact with water. For example, a square channel with a width of 10 ft and a water depth of 4 ft will have a P_w of 18 ft. The Manning's Roughness Coefficient (n) varies with the ditchbank material and the condition of that material. Some common roughness values are given in Table 1.

Table 1. Typical Manning's Roughness Coefficients for common ditch and canal conditions.

Material/Condition	Manning N value
Smooth concrete	0.012
Corrugated pipe	0.025
Smooth soil	0.03
Cultivated soil	0.04
Sluggish flow with high plant growth	0.065
Very sluggish flow with high plant growth	0.112

For Figure 2, the effects of aquatic vegetation on runoff time were calculated for various depths of runoff from a 128-acre grove through a ditch 1 mile long with 12 ft bottom width, 4.5 ft depth of water, and 0.1 ft per 1000 ft slope. Calculations were made for a clean ditch (no aquatic vegetation), for a sluggish-flow with high plant growth ditch, and for a ditch that was greatly impaired with aquatic weeds, resulting in very sluggish flow (Manning's Roughness Coefficient values of 0.03, 0.065, and 0.112, respectively).

The calculations show runoff times for a 3-inch event increasing from about 6 hours for a clean ditch to nearly 23 hours for the severe aquatic weed condition. For small rainfall events, the increase in drainage time will probably have insignificant effects on tree health and pumping costs. However, the increased drainage times resulting from clogged ditches during major rain events is likely to increase potential for waterlogging and root damage in addition to increasing drain-out periods 200-400%.

Cultural Control Measures

Drawdown

Draining water from ditches and allowing them to dry out can be an effective method for controlling aquatic vegetation. Water removal from ditches is an old reliable concept, practiced for years to kill aquatic plants. However, there are some species that can

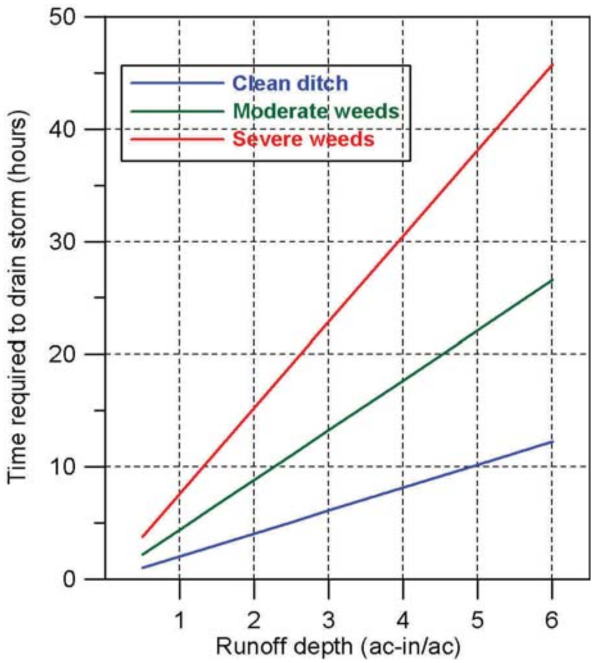

Figure 2. Effects of aquatic vegetation on the time required to drain various depths of runofffrom a 128-acre grove through a ditch 1 mile long with 12 ft bottom width, 4.5 ft depth of water, and 0.1 ft per 1000 ft slope.

withstand periods without water. In order to obtain good aquatic weed control, usually drawdown needs to be accompanied by the application of a herbicide. With organic farming, the use of conventional herbicides cancels certification standards, even in bordering ditches. Therefore organic growers must use mechanical means in conjunction with drawdown to remove vegetation.

Screening

Application of catch-screens in ditches is another concept that has been effective in some cases for vegetative control. This concept is popular with pumping systems that move massive amounts of water and materials into waterways. This technique allows plant material to be screened along the waterway before entering the intake pipes. As more restrictive measures become adopted by water management districts concerning aquatic weed discharges, it may become necessary to adopt screening procedures for the growers in those districts.

Debris baffles (Figure 3) on outfall structures reduce offsite discharges of floating aquatic vegetation into the primary canal system. The debris baffle, attached to the outfall structure, prevents floating debris from passing through the outfall culvert. The requirements to retrofit baffles on existing outfall structures are site specific. The baffle creates the potential for additional elevated water stages upstream of the structure if aquatic weeds are allowed to build up and restrict flow. Accumulated debris should be removed periodically to ensure free flow through the structure. Debris baffles should be used in conjunction with other aquatic weed control strategies.

Figure 3. Debris baffle installed on canal culverts. Credits: P. Whalen

Ribbon barriers (Figure 4) installed upstream of outfall structures reduce offsite discharges of floating aquatic vegetation into the primary canal system. Under typical low flow conditions, a barrier with an 18-inch skirt is recommended. If high flow conditions are typically experienced, a barrier with a 30-inch skirt is recommended. Ribbon barriers are most effective when attached to the bank and allowed to move vertically according to canal stage levels. Ribbon barriers should be utilized in conjunction with chemical or biological aquatic weed control programs.

Water hyacinths are floating aquatic plant species that grow to a height ranging from several inches to two feet. The plants are characterized by smooth leaves attached to a spongy bulb-shaped stalk. Reproduction is primarily through the production of daughter plants.

Hyacinth barriers (Figure 5) should be installed upstream of outfall structures to reduce discharges of water hyacinths into off-farm ditches and canals. Hyacinth barriers are not suitable for all sites, and

Figure 4. Ribbon barrier installed on canal. Credits: P. Whalen

should only be installed in ditches or canals with low flow potentials. Hyacinth barriers should be installed in combination with an aquatic weed removal program.

Figure 5. Hyacinth barrier installation. Credits: P. Whalen

Excavation

Excavation is perhaps one of the oldest and still most preferred methods of aquatic weed control (Figure 6). Usually, the process is done in one of two ways: either by a screen rake, which removes only the vegetation from the top of the water, or by earth removal, which allows for bottom weed, top weed, and ditch bank weed removal. Weeds chopped along canal banks with a disc or mower can wash back into the waterway, thus recreating the weed problem.

Removal of floating and submerged aquatic weeds can be accomplished using different types of equipment such as cranes, track-hoes, back-hoes, etc., depending on the location and the situation. Weeds should be removed and placed on the upper ditch

Figure 6. Mechanical aquatic weed removal from canal. Credits: P. Whalen

slope so that drainage will be directed away from the bank and slope. Oftentimes, significant amounts of sediment are removed from ditch bottoms during the process. Care should be taken to place fragmented vegetatively-propagated weeds (i.e. water hyacinth and hydrilla) away from the slopes because of their ability to re-establish themselves within the canal or ditch within a relatively short period of time.

Aquatic weeds should not be chopped along the canal bank with a disc, but rather within the grove site with a blade mower. Aquatic weeds chopped along canal banks with a chopper disc or mower have a tendency to wash back into the waterway, thus enhancing or exacerbating the weed problem. Weeds chopped along ditch banks also have the tendency to wash down the slope with rainfall, enter the drain pipes, and reenter the waterway. The same is also true for sediment or earth removal from canals. Until grass is re-established, sediments will move (with rainfall or dredging operations) down the slope, into the drains, and back into the canal.

Harvesting

Harvesting is a method accomplished by both dry and wet operations of equipment. Usually in dig operations, the aquatic environment is allowed to dry and then specially adapted machines cut the vegetation by sickle-bar or blade; the product is then removed and loaded onto platforms. These loaders remove the product off-site to other locations, such as pastures or other areas for livestock, or to be chopped.

The wet harvesting operation is similar to the dig in respect to loaded material. However, the cutting machinery is usually in the form of a paddle-wheel boat or a floating combine. This type of operation can be quite intensive and expensive for control of aquatic weeds. Most of this type of work is done on larger areas of marsh or in lakes.

Biological Controls

One of the most important ingredients for control of localized infestations of pests is the use of natural predators. Most native species of aquatic weeds are under some type of control to prevent their proliferation. In contrast, most of the aquatic weed problems in Florida come from exotics or non-native species of plants that have had no native predators to keep them in check. As a result, they have proliferated in size and quantity in their aquatic environments.

Scientists have traveled to the origin (home country) of some of the exotic species to search for natural predators that limit the growth of these aquatic weeds. In some cases, this research has identified predators that have been capable of controlling the weed species. However, there are frequently problems with the predator's ability to adapt to the Florida environment and getting approval to release the potential control organisms into the enviornment. Most of the invasive aquatic plant species have not been adequately controlled using biological control alone.

Research continues on new species and strains of predators, pathogens, and parasites that have potential for controlling aquatic weed species. As new biological control methods are introduced, citrus growers are encouraged to incorporate their benefits as part of an overall aquatic weed control program.

Insects and Diseases

Some exotic plant species have been controlled by introduction of biological control agents. The alligator weed flea beetle (*Agasicles hygrophila*) was introduced into the United States from South America in 1964. This beetle has done a remarkable job of reducing the problems with alligator weed. In fact, alligator weed is not considered a major aquatic problem in most areas of the state.

Various biological control agents have been tested on water hyacinths throughout the years. Of these predator introductions, the most effective have been two types of water hyacinth weevil (*Neochetina eichorniae* and *Neochetina bruchi)* and the water hyacinth mite (*Orthagalumna terebrantis*). In addition, the fungus, *Cercospona rodmanii,* has been imported and found to have some effect on the water hyacinth. When infected water hyacinths are introduced into areas with healthy hyacinths, some control results as the disease spreads and infects healthy plants.

Triploid Grass Carp

Triploid grass carp (Figure 7) feed upon aquatic vegetation. Triploid grass carp *(Clenopharyngodon idella*) are non-native fish with 3 sets of chromosomes, rather than the normal 2 sets, making them essentially sterile. Their introduction into water bodies requires permitting from the Florida Fish and Wildlife Conservation Commission in Tallahassee. Usually, the permitting requires a fish barrier retention structure on outfall structures. This is to contain the grass carp and reduce the chances of introduction to primary canals, streams, or lakes.

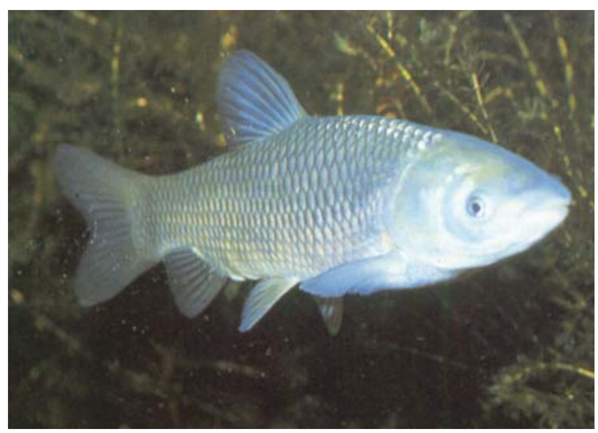

Figure 7. Triploid grass carp.

All grass carp used in Florida under this permit system must be certified as triploid by the Florida Fish and Wildlife Conservation Commission or the U.S. Fish and Wildlife Service. Instructions on purchasing these fish and the certification process are included with the Commission's permit, which must be received prior to possession of any grass carp. The one-page application for certification and possession of grass carp for control of aquatic weeds may be obtained by contacting:

Florida Fish and Wildlife Conservation Commission

620 South Meridian Street

Tallahassee, FL 32301

Telephone: (850) 488-4066

or (850) 488-4069

Since grass carp do not reproduce, a large number of fish must be introduced to initiate adequate weed control when weed pressure is high. Under appropriate conditions, grass carp can eventually attain weights of 30 pounds or more. Usually the best strategy for a high-density aquatic weed condition is to lower the weed density before the fish are introduced.

Grass carp are generally appropriate for control of submerged aquatic species such as hydrilla, elodea, and certain types of algae (Table 2). Biological control measures with herbivorous fish are long-term measures that must have aquatic weed hosts available at all times. Herbivorous fish are not quick-source eradicants of a massive weed problem. Most fish are host selective in nature, and prefer to feed on only a few weed species. Therefore, under a biological control program using grass carp, some groups of plants may seem to proliferate.

Implementation Considerations

- Targeted canals and ditches should maintain a minimum year- round water depth of 2 feet.
- Fish barriers should be installed to contain grass carp within targeted ditches.
- Stocking densities should be determined by the Florida Fish and Wildlife Conservation Commission.
- On-site inspection should be conducted by representatives of the Florida Fish and Wildlife Conservation Commission to determine the feasibility of using grass carp.
- Grass carp are effective at controlling submerged aquatic vegetation and can deter the growth of floating aquatic vegetation.
- Grass carp can withstand dissolved oxygen levels as low as 2 ppm.
- Recommended stocking size should be no less than 12 inches in length or about one pound in weight.

Chemical Control

The objective of an aquatic herbicide program is to control aquatic weeds within grove drainage ditches. In the past, citrus growers have relied extensively on chemical control for effective reduction of invasive weed species in and along waterways. Chemical control of aquatic weed species is normally accomplished using various types of herbicides. Usually these herbicides will fall into one or two of the following categories:

- Contact: applied materials must contact the plant surface (specifically the leaf) and desiccation follows (Figure 8).
- Systemic: materials that are applied and translocated from the point of contact throughout the plant (Figure 9).
- Selective: herbicides designated for use on specific species.
- Non-Selective: a herbicide that will kill a wide range of species.
- pre-emergent: herbicides specifically designed to kill weed species before or immediately after seedling emergence. No pre-emergent herbicides are labeled for aquatic weed control.
- Post-emergent: herbicides that are designed to kill weed species after plant emergence.

One of the primary criteria for evaluating an aquatic herbicide is understanding the chemical's environmental profile. The first step is to ensure that the product is registered for the intended use. These guidelines are specified on the product's EPA label. Beyond that, users should consider the toxicity of the

Figure 8. Wiper used to apply aquatic herbicides to grove ditches. Credits: J. Hebb

Figure 9. Turkey feeder used to periodically disperse fluridone pellets into a canal. Credits: L. Pell

herbicide and its impact on humans, fish and wildlife, restrictions on water use, and transportation concerns. Toxicity levels vary according to the chemistry and concentration of the aquatic herbicide as well as to the specific organisms. Use restrictions specified on the label may require a waiting period during which the treated water is not safe for use in irrigation, fish consumption, watering livestock, and/or swimming. Generally, water treated with most copper and chelated copper herbicides can be used immediately for irrigation, stock watering, swimming, fishing, and domestic use.

Other herbicides may have use restrictions of up to 30 days. Use considerations are also important when evaluating an aquatic herbicide. Proper usage is contingent on the correct identification of the plant species to be controlled. This can be done independently using a good aquatic vegetation guidebook (see references) or with the services of a professional biologist. Canal and ditch water applications are primarily focused on the control of submersed, rooted plants, and filamentous algae. Speed of effectiveness should also be considered when selecting herbicides for canal applications. Slow-acting herbicides can allow continued plant growth to impede water flow.

Once the proper herbicides have been identified for the application, competitive products and brands may then be compared based on ease of application. There are several factors that impact application criteria. Most important are the specific directions listed on the label. Some products must be applied more frequently than others such as diruon and fluridone that offer longer control. Visibility of the product also impacts ease of application. Some products are clear or gaseous when applied, making it difficult to see how effectively they have dispersed. Others are visible which facilitates down stream tracking of the application.

Variations in purchase price among the different chemistries may be offset by factors such as: product efficacy, application frequency, handling requirements, and related legal/risk costs. It is a good idea to evaluate the supplier's technical support network. Some aquatic herbicides are sold direct from the manufacturer, while others are marketed locally by knowledgeable herbicide distributors. IFAS Extension personnel can assist in identifying vegetation, calculating dosage requirements, and providing application equipment recommendations.

It is imperative to determine what aquatic species need to be controlled, and then to choose the appropriate control mechanism based on plant species. Most important of all, the operator should always read the herbicide label before mixing, loading, or applying a herbicide. ***The label is the law,*** and it is unlawful to detach, deface, alter, or destroy the label. It is also unlawful to use a pesticide in a manner that is inconsistent with or not specified on the label. The herbicide label contains a great deal of information concerning the product, and should be read carefully and thoroughly before use. Make sure that from the label you can determine the following:

- Signal word of toxicity to humans (i.e. Caution, Warning, Danger)
- Personal protective equipment needed (i.e. gloves, boots, coveralls, hats, aprons, eyewear, respirator)
- Environmental hazards (i.e. fish, mollusks, etc.)
- Environmental and weather conditions that may prohibit applications
- The type of weed species controlled by the herbicide
- Application rate under various aquatic conditions (i.e. murky water, clear water, etc.)
- Where the herbicide can be applied (i.e. water, ditchbank, etc.)
- Time of year for applying the herbicide (i.e. season, plant growth stage, etc.)
- Restrictions concerning other water uses (i.e. irrigation, livestock, fishing, etc.)

Some herbicides can kill submerged or emergent aquatic weed species that produce oxygen in the water. In addition, degradation of plant materials will also consume oxygen within the water column. As a result, dissolved oxygen levels can fall below levels that are needed to sustain fish populations. Therefore, treat early in the year before plants get out of control. When possible, selectively control species that shade out or crowd other native species. Avoid treatments on cloudy days when dissolved oxygen will naturally be lower. If a large portion of a water body is extensively covered with plants, treat no more than 1/3 to 1/2 of the area at one time. This will allow time between applications for oxygen recovery. During the winter months, optimal performance of the herbicide will be achieved when water temperatures are relatively warmer.

Aquatic Herbicides

There are several herbicides that can be used for aquatic weed control. Each material has advantages and disadvantages. The selection of the most appropriate material should be based on the target species, alternate control measures, and the effects on other aquatic organisms. Table 3 lists the LC_{50} values for some species. These values are the concentrations at which 50% of the population would be expected to die 96 hours after exposure.

The following lists commonly used aquatic herbicides, their mode of action, and target species. For details on application rates, treatment strategies, and aquatic weeds managed, the reader is directed to EDIS publication CH096 at http://edis.ifas.ufl.edu/CH096.

Copper Products

Copper products (include copper sulfate and copper chelates) are contact herbicides that are often used in combination with other contact herbicides. They are generally labeled for use in impounded waters, lakes, ponds, reservoirs, and irrigation systems. Copper sulfate may persist for up to 7 days before the free copper is precipitated to insoluble forms that are not active. As the hardness of the water increases, the persistence of the free copper decreases. The chelated coppers can be used where hard water may precipitate uncomplexed forms of copper too rapidly.

Copper sulfate can be very corrosive to steel and galvanized pipe, while chelated coppers are virtually non-corrosive. Contact with skin and eyes should be avoided. Copper sulfate may be toxic to fish species at recommended dosages. As water hardness decreases, toxicity to fish increases. Generally, the chelated coppers are nontoxic to trout, tropical fish, ornamental fish, and other sensifish at recommended dosages.

2 ,4-D Products

2,4-D is a selective, translocated phenoxy compound that is used as a post-emergent herbicide on ditch banks and emerged and floating aquatic weeds. Treated ditches should not be used to irrigate susceptible crops such as tomatoes, grapes, fruit trees, and ornamentals. More effective herbicidal activity is obtained when applied to actively growing plants. A rain-free period of at least 6 hours is required to insure lethal dose absorption by treated foliage.

Diquat

Diquat is a contact herbicide that is rapidly and completely inactivated by soil. It should not be applied to muddy or turbid water because the diquat will be inactivated. Diquat may be used in slowly moving bodies of water, ponds, lakes, rivers, drainage and flood control canals, ditches, and reservoirs.

Diuron

Diuron is readily absorbed through the root system and translocated to plant foliage. It can be applied to irrigation and drainage ditches that have been drained. The ditches should remain for a period of 72 hours to allow the diuron to be fixed into the soil. The control duration will vary with amount of chemical applied, soil type, rainfall and other conditions. However, control may last for 10-12 months.

Endothall

Endothall is a contact herbicide that breaks down fairly rapidy in water and soil. It is labeled for use in iIrrigation and drainage canals, ponds and lakes. Some formulations of endothall should not be used where fish are important since the fish may be killed by dosages necessary to kill weeds. (Hydrothol 191 must be used with caution at rates above 0.3 ppm by weight).

Fluridone

Fluridone is absorbed by the foliage and translocated into the actively growing shoots where destruction of the chlorophyll pigments occurs. It is labeled for use in lakes, ponds, ditches, canals, and reservoirs. Depending upon application and vegetation being controlled, control may last 1 year.

Glyphosate

Glyphosate is absorbed by foliage and translocated throughout the plant and root system, killing the entire plant. Glyphosate can be used for floating mats of aquatic vegetation, but should not be used for submersed or pre-emergent vegetation. It is registered for use in lakes, ponds, streams, rivers, ditches, canals, reservoirs, and other freshwater bodies.

Imazapyr

Imazapyr is absorbed by both foliage and roots and then translocated throughout the entire plant. It is labeled for non-irrigation ditchbanks and similar areas and provides control of existing and germinating seedlings throughout the growing season.

Triclopyr

Triclopyr induces characteristic auxin-type responses in growing plants. It is absorbed by both leaves and roots, and is readily translocated throughout the plant. Foliar applications have achieved maximum plant response to treatment when applied soon after full leaf development and soil moisture is adequate for normal plant growth. It is labeled for use on non-irrigation ditchbanks (an Experimental Use Permit required to use this procuct in water). The time required for 50 percent breakdown in soil is between 10 and 46 days depending on environmental conditions and soil type.

Herbicide Calculations

Definitions:

AI = active ingredient

ppm_v = parts per million by volume

ppm_w = parts per million by weight

Active ingredient (AI)

Eq. 1 -- Gallons of liquid formulation

gal = AI required / AI concentration

where AI required is in lb and AI concentration is in lb/gal

Eq. 2 -- Lb of dry formulation

lb = AI required / AI in formulation

where AI required is in lb and AI concentration is in % (expressed as decimal)

Herbicide applications to ponds or lakes

Eq. 3 -- Volume of pond (ft^3)

$V = A \times D$

where,

V = Volume of pond (ft^3)

A = surface area in ft^2

D = average depth (ft)

Eq. 4 -- Volume of pond (ac-ft)

$V = Ac \times D$

where,

V = Volume of pond (ac-ft)

Ac = surface area (acres)

D = average depth (ft)

Eq. 5 -- Volume of pond (ac-ft)

$V\ (\text{ac-ft}) = V\ (ft^3) / 43{,}560\ ft^2/ac$

Eq. 6 -- Total gal of chemical required

$gal = V(\text{ac-ft}) \times ppm_v \times 0.33$

Eq. 7 -- parts per million by weight

$ppm_w = AI / [V(\text{ac-ft}) \times 2.72]$

where,

AI = AI of chemical applied (lb)

V(ac-ft) = volume of water to be treated (ac-ft)

Eq. 8 -- Total lb AI required

$lb = \text{ac-ft} \times 2.72 \times ppm_w$ desired

Eq. 9 -- Total gal of liquid formulation

$gal = \text{ac-ft} \times 2.72 \times ppm_w / AI$

where,

gal = total gal of liquid formulation

ppm_w = desired ppm by weight of AI required

AI = AI of concentrate (lb/gal)

Acreage calculations

Eq. 10 -- Rectangular shape

$Acres = W \times L / 43{,}560\ ft^2/ac$

where,

W = ditch width (ft)

L = ditch length (ft)

Eq. 11 -- Circular shape

$Acres = 3.14 \times r^2 / 43{,}560\ ft^2/ac$

where:

r = radius of pond (ft)

Herbicide application coverage

Eq. 12 -- $Ac/hr = W \times V / 8.25$

where,

W = swath width (ft)

V = travel speed (mph)

Volume of herbicide concentrate required

Eq. 13 -- Herbicide concentrate needed

gal = AI_m / AI_h x A

where,

gal = volume of concentrate needed (gal)

AI_m = AI in mixture (lb)

AI_h = AI of herbicide (lb/gal)

A = area treated (acres)

Example Calculations

1. A grove requires a herbicide application at the rate of 1 pound of AI per acre. If the herbicide being applied is an emulsifiable concentrate with a 2 EC label, what are the gallons of liquid formulation required per acre?

Use Eq. 1.

Gal/ac = 1 lb AI / 2 lb/gal = 0.5 gal/ac

2. A grove requires 2 pounds of AI per acre for application purposes. A granular herbicide is selected and the container label states that it contains 20% AI of a compound. How many pounds of dry formulated herbicide are needed per acre?

Use. Eq. 2.

Lb/ac = 2 lb/ac AI / 0.20 AI = 10 lb/ac

3. A circular pond has a diameter of 300 ft. Find the volume of the pond if the average depth is 10 feet. How much chemical (gallons) is required to treat the pond if the rate of treatment calls for 5 parts per million by volume (ppm_v)?

Use Eq. 11 for area (Radius = 300/2 = 150 ft)

acres = 3.14 x $(150\ ft)^2$/ 43,560 = 1.62 ac

Use Eq. 3 for volume

ac-ft = 1.62 ac x 10 ft = 16.2 ac-ft

Use Eq. 6 to determine application rate

gal of chemical required = 16.2 ac-ft x 5 x 0.33=26.7 gal

4. If a chemical contains 4 lb AI /gal and 20 gal are sprayed into a ditch containing 5 ac-ft of water, find the ppm by weight of the applied material.

Total AI = 4 lbs/gal x 20 gal = 80 pounds AI

Use Eq. 7 to calculate ppm_w

ppm_w = 80 pounds AI / 5 ac-ft x 2.72 = 5.9 ppm_w

5. If herbicide is applied with a 6 ft boom operating at 2 mph, how many acres per hour is the grower covering?

Use. Eq. 12

Ac/hr = 6 ft x 2 mph / 8.25 = 1.45 ac/hr

6. A 50 acre block is to be sprayed with a herbicide that calls for 4 pounds active ingredient per acre. If the grower uses a 2E concentrate material, how much herbicide concentrate is required to spray the block?

Use Eq. 13

gal= 50 acres x 4 lb AI/ac / 2 lb AI/gal= 100 gal of herbicide concentrate needed

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Additional information is available through the searchable engine for University of Florida EDIS documents at: http://edis.ifas.ufl.edu.

Table 2. Preference by grass carp for common aquatic plants and their effectiveness in providing control in lakes and ditches.

Common name	Scientific name	Preference	Effectiveness
Alligatorweed	*Alternanthera philoxeroides*	Low	Low
Bladderwort	*Utricularia* sp.	High	High
Cattail	*Typha* sp.	Low	Low
Coontail	*Ceratophyllum demersum*	High	High
Duckweed	*Lemna minor*	High	Low
Fanwort	*Cambomba caroliniana*	High	High
Filamentous algae	*Spirogyra* sp., many others	Moderate	Low
Hydrilla	*Hydrilla verticellata*	High	High
Hygrophila	*Hygrophila polysperma*	High	*Moderate
Planktonic algae	Many species	Low	Low
Pondweed	*Potamogeton* sp.	Moderate	*Moderate
Sedges	*Cyperus* sp.	Low	Low
Smartweed	*Polygonum* sp.	Low	Low
Southern naiad	*Najas guadalupensis*	High	High
Spatterdock	*Nuphar luteum*	Low	Low
Spikerush	*Eleocharis* sp.	Low	Low
Water primrose	*Ludwiga* sp.	Low	Low
Water hyacinth	*Eichornia crassipes*	Low	Low
Watermeal	*Wolffia* sp.	High	Low
White waterlily	*Nymphaea odorata*	Low	Low
Willows	*Salix sp.*	Low	Low

* Suggested stocking rate is 20-100 fish per acre in canals, depending on the type of weed infestation.

Table 3. Toxicity of aquatic and ditchbank herbicides to selected aquatic organisms.

Material	Treatment rate[1] (ppm)	Toxicity (96-hr LC_{50})[2]		
		Bluegill and sunfish (ppm)	Rainbow trout (ppm)	Invertebrates (ppm)
Copper Sulfate	0.1-1.0			17.0[3]
Soft water		0.9	0.01	
Hard water		7.3	-	
Copper Chelate	0.1-1.0			19.0[4]
Soft water		1.2	<0.2	
Hard water		7.5	4	
2,4-D Amine	negligible[5]	524	377	184[6]
2,4-D BEE	1.25-2.5[7]	0.61	2	7.2[3]
Diquat	0.12-0.72	>115	21	>100[8]
Diuron	negligible	8.2	1.6	0.164
Imazapyr	negligible	>100	>100	>100[3]
Endothall (Aquathol)	1.0-5.0	501	529	320[9]
Endothall (Hydrothol)	0.1-3.0	1.2	1.3	0.36[5]
Fluridone	0.01-0.15	14.3	11.7	6.3[5]
Glyphosate (Rodeo)	negliglible	>1000	>1000	930[5]

[1]Estimated concentration in water after application according to label instructions.
[2]Toxicity varies according to experimental conditions. The 96-hr LC_{50} values are typical from various sources and represent the concentrations at which 50% of the population would be expected to die within 96 hours after exposure.
[3]Freshwater shrimp
[4]Blue shrimp
[5]Labeled only for foliar or ditchbank application, therefore concentrations in water are negligible.
[6]*Daphnia*
[7]Calculated for label rates of 26.7% G.
[8]*Gammarus fasciatus*
[9]*Daphnia,* 48 hr