WEED CONTROL IN IRRIGATION WATER SUPPLIES

This publication summarizes safe and effective techniques for managing aquatic weeds in irrigation ponds. It emphasizes preventive measures and the selection of cultural, mechanical, biological, and chemical management techniques appropriate for irrigation water supplies. The advantages, disadvantages, and environmental consequences of these methods are also discussed.

Introduction

Reliable sources of water for irrigation of crops are becoming increasingly important in North Carolina. The primary sources for irrigation water are small surface impoundments. In the past 25 years, more than 75,000 ponds have been constructed in the state for collection and storage of irrigation water. The same ponds may also be used for swimming, sport fishing, livestock watering, and aquaculture.

Unfortunately, these multiple-use ponds are often constructed poorly. Many have large areas of shallow water and receive substantial nutrient input from the surrounding watershed and other sources. The combination of shallow, clear water and excessive nutrient input inevitably results in dense growths of one or more species of aquatic plants.

In large bodies of water, plants provide habitat and food for gamefish and waterfowl, and they oxygenate the water. In small impoundments, however, weedy growths of algae and vascular aquatic plants interfere with irrigation operations and fish production (Figure 1). They also cause fish kills through nighttime oxygen depletion, and harbor vectors of human and animal diseases.

Preventive Measures

Pond Design and Construction

Weed management in ponds begins with proper pond construction. Guidelines for pond construction are available from the U.S. Department of Agriculture Soil Conservation Service (SCS); ask for Agricultural Handbook no. 590, *Ponds—Planning, Design, and Construction*. The SCS offers free assistance for redesigning new ponds if the landowner is a cooperator with the local Soil and Water Conservation District. An additional source of information is Cooperative Extension Service publication AG-424, *Pond Management Guide*.

The establishment and growth of weeds can be prevented by minimizing the amount of sunlight that reaches the bottom of the pond. The pond should be of

Figure 1. Weed problem in a North Carolina piedmont irrigation pond.

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adequate depth (minimum of 3 feet) throughout, and pond banks should have a slope of at least 1 to 4 (ratio of depth to distance from the edge) to minimize shallow areas in which growth begins.

In properly designed ponds, fertilization and pond dyes that block light penetration may also be used to prevent the establishment of aquatic weeds. For either of these techniques to be successful, the pond should have minimal outflow. Ponds fed by streams and large springs usually have substantial, continuous outflow and do not respond well to fertilization or pond dyes because the fertilizer or dye washes out. These techniques are also much less effective in poorly constructed ponds that have extensive areas in which the water is less than 3 feet deep.

Fertilization

Fertilization is a useful method for reducing light penetration. Nutrients released from the fertilizer stimulate the growth of planktonic algae, thereby increasing the turbidity (cloudiness) of the water and decreasing light penetration. Plankton growth is observed as a green or brown coloration of the water. Pond fertilization can be an effective way to suppress the growth of filamentous algae and submersed macrophytes. At the same time, it can enhance fish production in the pond. However, fertilization must be done correctly and must be continued once it is started. Fertilization should be done **only** if you plan to harvest fish regularly, or stunting of your fish may occur. A common mistake is to fertilize once or twice and then to stop. This results in the loss of the plankton bloom within a few weeks. The planktonic algae settles out, and the water column once again becomes clear. Filamentous algae and other weeds then grow rapidly as they absorb the nutrients that are released at the bottom of the pond by the decomposing plankton.

Another common mistake is to attempt to control emergent weeds (such as cattails, rushes, and grasses) and floating weeds (such as duckweed and watermeal) with fertilization. The added fertility will cause these plants to grow prolifically, making further weed control measures necessary. Never fertilize when filamentous algae or submersed macrophytes (weeds that grow beneath the surface only) are already present because the added nutrients will only compound the problem.

Begin fertilization in early spring when the water temperature reaches 60 to 65 degrees F. Several types of fertilizers are available for pond use, including a 10-34-0 (N-P-K) liquid aquacultural fertilizer and granular formulations, such as 20-20-5 or 8-8-2. The liquid fertilizer is normally applied at a rate of 1 gallon per surface acre, whereas the granular fertilizers are applied at 40 to 100 pounds per surface acre for the two formulations, respectively. If fertilizers with higher levels of nitrogen and phosphorus are used, the rate should be decreased proportionately.

Granular fertilizers should be placed on a platform 10 to 15 feet from the pond's edge, constructed so that the fertilizer is approximately 12 to 18 inches below the water surface. Fertilizer should be reapplied as soon as you can see a shiny object (such as a tin can lid nailed to the end of a stick) 18 inches below the water surface. The period between applications varies among ponds, but it will generally be from 4 to 6 weeks throughout the growing season. Continue fertilization until the water temperature stabilizes below 60 degrees F in the fall.

If the pond contains very soft, acidic water, liming may be needed to raise the pH to the desirable range (approximately 6.5 to 7.5). To determine the amount of lime to be applied, collect and dry a sample of the mud from the pond bottom and submit it for a soil test (available through the Cooperative Extension Service). The rate of lime application should be based on the lime requirement for the mud from the bottom.

Take care to avoid overfertilization or overliming. Overfertilization may lead to the development of noxious algal blooms. Die-off of the bloom and the decomposition of dead algae during the summer may also cause oxygen depletion, resulting in fish kills. Overliming may raise the pH of the pond water above 9.0 and enhance the development of undesirable blue-green algae, which cause odor problems and produce off flavors in fish. Additional information is available in Cooperative Extension Service publication AG-424, *Pond Management Guide,* or from a Wildlife Resources Commission fisheries biologist.

Pond Dyes

As an alternative to fertilization, a pond dye, such as Aquashade, can be used to reduce light penetration into the water column. This pond dye blocks the wavelengths of light that are necessary for photosynthesis. The dye also gives the water a bluish green color that some pond owners consider attractive. The upper 2 feet of the water column remain productive and provide food for fish. This dye is nontoxic to humans, pets, fish, wildlife, and plants. Aquashade is completely safe for use in irrigation water, water used for preparing pesticide sprays, and recreational ponds. Application to intensive aquaculture ponds may suppress the plankton bloom to an undesirable level and, in most cases, should be avoided. Application rates depend upon the volume of water to be treated and the particular weed. One quart is generally sufficient to treat 1 acre-foot of water (1 surface acre of water averaging 1 foot in depth) for routine weed control. Difficult species, such as hydrilla, may require 2 quarts per acre-foot. Treatments usually are effective for 6 months or occasionally longer, depending upon the rate of water loss from the pond and the amount of fresh water entering the pond. If dense growths of algae or other weeds are present, mechanical removal or a herbicide treatment may be needed before applying a pond dye.

Cultural Control

Cultural techniques modify the environment to make conditions less suitable for weed growth. They include drawdowns and the use of benthic barriers (such as fibrous screens). Drawdowns are effective mainly on submersed vegetation (for example, Brazilian elodea) and are not generally recommended unless the pond is larger than 1 acre and has a control structure that allows you to adjust the water level easily. A drawdown should be done during the winter when the combination of drying and exposure to cold temperatures will kill many aquatic weeds. Drawdowns during the warmer months are not recommended, because they stress fish populations and may enhance the spread of marginal species (such as cattails, rushes, and willows).

Fibrous screens, such as Texel, Aquascreen, and Bottom Line, can be spread over the pond bottom to block out sunlight, preventing photosynthesis and eliminating weed growth. These materials are very expensive (as much as $10,000 per acre), but they may be useful in controlling submersed weeds around access areas and water intakes where other management procedures cannot be used. Benthic barriers are largely ineffective on floating species (for example, duckweeds) and emergent species (such as cattails).

Mechanical Removal

Mechanical removal of weeds by seining, raking, chaining, or using a backhoe is both the most common and most expensive form of pond weed management. Mechanical removal may be necessary where immediate control is required or in circumstances where other methods cannot be used. Mechanical harvesting equipment is available but is expensive and usually impractical in small impoundments. The primary advantage of the mechanical method is that the vegetation is totally removed from the water column. No decaying vegetation is present, and thus there are no noxious filamentous algal blooms caused by nutrient release or fish kills caused by oxygen depletion. Also, there are no herbicide residues that could damage irrigated crops and other desirable vegetation or that would require other water-use restrictions. Disadvantages include the problem of disposing of the weed mass, which may be 95 to 97 percent water, the physical disruption of the shoreline caused by the movement of equipment, the ineffective removal of portions of the vegetation, and the dispersal of vegetative fragments that may take root elsewhere. Some aquatic weeds, such as alligatorweed, are amphibious and may become weeds in field crops and other terrestrial sites.

If a serious weed problem persists from year to year, a more viable option is to drain the pond and redesign it by excavating the shallow areas. This approach is quite expensive and requires the availability of an alternative source of irrigation water for an extended time.

Biological Control

Although many organisms (such as insects, mites, snails, ducks, geese, swans, manatees, and fish) may feed on weeds, only herbivorous fish have proven effective for controlling aquatic weeds in North Carolina farm ponds. Various species have been suggested as agents for aquatic weed control, including *Tilapia* species, various strains of the common carp *(Cyprinus carpio),* the Israeli carp and mirror carp, and the Chinese grass carp *(Ctenopharyngodon idella).*

Tilapia. The tilapia are tropical species that can suppress growth of aquatic vegetation (such as filamentous algae) when stocked at high rates (300 per acre). Two species of tilapia have been considered for weed control. The blue tilapia *(T. aurea)* feeds entirely on algae (both planktonic and filamentous) but does not readily consume submersed macrophyte vegetation. The redbelly tilapia *(T. zilli)* feeds primarily on submersed macrophytes rather than algae. However, both species reproduce rapidly and consume both the vegetation and the small animals living in the vegetation that are important food sources for desirable fish populations. Therefore, use of the tilapia may have unwanted environmental consequences. Tilapia cannot survive normal winter water temperatures in North Carolina, however. This is a benefit from an environmental standpoint, but annual restocking is necessary unless a warm water supply (such as thermal spring or power plant cooling reservoir) is available as a refuge in which the fish can overwinter.

Fish also may be seined in the fall before the onset of cold weather and either harvested for food or maintained indoors for restocking during the next growing season. The loss of fish in the fall when water temperatures are too cool for survival may require the removal and burial of large numbers of dead fish at the end of each season. Usually, they will be consumed by bass or predatory birds before they die.

Common Carp. Various strains of common carp, especially Israeli carp, have been widely recommended for aquatic weed control, mainly for filamentous algae, in North Carolina. These fish can suppress filamentous algae growth but can have detrimental effects on ponds. Carp control weeds by muddying the water and by consuming the vegetation. They can survive North Carolina winters and can also reproduce in ponds.

Figure 2. The grass carp.

Grass Carp. Sometimes referred to as white amur, grass carp (Figure 2) were introduced into the United States under quarantine in the 1960s. Research showed that they were very effective in controlling many species of aquatic vegetation. However, their possession in most states and interstate transportation was made illegal, because biologists feared an environmental calamity might occur if these fish escaped into the larger rivers. There they might find suitable spawning habitat, reproduce prolifically, and destroy natural aquatic plant communities that provide food and habitat for native sportfish and waterfowl.

In 1982, Malone and Sons Fish Hatchery in Lonoke, Arkansas, produced a grass carp that is incapable of reproduction. The fish's sterility results from disrupting the eggs during the developmental process, producing fish with an extra set of chromosomes (triploid). Because there is no danger of these fish reproducing if they escape, it is now legal to stock them in many states, including North Carolina.

The grass carp, particularly those that weigh between 4 and 15 pounds, may consume more than their own body weight of fresh vegetation in a single day, and they may grow to more than 50 pounds. This fish is totally herbivorous and does not feed on or compete with other freshwater fishes for food. Grass carp feed largely on submersed weeds (such as hydrilla, pondweed, and naiads) and are recommended primarily for control of this group of weeds. They occasionally feed on filamentous algae, duckweeds, and various emergent vegetation but generally do not provide satisfactory control of these species. Table 1 lists the weeds they do and do not control effectively. One disadvantage of using the grass carp is that these fish tend to eat all of the vegetation available and then begin to starve. If this occurs, it may be necessary to feed them. Grass clippings or commercially available trout and catfish feeds may be used to prevent starvation. One stocking of grass carp may give up to 10 years of weed control. This makes the use of grass carp highly competitive with other control methods, in spite of the apparently high initial cost ($7 to 8 per fish, depending upon quantity required and availability). **The use of grass carp is the preferred alternative for management of most species of submersed vegetation in small impoundments.**

You may purchase up to 150 triploid grass carp and stock ponds up to 10 acres in size in North Carolina without a permit. If you need more than 150 grass carp or plan to stock them in larger bodies of water, you will have to obtain a permit. Grass carp must be certified as triploid (sterile) and be purchased from an approved supplier. Contact the Division of Boating and Inland Fisheries in Raleigh at (919) 733-3633 for information on suppliers of triploid grass carp or to obtain a stocking permit application.

Grass carp are usually stocked at a minimum size of 10 to 12 inches to avoid predation by large fish, such a bass. Stocking 15 to 20 per vegetated acre is generally sufficient to control most problems with submersed weeds, whereas 50 or more may be necessary for even temporary suppression of algae or floating plants, such as duckweeds. Because of the high stocking rates, frequently unreliable results, loss of fish because of starvation, and the high cost of the fish, grass carp are rarely

Table 1. Relative Effectiveness of Grass Carp and Herbicides for Control of Common Aquatic Weeds in North Carolina

Species	Grass Carp	Endothall: Aquathol	Endothall: Hydrothol*	Diquat	2,4-D	Copper Compounds	Fluridone	Glyphosate
Algae								
Planktonic algae	NR	NR	E	E	NR	E	NR	NR
Filamentous algae	NR	NR	E	E	NR	G	NR	NR
Macroalgae (*Chara, Nitella)*	E	NR	E	E	NR	G	NR	NR
Free-Floating Plants								
Duckweed	NR	NR	NR	G	P	P	E	NR
Watermeal	NR	NR	NR	NR	NR	NR	G	NR
Mosquito fern (*Azolla*)	NR	NR	NR	G	F	NR	E	NR
Waterhyacinth	NR	NR	NR	G	E	NR	NR	G
Submersed Plants								
American elodea	E	E	E	E	NR	F	E	NR
Bladderwort	G	P	P	G	G	NR	E	NR
Brazilian elodea	G	P	P	E	NR	G	E	NR
Brittle (spiny) naiad	E	E	E	E	NR	NR	E	NR
Coontail	G	E	E	E	G	NR	E	NR
Creeping rush	G	NR	NR	F	NR	NR	E	NR
Eurasian watermilfoil	P	E	E	E	E	NR	E	NR
Hydrilla	E	E	E	E	NR	F	E	NR
Parrotfeather	P	E	E	G	E	NR	E	NR
Pondweeds (*Potamogeton*)	E	E	E	E	NR	NR	E	NR
Southern Naiad	E	P	P	F	NR	NR	G	NR
Proliferating spikerush	E	NR	NR	NR	NR	NR	E	NR
Variable-leaf milfoil	P	E	E	E	E	NR	E	NR
Widgeongrass	E	F	F	G	NR	NR	E	NR
Emergent/Floating-Leaf Plants								
Alligatorweed	NR	NR	NR	NR	P	NR	P	G
American lotus	NR	NR	NR	NR	G	NR	P	E
Bulrushes (*Scirpus*)	NR	NR	NR	F	G	NR	NR	E
Cattail	NR	NR	NR	F	F	NR	F	E
Common reed (*Phragmites*)	NR	NR	NR	NR	NR	NR	NR	E
Creeping waterprimrose	NR	NR	NR	NR	E	NR	P	E
Fragrant waterlilly	NR	NR	NR	NR	G	NR	G	E
Grasses	NR	NR	NR	F	NR	NR	NR	E
Pickerelweed	NR	NR	NR	P	G	NR	F	G
Rushes (*Juncus*)	NR	NR	NR	NR	P	NR	NR	G
Smartweeds	NR	NR	NR	F	G	NR	F	G
Spatterdock	NR	NR	NR	F	G	NR	G	E
Water pennywort	NR	NR	NR	G	G	NR	F	G
Watershield	NR	F	F	F	E	NR	G	F
Waterwillow (*Justicia*)	NR	NR	NR	F	E	NR	P	F

*Hydrothol formulations may be toxic to fish at application rates used for weed control.

KEY: NR = Not Recommended P = Poor F = Fair G = Good E = Excellent stocked for control of duckweeds or algae. For additional information on the use of grass carp, see AG-456, *Using Grass Carp for Aquatic Weed Management.*

Chemical Control

Diquat, endothal, glyphosate, and copper compounds are EPA-registered aquatic herbicides. They are safe for application in water that is used to irrigate crops when applied according to the label. These compounds are also safe for use in water used for other purposes provided that the applicator and those who use the water comply with all water-use restrictions specified on the label.

Fluridone (and in some cases 2,4-D), may have limited use for controlling aquatic weeds in irrigation water. Use these two compounds with extreme caution in waters used for irrigation of very sensitive crops, such as tobacco, tomatoes, peppers, and potatoes. The relative effectiveness of registered aquatic herbicides on various aquatic weeds is shown in Table 1.

Water-Use Restrictions. Irrigation restrictions for aquatic herbicides are based upon extensive research on persistence, crop sensitivity, residues in crops, and animal feeding studies. There are no restrictions for use of water for irrigation or other purposes following application of copper compounds for control of algae, because the recommended concentrations are not phytotoxic to crops and toxic concentrations do not accumulate in crop plants. Table 2 shows the length of time you must wait after applying an aquatic herbicide before you can use the water for irrigation and other purposes.

Studies conducted in North Carolina piedmont farm ponds demonstrated that concentrations of diquat decreased from 1 part per million (ppm) to nearly zero in less than 2 days after application. Endothall (Aquathol K) concentrations decreased from 2 ppm to 1 ppm within 14 days after application and to 0.5 ppm within 20 days after application. Crop plants are tolerant of higher concentrations of these compounds than those present after the required waiting periods, and toxic concentrations have not been found to accumulate in test plants. Therefore, there is a wide margin of safety in using these compounds in irrigation sources.

The half-life of glyphosate is about 14 days in water. Although glyposate is a broad-spectrum herbicide, it is recommended only for emergent aquatic weed control; therefore, only very low concentrations should occur in the pond water after application. The glyphosate that does enter the water is quickly and tightly bound to organic compounds. Therefore, when used according to label instructions, glyphosate is safe for control of emergent aquatic weeds in irrigation supply ponds.

Fluridone (Sonar) is more persistent in pond water than either diquat or endothall. It takes 2 months or longer before the residue diminishes to an undetectable level, depending upon water temperature and the rate of inflow and outflow from the pond. Even though fluridone is moderately persistent in water, only very low concentrations (maximum labeled rate is only 0.9 and 0.15 ppm for ponds and lakes, respectively) are required to control aquatic weeds. Most established crop plants have demonstrated tolerance at concentrations higher than those expected to occur in irrigation water, but seedling crops are quite sensitive and should not be irrigated with fluridone-treated water.

Results of field tests suggest that concentrations of fluridone toxic to crops may occasionally persist in pond water well beyond the 30-day waiting period specified on the label for irrigation. This information and the results of subsequent greenhouse testing suggest that the 30-day water-use restriction for irrigation after fluridone application may be insufficient, especially for seedlings and new transplants of sensitive crops, such as tobacco, tomatoes, and peppers. Therefore, use extreme caution if fluridone is required for weed control in pond water used for irrigation.

If fluridone has been applied to an irrigation pond and there is any question whether or not the water is safe for irrigation of a particular crop (after the end of the specified waiting period) a simple field bioassay may be used to assess the safety of the water. Water a very small area daily (use a sprinkling can to apply the water to a few plants) for 7 to 10 days and carefully observe the new growth (new leaves and the bases of young, immature leaves that are still growing) each day, beginning about 3 or 4 days after you begin irrigation. The appearance of new growth that is either white or pinkish instead of the normal green is a sign of fluridone toxicity. Symptoms usually appear within 7 to 10 days after irrigation of sensitive crops. In this case, the pond water is not yet safe to use for irrigation of that crop.

Choosing the Correct Herbicide

The first consideration in choosing the most effective aquatic herbicide for a particular situation is to identify the weeds correctly (Table 1). Several publications may aid in weed identification:

❑ *Aquatic and Wetland Plants of South Carolina* by Cynthia A. Aulbach-Smith and Steven J. de Kozlowski, available from the South Carolina Department of Natural Resources, 1201 Main Street, Suite 1100, Columbia, SC 29201, (803) 737-0800.

❑ *Florida Freshwater Plants. A Handbook of Common Aquatic Plants in Florida Lakes* by M.V. Hoyer, D.E. Canfield, C.A. Horsburgh, and K.P. Brown, available from IFAS Publications, University of Florida, P.O. Box 110011, Gainesville, FL 32611, (800) 226-1764.

❑ *How to Identify and Control Water Weeds and Algae,* 4th edition, edited by James C. Schmidt, available from Applied Biochemists, Inc., 5300 West County Line Road, Mequon, WI 53092.

❑ *Identification and Control of Weeds in Southern Ponds* by George W. Lewis and James F. Miller, available from the Cooperative Extension Service, University of Georgia, College of Agriculture, Athens, GA.

❑ *A Manual of Marsh and Aquatic Vascular Plants of North Carolina* by Ernest O. Beal, available from Agricultural Communications, Publications Office, Box 7603, Raleigh, NC 27695-7603.

It is necessary to know the weed species so that you can select the proper management procedures. Wrap samples of the weeds in a damp (not wet), absorbent paper towel, place them into a sealed plastic bag, and take it to your county Extension office. The agent will identify the weed and recommend an appropriate management strategy.

If the pond is used for fish production, consider the toxicity of the herbicide to fish. Two common aquatic herbicides, copper and Hydrothol 191 (amine formulation of endothall) are toxic to fish and should be used with extreme caution or avoided entirely. Copper sulfate (sometimes called Bluestone) is relatively toxic to many species of fish at or near the concentrations necessary for algae control. When copper sulfate enters the water, it immediately breaks down into its component copper ion (Cu^{++}) and sulfate ion ($SO4^{--}$). The free copper ion makes copper toxic. This effect is especially pronounced in the soft water found in most North Carolina ponds. If copper is required, one of the organic copper complexes, such as Cutrine-Plus, Komeen, or K-Tea, is much safer for the fish and more effective as an algicide. In the organic copper complexes, an organic molecule binds the copper ion so that free copper ions are not present in the water, thereby substantially reducing the toxicity to the fish.

Hydrothol 191 (either the liquid or granular formulation) is very toxic to fish; avoid using it in small impoundments where fish mortality is a concern. In larger impoundments, Hydrothol 191 may be used safely if only a small portion of the body of water is to be treated (for example, a cove or a localized, marginal weed mat). To avoid fish kills in this situation, apply the herbicide slowly, beginning at the back of the cove and at the bank and working outward toward open water. Fish can sense the herbicide and will swim away from the area of application. However, if a herbicide is applied from open water toward the bank or from open water into the cove, a fish kill will result. **Fish kills caused by direct herbicide toxicity usually occur within a few hours after pond treatment.**

Fish mortality also can occur because of the lowered oxygen concentration (oxygen depletion) in the water after application of an aquatic herbicide. This phenomenon occurs because bacteria and fungi use up the oxygen during decomposition of the dead plants. Fish kills resulting from oxygen depletion occur usually 2 to 3 days after pond treatment and are more likely to occur after applications of copper, Hydrothol 191, or diquat, because these compounds are active on the oxygen-producing phytoplankton as well as the higher plants. Therefore, in small ponds where fish mortality is a concern, use Aquathol (potassium salt of endothall) or fluridone if it is rated effective on the problem plant. These compounds are not active on phytoplankton, so this source of oxygen production remains viable. To prevent oxygen depletions in small impoundments, treat no more than one-fourth of the weed infestation at one time, especially if the weeds are dense and the water is warm (summer conditions). In large impoundments, the potential for fish mortality can be reduced by treating only one-third to one-half of the lake at one time; however, reduced weed control may result. If all or most of the pond or lake is covered with weeds, fish kills resulting from reduced oxygen levels may be avoided by postponing the herbicide application until the following year. The best time to apply most herbicides and to avoid fish kills is early in the spring when the water temperature is about 65 degrees F. The weed density is also lower at this time, and less vegetation is present to decay.

A third consideration in choosing a herbicide is cost. Aquatic weed control with herbicides may be relatively expensive. The cost depends upon the specific herbicide chosen, the problem plant (species), weed density, and other variables, such as water depth and current. Costs range from $50 to more than $300 per acre for filamentous algae and submersed weeds and generally increase in the order of copper sulfate, complexed copper, diquat, endothall, and fluridone.

Table 2. Waiting Periods (Days) and Setback Distances to Observe After Application of Aquatic Herbicides[1]

Herbicide	Irrigation	Fish Consumption	Livestock	Swimming	Drinking Water
Copper (copper sulfate and various organic copper complexes)[2]	NR[3]	NR	NR	NR	NR
2,4-D (various formulations)[4]	see label	see label	see label	see label	see label
Diquat					
Reward[5]	1-5	NR	1	NR	1-3
Weedtrine D	14	NR	14	1	14
Endothall[5]					
Aquathol K	7-25	3	7-25	NR	7-25
Aquathol (granular)	7	3	NR	NR	7
Hydrothol 191[6]	7-25	3	7-25	NR	7-25
Hydrothol 191[6] (granular)	7-25	3	7-25	NR	7-25
Fluridone				NR	
Sonar 4AS	7-30[7]	NR	NR	NR	¼ mile
Sonar SRP	7-30[7]	NR	NR	NR	¼ mile
Glyphosate					
Rodeo	NR	NR	NR	NR	½ mile

[1]Labels of specific products may change without notice. Check the most current label for changes in water use restrictions.

[2] Copper may be toxic to sheep and goats. Use of copper in ponds used for watering these animals should be avoided unless the animals can be provided with another source of drinking water for at least 3-5 days to allow dissipation. Copper (especially copper sulfate) also may be toxic to fish near the application rate required for control of certain weeds. Care should be taken to calculate the treatment rate carefully to avoid over-application and a possible fish kill.

[3]NR = No restrictions.

[4]Water-use restrictions vary by formulation and manufacturer. Most labels do not permit the use of 2,4-D in irrigation waters. Regardless, if the water is used for irrigating sensitive crops, 2,4-D should not be used. Most turfgrasses are tolerant of low concentrations of 2,4-D.

[5]Water-use restrictions vary depending on formulation, treatment rate, and site of application.

[6]Hydrothol formulations may be toxic to fish at levels used for weed control.

[7]Water use restrictions vary with formulation, site of application, and type and maturity of crop that is irrigated. In some cases, a 30-day restriction may be insufficient for irrigation of seedlings or new transplants of sensitive crops, such as tobacco.

Calculating the Amount of Herbicide to Use. Recommendations for application of herbicides are based on surface acreage (SA) or the final concentration of herbicide in the water. The surface acreage of rectangular pounds is easily calculated:

$$SA = \frac{\text{Length in feet x Width in feet}}{43{,}560}$$

For irregularly shaped ponds, and the surface acreage must be estimated by inscribing a sketch of the pond in a rectangle, measuring the dimensions of the rectangle, estimating the percentage of the rectangle occupied by the pond and calculating:

$$SA = \frac{\text{Length in feet x width in feet x (\% Occupied by pond)100}}{43{,}560}$$

The amount of herbicide needed for specific concentrations for ponds of differing average depths is usually indicated on the label. To measure the average depth, prepare a pole marked in 1-foot intervals. (Black electrical tape works well for this.) Lower this pole into the water at least four times at equally spaced intervals, going form one side to the other, and record the depths. Add the values together and divide by the number of measurements *plus* one. Repeat this procedure in at least three different directions and average these values for the average depth (D). The average depth of the *area to be treated* should be measured. In some cases, this may be the whole pond — for example, a Sonar treatment for duckweed or watermeal; in other cases, only a portion of the pond or lake may be treated (such as a marginal treatment with copper to control algae mats along the bank or in a cove). Although the required amount of herbicide often can be determined from a chart on the herbicide label, it is sometimes necessary to calculate it. If the label specifies treatment in terms of parts per million, gallons per acre-foot, or pounds of active ingredient (ai) per acre-foot and does not provide a chart, you will have to calculate the amount of herbicide to use. Acre-feet is an expression of pond or lake volume (of the area to be treated). One acre-foot of water weighs approximately 2.7 million pounds. To calculate the amount of active ingredient (ai) required on a weight basis (pounds), use the following equation:

$$\text{lb ai} = \text{SA} \times \text{D} \times \text{Desired Concentration (ppm)} \times 2.7$$

To calculate the amount of granular herbicide formulation, which is not 100 percent active ingredient, or to calculate the number of gallons of a liquid formulation, use the following formulas:

Granular formulation:

$$\text{lb} = \frac{\text{lb ai required} \times 100}{\text{percent ai}}$$

Liquid formulation:

$$\text{gal} = \frac{\text{lb ai required}}{\text{lb ai per gallon}}$$

Application Methods

Aquatic herbicides recommended for use in irrigation supplies are available in liquid, granular, or pellet formulations. Sophisticated equipment is not necessary to apply these herbicides to small impoundments or protected coves of larger lakes.

For control of submersed plants, pour liquid formulations, such as diquat, directly from the container while moving around the pond in a boat. The herbicide will disperse rapidly in the water. If the pond contains very dense vegetation, which will reduce mixing of the herbicide, or if the pond has a high flushing rate, the herbicide should be diluted and dispersed more evenly. Spraying the diluted herbicide on the surface ensures better coverage of dense mats of filamentous algae or submersed weeds that have reached the surface. Use a rake, paddle, or similar tool to break up dense surface mats of filamentous algae during spraying to allow penetration of the herbicide into the mats.

The herbicide may also be applied by placing the end of the spray wand beneath the surface and delivering the chemical just above the growing weeds. Injecting the herbicide in this manner is quite effective for controlling weeds that are in deeper water and have not yet reached the surface. If you use the injection method, carefully deliver the herbicide without stirring up the mud on the bottom, as suspended mud particles may absorb and inactivate the herbicide. Granular or pelletized herbicides can be broadcast by hand or with a hand-held spreader.

For control of floating or emergent plants, such as duckweed and cattails, apply the herbicide to the plants in a fine spray with a hand-held or backpack sprayer. Applying herbicides to floating and emergent vegetation usually requires the use of a nonionic surfactant (such as X-77, Cide-Kick, or Induce) to ensure good coverage and penetration through the waxy cuticle on the surface of the leaves. Check the label and follow the instructions carefully. Failure to include the required surfactant may result in ineffective weed control and unnecessary expenditures for retreatment. Surfactants are not needed for application of herbicides to algae and submersed vascular aquatic weed infestations because they have no waxy cuticle.

Whenever applying herbicides, *always* follow the recommended precautions regarding contact and handling of these chemicals. *Wear protective clothing, including boots, gloves, eye protection, and a respirator or dust mask as indicated on the product label.* Use these chemicals *only* according to the precise label instructions. *Never* apply any pesticide that is not labeled for aquatic use over or into the water. *Never* use any chemicals that no longer have the original labels attached, and *never* pour chemicals into any other container except the sprayer tanks. Dispose of all empty containers correctly. ***Always make safety your first priority!***

For additional information on herbicides and other aspects of aquatic weed management, see the aquatic weed section of the *North Carolina Agricultural Chemicals Manual*. (Single copies may be purchased from the Agricultural Publications Office, Box 7603, Raleigh, NC 27695-7603 or accessed on line at http://ipmwww.ncsu.edu/agchem/agchem.html.) Also see the Aquatic Weed Management web site under the NCSU Crop Science Department home page at http://www2.ncsu.edu/ncsu/cals/crop_sci/home/crop0000.html.

Prepared by
Stratford H. Kay, Crop Science Extension Specialist

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