
CHAPTER 7

HERBICIDE TECHNOLOGY AND APPLICATION CONSIDERATIONS

Aquatic herbicides can be used to manage aquatic vegetation effectively and cost efficiently. A herbicide formulation consists of an organic (carbon-containing) or inorganic active ingredient, an inert carrier and perhaps adjuvants. Every herbicide must be registered for use in the United States by the Environmental Protection Agency and a registration fee paid to the Michigan Department of Agriculture before it can be used here. About 200 herbicides (active ingredients) currently registered in the United States, but fewer than 10 are labeled for use in aquatic sites in Michigan.

The reason there are few aquatic herbicides is that the aquatic environment limits the number of compounds that will be effective for controlling aquatic plants and at the same time meet the rigid environmental and toxicological criteria necessary for registration. Aquatic herbicides must have the capacity to be taken up from the water by plants quickly and in sufficient amounts to be toxic to target plants and have sufficiently low toxicity to humans and to other organisms in the aquatic environment.

Several herbicides are packaged in a number of formulations, most of which are not registered for aquatic use. Always use the product labeled for aquatic sites — only these products offer low risk



and effective control and have labels with the appropriate use information for aquatic settings. Applying unlabeled products or products that do not specify aquatic sites violates both federal and state laws and regulations and may severely damage the environment and possibly harm the user.

Aquatic herbicides and algacides come in various formulations and can be used in a variety of situations. With careful selection and proper application rates and timing, aquatic herbicides are a selective (removing only the target pest without harming other species) lake management tool. Selectively removing exotic and other nuisance species can shift lake flora to more desirable native species that provide better habitat for fish and invertebrates.

Herbicide Selection

Several factors need to be considered in planning a successful aquatic herbicide program:

- (1) proper identification of the weed or weeds;
- (2) uses of the water to be treated;
- (3) goals outlined in the lake's management plan;
- (4) timing of the treatment;
- (5) water characteristics, including temperature, CaCO_3 , alkalinity, percent saturation of dissolved oxygen (D.O.), and water flow;
- (6) method of application;
- (7) probability of re-treatment, potentially within the same year;
- (8) impact on nontarget plants and animals;
- (9) weather — sunny, cloudy, rain; washout potential;
- (10) cost; and
- (11) permits and permission from appropriate agencies and property owners/managers to perform the treatment.

ABSORPTION CHARACTERISTICS
<p>Contact herbicides: copper, dibromide, endothall</p> <p>Systemic herbicides: 2,4-D, dichlobenil, fluridone, glyphosate</p>
PHYSIOLOGICAL PROCESSES
<p>Cell Division: dichlobenil</p> <p>Tissue Development: 2,4-D</p> <p>Photosynthesis: copper, dibromide, fluridone</p> <p>Respiration: endothall</p> <p>Nitrogen Metabolism and Enzyme Activity: glyphosate</p>
SELECTIVITY*
<p>Nonselective (broad-spectrum): copper, dibromide, endothall, glyphosate, dichlobenil</p> <p>Selective: 2,4-D, fluridone (rate dependent)</p> <p><small>* Selectivity depends on application rate and timing. Each of these compounds may be broad-spectrum or selective, depending on how they are used.</small></p>

Figure 7-1. Classification of aquatic herbicides and algaecides.

Herbicide Classification

Herbicides are commonly grouped according to chemical similarity or herbicidal properties. Properties by which herbicides are grouped are absorption characteristics, the plant processes that they affect and selectivity (Figure 7-1).

Absorption Characteristics

Contact Herbicides

Contact herbicides act quickly and are generally lethal to all plant cells that they contact. Because of this rapid action or other physiological reasons, they do not move extensively within the plant and are effective only where they contact plants. For this reason, they are generally more effective on annual herbaceous plants. Perennial and woody plants can be defoliated by contact herbicides, but they can regrow from unaffected plant

parts. Because contact herbicides do not kill the entire plant, re-treatment is necessary, sometimes two or three times per year.

Systemic Herbicides

Systemic herbicides are absorbed into the living portion of the plant and move within the plant (translocation). Systemic herbicides are absorbed at varying degrees by various plant parts. Systemic herbicides that are absorbed by plant roots are referred to as soil-active herbicides; those that are absorbed by leaves are referred to as foliar-active herbicides.

When applied correctly, systemic herbicides act slowly compared with contact herbicides. They must move to the part of the plant where the control action takes place. Systemic herbicides are generally more effective than contact herbicides for controlling perennial and woody plants. Systemic herbicides generally have more selectivity than contact herbicides.

When using systemic herbicides, use only the amount necessary for control. This amount will never exceed label rates but may be lower than label rates under some situations. Using some pesticides at labeled rates may result in a systemic herbicide working like a contact herbicide. Exceeding label rates is not only illegal but may cause the foliage to “burn” off before it can absorb and translocate the herbicide throughout the plant and into the root system. This leaves the roots intact and able to generate new top growth. This situation may lead to the undesirable need for additional treatments later in the season.

Plant Processes and Herbicidal Activity

Cell Division

Plants grow by increasing their number of cells and replacing old cells. This process is called cell division. If a herbicide can stop cell division by affecting one of the many complex processes involved, it can stop the plant from growing. If cell division is sufficiently affected, the plant will die. Herbicides that affect cell division are most effective when they are applied **preemergence** (before weed seeds germinate and begin to grow) or during early growth.

Tissue Development

During tissue development, plant cells become specialized and organized into units that perform particular functions in the plant. When a herbicide

causes abnormal tissue development, abnormalities such as twisting of stems and leaves may be evident. If sufficient abnormalities occur, plants can die. Herbicides that act in this manner are often called plant growth regulators (PGRs). 2,4-D is an example of a herbicide that interferes with tissue development.

Photosynthesis

Photosynthesis is the process by which plants use carbon dioxide, water and sunlight to produce molecules that are the building blocks for other more complex molecules that make up the plant body. Photosynthesis is a very complex process, and various herbicides disrupt it in different ways. Plant death may be slow when the photosynthesis process is disrupted.

Respiration

Plants produce compounds such as sugars and carbohydrates during photosynthesis. Plants then use these compounds through a series of processes known as respiration. Many herbicides affect respiration, although these are probably secondary reactions.

Nitrogen Metabolism and Enzyme Activity

Nitrogen is an essential plant nutrient and is involved in many plant processes. Its absorption and incorporation into plant compounds is referred to as nitrogen metabolism. Complex nitrogen-containing compounds called enzymes are essential to plant processes. Many herbicides affect plants by interfering with the enzymes associated with the processes.

Selectivity

Broad-Spectrum Herbicides

Broad-spectrum (sometimes referred to as non-selective) herbicides are used to control all or most vegetation. Glyphosate is an example of a broad-spectrum herbicide. Broad-spectrum aquatic herbicides can be used selectively under certain circumstances discussed later.

Selective Herbicides

Selective herbicides are those that are used to control certain plants but do not affect others. An example is 2,4-D, which can be used to control broad-leaved weeds with minimum impact on grasses. Herbicide selectivity is based on various plants' susceptibility or response to herbicides.

Many related physical and biological factors contribute to a plant's susceptibility to a herbicide. Physical factors that contribute to selectivity are:

- Herbicide placement.
- Formulation.
- Rate of application.

Biological factors that affect herbicide selectivity are :

- Physiological factors.
- Morphological factors.
- Stage of plant growth.

Selective application can be as simple as carefully placing the herbicide on target plants and avoiding nontarget plants. For example, when small amounts of purple loosestrife are growing among cattails, an experienced applicator using a handgun can control the loosestrife with minimum impact on the cattail community. This is an example of selective weed control by herbicide placement.

Herbicide formulation can also affect the selectivity of foliar-applied herbicides by increasing the herbicides' ability to enter the plant. Adjuvants may be added to one formulation by the manufacturer and not to another. This additive can increase a herbicide's ability to pass through the cuticle (the waxy coating on leaves) or aid in by-passing leaf hairs by reducing surface tension.

Selectivity can be affected by the amount of herbicide applied. For example, low doses of certain herbicides may selectively control exotic species while inflicting only minimal damage upon native species. The salt of endothall has been used at very low rates for the control of curly-leaf pondweed, and 2,4-D used at low rates has effectively controlled Eurasian watermilfoil with little or no impact on nontarget species. Higher rates of the same herbicide may control a much broader range of plant species.

For a herbicide to be effective, it must first contact or enter the plant tissue. Morphological characteristics such as thick cuticles, waxy coatings or hairs can affect a plant's susceptibility to herbicides by physically preventing entry of the herbicide into the plant. Likewise, leaf shape and angle can affect the entrance of herbicide into the plant. Broad, horizontally oriented leaves will intercept and retain a greater amount of herbicide than narrow, upright leaves such as those of grasses and cattails.

A herbicide must be absorbed directly into cells or move through the plant (translocated) to the site where it is active. Herbicides may be bound on the outside of some plants or bound immediately after

they enter the plant so that they cannot move to their site of activity. Some herbicides affect very specific biochemical pathways in plants. Therefore, they may be selective against a particular group or groups of plants because they are the only ones that have that particular pathway.

Growth stage can affect susceptibility in several ways. Young, actively growing annual plants that have not developed a cuticle or leaf hairs are more susceptible than mature plants to foliar-applied herbicides. The physiology of perennial plants changes during an annual growth cycle. During early stages of growth when upward transport of food reserves and other plant compounds is rapid, soil-active herbicides are readily absorbed and moved upward to the growing points and sites of herbicide activity. Conversely, foliar-active herbicides (e.g., glyphosate) are least effective during this time, allowing some plants to tolerate the treatment.

During late and postflowering periods, perennial plants are completing that year's growth cycle. At this time, they are translocating materials downward to the roots and are most susceptible to foliar-active herbicides, which move downward to the roots with the plant materials.

Lastly, certain plant parts may be susceptible to a herbicide while other parts of the same plant are not affected.

Environmental Factors that Affect Herbicide Application

Weather conditions, water movement, soil chemistry and water chemistry can greatly affect the success of aquatic herbicide applications. The applicator has little or no control over some of these factors but can control or compensate for some others. See Figure 7-2 for environmental factors that affect aquatic herbicide application.

Weather Conditions

Rainfall

The most obvious effect of rainfall on a herbicide application is to wash foliar-applied herbicides off the emergent plant before they can be adequately absorbed. This is a particular problem with slowly absorbed systemic herbicides such as glyphosate. It is also possible that rain can enter a water body at a rate that dilutes a herbicide to an ineffective concentration. The applicator should be aware of potential weather conditions and should schedule applications accordingly.

Wind

Windy conditions can cause poor foliar application coverage. Wind can also indirectly affect the ability of leaves to absorb herbicides. Windy conditions favor herbicide drift, so applications should not be made when wind is strong enough to cause drift.

Wind can also affect the efficacy of herbicide applications for submersed plant management. As previously stated, the herbicide must be in contact with submersed plants at sufficient concentrations for sufficient periods of time to achieve control. Wind can affect the efficacy of submersed weed control applications by causing water movement that carries the herbicide away from the target plant. Avoid windy conditions when making herbicide applications.

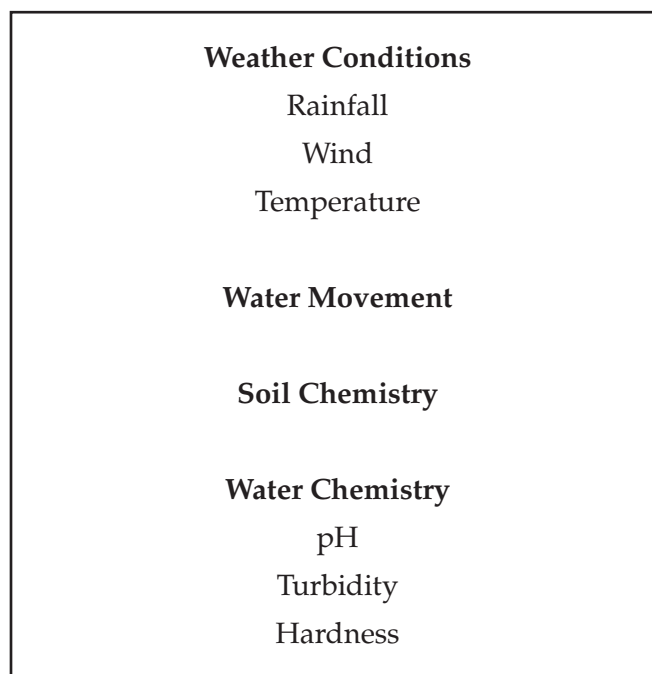


Figure 7-2. Environmental factors that affect aquatic herbicide application.

Temperature

Low temperature affects herbicide efficacy indirectly by affecting plant growth. At less than optimum temperatures plant growth slows down, and this may decrease herbicide absorption and activity. It has been suggested that temperature gradients within the water column have been a primary factor in the exchange of water between the shallow and open water regions of lakes.

Water movement

Most herbicides used for submersed aquatic weed management must be absorbed from the water into the target plants. A sufficient amount

of herbicide must be available in the water long enough for the herbicide to be effective. It is difficult to manage submersed aquatic weeds in rapidly flowing water where the herbicide is carried away from the plants with the water flow. Special techniques must be used even in slow-moving water.

Methods used when managing aquatic weeds in flowing water include:

1. Use of trailing hoses to aid sinking the herbicide and adhering it to the plants.
2. Use of special herbicide formulations for flowing water, such as slow-release pellets.
3. Use of rapidly absorbed herbicides.
4. Use of sequential applications or injection equipment to increase contact time.

Water chemistry

Aspects of water chemistry that affect herbicide efficacy include pH, turbidity and hardness. The applicator has little control over these conditions in lake water. However, the applicator can decide which herbicide to use or adjust the rate of application according to conditions. More importantly, the chemistry of dilution water can affect herbicide performance and the applicator can sometimes make adjustments for this.

A pH measurement indicates whether something is acidic or basic. The pH scale goes from 0 to 14, and 7 is neutral. Values below 7 indicate acidic conditions and values above 7 indicate basic (alkaline) conditions. The pH of water can affect the rate at which plants absorb some herbicides. Knowing how the herbicide you are using reacts in a given pH range will help you select the appropriate rate to use. Some herbicides have increased activity in acidic waters, so you can use lower rates to obtain successful control.

Turbidity

Particles suspended in the water affect the water's ability to transmit light. This is called turbidity. The particles can be biotic (plankton), organic or inorganic (clay, minerals). Organic or clay particles are of most concern to the applicator because they can inactivate herbicides by binding to them. You should be careful not to increase turbidity by disturbing the lake or pond bottom with the boat. Particulates in diluent water can also affect herbicide performance and even render chemicals ineffective. Always use diluent water that is as clean as possible and be careful to keep the suction end of a filler hose far enough from the lake bottom to avoid drawing in sediments.

Hardness

As discussed previously, water hardness is a factor of dissolved calcium, magnesium, iron and strontium. Knowledge of water hardness is important to the aquatic pest manager because it can have important effects on herbicide performance and environmental considerations.

Certain herbicides can react with hardness components in water. This may cause them to become inactive or precipitate (come out of solution). This can happen either in lake water or in the spray tank. Consult with your chemical representative for details specific to each pesticide product. If possible, using softened or distilled water might aid in the efficacy of certain treatments — glyphosate applications, in particular.

The herbicidal properties of copper are very sensitive to hardness compounds in water. Inorganic copper algacides are much more potent in soft water (<50 ppm calcium carbonate). Application rates must be adjusted downward accordingly to avoid nontarget impacts, especially to fish. When using copper in hard water, chelated forms of copper are much more effective because they stay in solution longer, are more readily absorbed by plants and are less toxic to fish.

Water chemistry is an important factor in the performance of herbicide applications. You have some influence over some of these factors, especially the source of diluent water for tank mixes. Take the following precautions when obtaining water for tank mixes:

- a. Use the cleanest water available. Avoid sediments.
- b. When tank mixing herbicides that are known to be inactivated by hard water, use the softest water available. If possible, use softened or distilled water; lake water is the next best choice. Avoid using well water.
- c. Minimize the amount of time that herbicides remain mixed in tanks.
- d. Read the label for special precautions or instructions.

Effects on Fish and Other Organisms

When used properly, aquatic herbicides are not toxic to fish, birds or other aquatic organisms. They are also short lived in the environment and do not accumulate in organisms. Under certain circumstances, however, fish kills can occur as a direct or indirect result of aquatic herbicide applications.

Fish kills are likely to occur as a direct effect of herbicide application only if a herbicide

formulation known to be toxic to fish is applied in an enclosed water body. This type of herbicide should never be used where fish cannot escape toxic concentrations. When coves are treated, application should begin near shore to give fish an opportunity to escape. Most aquatic herbicides have very low toxicity to fish, and the concentrations that occur after application of recommended rates is far below concentrations that are toxic to fish. Rates of copper sulfate recommended for difficult-to-control filamentous algae can be toxic to fish in enclosed ponds, however, and care should be taken when making this type of application.

The most common reason for fish kills due to aquatic herbicide application is the indirect effect of lowered dissolved oxygen (D.O.) in the water. When performing any herbicide treatment, it is vital to limit the amount of vegetation killed at any one time. When a herbicide application kills large amounts of aquatic vegetation, the decaying vegetation and lack of oxygen production may cause D.O. to become so low that fish cannot survive in the water. If a herbicide that is effective on higher plants is used, and phytoplankton is present, the potential for a fish kill is reduced because the phytoplankton will continue to produce oxygen. Review the product label statements — they may limit the percentage of the lake area treated during one application. See Figure 7-3 for effects of dissolved oxygen on warm-water pond fish.

The danger of fish kills is less in cooler water because it can hold more oxygen than warm water. For example, oxygen-saturated water at 65° F contains 9.2 parts per million oxygen, whereas water at 85° F contains only 7.5 parts per million oxygen.

To minimize the potential of fish kills, avoid herbicide applications to large areas of weeds, to warm water, during prolonged periods of cloudiness and in areas where fish movement is restricted. Manage large weed populations by a series of applications to portions of the water body, and/or treat during the spring when water temperatures are lower. As a rule, do not treat more than 30 to 50 percent of the surface area of any body of water at one time. If more than 50 percent needs treatment, treat only one-third to one-half of the area at any one time. Follow that with a second application two to three weeks later.

Herbicide-related fish kills, either direct or indirect, are not likely to occur as a result of partial area applications in large water bodies because if they can, fish will move to other parts of a lake to avoid adverse conditions. Nevertheless, take all precautions to avoid conditions that could lead to fish kills when applying aquatic herbicides.

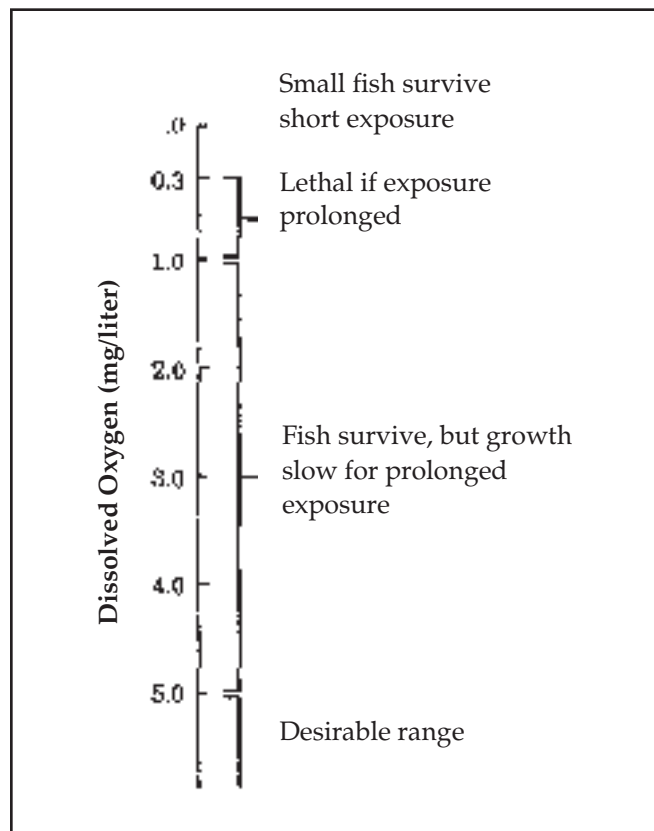


Figure 7-3. Effects of dissolved oxygen on warm-water pond fish.

Water Use Restrictions

The introduction of most aquatic herbicides into an aquatic environment requires restricting the use of the water until the herbicide has degraded, become inactivated or dissipated. Consequently, determining the present and potential uses of a body of water is one of the most critical steps in choosing an aquatic herbicide.

Restrictions on water use after a pesticide treatment are imposed for several reasons. Based upon data required for pesticide registration, residue tolerances, residue data and environmental fate, water use restrictions or precautions for drinking, swimming, fishing, irrigation, watering livestock and domestic uses may be placed on the label. This process ensures that the public will not come in contact with a herbicide at potentially harmful concentrations.

Water use restrictions also prevent people from disturbing the lake water and sediments which could reduce the effectiveness of the treatment. Compounds must be absorbed by the plants in large enough quantities to kill them. If swimmers enter the treated area before the plants absorb enough of the active ingredient, the sediment that they kick up may bind with the herbicide and render a treatment ineffective.

The period of restriction, which varies among herbicides, depends on the dosage and the persistence of the compound in the water. Some restrictions extend for only a few days, others may last for 12 months.

Other herbicide restrictions involve the type of water body to be treated. In many cases, a herbicide is restricted to a certain type of site, such as a pond (vs. a lake), an irrigation canal (vs. a drainage ditch), a ditch-bank (vs. a drainage ditch), a ditch-bank (vs. open water treatment), or non-flowing (vs. flowing) water.

Consult the Michigan Department of Agriculture and MDEQ regarding restrictions that may not be noted on the herbicide label. Restrictions are usually imposed for streams, public or multiple-use lakes, and reservoirs. Always consult herbicide labels and state agencies for detailed information.

Algaecides

Chemicals used to control algae are known as algaecides. Timing their application to obtain desirable results is critical. Treat with copper compounds on bright, sunny days when the algae are actively functioning and releasing oxygen. Early in algal bloom development, the algae may be dispersed throughout the water, whereas later the bloom may form a surface scum. Low concentrations of chemicals can be used to thin the algal populations during development. After a scum forms, treating only the upper 2 feet of the water with an algaecide is required. When treating algal scum, calculate the amount of chemical for the upper 2 feet, and spray it on the water surface or inject it just beneath the surface. This method can be used only with copper compounds. Because a rapid kill of algae can cause oxygen depletion, early season treatment when waters are cool and well oxygenated and algal populations are low is preferable to later treatments.

If treatment of attached algae is needed and the growth is underwater, the algaecide should be dispersed in the water. If mats of attached algae are floating, at least some of the compound should be dissolved in water and sprayed directly on the mats. Algaecides containing copper must come in direct contact with the algal cells to be effective.

Pesticide Fate

Aquatic pesticides have many potential fates. The most desirable fate is *absorption* by the target pest. If plants are your target pest, pesticides can be absorbed by the leaves, stems, flowers or roots. Generally, if they're not absorbed, the compounds will naturally degrade, either by *microbial action*

(bacteria and fungi), *chemically* (reaction with water and other molecules) or *photochemically* (sunlight), or by being chemically bound to sediments (adsorbed) and then broken down.

Microbial degradation (or *biodegradation*) is mediated by microorganisms that either change the compound into something else (*biotransformation*) or actually break it down to its elemental components. Biotransformation can change the original compound into one of either lower or higher toxicity.

Chemical degradation can occur through many pathways, the most common of which is oxidation (adding oxygen). Photochemical degradation, or *photolysis*, can also transform or degrade a pesticide. The process involves sunlight, either through direct interaction with the pesticide, or indirectly by sensitizing another compound that degrades the pesticide through the process of energy transfer. Adsorption is the process by which the pesticide is physically and/or chemically bound to soil particles. This occurs most frequently in soils with high organic matter content.

Once it's adsorbed to particulate matter or sediments, the pesticide can be broken down by one of the processes described above, either while still bound to the soil particles or after being released (*desorbed*). Adsorption to bottom sediments causes a herbicide to be unavailable. This is undesirable if toxic concentrations to the target plant were not reached or retained long enough for an effective treatment.

Other undesirable fates of pesticides remove or lessen the amount of pesticide available for the intended purpose. *Drift*, through the movement of water or wind during application, can not only lessen the amount available but can potentially harm nontarget areas and species. Applicators are liable for damage caused by drift to nontarget sites. Some pesticides are *volatile*. The more volatile a substance is, the more likely it is to have vapors associated with it as it evaporates. Few aquatic herbicides are volatile.

Timing of Treatment

Most aquatic herbicides are applied in mid- to late spring or early summer when the plants are young and growing vigorously and before they have gone to seed. Herbicide penetration and translocation are usually greatest before plants reach maturity. Not only are the weeds more susceptible at this stage, but there are fewer weeds to treat than there will be later in the season.

Another reason for early season treatment is that cool water contains more oxygen than warm

water and so provides a greater margin of safety for fish. Most aquatic herbicides should not be applied when the water is too cold (below 60°F), however. Though plants grow at these temperatures, they may not be metabolizing rapidly enough to take in sufficient quantities of herbicide for the herbicide to be effective. Treatment should also be delayed when there is a chance that heavy spring rains will wash the herbicide out of the target area or off the target plant. Consult your label for specific restrictions.

Except when preemergence herbicides are being used, plant growth should generally be visible at the time of treatment. Evidence indicates that autumn treatments of some species of submersed weeds are effective. For most species, however, plants have produced by fall seeds or algal spores, from which new plants will grow the following season.

Chapter 7 – Herbicide Technology and Application Considerations Review Questions

Write the answers to the following questions, and then check your answers with those in the back of this manual.

- Which statement regarding aquatic herbicides is false?
 - Their formulation consists of an organic or inorganic active ingredient, an inert carrier and perhaps adjuvants.
 - Every herbicide must be registered for use in the United States by the Environmental Protection Agency.
 - About 200 herbicides are registered for use on aquatic sites in Michigan.
 - None of the above.
- List seven of the considerations in planning a successful aquatic herbicide program.
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- Contact herbicides are generally more effective on perennial and woody plants than on annual herbaceous plants. True or False?
- Explain the differences between a contact herbicide and a systemic herbicide.
- When are herbicides that affect cell division most effective?
 - When the plant has reached full maturity.
 - During the plant's early growth period.
 - Before the weed seed germinates and begins to grow.
 - Both a and b.
 - Both b and c.
- A herbicide that causes abnormal plant tissue development is a _____.
- Which is an example of a herbicide that is used to control all or most vegetation?
 - PGR
 - Broad spectrum herbicides
 - Selective herbicides
 - Both a and c.
- Which will intercept and retain a greater amount of herbicide?
 - Narrow, upright leaves.
 - Broad, horizontally oriented leaves.
- Which statement about environmental factors affecting herbicide applications is false?
 - Washing foliar-applied herbicides off the plant before they can be fully absorbed is the most obvious effect of rainfall.
 - Windy conditions can affect the efficacy of submersed weed control by causing water movement.
 - High temperatures cause the plant to decrease herbicide absorption and activity.
 - Applications should not be made when the wind is strong enough to cause drift.
- The condition that occurs when particles suspended in the water affect the water's ability to transmit light is called _____.
- The introduction of most aquatic herbicides into an aquatic environment requires restricting the use of the water until the herbicide has:
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