Chemicals for the Control of Aquatic Weeds

Results of another *Weeds and Turf* field research project

APPLICATORS generally agree that an inexpensive, fast, dependable mechanical method of aquatic weed control is highly desirable.

Mechanical methods would eliminate many of the variables encountered in chemical control, and concern over water temperature, fish kill, water pH, etc., would be unnecessary if weeds were simply removed from water mechanically.

No such method, meeting all of these requirements, has been found, however.

Some attempts have been made, and some degree of success achieved, with nonchemical weed elimination, but the factor of economy in time, labor, and equipment has not been overcome. Mechanical methods are slow and cost operators and customers a great deal.

Chemical Curbs Most Economical

To date, the most economical methods for aquatic weed control are chemical ones. Chemicals are applied onto vegetation or introduced into water in amounts sufficient to kill unwanted growths.

Two general methods of control are followed. Chemicals may, first of all, be applied as liquids in one of several ways. They may be applied, in the same manner as terrestrial herbicides, to exposed vegetation and soil during a drawdown (lowering of the water level). Diluted liquids may be sprayed over the surface of the water or onto emersed vegetation as contact herbicides. Or concentrated herbicides may be poured into water so that toxicants will yield a predetermined final concentration upon dilution. In other cases it is necessary to inject chemicals through tubes or nozzles under water to give the desired distribution and concentration.

Granular application is the second method. Granules may also be applied to bare soil during a drawdown. They may be broadcast onto water by hand or by machine so they sink into water and dissolve and/or disintegrate to form the desired herbicidal concentration. In some cases where it is desirable to attack roots, granular methods work best. Granules may not be useful on thick matted vegetation because these particles do not readily penetrate the mat. Sometimes granules are evenly distributed on ice (maximum thickness suggested 8 inches) in late winter so that when the ice melts in spring (the time delay does not harm chemical effectiveness), the granules sink to the bottom. This technique works best as a complete treatment of a small water body rather than partial treatment of a large lake. On lakes there is the possibility that the ice pack may shift and misplace the granules.

Three Things to Watch For

After the contracted area has been surveyed, weeds accurately identified, and chemical chosen to do the job, there are three very important points to be considered for successful control: timing, dosage, and application method.

Timing. When should the chemical be applied for best results? Optimum control periods when plants are most susceptible differ with each species. Generally recommendations say to apply chemicals before weeds flower, while they are actively growing. All species do not flower at the same time, so this must be considered when surveying a job where several species are involved. For nonflowering species, the rule is usually to apply controls while active growth is taking place. Submersed species are best controlled before they become too plentiful. Best time, then, will be in the spring, although it is true that some exceptional species are more prominent later in the season.

With certain species of blue-green algae, according to Bennett (1963), toxic substances are produced when the organisms become plentiful and die. Domestic animals and fish are killed during "blooms" of species such as *Anabena* and *Glaeotrichia*. Thus treating early can be economically important to a client considering factors other than amounts of chemical and time required to do a job.

A second point in favor of treating weeds before they become plentiful is that if a heavy stand of weeds is killed at once, there may be excessive decay of the plants. Decay requires oxygen and water may become deficient in oxygen if too many weeds are decaying at the same time. Lessened oxygen in the water may result in fish suffocation. This occurrence is said to be a greater hazard in aquatic weed work than toxicity of the herbicides. Oddly enough, fish suffocation will occur naturally in late summer in infested lakes when water levels lower, and weeds begin to die. This occurrence indicates that the particular water body had too many weeds for the fish population. In fishing water, weeds should be kept at a level sufficient to provide oxygen in summer, but insufficient to cause oxygen depletion when weeds die in the fall.

If one suspects that treatment of a large stand of weeds may result in oxygen depletion, because

Mechanical control of aquatic weeds is too costly for wide use, and is frequently unsatisfactory to applicator and customer alike. But while chemical methods are effective, great care must be exercised in handling and application. This article, second in a series of three which began last month, outlines the types of compounds now available for water weed work. The third and final installment, on equipment and techniques, appears next month.

of decomposition, a waiting period is advised between partial or band treatments. Or spot treatments may be made. These are equally safe to fish and just as practical and effective.

Second point to be considered is *dosage*. How much should be applied to get the desired control and keep fish kill at zero? To obtain proper dosage figures, the area to be treated and the volume of the water body, must be calculated to determine chemical concentrations necessary to give the accepted recommendations.

Dosages for aquatic weed control are often stated in parts per million (ppm) of active ingredient which may be by weight, in pounds, or by volume, in gallons.

One part (pound) per million (pounds of water) in an acre of water one foot deep is 2.7 pounds (there are approximately 2,700,000 pounds of water in one acre-foot of water).

One part (gallon) per million (gallons of water) is 0.3 or 1/3 gallons, since there are approximately 300,000 gallons of water in an acre-foot (43,000 cubic feet of water).

Volume measurements are written "ppmv"; weight measures, "ppmw" (formerly simply ppm).

Tables or charts of dosage recommendations for various weeds will always be found on product labels. Sometimes in research bulletins recommendations are expressed in terms of active chemical and not by product. Often a single chemical can be found in various formulations under many trade names; researchers will usually use the chemical common name to avoid reference to registered trademarks. Operators who get the best buys and best results are those who read the label for the information about the chemical active ingredient.

The following descriptions of the major chemicals used and their phytotoxicity to aquatic weeds will help applicators decide which may be best suited to their jobs, and give novices a basis for further study of aquatic weed control. *Application methods* is the subject of the concluding installment of this series.

Specific Herbicides for Specific Weeds

An applicator may try to get results by using only one chemical for all jobs, but both his and his customers' satisfaction may not be as great as if he had chosen the particular herbicide suited to each job, and each customers' needs.

Sodium Arsenite

Sodium arsenite is an inorganic arsenical that has been used extensively for aquatic weed control. It is more effective on submersed weeds which do not have a waxy covering (Klingman 1961). It is usually applied as a spray and at times is injected under water for better distribution and to reduce the exposure hazard to operators.

For best control, sodium arsenite should be applied early in the growth season, when plants are actively growing.

Rates of 3 to 7 ppmw, depending upon the weed species (rarely more than 10 ppmw) of arsenic trioxide (the active ingredient) are required against most aquatic weeds. Waterlilies, cattail, bulrushes, sago pondweed, chara, and nitella are not susceptible to sodium arsenite at the usual rates of application (10 ppmw arsenic trioxide). Rates greater than 10 ppmw are not recommended because of hazard to fish and warm-blooded animals.

Considerable care is required

when using sodium arsenite because it is very toxic to man and animals. Contact with undiluted sodium arsenite or even drift from spray applications can harm unprotected skin. This is due to the sodium hydroxide (caustic soda) used to suspend the sodium arsenite in solution. Exposed skin of operators should be protected with gloves, salves, or lotions. Goggles or masks should be worn to protect the eyes. Water with more than 0.05 mg per liter should not be used for drinking, bathing, or irrigation. All treated waters should be restricted from all uses for at least three days. Domestic animals should not be permitted access to treated areas for at least this period and until heavy rain has washed the chemical residue from shoreline vegetation. Sodium arsenite should never be used in potable (drinkable) water supplies or lakes or streams which supply potable water.

Sodium arsenite does not remain in water indefinitely. In larger lakes treated marginally concentrations are usually reduced to safe levels after 3 days (Reed, 1963). In smaller lakes and ponds that are treated completely, a wait of 7 to 14 days is advised before using the water for recreational purposes.

Researchers have shown that arsenic can be found in significant amounts in bottom muds after treatment periods (Barkeley 1962). This residual concentration may have some temporary effect on microscopic organism populations and has been shown to have a direct effect on fish spawning. Barkeley (1962) showed that the most critical period for fish susceptibility to small arsenic concentrations is soon after egg deposition. Even 5 ppmw of arsenic limited the number of fish which hatched. Later the same 5 ppmw did not affect small fingerlings. Dupree (1958) determined that muscle tissue of adult goldfish and bluegills was not affected by arsenic concentrations in mud; that is, arsenic was not stored in edible muscle.

Manufacturers of sodium arsenite for aquatic work, such as Chipman Chemical Company, producers of Atlas "A", recommend dosage rates of 4 ppmw of arsenic trioxide for small lakes (less than 2 acres), and 5 ppmw for lakes larger than 2 acres but less than 10 acres. For very large lakes, treatments in the range of 10 ppmw are said to be successful against vulnerable weeds. Treatments for some filamentous algae species of the surface scum type can be accomplished with 4 ppmw. Sodium arsenite is not generally effective on submersed algae. Shoreline treatments of large lakes require 7½ ppmw if the shores are protected from heavy wave action and 10 ppmw if there is no protection and hence likely to be a lot of dilution.

Copper Sulfate

Copper sulfate has been a widely used algicide since 1904. The copper portion (Cu ion) of this inorganic metal compound kills algae at low concentrations.

Copper sulfate may be broadcast on water in dry crystal form. It is available in several particle sizes; the size partially determines the rate at which the solid chemical will dissolve. Heavy copper sulfate crystals are used for treatment of chara and nitella algae because the crystals sink to the bottom before completely dissolving. This builds up a higher concentration on the bottom where it will do the most good.

Filamentous algae are usually treated with a fine granular form of copper sulfate, which dissolves as it sinks in relatively shallow water.

Planktonic algae are treated with a fine dust or "snow" form so that copper is concentrated just under the surface.

With regard to rates, MacKenthun (1960) states; "Solubility of copper in water is influenced by pH and alkalinity, as well as temperature, and the dosage required for control depends not only on these factors, but also upon the species or genus variation of the organisms, and their resistance to copper sulfate." Dosage should be carefully calculated to include all of these factors so all troublesome species are controlled. If dosage is not figured properly, there may be an outbreak of an uncontrolled species after removal of a dominant species eliminates competition.

Although fish are killed at low rates in soft water, higher rates may be necessary in hard waters because the copper unites with negatively charged mineral ions and settles out. That copper which settles out will not kill weeds nor harm fish significantly.

Liquid spray systems may also be used to apply copper sulfate solution. This solution is corrosive and will damage galvanized tanks. Stainless steel, copper-lined, or other specially treated tanks are advised.

A less efficient application method which eliminates danger to sprayers is the burlap sack method. After the proper dosage rate has been determined, the required quantity of copper sulfate can be put in a gunny sack and towed across the water by a boat until the chemical is dissolved. This method also eliminates expensive equipment, although it is no less exacting.

In potable water supplies, copper sulfate concentration cannot exceed 3 ppmw of the copper ion, which is equal to 7.5 ppmw of copper sulfate, according to the standards of the U. S. Public Health Service (1946).

Best application time is in early spring before algae become plentiful enough to cause trouble. For hard-to-kill species, some researchers suggest multiple applications of lower rates rather than one heavy dose. Algae samples can be taken and observed under a microscope. From these samples, applicators can determine when populations reach the stage where they can be efficiently controlled. Copper sulfate is not a preventive treatment; that is, applications will do no good if there are no algae present to kill. Copper does not remain in water over a period of time to serve as a "pre-emergent" herbicide. Application of controls at a time when algae are just beginning to be abundant will stem outbreaks or "blooms" later in the season. This early application also reduces possibility that later sudden kill of heavy algae growth may deplete water oxygen content and pose a hazard to fish. Mackenthun (1958) states: "Summer fish mortalities occurring in many lakes throughout the country are a rather common occurrence and some are caused by this type of [algal decomposition] phenomenon."

2,4-D

The growth regulator 2,4-D has been used widely and successfully in its many forms against many aquatic weed species. Knowledge of the various forms is useful, because each form requires special applications and may work better against one species than another, or better in one situation than another.

Before going into the different forms of 2,4-D, differentiation between volatility and drift may be helpful.

Volatility is the ability of a

chemical to vaporize. Vapors may be carried on air currents to damage desirable crops or other plants.

True spray mist drift occurs when improperly applied chemicals are atomized by too high spray pressures. The particles or droplets formed by impact with air may float through the air to harm plants.

Low or nonvolatile chemicals may reduce the tendency of a chemical to vaporize and cause damage, but it does not eliminate the possibility of damage through drift. Drift is controlled by proper calibration of spraying pressure and proper choice of nozzle type.

2,4-D is produced in the acid form (2,4-dichlorophenoxyacetic acid). Modification of the acid portion of the molecule imparts to 2,4-D characteristics which make it more useful for purposes of aquatic weed control. Differences are generally in the form of increased or special solubilities or lower volatilities.

Crude 2,4-D has a low solubility in both water and oil. It is wholly unsuitable for use as an herbicide. To facilitate ease of handling and application, the 2,4-D acid is formulated into either an ester or an amine salt.

Salt formulations are obtained by neutralizing the 2,4-D acid with a salt to form a water-soluble amine. Sodium, potassium, and ammonium salts of 2,4-D may be sprayed in a water carrier or injected directly into water. They are not considered hazardous with respect to volatility.

Amine salts of 2,4-D, such as the alkylamines(di- or trimethylamine, di- or triethylamine) and the alkanolamines(di- or trimethanolamine, di- or triethanolamine), have somewhat higher water solubility than the sodium, potassium, and ammonium salts. Amine salts are also nonvolatile and have uses in common with these metallic salts. Amine salts, however, are generally more toxic to fish than the metallic salts (sodium and potassium).

Ester formulations are made by reacting the pure 2,4-D acid with an alcohol in the presence of a catalyst. This process is known as esterification. Depending upon the type of alcohol used in the reaction, the resultant formulation will give the appropriate ester of 2,4-D. For example, if the acid is reacted with isopropyl alcohol (rubbing alcohol), the resulting ester will be the isopropyl ester of 2,4-D.

A series of ester formulations (methyl, ethyl, isopropyl, butyl) are soluble in oil but not in water. These are volatile and hazardous to use near desirable crops or ornamentals. A more complex series of ester formulations having lower volatility includes the isooctyl (2 ethyl hexyl), butoxyethanol, and the propyleneglycolbutyl ether esters of 2,4-D. All ester forms must be emulsified for use in water. The addition of certain emulsifiers makes them especially toxic to fish because emulsifiers are themselves usually toxic.

Formulations of the water-soluble salts, including the amine salts, usually have surfactants added by the manufacturer to enhance penetration and absorption into plants. On especially hard-to-wet plants (those with waxy or hairy leaf surfaces), it is often necessary to add a wetting agent to the spray solution to overcome such penetration barriers. Ester formulations applied in oil penetrate plants very quickly and are more effective at lower rates than are the salts of 2,4-D.

Granular forms of 2,4-D for aquatic work will generally be a low-volatile ester such as the isooctyl. Granular formulations are becoming more widely used in still waters since they kill more completely in less time and often give longer lasting control through residual activity in bottom muds.

Since very small doses of 2,4-D will harm crop plants, treated water must not be used for irrigation.

Dacamine

A new product called Dacamine, produced by Diamond Alkali Company, is a special formulation of 2,4-D. Dacamine is said to be both water emulsifiable and oil soluble and to combine the effective penetration of ester forms of 2,4-D with the lack of volatility (toxic vapors) of normal amines. It is used in the same way as foliage-applied 2,4-D and is available in packages of 2 and 4 pounds of active ingredient per gallon of formulation. Dacamine is more viscous at lower temperatures than normally viscous esters of 2,4-D. The 2-pound material is less viscous than the 4-pound package. Viscosity does not change effectiveness of the herbicide, which is measured by the amount of 2,4-D acid per gallon.

Reports of the success of this new formulation come from Florida and Arkansas. Researchers report good control of alligatorweed in drainage ditches and waterways with 2 pounds of active material per acre. Waterplantain (*Alisma* sp.) was controlled in waters around rice fields with ¼ pound active per acre (Marrese and Sprayberry, 1963).

Silvex

Another growth regulator herbicide is 2,4,5-TP or silvex. Silvex behaves in much the same way as 2,4-D as far as translocation is concerned. Its method of killing is also the same, i.e. physiological imbalance and eventual death.

Application of the potassium salt of silvex, at 2 ppmw and under, gave good control of several higher aquatic plants in tests conducted by Gaylor and Houser (1962).

Results were obtained when silvex was poured into water before plants began to flower, while they were actively growing. Plants controlled were southern naiad, coontail, and American pondweed (*Potamogeton nodosus*). Chara, an alga, was not controlled by silvex since the compound has little effect on algae. Other weeds normally controlled with potassium silvex are: watermilfoil, elodea, cabomba, and waterlilies.

At recommended rates (3 ppmw and less), silvex is not dangerous to fish or warm-blooded animals. Ester forms cause taste problems in fish harvested for food. There is no taste change when the potassium salt of silvex is used. Of course, treated water must not be used for irrigation because of the herbicidal effect on desirable plants.

Esters of silvex can be applied to marginal vegetation in the same manner as to dry land growth, that is, used at the rate of approximately 1 gallon per 100 gallons of water with the vegetation sprayed to wet.

Dalapon

Dalapon is an herbicide effective against grassy weeds. It is generally applied to foliage, so it will be translocated throughout plants, rather than applied directly onto or into water.

For application to plants such as cattail, Timmons et. al. (1963), working in the West and Northwest, found that the sodium salt of dalapon applied at 20 pounds active acid equivalent per acre gave good control.

With the addition of diesel oil and an emulsifier or a wetting agent, the effectiveness increases.

Dalapon action decreases the

production of a waxy covering on leaves of cattail, according to Crafts (1961), and Timmons' research agrees in that wetting agents are not as important when doing a dalapon re-treat.

Timmons also found that mature cattails standing in some water are less resistant to single herbicidal applications of the sodium salt of dalapon. Klingman (1961), working in the East, on the other hand, states that cattail is best controlled with dalapon at 5 pounds per acre plus amitrole at 2 pounds per acre, with the cattail not standing in water. Controls are applied between flowering and seed formation. These variant research results could be due to different cattail species, or different weather conditions, or other conditions which might vary with geography.

At usual application rates, dalapon has no toxic effect on fish. Its toxicity to man compares with that of table salt, still it should be applied with caution and respect.

Diquat

Diquat is a new product being developed by California Chemical Company, Ortho Division, for application to water for control of floating and submersed nuisance weeds. It is a quaternary dipyridyl compound and is formulated to have 2 pounds of active ingredient per gallon.

Diquat is absorbed rapidly by leaves or roots and is distributed through the plant system. Diquat toxicity is triggered by sunlight which controls plant photosynthesis, that is, it will kill faster on a sunny day than on a cloudy day. Diquat may be applied to plants either as a foliage spray or as a concentrate poured into water.

Diquat is relatively nonselective, nonvolatile, has a low toxicity to fish at rates prescribed, and is about as toxic to man as 2,4-D. Treated waters are not to be used for human or animal consumption nor for irrigation for 10 days following treatment.

Diquat should not be applied if infested water is muddy because diquat is deactivated by contact with soil and also by contact with clay particles suspended in water.

Acrolein

Acrolein is a general cell toxicant used for aquatic weed control. Although it is highly flammable, highly reactive chemically, with an odor like tear gas, submersed weeds can be effectively controlled with acrolein. Application equipment which eliminates handling of the chemical reduces discomfort to operators and makes application safer. Acrolein is present at 85% concentration in the product Aqualin, marketed by Shell Chemical Corporation.

Acrolein is a fast-acting plant killer. Plants cease to generate oxygen minutes after acrolein is introduced into warm water (80°F). Cell breakdown and plant collapse follows in a few hours. In cool water, toxic effects may not be evident for 1 or more days.

Acrolein is effective against a wide range of weeds, but the compound must be injected as a solution under water for use against all types of weeds whether floating or submersed. Acrolein has been highly successful against weeds in canals and irrigation ditches in western United States. The chemical is usually applied from a stationary platform or boom in a canal. Rates are judged on volume and velocity of water passing the application point.

Depending upon temperature, water velocity, or species and density of weeds, acrolein is applied at various rates over a period of time from spray nozzles under water. The herbicide is "used up" as the blanket of treated water moves downstream, because of absorption of the chemical by the weed tissue and vapor loss. Therefore, in long canals it may be necessary to "reinforce the wave" at points downstream from the original application. Under certain conditions operators may expect effectiveness of acrolein up to 15 miles from application point, depending upon the species and density of the weeds.

Fish may be killed by acrolein at rates from 1 to 5 ppmv, depending upon the species. Fish will swim away from an acrolein blanket, and band or partial treatments of lakes with acrolein have been successful. Fish are given more of a chance when alternate swaths are treated after a 48-hour wait.

The quick kill and rapid detoxification or degradation of acrolein is an advantage when this chemical is used for complete lake renovation. At high rates, all fish will be killed and the lake can be restocked in a matter of days.

Aromatic Solvents

Some oil companies produce solvents such as naphtha, xylene, and benzene products suitable for control of submersed weeds in ditches and canals. These are chemicals with properties similar to paint thinners and drycleaning solvents. With emulsifiers added, these chemicals make relatively inexpensive aquatic herbicides.

Aromatic products are toxic, in low concentrations, to plant and animal life in streams. These products are also flammable and must be applied with care. Equipment for application is relatively simple: tank, pump, and nozzle boom. Many times it is advised that carbon dioxide be used instead of a pump to reduce fire hazard. If gravity feed can be used to introduce solvents, equipment is simplified even more.

Rates of use with aromatics are high compared with previously discussed herbicides. Weed kill is based on the velocity of water and the time that the blanket of treated water is exposed to the plants.

Endothall

Endothall is a contact herbicide and is the basic ingredient for three aquatic weed control products sold by the Pennsalt Chemicals Corporation.

Disodium endothall is the active ingredient of the product Aquathol. This fast-acting chemical (kills weeds in 3 to 7 days) can be used as a spray, granular, or injected liquid. It is effective against many common weeds found in lakes and ponds. Recommended rate of endothall for treatment of an entire area is 1 to 3 ppmw. Partial treatments where extra dilution must be considered require 2 to 5 ppmw. Endothall leaves a considerable margin of safety for fish; toxicity of endothall to fish is between 100 and 200 ppmw, depending upon species, age, water temperature, etc. Fish from treated areas may be eaten three days after treatment. Lakes or ponds may be used for swimming 24 hours after treatment.

Another inorganic salt, dipotassium endothall is combined with the potassium salt of silvex to produce the herbicide Aquathol Plus, which controls some additional weeds not controlled with endothall alone, such as elodea, cabomba, and waterhyacinth.

Action of Aquathol Plus is both

contact and systemic; some weeds are killed faster than others, the most resistant taking up to four weeks. Some emersed species such as arrowhead, burreed, and water-primrose will be killed with Aquathol Plus also. This formulation also leaves a margin of safety for fish.

A much more active aquatic herbicide is formed when endothall is formulated as the amine salt. The products Hydrothol 47 and Hydrothol 191 will control weeds with concentrations of 0.5 to 2.5 ppmw. The amine salts are more toxic to fish also (concentrations of 0.3 ppmw to 1 ppmw may kill them). Partial treatments with this chemical eliminate the danger because fish swim away from treated areas.

Hydrothol 47, at high rates, can be used for pond renovation. Complete kill of weeds and fish is quick and restocking can take place one or two weeks from treatment depending upon the extent of infestation.

Applicators are not expected to pick a single chemical from this partial list to do all jobs. Numerous chemicals are available and all have advantages and disadvantages depending upon what job needs to be done. From job to job, conditions will vary; desires of clients will vary widely also.

Check State Water Laws

Before any chemicals are applied to any waters, operators should seek information concerning state laws with regard to application of herbicides to water bodies. States such as Wisconsin and Minnesota require that an officer of the Water Pollution Board or the Conservation Department be present when chemicals are applied.

Some states simply require a permit, with all pertinent information submitted when the job is to be done. This information usually includes the size and location of the lake, inlets and outlets, the nature of the nuisance, the chemicals which will be applied and their concentrations. These laws make certain that contracting applicators know their business.

In the third and last installment of this series, we shall cover equipment and application techniques used in aquatic weed work. A bibliography is included with the final section, to be published next month.

Know Your Species

SAGO PONDWEED

(Potamogeton pectinatus)

Sago pondweed, one of the most costly water infesters, is also one of the most difficult to eradicate of all potamogetons.

Sago pondweed has adapted to many types of water conditions and this influences the losses it can cause. Irrigation ditches in the West are subject to infestation by sago pondweed. This rooted perennial grows so thickly that stands often block flow of water in irrigation ditches and thus damage crops needing water. Sago is the only pondweed that is resistant or tolerant to reasonable amounts of sodium arsenite. For this reason, identification must be accurate.

Sago is a very bushy pondweed with long, rounded, and many-branched stems. Stems are not upright; rather they are limp and bend with currents. Heavy infestations in lakes hinder wave action and contribute to stagnation.

Branching from stems are the slender leaves, distinctive in that they are rounded and threadlike, and taper to a point. In flowing water, groups of leaves are fanlike.

Small flowers are borne atop a spike which protrudes from the water only during blooming. It is an extension of the mainstem and does not arise from the juncture of leaf and stem. Pollen from this flower is carried by wind. The seeds of sago provide excellent duck food; this plant is protected and sometimes propagated on many waterfowl refuges.

Although sago pondweed produces an abundance of flowers with viable seeds, a major means of its spread is by root-runners or rhizomes. These runners give rise to many offshoots over a wide area. Very few plants can thoroughly infest relatively large areas. In summer, some root-runners produce tubers which overwinter and sprout new pondweeds the following spring.

Sodium arsenite, which controls other pondweeds, will not control sago pondweed. Some of the newer aquatic herbicides, such as endothall and Diquat, have proved successful and are being used against this widespread pest. Aromatic solvents and acrolein are used extensively in western irrigation canals and drainage ditches to control this nuisance plant.

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Drawing courtesy of the Regents of the University of Wisconsin, from N. C. Fassett, A Manual of Aquatic Plants, 1960, the University of Wisconsin Press.