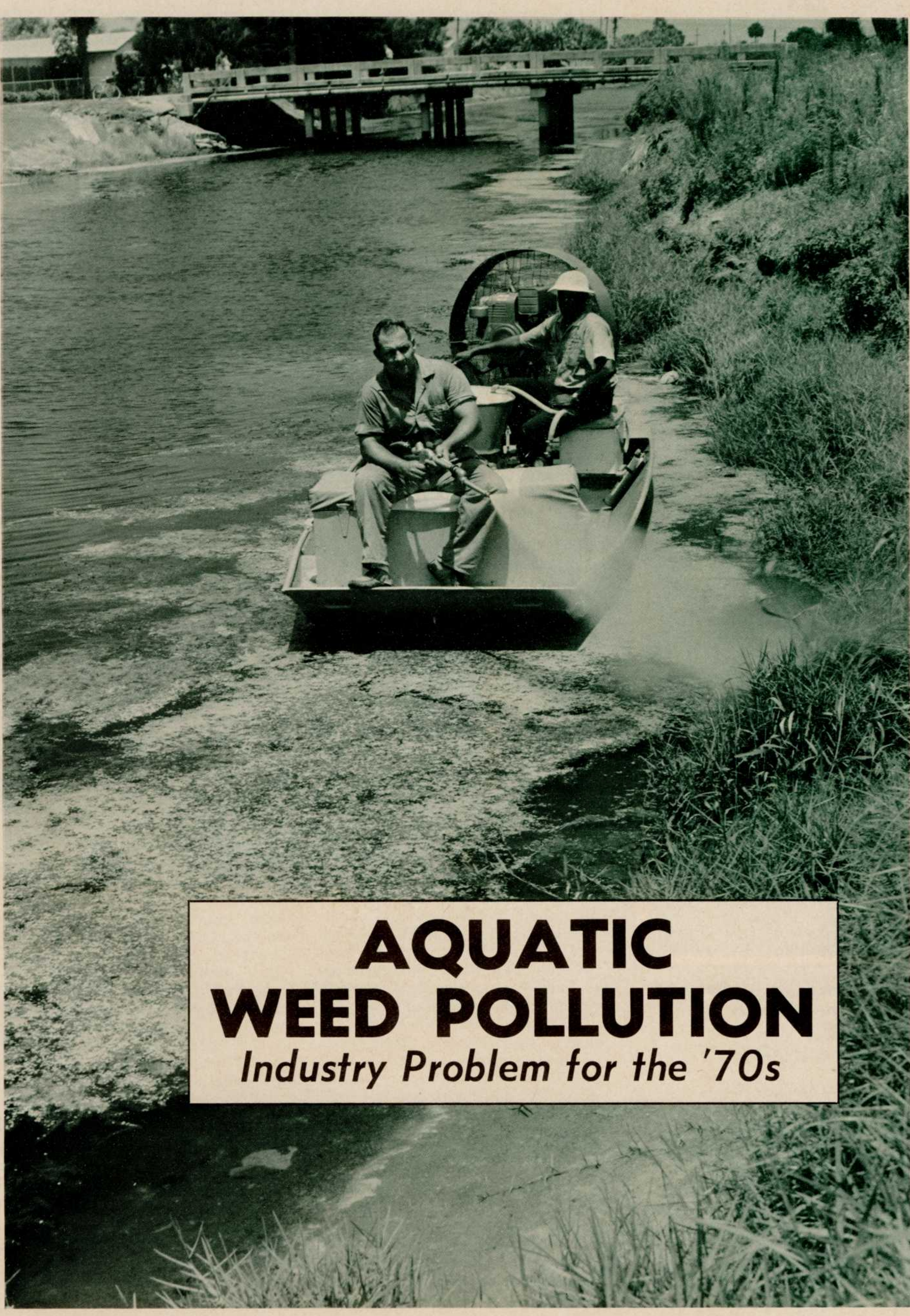

AQUATIC WEED POLLUTION

Industry Problem for the '70s

AQUATIC WEED CONTROL

AN INDUSTRY GROWS

By John E. Gallagher
Amchem Products, Inc., Ambler, Pa.

Gallagher: We now realize the necessity of a total environment concept."

GOING BACK beyond the introduction of 2,4-D to compare the early arsenal of water weed killers with the herbicides available today, it seems a little shocking to see that we still use sodium arsenite, copper sulfate, and aromatic solvents. This is not because they are perfect herbicides and no new ones have come along, but rather an indication of changes in policy to prevent too-rapid introduction of herbicides into our waters. There is a great deal of research under way — work that reflects the cooperative action of many agencies. Federal, state, and industry workers are quite often directly involved in a single project because the multiple-use concept of water utilization requires multiple responsibility for finding answers.

Recent renewal of USDA-ARS activity in aquatic weed control indicates the expanding need for answers beyond those of early work with irrigation and drainage areas of the United States. The amount of work was increased tremendously in 1957 when the Ft. Lauderdale, Florida, facility was established and research personnel were shifted to other weed problem areas. ARS soon found itself deeply involved in all phases of aquatic weed control.

The U. S. Army Corps of Engineers, responsible for keeping navigable waters open, had long been battling water hyacinth. In 1958 a bill authorizing an extensive aquatic plant control program involving eight states released funds for joint research projects and was responsible for the movement of research people into the field of aquatics. Another agency, Tennessee Valley Authority, suddenly has found itself the major experimenter in Eurasian milfoil control, putting increasing manpower and hours into resolving the ever-expanding problem in the chain of TVA lakes.

U. S. public health and water pollution agencies are becoming involved either directly in monitoring programs or indirectly through grant-in-aid programs such as the work being conducted by Dr. John Lawrence at Auburn University in Alabama. This work is concerned with the relationship of weed growth and water pollution. Perhaps the catalyst in the whole resurgence of interest in aquatic weed work is the developing philosophies of the new Environmental Protection Agency. The concern over what is going into our waters is requiring far more complex tests now than ever before. We in industry have to account for residues in waters as well as in fish. We are now concerned with effects on fish production and the total food chain. We are doing research to investigate possible effects on crops irrigated with treated waters and may concern ourselves with stock watering and human consumption.

Submersed Weed Species

Early aquatic weed control work was primarily with pondweed species in western irrigation canals. The species most frequently subject to test was sago pondweed *(Potamogeton pectinatus)*.

Recently (that is, over the past ten years), aquatic weed research has also been oriented toward other submersed species. The rapid spread of Eurasian milfoil *(Myriophyllum spicatum)* throughout the United States, and the more regional problem of Florida elodea *(Hydrilla verticillata)* has caused a marked increase in the number of projects proposed and carried out.

The problem of Eurasian milfoil has been receiving the greatest amount of attention judging by the scale and number of agencies involved. TVA, U. S. Army Corps of Engineers, USDA, the U. S. Department of Interior, the Florida Game and Fish Commission, as well as many individual states, are working to control Eurasian milfoil.

The rapid spread of milfoil following its normal pattern of unobtrusive introduction, a 3- to 4-year period of establishment, and a sudden crisis situation, has been responsible for several crash programs attempting to stem the tide. Perhaps the most fortunate characteristic of milfoil is its susceptibility to 2,4-D, established early in the USDI research program conducted by Steenis in the late 1950's. Recent efforts have been directed toward developing new application methods

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AQUATIC WEED CONTROL

USING AVAILABLE TOOLS

By Andy L. Price
Asgrow Florida Co., subsidiary of Upjohn, Plant City, Fla.

TREATMENT of submersed aquatics is done by one of the following tools: (1) Research—knowledge is a tool provided by research to guide us toward our goal of proper vegetation management; (2) Biological, (3) Chemical, and (4) Equipment.

Research is the prime factor of our survival. The weed problems and areas are known. As we become better informed citizens and learn to restrict our importations of noxious flora and fauna, research will provide us with the necessary tools to survive and master our environment.

Biological tools presently available range from *Marisa* snails to species of the carp family which feed upon submersed aquatics to the *Agasicles*,n.sp. beetles feeding on alligator weed. The use of biological tools is still largely in the hands of Federal and state research agencies seeking more data prior to full scale introduction.

Wholesale importation and use in the United States by well meaning, but perhaps uniformed civic lake and waterway associations of biological organisms could produce disasterous results. It is urged, therefore, that the public obtain council with their state and Federal agencies prior to purchasing any biological control agents.

In the case of herbicides, we need to overcome the image of the skull and cross-bones of past decades and begin to light a candle rather than continue to curse the darkness.

The term herbicide should be stressed to overcome public misinformation of pollution in our environment.

Today, aquatic herbicides are commercially available in either granular or liquid formulations. Thickening agents are rapidly becoming a useful tool for the applicator to work under more adverse conditions with greater safety. Granular formulations are particularly useful on marginal aquatic problems along shorelines. And in specific cases for whole lakes where the granular fromulation control rate is based upon surface acres rather than a depth factor. The weed species being combated and the locale determine the herbicide to choose.

Liquid formulations offer more rapid weed control and in many cases are less expensive to apply. From an applicators view the liquid form's ability to disperse often enables his to achieve control in inaccessable areas.

Equipment—I use the term equipment rather than mechanical control since the control of noxious weeds is attained only when the plants are contacted by a hyacinth bucket, mower blade, or sprayed by a herbicide. Therefore, in essence anything mechanical is merely a carrier to bring about control.

In the aquatic field, application control equipment is unique, in the sense that there are few, if any firms presently producing tools specifically for aquatic use. To qualify this statement, there are known firms producing drag lines and aquatic harvesting mowers, but almost nonexistant are firms which produce a packaged aquatic herbicide application unit.

The aquatic applicator of necessity must research and develop his own equipment to treat specific weeds in specific locales. Many units now in use represent years of trial and error and a great deal of expense.

The candle has been lit and with the cooperation and coordination of all segments of the industry and the public we can regain usage of our lakes and rivers—our 'Wilderness Lost."

Price: "Methods will be forthcoming to regain usage of our lakes and rivers."

AQUATIC WEED CONTROL

THE STRIP METHOD

By L. E. Bitting, Sr.
Old Plantation Water Control Dist., Plantation, Fla.

Bitting: "The strip method can be utilized in many problem situations."

NOXIOUS SUBMERSED WEEDS in the waterways of Old Plantation Water Control District must be controlled or its drainage facilities, developed at great cost for the express purpose of protecting homes and industry from flooding, will be useless.

In past years when Southern Naiad was our number one problem, and before weed control was begun, water stage differentials of three and one-half feet over a reach of one and three quarters miles at times continued for almost two weeks. In such a situation, modern and adequate drainage pumps were idled for lack of water, while nearby lands were flooded.

Now, Hydrilla, a harder to kill plant having phenomenal regenerative capabilities, poses an even greater threat. A typical marginal infestation of Hydrilla, if left unchecked, will cover a canal from bank to bank and from bottom to top. Small canals in remote areas may reasonably be given a full volume herbicide treatment and good control is obtainable with predictable results. However, large volume waterways in urban areas demand completely different management.

STRIP TREATMENT

Although marginal strip treatment is not a new concept in aquatic weed control, it may be helpful to note some of its advantages and disadvantages for those who contemplate its use for the first time.

This method is economical because only a portion of a given waterway is treated to control concentration, and if treatment is begun before weeds cover the entire submerged area, this may be enough to halt their spread. Damage to aquatic organisms is vastly reduced as compared with full volume treatment, and the normal ecological balance is soon restored.

Some faults of the strip method are: There is occasionally poor or no control due to dilution; adverse effects of the variables in weed control tend to be magnified, thus loss of time and material is more frequent; unharmed plant segments provide material for reinfestation; it is more difficult to plan efficient rates and application procedures because of irregularities in weed stand, depths, flows, cross-sections, etc.

APPLICATION

As an example, the infested margin of a canal was measured and found to average 20 feet in width and 8 feet in depth, thus an imaginary triangle with a cross-section of 80 square feet. Our aim was to treat this section with Acrolein at the rate of 7 p.p.m./v. Treatment was begun on June 25, 1968, with others following periodically and with rates running from 7 to 9 parts per million.

RESULTS

In seven days, plants were defoliated and limp. Twelve days after treatment, algae was gone and the surface clear of Hydrilla. Acceptable control continued for about six months in nearly all treated margins.

FISH KILL

Fish kill was far lighter than expected. An initial pick-up was made the day after treatment with follow-up as needed.

TECHNIQUE

Since Acrolein is very toxic to fish and this canal had a high fish population, a high fish loss was possible. However, as stated previously, loss was low and the method of application was believed to be an important factor. As the sprayboat advanced in shallow, edge waters, fish were constantly observed darting into deep center waters. Acrolein was injected 2-4 feet from the water's edge and allowed to spread through the Hydrilla stand. Evidently, very few fish returned to this chemical cloud, but rather stayed in fresh center waters thus escaping lethal contact.

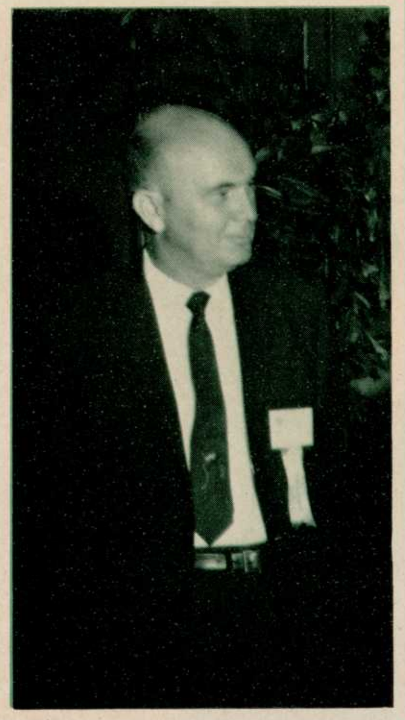
A relatively long treatment section does not seem to be detrimental as long as only one margin is treated

(Continued on page 18)

AQUATIC WEED CONTROL

MECHANICS OF SPRAYING

By Frank L. Wilson
Polk County Mosquito Control, Eaton Park, Fla.



Wilson: "Understanding of the major principles increase your percentage of success."

WE APPLY HERBICIDES as a spray because:

—Water is a cheap readily available herbicide carrier.

—Small amounts of herbicide can be diluted in water and spread evenly over the entire area being treated.

—Large areas can be treated rapidly.

It sounds simple, yet many different factors from chemistry and physics are involved in spray application. Each of these factors can be compared to a brick in a wall, it plays a part but it is not the entire wall. Because of this, the following factors have been listed individually.

Spray Formulations

Most chemicals have to be modified in some manner so that they will mix with water. We call these different types of formulation. There are three major ones.

1. Solution—In this category the chemical can be dissolved by or mixed with water. The resulting solution does not separate into water and chemical if allowed to stand. Alter initial mixing agitation is not required. Most herbicides fall in this category.

2. Emulsions — This category of formulation is used to mix oil or oil-like chemicals with water. The better the grade of emulsion, the less agitation it requires to keep it mixed with water. A good emulsion looks like milk.

3. Wettable powders — Formulation of this type contain a pesticide that has been mixed with or sprayed on a "carrier" powder. The entire mixture has been treated with a wetting agent so that it will mix with water. Formulation of this type requires constant agitation.

The purpose of each of these types of formulation is to allow the use of water as a physical carrier so that small amounts of a pesticide can be spread uniformly over a large area. As soon as the spray hits the plant, the water part of the spray starts to evaporate or dry. As this occurs the herbicide comes in contact with the leaf and is deposited. As soon as the chemical is deposited it can begin to act.

Morphological Characteristics

The physical characteristics of a plant influence retention and uptake of an herbicide. Leaf shape, leaf position, type of leaf surface and the density of leaves all play major roles in the problem of getting enough herbicide into a plant to kill it. Collectively, the physical characteristics of a plant act as a group of "obstacles" to successful herbicide application. We must apply our herbicide in a manner to bypass or circumvent these obstacles in order to achieve weed control.

Plant characteristics that influence retention and uptake of herbicides.

- Leaf Shape
  - Broad—generally easier to kill
  - Narrow—generally harder to kill
- Leaf Position
  - Horizontal—holds spray well
  - Upright—spray tends to run off
- Leaf Surface
  - Waxy—spray beads, runs off
  - Hairy—spray held out away from leaf surface
  - Sculptured—sculpturing may channel spray—increases run off
- Leaf Density
  - Heavy—many leaves
  - Light—few leaves

Nozzles

There many techniques and devices that have been developed for shattering a liquid into the small droplets that we call spray. All these devices use some form of energy to break up the liquid and create the tremendously expanded surface of many droplets. The most frequently used type of nozzle in weed control operation is the hydraulic pressure nozzle. For our purposes there are three main types of this nozzle which are identified by the spray patterns they create.

1. Straight stream jet—the spray emerges from a central orifice as a solid stream and breaks up into spray several feet from the nozzle.

2. Hollow Cone—the spray passes through a whirl plate and acquire a high revolution per minute before it passes through the spray disc orifice. Centrifugal force makes the stream form a hollow cone pattern.

Most of our adjustable spray guns such as the spray master, spraymeiser or "orchard" guns can be adjusted to produce either 1 or 2.

3. Flat fan patterns—these are nozzles in which the orifice is milled oblong so that the spray pattern is long and narrow.

a. Tee jet and Vee jet nozzles —these flat fan nozzles are most commonly used on spray booms. They provide very even coverage of a swath. Tee jets are low volume nozzles, Vee jets are high volume nozzles.

b. Off center nozzles (O. C. type) these nozzles provide a wide off-set flat fan spray, under proper conditions they can be used to cover as much as a 30-foot swath.

Surface Tension

Molecules are the sub-microscopic "bricks" of which all things are made. Each molecule exhibits "forces" or "pull" similar to a magnet. Water has surface tension because of its molecular structure which causes each water molecule to have a strong attraction for other water molecules. Molecules on the surface are pulled inward because there are no water molecules on the other side to exert force to pull. This inward force causes water to stay in the smallest possible area, which is a sphere or drop; in other words, surface tension causes water to form a "skin" and makes it form drops.

Spray Droplet Formation

The physicist recognizes several modes of droplet formation, however for our purposes weed control spray droplets are formed by two methods, aerodynamic breakup and instant atomization.

In aerodynamic breakup, the spray issues from the nozzle in a solid jet at high speed. At these high velocities the liquid jet travels straight initially, then due to aerodynamic forces, tends to be stripped apart into "primary" droplets. These droplets are tear shaped. The length of the tail on the primary droplet is proportional to the speed of the droplet at the time of break up. The higher the velocity of the drop the more the tail is elongated. Surface tension acts on this elongated tail causing it to break up into many secondary droplets.

Instant atomization is characterized by the spray issuing from the nozzle in a thin sheet. Due to the resistance format this sheet first develops "ridges" that separate from the sheet as filaments or threads of spray. Surface tension then reduces the threads into droplets.

The lower the spraying pressures, the lower the velocity of the spray. The lower the velocity, the less aerodynamic force present to shatter the spray into droplets. In other words, low pressure results in larger spray droplets.

Viscosity

Viscosity is the resistance a liquid has to flowing. We add thickeners, such as Vistik, to form a spray with syrup-like consistency.

Spray Droplet Size

Spray droplet size is governed by surface tension, viscosity and spray velocity.

Surfactants

Each of us has seen droplets of water on a newly-waxed car. We know that these droplets "stand up" and do not spread over or wet the waxed surface. This phenomena is caused by surface tension. Water can "wet" a substance if its molecules are attracted to the molecules of the substance being sprayed. If these two groups of molecules tend to repel each other then the water forms "beads" such as we see on a waxed car.

In most plants the outer layer of each leaf is made up of wax-like components. Herbicides that are applied as sprays to such plants tend to "bead" or even run off the leaves. In order to overcome this problem we add surfactants to our sprays.

"Surfactant" is a coined word which combines the words "Surface active agent." It is probably easiest to visualize the action of a surfactant as a chemical "public relations" compound. A good surfactant has two positions on its molecule. One of these poles is attractive to wax, the other pole is attractive to water.

When a spreader-sticker type surfactant is added to a spray it remains relatively inactive until the mixed spray is forced from the nozzle and spray droplets are formed. At this point the water-loving end of the surfactant molecules turns inward and the oil or wax-loving end of the molecule orients to the outside of the droplet. Upon impact with the leaf the surfactant forms a "go between" layer linking water to wax.

With surface tension reduced or eliminated the spray spreads on the leaf surface rather than forming a drop. Due to this spreading, greater efficiency is achieved through better coverage. In some cases it is even possible to reduce the amount of herbicide required by the addition of a surfactant.

Coverage

In order to obtain consistent herbicide kills it is necessary to apply sprays so that even coverage is achieved over the entire area. If we can use a boom-type sprayer that can be driven at a known speed while applying a known amount of spray per minute we can apply a very precise amount of herbicide

(Continued on page 49)

Bitting *(from page 14)*
at a time. An interval of at least a week should be allowed between treatments.

EQUIPMENT

The application pipe was a ten foot length of ½ inch thin wall electrical conduit with three inches of the outer end curved down to aid injection and shed trash.

Chemical was educted into the spray system as opposed to a pressure activated system; metering was accomplished by an orifice plate in the eductor line. Various apertures may be used to accommodate the desired output and boat speed. Gasoline may be used to calibrate the equipment.

MISCELLANEOUS OBSERVATIONS

Herbicidal activity of Acrolein was much slower than was normally observed in full volume treatment even though summer temperatures prevailed.

In several instances, small feeder canals were treated on one margin only. Filamentous algae were removed and the margin remained clear for two to three months while the opposite edge supported the usual heavy growth.

The fact that Acrolein requires a relatively short contact time, and degrades rapidly, makes it useful for marginal strip use.

We hope that research will soon bring a compound into practical use that will be non-toxic to fish as well as an effective control agent, but until then, Acrolein and the strip method can be utilized in many problem situations.

Gallagher *(from page 12)*
and formulations. Ease of applying 2,4-D granules was improved by Amchem's Spreader Disc for helicopters and the West Point Products Aeriblower for shoreline boat application. Last year, based on previous test plot work, the dimethyl amine form of 2,4-D was applied large scale during the month of May with considerable success. Steenis (1) has been utilizing fluctuating tidal movement to minimize operational difficulties. In its efforts to control milfoil in 1969 the Engineers utilized both helicopter and boat blower systems for applying granular 2,4-D. In Florida a multiple-agency operation organized a large-scale test program and used everything from an airboat to a helicopter to apply a wide range of herbicides and formulations to control Eurasian milfoil which had become a potential hazard to its resort spring attractions. A number of materials were effective, but all are more expensive than 2,4-D. Although 2,4-D is a partial chemical answer to this particular species, milfoil spreads so fast that no single approach is adequate. The 15 papers presented at a one-day TVA conference on watermilfoil research and control gives an idea of the scope of research activity by personnel involved with the species.

Elser (2), responsible for directing the operational weed control work in Maryland, reports that the decline of tremendous acres of Eurasian watermilfoil in the Chesapeake Bay could be pathological. Two diseases, Lake Venice and Northeast (names for convenience as they have not yet been positively identified and classified) were generally found in the regions of large-scale milfoil decline. Elser reports that Suzanne Bayley of Johns Hopkins University determined that the Northeast disease organism is a filterable agent, possibly a virus. A small controversy exists in the minds of several researchers as to whether the "disease" is in reality a response to high salinity associated with salt water intrusion which occurred over a period of drought years.

The amount of work on other submersed species is generally related to problem size and rate of increase. Florida elodea is rapidly becoming a major weed problem in Florida waters. Blackburn (3) found that acrolein, aromatic solvents, copper sulfate and a diquat-copper sulfate mixture provided temporary control, but the diquat-copper sulfate is the only treatment not highly toxic to fish. Other work on elodea reported over the past few years shows copper sulfate mixtures of copper sulfate and diquat, diquat plus endothall, and blackstrap molasses added to phenoxy compounds controlled this species. Ware (4) reported that 100 lb. of copper sulfate per surface acre provided economical control of elodea. Larger crystals produced better control. Foret (5) used blackstrap molasses as a source of aconitic and itaconic acid and glucose. These materials added to phenoxy compounds increased control of elodea and other submersed species. In the laboratory at Ft. Lauderdale where the nutritional and reproductive studies of Florida elodea simulate field conditions, Weldon (6) found that the WASM formulation of endothall doubled or quadrupled effectiveness in field trials.

(Continued on page 34)

Most common method of aquatic pesticide application is airboat.

Gallagher *(from page 18)*

Sago pondweed and other potamogeton species still constitute a severe problem in the waters of the western irrigation systems. The partially-satisfactory aromatic solvents with their inherent danger to fish are being used, but search for a better solution continues. New herbicides are constantly being screened and new application techniques have been developed to make the current materials more same. Work pertaining to nutritional requirements for establishment and the physiological aspects of temperature and planting depths is under way on several submersed weed species. Bruns (7) showed that acrolein applied at 0.6 ppmw volatilized as the treated waters moved downstream. Calculated losses were equal to 22% at one mile, 53% at 3 miles and 98% at 19 miles. Weed injury was still occurring at mile 18. Hathrop (8) reported that a low-rate long-contact period of acrolein application had been successful in the Columbia River Basin Project. Concentrations of 0.1 ppmw over a 48-hour period provided excellent control of sago pondweed in canals carrying 300 CFS and in laterals carrying 150 to 300 CFS.

Copper sulfate is being used in a similar manner to control higher plants as well as algae. Bartley (9) controlled both sago and leafy pondweed over several miles of ditch with daily applications of 0.5 ppmw copper sulfate. A 6- to 8-week treatment period was needed to produce the desired effect. Of importance here was the lack of copper build-up in canal-bottom soils. Apparently pondweeds extract copper efficiently from treated water. With a single dump application of 411 lb. in a 411 CFS flow canal (standard algae control rate is 1 lb./CFS) Bruns (7) found that 95% of the copper in 23 miles of canal was sorbed by suspended particles which dropped to the bottom and re-released the copper. No build-up occurred. In neither test were fingerling trout injured.

Riemer (10) partially filled a void in the knowledge of the action of copper in his work dealing with the behavior of copper sulfate in small ponds. He verified the ability of plants to keep the copper suspended when he showed that a heavy bloom of algae reduced the amount of copper in the water. He also showed that larger granules which sink to the pond bottom permit less copper sulfate to get into solution than the theoretical expected amount, yet at the same time that part which goes into solution mixes rapidly throughout the water system. Riemer's hypothesis that the copper applied as large granules may be adsorbed on the bottom muds possibly explains why Ware felt he had achieved more effective control with larger granules. Perhaps concentration at the stem-root zone permitted greater adsorption by the plant.

Much additional work on the control of submersed species is in the literature and more is yet to be reported. This work varies from cultural characteristics of individual species to broad-spectrum response to herbicides. Riemer (11) determined that under New Jersey conditions cabomba *(Cabomba caroliniana)* over-winters primarily as vegetative portions of the plant. No viable seed was produced either in the laboratory or in field experiments. In the laboratory test optimum growth occurred at pH 6.0 in aerated water with low levels of calcium.

In terms of new chemicals or new uses for old chemicals total water treatments of diuron, endothall dihydroxy aluminum salt, Fenac, and dichlobenil control submersed species. Walker (2) reported that diuron in gelatin capsules weighted with sand controlled cladophora and spirogyra in cold-water ponds for three months. Pierce (13) and Hambric (14) had excellent control of a wide range of submersed species with diuron. Pierce indicated that at 0.6 to 1.0 ppm myriophyllum, eleocharis, and acicularis were resistant. Most of the filamentous algae appeared susceptible. Hambric found that 2 lb./surface acre controlled a wide range of species, dispersal throughout the water system was excellent, and apparently there was immediate absorption with resultant kill since extensive water exchange did not reduce the effectiveness of the treatment.

In current Amchem research Fenac applied at the 1 to 5 ppmw needed to provide disappearance information for label purposes controlled many submersed aquatic species, particularly pondweed, and also the fringe growth of cattails *(Typhus* spp.) commonly found around ponds.

Dichlobenil studied more for the control of emersed than for submersed species was applied preemergence to Illinois ponds in December by Hiltebran (15). Rate of 16 to 20 lbs. prevented the growth of *Potamogeton pectinatus;* lower rates did not control *P. foliosis.* Yeo (16) knocked down American and curlyleaf pondweed, small pondweed, elodea, cattail, and cladophora in four weeks with 10 lb./A.

Regarding endothall, Patterson (17) refers to the dihydroxy aluminum salt as a particulate carrier which brings the herbicide in direct contact with aquatic weeds. Cortell (18) confirmed the advantage of its direct and prolonged contact with the plant.

Although this is a paper dealing with aquatic weed control research in the United States, the work of Wile in Ontario and Thomas on Prince Edward Island should be included. In both instances the work was stimulated by use demands. Ontario Water Resources Commission maintains aquatic weed research studies for answering the many requests for assistance in maintaining provincial farmponds and recreation waters. Thomas, Fisheries Research Board of Canada, worked out the details for 2,4-D granular control where eelgrass *(Zostera marina)* had become a severe problem in maritime province oyster beds.

The association of aquatic weeds and high nutrient levels in polluted waters has stimulated interest in that relationship. Investigating the effects of pollution on aquatic growth and development, Denton (19) selected three species: alligatorweed *(Alternanthera philoxeroides)*, parrotfeather *(Myriophyllum brassiliense)*, and water hyacinth *(Eichhornia crassipes)* growing in polluted and unpolluted waters. The plants were analyzed for ash, carbon, nitrogen, phosphorus, calcium, magnesium, potassium, and sodium. Samples of water and bottom muds were analyzed for the same elements. Plant ash varied with water hardness but the carbon content differed little with the environment. Plant nitrogen, magnesium, and sodium varied considerably with the concentration of these elements in the water and bottom soils. Riemer (20) analyzed 30 species of aquatic plants and their surrounding waters, checking 12 chemical elements. The data was recorded but not interpreted. Ryan (21) reported the effects of fertilization on the growth and mineral composition of anacharis, two myriophyllum species, and *Potamogeton* pulcher. In a two-year study the four species showed unlimited consumption of nitrogen, phosphorus and potassium when fertilized. Anacharis and *Potamogeton pulcher* fertilized showed significantly higher yields than in control pools. Unfertilized *Myriophyllum spicatum* produced the greater yield. *Myriophyllum heterophyllum* responded to fertilization in 1967, but not in 1968. This effect of excess nutrients was evident at Ft. Lauderdale where it was found that high levels were toxic to hydrilla.

The current indication is that more work will be done on this aspect, stimulated in part by attempts to utilize aquatic vegetation as a feed supplement, and also the possibility of utilizing aquatic plants to trap excess nutrients in runoff water.

Otto (22) used nitrogen and phosphorous at two enrichment levels but did not increase the total vegetative mass of *Potamogeton nodosus* or *P. pectinatus*. The two species have low nutrient level requirements which are met primarily by the parent vegetative propagule.

Emersed Weed Species

In the United States the most important emersed aquatic weed species are water hyacinth *(Eichhornia crassipes)* and alligatorweed, both serious problems in navigable waters. Research for controlling these weeds is also important because mats of them provide ideal mosquito-breeding conditions. The phenoyx compounds seem to offer the best control, 2,4-D for water hyacinth and 2,4,5-TP (silvex) for alligatorweed.

Among new chemicals, in the water hyacinth work by Weldon and Blackburn (23) 3 lb./A ametryne was very effective. Associated residual studies showed that at that rate ametryne remained in the water in the treated area for 32 days. The problem of drift to susceptible crops precipitated work with ametryne. To avoid the hazard of drift and also of volatility Ball shifted to an oil-soluble amine form of 2,4-D applied through the Microfoil boom for treating hyacinths in the Loxahatchee Reservoir, situated in the center of the vegetable growing area around Lake Okeechobee in Florida.

Alligatorweed is still included in test programs because we do not have a herbicide that is satisfactory in all situations. Weldon and his co-workers (24) found that 5 and 10 lb./A of granular dichlobenil controlled rooted emersed plants, but not floating ones. Spencer (25) reported that 12 lb./A of silvex plus 3 lb. ai of amitrol-T maintained 40% control of alligatorweed after a 12-month period. In an all-out attempt to eradicate alligatorweed in a California test, Pryor (26) achieved complete kill with a drench of 1 qt. of Vampam plus 1 gallon of weed oil in 25 gallons of solution per 100 sq. ft.

Although a few years ago 8 lb./A of 2,4-D seemed to be controlling water chestnut *(Trapa natans)*, resurgent and spreading infestations are now requiring further research. Results of a test program started in 1965 by Steenis and Elser (27) indicate that mixtures of 2,4-D and dicamba applied to immature developing seeds cause these to rot. Seeds treated at maturity are sterilized. Treatments made before flowering had no effect on the seed viability or development.

In the lily family a two-year test program conducted by Weldon and Blackburn (28) showed that 4 lb./A of dichlobenil applied in summer to early fall produced 90% control of fragrant white waterlily *(Nymphaea odorata)* and was more effective than in 8 lb./A rate applied during the winter. Taylor (29) agreed with Weldon and Blackburn on white waterlily, but suggested that 10 lb./A be used for the complete control of spatterdock *(Nuphar advena)*. The best application time in the southeastern states was during the period of active growth. Comes and Marrow (30) recorded 99% control of white waterlily three months after Aril treatment with 7.5 and 15 lb./A of dichlobenil. Riemer (31, 32) investigated the effects on spatterdock of varying frequencies of defoliation, of a combination of defoliation plus 2,4-D, and of the effects of 2,4-D plus ETHREL (2-chloroethylphosphonic acid). He reported that defoliation depleted food reserves, the greater loss being associated with the greater number of prunings. Three trimmings plus 40 lb./A 2,4-D BEE provided complete kill with no regrowth the year following treatment. The addition of ETHREL to 2,4-D as a tank spray mix or as a separate application using 4 lb. of 2,4-D plus 6000 ppm ETHREL provided complete knockdown. A later check of the plot area revealed that the rhizomes from the treated area were unhealthy and spongey-looking, while those from the check plots and 2,4-D along were healthy and sprouting.

Ditchbank Weed Control

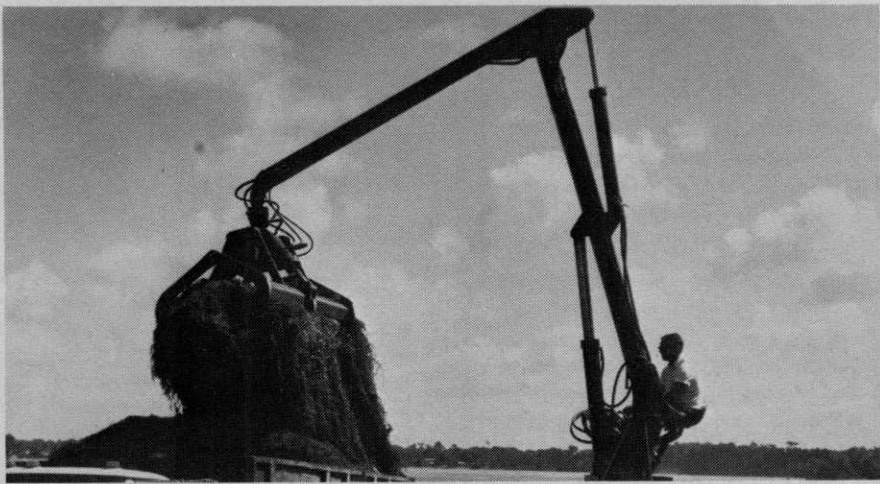
Ditchbank weed control retains high research priorities because of the intensity of irrigation and drainage area problems. The USDA-ARS aquatic and noncrop weed control groups are working on the major weed species such as reed canarygrass *(Phalaris arundinacea)*, carax and hardstem bulrush *(Scirpus acutus)*. Much of the work is investigating physiological aspects. The growth habits of problem plants and their place in the succession of vegetation as well as their competitive characteristics are being studied quite intensively. Of particular importance are the ecological studies which show changing weed populations.

Discussing the joint problem of reed canarygrass control and plant succession Hollingsworth and Comes (33) showed that applications repeated up to five times produced better kill of reed canarygrass than single applications of a higher rate. They also reported that amitrol-T was superior to amitrole alone. Plant succession favored establishment of bluegrass and redtop over a naturally-occurring weed mixture. Oliver (34) noted excellent control of annual broadleaf weeds and good grass tolerance with 0.25 lb./A of picloram and with a 1.4 lb./A of fenac on irrigation rights-of-way. The effectiveness of these materials suggested a 2-year weed control period might be possible. Kemper (35) controlled headstem bulrush with treatment rates of 2.2 and 4.4 lb./A methanearsonate. Spring treatments were superior to those in mid-summer and early fall. The spring treatment showed less than 10% regrowth in the second year. McHenry (36) verified Kemper's results but preferred mid-summer application. In McHenry's test, 1 lb./A of DSMA was second to the 2 lb. rate of a low volatile ester of 2,4-D. 2,4-D is an effective treatment, but drift is an inherent danger to susceptible crops.

Herbicide Residues

The question of pesticide residues is becoming the most critical aspect of aquatic weed control. With chemical methods the concern is the herbicide itself. With mechanical methods it is the re-release of nutrients into the water, creating more favorable environments for weed re-establishment. We must know the degradation and disappearance time of any herbicide placed in water, and also residues in fish and bottom organisms which make up the biological food chain.

Averitt (37) recorded a decreasing herbicide concentration over a 22-day period when 2,4-D dimethylamine sale was applied to Louisiana waters. Initial concentrations went from 189 and 269 ppm to 19 and 10 ppm. Daly, Funderburk and Lawrence (38) showed a differential disappearance of paraquat, diquat, and 2,4-D BEE applied to Lake Seminole for the control of Eurasian water milfoil. There was only a trace of paraquat and diquat after 24 hours but the 2,4-D formulation lasted through the 7-day sampling period. All materials controlled the weed. Paraquat residue was higher in soil and milfoil than in the water. The 2,4-D formulation prevented reinfestation for a much longer time. This data in part verifies the earlier work of Frank (39) who found that 1.33 ppm initial concentration in a still pond was reduced to 0.019 in 19 days and 0.001 ppm ibn 36 days.


Sheer volume is a major problem with mechanical harvesting of aquatic weeds.

The USDA-ARS group is most active in this aspect of aquatic weed work, having endothall, dichlobenil, 2,4-D, amitrole, TCA, ametryne and acrolein under test either as direct application to water or as indirect application associated with ditchbank spraying. Dyes have been used to study channelling as well as stratification of substances introduced in to canal waters. The dilution factor is of most concern in moving waters. Dyes have also been used by Steenis and others in determining flow currents associated with using diquat and 2,4-D amine salts in back coves of Chesapeake Bay tidal flats.

The second aspect of herbicide residues associated with aquatic weed control pertains to those waters used for crop irrigation. Two USDA facilities, both in the Western Irrigation Region, are studying the effects on crops of known quantities of herbicides applied in fixed volumes of irrigation through both sprinkler and furrow methods. The crops being studied represent the crop grouping established by the U. S. Food and Drug Administration and include sugar beets, beans, corn, wheat, and potatoes. These experiments are generally carried through to yield to determine cumulative ef-

 For More Details Circle (135) on Reply Card fects as well as immediate formative effects. At the present time acrolein, silvex, 2,4-D, fenac, amitrol-T, picloram, and pyriclor have been tested either by Bruns at Prosser, Washington or by Hodgeson at Bozeman, Montana.

Biocontrol of Aquatics

Because of the lack of specialists, it appears that aquatic weed research people are having to wear several hats.

In line with this philosophy is the biocontrol work under way at the USDA station at Ft. Lauderdale, Florida with snails; a tilapia study in California; and a manatee and beetle program in Florida.

Reviewing the animals which were under study as aquatic phytophagous agents Butler (40) referred to insects, molluscs, fish, ducks, and manatees.

Florida is "where the action is" at the present time. In this state the snail, the flea beetle, and the manatee have been utilized to control submersed weeds and alligatorweed. Blackburn and Andres (41) indicate that the snail *Marisa cornvarietis* L. is quite hardy, surviving in a temperature range of 48 to 100° F, can live in polluted waters, and can tolerate a salinity of 2500 ppm. The snail feeds quite actively and is indiscriminate in its eating habits. This is an advantage in that it will keep all vegetation down. Marisa also feeds on disease-bearing snails without transmitting diseases harmful to man, an additional benefit. The disadvantage is that marisa could feed on aquatic crops, such as rice, waterchestnut, and watercress. Perhaps the greatest problem will be producing enough snails to be of value in the area where they will adapt. Field tests show that fairly high populations are needed—8000 per acre stocked in Florida cleaned up ponds and kept them clean over a two-year period.

The so-called mighty mite of biocontrol is the flea bettle *(Agasicles* n. sp) with its single-minded food habit. It apparently lives only on alligatorweed. This insect, imported through the USDA-ARS Entomological Department from Argentina, has been released in the United States at several locations. Zeiger (42) reported successful introduction to Florida waters. He indicates the two characteristics needed—survival and rapid adaptation — were met with apparent satisfactory control of alligatorweed. Blackburn and Andres suggest that the beetle might not be the final answer since it does not prove effective in the Savannah, Georgia, program.

Mechanical Weed Control

The primary objection to mechanical control in the past has been the fact that the methods used frequently spread species which propagate vegetatively. The early collection and compressing of weed masses also returned the nutrients to the water, ultimately supporting a greater weed population. This is apparently changing. Bryant (43) discussed a new and more efficient harvester system which transports the weed mass to the shore and hauls it away. He also noted that a Wisconsin state law now requires weed removal in any weed-cutting operation. The Water Witch uses high pressure to blast weeds from swimming areas, but makes no provision for weed collection and site removal.

Conclusion

To sum it all up, one must say that there is a tremendous amount of aquatic weed research under way. More importantly, understanding of aquatic weed control is progressing to the point of our realizing the necessity of a total environment concept. Research is no longer a shotgun or hit-or-miss concept involved with only a single aspect of the problem. The realization that our natural resources will not last forever at the rate we are using or destroying them is making us all conscious of the need to act as part of a total environment rather than for individual needs alone.

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Wilson *(from page 17)*

per acre. It is almost impossible to apply sprays with hand-held guns and achieve uniform coverage. An alert sprayman can achieve a satisfactory degree of coverage, however it takes constant concentration.

Knowledge of the various factors that make up the mechanics of spray application will not guarantee a total absence of herbicide application failures; however, a thorough understanding of the major principles involved will increase your percentage of successes.

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