FIELD EVALUATIONS OF NEWER AQUATIC HERBICIDES[1]

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Atlanta, Georgia

Presented at the Eighteenth Annual Conference

Southeastern Association of Game and Fish Commissioners

Clearwater, Florida, October, 1964

ABSTRACT

The results of 116 aquatic weed control experiments using 10 herbicides and their combination are discussed.

Included are data for pre-emergent soil application during winter draw-down, pre-emergent total pond treatments and post-emergent applications.

Pre-emergent soil application during winter drawdown was comprised of 31 experiments, testing varying concentrations of eight different soil sterilants for the control of rooted aquatic weeds.

D.M.A. (disodium monomethylarsonate) showed promise as a pre-emergent control of southern watergrass *(Hydrochloa carolinensis).*

Also, fenac (2,3,6 trichloro phenyl acetic acid) was effective in clearing fishing areas in ponds heavily infested with a variety of aquatic plants. Both liquid and granules were used at concentrations of 10 lbs. and 20 lbs, active ingredients per acre. Best results were obtained when even distribution of the herbicides was accomplished.

Other soil sterilants tested gave varying degrees of control but were not considered effective enough to be recommended.

Fourteen pre-emergent total pond treatments indicated that simazine (2-chloro-4, 6-bis (ethylamino)-s-triazine), atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and prometryne (2,4-bis (isopropylamino)-6-methylthio-s-triazine) effectively inhibited the development of filamentous algae at concentrations of .5 and 1.0 ppm. However, in each case the development of phytoplankton blooms were adversely affected for several weeks. Each herbicide was applied by broadcasting the material mixed with water over the surface of the pond. The more soluble atrazine and prometryne appeared to be better adapted to this simple application technique than did simazine.

Post-emergent applications included the results of 51 field experiments using six herbicides and their combinations. Diquat(1:lethylene-2:2-′ dipyridylium dibromide)) and paraquat (1:1-ethylene4,4′-dipyridylium dichloride) were found to be effective non-selective herbicides at concentrations ranging from .20 to 10.0 ppm. Duckweed was found to be the most susceptible plant to these herbicides, while members of the

[1] This work was undertaken with Federal Aid to Fish Restoration Funds under Dingell-Johnson Project F-11-R, Pond Management Evaluations.

lily family appeared to have the greatest tolerance. Spot applications indicated that these contact herbicides are suitable for clearing fishing areas of certain species of aquatic vegetation within a two-week period.

The triazine herbicides simazine (1), atrazine (2) and prometryne (3) effectively controlled filamentous algae and showed promise for controlling several species of vascular plants. At concentrations used for filamentous algae control, virtually all phytoplankton was removed and did not develop properly for varying periods of time, depending on the concentrations used and the amount of water exchange.

Two tests using atrazine at .08 and .16 ppm satisfactorily removed heavy *Microcrystis* blooms which were immediately replaced by more desirable plankton algae.

Also, data are included for two experiments using paraquat-fenac and paraquat-prometryne combination to determine if the addition of residual herbicides would give longer-lasting control. Each treatment cleared fishing areas for a period of sixty days. In addition, a burlap bag filled with fenac pellets was staked out in a weed bed in an attempt to find a simple and effective means of controlling aquatic vegetation around fishing docks and piers. However, this treatment was considered unsuccessful since a circle have a radius of only 2.5 feet was cleared of *Myriophyllum heterophyllum* with a 30-day period.

INTRODUCTION

In the past several years, many new herbicides, primarily designed for terrestrial use, have also been tested in an aquatic environment. Several of these herbicides have been found to be effective for controlling aqquatic vegetation and are now widely used. Even though most aquatic plants can be controlled chemically, many weed problems are unique, requiring specific techniques. The following data gives the results of such tests in addition to conventional weed control experiments using newer aquatic herbicides.

RESULTS OF PRE-EMERGENT SOIL APPLICATIONS USING SEVEN SOIL STERILANTS DURING WINTER DRAWDOWN

Many ponds are too large to be economically treated in their entirety; therefore, seven readily available soil sterilants were applied to exposed mud flats (previously the littoral zone) during winter drawdown, in an attempt to create fishing areas the following season.

Fisheries workers have found that winter drawdowns often improve the quality of the fish population, but does not significantly reduce the amount of aquatic vegetation (Pierce, 1963) (Eschmeyer, 1947). Therefore, in order to benefit from the drawdown, fishing areas must be made available during the following fishing season. Using this fisheries management technique, the results of thirty-one (31) separate field tests are discussed below.

During the winter of 1962, a seven-acre pond was drained, exposing the portions of the bottom heavily infested with southern water-grass *(Hydrochloa carolinensis)*. A series of one-tenth acre plots was then marked off and treated with varying concentrations of soil sterilants. Each plot was sprayed in order to obtain maximum coverage. Simazine (1) and atrazine (2) were tested at 20 lbs., 40 lbs. and 80 lbs. active ingredients per acre while prometryne (3) was applied at 40 lbs. and 80 lbs. active ingredients per acre.

Six weeks after the treatment ,the pond was refilled. Only 10% control was recorded during the following spring and summer, indicating that these herbicides are not designed for controlling southern water-grass using the above technique and concentrations. However, a one-half (½) acre pond was cleared of a heavy infestation of southern watergrass *(Hydrochloa carolinensis)* by using 5 ppm simazine. [1] It should be mentioned that it took approximately six weeks before the grass died out and that terrestrial plants adjacent to the pond were also affected. A few small bream were found dead the day after the treatment leading the authors to believe that the fish died from direct contact or consumption of the herbicide and not from oxygen depletion, since no decay was noted for at least three (3) weeks after the application. Such treatments are not considered feasible since the cost per acre exceeds $175.00.

Other soil sterilants applied to exposed mud flats containing southern watergrass included Vacate (dimethylene-Boron trioxide) and D.M.A. (disodium monomethylarsonate). These granular forms were applied at the rates of 10 lbs. and 25 lbs. active ingredients per acre respectively, and only the D.M.A. gave any degree of control the following spring. Heavy regrowth occurred by mid summer, however. See table 1 for additional information.

Fisheries workers have found that fenac is an effective herbicide for controlling certain species of aquatic plants. Frank, Hodgson, Comes and Timmons (1962) found that 20 lbs. per acre of the sodium salt of fenac applied to a canal bottom in the fall provided 93% to 99% control of sago pondweed *(Potamogeton pectinatus)* the following irrigation season.

Similar tests conducted in New Jersey by Gallagher and Collins (1963) found that 15 lbs. per acre of fenac gave seasonal control of sago pondweed, elodea, water stargrass and bladderwort.

During the winter of 1963, the authors conducted sixteen drawdown experiments using both liquid and granulated fenac (4) at the rates of 10 lbs. and 20 lbs. active ingredients per acre. These tests resulted in excellent control of *Eleocharis acicularis, Myriophyllum heterophyllum, Juncus repens, Utricularis sp., Hydrotrida caroliniana, Najas guadalupensis* and *Potamogeton diversifolius* during the following spring and summer. However, the lilies *Nymphaea odorata, Nuphar advena* and *Brasenia schreberi* were unaffected. Comparable results were noted when using common amounts of active fenac liquid and granules, if the liquid form was diluted and sprayed evenly over the plot. However, poor control was obtained when the liquid fenac was diluted and broadcast by hand over the mud flat. This indicated that complete coverage may be necessary for satisfactory results.

Four winter drawdown weed control experiments, using the granulated form of the soil sterilant tritac (2,3,6-Trichlorobenzyloxyproponol) at the rate of 15 lbs. active ingredients per acre resulted in relatively poor control the following spring and summer. As was experienced with other soil sterilants, members of the lily family were virtually unaffected. In one plot, *Najas guadalupensis, Myriophyllum heterophyllum, Chara sp.* and *Isoetes sp.* were reduced by 75% the following spring, but regrowth was heavy by mid summer. A plot treated during early spring and containing "sprouting" *Eleocharis acicularis* and *Juncus repens was* completely cleared of these aquatic species; however, regrowth was rapid soon after inudation. This rapid regrowth after flooding indicated to the writers that this material is very soluble and is thererfore quickly leached below lethal levels.

One experiment using M.B.C. (sodium borate-sodium chlorate) at the rate of 400 lbs. active ingredients per acre further indicated that extremely soluble herbicides are not suitable as pre-emergent herbicides if applied during winter drawdown. No control of *Nymphaea odorata, Brasenia schreberi, Nuphar advena, Hydrotrida, Eleocharis acicularis* or *Utricularia sp.* was noticeable during the spring and summer following treatment.

See tables 1-5 for additional winter drawdown soil sterilant application data.

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[1] Additional information on this experiment is available in table 11 under "Post Emergent Experiments Using Simazine."

TABLE 1

RESULTS OF TREATING EXPOSED MUD FLATS WITH SOIL STERILANTS DURING WINTER DRAWDOWN

Herbicide	Date Treated	Species	Method of Application	Pound/Acre Acid Equivalent	Per Cent Control The Following Spring (March-May)	Summer (June-August)
Simazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	80 lbs.	10%	10%
Simazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	40 lbs.	10%	0%
Simazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	20 lbs.	10%	10%
Atrazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	80 lbs.	10%	10%
Atrazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	40 lbs.	10%	10%
Atrazine 80w	2-7-62	Hydrochloa carolinensis	Sprayed	20 lbs.	10%	10%
Prometryne	2-7-62	Hydrochloa carolinensis	Sprayed	80 lbs.	10%	10%
Prometryne	2-7-62	Hydrochloa carolinensis	Sprayed	40 lbs.	10%	10%
D. M. A.	2-7-62	Hydrochloa carolinensis	Broadcast	25 lbs.	10%	10%
Vacate*	2-7-62	Hydrochloa carolinensis	Broadcast	10 lbs.	10%	50%

* 3 (B-chlorophenyl)-1-1-dimethylurea Boronn trioxide

TABLE 2

RESULTS OF TREATING EXPOSED MUD FLATS WITH SOIL STERILANTS DURING WINTER DRAWDOWN

Herbicide	Date Treated	Species	Method of Application	Pound/Acre Acid Equivalent	Per Cent Control The Following Spring (March-May)	Summer (June-August)
Liquid Fenac	1-29-64	Nymphaea odorata	Sprayed	20 lbs.	0%	0%
		Brasenia schreberi			0%	0%
		Nuphar advena			0%	0%
		Hydrotrida caroliniana			100%	100%
		Eleocharis acicularis			100%	100%
		Utricularia sp.			100%	100%
Liquid Fenac	10-15-63	Najas marina var. gracilis	Broadcast	20 lbs.	20%	20%
Liquid Fenac	10-15-63	Najas marina var. gracilis	Broadcast	10 lbs.	0%	0%
Liquid Fenac	1-30-64	Brasenia schreberi	Sprayed	20 lbs.	0%	0%
		Myriophyllum hetero-phllum			100%	100%
		Juncus repens			100%	100%
		Utricularia sp.			100%	100%
		Potamogeton diversi-folius			100%	100%

TABLE 3

RESULTS OF TREATING EXPOSED MUD FLATS WITH SOIL STERILANTS DURING WINTER DRAWDOWN

Herbicide	Date Treated	Species	Method of Application	Pound/Acre Acid Equivalent	Per Cent Control The Following Spring (March-May)	Per Cent Control The Summer (June-August)
Liquid Fenac	1-30-64	Myriophullum heterophyllum	Sprayed	10 lbs.	100%	90%
		Brasenia schreberi			0%	0%
		Juncus repens			100%	90%
		Utricularia sp.			100%	90%
		Potamogeton diversifolius			100%	90%
Liquid Fenac	2 - 4-64	Myriophullum heterophyllum	**Sprayed**	20 lbs.	85%	85%
		Najas quadalupensis			85%	85%
Liquid Fenac	2 -4-64	Myriophyllum heterophyllum	Sprayed	10 lbs.	75%	75%
		Najas quadalupensis			75%	75%
Liquid Fenac	3 - 6-64	Eleocharis acicularis	Sprayed	20 lbs.	100%	100%
		Juncus repens			100%	100%

TABLE 4

RESULTS OF TREATING EXPOSED MUD FLATS WITH SOIL STERILANTS DURING WINTER DRAWDOWN

Herbicide	Date Treated	Species	Method of Application	Pound/Acre Acid Equivalent	Per Cent Control The Following Spring (March-May)	Summer (June-August)
Fenac 10G	10-15-63	Najas marina var.	Broadcast	20 lbs.	60%	40%
		gracilis	Broadcast	10 lbs.	30%	10%
Fenac 10G	10-15-63	Najas marina var.	Broadcast	10 lbs.	50%	0%
		gracilis	Broadcast	10 lbs.	50%	40%
Fenac 10G	10-15-63	Najas marina var. gracilis				
Fenac 10G	10-15-63	Najas marina var. gracilis				
Fenac 10G	1-29-64	Nymphaea odorata	Broadcast	10 lbs.	0%	0%
		Brasenia schreberi			0%	0%
		Nuphar advena			0%	0%
		Hydrotrida caroliniana			100%	100%
		Eleocharis acicularis			100%	100%
		Utricularia sp.			100%	100%
Fenac 10G	1-30-64	Brasenia schreberi	Broadcast	10 lbs.	0%	0%
		Myriophyllum hetero-phyllum			100%	90%
		Juncus repens			100%	90%
		Utricularia sp.			100%	90%
		Potamogeton diversi-folius			100%	90%
Fenac 10G	2 - 4-64	Myriophyllum hetero-	Broadcast	10 lbs.	90%	90%
		phyllum			100%	100%
		Najas guadalupensis				
Fenac 10G	3 - 6-64	Eleocharis acicularis	Broadcast	10 lbs.	100%	100%
		Juncus repens			100%	100%

TABLE 5

RESULTS OF TREATING EXPOSED MUD FLATS WITH SOIL STERILANTS DURING WINTER DRAWDOWN

Herbicide	Date Treated	Species	Method of Application	Pound/Acre Acid Equivalent	Per Cent Control The Following Spring (March-May)	Per Cent Control The Summer (June-August)
Tritac-10G	1-29-64	Nymphaea odorata	Broadcast	15 lbs. /ac.	0.0%	0.0%
		Brasenia schreberi			0.0%	0.0%
		Nuphar advena			0.0%	0.0%
		Hydrotrida caroliniana			10%	0.0%
		Eleocharis acicularis			10%	0.0%
		Utricularia sp.			10%	0.0%
Tritac-10G	1-30-64	Myriophyllum hetero-	Broadcast	15 lbs. /ac.	10%	10%
		phyllum			10%	10%
		Juncus repens			0.0%	0%
		Brasenia schreberi			10%	10%
		Potamogeton sp.			10%	10%
		Utricularia sp.	Broadcast	15 lbs. /ac.	75%	50%
Tritac-10G	2 - 4-64	Najas quadalupensis			75%	50%
		Myriophyllum hetero-			75%	50%
		phyllum			75%	50%
		Chara sp.	Broadcast	15 lbs /ac.	100%	35%
		Isoetes sp.			100%	35%
Tritac-10G	3 - 6-64	Juncus repens				
		Eleocharis acicularis				
M.B.C.	1-29-64	Nymphaea odorata	Broadcast	400 lbs. /ac.	0.0%	0.0%
		Brasenia schreberi			0.0%	0.0%
		Nuphar advena			0.0%	0.0%
		Hydrotrida caroliniana			0.0%	0.0%
		Eleocharis acicularis			0.0%	0.0%
		Utricularia sp.			0.0%	0.0%

PRE-EMERGENT ADGAE CONTROL EXPERIMENTS USING TABDE TRIAZINE HERBICIDES

In recent years, the algicidal properties of triazine hericides have been teseted by fisheries workers (Snow, Grisby, Peters and Richards). Snow (1963) found that simazine greatly reduced the net algae *Hydrodicton* is bass spawning and rearing ponds and that bass fingerling production was high in these waters.

The warm water branched alga *Pithophora* commonly infests ponds in the Southeast. Past chemical controls included delrad (dehydroabrietylamine acetate) (Lawrence (1954), copper sulphate (Snow 1956), and sodium arsenite (Surber 1959, Lawrence 1957. These chemicals were found to be either too costly, were toxic to fish food organism (Snow 1956, Surber and Meehean 1931, Lawrence 1957).

In searching for a better algicide, Snow (op. cit.) found that 3 ppm to 5 ppm simazine (1) was effective in controlling *Pithophora, Hydrodictyon* and *Zygnema* with no reduction in zooplankton, or other animal life. However, the phytoplankton was greatly reduced and did not develop for several weeks afeter treatment. This was found to be the only noticable ill effect in using this herbicide and possibly could be remedied by using different techniques, concentrations or timing.

During the spring of 1964, simazine (1), atrazine (2) and prometryne (3) were applied to recently flooded hatchery ponds to determine their effectivesness in preventing filamentous algae development.

Each of the hatchrey ponds selected, previously contained *Pithophora, Zygnema, Oedogonium, Rhizoclonium* and *Ulothrix.* All ponds flooded in March and treated with one of the triazine herbicides.

These wettable powders were mixed with water and broadcast over the pond's surface from the bank. Complete coverage was not obtained, however, a uniform blending was noted within an hour after treatment.

The following data gives the results from testing each of the three triazine herbicides using the above techniques.

SIMAZINE:

Six field tests indicated that this herbicide defintely discouraged the development of filamentous algae in hatchery ponds at concentrations of .5 to 1 ppm.

No filamentous algae became established in any of the ponds for a period of thirty days, and with only one exception, no infestation was indicated within sixty days. As was found by other fisheries workers, phytoplankton development was significantly reduced by simazine treatments. The authors noted that no filamentous algae became estiblished during the long period the phytoplankton blooms were developing, indicating that lethal concentrations were present in the pond mud but not in the water. Table 6 gives additional algae control information using simazine.

ATRAZINE:

The development of branched and unbranched filamentous algae was significantly suppressed using this algicide as a pre-emergent.

No infestation was apparent within sixty days using 1 ppm atrazine; however, two of the three ponds treated with .5 ppm developed filamentous algae within thirty days. This material is more solule than simazine; therefore excessive leaching may account for the infestation experienced at the lower concentrations. See table 7 for additional pre-emergent data using atrazine.

PROMETRYNE:

A 1 ppm concentration of this highly coluble triazine berbicide completely discouraged filamentous algae development in three hatchery ponds for a period of sixty days. As was experienced with sima-

TABLE 6

WEED CONTROL EXPERIMENTS

USING SIMAZINE AS A PRE-EMERGENT CONTROL OF FILAMENTOUS ALGAE

Date Treated	Previous[1] Problem Species	Method of Application	Acid Equivalent Concentration	PER CENT INFESTATION 10 days	30 days	60 days
3 - 9-64	Pithophora Oedogonium Zygnema	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Zygnema Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Zygnema Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	0.0%	30.0%[2]
3-24-64	Pithophora Zygnema Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Zygnema Rhizoclonium	Broadcast	0.5 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Zygnema Rhizoclonium	Broadcast	0.5 p. p. m.	0.0%	0.0%	0.0%

1 Species found in adjacent ponds not treated with herbicides
2 Water rose above level where treatment was made

TABLE 7

WEED CONTROL EXPERIMENTS

USING SIMAZINE AS A PRE-EMERGENT CONTROL OF FILAMENTOUS ALGAE

Date Treated	Previous[1] Problem Species	Method of Application	Acid Equivalent Concentration	PER CENT INFESTATION 10 days	30 days	60 days
3 - 9-64	Pithophora Oedogonium Zygnema	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Ulothrix Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3 - 9-64	Pithophora Oedogonium Zygnema	Broadcast	0.5 p. p. m.	0.0%	10.0%	retreat
3-24-64	Pithophora Ulothrix Rhizoclonium	Broadcast	0.5 p. p. m.	0.0%	50.0%	retreat
3-24-64	Pithophora Ulothrix Rhizoclonium	Broadcast	0.5 p. p. m.	0.0%	0.0%	0.0%

[1] Species found in adjacent ponds not treated with herbicides.

TABLE 8

WEED CONTROL EXPERIMENTS

USING SIMAZINE AS A PRE-EMERGENT CONTROL OF FILAMENTOUS ALGAE

Date Treated	Previous[1] Problem Species	Method of Application	Acid Equivalent Concentration	PER CENT INFESTATION 10 days	30 days	60 days
3 - 9-64	Pithophora Oedogonium Zygnema	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Ulothrix Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	0.0%	0.0%
3-24-64	Pithophora Ulothrix Rhizoclonium	Broadcast	1.0 p. p. m.	0.0%	5.0%	0.0%

[1] Species found in adjacent ponds not treated with herbicides.

zine and atrazine, phytoplankton development was definitely suppressed for a period of four to six weeks. See table 8 for additional pre-emergent prometryne application data.

Since the development of phytoplankton is necessary for top fish production and aquatic weed control, the authors concluded that these soil sterilants should be applied to the soil prior to flooding. If very limited soil-water exchange of these triazine herbicides exists, such a technique should control filamentous algae developing on the pond bottom without significantly affecting the phytoplankton. This belief is substantuated by the fifteen field tests discussed above, since the plankton algae became established before filamentous algae appeared.

POST EMERGENT WEED CONTROL EXPERIMENTS

Fisheries workers are constantly searching for effective aquatic herbicides having a wide range of control. Such herbicides must have a relatively low toxicity to fish and fish food organisms, particularly when used in hatcheries.

Tests have shown that phenoxy type herbicides are relatively slow acting which may or may not be desirable, depending on the situation. When rapid control is desirable, contact herbicides are generally substituted for the phenoxy types. Commonly used aquatic contact herbicides include sodium arsenite, copper sulphate, and delrad (dehyproabietylamine acetate). The two former herbicides were found to be detrimental to fish production (Snow 1956 and Lawrence 1957, Surber and Meehean 1931) while the latter treatments were expensive and of short duration (Lawrence 1954).

In an effort to locate more desirable aquatic herbicides, the authors conducted sixty-five post-emergent field experiments using six (6) different compounds and their combinations on 31 species of aquatic plants.

The following discussions and tables give the results of these experiments.

DIQUAT (9) and *PARAQUAT* (10)

These two quatenary bipyridyl chemicals have been subjected to extreme aquatic herbicides evaluation tests for the past four years. Previous tests made in the laboratory, plastic pools and limited field applications indicated that these herbicides effectively controlled many species of submerged and emerged aquatic plants for periods as long as several months at concentrations ranging from 0.2 to 0.5 ppm cation (Lawrence, Funderburk, Blackburn and Beasley 1961). Diquat was found to be safe for many fresh-water fish at concentrations up to 10 ppm cation, and paraquat appeared safe at concentrations greater than 5 ppm cation. Also, Lawrence (op. cit) and his colleagues found no harmful effects upon fish or fish food organisms in plastic pools treated with 5 ppm diquat and paraquat; the concentration found effective for obtaining 80% to 100% kill of fifteen species of aquatic plants.

Other research indicated that diquat adversely affected plankton at .5 ppm cation, but recovery was rapid. In addition, an increase of benthic organisms was noted soon after treatment and was attributed to increased organic decay present on the pond bottom. (Tatum and Blackburn 1963).

Field observations made by the writers indicated that plankton and benthic organisms were not significantly affected in ponds treated with dipuat and paraquat at concentrations varying from .03 to 2.00 ppm. Fish were not killed in ponds treated at concentrations as high as 10.00 ppm.

The following data were collected during thirty-three field tests using these two contact herbicides for the control of 18 species of aquatic plants. The present control was determined at 10, 30 and 60 day intervals and are recorded in tables 9 and 10 of this report.

Of the aquatic species treated, members of the duckweed family were found to be the most susceptible to diquat and paraquat while the lilies showed the strongest resistance.

Other aquatic species found to be highly susceptible to diquat and paraquat included *Najas guadalupensis, Callotriche sp.*, floating *Pithophora sp., Hydrodictyon sp., Utricularia sp.*, and *Jussiaee decurrens.*

Earlier workers found that these herbicides are rapidly absorbed by the clay colloid and apparently are not released under natural aquatic conditions (Lawrence, Funderburk, Blackburn and Beasley 1961). This was apparent to the writers when treating turbid ponds or when aquatic vegetation closely adheared to the pond bottom. Such conditions resulted in poor control.

Marginal species such as *Alternanthera philoxeroides, Leersia oryzoides* and *Hydrochloa carolinensis* were effectively controlled when their foliage was "sprayed to wet" with paraquat. The addition of a sticking agent ("All" detergent) appeared to assist in the herbicidal activity of paraquat when foliage treatments were made.

Even lilies have been defoliated for a short period of time when complete coverage was obtained using a wetting or sticking agent with diquat and paraquat.

Tests in other areas have shown diquat and paraquat's herbicidal activities are enhanced during periods of phtosynthesis. Therefore, a better kill can be expected if these herbicides are applied during periods of limited light (dusk). This allows maximum lateral translocation of the herbicides during the inactive periods; thereby killing more plant tissue during the next light period. Otherwise, cell destruction is limited to the point of contact, resulting in only scattered brown spots. However, no appreciable difference was noted between daylight and dark period treatments when complete uniform coverage was experienced. (MacKenzie, John W., Personal Communications).

Field tests found these highly active and relatively non-selective contact herbicides to be adaptable for spot treatments. A .5 acre fishing area was cleared of *Nitella, Hydrotrida, Myriophyllum heterophyllum* and *Potamogeton diversifolius* when treated with 1 ppm diquat cation. Within two weeks, the treated area was cleared of all vegetation and fishing was reported to be good. Wind action moved the toxic mass parallel to the shore line, killing an additional .25 acre area before it became too dilluted to be effective.

Another .5 acre fishing area was made possible using 2.5 ppm diquat for the control of *Myriophyllum heterophyllum.* The lily, *Brasenia,* was also present but was not affected. Since the lily infestation was very light, fishing in the area was not hampered after the water milfoil was removed. Water currents moved the toxic mass downstream killing an additional .25 acre area.

Three spot treatments using paraquat at rates of .04 ppm and 2.5 ppm cleared fishing areas infested with *Myriophyllum heterophyllum, Utricularia* and *Hydrotrida caroliniana* within two weeks. As was experienced with diquat, members of the lily family along with *Nymphoides aquaticum* were not affected.

For additional weed control experiments using diquat and paraquat, see tables 9 and 10.

SIMAZINE (1)

Snow (op. cit.) found this symmetrical triazine to be effective for controlling *Pithophora* and *Hydrodictyon* in hatchery ponds while Walker (1959) also controlled certain vascular plants in polyethylene enclosures.

Fifteen field tests proved simazine to be an effective post-emergent algicide at concentrations ranging from .75 to 1.00 ppm.

Each pond was treated using the simple broadcast method described previously in this report. Full effects of the treatments were not noticable for at least two weeks. Also, re-infestation was always experienced if the water fluctuated above the previously treated water level. However, if the pond was treated while it was at maximum height, no correlations between re-infestations and water level was evident. This indicated to the authors that simazine, at concentrations tested, did not maintain toxic levels in the water; therefore, if post treatment water levels rose, inundating virile algae, re-infestation occurred. As was previously mentioned, phytoplankton blooms were greatly reduced at all concentrations tested and did not satisfactorily re-establish for periods as long as one month.

The rooted aquatics *Zannichellia, Potamogeton diversifolius, Hydrolea* and *Myriophyllum heterophyllum* were controlled with 1 ppm simazine. *Hydrocotyle* was not affected at 1 ppm or *Eleocharis acicularis* at 1.5 ppm.

See table eleven (11) for additional weed control experiments using simazine.

ATRAZINE (2)

This triazine herbicide was found to be very similar to simazine except for its higher rate of solubility and was found to be an effective control for algae and some vascular plants. Since the rate of dispersion is closely associated with the degree of solubility, this herbicide proved to be more adaptable to the simple broadcast-application method than was the less soluble simazine.

Nineteen field tests produced excellent control for filamentous algae using 1.00 ppm atrazine. In one instance *Najas guadalupensis* was also killed at this concentration.

In two field tests, the warm water algae *Pithopora* was controlled at .5 ppm atrazine. However, in one experiment using 1 ppm atrazine, this branched alga became re-established within thirty days. This regrowth was attributed to fluctuating water levels, the effects of which have previously been mentioned.

The alga plankton *Microcystis* was controlled at .08 and .16 ppm atrazine and was replaced by a more desirable plankton algae within one week. Such treatments cost approximately $1.00 per acre foot and are therefore as economical as most algicides presently on the market.

Higher concentrations (.5 to 1 ppm) eliminated all phytoplankton for periods as long as one month. In three instances brood channel catfish appeared to suffer from lack of oxygen five days after the ponds were treated with 1 ppm atrazine for the control of *Oedogonium, Zygnema* and *Pithophora*. In each pond, the bottom was clearly visible at a depth of five feet, indicating the complete absense of phytoplankton or other suspended matter. When the fish were observed on the surface, fresh water was sprayed over the pond. Within thirty minutes the fish left the surface and returned to their normal activities. The possibility of temporarily removing all oxygen producting life should be taken into consideration in waters having a high B.O.D., particularly if surface wind action is limited or other aeration means are not readily available.

See table 12 for additional weed control experiments using atrazine.

PROMETRYNE (3)

This triazine herbicide was found to be one of the most effective algicides tested.

Branched and unbranched algae forms were eliminated at .5 to 1.5 ppm prometryne. In one instance, *Eleocharis acicularis* was re-

TABLE 9

POST EMERGENT WEED CONTROL EXPERIMENT USING DIQUAT

Species	Method of Application	Cation Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Pithophora	Broadcast	10.00 ppm	100	100	100
Pithophora	Broadcast	8.00 ppm	100	100	100
Pithophora	Broadcast	5.00 ppm	100	100	100
Lemna	Sprayed	2.50 ppm	100	100	100
Eleocharis acicularis			100	100	100
Hydrochloa carolinensis			95	100	100
Typha latifolia			50	100	100
Hydrochloa carolinensis	Sprayed	2.50 ppm	90	90	90
Myriophyllum heterophyllum	Sprayed &	2.5 ppm[1]	90	100	100
Brasenia schreberi	Pumped down		10	10	10
Eleocharis acicularis	Sprayed	2.00 ppm	100	100	100
Nitella	Pumped down	1.0 ppm[1]	90	100	100
Hydrotrida carolinana			90	100	100
Myriophyllum heterophyllum			90	100	100
Potamogeton diversifolius			90	100	100
Eleocharis acicularis	Broadcast	50 ppm	10	10	10

[1] Spot treatment.

TABLE 9 (cont.)

POST EMERGENT WEED CONTROL EXPERIMENT USING DIQUAT

Species	Method of Application	Cation Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Eleccharis acicularis	Sprayed	.40 ppm	100	**100**	**100**
Nuphar advena			20	**0**	**0**
Juncus repens			40	0	0
Nuphar advena	Sprayed & Pumped down	.40 ppm	10	0	0[1]
Hydrocotyle	Sprayed & Pumped down		10	0	0
Eleccharis acicularis	Sprayed & Pumped down		25	15	0
Najas guadalupensis	Sprayed	.40 ppm	100	100	100
Pithophora	Sprayed	.33 ppm	50	50	50
Hydrodictyon			50	50	50
Lemna	Broadcast	.25 ppm	100	100	100
Lemna	Broadcast	.25 ppm	50	25	Retreated[1]
Lemna	Sprayed	.25 ppm	100	100	100
Lemna	Sprayed	.25 ppm	100	100	100

[1] Turbid water.

TABLE 9 (cont.)

POST EMERGENT WEED CONTROL EXPERIMENT USING DIQUAT

Species	Method of Application	Cation Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Najas guadalupensis Pithophora Hydrodictyon	Sprayed	.25 ppm	100	100	100
Lemna	Broadcast	.20 ppm	100	100	
Pithophora	Pumped down	.20 ppm	85	85	75
Callitriche sp	Broadcast	.20 ppm	100	100	100
Lemna	Broadcast	.20 ppm	0	0 [1]	Retreated
Lemna	Broadcast	.20 ppm	95	95	50
Pithophora Hydrodictyon	Broadcast	.20 ppm	90	90	75
Lemna	Broadcast	.10 ppm	90	20	Retreated
Wolffia	Sprayed	.03 ppm	50	50	50
Alternanthera philoxeroides	Sprayed to wet	1 qt. to 5 gals. ater	95	75	20

[1] Turbid water.

TABLE 10

POST EMERGENT WEED CONTROL EXPERIMENT USING DIQUAT

Species	Method of Application	Cation Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Myriophyllum heterophyllum	Sprayed & Pumped down	2.5 ppm[1]	90	100	100
Nuphar advena			10	10	10
Brasenia schreberi			10	10	10
Utricularia			90	100	100
Myriophyllum heterophyllum	Sprayed & Pumped down	.40 ppm[1]	90	100	100
Nuphar advena			10	10	10
Brasenia schreberi			10	10	10
Utricularia			90	100	100
Hydrotrida carolinana	Pumped down	.40 ppm[1]	85	20	0
Nuphar advena			10	0	0
Nymphoides aquaticum			10	0	0
Myriophyllum heterophyllum			85	20	0
Alternanthera phfloxeroides	Sprayed	.20 ppm	100	100	100
Jussiaea decurrens			100	100	100
Panicum hemitomum			10	10	10
Alternanthera phfloxeroides	Sprayed to wet	1 gal paraquat/20 gals.[2] water plus 1 pt. "All" detergent	95	95	95
Leersia sp.	Sprayed to wet	1 qt. paraquat, 30 gals.			
Hydrochloa carolinensis		water	95	95	95
		½ pt. sticking agent/½ acre	100	100	100

[1] Spot treatment.
[2] Sprayed entire margin of pond. Equivalent to 3 gals. paraquat/acre infestation.

TABLE 11

POST EMERGENT WEED CONTROL EXPERIMENT USING SIMAZINE

Species	Method of Application	Acid Equivalent Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Zannichellia Pithophora Hydrodictyon	Broadcast	.75 ppm	85 85 85	Retreated	
Hydrodictyon	Broadcast	.75 ppm	100	100	30
Oedogonium	Broadcast	1.0 ppm	50	75	30
Zygnema	Broadcast	1.0 ppm	50	75	30
Pithophora	Broadcast	1.0 ppm	50	75	30
Eleocharis acicularis Hydrocotyle	Broadcast	1.0 ppm	25 10	60 10	
Myriophyllum heterophyllum Hydrolea	Broadcast	1.0 ppm	25 35	100 100	
Filamentous algae Potamogeton diversifolius	Broadcast	1.0 ppm	100 20	100 90	
Eleocharis acicularis	Broadcast	1.5 ppm	0	0	0
Hydrochloa carolinensis	Pumped down	5.0 ppm	0	20	100*

* No regrowth the following year.

TABLE 12

POST EMERGENT WEED CONTROL EXPERIMENT USING ATRAZINE

Species	Method of Application	Acid Equivalent Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Non-branched filamentous Algae	Broadcast	1.00 ppm	75	100	100
Non-branched filamentous Algae	Broadcast	1.00 ppm	75	100	100
Non-branched filamentous Algae	Broadcast	1.00 ppm	75	100	100
Najas guadalupensis Non-branched Filamentous Algae	Broadcast	1.00 ppm	25 75	100 100	100 100
Rhizoclonium Ulothrix	Broadcast	1.00 ppm	100	100	100
Rhizoclonium	Broadcast	1.00 ppm	100	100	100
Pithophora	Broadcast	1.0 ppm	100	90	Retreated[1]

[1] Water rose above level where treatment was made.

TABLE 12 (cont.)

POST EMERGENT WEED CONTROL EXPERIMENT USING ATRAZINE

Species	Method of Application	Acid Equivalent Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Oedogonium	Broadcast	1.00 ppm	75	50	Retreated[1]
Zygnema			75	50	
Pithophora			75	50	
Oedogonium	Broadcast	1.00 ppm	100	100	100[2]
Zygnema			100	100	100
Pithophora			100	100	100
Pithophora	Broadcast	.50 ppm	100	100	100
Pithophora	Broadcast	.50 ppm	100	100	100
Microcystis	Broadcast	.16 ppm	100	100	100
Microcystis	Broadcast	.08 ppm	100	100	100
Microcystis	Broadcast	.16 ppm	100	100	100

[1] Water rose above level where treatment was made.
[2] Consisted of seven separate experiments.

TABLE 13

POST EMERGENT WEED CONTROL EXPERIMENT USING PROMETRYNE

Species	Method of Application	Acid Equivalent Concentration	PER CENT CONTROL 10 days %	30 days %	60 days %
Pithophora	Broadcast	1.50 ppm	100	100	
Oedogonium	Broadcast		100	100	100
Zygnema		1.00 ppm	100	100	100
Pithophora			100	100	100
Pithophora	Broadcast	1.00 ppm	75	100	100
Pithophora	Broadcast	1.00 ppm	100	50	Retreated[1]
Pithophora	Broadcast	1.00 ppm	30	Retreated[1]	
Pithophora	Broadcast	1.00 ppm	100	75	Retreated[1]
Hydrochloa caroliensis	Broadcast	.75 ppm	5	0	0
Non-branched Filamentous Algae	Broadcast	0.50 ppm	100	100	100
Eleocharis acicularis			100	100	100

[1] Water rose above level where treatment was made.

TABLE 14

POST EMERGENT WEED CONTROL EXPERIMENTS USING DIFFERENT COMBINATIONS OR TECHNIQUES

Herbicides and plot size	Species	Method of Application	Concentrations	PER CENT KILL IN: 10 days	30 days	60 days
Paraquat and Fenac-10G in .5 acre plot	Hydrotrida carolinana Myriophyllum heterophyllum Eleocharis acicularis	Pumped down paraquat and broadcast (Fenac-G)	.4 ppm paraquat 20 lbs. active Fenac	95%	95%	75%
Paraquat and Prometryne in .5 acre plot	Najas quadalupensis Oedogonium Rhizoclonium	Sprayed and pumped down. Added prometryne seven days later.	.20 ppm paraquat 1.0 ppm prometryne	100% 100% 100%	100% 100% 100%	100% 100% 100%
Fenac-10G	Myriophyllum heterophyllum	Staked out in a burlap bag.	2.5 lbs. active Fenac	in 2.5 ft. radius around bag.	100%	

moved at .5 ppm. However, *Hydrochloa carolinensis* was not significantly affected at a .75 ppm concentration.

In three instances, algae regrowth appeared within thirty days after treatment but was associated with fluctuating water levels as previously explained.

This herbicide is very soluble and was therefore found to be well adapted to the simple broadcast-application method.

At 1. ppm, prometryne and atrazine gave excellent control of filamentous algae within ten (10) days; whereas, comparable concentrations of the less soluable simazine took longer. Therefore, if immediate control of filamentous algae is desired, the two former triazines are recommended.

See table 13 for additional prometryne data.

FENAC (4)

This soil sterilant, previously mentioned as an effective pre-emergent herbicide, was also tested as a post-emergent and found effective for controlling *Potamogeton natans* at 1 ppm.

POST EMERGENT WEED CONTROL EXPERIMENTS USING DIFFERENT HERBICIDE COMBINATIONS OR TECHNIQUES

In an effort to find effective means of clearing fishing areas in large impoundments, heavily infested with aquatic weeds, two herbicide combinations were tested. One combination consisted of a fast acting contact herbicide (paraquat) and an effective soil sterilant (fenac). The other combination included paraquat and the triazine prometryne. Both combinations proved effective for clearing .5 arce plots for sixty days; however, the latter combination was considerable better.

Also, a burlap bag partially filled with twenty-five lbs. of fenas pellets (2.5 lbs. active) was staked out in a bed of *Myriophyllum heterophyllum* to determine if lethal concentrations would slowly leach out of the bag, thereby, opening up a sizeable fishing area. However, within thirty days, an area having a radius of only 2.5 feet was recoated. Even though the results of this test were considered poor, other herbicides should be tested in this manner in an attempt to find a simple means of reducing aquatic vegetation from around fishing docks and piers.

For additional information, see table 14.

SUMMARY

On the basis of the data obtained in these exepriments, the following general conclusions are apparent.

1. Fenac (4) proved to be an effective aquatic herbicide for clearing fishing areas in large weedy ponds when applied to exposed mud flats during winter drawdowns at rates of 10 and 20 lbs. active ingredients per acre. Members of the lily family were not affected, however. Fenac was also found to be an effective post-emergent aquatic herbicide for controlling *Potamogeton natans* at 1 ppm.
2. Simazine, atrazine and prometryne were found to be effective pre and post-emergent filamentous algicides. No filamentous algae developed in ponds unless the water later rose above the level at which treatment occurred. Therefore, all treatments should be made when the pond water level is maximum. All applications ranging from .5 to 1 ppm inhibited or eliminated plankton algae growth for periods as long as six (6) weeks.

Microcystis blooms were removed and rapidly replaced with more desirable plankton algae when .08 and .16 ppm atrazine was applied. Since these materials are such effective algicides, it is recommended that they be applied to the soil prior to flooding; thereby, retaining their filamentous algae control properties without significantly reducing the desirable phytoplankton development.

3. Diquat and paraquat exhibited non-selective herbicidal properties at concentrations ranging from .25 to 10. ppm cation. Most aquatic plants were satisfactorily controlled at concentrations between .25 and .5 ppm cation. Members of the duckweed family were found to be the most susceptible plants treated, while the lilies appeared to be the most tolerant. No adverse effects on fish, fish food organisms or plankton were encountered when using these herbicides.

However, oxygen depletion can be expected when treating rank growths of susceptible plants since these contact herbicides kill extremely rapidly. When spraying these herbicides on emergent vegetation, complete coverage should be obtained. This can be better accomplished by using a wetting agent.

These herbicides, at concentrations ranging from .4 to 2.5 ppm cation, effectively cleared aquatic vegetation from fishing areas (spot treatments) in large impoundments for a period of sixty (60) days.

HERBICIDES TESTED[1]

(1) Simazine (2-chloro-4,6-bis(ethylamino)-s-triazine)
(2) Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine)
(3) Prometryne (2,4-bis(isopropylamina)-6-methylthio-s-trazine)
(4) Fenac (2,3,5 trichloro phenyl acetic acid)
(5) Vacate (Disodium tetra Borate Penta and Decahydrate plus 3 (B-chlorophenyl)-1-1-dimethylurea)
(6) D.M.A. (disodium monomethylarsonate)
(7) M.B.C. (Sodium borate-Sodium Chlorate)
(8) Tritac (2,3,6-Trichlorobenzyloxyproponol)
(9) Diquat (1:1-ethylene-2:2'-dipyridylium dibromide)
(10) Paraquat (1:1-ethylene-4,4'-dipyridylium dichloride)

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[1]Herbicides provided through the courtesy of Geigy Chemical Company, Amchem Chemical Company, Diamond Chemical Company, Hooker Chemical Company and California Chemical Company.

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A REPORT ON THE USE OF KARMEX TO CONTROL FILAMENTOUS ALGAE IN FISH PONDS

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ABSTRACT

Several chemicals that have been used in fish culture for the control of filamentous algae are discussed. Their effects on fish and fish-food organisms in ponds are reviewed.

Results obtained from applications of Karmex to 26 ponds are presented. Data show that Karmax was effective against several forms of filamentous algae at rates above one-half pound per surface acre. Rates up to three pounds per surface acre had no adverse effects on fish or fish-food organisms.

[1]U. S. Dept. of the Interior, Fish Farming Experimental Station, Stuttgart, Arkansas