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AQUATIC WEED CONTROL IN FISH PONDS

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VII/E-1

AQUATIC WEED CONTROL IN FISH PONDS

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CONTENTS

Abstract

Results of 30 years of aquatic weed control research in fish ponds at this Station are summarized. This summary includes a listing of important algae genera and aquatic weed species, and information on pond construction features of significance in aquatic weed control, as well as mechanical, biological, and chemical control techniques. Included in discussions on chemical control techniques are data on fish toxicity of each herbicide as well as effective rates of application for use under pond conditions.

LUTTE CONTRE LA VEGETATION AQUATIQUE DANS LES ETANGS DE PISCICULTURE

Résumé

Ce document fait le point des résultats de trente années de recherche sur la lutte contre la végétation aquatique dans les étangs de pisciculture de cette station expérimentale. Il contient une liste des principales algues et plantes aquatiques ainsi que des renseignements sur les caractéristiques de construction des étangs revêtant une importance pour le contrôle de la végétation aquatique ainsi que sur les procédés mécaniques, biologiques et chimiques de lutte contre cette végétation.

L'examen des moyens de lutte chimique comporte des données sur la toxicité des divers herbicides à l'égard du poisson ainsi que sur les doses pratiques recommandées dans les conditions de pisciculture en étang.

LUCHA CONTRA LAS MALAS HIERBAS ACUATICAS EN LOS ESTANQUES PISCICOLAS

Extracto

Se resumen los resultados de 30 años de investigaciones en esta Estación, en la lucha contra las hierbas adventicias acuáticas en los estanques piscícolas. Este resumen comprende una lista de importantes géneros de algas y especies de plantas adventicias acuáticas, así como información sobre características de la construcción de estanques de importancia para la lucha contra las hierbas adventicias acuáticas, así como las técnicas de lucha mecánica, biológica y química. Junto con las discusiones sobre las técnicas de lucha química figuran datos sobre toxicidad para los peces de cada uno de los herbicidas, así como las cantidades efectivas en que han de aplicarse, para su utilización en las condiciones de los estanques.

VII/E-1

1 INTRODUCTION

Weed infestations vary in different types of fish ponds. In a new pond, weeds will usually appear during the first year or two if the pond is not fertilized. If water is clear, within a few months weeds will fill major portions of the pond. If water is muddy most of the time, there will be limited weed growth except in shallower, marginal areas. Swingle (1945), reported total fish production was practically the same in weed-filled and muddy ponds, but the catch of fish was greater in muddy ponds since weeds were not present to interfere with angling.

Ponds with fluctuating water levels, even though fertilized, often become partially o completely filled with weeds. During summer months, when the water level recedes, weeds invade the wet, exposed pond edge. When the water level returns to normal, as a result of winter rains, many species of these weeds continue to grow and begin their invasion of deeper waters.

Hatchery ponds are excellent habitats for all kinds of aquatic weeds since they are drained one or more times during warm months of each year. Even though these ponds are immediately refilled with water the bottoms are exposed to sunlight for several weeks because of difficulty in obtaining a phytoplankton growth in newly-filled ponds. This clear water period gives the weeds an excellent opportunity to become established.

2 AQUATIC WEED IDENTIFICATION

Aquatic weeds can be defined as those unwanted and undesirable plants growing in an aquatic environment and refer only to those plants which are adapted to grow and reproduce under such aquatic conditions. A knowledge of the identity of several hundred species of aquatic plants, which interfere with fish pond operations, is necessary if efficient and effective chemical control practices are to be employed. As an aid in both identification and use of control measures the following simple outline of major plant groups based upon their shape, size, and growth habits has been developed.

Algae

- Planktonic (e.g. *Microcystis*, *Anabaena*)
- Filamentous (e.g. *Spirogyra*, *Pithophora*, *Chara*, *Nitella*)

Submerged weeds (e.g. *Potamogeton*, *Elodea*, *Ceratophyllum*, *Utricularia*)

Emersed weeds (e.g. *Nymphaea*, *Hydrocotyle*)

Marginal weeds (e.g. *Juncus*, *Typha*, *Carex*, *Sarpus*, *Sparganium*, grasses)

Floating weeds (e.g. *Pistia*, *Eichhornia*, *Trapa*, *Lemna*, *Salvinia*, *Azolla*)

3 PREVENTION OF WEED GROWTHS IN NEW PONDS

The simplest and easiest method for control of aquatic weeds is to prevent their establishment in a pond. Proper construction of the pond is a major step in this type of control. Before construction is started, the proposed pond site should be checked to dete mine that it meets the requirements for a good pond as described by Lawrence (1949). Construction features include: (i) a dam sufficiently high to produce an impoundment with a minimum of water not less than 0.5 m in depth; (ii) deepening of the pond edge to reduce the hazard of marginal and shallow water weed growth; (iii) shaping and sodding of the pon edge above water level to reduce the area where marginal weeds could appear; (iv) a diversion ditch, if necessary, to carry excessive and/or muddy water around the pond, thus permitting fertilization of the pond from early spring until fall.

After a pond is properly located, constructed, and filled with water, the next step prevention of aquatic weed growth is proper fertilization of the impounded water. If the pond water clears periodically, because of irregular fertilization or too large an inflow of water, sufficient sunlight often reaches the bottom for submerged weed growth to start. Therefore, it is necessary that regular fertilization of the pond, as recommended by Swingle and Smith (1942) be practised. A platform method for applying fertilizer, described by Lawrence (1952), is more efficient than the old broadcast method in that less labour is required in applying it plus the fact that plant nutrients dissolve in the top waters before they come into contact with the soil. Thus, there is a reduced likelihood of phosphorus and potash being bound on to clay particles in the bottom muds before phytoplankton can utilize them.

A pond that is properly constructed and fertilized supports a minimum of aquatic weed growth. The few weeds that appear along the pond edge must be removed immediately. Protection from aquatic weed invasion exists only as long as the preventative practices described above are kept in operation.

4 CONTROL TECHNIQUES

Since the establishment of the Farm Ponds Project on the Alabama Agricultural Experiment Station in the early 1930s research has been in progress to find means of eliminating unwanted aquatic plant growths in ponds without interfering with fish production. Techniques which have been tried and results that have been obtained are briefly outlined below. For simplicity, these techniques will be separated and classified as biological, mechanical, or chemical methods.

4.1 Biological methods

4.1.1 Inorganic fertilization

Application of inorganic fertilizer during winter months promoted growths of filamentous algae over masses of rooted aquatic weeds and resulted in the elimination of many species of submerged weeds when the weather became hot in the spring. Fish production in such treated ponds was of an explosive nature. Elimination of weed cover allowed bass to eat small bluegills and the released pressure on bluegill food supply, plus additional food produced by decomposing plants, resulted in tremendous growth of fish. This method cannot be used in ponds receiving large amounts of flood water or those with muddy water during late winter or early spring months (Swingle and Smith, 1947).

Applications of inorganic fertilizer to weed-free ponds during warm months has promoted growths of planktonic algae resulting in sufficient shading to prevent establishment of submersed and emersed species of weeds.

4.1.2 Fish

Carp: common carp (Cyprinus carpio) in sufficient numbers (400 per ha or more) roiled the bottom muds and the resulting muddy waters prevented submersed aquatic weed growth by shading.

The Israeli strain of common carp in limited numbers (55 per ha) has controlled the branched alga Pithophora and mono-filament algae in ponds.

Tilapia: T. mossambica and T. nilotica in sufficient numbers have controlled Pithophora and other filamentous algae in ponds during the warmer months.

Tilapia melanopleura in sufficient numbers have controlled filamentous algae and a number of submersed weeds in ponds during the warm months.

Grass carp (Ctenopharyngodon idella): In limited trials this species has eliminated filamentous algae, submersed and emersed weeds in small pools, (Avault, 1965).

4.2 Mechanical methods

4.2.1 Cutting

Emersed type weeds and some submersed species have been controlled by periodic cuttir plus regular fertilization. Normally two years of cutting were necessary to completely eliminate the emersed species. If fertilization was not practised during this two-year cutting period, the emersed weeds were replaced by submersed species. Thus, any cutting operation had to include an adequate fertilization program to be successful.

4.2.2 Deepening of pond edge

In old fertilized ponds repeated removal of marginal weeds including the soil (by shc hoe or mechanical digger) in the shallow water gradually deepened the marginal water areas prevented weed reinfestation by elimination of suitable habitat. Thus, a deepened pond ec (no water less than 0.5 m in depth) was recommended as a construction feature for all ponc

4.2.3 Beating

Several mono-filament forms of filamentous algae have been eliminated from fertilizec ponds by beating with a cane pole or agitation of the floating algae masses.

4.2.4 Shading

Dyes: Partial control of filamentous algae and submersed weeds have been obtained bj shading with dyes in the early spring. However, the dyes used (nigrosine and pontamine green) were unstable in pond waters and the colour faded rapidly. Thus, the shading effec was temporary, and repeated (weekly) applications of dyes had to be made to maintain the desired shading effects.

The floating box and submersed bag technique for applying chemicals to the surface oi a pond were a result of this research with dyeing pond waters.

Silt: Submersed and emersed weeds have been eliminated from ponds in which the wate periodically was muddy. Such muddy water shaded the pond bottom and deposited silt on lea and stems of plants which aided in their control.

4.2.5 Light requirements of plants

Laboratory studies have produced some information on shading effects produced by fert lization, dyes, and silt. Brazilian elodea (Elodea densa) had low light intensity requir ments (optimum growth at 10 foot-candles), and was killed by exposure to intensities greater than 200 foot-candles. Waterstargrass (Heteranthera dubia) had high light intensi requirements (optimum growth above 600 foot-candles), and was retarded by exposure to inte sities less than 50 foot-candles. With each species more vigorous growth was obtained by exposure to the red end of the spectrum and less vigorous growth was produced by exposure to the blue end of the spectrum (Blackburn, 1961).

In the laboratory Pithophora, southern naiad, (Najas quadalupensis) water-thread por weed (Potamogeton diversifolius) Brazilian elodea, and waterstargrass were successfully grown in 4-litre glass jars under light intensity of 60 to 100 foot-candles for a duratior of ten hours per day.

Under slightly different laboratory conditions Pithophora, waterstargrass, common duckweed (Lemna minor), alligatorweed (Alternanthera philoxeroides) and waterhyacinth (Eichhornia crassipes) were successfully grown in 4-litre glass jars at light intensity oi 600 to 800 foot-candles for a duration of 14 hours per day (Lawrence, 1964b).

Laboratory tests demonstrated that a short exposure (five to ten minutes) to a sufficent intensity of ultra violet light (2,537 A°) would cause death of duckweed.

4.3 Chemical methods

The techniques presented under this section are those developed or tried at this Station and do not imply that the same results would be obtained by the same concentrations of a given chemical on the same or other plant species in different areas of the world, or in the same areas with different soil, water, or climatic conditions (Lawrence, 1962 and in press).

4.3.1 Copper sulphate

Toxicity to fish

Formulation	Concentration in ppm safe to Bass1/	Bluegill2/	Fathead3/
Fine crystals	1 to 3	1 to 3	1
Application range: 0.1 to 1.0 ppm			

1/ Bass - Micropterus salmoides
2/ Bluegill - Lepomis macrochirus
3/ Fathead - Promelas pimephales

Periodic treatments at 10 to 14 day intervals at rates of 0.7 to 1.0 kg per surface ha and applied to the surface layer of water have effectively controlled the abundance of most blue-green algae (primarily Microcystis and Anabaena). Minimum rates of application were used to prevent too rapid and too extensive kills of these algae and subsequent death of fish from oxygen depletion because of plant decomposition.

Applications of 1 ppm or more have been fairly effective in controlling Chara. However, in certain waters 1 ppm has been toxic to fish.

Applications of 1 ppm have been unpredictable in their effectiveness as an algicide for the filamentous algae Oedogonium spp., Zygnema spp., Hydrodictyon spp., and Rhizoclonium spp.

Concentrations of copper sulphate that can be tolerated by fish have been ineffective as an algicide for Pithophora spp.

4.3.2 Sodium arsenite

Toxicity to fish

Formulation	Concentrations in ppm safe to Bluegill	Bass	Fathead
Salt	18	12	8

Application range: 2 to 4 ppm As_2O_3

The concentrations indicated have provided excellent control of many branched, net and monofilament algae species as well as for most submersed weed species. Reliable results have been obtained over a wide range of pond conditions.

Concentrations in excess of those indicated have been ineffective on Chara spp., Nitella spp., slender spikerush, needle rush (Juncus roemericanus), and southern watergrass.

VII/F-1

Herbicidal activity of sodium arsenite on the filamentous algae Hydrodictyon and Pithophora has been variable depending upon the stage of growth when chemical was applied.

Concentrations greater than 4 ppm As_2O_3 have reduced warm-water fish production in treated ponds.

Arsenic was found to accumulate in plankton and in bottom muds. Its accumulation was apparently due to replacement of large amounts of phosphorus by arsenic in both the plankton and muds of treated ponds (Lawrence, 1958). Arsenic concentrations in bottom muds were reduced by repeated draining and refilling of ponds.

Fish living in arsenic-treated water accumulated arsenic in scales, fins and in liver tissue, but did not accumulate it in muscular and connective tissue (Dupree, 1960).

4.3.3 2,4-D — 2,4-Dichlorophenoxyacetic acid

2,4-D	BE	-do-	butyl ester
-do-	ME	-do-	methyl ester
-do-	IPE	-do-	isopropyl ester
-do-	ICE	-do-	isooctyl ester
-do-	BEE	-do-	butoxy ethanol ester
-do-	EE	-do-	ethyl ester
-do-	PGBEE	-do-	propylene glycol butyl ether ester
-do-	ACA	-do-	acetamide
-do-	AA	-do-	alkanolamine
-do-	DMA	-do-	dimethylamine
-do-	Dacamine	-do-	duomeen-o-amine
-do-	Emulsamine	-do-	oil soluble amine

Toxicity to fish

Formulation	Concentration in ppm safe to			
	Bass	Bluegill	Fathead	Trout 1/
Acid	10	10	10	10
Na salt	400	200		112
NH_4	400	100		
AA		4		
IPE	1	1	1	
BE	2.5	2.5		
PGBEE	2	2	2	

Application range: 4.5 to 22 kg per ha

1/ Rainbow trout - Salmo gairdneri

The lower rate has provided effective control of emergent and marginal weeds by repeated spraying with an ester formulation in diesel fuel as carrier (Snow, 1949).

Selective control of certain broadleafed emergent and marginal weeds has been obtained by spraying with ester or amine formulation in water carrier. With most species much more effective control has been obtained when 0.25 percent of a good emulsifying agent was added to the 2,4-D solutions.

Growths of slender spikerush (needlerush) and southern water-grass have been successfully controlled in ponds by draining, removing the rank growth, and allowing the weed to start regrowth on the empty pond bottom. This regrowth was then sprayed with an ester formulation in diesel fuel as carrier, and resprayed within one week to control plants missed by the first application. The pond bottom was then flooded.

All formulations have been ineffective as control agents for Pithophora spp. as well as for most other forms of algae.

2,4D acid was found to be rather non-toxic to fish (no kills of warm-water species at 10 ppm). The butyl ester was non-toxic to these same species at 2.5 ppm whereas the propylene glycol butyl ether ester was non-toxic at 2.0 ppm. Solvents and emulsifiers used with the various ester formulations of 2,4-D varied in toxicity to warm-water species of fish, but minimum toxic concentrations were in the range of 5 ppm or less.

4.3.4 Silvex - - - - - 2(2,4,5-trichloeophenoxy) propionic acid

-do- ,BEE	butoxy ethanol ester
-do- ,PGBEE	propylene glycol butyl ether ester
-do- ,K	potassium salt

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10.
BEE	2	2	2
PGBEE	2	2	2
K	10	10	10

Application range: 4.5 to 22 kg per ha; 1 to 5 ppm

Lower rates have provided control of several hard-to-kill emersed and marginal weeds by spray application of an ester formulation in diesel fuel or water solution. The addition of 0.25 percent of a good emulsifying agent has increased the effectiveness of both spray solution combinations.

At concentrations of 2 to 5 ppm, ester formulation in water has provided excellent control of most sumbersed and emersed weeds in ponds, and has provided sufficient soil residual to prevent reinfestation for periods up to three years. The same results have been obtained using maximum rates of an ester formulation impregnated onto clay granules.

All formulations, even at maximum rates, have been ineffective as control agents fo Pithophora spp., Chara spp., and most other forms of filamentous algae.

4.3.5 2,4,5-T—2,4,5,-trichlorophenoxyacetic acid

-do-	BEE	-do-	butoxy ethanol ester
-do-	PGBEE	-do-	propylene glycol butyl ether ester

VII/E-1

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10
BEE	2	2	2
PGBEE	3	3	3

Application range: 4.5 to 9 kg per ha

Primarily effective as a control agent for woody marginal species of plants, best results have been obtained by spraying an ester formulation in a diesel fuel carrier with 0.25 percent of an emulsifying agent added.

It is ineffective as a control agent for most emersed and submersed weeds and algae in ponds, even at the maximum rate.

4.3.6 MCP_2-methyl - 4- chlorophenoxyacetic acid

-do- AA -do- Alkylamine salt

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10
AA	710	710	710

Application range: 4.5 to 22 kg per ha

Specified rates provided adequate control of marginal and floating weeds by spray application of ester formulation in diesel fuel as carrier. All chlorophenoxyacetic compounds (2,4-D; silvex; 2,4,5-T; MCP) are volatile, the ester formulation being more volatile than the amines. So, due care has to be exercised in spraying these chemicals to avoid damage to desirable surrounding vegetation.

4.3.7 Dichlone 2,3 dichloro-4-naphthoquinone

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Wettable powder	0.1	0.1	0.1

Application range: 0.15 ppm

At rates non-toxic to warm-water fish (less than 0.1 ppm), this chemical has been ineffective as a control agent for blue-green algae.

4.3.8 Delrad, (Rosin amine D acetate)- - -'-dihydroabietylamine acetate

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acetate	0.6	0.6	0.6

Application range: 0.25 to 0.50 ppm

This chemical has given varied results as an algicide in ponds. Under certain conditions a single application has given fair control of the branched algae Pithophora spp., and the net algae Hydrodictyon spp., and in other situations the chemical was practically inactive. The chemical was fairly rapidly deactivated in pond waters, thus adding to its inability to give reliable algae control. This deactivation was believed to have been due to exposure to ultra-violent light.

This chemical was fairly toxic to warm-water species of fish (maximum safe concentration was 0.6 ppm). When making marginal applications to ponds, young bluegills and bass caught in fairly high concentrations of the chemical have been killed. However, when the chemical was applied by the float technique, three applications of 0.3 ppm in ponds during the period bass spawned had no harmful effect upon the eggs or young fish.

In other pond tests, no difference in fish production in delrad-treated and untreated ponds was detected. This chemical was not toxic to the green or blue-green plankton algae present in treated ponds.

4.3.9 Diquat—1-1'-ethylene- 2,2'dipyridylium dibromide
-do- dichloride

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass	Bluegill	Fatheads
Dibromide salt	20	20	20
Dichloride salt	20	20	20

Application range: 1 to 4.5 kg per ha; 0.2 to 1.0 ppm (cation)

This chemical at rates of 1 to 2 kg (cation)/surface ha has provided excellent control of many submersed and floating species of weeds. Herbicidal activity has usually been noted within a few hours. This herbicide was absorbed onto the mud and organic matter on the pond bottom within 14 days.

Diquat cannot be used in muddy or silty waters because of rapid adsorption onto suspended clay and organic particles. It is relatively ineffective on submersed weeds whose leaves and stems are silt- or algae-laden.

This chemical has produced a kill of the blue-green alga, Anabaena, within 24 hours at a concentration of 0.5 ppm. It appeared to be very toxic to mono-filamentous algae and produced 80 percent control of Pithophora at concentrations of 0.7 ppm.

Small amounts, say, 0.2 to 0.5 kg per ha of this chemical in combination with 2,4-D, fenac or similar compounds has produced more rapid and complete herbicidal activity on many submersed weeds than could be obtained with either chemical alone.

Mixed with water and 0.25 percent wetting agent, diquat at lower rate has provided control of marginal weeds, including grasses, for periods of six to eight weeks.

4.3.10 Paraquat—1:1' -dimethyl -4.4' -bipyridylium di (methyl sulphate)dichloride

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Di (methyl sulphate) safe	5	10	10
Dichloride salt	5	10	10

Application range: (1 to 4.5 kg per ha); 0.1 to 1.0 ppm (cation)

This chemical at rates of 1 to 2 kg(cation)/surface ha has provided more complete :ontrol of submersed weeds than diquat, but it is less effective as a control agent for 'loating weeds.

Herbicidal injury from paraquat is slower in appearing than with diquat, but under ıdverse conditions of an alga covering on plants, etc., is more certain to be achieved. ,ikewise the persistence of paraquat in water may be twice as long as for diquat.

As with diquat, this chemical is rapidly adsorbed onto clay and organic particles, hus it cannot be used in muddy or silty waters.

Paraquat has controlled the blue-green algae Anabaena, and Pithophora, at concentra- :ions ranging from 0.5 to 1.0 ppm.

Mixtures containing equal parts of diquat and parquat have provided excellent control ıf submersed weeds and filamentous algae.

Combinations of paraquat and 2,4-D, fenac, etc., were equally effective as those usin iquat.

4.3.11 Simazine—3-chloro-4,6-bis (ethylamino)-s-triazine

Toxicity to fish

Formulations	Concentrations in ppm safe to Bass	Bluegill	Fatheads
Wettable powder	40	10	10

Application range: 2 to 11 kg per ha

At the higher rate, this chemical controlled all sumbersed and emersed weeds plus ilamentous and plankton algae. Residual simazine was detected in water and soil for 18 onths following treatment. Growth of filamentous and planktonic algae was severely nhibited for two summers, but for a much shorter period at the lower rate.

This chemical is relatively non-toxic to warm-water species of fish, but because of ts algicidal properties it has interfered with fish production.

4.3.12 Diuron —3-(3,4-dichlorophenyl)-1,1 dimethylurea

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Wettable powder	5	10 (laboratory) 1 (ponds)	15 (laborator 1 (ponds)

Application range: 1 to 11 kg per ha

Treatments in ponds located on piedmont and coastal plains soils were effective only t maximum rates on Pithophora and many submersed and emersed weeds. No regrowth of aquat eeds or filamentous algae occurred in these ponds for six months.

Diuron at the higher rate seriously interfered with fish production in experimental onds. Toxicity to fish became evident 14 to 21 days after the chemical was applied.

4.3.13 Borascu — Anhydrous polyborate

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Salt	20	20	20

Application range: 110 to 225 kg per ha

Pond treatments at rates of 225 kg per ha gave a very limited degree of control of *Pithophora* and no control of either submersed or emersed weeds.

4.3.14 TCA-Trichloroacetic acid

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Acid	10 plus	10 plus	10 plus

Application range: 2 to 18 kg per ha

The maximum rate provided no control of submersed aquatic weeds. A combination of minimum rate of TCA with 2,4-D and a good wetting agent provided effective control of cattail (*Typha* spp.)

4.3.15 Roccal, Alkyl-dimethyl-benzyl-ammonium chloride

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Salt	1	1.5	1

Application range: 0.25 to 0.5 ppm

This chemical at maximum concentration has given rapid control of mono-filamentous algae for short periods (10 to 14 days) when the water temperature was below 70°F (21°C). At higher temperatures the chemical was ineffective as an algicide.

In addition to its algicidal properties, the chemical was an effective bacteriacide; thus it has been useful in combating certain infections of fish.

4.3.16 Amitrol — 3 amino-1,2,4-triazole

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	710	710	710

Application range: 1 to 5.5 kg per ha

This chemical showed certain herbicidal properties on emersed aquatic weeds, but when used alone provided poor control. In combination with some chlorophenoxyacetic compounds, amitrol has shown certain synergistic properties.

This chemical was relatively non-toxic to fish at fairly high concentrations, and has not exhibited any pathological effects on test fish.

4.3.17 Dalapon—2,2-dichloropropioniac acid

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	1000	80	710

Application range: 11 to 33 kg per ha

Maximum rates controlled marginal grasses in empty ponds when applied as a water spray with a watering agent.

4.3.18 AMS (ammata)—Ammonium sulphate

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Salt	10	10 m	10

Application range: 1. · 22 kg per ha

This chemical at maximum rate controlled certain submersed and marginal weeds in shallow water areas of ponds.

4.3.19 Diesel fuel

This material is fairly effective for temporary control of floating weeds when applied as a spray. It also increased the herbicidal activity of chlorophenoxyacetic compounds on emergent growths of aquatic weeds.

Rates of application in excess of 75 litres per ha (20 gallons per acre) have imparted flavours to fish for four to six weeks.

Diesel fuel application also controlled the air-breathing immature insects inhabiting treated ponds.

4.3.20 Fenac—2,3,6-trichlorophenylacetic acid

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Disodium salt	10	10	10

Application range: 5.5 to 11 kg per ha

This chemical, which is most effective herbicidally through the root system of plants, has provided partial to complete control of all submersed and emersed weeds in a pond for a period of 18 months or longer. It was most effective at the maximum rate indicated. It wa ineffective in the control of Chara, Nitella and filamentous algae.

Due to its lack of algicidal properties, treatments at the highest rate indicated have had no harmful effects on fish production in ponds.

4.3.21 Dichlobenil (casoron)—2,6 dichlorobenezonitrile

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	2	2	2

Application range: 2 to 9 kg per ha

This is one of the most volatile compounds that has been tested as an aquatic herbicide. Herbicidal effectiveness upon emersed weed growth has been drastically different under laboratory and field conditions. A rate of 2 kg per ha applied as a spray completely killed alligatorweed within 10 days in the laboratory, while a rate of 9 kg per ha only acted as a defoliant in field spray applications.

Limited research to date shows some promise that underwater treatments the rate of 9 kg per ha may control some submerged weeds.

The chemical was relatively non-toxic to fish and apparently decomposed rapidly and produced no effects upon fish production.

4.3.22 Endothal—3,6 endoxohexohydrophtalic acid

-do- (TD47, A1-4) -do- di(N,N-dimethylalkylamine) salt

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass	Bluegill	Fatheads
Disodium salt	10	10	10
TD47, A1-4	1	1	1

Application range: 5.5 to 11 kg per ha; 1 to 2 ppm

Treatments of endothal at maximum rates have provided control of many submersed weeds for periods of four to eight weeks in pools and ponds. This chemical is primarily a contact type, thus its effects were of a temporary nature if the species present were capable of regrowth from root stocks. If the species was not capable of root stock regrowth, then the species could be eliminated by this treatment, provided no seeds were present to repopulate the treated area.

No algicidal properties were noted for this chemical at any rate of application.

The di (N,N dimethylalkylamine) salt of endothal enhanced its activity against numerous hard-to-kill water weeds, but this chemical eliminated the fish population wherever it was tested.

5 SPECIALIZED TECHNIQUES FOR EVALUATING AQUATIC HERBICIDES

5.1 Laboratory methods

Techniques were developed for culturing submersed and emersed aquatic plants under artificial light at a constant temperature.

Standardized techniques were also developed for treatment of submersed and emersed aquatic weeds with a candidate herbicide, and for evaluating the resulting herbicidal activity upon test plants.

A total of 1,500 different chemical compounds were evaluated by these laboratory methods. Only 120 of these compounds exhibited 95 percent or greater overall herbicidal activity at a concentration of 5 ppm active ingredients. Only 16 of these herbicidally active compounds were non-toxic to fish at 10 ppm (Lawrence, 1964b).

The general susceptibility of test plants from least to highest susceptibility to all of the chemicals tested was as follows: alligatorweed, Pithophora, stargrass, Brazilian elodea, waterthread pond weed, southern naiad, common duckweed, waterhyacinth.

5.2 Plastic pool method

Techniques were developed for culturing communities of submersed, emersed and floating weeds in shallow plastic pools whose bottoms were covered with soil. This research has provided a better understanding of conditions conducive to the establishment of weed communities in ponds, as well as their long-term (one year) effects upon fish and fish-food organisms production under simulated field conditions in plastic pools (Lawrence, 1964a).

A total of 105 replicated herbicidal treatments have been evaluated by the plastic pool technique. The succeptibility of aquatic weeds to herbicide in these pools was of the same general order as that given for laboratory tests.

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