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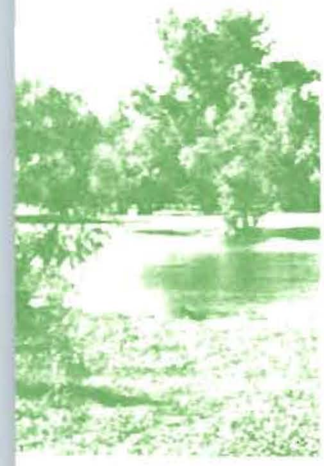

AQUATIC PLANT CONTROL RESEARCH PROGRAM

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US DEPARTMENT OF AGRICULTURE/CORPS OF ENGINEERS COOPERATIVE AQUATIC PLANT CONTROL RESEARCH—ANNUAL REPORT FOR FY 1983

Chemical Control Technology

by

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This report presents the results for FY83 of an ongoing program to evaluate chemical formulations for their potential use in aquatic plant management and control.

Of the several controlled release herbicide formulations evaluated in FY83, two monolithic polycaprolactone fibers containing fluridone have been

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found to have significant potential. These fibers, designed to maintain herbicide-plant contact over a period of four to six weeks, were proven effective in controlling hydrilla (Hydrilla verticillata Royle) at 2.2 kg a.i./ha (active ingredient per hectare) in flowing water in large outdoor aquaria. Under the same conditions, the commerical formulation Sonar® 4AS provided no hydrilla control. Two silicate capsules of dichlobenil showed promising results in the laboratory and were selected for evaluations in large outdoor aquaria in which long-term control of hydrilla regrowth was assessed.

Research concerning application of glyphosate indicated that decreasing carrier volume increased phytotoxicity of glyphosate to waterhyacinth, mainly by enhancing herbicide retention and penetration. A treatment of 1.7 kg a.e./ha (acid equivalent per hectare) glyphosate in 438 L/ha water carrier resulted in faster and longer lasting control than did 2.8 kg a.e./ha in 935 L/ha. Long-term effects from glyphosate on torpedograss in standing water were significantly reduced compared to activity achieved on ditchbanks. Studies with ^{14}C-glyphosate indicated that herbicide translocation was impeded in standing water. Sulfumeturon at 0.02 kg a.i./ha completely eradicated waterhyacinth in a 0.07-ha pond in Fort Lauderdale. Residue analyses indicated that levels of 1.3 to 1.6 µg/L sulfumeturon were present in water 24 hr after application. Herbicide residues in water then decreased rapidly and were detectable in only one of six samples (1.1 µg/L) two weeks after treatment. Residues in all sediment samples and all fish samples were below detection limits.

PREFACE

The work reported herein was performed under Agreement No. 12-14-7001-992 between the US Department of Agriculture (USDA) and the US Army Engineer Waterways Experiment Station (WES). Funds for the work were provided by the Office, Chief of Engineers (OCE), under Department of the Army Appropriation No. 96X3122, Construction General, 902740, through the Aquatic Plant Control Research Program (APCRP) at WES. Mr. E. Carl Brown was OCE Technical Monitor.

This report was prepared by Drs. Thai K. Van and Kerry K. Steward, and Ms. Ann O. Jones and Mr. Richard D. Conant, Jr., Aquatic Plant Management Laboratory, USDA, Fort Lauderdale, Fla.

The principal investigator at WES was Dr. Howard E. Westerdahl. During preparation of this report, Mr. J. Lewis Decell was APCRP Manager. Dr. John Harrison was Chief, Environmental Laboratory, WES. The report was edited by Ms. Jamie W. Leach of the WES Publications and Graphic Arts Division.

During the preparation of this report, COL Robert C. Lee, CE, was Commander and Director of WES and Mr. F. R. Brown was Technical Director. At the time of publication, COL Allen F. Grum, USA, was Director and Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.873	square meters
feet	0.3048	meters
pounds (mass)	0.4535924	kilograms
pounds (mass) per gallon	0.12	kilograms per liter

Part I: INTRODUCTION

Chemical control through proper use of herbicides is currently the most widely used method for managing aquatic weeds. Herbicides are labor, equipment, and energy efficient, and can provide reliable and economical weed control. However, one of the major factors limiting the use of herbicides has been the availability of effective chemicals approved for use in aquatic weed control. And worse, the number of herbicides registered for aquatic use has decreased dramatically in recent years. This decrease is due to the loss of registration of older chemicals, and to the reduction in numbers of new chemicals being developed by the agrichemical industry for aquatic use, usually because of the limited economic market and the rapidly increasing costs of developing, evaluating, and marketing new chemicals.

Better aquatic herbicides are critically needed and the search for new chemicals and new application technology should be expanded. The principal objective of this project is to evaluate new or improved herbicides or herbicide formulations for their potential use in the management of aquatic weeds. These evaluations are conducted in both controlled environment laboratory aquaria and larger outdoor aquaria containing various growth stages of submersed, emergent, or floating nuisance aquatic plants.

Fluridone (1-methyl-3-phenyl-5-[3(trifluoromethyl)phenyl]-4(1H)-pyridinone) is a new preemergence herbicide developed for use in cotton (Waldrep and Taylor, 1976). The chemical was later proven effective for controlling hydrilla (Hydrilla verticillata L.F. Royle) and several other submersed aquatic vascular plants in relatively lentic habitats (Arnold, 1979). However, treatments with fluridone in flowing water have provided variable results, probably because the herbicide disperses away from application sites before the necessary time of herbicide-plant contact may be achieved. During FY83, several monolithic polycaprolactone fibers containing fluridone were evaluated for control of hydrilla in flowing water. These fibers were designed to prolong plant contact through timed release of the herbicide, thereby increasing the chances for plant uptake.

Dichlobenil (2,6-dichlorobenzonitrile) has been shown to have high activity against several aquatic species (Walker, 1964; Weldon et al., 1968; Steward, 1980). In this past year, several controlled release formulations of dichlobenil were evaluated for their potential to maintain inhibitory levels of the chemical in water for long-term control of hydrilla regrowth from propagules.

Glyphosate [N-(phosphomethyl)glycine] was recently registered for control of emerged grasses, broadleaf weeds, and brushes growing in and around aquatic sites. The studies reported herein were initiated to determine if glyphosate was herbicidally active on various economically important floating aquatic weed species. Efforts were also made to improve glyphosate phytotoxicity through variations in methods of herbicide application. The effects of flooding on herbicide translocation were investigated in two species of emerged grasses.

Aquatic weeds treated in FY 1983 are listed below:

Alligatorweed	Alternanthera philoxeroides (Mart.) Griseb.
Cabomba	Cabomba caroliniana, var. multiparita
Hydrilla	Hydrilla verticillata Royle
Hygrophila	Hygrophila polysperma (Roxb.) Andeson
Lemon bacopa	Bacopa caroliniana (Walt.) Robins
Maidencane	Panicum hemitomon Schult.
Spikerush	Eleocharis baldwinii Michx.

Torpedograss	*Panicum repens* L.
Waterhyacinth	*Eichhornia crassipes* (Mart.) Solms
Waterlettuce	*Pistia stratiotes* L.
Watermeal	*Wolffia* spp.
Watermilfoil	*Myriophyllum spicatum* L.

The names and sources of chemical compounds evaluated in 1983 are listed in Table 1.

Part II: MATERIALS AND METHODS

A. EVALUATION OF CONTROLLED RELEASE FORMULATIONS

Controlled Release Formulations

Fluridone

Four different monolithic fibers of fluridone (25 percent a.i.)* were provided by the Southern Research Institute, Birmingham, Alabama. The herbicide fluridone was incorporated into fibers prepared from polycaprolactone, a biodegradable polymer. The fibers were designed to entangle with submersed vegetation and thus not be carried downstream in flowing water applications. The monolithic fibers were made to different filament diameters in order to achieve different herbicide release rates.

The Black Charm (BC) pellet formulation (5 percent a.i.) and the liquid Sonar® 4AS (4 lbs a.i. per gallon)** were obtained from Elanco, Indianapolis, Indiana.

Dichlobenil

Three rubber capsules containing dichlobenil (20 percent a.i.) were received from Phillips Duphar BV, Holland. Four silicate capsules formulations (7 to 13.4 percent dichlobenil) were received from Washington University, St.

* a.i. = active ingredient.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

Louis, Missouri. The dichlobenil capsules were designed to sink to the bottom muds and release the herbicide near the sediment-water interface where plant growth originates and where propagating structures are located.

2,4-D

The polymer (GMA)2,4-D formulation in clay pellets (17 percent a.i.) was received from Dr. Frank Harris, Wright State University, Ohio. Previous studies with these Poly(GMA)2,4-D indicated that herbicide release was near zero-order over a period of several months.

Static Water Test to Determine Release Profiles

Herbicide release profiles in static water were determined under controlled laboratory conditions at 28±2C. Treatments of various CR formulations of fluridone and 2,4-D were made to 3.7 L of water with amounts calculated to produce a herbicide concentration of 10 mg/L, assuming complete release. Treatments of the dichlobenil formulations were made in screw-cap erlenmeyer flasks. The flasks were tightly capped to minimize loss of herbicide through volatility. All treatments were replicated four times.

Natural water from a dug pond on the Fort Lauderdale Agricultural Research Center grounds was used. Water quality was monitored monthly in March, June, September, and December (Table 2). For interlaboratory comparisons, herbicide release profiles were also determined in reconstituted distilled water at pH 8.0, containing 192 mg $NaHCO_3$, 120 mg $CaSO_4 \cdot 2H_2O$, 120 mg $MgSO_4$, and 9 mg KCl per liter (Marking and Dawson, 1973). Water samples were taken from each container at various times throughout the experiment for herbicide determinations.

At the conclusion of the static tests, the herbicide formulations were collected and extracted in methanol (3x100 ml) for 24 hours. Extracts were then analyzed to determine the amount of herbicide that was still incorporated in the formulation matrices.

Flowing Water Test and Bioassay of Hydrilla

Several CR formulations of fluridone were bioassayed for efficacy in controlling hydrilla in flowing water. Natural pond water was continually pumped into a system of 24 large outdoor aquaria. The dimensions of the aquaria were 77 cm wide by 219 cm long (1.7×10^{-4} ha) with depth varying from 50 to 56 cm. The normal volume of these containers after adding soil was 850 to 950 L. Uniform low water pressure was maintained by constant overflow in a standpipe, and flow to individual aquaria was regulated by small pet cock valves to provide one volume change every 24 hours. The outflow water was collected at 25 cm below surface and passed through a charcoal filter before discharge.

Hydrilla plants were established in 30x30 cm square aluminum trays, 15 cm deep. Six trays were placed in each culture aquaria and allowed to grow for 6 months before chemical treatment was applied. All fluridone formulations were applied at 2.2 kg a.i./ha on 31 August 1983. Herbicide residues in the flowing water were determined at various times during the experiment, and phytotoxic responses to the herbicide treatments were recorded.

Herbicide Analyses

Complete details of the analytical procedures used for determining fluridone, dichlobenil, and 2,4-D residues have been discussed in a previous publication (Van and Steward, 1983). Briefly, the herbicides were analyzed by high pressure liquid chromatography with a Perkin-Elmer Series 3B HPLC, a Perkin-Elmer LC 75 variable wavelength detector, and a Perkin-Elmer Sigma 10 integrator. The chromatographic column was Perkin-Elmer/HS-5 C_{18} (reversed phase). The mobile phase was acetonitrile:1% acetic acid (1:1) with a flow rate of 2.0 mL/min. Optimum wavelengths were determined to be 236 nm for fluridone, 238 nm for dichlobenil, and 232 nm for 2,4-D.

B. EVALUATION OF CONVENTIONAL FORMULATIONS

Laboratory Evaluation Techniques for Submersed Type Aquatic Plants

Apical sections of submersed plants were planted in a standard soil mix in small plastic pots and placed in 3.8- or 19-L jars filled with pond water. Plants were then allowed to become established for approximately one week under controlled conditions of temperature (25°C) and light (25 to 40 $\mu E/m^2/sec$), from Gro-lux fluorescent tubes, 14-hr photoperiods. The plants were treated by injecting treatment solutions into the water with a hypodermic syringe. The treatments were then evaluated biweekly for phytotoxicity for a period of 8 to 14 weeks depending on the herbicide. Phytotoxicity ratings were made on a scale of 0 to 100 percent injury: 0 percent = no injury, and 100 percent = complete elimination of live plant tissue.

Greenhouse Evaluation Techniques for Emergent and Floating Type Aquatic Plants

Plants to be treated were grown in polyethylene-lined, 12 L capacity plastic containers, and allowed to become established in a screenhouse for a period of approximately two to four weeks prior to treatment. Each replicated treatment was applied by placing the container in a 929-cm^2 enclosure with an open top. The plants were then uniformly sprayed with a small atomizer. The total spray volume was equivalent to 935 L/ha. Following application of the chemicals, the plants were moved to the screenhouse where treatments were periodically evaluated for phytotoxicity.

Evaluation Techniques in Outside Aquaria

Evaluations were conducted in aquaria of two sizes and types. One type consisted of circular, vinyl-lined containers manufactured for use as swimming or wading pools. The dimensions were 3.05 m in diameter (7.3×10^{-4} ha) with a maximum depth of 60 cm. The pools were filled to a 53 cm depth, which resulted in a volume of 3870 L.

The second type of aquarium consisted of rectangular-shaped concrete boxes. The interior of each box was covered with two coats of white epoxy paint. The dimensions were 77 cm wide x 219 cm long (1.7×10^{-4} ha) with depth varying from 56 to 65 cm.

When these aquaria were used to evaluate herbicide efficacy on submersed plants, apical cuttings of individual species were established by planting 15 cuttings 15 cm long in 30x30x15 cm aluminum trays. The trays were filled with standard soil mix (70 percent sand and 30 percent organic peat) supplemented with 5 percent (v/v) manure. Twelve trays were placed in each of the aquaria. The plants were subjected to a continuous water flow until treatments were applied. For evaluation of herbicide efficacy on floating plant species, field-collected plants were established in the aquaria and allowed to completely cover the water surface before treatment.

All chemical treatment rates were replicated a minimum of three times and were applied on an area (kilograms per hectare) or volume (milligrams per liter) basis.

Herbicide Translocation Studies

A procedure was developed to study herbicide movement via the interconnecting stolon from the parent to the offshoot plant of waterhyacinth and water lettuce. Parent plants were established in 3.8-L jars, each with an offshoot plant placed in an adjoining jar. The parent and offshoot plants were connected by healthy stolons. Herbicides were applied in a 935 L/ha total spray solution using an atomizer type sprayer. The chemical was applied to the parent with the offshoot plant shielded to prevent contamination with the spray. Each treatment was replicated four times. Observations were based on visual ratings of percent injury to both the parent and offshoot plants of each treatment.

In other studies, the absorption and translocation of radioactive labeled glyphosate were investigated in waterhyacinth, water lettuce, and torpedograss. The ^{14}C-methyl label glyphosate (specific activity = 1.95 μCi/mmole) was converted from the acid to the isopropylamine salt by adding the following to 2.29 mg labeled acid: 1.3 ml deionized water, 2 μl isopropylamine, 1.7 μl commercial glyphosate, and 3.2 μl X-77. This gave a solution equivalent to 2.24 Kg glyphosate in 935 L water, so that the 10 μl which was applied contained 0.2 μCi.

Waterhyacinth and water lettuce plants were selected for uniformity of size (approximately seven leaf stage). All plants were allowed to establish for 3 days prior to treatment. A 10-μl droplet of ^{14}C-glyphosate was applied to a recently mature leaf of each plant. This was usually the third or fourth leaf from the apex. The treated plants were harvested six days after treatment, and were separated into treated leaf, above treated leaf, below treated leaf, daughter plants, crown with apical meristem, and roots. Each plant part was then combusted and the ^{14}C determined by liquid scintillation counting.

The effect of flooding on ^{14}C-glyphosate translocation in torpedograss and maidencane was investigated. Rhizome tips, approximately 15 cm long with 4 to 6 nodes, were planted outdoor in narrow troughs of 180x20x5 cm. The plants were 60 to 80 cm in height at the time of treatment, and were in bloom or in subsequent stages of seed maturation. One leaf (third or fourth from apex) was selected from each plant. The leaf was covered with an aluminum foil mask. Commercial glyphosate at 2.24 Kg/ha with 0.25% X-77 was then sprayed on the entire plant. Immediately after spraying, the aluminum foil cover was removed and radioactive herbicide was applied. This technique was used to make the ^{14}C treatment similar to a spray application. The plants were harvested 10 days after treatment and were sectioned into different plant parts as above. The pattern of ^{14}C accumulation in the rhizome system was investigated by further sectioning the rhizome into individual nodes before combustion. A map was drawn of the rhizome system of each plant indicating the location of the individual nodes. The levels of ^{14}C were then superimposed on the rhizomme map to illustrate the direction of ^{14}C translocation in the rhizome system.

Field Evaluation

The persistence of sulfumeturon in the aquatic environment after chemical treatment of waterhyacinth was investigated in a cooperative study with DuPont Company.

The study was conducted in a 0.07-ha dug pond on the Fort Lauderdale Agricultural Research and Education Center (AREC) grounds. The pond had a mean depth of 1.2 m and was about 80 percent covered with waterhyacinth at the time of treatment. The waterhyacinth appeared free of any disease, but did exhibit evidence of moderate feeding by waterhyacinth weevils, Neochetina spp.

The herbicide sulfumeturon (20 g a.i./ha) was applied from the bank with a rotating handle spray gun calibrated to deliver 1400 L/ha. The surfactant X-77 at 0.25 percent was used.

Water and hydrosoil samples were taken from two different sites in the pond before treatment and at various times after treatment. Water samples were collected at three different depths from each site in 1-L polyethylene bottles fitted into a specially designed housing that allowed the cap to be removed and replaced at any desired depth. A liner-type core sampler fitted to a 3.4-m galvanized pipe handle was used to collect hydrosoil samples. Each core was 20 cm deep and 5 cm in diameter.

Bluegills (<u>Lepomis</u> <u>macrochirus</u>) and catfishes (<u>Ictalurus</u> <u>punctatus</u>) were also collected at various times before and after treatment for residue analyses.

The water, hydrosoil, and fish samples were shipped to E.I. DuPont de Nemours and Company, Wilmington, Delaware, to be analyzed for chemical residues.

Part III: RESULTS AND DISCUSSION

A. EVALUATION OF CONTROLLED RELEASE FORMULATIONS

<u>Fluridone</u>

Time-course uptake and relationship of herbicide concentration vs. exposure were investigated to determine what specifications of controlled release formulations are desirable to optimize the effects of fluridone on the target plant and the aquatic ecosystem. Apical sections of hydrilla 5 cm long were exposed each to a 40-ml diquat-^{14}C solution (a total of 2.0×10^{-2} µCi giving a diquat cation concentration of 0.10 mg/L) or fluridone-^{14}C (a total of 1.7×10^{-2} µCi giving 0.05 mg/L fluridone). After different exposure time periods varying from 2 hours to 21 days, the treated plant sections were collected and combusted for liquid scintillation counting.

Figure 1 illustrates the uptake of radioactive carbon ^{14}C from ^{14}C-diquat or ^{14}C-fluridone by hydrilla during a 21-day period. Diquat was taken up rapidly and a maximum tissue level of ^{14}C was observed within 4 days after treatment. The plants began to decompose after 7 days. The decline in radioactivity in the plant tissues during the second week after treatment was probably due to leaching and/or breakdown of the ^{14}C from the decaying plant tissues.

A much slower uptake rate was obtained with the ^{14}C-fluridone treatment (Figure 1). The initial rise in radioactivity in hydrilla tissues observed at the first sampling 2 hours after treatment probably represents the passive dif-

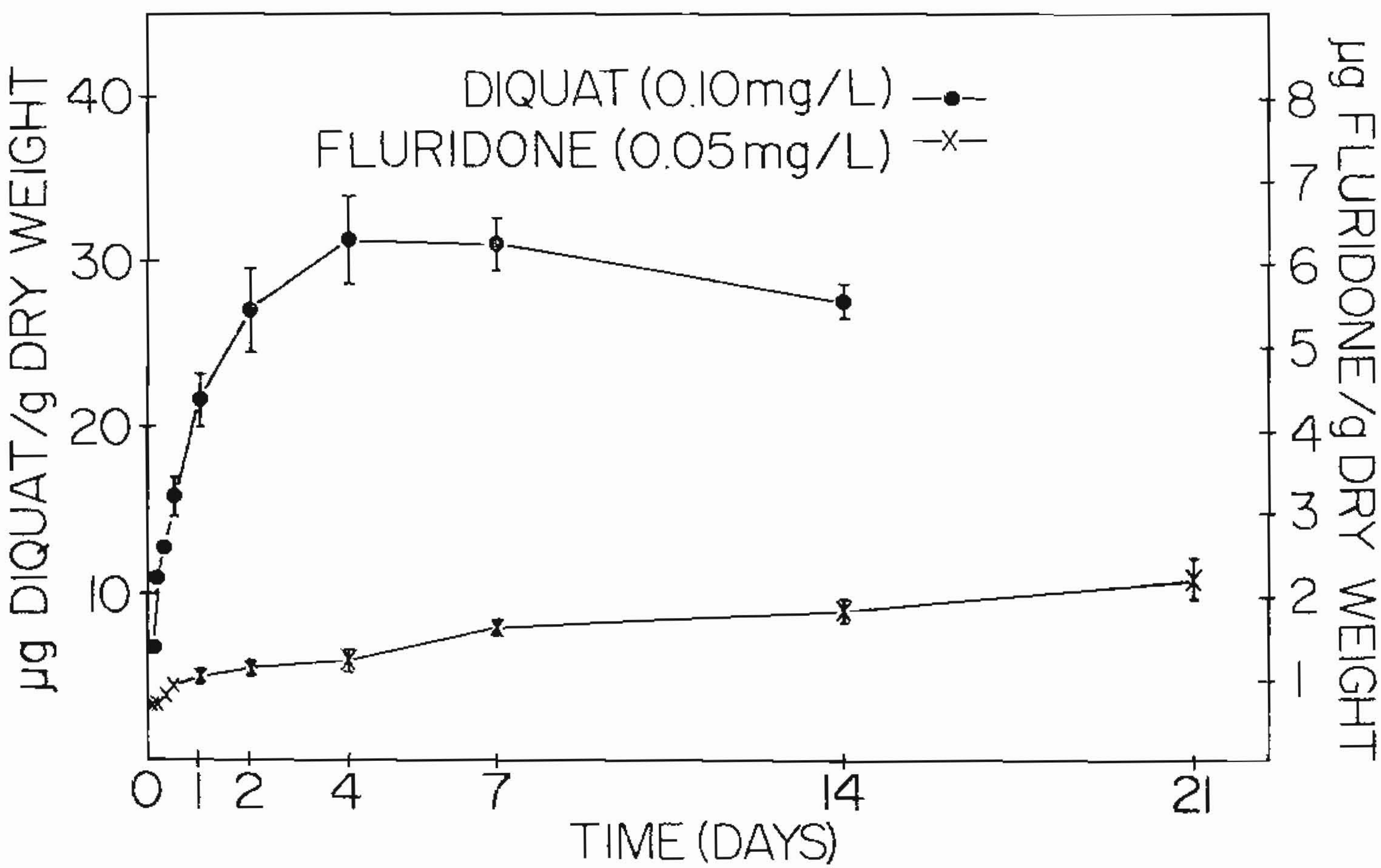

Figure 1. Uptake of ^{14}C-diquat and ^{14}C-fluridone by hydrilla. Bars indicate ± standard error for each time interval.

fusion and/or adsorption of ^{14}C-fluridone in intercellular free space. The slower long-term phase of uptake was probably due to metabolic accumulation which appeared to continue at a fairly constant rate for at least 21 days.

The data presented for the uptake of fluridone suggested that the herbicide must remain in contact with the plant for a comparatively long time before herbicide concentration is present in the plant tissues at levels sufficient to achieve weed control. A study was conducted to investigate the response of hydrilla to various concentrations and exposure periods of fluridone. The liquid Sonar® 4AS was applied at concentrations of 0.05, 0.10, 0.25, and 0.50 mg/L fluridone. Each of the four treatment rates of fluridone was in contact with the plants for periods of 3, 6, 12, 24, 48, 96, and 168 hours. After each exposure time period, the plants were removed from the treatment aquaria and placed in a running bath of pond water for 30 min to remove any adhering herbicide. The plants were then placed in a 4-liter glass jar containing fresh pond water, and phytotoxic responses were observed during a period of 14 weeks. Table 3 indicates that over 90 percent control of hydrilla was obtained in all treatments from 0.05 to 0.50 mg/L of fluridone, when the plants were exposed to the chemical continously throughout the 14-week experiment. However, no significant plant injury was obtained by exposing hydrilla plants up to 1 week to a concentration of 0.10 mg/L fluridone. The 0.10 mg/L fluridone treatment would be equivalent to a field treatment rate of 2 lbs a.i./acre to a body of water 6 to 7 feet deep. Increasing the treatment levels of fluridone to 0.25 or 0.50 mg/L resulted in effective hydrilla control with a required exposure time period of 7 and 4 days, respectively (Table 3). However, these treatment levels may become cost prohibitive for practical hydrilla control.

The slow uptake of fluridone and the required long exposure time to this herbicide may present a problem in the control of hydrilla with fluridone in flowing water, such as in irrigation and drainage canals. One logical approach to this problem would be to incorporate the chemical in a CR formulation. The CR formulation would be designed to provide adequate plant contact through timed release of the herbicide, thereby increasing the chances for plant uptake.

Herbicide release profiles were constructed for the release of fluridone from the CR monolithic fibers and the BC pellets into reconstituted water (Figure 2) and natural pond water (Figure 3). Release of fluridone from all of the formulations tested was first-order as expected. The BC pellets released over 60 percent of their fluridone within the first 3 days after treatment in reconstituted water. Herbicide release then slowed down gradually, and was complete in about 10 days. Furthermore, only 70 to 80 percent of the available fluridone was released from the BC pellets in natural pond water and in reconstituted water, respectively.

For the CR fibers, release rates appeared to depend on the different fiber sizes, with the thinner fibers releasing herbicide at much faster rates. For the 8-mil fiber, most of the release was completed in about 10 to 15 days. On the other hand, herbicide release continued over a period of 40 to 50 days in the 30-mil and 45-mil fibers. Only 65 to 80 percent of the available herbicide was released from the 30-mil and 45-mil fibers.

Study of the accountability of fluridone conducted at the termination of the experiment indicated that 12 and 23 percent of available fluridone still remained in the 30-mil and 45-mil fiber, respectively (Table 4). By adding up what had been released into water and what was left in the fibers, the total fluridone recovery was 90 percent or higher for all fiber sizes. Similarly, total recovery from BC pellets averaged 89 percent in reconstituted water and 91

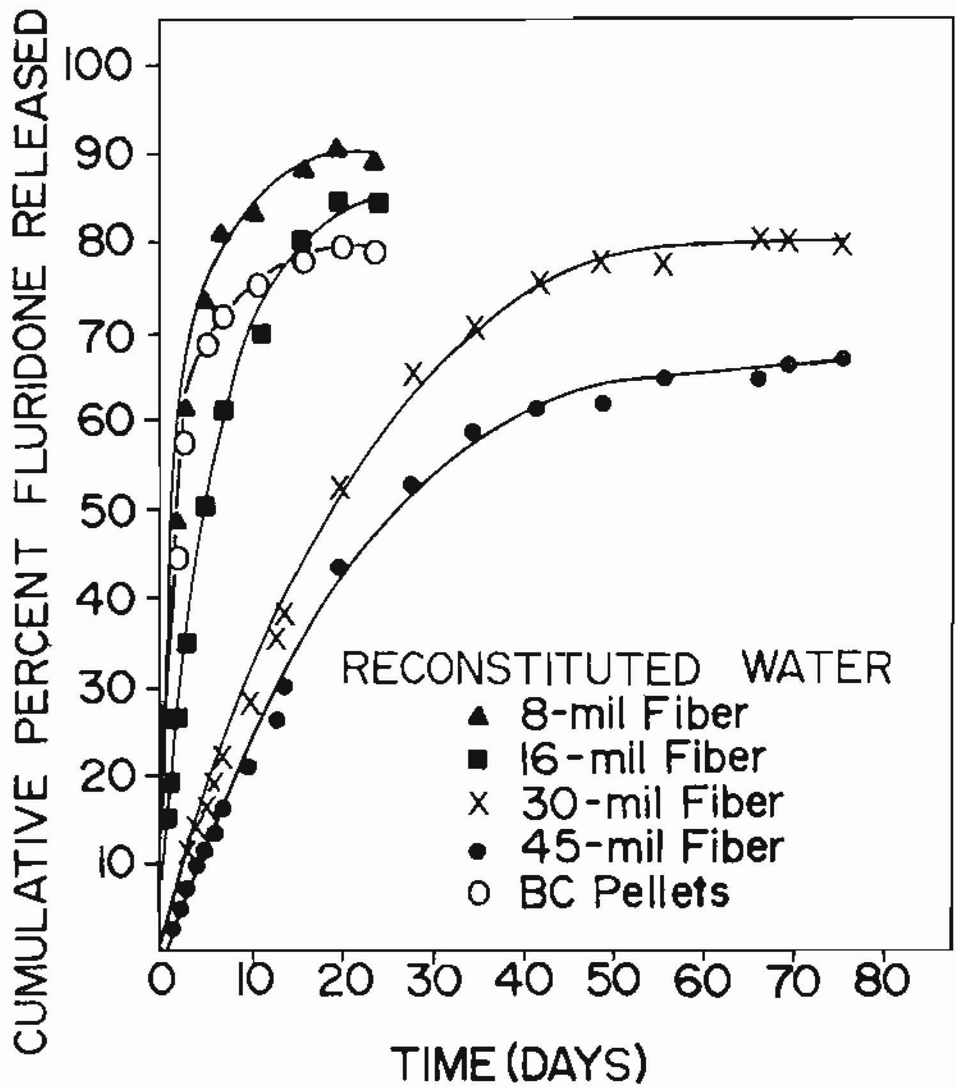

Figure 2. Cumulative percent release of fluridone from polycaprolactone monolithic fibers and BC pellets into reconstituted water

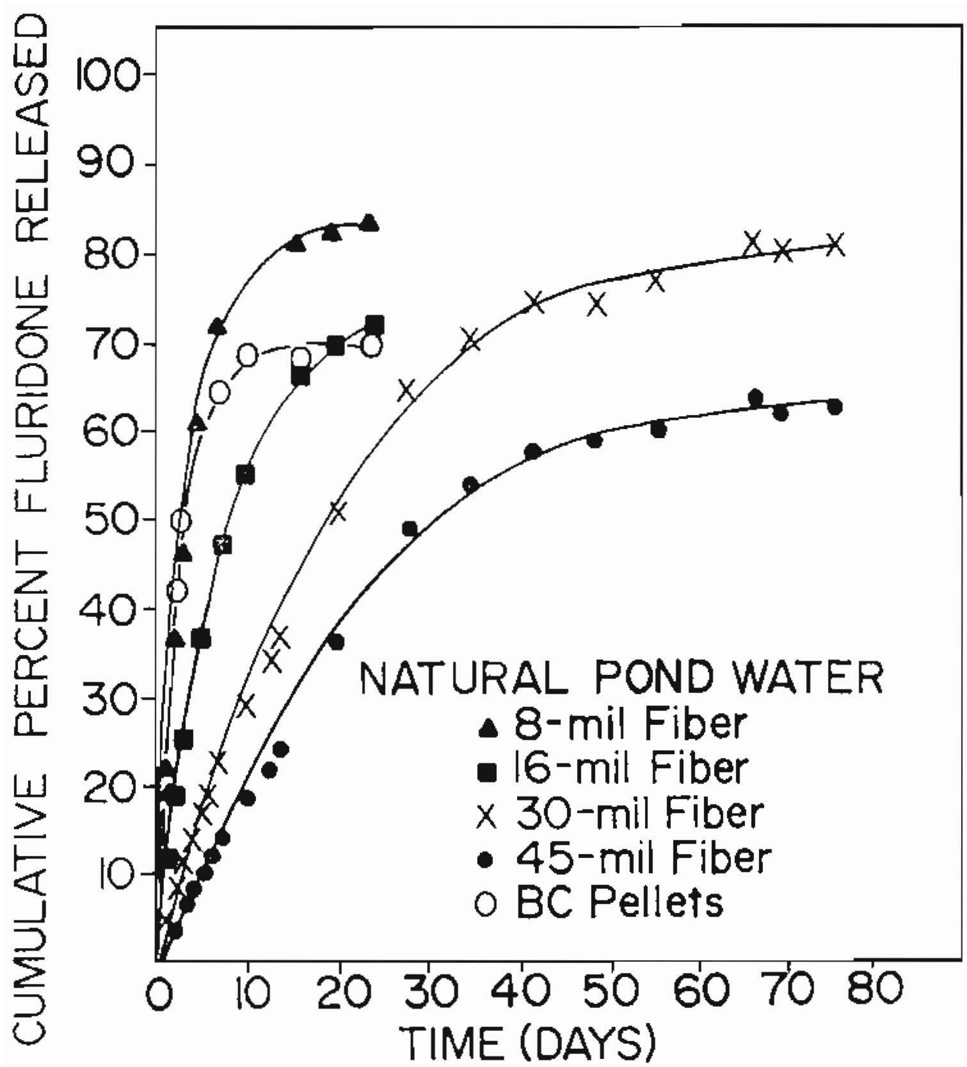

Figure 3. Cumulative percent release of fluridone from polycaprolactone monolithic fibers and BC pellets into natural pond water

percent in natural pond water.

The fluridone-loaded fibers and the BC pellets were evaluated for efficacy in controlling hydrilla in flowing water in large oudoor aquaria. The conventional liquid formulation Sonar® 4AS was included for comparison. Table 5 shows herbicide residues in the flowing water from the Sonar® 4AS treatment at 2.2 Kg a.i./ha. A residue level of about 400 µg/L fluridone was expected based on the water volume in the treatment aquaria. However an initial level of 980 µg/L was observed, indicating that the herbicide was not evenly distributed over the entire water depth 2 hours after treatment. The herbicide concentrations then decreased rapidly to about 102 µg/L fluridone after 1 day due to water flow, and then disappeared completely by Day 7 posttreatment.

A concentration of 54 µg/L fluridone was measured in treatment of the BC pellets 2 days after treatment (Table 6). The fluridone concentration then decreased sharply after 7 days, but was maintained at 3 to 5 µg/L in the flowing water over a period of 3 weeks. The BC pellets had been found to complete most of herbicide release after about 10 days in water (Figure 3). In the flowing water test, the pellets sank to the bottom muds. Hydrosoil may have acted as a second barrier to the herbicide release through soil adsorption and desorption. Also, a slower water flow near the soil-water interface may have contributed to the extended presence of the herbicide in flowing water.

In the CR fiber treatments, the herbicide concentrations in flowing water were always low, but maintained over a period of several days depending on the fiber sizes (Table 6). The 16-mil fiber treatment continued to release the chemical over a 2-week period, with a maximum level of 36 µg/L fluridone measured on Day 7. For the 30-mil fibers, the measured herbicide levels were mostly below 14 μg/L but maintained over 42 days. In the 45-mil fiber treatment, residue levels were all the time below 11 μg/L but, again, lasted for 42 days.

Typical discoloration of the hydrilla tips was observed in all fluridone treatments 7 days after the chemical was applied. However, plants treated with the liquid Sonar® 4AS appeared to recover rapidly while treatments of 30-mil and 45-mil fibers continued to show increased plant damage. Table 7 shows the effect of various fluridone formulations on chlorophyll content of hydrilla 6 weeks after treatment. The most severe chlorophyll damage was observed in plants treated with 30-mil and 45-mil fibers. The BC pellets reduced chlorophyll contents by 32 percent as compared to the level in control plants. The high chlorophyll contents in treatments of Sonar® 4AS and 16-mil fiber reflected plant recovery from the herbicide treatment.

Weed control by the various formulations of fluridone applied at 2.2 kg a.i./ha in flowing water in outdoor aquaria are presented in Table 8. The 30-mil and 45-mil monolithic fibers provided about 80 percent control of hydrilla after 16 weeks posttreatment. Significant reductions were obtained in both shoot and root dry weights. Under the same conditions, the conventional liquid formulation Sonar® 4AS was not effective.

The various fluridone treatments did not affect hydrilla tuber density and tuber germination (Table 9). These tubers might have been formed before chemical treatment was applied.

Dichlobenil

The herbicide release profiles of the various rubber FUN dichlobenil formulations are presented in Figure 4 (reconstitued water) and Figure 5 (natural pond water). Release appeared to be first-order in all of the formulations tested. The reference formulation Casoron-GSR was found to release over 80 per-

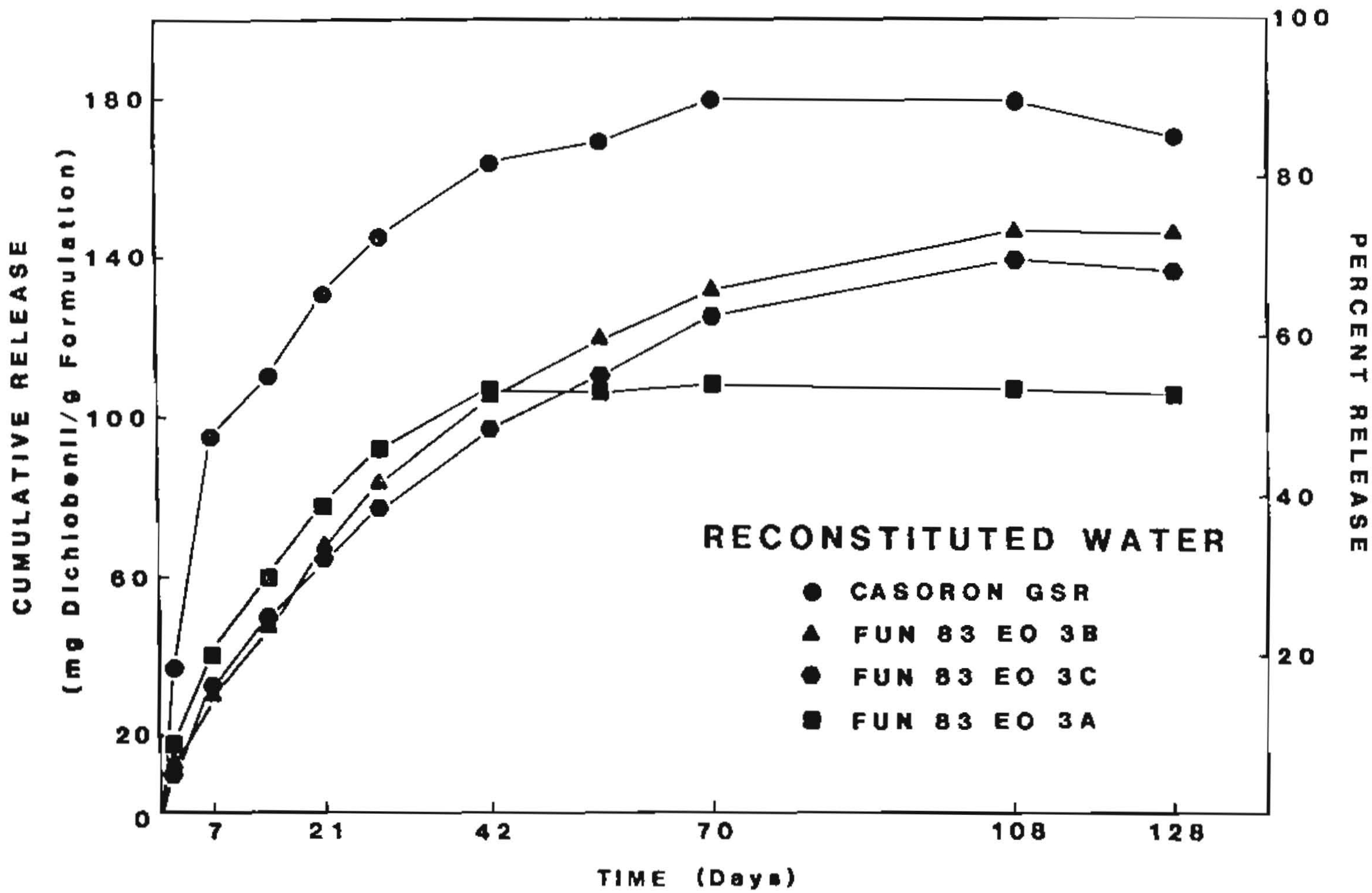

Figure 4. Cumulative release of dichlobenil from various rubber capsules and Casoron® GSR into reconstituted water

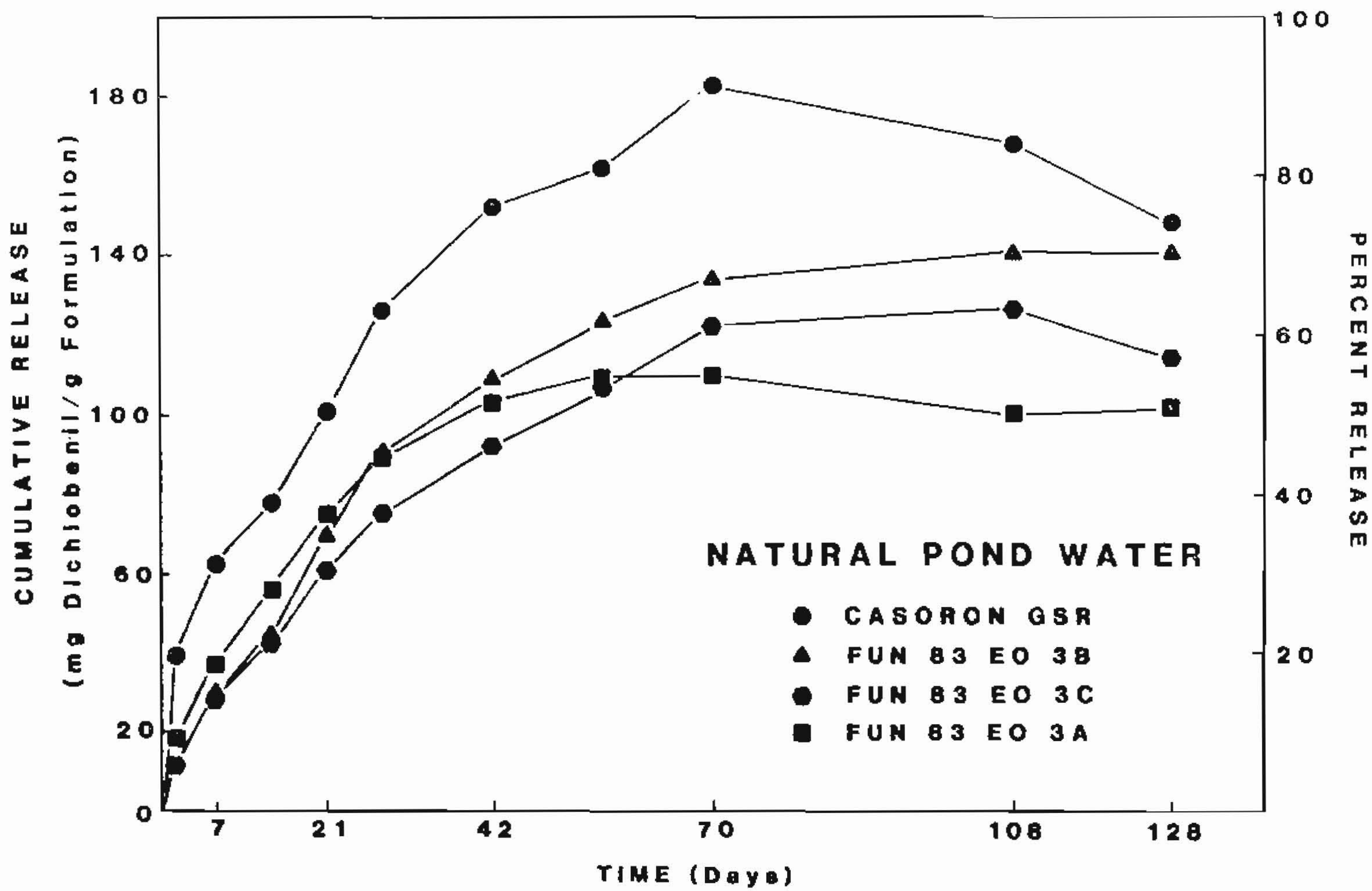

Figure 5. Cumulative release of dichlobenil from various rubber capsules and Casoron® GSR into natural pond water

cent of its dichlobenil within 40 days after treatment. Much slower release rates were obtained with the three FUN formulations under similar conditions. Formulation FUN 3A gave relatively higher release rates during the first four weeks after treatment; however, the release ceased after approximately 40 days when 53 percent of the dichlobenil had been released into reconstituted water (Figure 4). Herbicide release from the other two FUN formulations was somewhat similar and was completed in about 110 days, when 75 and 70 percent of the dichlobenil had been released from the formulations 3B and 3C, respectively. All formulations retained integrity during the test; however, formulation 3B was observed to float in all treatments.

Although a 4-month release (formulations 3B & 3C) appears satisfactory, the data suggested that one-third (3B & 3C) to one-half (3A) of the dichlobenil in the formulation may not become available for plant uptake. The buildup of herbicide in the experimental flasks might have prevented a complete release of dichlobenil from the rubber formulations; however, results of methanol extraction (Table 10) suggested that the total available dichlobenil in the formulation 3A may be less than those indicated by the formulator. Duplicated samples of 50 mg of each formulation were extracted in 1 liter of methanol. We expected to see 10 mg/L dichlobenil in the methanol extracts. However, only 58, 95, and 86 percent of the expected dichlobenil were recovered from formulations 3A, 3B, and 3C, respectively (Table 10). These data corroborate well with data in Figure 4. Unfortunately, it was uncertain if the methanol extraction was adequate because of: 1) the formulation matrix insolubility in all solvents tested, including methanol; and 2) unsuccessful efforts of grinding the formulations before extraction.

Four silicate capsules containing dichlobenil were received from Washington

University, St. Louis, Missouri. Methanol extraction of these formulations (Table 11) indicated that 79 to 98 percent of the expected dichlobenil was recovered in the extracts. Table 12 shows the cumulative release of dichlobenil from the silicate formulations in static reconstituted water and natural pond water. Formulation CT-12-11-82-1 gave highest release rates, and release appeared to cease after about 2 months posttreatment (Figure 6). This 2-month release may be too fast for practical use in the control of hydrilla regrowth from propagules. Formulation CT-12-18-82-1 with a 6-month release (Figure 7) appears promising. However, the data suggested that up to one-third of the available dichlobenil may be locked up in the formulation matrix and thus not available for plant uptake. The formulations CT-12-10-82-1 and CT-12-18-82-2 continued slow release to all treatments after 180 days. Regression analysis of the data indicates that CT-12-10-82-1 would release 70 pecent of its dichlobenil in about 7 months.

2,4-Dichlorophenoxy Acetic Acid

Earlier evaluations of the formulation Poly(GMA)2,4-D have shown promising results. Herbicide release was near zero-order over a period of several months. During FY 83, cooperating formulators at Wright State University attempted to produce large quantities of Poly(GMA)2,4-D for use in field evaluations. Our contribution to this project was to verify the release characteristics of the experimental formulation in the laboratory before it was to be used in large-scale field trials.

During HPLC analyses, however, we observed a large unknown peak which eluted several minutes after the 2,4-D peak. This peak had not been observed in evaluations of other Poly(GMA)2,4-D received in previous years. Table 13 indicates that the unknown peak had the same retention time and absorbance ratio as

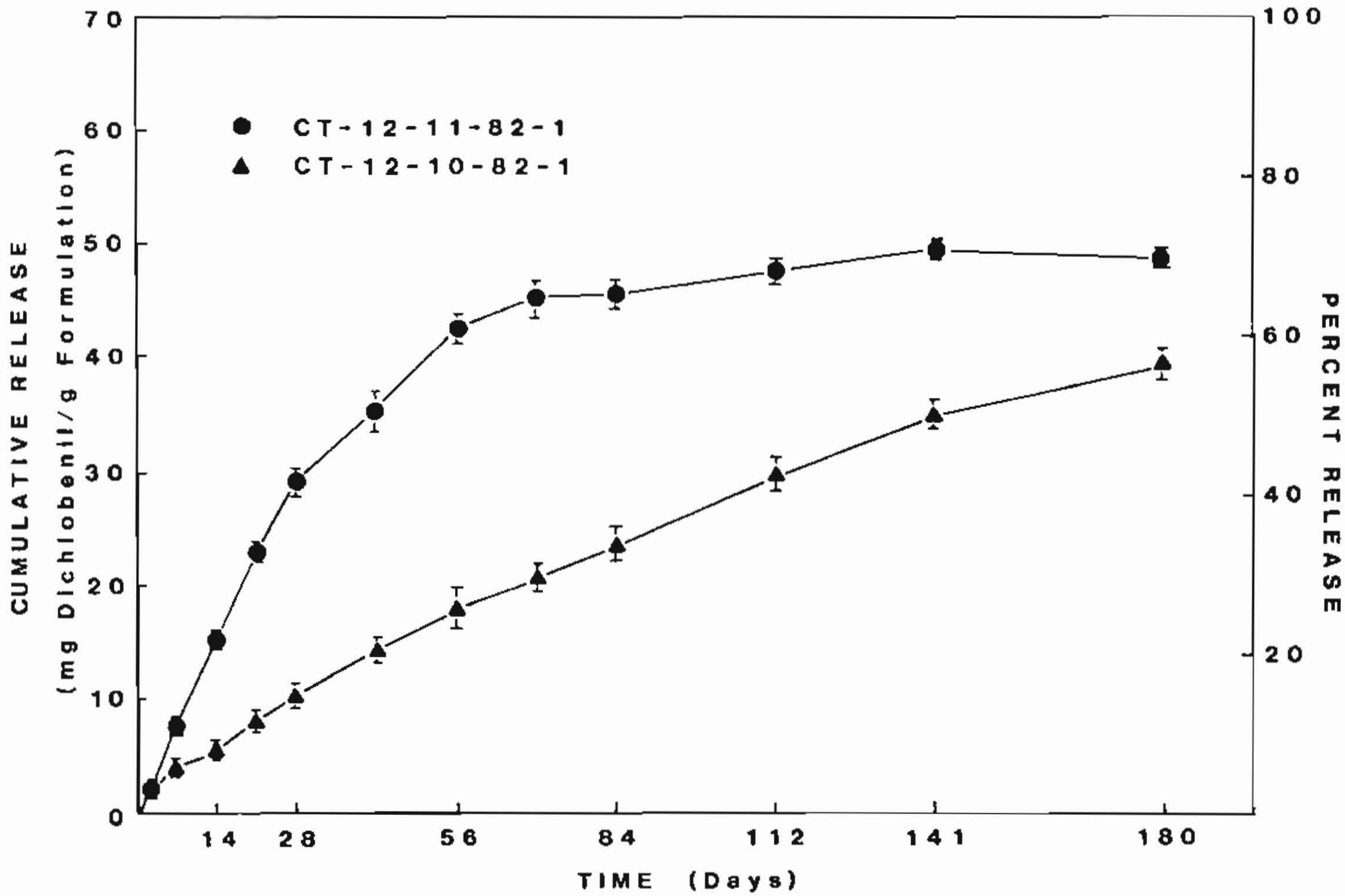

Figure 6. Cumulative release of dichlobenil from two silicate capsules (7 percent a.i.) into reconstituted water. Each point is the mean of four replicates ± S.E.

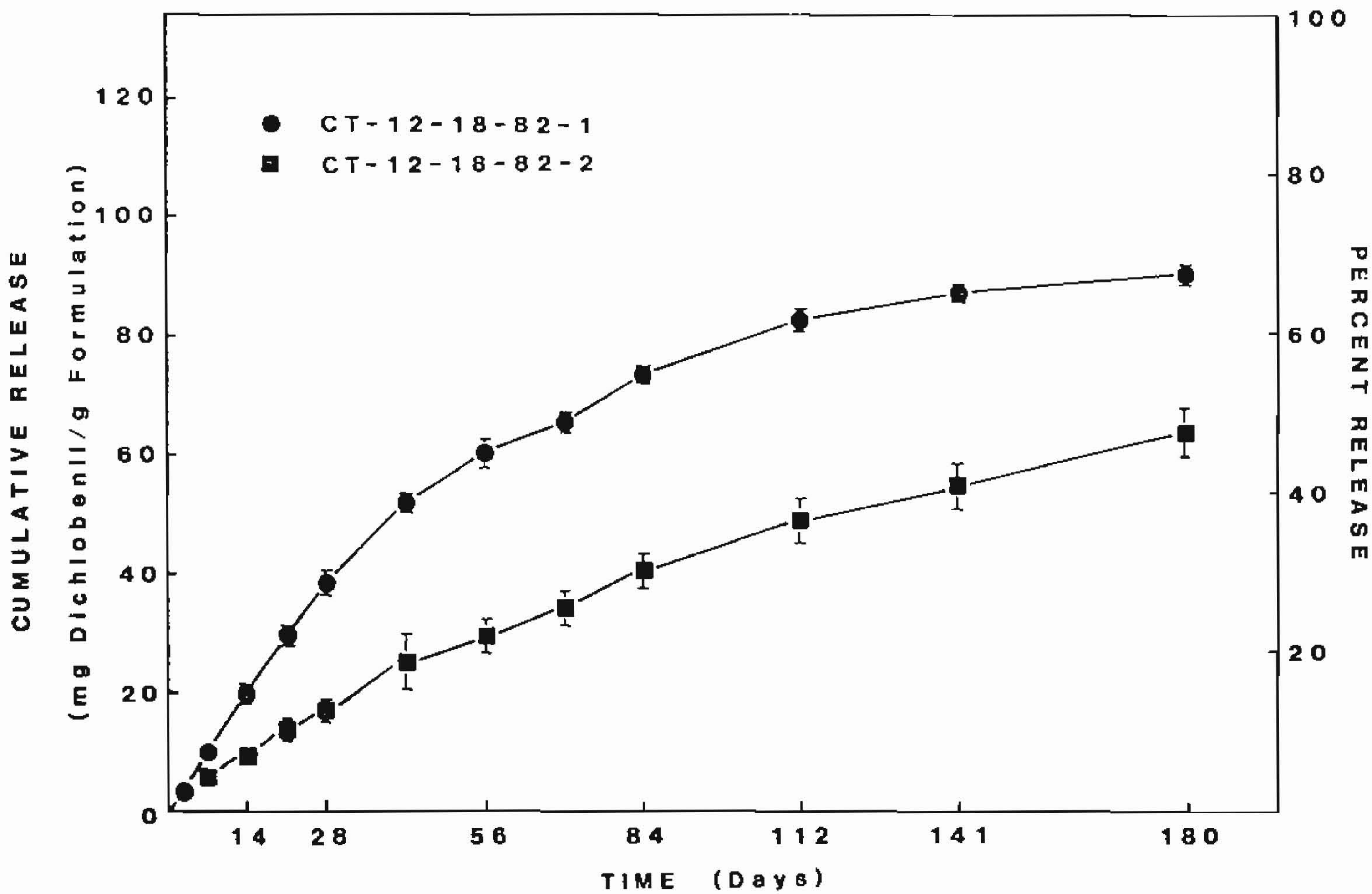

Figure 7. Cumulative release of dichlobenil from two silicate capsules (13.4 percent a.i.) into reconstituted water. Each point is the mean of four replicates ± S.E.

2,4-D methyl ester. This preliminary identification was later confirmed when the formulator reported that methanol had been added during the up-scale production of the Poly(GMA)2,4-D.

Chemical release from the Poly(GMA)2,4-D in static water is summarized in Table 14. A large amount of chemical (85 mg/g pellet) was released within 24 hours in deionized water in the form of methyl ester (ME). In another test, this large initial release was observed to occur immediately after the pellet was immersed in deionized water, suggesting 2,4-D ME was not chemically bound to the GMA polymer. The slow increase of 2,4-D ME in water with time (Table 14) may be attributed to chemical desorption from the clay matrix.

The released 2,4-D ME appeared to undergo hydrolysis slowly to 2,4-D, as levels of 2,4-D acid in deionized water (pH 6.3) increased from trace amounts on Day 1 to 24 mg/g pellet on Day 6. The rate of hydrolysis of 2,4-D ME appeared to be pH dependent. In reconstituted water (pH 8.0) hydrolysis was faster, and both forms of 2,4-D and 2,4-D ME were present in equal amounts within 24 hours after treatment. By Day 6, hydrolysis was about complete and most of the released chemical was recovered as 2,4-D acid.

Based on the above findings, a decision was made by the Corps to cancel the FY 83 plans for field testing of Poly(GMA)2,4-D.

B. EVALUATION OF CONVENTIONAL FORMULATIONS

Floating Weeds

Glyphosate successfully controls waterhyacinth and water lettuce (Table 15). With waterhyacinth a rate of 2.8 Kg a.e./ha* was required for control. Decomposition and sinking of the plants were evident 40 to 60 days after treatment. Once sinking occurred, little or no regrowth was observed. Water lettuce was less susceptible to glyphosate (Table 15). Commercially acceptable

* a.e. = acid equivalent.

control of water lettuce required 4.5 Kg a.e./ha glyphosate or higher.

These rates of glyphosate represent a relatively high cost for practical control of the subject floating weed species. Several studies with glyphosate have indicated that phytotoxicity of the herbicide generally increases when applied in lower water carrier volumes. Glyphosate would be especially suitable for use in low-volume treatments of waterhyacinth and water lettuce because it is absorbed rapidly by these floating species and translocated throughout the plant (Tables 16 and 17).

The effects of various combinations of herbicide rates and spray volumes on glyphosate phytotoxicity to waterhyacinth were investigated. The different spray volumes were obtained by changing nozzle size and pressure. The surfactant X-77 was added to maintain a constant level of 0.5% v/v in all final spray mixtures. Figure 8 indicates that glyphosate performance may be enhanced by using lower carrier volumes. Effective control of waterhyacinth was achieved at a rate of 1.7 Kg a.e./ha if applied using a spray volume of 187 L/ha. As the volume of spray was increased to 935 L/ha, the herbicidal activity of glyphosate decreased. Increasing the herbicide rates masked these differences (Figure 8).

A similar study conducted on water lettuce, however, showed no significant differences in glyphosate activity between the three spray volumes at any treatment rates varying from 1.7 to 3.4 Kg a.e./ha (Figure 9). This lack of response to different spray volumes may be related to the leaf surface characteristics of the water lettuce. A dye technique was used to compare herbicide retention and runoff after glyphosate treatments to waterhyacinth and water lettuce. The sulfonine red dye was added to the spray solution. The spray that remained on the leaf surface was washed off immediately with deionized water, brought to equal volume, and absorbance was measured spectrophotometrically

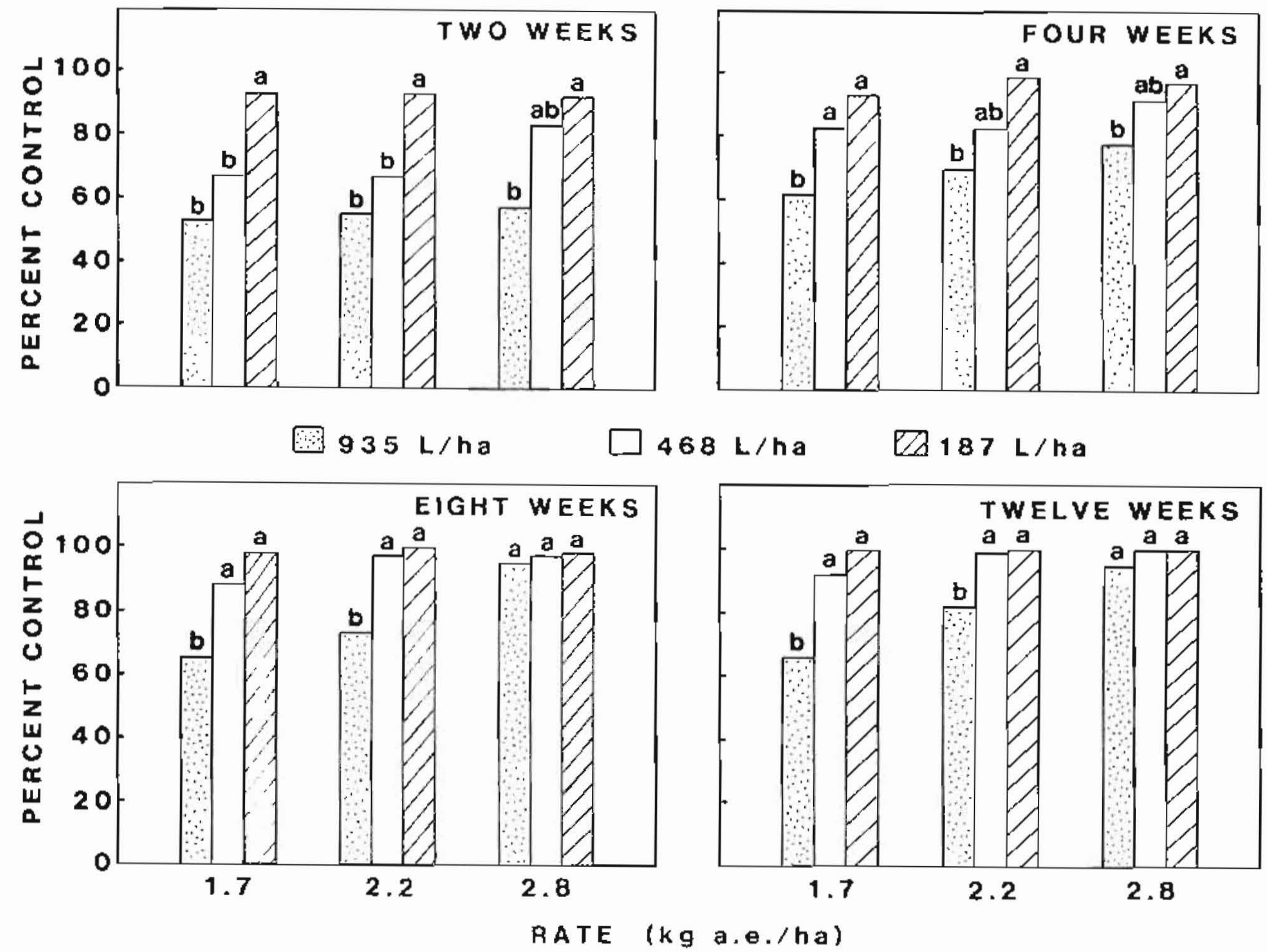

Figure 8. Effect of herbicide rate and carrier volume on glyphosate toxicity to waterhyacinth. Bars with different letters are significantly different at the P=0.05 level using the Waller-Duncan test

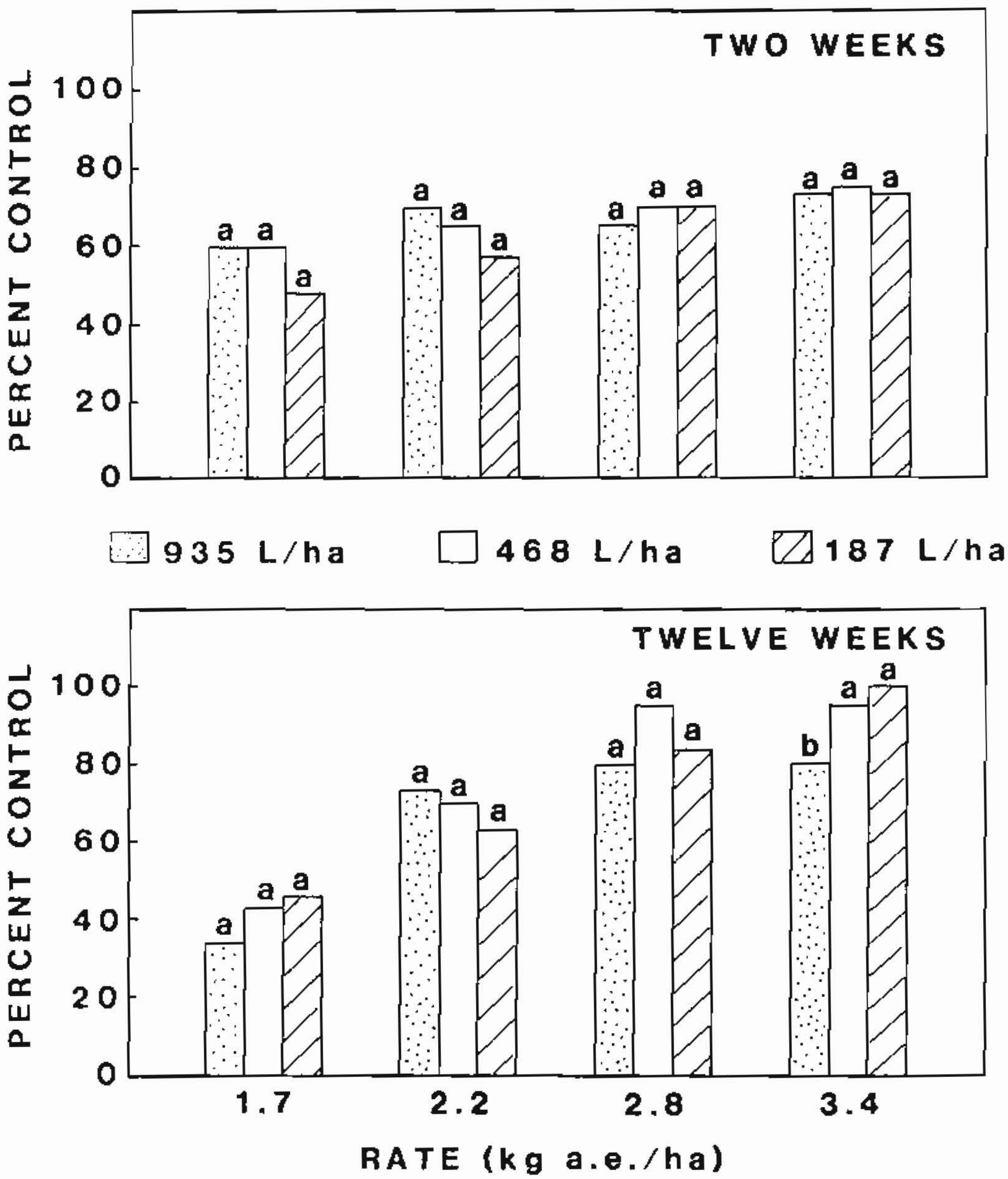

Figure 9. Effect of herbicide rate and carrier volume on glyphosate toxicity to water lettuce. Bars with different letters are significantly different at the P=0.05 level using the Waller-Duncan test

(Table 18). As the carrier volume was doubled from 438 to 935 L/ha in water lettuce, spray retention as determined by absorbance was also doubled. However, this was not the case with waterhyacinth, indicating that herbicide runoff from the hyacinth leaf surface may become a factor in the reduction in glyphosate activity when the spray volume was greater than 438 L/ha. On the other hand, loss of herbicide through runoff appeared to be minimal in the difficult-to-wet water lettuce, and should not be a factor affecting glyphosate activity at spray volumes up to 935 L/ha.

Sulfumeturon is DuPont's newest herbicide for use in noncropland areas. Previous studies indicated that the herbicide is effective at very low rates on numerous economically important aquatic weed species. The study described herein was conducted in Fort Lauderdale on a 0.07-ha pond infested with waterhyacinth to determine residue levels and persistence of sulfumeturon in the aquatic environment after chemical treatment. The herbicide rate used was 0.02 Kg a.i./ha which provided complete eradication of the waterhyacinth in the pond 3 months after treatment.

Water samples were collected from three different depths at two stations east and west of the pond. From Table 19, the highest sulfumeturon concentration detected was 1.6 µg/L from 0.1 m below the water surface on Day 1 posttreatment. On the same day, the highest herbicide residue level detected near the bottom of the water column was 1.4 µg/L. The sulfumeturon concentrations decreased to 1.0 - 1.3 µg/L by Day 3. On Day 14, only one water sample contained 1.1 µg/L sulfumeturon. And by postreatment Day 28, the sulfumeturon concentrations in water were below detection limits (<1.0 µg/L) in all water samples.

Sediment samples were collected before treatment and on posttreatment days

1, 3, 7, and 14. None of the sediment samples contained detectable sulfumeturon concentrations (0.2 ng/g). Similarly, the sulfumeturon concentrations in all of the fish samples from day 3 through day 28 were below detection limit (20 ng/g).

The results suggest that sulfumeturon used at 0.02 Kg a.i./ha to control waterhyacinth is not persistent in the water and sediment, and does not accumulate in the edible flesh of fish.

Table 20 indicated that the surfactant Emphasizer® used at 1, 2, and 3% v/v of the spray mixture had no effects on the herbicidal activity of 2,4-D towards waterhyacinth.

In another study, the susceptibility of watermeal to various aquatic herbicides was determined. Treatments were applied over the top (Table 21) or injected into water (Table 22).

Emergent Weeds

Previous studies indicated that the efficacy of glyphosate was reduced when applied to torpedograss cultured in outside aquaria under simulated flooded conditions (Steward, 1982). Field observations also indicated that control of torpedograss with glyphosate in standing water was generally of shorter duration compared to control achieved on ditchbanks (Baird et al., 1983). In the following studies, the effects of flooding on ^{14}C-glyphosate translocation in torpedograss were investigated.

Time-course studies of ^{14}C-glyphosate movement in torpedograss (Tables 23 and 24) indicated that the amount of ^{14}C translocated continued to increase during the 7-day experiment. An average of 2.9, 10.7, and 22.1 percent of the ^{14}C applied was translocated out of the treated leaf at 1, 3, and 7 days after treatment, respectively. Since control of torpedograss requires that all rhizome buds be killed, further efforts were made to investigate the direction of translocation in the rhizome system. A definite pattern was observed with lowest ^{14}C accumulation in basal node segments and greatest accumulation near the rhizome tip, indicating a typical phloem transport in a source-to-sink pattern for glyphosate in torpedograss.

The translocation of ^{14}C from ^{14}C-glyphosate in torpedograss was reduced by a flooding growth habitat (Table 25). The amounts of ^{14}C translocated out of the treated leaf were 21.3 and 13.3 percent of the total ^{14}C applied under non-flooded and flooded conditions, respectively. However, the accumulation of ^{14}C per g dry weight rhizome was almost similar in both cases (Table 26).

Glyphosate appears to move in the assimilate stream as would be expected of a phloem-mobile substance. Therefore, movement of the herbicide is expected to be controlled by those factors influencing assimilate translocation. It was observed that the flooding habitat reduced growth of torpedograss as much as 50 percent (Table 27). This growth reduction may have been responsible for the observed difference in amounts of ^{14}C translocation in the two growth habitats. When all rhizome buds are not killed, those inactive near the base may not accumulate a lethal amount of herbicide, and may therefore survive.

Table 28 shows the susceptibility of spikerush to various aquatic herbicides. Diuron and terbutryn provided complete control at all treatment rates from 0.63 to 5.0 mg/L. Fluridone effected 80 to 90 percent control after 10 weeks at rates varying from 0.16 to 1.25 mg/L. On the other hand, copper, 2,4-D, potassium endothall, and dicamba were found ineffective at rates up to 5.0 mg/L.

Submersed Weeds

Previous studies showed that hygrophila, green cabomba, and lemon bacopa

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The results suggest that sulfumeturon used at 0.02 Kg a.i./ha to control waterhyacinth is not persistent in the water and sediment, and does not accumulate in the edible flesh of fish.

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Submersed Weeds

Previous studies showed that hygrophila, green cabomba, and lemon bacopa were tolerant to most aquatic herbicides at levels currently being used for hydrilla control. In the comparative evaluation studies reported herein, the selectivity in herbicide responses between hydrilla and these new weed species was confirmed (Table 29). Hygrophila and green cabomba were tolerant to diquat, endothall K, copper, and various combinations of these herbicides at treatment rates that were effective in controlling hydrilla. Lemon bacopa was tolerant to endothall K and copper, but was about equally sensitive to diquat as compared to hydrilla. Diuron and terbutryn were both effective against all these species and hydrilla at treatment rates of 0.5 mg/L or higher (Table 30).

PART IV: REFERENCES

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Table 1

Names and Sources of Chemicals Evaluated in Fiscal Year 1983

Common Name	Chemical Name	Source
Copper EDA	Copper-Ethylenediamine Complex	Sandoz, Inc., Crop Protection Komeen 480 Camino Del Rio South, San Diego, CA 92108
2,4-D DMA	Dimethylamine salt of 2,4-dichlorophenoxy acetic acid	Union Carbide Agricultural Products Co., PO Box 12014, Research Triangle Park, North Carolina 27704
Dicamba	3,6-dichloro-o-anisic acid	Vesicol Chemical Corporation, 341 East Ohio Street, Chicago, Illinois 60611
Dichlobenil	2,6-dichlorobenzo-nitrile	Uniroyal Chemical, Spencer Street, Naugatuck, Connecticut 06770
Diquat	6,7-dihydrodipyrido (1,2-α:2',l'c) pyrazinedilum dibro-mide	Chevron Chemical Company, Ortho Division, 940 Hensley Street, Richmond, California 93710
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	E.I. duPont de Nemours & Co., Biochemicals Department, Wilmington, Delaware 19898
Endothall	Salts of 7-oxabicyclo (2.2.1)heptane-2,3-dicarboxylic acid	Pennwalt Corporation, Agricul-tural Chemical Division, 1630 East Shaw Avenue, Freshno, California 93710
Fenac	Salts of 2,3,6-tri-chlorophenylacetic acid	Union Carbide, Agricultural Products Co., Inc.
Fluridone	1-methyl-3-phenyl-5-(3-(trifluoromethyl)-phenyl)-4(1H)-pyridi-none	Lilly Research Laboratories, Division of Eli Lilly and Co., P.O. Box 708, Greenfield, Indiana 46140

(Continued)

Table 1 (cont.)

Names and Sources of Chemicals Evaluated in Fiscal Year 1983

Common Name	Chemical Name	Source
Glyphosate	N-(phosphonomethyl)-glycine	Monsanto Co., Agricultural Products, St. Louis, Missouri 63166
Simazine	2-chloro-4,6,bis(ethyl-amino)-s-triazine	Ciba-Geigy Corporation, Agricultural Division, P.O. Box 11422, Greensboro, North Carolina 27409
Sulfometuron	Methyl 2-{[[[(4,6-di-methyl-2-pyrimidinyl) amino]-carbonyl]amino] sulfonyl]benzoate	E.I. duPont deNemours & Co. Wilmington, Delaware 19898
Terbutryn	2-(tert-butylamino)-4-ethylamino)-6-(methyl-thio)-s-triazine	Ciba-Geigy Corporation
AC 925	Confidential	American Cyanamid Company P.O. Box 400 Princeton, NJ 08540
P-333	Confidential	ICI Americas Inc., P.O. Box 208, Goldsboro, NC 27530
Casoron GSR	Slow release formulation of dichlobenil	Duphar B.V., Crop Protection Division, P.O. Box 632, 1000 AP Amsterdam, Netherlands
CT-12-10-82-1 CT-12-11-82-1 CT-12-18-82-1 CT-12-18-82-2	Controlled release formulation of dichlobenil	Dr. Curt Thies, Washington Univ., St. Louis, Missouri 63130
FUN 83 EO 3A FUN 83 EO 3B FUN 83 EO 3C	Controlled release formulation of dichlobenil	Duphar B.V.
Fluridone monolithic fiber	Controlled release formulations of fluridone	Dr. Richard Dunn, Southern Research Institute, 2000 Ninth Ave., South Birmingham, AL 35205
Poly (GMA) 2,4-D	2,4-dichlorophenoxyacetate/glycerylmethacrylate	Dr. Frank Harris, Wright State University, Dayton, OH 44231

Table 2

Water Quality Control

Analysis

Date	Oxygen ppm	Conductivity µmhos	pH	Alkalinity mg/L $CaCO_3$	Hardness mg/L $CaCO_3$	Air Temp °C	Water Temp °C
March 83	5.0	343	7.6	143	182	22.5	23.0
June 83	4.5	351	7.5	150	180	28.5	27.5
Sept 83	3.5	339	7.7	152	178	28.0	27.8
Dec 83	3.0	337	7.6	144	179	19.5	23.0

Date	PO_4-P mg/L	NO_3-N mg/L	NH_4-N mg/L	K mg/L	Solids: Total mg/L	Solids: Suspended mg/L
March 83	BDL	0.16	0.37	0.71	280	7.5
June 83	BDL	0.20	0.42	0.95	245	8.0
Sept 83	BDL	0.02	0.20	0.20	255	13.6
Dec 83	BDL	0.30	0.20	0.40	240	2.5

Table 3

Response of Hydrilla to Various Concentrations and Exposure Periods of Fluridone under Greenhouse Conditions

Fluridone Treatment (mg/L)	Exposure Time (hrs.)	Percent Control[1/] - Weeks Posttreatment							
		1	2	4	6	8	10	12	14
0.05	3	3	0	12	12	10	12	7	10
	6	0	0	8	8	12	17	18	28
	12	0	0	7	7	12	15	15	17
	24	10	0	10	10	20	20	20	20
	48	10	0	10	10	20	20	17	25
	96	17	10	5	10	17	22	25	28
	168	10	10	10	20	33	28	40	43
	2352[2/]	13	20	17	17	48	65	95	95
0.10	3	0	3	12	12	12	12	10	22
	6	3	3	8	8	18	18	17	32
	12	10	3	10	10	12	13	8	10
	24	13	3	10	10	20	20	20	33
	48	17	3	8	8	22	22	20	32
	96	18	13	15	18	45	43	50	60
	168	17	15	10	18	37	45	42	38
	2352[2/]	13	17	10	10	55	68	93	87
0.25	3	0	3	13	12	17	15	10	12
	6	0	5	10	10	20	25	37	45
	12	10	5	10	18	23	25	22	18
	24	13	3	17	17	38	43	45	48
	48	22	7	22	22	55	75	75	63
	96	20	15	20	23	72	72	77	82
	168	13	12	17	17	53	70	82	92
	2352[2/]	13	13	18	20	59	72	90	90
0.50	3	0	10	18	12	20	25	18	23
	6	0	5	10	13	15	25	30	43
	12	13	10	18	18	23	50	47	40
	24	18	7	20	20	48	63	68	73
	48	20	17	22	27	67	85	77	75
	96	18	13	23	28	32	85	92	93
	168	10	10	20	20	33	90	90	95
	2352[2/]	10	17	17	20	67	80	95	95
Control	0	0	0	0	0	0	3	3	3

1/- Average of three replicates.

2/- Continuous exposure of the plants to the chemical treatment throughout the 14-week experiment.

Table 4

Accountability of Fluridone in Static Tests with Reconstituted Water and Natural Pond Water After 76 Days Posttreatment

Treatments	Percent Fluridone Recovered[1/]		
	Water	Fiber	Total
	(%)	(%)	(%)
BC Pellets			
RCW[2/]	79± 1	10± 1	89
NPW[2/]	72± 1	18± 1	91
8-mil Fiber			
RCW	89± 2	8± 1	97
NPW	86± 1	9± 1	95
16-mil Fiber			
RCW	88± 1	6± 1	94
NPW	82± 2	11± 1	93
30-mil Fiber			
RCW	80± 4	12± 1	93
NPW	81± 1	11± 1	92
45-mil Fiber			
RCW	67± 2	23± 1	91
NPW	63± 1	27± 1	90

1/ Means of four replicates ± S.E.

2/ RCW, reconstituted water; NPW, natural pond water.

Table 5

Fluridone Residue after Treatment with Sonar® 4AS at 2.2 Kg a.i./ha in Flowing Water in Outdoor Aquaria[1/]

Tank Number	µg/L Fluridone - Days after Treatment 1/12	1/4	1	2	7	14
B4	801	569	104	31	BDL[2/]	0
B6	995	678	73	26	BDL	0
B11	974	584	100	24	BDL	0
C2	1150	658	130	34	BDL	0
Average	980	622	102	29	BDL	0

[1/] Aquaria 0.6 m deep with flowing water to provide one complete water exchange every 24 hours.

[2/] BDL, less than 1 µg/L.

Table 6

Fluridone Residue After Treatment with BC Pellets and Polycaprolactone Fibers at 2.2 Kg a.i./ha in Flowing Water in Outdoor Aquaria[1/]

Formulations	µg/L Fluridone[2/] - Days after Treatment 2	7	14	21	28	35	42	49
Pellets BC	54±6	20±1	5±1	3±1	BDL[3/]	0	0	0
Fibers 16-mil	32±6	36±2	5±1	BDL[3/]	0	0	0	0
Fibers 30-mil	13±2	14±2	9±1	8±2	4±1	3±1	2±1	BDL[3/]
Fibers 45-mil	10±1	11±2	7±1	6±1	4±1	3±1	3±1	BDL

[1/] Aquaria 0.6 m deep with flowing water to provide one complete water exchange every 24 hours.

[2/] Means of four replicates ± S.E.

[3/] BDL, less than 1 µg/L.

Table 7

Chlorophyll Contents of Hydrilla Tips Treated with Various Formulations of Fluridone at 2.2 Kg a.i./ha in Flowing Water in Outdoor Aquaria[1/]

Formulations	Total Chlorophyll[2/] (mg/g fresh weight)	a/b Ratio
Liquid 4AS	1.519[a]	2.24[a]
Pellets BC	0.972[b]	1.68[b]
Fibers 16-mil	1.373[a]	2.23[a]
Fibers 30-mil	0.424[c]	1.63[b]
Fibers 45-mil	0.443[c]	1.53[b]
Control	1.423[a]	2.39[a]

1/ Aquaria 0.6 m deep with flowing water to provide one complete water exchange every 24 hours.

2/ Values in a column followed by the same letter are not significantly different at the 5% level as determined by the Waller-Duncan Test. Each value is the mean of six replicates.

Table 8

Hydrilla Control by Various Formulations of Fluridone Applied at 2.2 Kg a.i./ha in Flowing Water in Outdoor Aquaria 16 Weeks After Treatment[1/]

Treatments	% Injury	Dry Weights (g)[2/]		
		Shoots	Roots	Tuber
Liquid 4AS	22	30.6[ab]	0.83[a]	19.9[a]
Pellets BC	52	12.5[bc]	0.49[ab]	17.1[a]
Fibers 16-mil	15	39.7[a]	0.93[a]	22.7[a]
Fibers 30-mil	84	5.7[c]	0.27[b]	15.3[a]
Fibers 45-mil	78	4.2[c]	0.20[b]	11.1[a]
Control	18	36.1[a]	0.74[ab]	14.2[a]

1/ Aquaria 0.6 m deep with flowing water to provide one complete water exchange every 24 hours.

2/ Values in a column followed by the same letter are not significantly different at the 5% level as determined by the Waller-Duncan Test. Each value is the mean of four replicates.

Table 9

Hydrilla Tuber Density and Tuber Germination as Affected by Treatment of Various Fluridone Formulations at 2.2 Kg a.i./ha in Flowing Water in Outdoor Aquaria[1/]

Treatments	Number of Tubers/Tray	% Germination
Liquid 4AS	224[a]	62[b]
Pellets BC	176[a]	68[b]
Fibers 16-mil	231[a]	75[ab]
Fibers 30-mil	180[a]	64[b]
Fibers 45-mil	150[a]	71[ab]
Control	200[a]	85[a]

1/ Aquaria 0.6 m deep with flowing water to provide one complete water exchange every 24 hours.

2/ Values in a colummn followed by the same letter are not significantly different at the 5% level as determined by the Waller-Duncan test.

Table 10

Methanol Extraction of Various Dichlobenil Formulations

Formulations[1/]	mg/L Dichlobenil Recovered			
	Day 1	Day 7	Day 23	Day 31
FUN 83 EO 3A	5.1	6.0	5.8	5.8
FUN 83 EO 3B	3.5	6.2	9.1	9.5
FUN 83 EO 3C	5.7	8.4	8.5	8.6
Casoron GSR	9.7	9.8	-	-

[1/] Duplicated samples of 50 mg of each formulation were extracted in 1 liter of methanol. The expected level of dichlobenil in the methanol extracts was 10 mg/L, assuming that all formulations have 20 percent a.i.

Table 11

Verification of the Total Available Dichlobenil Content in the Various Silicate Formulations by Methanol Extraction

Formulations	Reported Percent a.i.	Percent dichlobenil Recovered [1/]	Measured Percent a.i.
CT-12-10-82-1	7.0	79	5.5
CT-12-11-82-1	7.2	93	6.7
CT-12-18-82-1	13.4	98	13.1
CT-12-18-82-2	13.4	88	11.8
Casoron GSR	20.0	98	19.6

[1/] Average of three replicates

Table 12

Laboratory Evaluations of Various Silicate Formulations of Dichlobenil in Static Reconstituted Water and Natural Pond Water. Date treated: 16 March 1983

Treatments	Total (mg) Applied[1]	Cumulative Dichlobenil Released (mg/L) - Days After Treatment 2	7	14	21	28	42	56	70	84	112	141	180
CT-12-10-82-1													
RCW[2]	142.0	0.23	0.58	0.66	1.02	1.17	1.87	2.25	2.64	2.98	3.98	4.81	5.52
	142.6	0.23	0.59	0.73	1.13	1.42	2.22	2.63	2.98	3.78	4.65	5.42	6.03
	142.4	0.25	0.61	0.90	1.27	1.64	2.25	3.10	3.38	3.64	4.62	5.22	5.87
	143.3	0.26	0.63	0.95	1.20	1.68	1.99	2.41	2.95	3.23	3.99	4.72	5.33
	Average	0.24	0.60	0.81	1.16	1.48	2.08	2.60	2.99	3.41	4.31	5.04	5.69
NPW[2]	142.9	0.24	0.50	0.66	0.78	0.96	1.86	1.20	1.44	1.59	1.70	1.92	2.21
	142.9	0.26	0.57	0.79	0.98	1.17	1.75	1.79	1.92	2.07	2.47	2.77	3.19
	142.9	0.31	0.61	0.80	1.22	1.34	1.58	2.01	2.00	1.96	2.09	1.98	1.98
	142.9	0.26	0.45	0.54	0.64	0.73	0.99	0.95	1.02	1.12	1.08	1.20	1.38
	Average	0.27	0.53	0.70	0.90	1.05	1.54	1.49	1.60	1.68	1.84	1.97	2.19
CT-12-11-82-1													
RCW[2]	139.0	0.28	0.96	1.97	2.95	3.72	4.50	5.54	5.68	6.10	6.66	6.77	6.74
	139.1	0.28	1.08	2.06	3.20	4.14	4.74	6.06	6.48	6.54	6.77	6.94	6.84
	138.5	0.28	1.10	2.03	3.20	4.02	5.06	6.00	6.44	6.60	6.58	6.99	6.90
	138.9	0.28	1.17	2.40	3.39	4.32	5.22	6.00	6.52	6.05	6.42	6.83	6.68
	Average	0.28	1.08	2.12	3.18	4.05	4.88	5.90	6.28	6.32	6.61	6.88	6.79
NPW[2]	138.9	0.38	1.10	2.16	2.81	3.42	3.72	4.92	5.30	5.12	6.09	6.20	6.46
	138.9	0.34	1.26	2.36	3.09	3.56	3.97	4.96	5.16	5.24	5.67	5.94	5.99
	138.9	0.34	1.11	2.01	2.81	3.30	3.80	4.77	4.88	5.32	5.49	5.74	5.92
	138.9	0.33	1.11	2.15	2.98	3.38	3.85	4.78	4.63	4.73	5.23	5.39	5.46
	Average	0.35	1.14	2.17	2.92	3.42	3.84	4.86	4.99	5.10	5.62	5.82	5.96

(Continued)

Table 12 (Continued)

Treatments	Total (mg) Applied[1/]	Cumulative Dichlobenil Released (mg/L) - Days After Treatment 2	7	14	21	28	42	56	70	84	112	141	180
CT-12-18-82-1													
RCW[2/]	74.4	0.20	0.61	1.34	1.95	2.50	3.73	4.04	4.68	4.95	6.08	6.60	7.01
	73.6	0.23	0.75	1.52	2.31	3.02	3.88	4.56	4.94	5.16	6.05	6.36	6.55
	75.3	0.20	0.68	1.40	2.19	3.01	3.91	4.52	5.00	5.07	6.39	6.58	6.79
	75.1	0.23	0.82	1.67	2.41	2.87	3.96	4.83	4.80	-	-	-	-
	Average	0.22	0.72	1.48	2.22	2.85	3.87	4.49	4.86	5.06	6.17	6.51	6.78
NPW[2/]	74.6	0.22	0.79	1.54	2.17	2.55	2.97	4.17	3.86	4.63	5.42	5.65	5.81
	74.6	0.22	0.58	1.03	1.45	1.88	2.38	3.02	3.03	3.64	4.33	4.80	5.46
	74.6	0.22	0.76	1.47	2.04	2.58	3.00	3.85	3.87	4.37	5.18	6.00	5.88
	74.6	0.24	0.65	1.36	1.82	2.35	2.87	3.60	3.68	4.30	4.81	5.32	5.30
	Average	0.22	0.70	1.35	1.87	2.34	2.80	3.66	3.61	4.24	4.94	5.44	5.61
CT-12-18-82-2													
RCW[2/]	74.4	0.26	0.66	1.07	1.60	1.86	3.38	3.10	3.52	3.99	4.95	5.38	6.35
	74.6	0.20	0.46	0.76	1.13	1.34	2.22	2.45	2.86	3.30	4.21	4.66	5.40
	74.7	0.20	0.44	0.76	1.11	1.54	2.16	2.54	3.03	3.67	4.26	4.94	5.54
	74.3	0.17	0.39	0.66	0.94	1.14	1.90	2.18	2.48	3.02	3.56	4.02	4.87
	Average	0.21	0.49	0.81	1.19	1.46	2.42	2.57	2.97	3.50	4.25	4.75	5.54
NPW[2/]	74.6	0.22	0.40	0.60	0.85	1.15	1.67	1.90	1.77	2.12	2.58	2.94	3.63
	74.6	0.22	0.39	0.53	0.59	0.77	1.16	1.20	1.18	1.30	1.43	1.68	1.96
	74.6	0.19	0.36	0.51	0.57	0.70	1.02	1.02	1.03	1.16	1.35	1.50	1.47
	74.6	0.17	0.34	0.46	0.66	0.91	1.28	1.51	1.59	1.92	2.22	2.48	2.89
	Average	0.20	0.37	0.52	0.67	0.88	1.28	1.46	1.39	1.62	1.90	2.15	2.49

1/ - Treatments applied to 1 liter of water with amounts calculated to produce a maximum cumulative concentration of 10 mg/L dichlobenil, based on reported percent a.i. of the formulations.

2/ - RCW, reconstituted water; NPW, natural pond water.

Table 13

Retention Times and Absorbance Ratios of 2,4-D, 2,4-D Methyl Ester (ME), 2,4-D Ethyl Ester (EE)

Peak	Retention Time (min)	Absorbance 1/		
		230 nm	285 nm	Ratio
Standards:				
2,4-D	2.8	0.050	0.011	4.54
2,4-D ME	4.4	0.116	0.024	4.83
2,4-D EE	4.8	0.073	0.014	5.21
Poly (GMA) 2,4-D:				
#1 2/	2.8	0.063	0.014	4.50
#2	4.4	0.087	0.018	4.83

1/ Mean of 6 replicates

2/ After hydrolysis

Table 14

Chemical Release from Poly (GMA) 2,4-D in Static Water

Water Treatment	mg Chemical Released/g Formulation [1/]								% Total a.i. Recovered
	Day 1		Day 2		Day 3		Day 6		
	2,4-D	2,4-D ME	2,4-D	2,4-D ME	2,4-D	2,4-D ME	2,4-D	2,4-D ME	
DIW[2/]	BDL	85.4	8.9	109.9	14.6	116.5	24.2	122.0	86.1
RCW[2/]	51.6	46.0	100.0	16.3	121.2	13.3	154.5	6.5	94.7
NPW[2/]	24.4	74.3	58.4	54.0	90.4	43.1	146.7	5.0	91.9

1/ Values are means of four replicates

2/ DIW, deionized water, pH=6.3; RCW, reconstituted water, pH=8.0; NPW, natural pond water, pH=7.5.

Table 15

The Effect of Glyphosate on Waterhyacinth and Water Lettuce

12 Weeks After Treatment

Glyphosate (Kg a.e./ha)	Percent Control[1/]	
	Waterhyacinth	Water Lettuce
2.2	65 ± 10	38 ± 8
2.8	93 ± 3	52 ± 10
3.4	95 ± 3	49 ± 12
3.9	100 ± 0	68 ± 10
4.5	97 ± 2	75 ± 6
Check	5 ± 2	3 ± 2

[1/] Average of three replicates ± S.E

Table 16

Translocation of Selected Herbicides Between Parent and Offshoot Waterhyacinth Plants

Chemical	Rate (Kg a.i./ha)	Percent Injury		Index of Translocation[1/]
		Parent	Offshoot	
2,4-D	2.24	100	47	0.5[b]
Glyphosate	2.24	100	98	1.0[a]
Sulfometuron	0.02	100	88	0.9[a]
AC-925	0.56	100	99	1.0[a]
Control	--	19	20	--

[1/] The interconnecting stolon between the parent and offshoot plants provided a mechanism whereby the two plants could be separated and treated individually. Index of translocation = percent injury to untreated connected offshoot plants/percent injury to treated parent plants.

Table 17

Distribution of ^{14}C as a Percentage of the Total ^{14}C-Glyphosate Applied

Plant Part	% of total dpm applied [1/] Hyacinth	Lettuce
Treated leaf	5.1 ± 1.4	4.3 ± 0.4
Above treated leaf	5.9 ± 0.8	9.9 ± 0.3
Below treated leaf	0.5 ± 0.1	1.5 ± 0.2
Crown	2.2 ± 0.3	2.6 ± 0.1
Roots	17.2 ± 3.2	14.8 ± 0.4
Daughter plants	6.0 ± 1.5	5.7 ± 1.1
Total minus treated leaf	31.7 ± 3.4	34.3 ± 2.0

[1/] Average of four replicates ± S.E.

Table 18

The Effect of Spray Volume on the Retention of Sulfonine Red Dye on the Leaf Surfaces of Waterhyacinth and Water Lettuce

Species	Spray Volume (L/ha)	Absorbance (OD/cm^2)
Hyacinth	187	0.0008[a]
	438	0.0015[b]
	935	0.0017[b]
Lettuce	187	0.0007[a]
	438	0.0018[b]
	935	0.0030[c]

[1/] Values followed by the same letter are not significantly different at the 5% level as determined by the Waller-Duncan test.

Table 19

Residues of Sulfumeturon in Water, Sediment, and Fish Samples Before and After Chemical Treatment at 0.02 Kg a.i./ha to a Waterhyacinth Pond

Sampling Area	Sulfumeturon Residues (µg/L)										
	Pre Appli-cation	0 Hours	3 Hours	6 Hours	12 Hours	18 Hours	24 Hours	3 Days	7 Days	14 Days	28 Days
Water 1/											
East-Surface	<1.0	<1.0	1.0	<1.0	<1.0	1.0	<1.0	1.0	<1.0	<1.0	<1.0
East-Middle	<1.0	<1.0	<1.0	<1.0	<1.0	1.5	1.3	1.3	1.1	1.1	<1.0
East-Bottom	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	1.2	<1.0	<1.0	<1.0
West-Surface	<1.0	<1.0	<1.0	1.3	<1.0	1.5	1.6	1.0	1.0	<1.0	<1.0
West-Middle	<1.0	<1.0	<1.0	<1.0	1.1	<1.0	1.4	1.2	<1.0	<1.0	<1.0
West-Bottom	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	1.0	<1.0	<1.0	<1.0
Soil 2/											
East	<0.2	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	
West	<0.2	-	-	-	-	-	<0.2	<0.2	<0.2	<0.2	-
Fish 3/	<20	-	-	-	-	-	-	<20	<20	<20	<20

1/ Water spiked at 0.75 µg/L = 0.655 µg/L = 87% recovery. Detection limit = <1.0 µg/L.

2/ Detection limit = 0.2 ng/g.

3/ Detection limit = 20 ng/g.

Table 20

Effect of the Surfactant Emphasizer® on Herbicidal Activity of 2,4-D Toward Waterhyacinth

2,4-D Rate (Kg/ha)	Emphasizer Rate (% v/v)	Percent Control [1/]
0.0	0	5[b]
	1	8[ab]
	2	12[ab]
	3	13[a]
0.6	0	13[b]
	1	35[a]
	2	18[b]
	3	7[b]
1.1	0	80[a]
	1	72[a]
	2	58[a]
	3	82[a]
2.2	0	82[a]
	1	100[a]
	2	90[a]
	3	100[a]

[1/] Within each rate of 2,4-D values followed by the same letter are not significantly different as determined by the Waller-Duncan test.

Table 21

Laboratory Evaluations of Several Aquatic Herbicides Applied Over the Water Surface for Efficacy Towards Watermeal

Chemical Treatment Rates (Kg a.i./ha)	Percent Injury [1/] - Weeks Posttreatment					
	1	2	4	6	8	10
2,4-D DMA[2/]						
2.2	0	10	13	30	33	27
4.5	3	3	10	17	30	27
9.0	0	0	13	20	33	28
17.9	7	10	13	13	33	28
Dicamba + 2,4-D[3/]						
1.7	0	0	7	13	37	23
3.4	3	3	3	20	27	23
6.7	10	13	32	40	73	62
13.4	33	43	67	87	88	72
Diquat						
2.2	60	68	85	95	96	90
4.5	80	90	95	93	98	98
9.0	85	82	95	93	99	100
17.9	87	83	95	95	100	100
CONTROL	0	0	0	13	33	30

1/ Average of three replicates

2/ Dimethylamine salt

3/ As Banvel 720®

Table 22

Laboratory Evaluations of Several Aquatic Herbicides

Injected into the Water for Efficacy Towards Watermeal

Chemical Treatment Rates (mg/L)	Percent Injury 1/ - Weeks Posttreatment 1	2	4	6	8	10
Diuron						
0.5	3	0	3	7	23	7
1.0	10	0	20	20	33	17
2.0	3	3	57	63	85	63
4.0	7	3	72	73	90	72
Potassium Endothal						
1.0	0	0	7	13	37	23
2.0	3	3	3	20	27	23
4.0	10	13	32	40	73	62
8.0	33	43	67	87	88	72
Fluridone						
0.025	3	20	40	58	90	65
0.05	3	13	50	75	87	63
0.10	0	23	38	80	87	70
0.25	3	13	55	82	90	77
Terbutryn						
0.5	7	10	30	85	93	68
1.0	0	13	45	73	90	82
2.0	7	23	65	73	87	78
4.0	23	23	73	75	92	78
Simazine						
1.0	0	0	20	23	23	--
2.0	0	0	20	40	42	--
1.0 Split 2/	0	0	10	3	0	--
2.0 Split 2/	0	0	10	3	0	--
Diquat + Cu						
0.37 + 0.33	23	20	58	57	72	72
Control	0	0	0	13	33	30

1/ Average of three replicates

2/ Split treatment 7 days apart

Table 23

Absorption and Translocation of ^{14}C as a Percentage of Total ^{14}C-Glyphosate Applied to Torpedograss at Intervals After Treatment

Plant Parts	Percent of ^{14}C applied 1/- - Days after treatment 1	3	7
Treated leaf	10.57 ± 3.08	26.49 ± 4.76	21.31 ± 4.40
Treated shoot (minus tr. leaf)	0.90 ± 0.04	3.06 ± 0.31	5.09 ± 0.59
Non-treated shoot	0.98 ± 0.17	4.79 ± 0.62	9.60 ± 1.06
Rhizome	0.63 ± 0.05	1.98 ± 0.31	4.36 ± 0.61
Roots	0.43 ± 0.06	0.89 ± 0.06	3.06 ± 0.59
Total translocation	2.93 ± 0.15	10.69 ± 1.12	22.11 ± 2.67
Total recovery	13.52 ± 3.12	37.21 ± 5.61	43.42 ± 6.35

1/- Average of four replicates ± S.E.

Table 24

Distribution of ^{14}C Accumulation in Various Plant Parts as a Percentage of Total ^{14}C Translocated in Torpedograss at Intervals After Treatment with ^{14}C-Glyphosate

Plant Parts	Percent of ^{14}C translocated [1/-] Days after treatment 1	3	7
Treated shoot	30.8 ± 2.0	28.4 ± 4.5	23.1 ± 0.5
Non-treated shoot	33.3 ± 1.6	44.7 ± 4.0	43.6 ± 2.0
Rhizome	21.5 ± 1.5	18.4 ± 1.9	19.7 ± 1.2
Roots	14.6 ± 1.3	8.5 ± 1.6	13.6 ± 1.0

1/- Average of four replicates ± S.E.

Table 25

Absorption and Translocation of ^{14}C as a Percentage of Total ^{14}C-Glyphosate Applied to Torpedograss Grown Under Flooded and Non-flooded Conditions [1/]

Plant Parts	Percent of total ^{14}C applied	
	Non-flooded	Flooded
Treated leaf	23.5	20.9 NS
Treated shoot (minus tr. leaf)	8.5	7.0 NS
Non-treated shoot	3.5	1.5 **
Rhizome	5.9	3.0 **
Roots	3.4	1.8 *
Base	3.2	2.4 NS
Total translocation (Apex)	21.3	13.3 **
Total translocation (whole plant)	24.5	15.7 **
Total recovery (Absorpn. + Transloc.)	48.0	35.7

1/ Data are mean values of four replicates. Asterisks indicate means significantly different at the 1% (**) and 5% (*) levels, as determined by Student's t-test.

Table 26

Distribution of ^{14}C in Various Plant Parts as a Percentage of Total ^{14}C Translocated in Tropedograss Grown Under Flooded and Non-Flooded Conditions [1/]

Plant Parts	Percent of total ^{14}C translocated	
	Non-flooded	Flooded
Treated shoot	40.3	52.6 *
Non-treated shoot	16.2	10.8 *
Rhizome	27.8	22.9 NS
Roots	15.8	13.7 NS

1/ Data are mean values of four replicates. Asterisks indicate means significantly different at the 5% level, as determined by Student's t-test.

Table 27

Effect of Flooding on Dry Weight of Torpedograss

Plant Parts	Dry Weight (g)[1/]		
	Non-flooded	Flooded	
Apex			
Treated leaf	0.05	0.05	
Treated shoot (minus tr. leaf)	2.12	1.72	
Non-treated shoots	2.00	1.65	
Rhizome	3.76	1.54	
Roots	0.96	0.70	
Total apex	8.89	5.66	(64%)
Base			
Shoots	21.32	8.72	
Rhizome	10.82	4.37	
Roots	4.89	1.39	
Total plant	45.92	20.14	(44%)

[1/] Data are mean values of four replicates.

Table 28

Laboratory Evaluations of Several Aquatic Herbicides

for Efficacy Towards Spikerush

Chemical Treatment Rates (mg/L a.i.)	Percent Injury [1/] - Weeks Posttreatment					
	1	2	4	6	8	10
COPPER EDA[2/]						
0.63	17	17	10	3	3	3
1.25	15	12	5	7	5	5
2.50	28	22	15	5	5	8
5.00	18	15	7	10	5	8
DICAMBA + 2,4-D						
0.63	13	3	5	5	10	12
1.25	3	3	7	5	8	10
2.50	12	12	10	7	13	12
5.00	13	15	23	27	42	58
DICHLOBENIL						
0.63	13	15	33	40	58	72
1.25	23	28	38	43	73	82
2.50	7	8	27	35	72	83
5.00	2	3	33	37	82	90
DIQUAT						
0.31	2	2	7	12	8	8
0.63	3	2	15	30	32	32
1.25	18	12	23	52	67	62
2.50	15	12	77	77	85	85
DIURON						
0.63	17	20	95	95	95	100
1.25	7	7	78	95	95	100
2.50	0	7	95	95	95	100
5.00	12	13	95	95	95	100

(Continued)

Table 28 (Continued)

Laboratory Evaluations of Several Aquatic Herbicides

for Efficacy Towards *Spikerush*

Chemical Treatment Rates (mg/L a.i.)	Percent Injury [1/] - Weeks Posttreatment					
	1	2	4	6	8	10
ENDOTHALL AMINE (liquid)						
0.63	37	75	83	82	75	70
1.25	65	80	90	88	77	58
2.50	58	85	87	93	87	83
5.00	45	85	80	95	95	95
POTASSIUM ENDOTHALL						
0.63	17	12	8	7	8	25
1.25	12	8	5	7	12	18
2.50	17	12	12	13	18	22
5.00	32	25	37	35	25	25
FENAC						
0.63	7	8	10	7	23	28
1.25	12	10	17	27	52	83
2.50	13	13	45	82	85	95
5.00	17	18	72	85	85	95
FLURIDONE						
0.16	12	12	20	28	80	93
0.31	5	3	10	12	70	85
0.63	0	7	12	15	82	85
1.25	8	8	17	17	85	82
SIMAZINE						
0.63	0	0	23	50	78	83
1.25	3	8	65	92	95	100
2.50	0	3	83	95	95	100
5.00	3	10	95	95	95	100

(Continued)

Table 28 (Continued)

Laboratory Evaluations of Several Aquatic Herbicides

for Efficacy Towards Spikerush

Chemical Treatment Rates (mg/L a.i.)	Percent Injury [1/] - Weeks Posttreatment 1	2	4	6	8	10
TERBUTRYN						
0.63	7	7	95	95	95	100
1.25	0	3	95	95	95	100
2.50	3	15	95	95	95	100
5.00	13	33	95	95	95	100
2,4-D DMA [3/]						
0.63	7	13	10	7	10	12
1.25	7	8	12	15	15	13
2.50	13	15	18	18	18	18
5.00	7	5	7	7	5	8
POTASSIUM ENDOTHALL + 2,4-D						
0.32 + 0.32	3	0	2	0	3	10
0.63 + 0.63	0	5	7	8	12	12
1.25 + 1.25	10	10	7	12	17	20
2.50 + 2.50	17	17	38	37	35	37
CONTROL	0	0	10	12	12	10

[1/] Average of three replicates

[2/] Ethylene diamine complex

[3/] Dimethylamine salt

Table 29

Laboratory Evaluations of Selected Herbicides for Phytotoxicity Toward

Combined Hydrilla (H), Hygrophila (HP), Green Cabomba (CA), and Lemon Bacopa (BA)

Chemical Designation	Rate (mg/L)	Posttreatment Control, Percent [1/] 2 Weeks H	2 Weeks HP	2 Weeks CA	2 Weeks BA	4 Weeks H	4 Weeks HP	4 Weeks CA	4 Weeks BA	6 Weeks H	6 Weeks HP	6 Weeks CA	6 Weeks BA	10 Weeks H	10 Weeks HP	10 Weeks CA	10 Weeks BA
Diquat	0.25	52	17	10	32	93	25	20	77	100	28	30	100	82	42	23	100
	0.50	85	18	10	55	92	27	13	100	100	40	17	100	85	72	83	100
	1.0	88	68	3	80	97	72	7	100	100	77	23	100	98	88	58	100
	1.5	95	95	28	83	95	98	33	98	100	100	40	100	98	100	47	100
Endothall K	1.0	35	3	7	0	83	7	7	3	83	7	13	7	73	0	20	0
	2.0	75	0	0	0	93	0	0	0	98	0	3	0	95	3	10	0
	3.0	80	25	20	10	90	20	13	7	95	20	13	3	95	17	20	0
	5.0	83	38	10	12	95	40	7	13	98	32	17	13	95	57	18	8
Cu	0.25	37	3	3	3	35	0	0	0	37	0	0	0	7	0	0	0
	0.50	80	7	10	10	73	3	0	0	78	0	3	0	25	3	10	0
	1.0	85	0	7	3	78	0	0	0	80	3	0	7	81	7	23	7
	2.0	85	13	17	17	92	7	13	7	93	10	30	15	87	40	35	27
	5.0	92	32	17	30	97	33	13	30	100	50	23	37	98	32	47	45
Diquat + Cu	0.25 + 0.25	72	7	7	32	80	10	13	92	100	10	30	100	97	18	25	100
	0.25 + 0.50	92	22	15	35	90	15	15	83	100	25	27	97	93	32	27	97
Endothall K + Cu	1.0 + 0.25	65	3	13	7	78	3	10	3	100	3	13	3	80	0	7	0
	1.0 + 0.50	95	12	17	13	88	3	13	10	90	3	17	13	72	0	22	7
Control	-	0	0	0	0	8	3	0	3	7	0	7	3	3	0	17	3

1/ Average of three replicates.

Table 30

Laboratory Evaluations of Diuron and Terbutryn for Phytotoxicity Toward Combined Hydrilla (H), Hygrophila (HP), Green Cabomba (CA), and Lemon Bacopa (BA)

		Posttreatment Control, Percent [1/]															
		2 Weeks				4 Weeks				6 Weeks				10 Weeks			
Chemical Designation	Rate (mg/L)	H	HP	CA	BA	H	HP	CA	BA	H	HP	CA	BA	H	HP	CA	BA
Diuron	0.25	0	0	0	0	0	0	0	78	57	20	20	100	73	70	97	100
	0.50	0	0	7	0	0	85	73	100	57	100	100	100	87	100	100	100
	1.0	0	3	0	7	30	100	33	100	50	100	97	100	87	100	100	100
	1.5	0	3	0	7	80	80	98	100	80	100	100	100	100	100	100	100
Terbutryn	0.25	0	0	0	0	7	78	80	100	17	100	100	100	67	100	100	100
	0.50	0	48	10	48	20	100	98	100	40	100	100	100	87	100	100	100
	1.0	20	42	7	67	40	98	97	100	77	100	100	100	93	100	100	100
	2.0	27	95	37	85	17	100	100	100	70	100	100	100	97	100	100	100
Control	-	0	0	0	0	8	3	0	3	7	0	7	3	3	0	17	3

[1/] Average of three replicates.