Aquatic weed control studies

A Water Resources Technical Publication

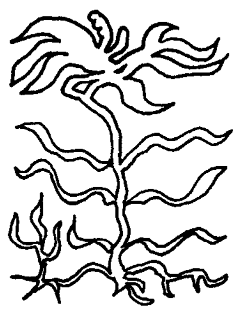
RESEARCH REPORT NO. 2

United States Department of the
INTERIOR
Bureau of Reclamation

BUREAU OF RECLAMATION
FLOYD E. DOMINY, COMMISSIONER

RESEARCH REPORT NO. 2

A Water Resources Technical Publication



Aquatic weed control studies

by N. E. Otto and T. R. Bartley

Water Conservation Branch
Division of Research
Office of Chief Engineer

UNITED STATES DEPARTMENT OF THE INTERIOR
STEWART L. UDALL, SECRETARY

In its assigned function as the Nation's principal natural resource agency, the Department of the Interior bears a special obligation to assure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity, and security of America, now and in the future.

First Printing: 1966

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON: 1966

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, or the Chief Engineer, Bureau of Reclamation, Attention 841, Denver Federal Center, Denver, Colo., 80225. Price 35 cents.

PREFACE

This research report is offered for use by the technical staffs of the Bureau of Reclamation and the Agricultural Research Service, irrigation and water districts, water boards, fish and wildlife agencies, universities, engineering and biological consultants, herbicide manufacturers, and others having an interest in the control of aquatic weeds.

Submersed aquatic weeds are a major operational problem for irrigation systems. Infesting 65 percent of all irrigation channels in the 17 Western States, aquatic weed growths, uncontrolled, cause a reduction in water-carrying capacity that may exceed 50 percent of the design capacity. In addition to reducing channel capacity, aquatic weeds cause sedimentation, aggravation of erosion, increased seepage and evaporation, breakage of canal banks, water logging of adjacent lands, aggravation of alkaline conditions on farm lands, and plugging of all types of structures.

The cost of controlling aquatic weeds amounts to as much as 40 percent of the total operation and maintenance expenditures for canals. Surveys show an average cost of $42 a mile for control measures. Mechanical control methods—chain dragging, use of power equipment, weed burning in drained canals, and other expedients—are expensive and, at best, provide only temporary relief.

Since 1946, scientists in the Bureau of Reclamation's Division of Research in Denver have conducted research in the Division's greenhouses and laboratories to determine the trend of herbicidal activity on pondweeds. The research is coordinated with Bureau of Reclamation regional offices and the Crops Research Division, Agricultural Research Service (ARS) of the Department of Agriculture.

The discovery of arcmatic solvent aquatic weed killers by Bureau and ARS researchers in 1947 provided an economical method for controlling weeds in small canals. Continuing research is needed, however, to develop similar methods for use in large canals, and to improve the permanence of treatments. Also required are more studies on biological problems related to animal organisms such as clams, sponges, and bryozoans, and on herbicidal residues and toxicity of chemical agents used by the Bureau for weed control.

The results of aquatic weed control research described in this Research Report were originally presented in the Bureau's Report WC–21, "Annual Progress Report of 1964 Laboratory Studies on Aquatic Weeds," issued by the Water Conservation Branch, Division of Research, May 20, 1965.

Included in this publication is an informativve abstract and list of descriptors, or keywords, and "identifiers". The abstract was prepared as part of the Bureau of Reclamation's program of indexing and retrieving the literature of water resources development. The descriptors were selected from the *Thesaurus of Descriptors,* which is the Bureau's standard for listings of keywords.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of Mr. Victor Miyahara, Laboratory Technician of the Agricultural Research Service, assigned to the Biological Investigations Section, in conducting many aspects of the studies covered in this report; Mr. W. Batts for the photography; and the chemical manufacturers who supplied the various materials for evaluation tests.

CONTENTS

Tables

Tables—Continued

Figures

INTRODUCTION

Laboratory and field investigations conducted on biological problems are often widely diverse and deal with many types of aquatic organisms found in the aquatic environmental complex of irrigation distribution systems. Many studies and tests are never carried beyond an exploratory state because of lack of potential indicated in preliminary results. This report covers progress made on various types of these studies conducted during 1964, as well as those investigations which are considered long term and are not sufficiently complete for conclusive interpretations.

A number of the tests and studies reported were suggested from cooperative field investigations and observations made on operating irrigation canals.

The following laboratory studies, which are in various stages of completion, are discussed: influence of low-rate acrolein application on the growth and propagule productivity of pondweeds, results of preliminary evaluations of algaecides and aquatic herbicides, evaluation of aromatic solvents and rates of emulsifiers used to disperse these aquatic herbicides, evaluation tests of additives to enhance the phytotoxic properties of aromatic solvents, and results of tests on laboratory-prepared pelletized formulations of aquatic herbicides for soil application.

Studies were continued to investigate further the influence of soil-type on the growth and propagule production of pondweeds. The dissolved oxygen content and alkalinity of interstitial water occurring in aquatic soils were determined by microanalytical techniques.

SUMMARY

Greenhouse studies were conducted to determine the trend of herbicidal activity of acrolein on pondweeds, as influenced by variations in contact time and concentration. Results of these standing water tests indicated that the 1.0 part per million concentration with a 24-hour exposure would provide sufficient injury on pondweeds for further study of the low-rate treatments influence on the plants' growth and propagule production capacity. Potted cultures of sago and American pondweeds that were 2, 4, and 6 weeks old at time of treatment were exposed to the low-rate acrolein concentrations in a flowing water test facility located in the greenhouse. Plants were then subjected to weekly observational injury and regrowth ratings for 4 weeks. At the end of this time period the fresh and dry rates were determined, as well as the tuber production of sago pondweed.

Results indicated that the total plant growth was significantly reduced by low-rate acrolein treatment. The total plant production of both untreated pondweed species averaged 68.63 percent greater than treated plants, as expressed by dry weight. However, dry-weight plant production did not differ significantly between the three age groups.

Sago pondweed propagule production was significantly reduced by the treatment as compared to untreated plants. American pondweed propagule production data were not available because of a lack of winter bud development. An age relationship was evident in that the youngest treated plants produced the least number of propagules, suggesting that some advantages might be obtained by treating younger plants. Mean weekly observational injury ratings indicate maximum injury could be obtained from the low-rate acrolein by treating plants at the median age of 4 weeks. These data again were not substantiated by the dry-weight production data.

Weekly injury and regrowth estimate ratings for each species of the 2-, 4-, and 6-week treatment ages were combined to calculate the regression of injury symptoms and regrowth over the 4-week observational period. Sago pondweed exhibited maximum injury symptoms during the first week with a slight decline in injury symptom for 4 weeks. American pondweed showed a positive regression or increase in injury over the 4-week rating period. Regrowth estimates showed positive curvilinear tendencies that increased gradually through the first 3 weeks after treatment, followed by a significant upturn in regrowth rate between the third and fourth weeks. These data suggest that pondweeds should be retreated at this time to maintain plant size at a level comparable to the original size when treated, as has also been shown by field tests. The results of this laboratory study indicate in some detail the promising potential of low-rate, long contact treatments for suppressing the growth of pondweeds in an irrigation canal to a level that will not seriously impede the flow of water.

A limited number of new herbicidal chemicals were evaluated for effectiveness in controlling rooted submersed aquatic weeds. A few of these materials showed some degree of herbicidal activity on pondweeds, but were not considered as being particularly promising.

Data are presented on the results of preliminary evaluation of 20 compounds for algaecidal activity on the filamentous green algae *Oedogonium* and *Rhizoclonium*. Two of these compounds, which are formulations of endothal, exhibited greater activity than did copper sulfate, indicating some potential for use in irrigation canals. These data suggest the need for more critical evaluation under field conditions. A number of compounds, known to possess good algaecidal activity on green algae, were subjected to activity tests on *Cladophora,* a species that has been reported to be difficult to control. A number of these materials showed good activity, but generally required higher concentrations than those needed for other species used in laboratory tests.

Laboratory test results on the physical and chemical requirements, and the herbicidal activity of aromatic solvent aquatic herbicides, proposed for use by Bureau projects, are given. Results of evaluations of these materials indicated that they were all

788-773 O-66—2

suitable for use in controlling submersed aquatic weeds in irrigation systems.

A few compounds were subjected to biological evaluations to test their ability to enhance the phytotoxic properties of aromatic solvent herbicides. None of the compounds produced any significant increase in the phytotoxic properties of solvent herbicides on pondweed species.

Field personnel have reported that an experimental emulsifier, used to disperse xylene, had shown satisfactory performance when used at less than normal concentrations of 1.0 percent. Emulsifier stability tests conducted in the laboratory revealed that this material produced relatively unstable emulsions as compared to a routinely used emulsifier. Subsequent herbicidal activity tests using this experimental emulsifier to disperse a xylene herbicide indicated a reduction in phytotoxicity when compared to xylene with a standard emulsifier. The results of these tests also indicated that when either emulsifier was used below the 1.0 percent level, volume to volume with xylene, the herbicidal activity on pondweeds was reduced. Results of this study indicate that the emulsion stability test, as previously developed in this laboratory, is a good indicator of the performance of an emulsifying material for dispersion of solvents in irrigation canals. Also, it was determined that excessive mechanical agitation of an emulsifier-xylene combination can improve the performance of poor emulsifying compounds.

Field observations have been reported that suggest the possible existence of a relationship between aquatic soil texture and the extent of sago pondweed infestations, as well as a selectivity of depth of tuber-bearing rhizomes. An exploratory study was designed to demonstrate the occurrence of any such relationship and also to determine the soil oxygen and the calculated carbon dioxide content of the soil-water in tuber-producing zones of aquatic soils. Fixed-site sampling devices were successfully used to repeatedly obtain interstitial soil-water samples for subsequent microanalyses for dissolved oxygen and alkalinity. The resulting data did not indicate any obvious relationship between aquatic soil type, the oxygen and calculated equivalent carbon dioxide content (determined from water alkalinity) of interstitial water, and the extent or depth selectivity of sago pondweed tubers produced in the test aquaria soil.

Pellets of the silvex acid prepared by coating the acid with a vinyl resin increased the number of crops of sago pondweed killed when compared to the uncoated herbicides at the 20- and 40-pound-per-acre rates in a soil application. Time required to complete the total number of crop kills was reduced somewhat by the coated material treatments.

Influence of Low-rate Acrolein Applications on the Growth and Propagule Production of Pondweeds

Weed control personnel of the Columbia Basin project, Ephrata, Wash., have been conducting field tests for the past 3 years on low-rate, long-contact acrolein treatments to control submersed aquatic weeds in irrigation canals (1).[1] These applications are begun when rooted aquatic weeds are 4 to 6 inches in length and are repeated as regrowth from the parent plants again reach the 4- to 6-inch length. Treatments consisted of applying acrolein at a rate of approximately 0.1 part per million (p.p.m.) for a period of approximately 48 hours. Five to six treatments are required during a growing season. These treatments produce a limited amount of injury symptom to the plants that has been difficult to evaluate and describe, as compared to the herbicidal response produced by routine aromatic solvent or higher rate acrolein treatments (2). This low-rate herbicidal response has been referred to as more of a growth-suppressive effect rather than a rapid kill of vegetative tissue.

Greenhouse studies were conducted to study the influence of low-rate, long contact period treatments on the growth and regrowth pattern, as well as the propagule production, of sago pondweed, *Potamogeton pectinatus* L. and American pondweed, *P. nodosus Poir.* It was thought that laboratory studies of this type could better describe some of the growth-suppression responses of the plants to these treatments than the gross effects that have been observed in field situations. This information would be useful to field personnel in evaluating the relative effectiveness of treatments and in establishing treatment schedules to obtain maximum results.

[1] Numbers in parentheses refer to literature cited at the end of the report.

Influence of Contact Periods and Concentrations on Plant Injury

Exploratory greenhouse tests were conducted in standing water to determine the trend of the herbicidal activity of acrolein on pondweeds, as influenced by variations in contact-time and concentrations. This information on the pondweed's response to various contact periods and of concentrations of acrolein under greenhouse conditions was considered to be a necessary prerequisite to conducting low-rate, long-contact period studies in flowing water. Data from such tests suggested the optimum herbicidal concentration and contact time that would produce easily differentiated injury symptoms between any combination of variables under which the plants might be treated. Too little injury as well as extensive injury serverly limits the observer's ability to differentiate between treatments.

The results of the exploratory time-rate, static-water tests with acrolein are given in table 1. The laboratory culture and herbicidal evaluation test methods used correspond to those described by Frank, Bartley, and Otto (3). The herbicidal activity rate scale used is described as follows:

0=No apparent injury
1–2–3=Slight injury
4–5–6=Moderate injury
6–7–8=Severe injury, but with some regrowth at the end of the 3-week observation period
10=Total kill of all plant material without regrowth.

The average injury ratings for each acrolein concentration-contact period given in table 1 are graphically shown in figure 1. These data indicate a

Table 1

HERBICIDAL ACTIVITY OF ACROLEIN ON PONDWEEDS AS INFLUENCED BY VARIATIONS IN CONTACT TIME AND CONCENTRATIONS IN STANDING WATER [1]

Acrolein concentration (p.p.m.)	Contact period (hours)	Weekly injury scale ratings obtained on potted cultures of rooted aquatic weed species						Average rating
		E. canadensis		P. nodosus		P. pectinatus		
		1 week	2 weeks	1 week	2 weeks	1 week	2 weeks	
50	1½	6	9. 5	4	6	6	7. 5	6. 5
150	½	5. 5	9. 5	4	6	6	7. 5	6. 4
10	6	3	5	3	5	4	5	4. 2
15	4	3	5	3	4. 5	4	5	4. 1
25	3	5	5. 5	4. 5	5	5. 5	6	5. 3
10	48	----------	----------	5	5. 5	7	7. 5	6. 3
1	48	----------	----------	4	4	5	6	4. 8
0. 1	48	----------	----------	0	. 5	. 5	. 5	. 4
0. 01	48	----------	----------	0	1. 3	0	0	. 3
10	96	----------	----------	4	6. 5	5	7	5. 6
1	96	----------	----------	3	5	3	5. 5	4. 1
0. 1	96	----------	----------	0	0	0	1	. 25
0. 01	96	----------	----------	0	0	0	. 5	. 1

[1] The 20-liter glass aquaria used in this test were filled to the top and sealed with plastic covers during treatment periods to prevent volatilization loss of the herbicide.

significant breaking point in the activity of acrolein at concentrations below the 1.0 p.p.m. level in both 48- and 96-hour exposures. There also appears to be a slight decline in activity at all rates as the contact time was increased from 48 to 96 hours. It is interesting to note that under greenhouse conditions the herbicidal activity at the 1.0 p.p.m. level for the 48-hour period is not a great deal less than the activity exhibited at the higher-rate, short-contact period tests, such as 25 p.p.m. for 3 hours. The 25- and 50-p.p.m. concentrations applied over a period of 3 and 1½ hours, respectively, approach the application rates normally recommended by the herbicide manufacturer for aquatic weed control in irrigation canals.

On the basis of the data given in figure 1, the 1.0-p.p.m. level was selected as the optimum for further testing. This herbicide concentration was then tested in a flowing water situation in the greenhouse at both 24- and 48-hour exposure periods. It was found that 24-hour contact periods did not differ greatly from 48-hour periods so that the 24-hour contact period was selected to conduct the age relationship and propagule production study.

Because of the volatile nature of acrolein it was decided that the long contact, low-concentration studies could best be conducted in a flowing water situation using a continuous addition of herbicide. A continuous application of a herbicidal solution would maintain a more reliable herbicidal concentration over long contact periods than would be obtained in a static water treatment. In standing water the herbicidal concentration would continually decline due to adsorptive losses on plants, culture pots, soil, and the walls of the test aquaria.

Herbicidal Response of Pondweeds Treated at Different Ages

To conduct long-term studies, potted cultures of the two previously mentioned pondweeds are grown, treated, rinsed, and held for observation under flowing water conditions in a test flume facility located in the greenhouse. Water is recirculated through the flume, shown in figure 2, at a rate of 195 gallons per minute from an outside ponded water source, figure 3. Water temperature was monitored throughout the study and ranged from 21° to 24° C.

Plant cultures were established by planting six vegetative propagules of uniform size and obtained from the same source in each soil-filled, 4-inch clay pot. Five pot replications for each species were used in all treatments. The plants were treated at age groups of 2, 4, and 6 weeks.

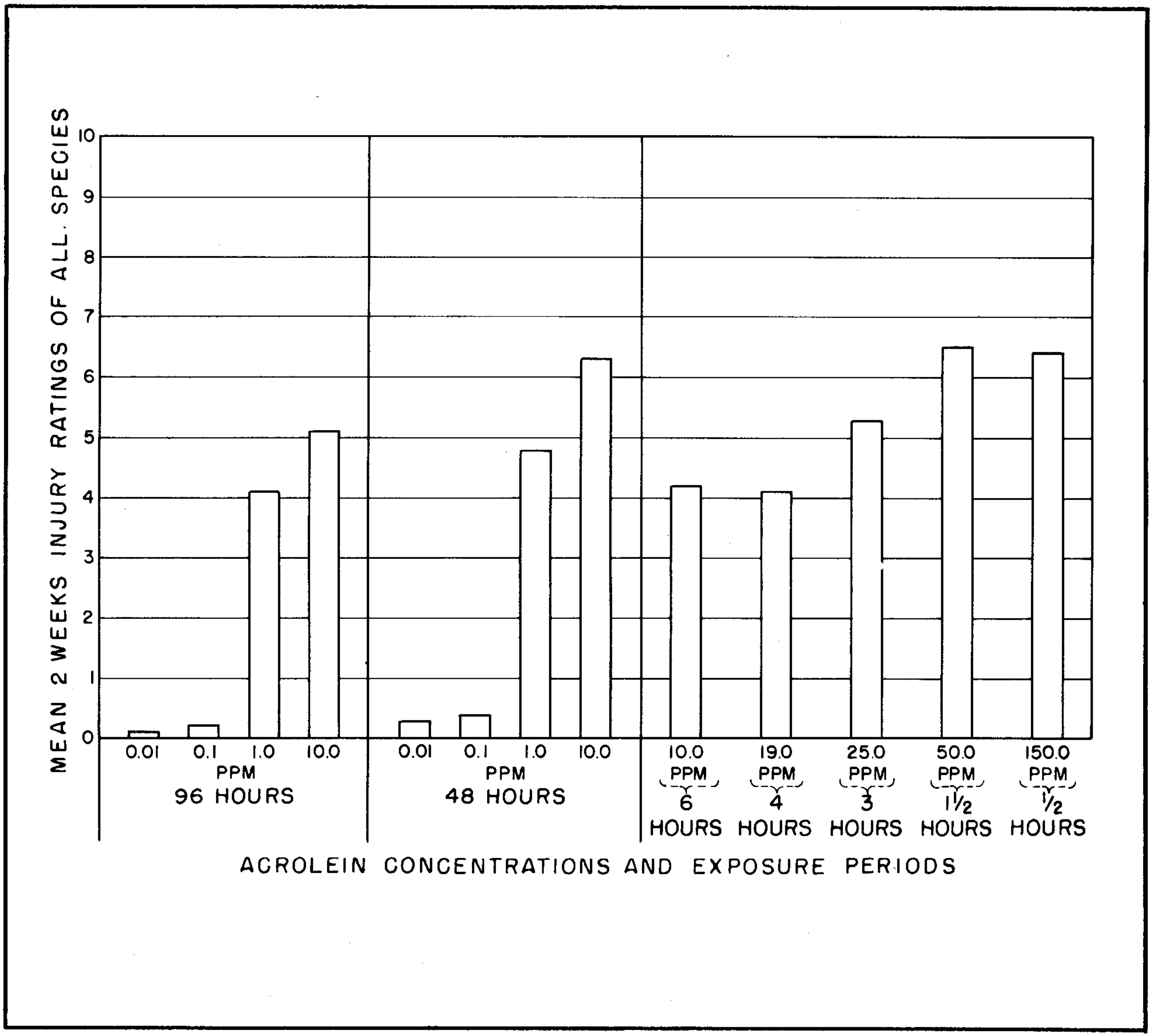


Figure 1.—Herbicidal Activity Produced by Various Rates of Acrolein and Contact Periods on Pondweeds in Static Water Greenhouse Tests.

Herbicidal treatment consisted of a continuous application of a water-diluted acrolein solution to provide an average concentration of 1.0 p.p.m. for a period of 24 hours. The herbicidal solution was applied by gravity feed through a plastic hose and hypodermic needle. Metering of the calculated drip rate was regulated with a pinch clamp. Treatments were made in one channel of the compartmented test flume that is constructed to allow wasting of the treated water from each of the three channels. Waterflow rate in the treatment channel was reduced during treatments to maintain a balance between wasted outflow and available inflows from the pond and tap water sources. Herbicide application rates were calibrated to these measured waterflow rates.

A 6-inch water depth in the channels of the flume was maintained by head and tail check gates, so that the plants were always covered. The treated plants were rinsed in the treatment channel for 2 hours following herbicide application. All rinse water was wasted.

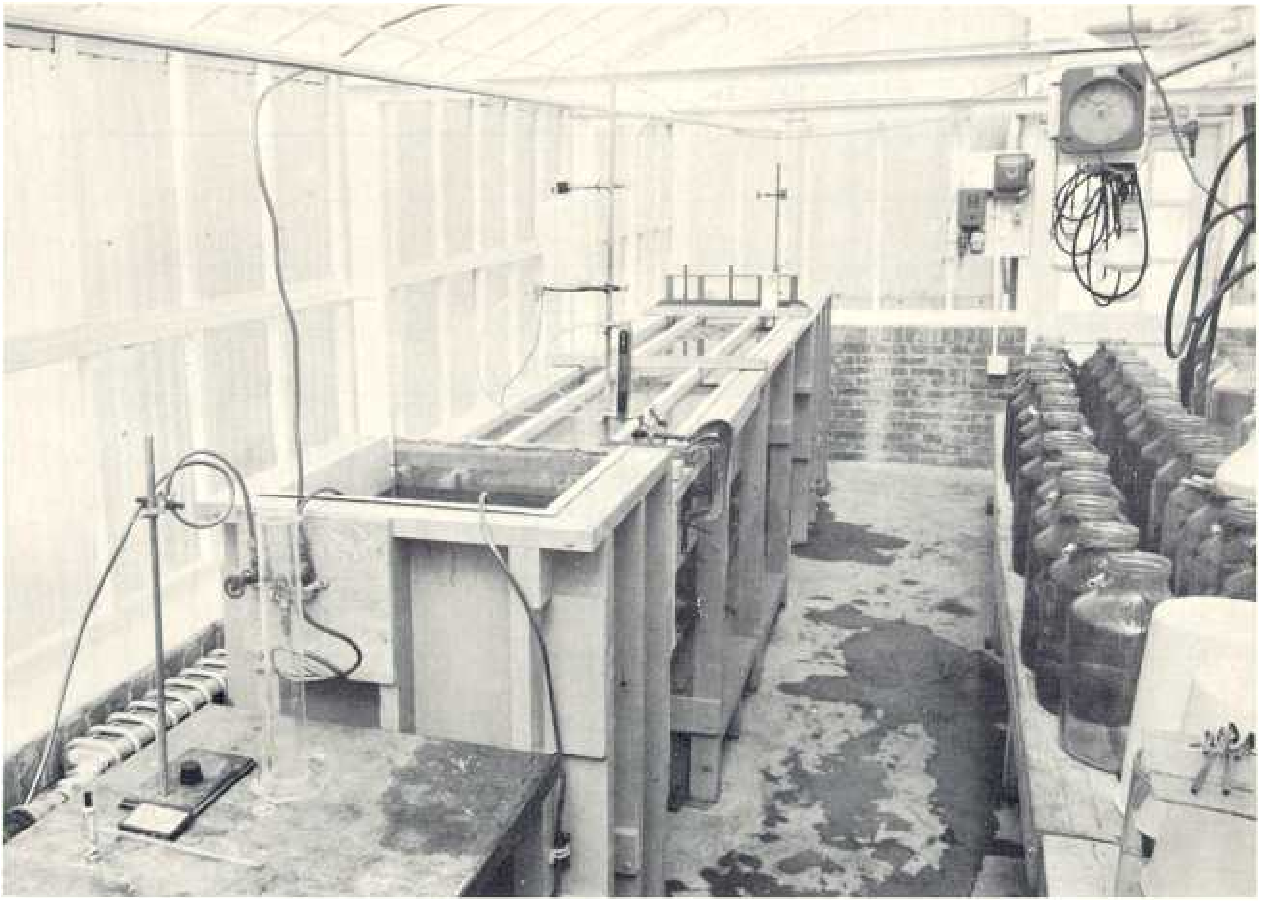


Figure 2.—Test Flume Facility Utilized to Recirculate Water From a Small Outdoor Pond for Detailed Study of Pondweeds in a Flowing Water Situation.

Plants were subjected to weekly observational injury ratings for 4 weeks, after which time fresh and dry weights were determined.

The 0 to 10 injury scale utilized in this study was essentially that used in routine herbicidal evaluation tests as described by Frank et al. (3) and in Report No. WC–13 (4). Plant regrowth was not considered in this cited rating system. The amount of senescence of untreated check plants was rated as injury and deducted from the injury rating of treated plants. During the course of the 4-week observation periods, estimates were made of plant regrowth and vigor. These regrowth rates were indexed by an arbitrary numerical system where, 0 = no regrowth and 10 = maximum growth attainable by check plants. Also, at the end of the 4-week rating period, determinations were made of numbers of tubers produced and their respective fresh and dry weights. Replicated pots of untreated plants were utilized for comparative purposes throughout the study. Morphological observations and growth measurements were made on untreated and treated plants. Resulting data were analyzed for statistical significance by analysis of variance and establishment of regression formula, as described by Snedecor (5).

Total Plant Fresh and Dry Weight Determinations

The mean fresh and dry weights of treated and untreated plants, harvested 4 weeks after treatment, are given in table 2 on a per pot basis. Plant weights shown represent the average of five-pot replications of each species that are classified according to plant age at time of treatment and represent all stem, rhizome, leaf, and root tissue, less vegetative propagules, which were handled separately. Dry weights are expressed as oven-dry weights. Plant

Figure 3.—Small Outdoor Pond Used as a Water Supply Reservoir for Recirculating Water Through the Test Flume.

Table 2

FRESH AND DRY WEIGHTS OF PONDWEEDS HARVESTED 4 WEEKS AFTER LOW-RATE ACROLEIN TREATMENT. MEAN WEIGHT OF ALL VEGETATIVE TISSUE PER POT, LESS PROPAGULES

Plant age at treatment (weeks)	Sago pondweed				American pondweed			
	Untreated		Treated		Untreated		Treated	
	Fresh weight (grams)	Dry weight (grams)	Fresh weight (grams)	Dry weight (grams)	Fresh weight (grams)	Dry weight (grams)	Fresh weight (grams)	Dry weight (grams)
2	7. 16	0. 553	3. 48	0. 251	8. 61	0. 674	1. 75	0. 106
4	7. 75	. 611	3. 37	. 232	9. 25	. 779	2. 80	. 163
6	9. 54	. 855	2. 86	. 198	10. 49	. 935	5. 14	. 425

ages at time of harvest would be 6, 8, and 10 weeks for the three ages of plants used.

Dry weight data were selected as being the most indicative of plant productivity and are graphically represented in figure 4, as well as the dry weight to fresh weight ratios. The dry weight to fresh weight ratios did not differ significantly between either species of untreated plants, showing only a slight increase with plant age. Only treated American pondweed exhibited some variability between the three treatment ages.

Results of these analyses indicate that a significant difference occurred (at the 5-percent level) between treated and untreated plants in both species of any age group. Untreated American pondweed produced 70.98 percent more dry weight tissue than did treated plants when averaged over the three age groups. Untreated sago pondweed plant dry weight averaged 66.27 percent greater than treated plants. Other differences that occurred between treatment age groups of both treated and untreated plants were less significant (<5 percent), although there

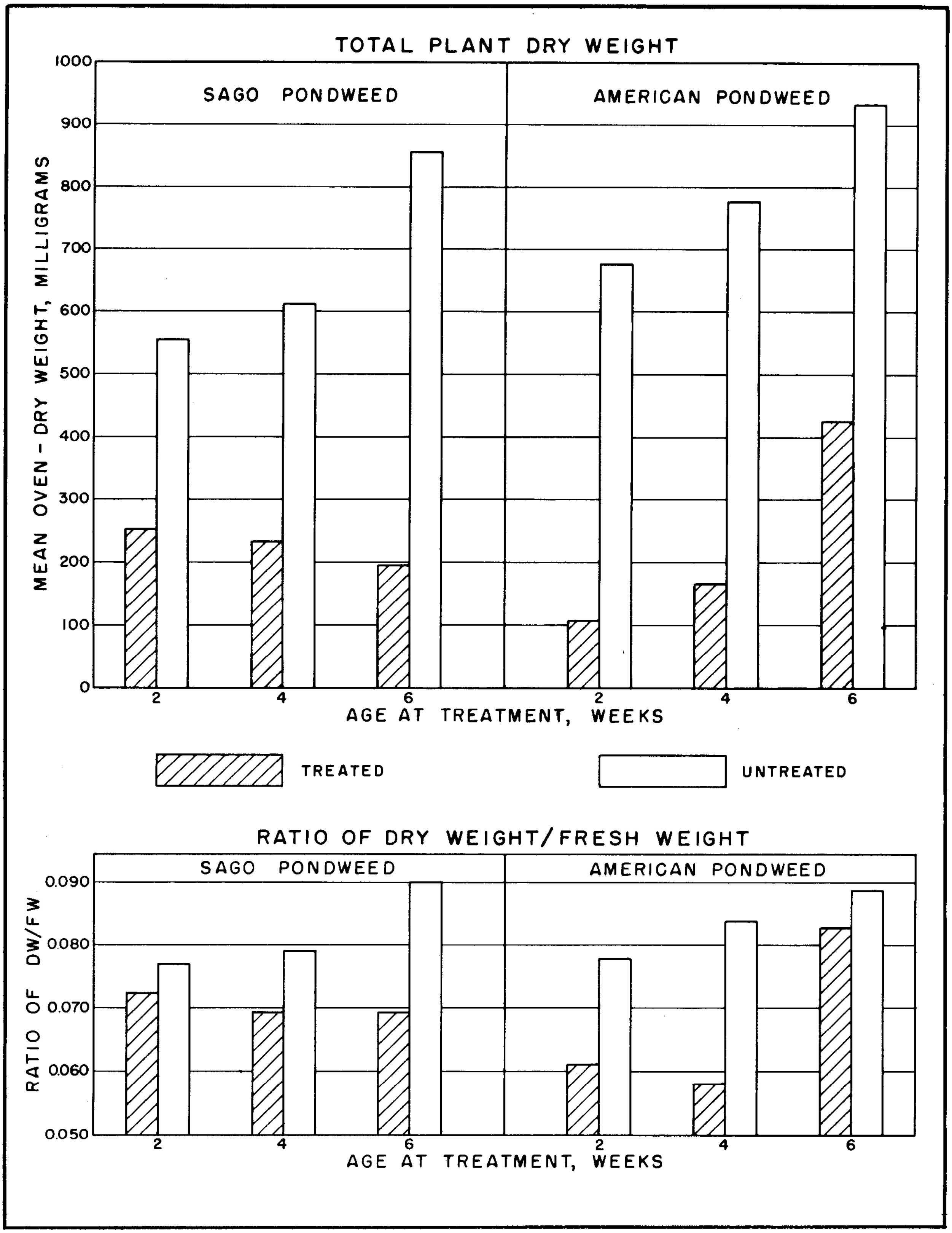


Figure 4.—Oven-dry Weights and Ratio of Dry Weight/Fresh Weight of Pondweeds Harvested 4 Weeks After Low-rate Acrolein Treatment. Values Are Means of 5-pot Replications per Treatment of All Vegetative Tissue, Less Propagules.

was some trend of increased plant weight with older plants in both untreated species and treated *P. nodosus*.

It is concluded from these data that the low-rate acrolein treatment significantly reduced the overall dry weight production of the pondweeds, but that plant age at time of treatment was not significant (<5 percent) in obtaining maximum herbicidal response. Variations between both species of treated and untreated dry weight to fresh weight ratios differed slightly, but were significant at less than the 5-percent level.

Effects of Treatments on Vegetative Propagule Production

Propagule production was another factor considered in this study to establish some criteria to evaluate and describe the herbicidal response of pondweeds to low-rate, long-contact treatments with acrolein. Results of the average propagule production determinations obtained on treated and untreated sago pondweed of the three age groups are given in figure 5. Propagule production data on American pondweed were not obtained because of a lack of winter bud development.

Sago pondweed propagule production data were subjected to analysis of variance tests to determine the significance of differences, between treated and untreated plants, between age groups, and replications. The resulting statistics indicate that the treatments significantly reduced the average number of tubers (5 percent) produced per pot in each age group, as compared to untreated plants. However, other differences between treatment age groups of treated and untreated plants were significant at less than the 5-percent level, with the exception of comparisons between 2-week and 6-week treated plants that showed (5 percent) significance. Likewise, average dry weight per tuber differed significantly between treated and untreated plants at all age levels. Comparisons with respect to age groups of both treated and untreated plants were less significant (<5 percent) with the exception of the 2- and 6-week plants, which differed (5 percent).

Tuber production data suggest that some advantages might be obtained by making applications of low-rate acrolein treatments to younger plants. This is especially evident in making comparisons between 2- and 6-week treatment ages, as shown in figure 5.

Observational Estimates of Plant Injury and Regrowth

Observational estimates of plant injury obtained over the 4-week period on plants 2, 4, and 6 weeks old at treatment are given in table 3 as means of five-pot replications, combining the two species.

Table 3

AVERAGE OBSERVATIONAL INJURY RATINGS OBTAINED OVER A 4-WEEK PERIOD FOLLOWING LOW-RATE ACROLEIN TREATMENT

Plant age at treatment (weeks)	Mean injury obtained on sago and American pondweeds over 4 weeks
2	4.90
4	6.45
6	3.90

These data suggest that maximum injury symptoms could be obtained by treating plants at the 4-week age level. Results of analysis of variance tests on these data show no significant differences between treatment ages (<5 percent, where $F=1.88$ and $F_{.05}=4.26$). However, these suggested trends are in agreement with the results of laboratory studies previously reported (6), indicating that younger plants are less susceptible to injury from aromatic solvents than older plants followed by a subsequent decline in activity of solvent as plant maturity is reached.

These statistics agree with the dry weight production data shown in figure 4, where plant age was not a significant factor (<5 percent) in obtaining maximum plant injury.

Observations on the response of pondweed (primarily sago pondweed) species to low rate acrolein treatments have been rather difficult to describe and to determine when retreatments might be required. Injury rating data from the greenhouse study reported herein were further utilized to attempt to describe the amount and pattern of injury accrued from the treatments and estimates made on the rate of plant regrowth. The weekly injury ratings obtained over 4 weeks for each species, combining the 2-, 4-, and 6-week age groups and regression formulae, were calculated to show the trend of injury symptoms. Also, the weekly regrowth estimate data were likewise combined and regression

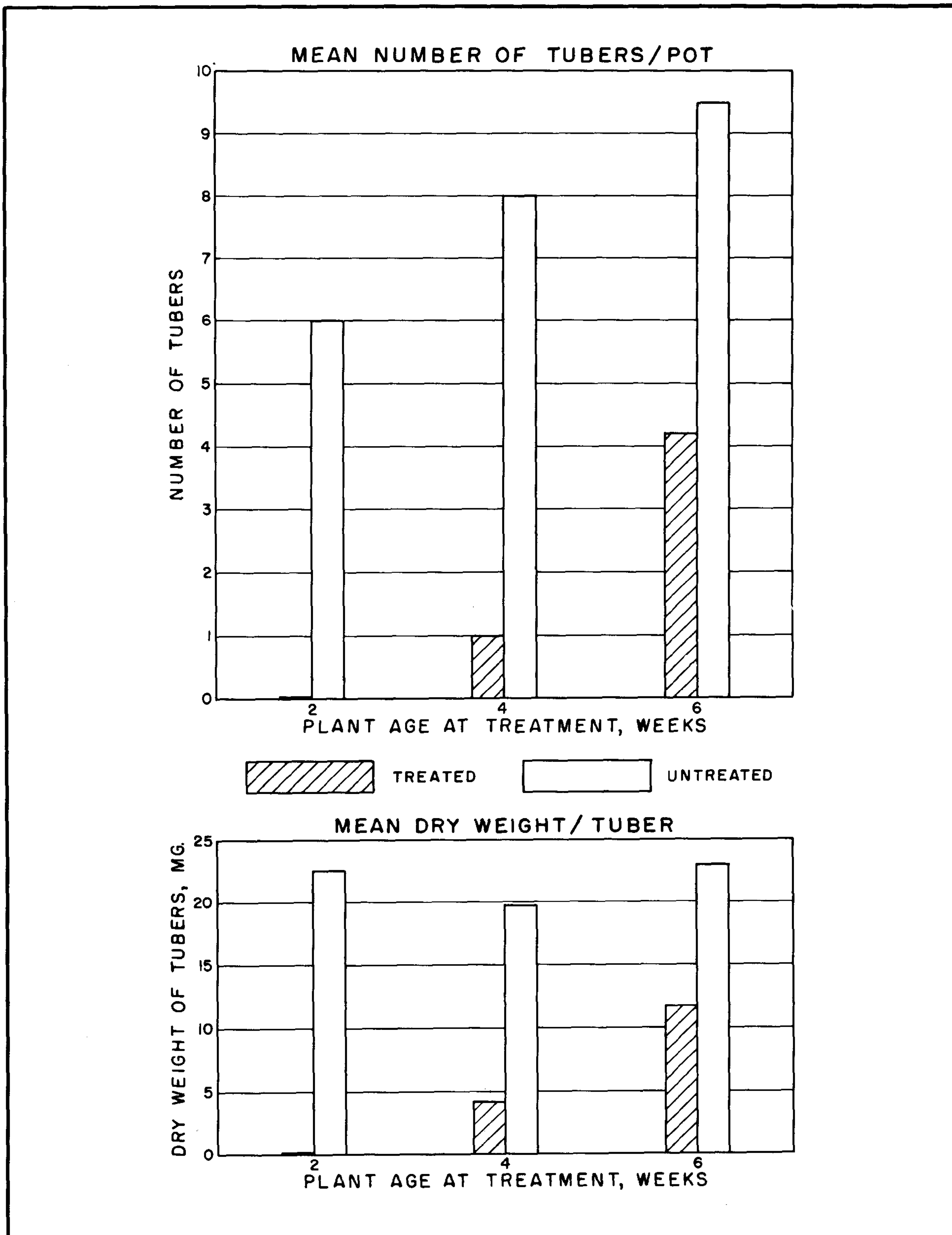


Figure 5.—Vegetative Propagule Production of Treated and Untreated Sago Pondweed, Harvested 4 Weeks After Low-rate Acrolein Treatment. Values Are Means of 5-pot Replications per Treatment.

lines established to give some concept of plant recovery during the 4 weeks of observation.

The regression formulae calculated for weekly injury ratings and regrowth estimates are given as follows:

Observational injury ratings

Sago pondweed, $Y=-0.053X+4.33$

American pondweed, $Y=0.953X+1.85$

Regrowth estimate ratings

Sago pondweed, $Y=-42.45X+197.45$ (calculated as $\frac{1}{Y}\times 100$ to fit a smooth curve to the data)

American pondweed, $Y=-31.21X+153.28$ (calculated as $\frac{1}{Y}\times 100$ to fit a smooth curve to the data).

All regressions were tested for deviation from linearity and found to be linear at the 5-percent level. However, the regrowth regressions were calculated to fit a smooth curvilinear regression to illustrate the period of greatest regrowth, although they did not greatly differ from linear.

The regression statistics of injury and regrowth ratings and individual mean weekly ratings of the 5-pot replications per 2-, 4-, and 6-week-age groups for each species are graphically represented in figure 6.

Weekly injury on sago pondweed exhibited an almost horizontal regression, with a slightly negative slope. Results of this study suggest that maximum injury symptoms from low-rate acrolein treatments can be observed within the first week following treatment with little significant change in the appearance of the parent plant tissue as time progresses. This laboratory observation seems to agree with gross observations reported by field personnel. If this plant response to the treatment is characteristic it indicates a desirable guideline for weed treatment in irrigation canals, suggesting a rapid absorption of the toxicant with a fairly rapid death of tissue. However, this lack of change of overall appearance of the originally treated plant tissue in 2 to 4 weeks following treatment would limit the usefulness of this factor as a guide for need of retreatment.

American pondweed responded somewhat differently to the treatments than did sago pondweed, notably evidenced by increased injury symptom with time. This positive slope of the regression suggests a reduced susceptibility of the species to the treatment or possibly only a slower rate of response. This characteristic is not unlike that observed in the laboratory when this species is treated with other contact herbicides such as aromatic solvents. Field evaluation of this species with low-rate, long-contact treatments of acrolein have not been made to the knowledge of the authors. Some caution would have to be exercised in establishing an early overall rating or evaluation of low-rate acrolein treatments on American pondweed. Like sago pondweed, a gross observational effect of injury on originally treated tissue of American pondweed as an index of retreatment need would be of limited value, although an almost opposite characterization exists.

The weekly regrowth estimate provides some index to timing of retreatments with the low-rate applications. Both species demonstrated a somewhat similar curve of stem and leaf regeneration. This regrowth pattern indicates a gradual recovery up to 3 weeks after treatment. The regrowth curve begins to steepen rapidly between the third and fourth weeks. Interpreting these data from the standpoint of growth suppression, retreatments should be considered at this 3- to 4-week period to maintain the plants to a size not greatly restrictive to the flow of water in a conveyance channel.

Measurements and Observations of Gross Plant Morphology

The results of observations and measurements to describe some of the gross morphology of the pondweeds used in this study are given in table 4.

Growth measurement data were not subjected to statistical analyses because of the small amount of sampling and rather wide range of variability of the observations. The data, although not conclusive, do indicate the trends of growth characteristics of the plants to the low-rate acrolein treatments. The treated plants of both species and all age groups exhibited a general decline in terminal length and numbers of leaves and branches as compared to untreated check plants at the end of the 4-week observation period. The 4-week age group plants appeared to be more reduced in stature compared to the 2- and 6-week age plants. This apparent maximum growth-suppressive effect at the midage group might be analogous to the maximum mean injury

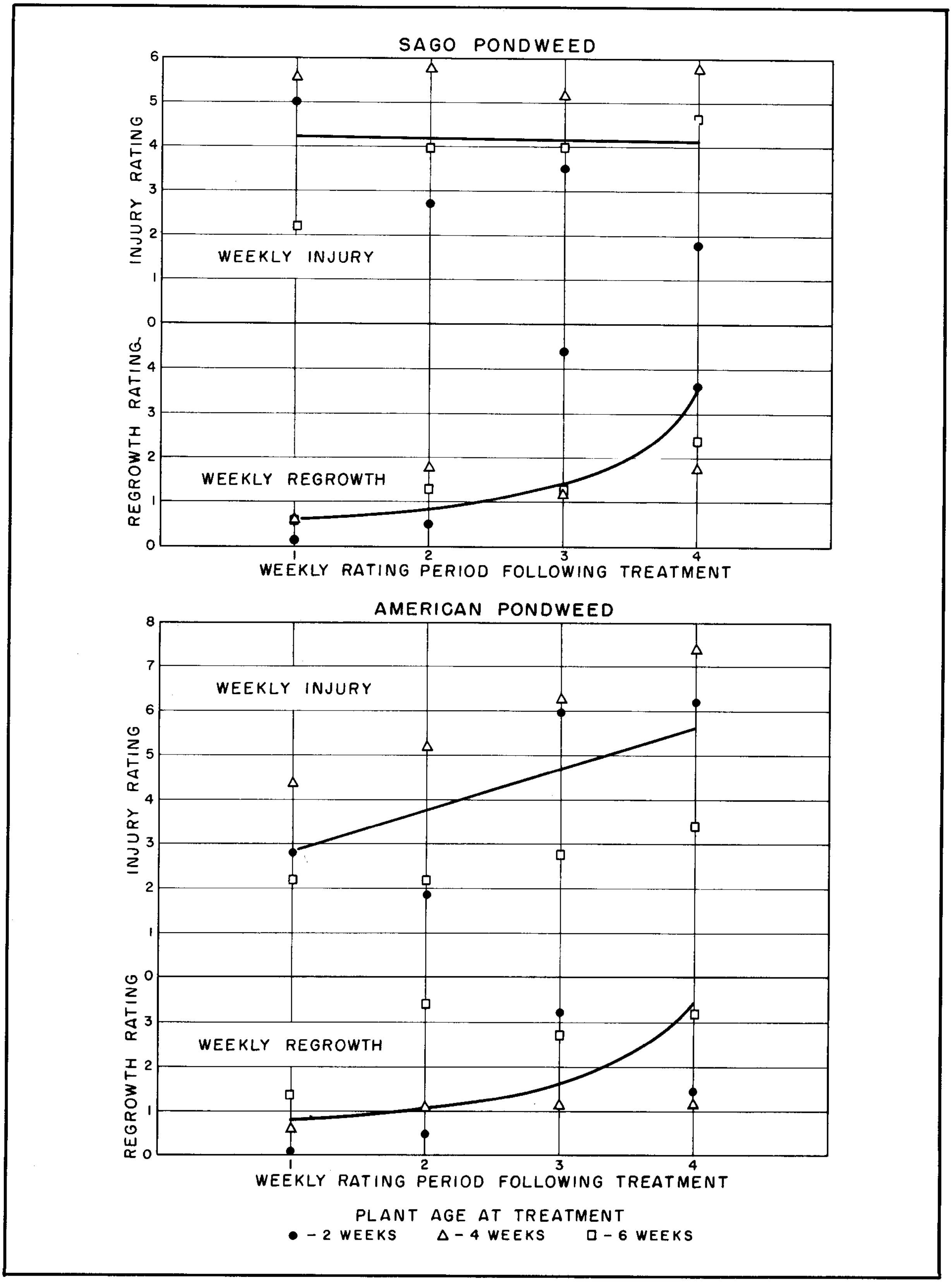


Figure 6.—Mean Weekly Injury and Regrowth Estimates, With Respective Regressions, of Pondweeds Treated with Low-rate Applications of Acrolein.

Table 4

GROSS MORPHOLOGICAL OBSERVATIONS OF TWO PONDWEED SPECIES UNTREATED AND TREATED WITH LOW RATES OF ACROLEIN. AVERAGE MEASUREMENT OF THREE POTS PER SPECIES

Age of plant at observation (weeks)	Pondweed species and treatment	Mean growth measurements and observations		
		Terminal length (inches)	Number of branches or leaves	Flower and/or fruit development
2	Sago, untreated	12.99 (33.0 cm)	Branches, 6.0	None.
2	American, untreated	9.45 (24.0 cm)	Submersed leaves, 5.0 Floating leaves, 0.0	Do.
4	Sago, untreated	15.94 (40.5 cm)	Branches, 7.5	Do.
4	American, untreated	20.67 (52.5 cm)	Submersed leaves, 4.5 Floating leaves, 4.0	Initial flower budding.
6	Sago, untreated	16.65 (42.3 cm)	Branches, 11.3	None.
6	American, untreated	20.98 (53.3 cm)	Submersed leaves, 5.0 Floating leaves, 4.0	Flowering.
6	Sago, acrolein treatment	10.35 (26.3 cm)	Branches, 6.3	None.
6	American, acrolein treatment.	5.91 (15.0 cm)	Submersed leaves, 4.6 Floating, 0.5	Do.
8	Sago, acrolein treatment	7.87 (20.0 cm)	Branches, 4.6	Do.
8	American, acrolein treatment.	9.45 (24.0 cm)	Submersed leaves, 1.7 Floating leaves, 1.0	Do.
10	Sago, acrolein treatment	7.87 (20.0 cm)	Branches, 5.3	Do.
10	American, acrolein treatment.	19.53 (49.6 cm)	Submersed leaves, 4.3 Floating leaves, 1.3	Do.
6	Sago, untreated	14.57 (37.0 cm)	Branches, 11.0	Do.
6	American, untreated	17.17 (43.6 cm)	Submersed leaves, 5.3 Floating leaves, 4.3	Flowering.
8	Sago, untreated	12.99 (33.0 cm)	Branches, 13.3	None.
8	American, untreated	18.23 (46.3 cm)	Submersed leaves, 4.3 Floating leaves, 5.0	Flowering.
10	Sago, untreated	14.69 (37.3 cm)	Branches, 12.6	None.
10	American, untreated	17.95 (45.6 cm)	Submersed leaves, 6.3 Floating leaves, 2.3	Fruiting.

rating attained with 4-week plants shown in table 3, although the significance of an age relationship is questionable as related in the dry weight data. Also, growth measurement data on treated plants 4 weeks after treatment indicate that, as a whole, the pondweeds were somewhat smaller than at the time of treatment within any age group. This would indicate that the treatments caused sufficient injury to both species and within all age groups with an occasional exception, to create an overall reduction in plant size or more accurately a reduced volume density of plant material that would restrict waterflow in a conveyance channel. This same effect was shown by the previously described plant dry weight data.

Growth characteristics of the untreated check plants obtained at 6, 8, and 10 weeks, as compared with original growth measurements made at 2, 4, and 6 weeks, showed a decline in mean terminal length in the 4- and 6-week age groups, with a slight increase in the 2-week age group of plants. All age groups and species did, however, exhibit an increase of leaf and branch development as the plants aged. The reduction in mean terminal length with older plants can only be attributed to sampling error, as the same plant may not have been sampled each time. It is also possible that some original stems and leaf tissue may have been lost due to senescence or mechanical damage.

Although the data obtained from this study cannot be considered conclusive because the results are based on a relatively small amount of sampling and replication, the effectiveness of low-rate, long-contact acrolein treatments shows significant trends to indicate some growth-suppressive effects. These results are in general agreement with results reported from numerous field tests on the Columbia Basin project.

The results of these laboratory studies with supporting observations reported from field studies indicate the promising potential of low-rate, long-contact period treatments in reducing submersed aquatic weed growth in irrigation canals to an extent not considered critical to water conveyance. Continuing laboratory and field studies evaluating the response of submersed aquatic weeds to low-rate, long-contact period applications are planned. These studies will include other types of contact herbicides and the influence of retreatments on the weed infestations.

Evaluation of Selected Herbicidal Compounds on Rooted Submersed Aquatic Weeds

A limited number of chemical compounds have been evaluated for activity on submersed aquatic weeds during the past year. These materials were either submitted to the Bureau laboratories by manufacturers for evaluation of their algaecidal and/or herbicidal potential or may be materials that are suggested for specific herbicidal tests from other areas of research being conducted in the laboratory or the field.

These materials are subjected to herbicidal activity tests by treating greenhouse grown cultures of sago pondweed, American pondweed, and waterweed, *Elodea canadensis* Michx. Details of culture and evaluation procedures are those described by Frank et al. (3). Generally, the potted cultures of the previously indicated aquatic weeds are exposed to the candidate compounds in 20-liter aquaria maintained in greenhouses. The test sequence usually follows the pattern of a preliminary continuous contact test, followed by tests with reduced exposure time, and may be finally tested in a flowing water situation. Test methods, although basically similar, are modified to fit the specific type of material. Likewise, the concentration of the material under test may be varied as knowledge of the material may suggest.

The herbicidal injury rating system used is that described by Frank et al. (3) with modifications that are described in the section of this report on evaluations of aromatic solvent-type herbicides. Results of the herbicidal activity tests of each compound are tabulated as follows:

Laboratory No.: 888

COMPOUND: N-COCO 1, 3 PROPYLENE DIAMINE DIACETATE SALT
FORMULATION: 50 PERCENT A.I. IN WATER AND ISOPROPANOL

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	3	7	6	5	6	9	10	10	5.3	8.8
P. nodosus	2	7	5	5	5	8	10	10	4.8	8.3
E. canadensis	4	8	6	5	6	10	10	10	5.8	9

Laboratory No.: 889

COMPOUND: N-COCO PRIMARY AMINE ACETATE SALT
FORMULATION: 50 PERCENT A.I. IN WATER AND ISOPROPANOL

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	4	9	7	6	7	10	10	10	6.5	9.3
P. nodosus	3	8	4	3	6	9	10	10	4.5	8.8
E. canadensis	3	6	5	4	6	7	10	10	4.5	8.3

Laboratory No.: 890

COMPOUND: DIMETHYL HYDROGENATED—TALLOW FURFURYL AMMONIUM CHLORIDE
FORMULATION: 40 PERCENT SOLUBLE IN TAPWATER
20 PERCENT SOLUBLE IN SEA WATER

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	2	6	5	5	3	7	8.5	10	4.5	7.1
P. nodosus	1	3	4	3	2	7	9	10	2.8	7
E. canadensis	1	4	4	3	4	9	10	10	3	8.3

Laboratory No.: 892

COMPOUND: DICOCO DIMETHYL QUATERNARY AMMONIUM CHLORIDE
FORMULATION: 75 PERCENT A.I. IN AQUEOUS ISOPROPANOL

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	4	5	6	--------	10	10	10	--------	5	10
P. nodosus	3	4	5	--------	10	10	10	--------	4	10
E. canadensis	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Laboratory No.: 893

COMPOUND: TALLOW DIAMINE
FORMULATION:

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	4	5	4	--------	10	10	10	--------	4. 3	10
P. nodosus	3	4	4	--------	10	10	10	--------	3. 7	10
E. canadensis	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Laboratory No.: 899

COMPOUND: WATER SOLUBLE ACID EXTRACT (BYPRODUCT OF FATTY ACID DISTILLATIONS)
FORMULATION: MAKEUP UNKNOWN

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	0	0	0	0	2	8	9	10	0	7. 3
P. nodosus	0	0	0	0	2	6	5	10	0	5. 8
E. canadensis	0	0	0	0	1	7	10	10	0	7

Laboratory No.: 900

COMPOUND: NBC OIL (BYPRODUCT OF FATTY ACID DISTILLATIONS)
FORMULATION: MAKEUP UNKNOWN

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	0. 5	0	0	0	2	3	6	10	0. 1	5. 3
P. nodosus	1	0	0	0. 5	1	3	5	8	0. 4	4. 3
E. canadensis	1	1	2	1	1	1	10	10	1. 3	5. 5

788-773 O-66—4

Laboratory No.: 901

COMPOUND: NITROGEN DISTILLATE (BYPRODUCT OF FATTY ACID DISTILLATIONS)

Weekly injury scale ratings of compounds evaluated for herbicidal activity on aquatic weeds, standing water—Continuous contact test—Conducted in greenhouse

Potted cultures of rooted aquatic weed species	Injury ratings 1, 2, 3, and 4 weeks following treatment								Average rating	
	Herbicide conc., 5 p.p.m.				Herbicide conc., 100 p.p.m.				5 p.p.m.	100 p.p.m.
	1	2	3	4	1	2	3	4		
P. pectinatus	0.5	0.5	0	0	2	2	6	6	0.3	4
P. nodosus	0.5	0.5	0	0	2	3	5	6	0.3	4
E. canadensis	0	0	0	0	2	2	6	5	0	3.8

Results of these few greenhouse evaluations of experimental compounds did not reveal any compound of exceptional promise. Samples No. 892, 893, 888, 889 exhibited good activity at the 100-p.p.m. level, but much less at the 5-p.p.m. concentration. None of the materials produced sufficient overall herbicidal activity (combining the activity ratings of both concentrations) in the static water tests to warrant additional evaluation in limited contact period tests.

Results of Algaecidal Evaluation Tests of Selected Compounds

Attached filamentous green algae present serious operational problems to water distribution systems by seriously reducing the capacity of concrete-lined canals and other irrigation structures. Colonies of filamentous algae also create problems in unlined irrigation canals by breaking loose from the attaching medium and clogging siphon tubes, fouling trashracks and pump inlets, and increasing waterflow resistance by being caught on rooted submersed weeds. Because of the extensiveness of the algae problems on Bureau projects, a laboratory algaecidal evaluation program was initiated during 1963 as part of the overall weed control research program.

The presently used procedures for culturing and evaluating the potential activity of a candidate algaecide are reported in detail in Report No. WC–13 (4) and essentially consist of treating a small mass of algae filaments in a standing water test. This mass of filaments is estimated by volume to equal 0.5 to 1.0 gram fresh weight. In routine algaecidal evaluation, algae sample sizes are estimated.

Algae cultures used in evaluation tests are laboratory grown in an inorganic nutrient solution under temperature regimes of 60° to 70° F. and 150 to 200 ft.-c. of cool-white fluorescent illumination. Algae cultures are usually mixed species of *Oedogonium* or *Rhizoclonium* growing in association with occasional unicellular green specimens and filamentous blue-green algae. *Cladophora* spp. have also been successfully cultured under these conditions and are being utilized in evaluation tests.

Aqueous solutions of the algaecidal compounds are made up in concentrations of 10, 5, 1, 0.5, 0.25, 0.1, and 0.05 p.p.m. of active ingredients in initial tests. Subsequent tests often include the same range of treatment concentrations, but with reduced number of individual test concentrations. Copper sulfate solutions are used in each test as a comparative standard.

Algal filaments taken from the culture medium are exposed to the algaecidal concentrations for a period of 60 minutes, then removed and rinsed in running tapwater for three cycles of container filling and drainage. The treated algae specimens are then held in tapwater-filled quart jars for observation and injury rating. Treatment solution, rinse water, and holding water temperatures are all held to a range of 70° to 75° F. During periods in the summer months when tapwater chlorination is high, it was found necessary to limit the direct use of running tapwater. Rinse water during these periods is dechlorinated by agitation and followed by a period of standing in an open container for 2 to 4 hours.

A number of compounds were tested for algaecidal activity on *Oedogonium* and *Rhizoclonium* spp. in 1964. The results of these tests are listed in table 5. Observational estimates of injury are based on the 0 to 10 scale, described as follows: 0=no injury; 1, 2, 3=slight injury, as evidenced by some bleaching; 4, 5, 6=moderate injury, some cell division; 7, 8, 9=severe injury; 10=complete kill of initial culture.

The mean activity ratings given in table 5 were obtained by determining the average injury rating obtained at all chemical concentrations over the 2-week observation period. This average activity rating provides some index for comparing chemicals.

A few of the more promising compounds were ranked according to highest mean activity ratings and are listed accordingly in table 6. Statistical analysis for significance in ranking would not be justified because these are preliminary tests and the data are useful mainly in eliminating compounds that show limited activity.

Two compounds (Nos. 915 and 894) exhibited activity equal to or better than copper sulfate. Test results of these two compounds show sufficient activity to warrant further tests, including field evaluation. Both materials are commercially available as experimental aquatic herbicides and are water soluble formulations, which simplifies application. A limited amount of field test data on the algaecidal properties of these materials have been reported by the manufacturer. Copper sulfate, used extensively as an algaecide, is reported here for comparative purposes.

Table 5

RESULTS OF PRELIMINARY EVALUATION OF SELECTED COMPOUNDS FOR ALGAECIDAL ACTIVITY ON MIXED CULTURES OF THE FILAMENTOUS GREEN ALGAE *RHIZOCLONIUM* SPP. AND *OEDOGONIUM* SPP.

Laboratory No.	Algaecidal compound	Weekly injury ratings obtained at a given concentration of chemical in p.p.m. of active ingredient												Mean activity rating [1]
		1 week						2 weeks						
		5.0	1.0	0.5	0.25	0.1	0.05	5.0	1.0	0.5	0.25	0.1	0.05	
	Copper sulfate, concentrated as copper [2]	10	7	4.6	2.6	1.2	0.8	10	7.8	6.2	3.8	1.8	1.2	4.4
	2-chloro-4,6-bis(ethylamino)-s-triazine	7	4	2	2	1	1	7	4	2	2	1	1	2.8
909	75 percent 3,4 dichloro benzyl methylcarbamate	----	----	----	----	----	----	----	----	----	----	----	----	----
	25 per cent 2,3 isomer of above	5	4	3	2	1	1	4	4	2	2	1	1	2.5
887	5 bromo-3-sec-butyl-6-methyl-uracil	2	.5	.5	0	0	0	2	1	1	0	0	0	.6
893	Diamine (tallow)	7	4	.5	1	0	0	7	4	1	1	0	0	2.1
903	1,2,3,4,9,9-hexachloro-1,4-methano-1,4,4a,8a-tetra-hydro-5,8-naphthaquinone	1	0	0	0	0	0	1	.5	0	0	0	0	.2
904	5,8-dihydroxy-1,2,3,4,9,9-hex-achloro-1,4-methano-1,4-dihydro-naphthalene	1	0	0	0	0	0	1	0	0	0	0	0	.2
899	Water soluble acid extract (chemical unknown)	5	3	1	1	0	0	5	4	3	2	1	1	2.2
900	NBC oil (chemical unknown)	6	3	3	2	1	0	6	3	3	2	1	1	2.7
901	Nitrogen distillate (chemical unknown)	0	0	0	0	0	0	1	0	0	0	0	0	.1
888	N-coco 1,3 propylene diamine diacetate	10	3	0	0	0	0	10	4	2	2	0	0	2.6
889	N-coco primary amine acetate	9	5	1	1	0	0	9	7	3	1	0	0	3.0
890	Dimethyl hydrogenated-tallow furfuryl ammonium chloride	7	1	0	0	0	0	7	5	2	1	0	0	1.9
894	Mono (N,N dimethylalky-amine) salt of 3,6-endoxo-hexahydrophthalic acid	9	5	3	5	1	1	10	7	5	5	2	1	4.5
895	Copper nitrate, concentrated as copper	9	7	5	2	0	0	10	8	5	3	2	0	4.3
896	Copper chloride, concentrated as copper	9	5	3	2	0	0	9	6	3	2	0	0	3.3
897	Copper sulfate solution, concentrated as copper	9	5	3	2	1	0	9	5	3	2	2	1	3.5
891	Dimethyl sulfoxide	0	0	0	0	0	0	0	0	0	0	0	0	0
891	Dimethyl sulfoxide as a 10 percent additive to copper sulfate	8	5	2	1	0	0	10	7	5	1	0	0	3.3
915	Di (N,N dimethylcocoamine) salt of 3,6-endoxo-hexa-hydrophthalic acid	10	9	8	5	2	1	10	9	8	5	2	1	5.8
881	1-(3-chloroallyl)-3,5,7-triaza-1-azoniaadamantane chloride	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] Mean activity rating for a given compound is the average of combined injury rating at all concentrations over the 2-week observation period.

[2] Injury for copper sulfate is means of five separate evaluation tests.

Table 6

COMPARISON OF COMPOUNDS EXHIBITING HIGHEST ALGAECIDAL ACTIVITY ON THE FILAMENTOUS GREEN ALGAE *RHIZOCLONIUM* AND *OEDOGONIUM*

Laboratory No.	Algaecidal compound	Mean activity rating number
915	Di(N,N-dimethylcocoamine) salt of 3,6-endoxo-hexahydrophthalic acid.	5. 8
894	Mono (N,N-dimethylalkylamine) salt of 3,6-endoxo-hexahydrophthalic acid.	4. 5
	Copper sulfate, concentrated as copper.	4. 4

Exploratory tests were conducted to study the potential of utilizing *Cladophora* in our algaecidal evaluation program as a secondary test organism. These algae are known to produce dense infestation in canals on a number of projects. Algae in this genus have been reported to show some tolerance to normal copper sulfate treatments and can often be controlled only by significant increases in copper concentrations. A few compounds that have shown good algaecidal activity on *Oedogonium* and *Rhizoclonium* were evaluated for their activity on *Cladophora*. The results of some of these tests are given in table 7. The range of toxicant concentration was broadened in some of the tests because of resulting low activity in preliminary tests.

Table 7

RESULTS OF PRELIMINARY EVALUATION OF SELECTED COMPOUNDS FOR ALGAECIDAL ACTIVITY ON THE FILAMENTOUS GREEN ALGAE *CLADOPHORA* SPP.

Laboratory No.	Algaecidal compound	Weekly injury ratings obtained at a given concentration of chemical in p.p.m. of active ingredient												Mean activity rating [1]
		1 week						2 weeks						
		5.0	1.0	0.5	0.25	0.1	0.05	5.0	1.0	0.5	0.25	0.1	0.05	
	Copper sulfate, concentrated as copper [2]	6. 5	2. 5	1. 5	0. 8	0. 5	0	9. 5	3. 5	2	0. 8	0. 5	0	2. 3
894	Mono (N,N dimethylalkylamine) salt of 3,6-endoxohexahydrophthalic acid	7	4	1	0	0	0	8	4	1	0	0	0	2. 1
816	Acrolein (acrylaldehyde) container not sealed during treatment	2	0. 5	0	0	0	0	2	1	0	0	0	0	. 4
816	Acrolein (acrylaldehyde) container sealed during treatment	10	9	5	2	1	0	10	10	5	2	1	0	5. 5
915	Di (N,N dimethylcocoamine) salt of 3,6 endoxo-hexahydrophthalic acid	10	9	7	4	2	1	10	10	9	5	3	2	6. 0
		10 p.p.m.	5 p.p.m.	0. 1 p.p.m.	-----	-----	-----	10 p.p.m.	5 p.p.m.	0. 1 p.p.m.	-----	-----	-----	------
757	1:1′-ethylene-2:2′-dipyridylium dibromide cation	10	10	3	-----	-----	-----	10	10	9	-----	-----	-----	8. 7
751	Tributyltin chloride with solubilizer	10	10	0	-----	-----	-----	10	10	0	-----	-----	-----	6. 7
753	Bis (tri-n-butyltin) oxide with solubilizer	10	10	0	-----	-----	-----	10	10	0	-----	-----	-----	6. 7
701	Silver methanearsonate	10	10	0	-----	-----	-----	10	10	0	-----	-----	-----	6. 7

[1] Mean activity rating for a given compound is the average of combined injury ratings at all concentrations over the 2-week observation period.

[2] Injury for copper sulfate is means of two separate evaluation tests.

Algaecidal compounds No. 816 and 915 showed good activity on *Cladophora* as compared to copper sulfate, which was much less toxic to this algae than to *Oedogonium*. The low activity demonstrated when testing acrolein in open containers could be attributed to loss of toxicant by volatilization. Acrolein appeared to be only slightly less toxic to *Cladophora* than to *Oedogonium* or *Rhizoclonium*, as previously reported (2).

Regional personnel at Boise, Idaho, requested testing the algaecidal activity of acrolein on *Cladophora*. They are considering the possibility of conducting experimental field tests with this material on an algae infestation that has never responsed to copper sulfate treatments. These few laboratory tests indicate that field testing of acrolein for controlling algae infestations of *Cladophora* would be justified.

Compounds No. 757, 751, 753, and 701 all showed good activity at the 10-p.p.m. and 5-p.p.m. level. These compounds have exhibited high activity on filamentous algae in past years' tests and were included this year to test their activity on *Cladophora*. These materials are considered as potential toxicants for use in antifouling coatings on concrete canal linings. Compound No. 757 appears to have some developmental potential for application to the total water volume of a canal for algae control.

Evaluation of Aromatic Solvents for Use by Bureau of Reclamation Projects and Cooperating Irrigation Districts

Samples of xylene and aromatic solvents were received for testing for suitability as aquatic herbicides pursuant to requests from regional and project offices. These samples were analyzed for conformance to physical and chemical requirements and tested for herbicidal activity on three species of submersed aquatic weeds. These tests were performed for the purpose of obtaining data useful to regional and project offices in selecting suitable aquatic herbicides, and provide information useful for further development and improvement of specifications and requirements for this type of aquatic herbicide.

Samples were tested for conformance to physical and chemical requirements listed in the tentative specifications included in Chemical Engineering Laboratory Report No. SI–17 (9). The results of the test for aromaticity of samples are tabulated in table 8.

All samples tested had an aromatic content greater than the minimum requirement of 85 percent.

Table 8

ANALYSES OF AROMATIC SOLVENTS AND XYLENE SAMPLES FOR HYDROCARBON TYPES BY ASTM DESIGNATION: 1319

Laboratory sample No.	Hydrocarbon type (percent by volume)		
	Saturates	Olefins	Aromatics
871	0.9	0	99.1
872	.3	0	99.7
873	1.1	0	98.9
874	4.6	0	95.4
875	3.6	0	96.4
876	.8	0	99.2
882	1.6	0	98.4
883	1.9	0	98.1

Distillation range tests of aromatic solvents for conformance to physical requirements for the samples are included in table 9.

Table 9

RESULTS OF DISTILLATION RANGE TESTS OF AROMATIC SOLVENTS FOR CONFORMANCE TO PHYSICAL REQUIREMENTS

Specified requirements	Flash point ° F.	Distillation range ASTM D86–54 ° F. at 760 mm. hg. pressure				End point	Percent water
		Initial boiling point	Temperature at which percent distillate by volume was recovered				
			10 percent	50 percent	90 percent		
Laboratory sample No.	Minimum	240° minimum	Greater than 265°	Less than 320°	Less than 380°	420° maximum	0.2 maximum
874	81	270	277	279	285	311	None.
882	81	271	273	273	275	280	Do.

Table 10

RESULTS OF DISTILLATION RANGE TESTS OF XYLENE SAMPLES FOR CONFORMANCE TO PHYSICAL REQUIREMENTS

Specified requirements	Flash point °F.	Distillation range ASTM D56-54, degrees F. at 760 mm. hg. pressure				Percent water	Specific gravity at 60°/70° F.
		Initial boiling point	Temperature at which percent distillate by volume was recovered		End point		
			5 percent	90 percent			
Laboratory sample No.	75° minimum	253° minimum	Greater than 266°	Less than 293°	311° maximum	0.2 maximum	0.850 minimum 0.870 maximum
871	80	268	274	279	281	None	.868
872	83	270	274	281	283	do	.869
873	83	272	274	279	281	do	.868
875	78	268	272	283	295	do	.868
876	77	268	272	277	280	do	.869
883	81	266	273	280	291	do	.860

The results of distillation range tests of xylene samples for conformance to specified requirements are listed in table 10.

Each sample of solvent was subjected to a herbicidal activity test by treating potted cultures of sago pondweed, American pondweed, and waterweed in a flowing water situation. Details of this greenhouse culture and herbicidal evaluation technique are similar to that described by Frank et al. (3).

The flowing water test is conducted in a small flume where treatment water is recirculated at a volume of 0.166 c.f.s. and a surface velocity of 0.63 f.p.s. The herbicidal solvent is dispersed in the treatment water with an anionic-nonionic surfactant (laboratory sample No. 755), which is used at a concentration of 1.5 percent by volume of solvent.

Replicated potted cultures of each species are treated at herbicidal concentrations of 200 and 600 p.p.m. active ingredient (ai). The plants are exposed to the recirculated herbicidal solution for a period of 30 minutes, then removed to a 20-liter aquaria for rinsing. The treated plants are held in the rinse container for about 30 minutes and then placed in a 20-liter glass aquaria for a 3-week period of injury observation.

Water temperature during plant culture, treatment, rinse, and post-treatment observation is controlled in a range of 19° to 24° C.

Herbicidal injury ratings used are similar to those

Table 11

HERBICIDAL ACTIVITY OF AROMATIC SOLVENT AND XYLENE SAMPLES ON SUBMERGED AQUATIC WEEDS

Laboratory sample No.	Solvent concentration (p.p.m.)	Injury scale rating [1]			Activity index No. [2]
		E. canadensis	P. nodosus	P. pectinatus	
871	200	2.7	2.5	3.2	2.8
	600	5.3	3.7	5.3	4.8
872	200	3.7	2.8	2.8	3.1
	600	5.7	4.2	5.0	5.0
873	200	2.0	2.2	1.8	2.0
	600	4.0	4.2	5.0	4.4
874	200	3.0	3.5	4.0	3.5
	600	4.3	4.3	5.5	4.7
875	200	1.7	3.0	4.0	2.9
	600	5.0	3.5	5.0	4.5
876	200	3.7	4.0	4.2	4.0
	600	4.7	4.5	6.2	5.1
882	200	4.0	3.0	4.0	3.7
	600	6.0	4.5	6.0	5.5
883	200	Sample not tested			
	600				
Industrial grade xylene [3]	200	3.7	3.7	4.0	3.8
	600	5.3	4.5	5.5	5.1

[1] Each figure represents the mean of three weekly injury scale ratings.

[2] Activity index number obtained by determining the average of the mean injury scale ratings for each species tested.

[3] Used as a standard contact herbicidal solvent for comparative purposes.

described by Frank et al. (3) with some slight modifications that are used to rate contact herbicides. In general, the maximum attainable injury rating for aromatic solvents seldom exceeds 8 on the 0 to 10 scale, where 0=no injury and 10=complete kill without regrowth. Also, injury by contact herbicides is limited to above ground plant parts only, whereas with some systemic-type herbicides the injury ratings may include effects on root and rhizome tissue.

The results of herbicidal activity tests on solvent samples described in this report are summarized in table 11. The samples of aromatic solvents and xylenes tested during the past year met all specified requirements. The herbicidal activity ratings of all materials tested were quite similar.

Aromatic solvents submitted for acceptance tests for use by Bureau of Reclamation projects or cooperating irrigation districts have continually improved over the years. The past year's evaluation of these materials illustrates the increasing uniformity of this type of aquatic herbicide.

Evaluation of Additives to Enhance the Phytotoxicity of Aromatic Solvent Herbicides

Large quantities of aromatic solvent herbicides are used annually on Bureau of Reclamation and associated irrigation projects for aquatic weed control. Any improvement in the phytotoxicity of these solvent herbicides by the use of improved solvents or surfactants as well as additives could result in a considerable monetary savings. Occasionally a few compounds come to the attention of investigators having certain physical properties or having exhibited herbicidal characteristics that would suggest their possible combination with solvents. Combining herbicides and additives possessing certain selective characteristics to obtain formulations having increased herbicidal effectiveness has proven to be very successful, as evidenced by numerous herbicide combinations of soil sterilant herbicides now commercially available.

A number of such materials have been tested over the years in the laboratory, but none of them have exhibited sufficient increases in activity to warrant further development. A few additional compounds were subjected to herbicidal activity tests evaluating various combinations of additives to emulsified xylene during the past year. Techniques used in these tests are those methods routinely used and previously mentioned (3). Results of these tests are presented in table 12.

Table 12

HERBICIDAL ACTIVITY OF SELECTED COMPOUNDS WHEN COMBINED WITH EMULSIFIED XYLENE. HERBICIDAL CONCENTRATION OF XYLENE IS 200 P.P.M., DISPERSED WITH 1.5 PERCENT EMULSIFIER V/V WITH XYLENE UNLESS OTHERWISE INDICATED. ALL ADDITIVES ARE INCLUDED AS A V/V PERCENTAGE OF XYLENE

Herbicidal mixture	Potted cultures of rooted aquatic weed species	Contact period	Injury rating 1, 2, 3, and 4 weeks following treatment [1]				Average rating
			1	2	3	4	
Xylene (check) with 1.5 percent nonionic-anionic emuslifier.	E. canadensis	30 minutes standing water.	5	7	6	5	------
	P. nodosus		5. 5	7	5. 5	5	------
	P. pectinatus	do	6. 5	8	6. 5	5	6
50.0 percent tallow diamine (Lab. No. 893) as additive with 100 p.p.m. concentrate of emulsified xylene.	E. canadensis	do	2	3	2	3	------
	P. nodosus	do	3	5	4	3	------
	P. pectinatus	do	3	4	4	4	3. 3
50.0 percent dicoco dimethyl quaternary ammonium chloride (Lab. No. 892) as additive with 100 p.p.m. concentrate of emulsified xylene.	E. canadensis	do	4	9	6	3	------
	P. nodosus	do	6	8	5	4	------
	P. pectinatus	do	5	9	6. 5	6	5. 96
0.05 percent dimethyl sulfoxide (Lab. No. 891) as additive with emulsified xylene.	E. canadensis	do	6	6	6	5	------
	P. nodosus	do	6	6	7	7	------
	P. pectinatus	do	6	6. 5	6. 5	5	6. 1
0.1 percent dimethyl sulfoxide as additive with emuslified xylene.	E. canadensis	do	5	5	4	4	------
	P. nodosus	do	4. 5	4. 5	4. 5	4. 5	------
	P. pectinatus	do	6	7	7	6	5. 2

See footnotes at end of table.

Table 12—Continued

Herbicidal mixture	Potted cultures of rooted aquatic weed species	Contact period	Injury rating 1, 2, 3, and 4 weeks following treatment [1] 1	2	3	4	Average rating
1.0 percent dimethyl sulfoxide as additive with emulsified xylene.	E. canadensis	30 minutes standing water.	6	6	6	5	
	P. nodosus		6. 5	6. 5	6. 5	6	
	P. pectinatus	do	6. 5	6. 5	5. 5	4. 5	5. 96
Xylene (check) with 1.0 percent nonionic-anionic emulsifier.	E. canadensis	do	7	4	4		
	P. nodosus	do	5	5	5		
	P. pectinatus	do	6	5	5		5. 1
0.9 percent nonionic-anionic emulsifier, 0.1 percent diquat (Lab. No. 757) as additive with emulsified xylene.	E. canadensis	do	5	4	4		
	P. nodosus	do	5	5	5		
	P. pectinatus	do	5	5	5		4. 3
0.75 percent nonionic-anionic emulsifier, 0.25 percent diquat as additive with emulsified xylene.	E. canadensis	do	6	4	4		
	P. nodosus	do	5	5	5		
	P. pectinatus	do	5	5	5		5. 0
0.5 percent nonionic-anionic emulsifier, 0.5 percent diquat as additive with emulsified xylene.	E. canadensis	do	5	4	4		
	P. nodosus	do	5	5	5		
	P. pectinatus	do	5	5	5		4. 3
Xylene (check) with 1.5 percent nonionic-anionic emulsifier.	P. nodosus	do	4	3	3	3	
	P. pectinatus	do	5	3	4	4	3. 6
50.0 percent dimethyl sulfoxide (check)	P. nodosus	do	0	0	0	. 5	. 1
	P. pectinatus	do	0	0	0	. 5	. 1
0.1 percent dimethyl sulfoxide as additive with emulsified xylene.	P. nodosus	do	4. 5	5. 5	5	5	
	P. pectinatus	do	7	7	6. 5	6. 5	5. 9
1.0 percent dimethyl sulfoxide as additive with emulsified xylene.	P. nodosus	do	5	5. 5	5. 5	5	
	P. pectinatus	do	5	3. 5	4	4	4. 7
5.0 percent dimethyl sulfoxide as additive with emulsified xylene.	P. nodosus	do	3. 5	3. 5	3	3	
	P. pectinatus	do	5	3	3. 5	3. 5	3. 5
10.0 percent dimethyl sulfoxide as additive with emulsified xylene.	P. nodosus	do	3. 5	3	3. 5	3. 5	
	P. pectinatus	do	5	3	3. 5	3. 5	3. 6
50.0 percent dimethyl sulfoxide as additive with emulsified xylene.	P. nodosus	do	2. 5	3	3	3	
	P. pectinatus	do	2. 5	2. 5	3	3	2. 8
Xylene (check) with 1.5 percent nonionic-anionic emulsifier.	E. canadensis	30 minutes [2] flowing water.	1	1			
	P. nodosus		3	4			
	P. pectinatus	do	4	4			2. 8
1.0 percent dimethyl sulfoxide as additive with emulsified xylene.	E. canadensis	do	1	1			
	P. nodosus	do	1. 5	1. 5			
	P. pectinatus	do	1. 5	1. 5			1. 3
0.1 percent dimethyl sulfoxide as additive with emulsified xylene.	E. canadensis	do	. 5	. 5			
	P. nodosus	do	3	2			
	P. pectinatus	do	4. 5	4. 5			2. 5

[1] Weekly means are obtained from 2-pot replications per species.
[2] Tests conducted in greenhouse flowing water test canal.

None of the herbicidally active additive combinations with xylene showed any significant increase in activity over that produced by emulsified xylene alone. A few of the additives caused some reduction in overall activity, as compared with the solvent checks. Three of these compound additives, such as the tallow diamine, diquat, and the dicoco quaternary ammonium compound have shown some activity on pondweeds in static water greenhouse tests. It was thought that perhaps the overall activity of xylene might be enhanced by combining known active compounds with the solvent type aquatic herbicides. These preliminary tests did not support the hypothesis. Further tests of this type utilizing other compounds and combinations are anticipated, as might be suggested in future studies.

Dimethyl sulfoxide is an organic solvent that has been reported to have a unique quality for vastly improving the absorption of herbicides and insecticides (8). Investigations with this solvent have primarily been with systemic pesticides and to our knowledge its use with contact aquatic herbicides has not been studied. Dimethyl sulfoxide was included in tests to evaluate its potential for enhancing solvent-type treatments. Results of some of the initial standing water tests indicated an increase in herbicidal activity, as shown in the standing water tests in table 12. This increased activity over the xylene check was especially evident when dimethyl sulfoxide was combined with xylene at concentrations of 0.1 and 1.0 percent v/v with xylene. Further evaluations of these percentage combinations with xylene in a flowing water test showed negative results.

In flowing water tests, the dimethyl sulfoxide additive caused some reduction in the activity of xylene on pondweeds. It is possible that the dimethyl sulfoxide solvent may have had some influence on the emulsification of xylene, as there was an indication of some emulsion breakdown, especially at the higher concentrations which would cause an inadequate dispersion of the herbicidal mixture throughout the test flume. During all of the standing water tests, the herbicidal solution was agitated a number of times. The use of other types and concentrations of emulsifiers in dimethyl sulfoxide combinations with xylene might also be of some benefit, although present data do not support further investigation at this time. Tests using dimethyl sulfoxide with systemic aquatic herbicides is anticipated.

Laboratory Comparisons of Two Emulsifiers and Various Rates Used To Disperse Aromatic Solvent Aquatic Herbicides

Emulsifier manufacturers develop new and improved emulsifiers for agricultural pesticides. Many of these materials are submitted to the Denver laboratory for evaluation of suitability for use in dispersing aromatic solvent aquatic herbicides for pondweed control. Occasionally these emulsifying agents come to the attention of field personnel for their consideration of use and purchasing. One such material, designated as emulsifier No. 1 in this report was given a limited field test by personnel of the Columbia Basin project and the results reported indicated satisfactory performance at a much lower rate than the 1.0- to 1.5-percent concentration routinely used in aromatic solvent aquatic weed treatments. This suggested laboratory tests to study the potential of reducing concentrations below the 1.0-percent level with this experimental emulsifier.

This particular emulsifier was previously submitted for laboratory testing and the results indicated it was questionable for use in dispersing aromatic solvents. The laboratory test method used to evaluate emulsifiers is that developed in the Denver laboratory and is described in Report No. W-1 (9). The suitability of the emulsifier to disperse solvent herbicides is based on the premise of the stability of the oil-water emulsion produced. The index of this stability is based on the amount of cream layer and/or oil that separates from the water medium during a given period of standing. The results of the stability test on this emulsifier is given in table 13, along with a nonionic-anionic emulsifier that is commonly used in the field (designated as emulsifier No. 2). Emulsifier No. 2 (laboratory sample No. 755) is used for comparative purposes throughout the study.

The results of the emulsion stability tests indicate that emulsifier No. 1 would be of questionable use for dispersing aromatic solvents for acquatic weed control even at the higher concentrations. Because of the rather poor emulsion stability characteristics produced by emulsifier No. 1, it was subjected to biological evaluation tests to ascertain the materials

Table 13

RESULTS OF LABORATORY EMULSIFIER STABILITY TESTS

Laboratory sample No.	Percent emulsifier by volume with xylene	Mean results of two test replications — Divisions of cream and oil separation after standing for 1, 2, and 4 hours						Suitability rating at a given emulsifier concentration
		1 hour		2 hours		4 hours		
		Cream	Oil	Cream	Oil	Cream	Oil	
741 [1]	1.0	Not tested at this concentration						
(Emulsifier No. 1)	1.5	15	0	20	Tr.	26	Tr.	Poor.
	2.0	14	0	22	Tr.	32	Tr.	Do.
755 [2]	1.0	0	0	1	0	2	Tr.	Excellent.
(Emulsifier No. 2)	1.5	0	0	0	0	Tr.	0	Do.
	2.0	0	0	0	0	1	0	Do.

[1] Composition unknown.
[2] Nonionic-anionic blend: anionic portion is calcium salt of dodecyl benzene sulfonic acid—nonionic portion is composed of polyoxyethylene ethers.

relative phytotoxic properties on submersed aquatic weeds when used to disperse xylene. Suitable performance of the experimental emulsifier in the field test might be linked to some synergistic effect or a phytotoxic property of the emulsifier additive in the event inadequate xylene dispersions occurred, as might be suggested from the emulsion stability tests. It must be recognized that poor emulsion stability performance as indicated by the laboratory tests could, in certain situations, be overcome in field applications by agitation action of application pumps, herbicide injection in canal water, and at canal drops.

An exploratory standing water, 30-minute exposure test was conducted to test the relative phytotoxicity of both emulsifiers at ¼ percent on excised shoots of waterweed. Results of this one test indicated that both compounds were equally injurious to waterweed shoots. The injury symptoms, however, were slight, limited primarily to a slight burn of the leaf tissue. The plants recovered quite rapidly.

Additional laboratory tests were conducted to evaluate the overall injury effects of the two emulsifiers on rooted aquatic weeds when used to disperse 200 and 600 p.p.m. concentrations of xylene. These tests were conducted on 5-week old plants in a standing water situation with a 30-minute contact period, followed by a 15-minute standing water rinse. Water temperatures during treatment and rinse were maintained at 21° C. Treated plants were observed weekly and rated for injury on the 0 to 10 scale. Results of this test are summarized in table 14.

Results of tests given in table 14 show that the emulsifier No. 1 xylene combination produced less overall injury on all species at any one emulsifier concentration than did the emulsifier No. 2 xylene combination. There was a significant reduction of herbicidal activity with both materials as the emulsifier concentration was decreased. This reduction in herbicidal activity becomes more critical as the emulsifier was used at less than the 1.0-percent level. It was assumed that this loss of herbicidal activity at reduced emulsifier concentrations and with emulsifier No. 1 was due to inadequate dispersion of the xylene herbicide throughout the test aquaria. The herbicidal solutions were agitated by stirring once during the 30-minute test period.

A series of flowing water tests was conducted to evaluate the hypothesis that the reduced herbicidal

Table 14

COMPARISON OF VARIOUS CONCENTRATIONS OF TWO EMULSIFIERS ON THE HERBICIDAL ACTIVITY OF XYLENE ON AQUATIC WEEDS IN A STANDING WATER, LIMITED CONTACT PERIOD TEST

Emulsifier concentration v/v percentage of xylene	Xylene concentration (p.p.m.)	Emulsifier No.	Mean injury ratings obtained over 4 weeks on potted cultures of aquatic weed species			Mean injury, all species
			Sago pondweed	American pondweed	Waterweed	
0. 25	200	[1] 1	1. 25	1. 25	0. 00	0. 8
. 50			1. 00	. 75	. 75	. 8
1. 00			1. 75	1. 00	. 50	1. 1
2. 00			2. 75	2. 75	. 75	2. 1
. 25	600	[1] 1	1. 25	1. 00	. 25	. 8
. 50			2. 25	. 75	1. 75	1. 6
1. 00			2. 00	1. 75	1. 00	1. 6
2. 00			3. 50	2. 75	3. 00	3. 1
. 25	200	2	1. 50	2. 00	. 75	1. 4
. 50			3. 00	3. 50	2. 75	3. 1
1. 00			4. 00	4. 00	4. 00	4. 0
2. 00			5. 00	5. 00	4. 25	4. 8
. 25	600	2	2. 25	2. 25	1. 25	1. 9
. 50			3. 00	3. 00	2. 75	2. 9
1. 00			4. 25	4. 25	4. 50	4. 3
2. 00			6. 50	6. 50	6. 25	6. 4

[1] All tests using emulsifier No. 1 showed signs of emulsion instability by extensive injury symptoms on floating plant material.

activity of xylene containing emulsifier No. 1 was because of inadequate dispersion of xylene.

Tests were conducted in the same manner used to routinely test aromatic solvents for herbicidal activity as previously mentioned. The potted cultures of pondweeds used in this study were approximately 5 weeks old when treated. Water temperature during treatment and rinsing was maintained between 20° and 22° C. Results of two replicated tests evaluating the emulsifying compounds' effect on the activity of xylene under flowing water conditions are summarized in table 15.

Data in table 15 demonstrate the effects of continued mechanical agitation on the dispersion of the xylene toxicant over the plants, irrespective of emulsifier concentration and emulsifier type. There is no significant difference between the two materials at any concentration except at the 1.0-percent level of emulsifier No. 1, which showed a slight increase in mean activity. The agitation produced in the recirculating test canal is excessive, as evidenced by considerable foaming of the emulsifier-xylene emulsion during test. This degree of continuous agitation through the reach of an irrigation canal during treatment could not be obtained. The flowing water test substantiates the hypothesis that reduced herbicidal activity produced in the standing water tests with emulsifier No. 1 is primarily one of emulsion instability. Agitation aids considerably in the dispersions of a solvent regardless of emulsifier quality and quantity.

It can be concluded from these laboratory tests that emulsifier No. 1 would be of questionable use in a field situation unless a condition of considerable agitation would exist throughout the canal or unless a more stable xylene water emulsion could be produced by some manner of injection into application pumps. This factor has never been studied in our laboratory investigations, but has been considered to be of importance.

Also, the emulsion stability test as presently used in our laboratory is a reliable method for evaluating the performance of an emulsifier's ability to adequately disperse aromatic solvent aquatic herbicides. In addition it seems likely that a reduction of emulsifier concentration much below the 1.0-percent level of either emulsifier would have some adverse effect on the success of a solvent treatment because of inadequate xylene dispersion.

Laboratory studies of this nature are quite limited in scope and cannot include all factors existing in a field situation, such as long reaches of canal, water velocity, dense weed infestations, water quality, suspended materials, to name a few. Many of these factors could possibly influence the dispersion of a xylene treatment or oil-water emulsion stability. Reduction in emulsifier concentration to provide for adequate toxicant dispersions can only be tested in a field situation. However, present evidence from laboratory tests would not support a reduction of emulsifier level much below the 1.0-percent level with presently available emulsifying compounds.

Table 15

COMPARISON OF VARIOUS CONCENTRATIONS OF TWO EMULSIFIERS ON THE HERBICIDAL ACTIVITY OF XYLENE ON AQUATIC WEEDS IN A FLOWING WATER, LIMITED CONTACT PERIOD TEST

Emulsifier concentration, v/v percentage with a 600-p.p.m. herbicidal concentration of xylene	Emulsifier No.	Mean injury ratings of 2 separate tests over 3 weeks on potted cultures of aquatic weed species			Mean injury, all species
		Sago pondweed	American pondweed	American waterweed (Elodea)	
1.00	1	6.3	6.0	6.2	6.2
.50	1	5.7	5.0	5.3	5.3
.25	1	6.2	4.8	5.0	5.3
1.00	2	5.4	5.1	5.8	5.4
.50	2	6.0	5.0	5.7	5.6
.25	2	6.2	4.8	5.0	5.3

Study of the Influence of Aquatic Soil Composition and Dissolved Interstitial Gases on Sago Pondweed Propagule Production

Field studies of the submersed aquatic environment have in certain instances suggested a possible relationship between aquatic soil texture and the extent of sago pondweed infestations. There have been some indications that certain canal soils containing high clay and fine silt fractions are less densely infested or may completely lack rooted pondweed growths. More recent field observations made by cooperating investigators on the Columbia Basin project (10) have indicated from canal soil bisect studies that sago pondweed subterranean tuber production seems to be more extensive in areas where there are changes in the texture of canal soil deposits. Tuber production was reported to be greatest near the interface of a change from one soil texture to another, especially where a thin organic layer was deposited. These suggested relationships between soil composition and/or density and extent of root and rhizome growth may simply be mechanical, where the plant roots and tuber-bearing rhizomes would more commonly penetrate the less dense substrate. However, other environmental factors that are known to influence root and rhizome growth of terrestrial plants might be considered. Soil oxygen and carbon dioxide are known to influence the root growth of terrestrial plants, but little information is available in the literature on factors influencing rooted submersed aquatic weed growth.

Dissolved oxygen content of aquatic soil interstitial water was briefly investigated by one of the authors in field situations during the summer of 1963 (4). Results of these few observations indicated the occurrence of detectable quantities of dissolved oxygen in the first few inches of a number of aquatic soils in irrigation canals. Determination of the soil-water oxygen content at greater depths and in more compact soil was not obtained because of sampling difficulties and stream water contamination.

An exploratory study was established during the summer of 1964 to further investigate the possible influence of aquatic soil composition, soil-water oxygen and equivalent carbon dioxide content on the development of sago pondweed tubers. This study was conducted outside of the greenhouse area, utilizing the water source from the small pond shown in figure 3. Various combinations of soil, silt, gravel, and organic matter were placed in one-half sectioned, 55-gallon steel barrels for culture media to grow pondweeds. Water was recirculated from the pond through the culture barrels at a rate of 8 gallons per minute. The experimental setup is shown in figure 7.

Dissolved oxygen and equivalent carbon dioxide analysis of soilwater samples required a sampling technique for obtaining water samples of various soil depths without contamination of the soil sample zone with above soil or recirculated water. In conducting the 1963 field studies on interstitial oxygen a sampling device described by Eriksen (11) was found to be reliable in shallow soils. A slightly modified version of the sampling device is shown in figure 8.

Details on the use of this interstitial water sampling device and the Micro-Winkler techniques used in analyses for dissolved oxygen are given in the Appendix of Report WC–13 (4). The interstitial water sampling device is suitable for use in a fixed site at a given soil depth, as well as for portable field

Figure 7.—Plant Culture Equipment Used to Study the Influence of Aquatic Soil Composition and Interstitial Dissolved Gases on Sago Pondweed Tuber Growth.

use. A number of similar devices, as shown in figure 8, were constructed and located at various soil depths in the culture barrels. Exploratory tests of fixed-site water sampling and subsequent microanalysis for dissolved oxygen and alkalinity were shown to produce reasonably reliable results. The sampling technique used was similar to that described in Report No. WC–13, except that the initial water obtained from the sampler (approximately 5–8 ml.) for each analysis was discarded. This always provided a fresh water sample that would reflect the soil-water quality at the time of sampling. All stream water samples were collected directly into the syringe pipette for microanalysis. Dissolved oxygen determinations were accomplished in the same manner as used in the 1963 studies (4). Equivalent carbon dioxide content was determined by the calculation method described in U.S. Geological Survey Water Supply Paper 1454 (12). According to the authors this technique is applicable to unpolluted water whose dissolved solid content does not exceed 500 to 800 p.p.m. Basically, this technique consists of a water alkalinity determination (bicarbonate, HCO_3^{-1}, concentration in p.p.m.) by titration with standard sulfuric acid. The equivalent part per million carbon dioxide concentration is calculated from this HCO_3^{-1} concentration by mass law and stoichiometric equations. Formulae for calculating the bicarbonate and carbon dioxide concentrations of the sample are generalized as follows:

Alkalinity determinations:

$$\text{ppm of alkalinity as } HCO_3^{-1} = \frac{1{,}000}{\text{ml of sample (working volume of syringe pipette 4.43 ml)}} \times \text{ml of acid used in titrating water sample from pH 8.25 to pH 4.5}$$

Equivalent carbon dioxide concentration:

$$\text{ppm } CO_2 = \text{Conversion factors taken from a table in USGS Paper 1454 that relates the term } 1.589 \times 10^6(H+) \text{ at the initial pH of the water sample being analyzed.} \times \text{ppm concentration of } HCO_3^{-1} \text{ determined in the acid titrations.}$$

Titrations were made with a standard model pH meter using miniature glass and calomel electrodes.

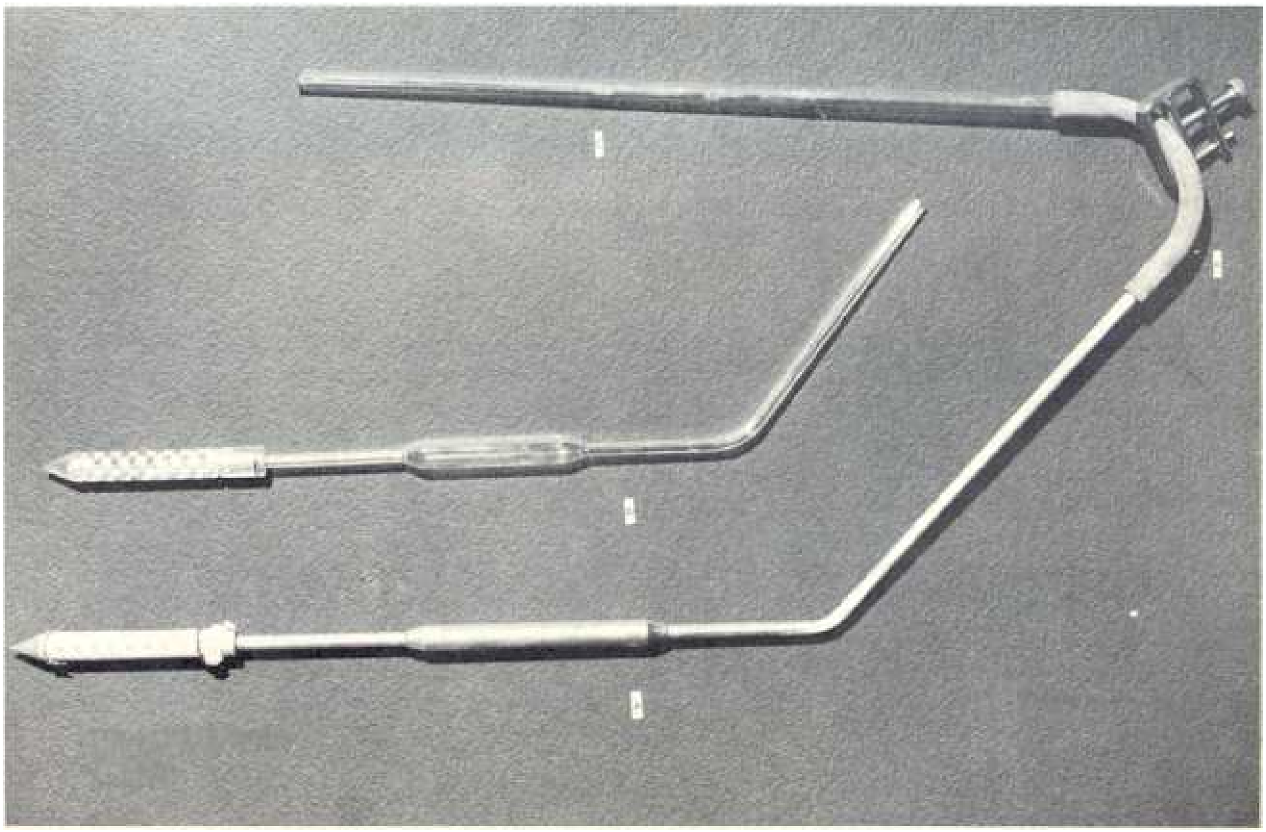


Figure 8.—Sampling Devices Used to Obtain Aquatic Soil Interstitial Water for Dissolved Oxygen and Alkalinity Analyses.

The limitation of small water sample size (4.43 ml.) available from the fixed site sampler was questioned. A number of analyses were made comparing the small samples with larger sample volumes and the method was found to be sufficiently sensitive for this exploratory study.

The various combinations of soil types, depths of fixed soil-water samples, and initial propagule plantings used in this study are given in table 16. All sampling and planting depths given are from the soil-water interface.

The sampling probes were positioned in the soil and propagules planted on June 11, 1964. Tubers were harvested on August 11, 1964.

Upon completion of a 2-month observation and water sampling period, the culture barrels were drained and all tubers harvested. Counts were made with respect to number of tubers produced at various soil depths and locations, as well as determinations made of their respective fresh and dry weights.

Results of mean soil-water, dissolved oxygen, and alkalinity (as HCO_3^{-1}) analyses made during the 2-month study are tabulated in tables 17 and 18.

The dissolved oxygen content of the culture water (7.60 p.p.m.) averaged somewhat higher than the saturation value of 6.90 p.p.m. for mean water temperatures of 25° C. at an altitude of 5,000 feet above sea level, but corresponded favorably with canal water determinations made in 1963. (See table 18 for water temperatures.) Possibly this is an analytical error of the microdetermination, although previous comparisons made with larger samples, analyzed by standard Winkler methods, indicated an accuracy of ±2 percent (4). Inasmuch as these oxygen determinations were made during active photosynthetic periods the O_2 level would be expected to be greater than the saturation value.

Dissolved oxygen determinations from aquatic soil sampling indicated a rapid loss of O_2 within a few days after the soil was saturated. A general anaerobic condition existed in the soil within 2 to 3 weeks after the test was started. Oxygen data at the 1- to 3-inch soil depth in this synthetic situation were not comparable to that found in canals during the summer of 1963. This could be attributed to either stream water contamination of the soil-water

Table 16

COMBINATIONS OF SOIL TYPES, INTERSTITIAL SOIL WATER SAMPLING, AND TUBER PLANTING DEPTHS USED IN SAGO PONDWEED PROPAGULE STUDY

Barrel No.	Water sampler No.	Location of fixed water sampler, depth in soil	Soil type and/or combination	Depth at which initial sago pondweed tubers were planted [1]
1	1B	2 inches below the soil surface.	Top soil, obtained from a local nursery.	2 inches from the soil surface.
1	1A	6 inches below the soil surface.	Total soil depth 8 to 9 inches	6 inches from the soil surface.
2	2	2½ inches below the soil surface.	¼-inch screened and washed gravel mixed with approximately 2 percent top soil. (Total soil depth 6 to 7 inches.)	2½ inches below the soil surface.
3	3B	3 inches below soil surface just below upper gravel layer.	Top soil, with two separate ¼-inch gravel layers 1 inch in thickness. The upper gravel layer was combined with a peat moss-organic fertilizer mix and located 2 inches below the soil surface.	2 inches below the soil surface. One inch above the upper gravel layer.
3	3A	6½ inches below the soil surface.	Top soil as in 3B. Lower ¼-inch gravel layer 6 inches below the soil surface. (Total soil depth in barrel No. 3, 8 to 9 inches.)	6½ inches below the soil surface in the center of the lower gravel layer.
4	4	4 inches below the soil surface.	Very fine screened silt obtained from a local irrigation canal. (Yokum ditch.) (Total soil depth 6 inches.)	4 inches below the soil surface.

[1] *A total of 40 tubers of uniform size were planted in each barrel.* This total number was equally divided between the two planting depths in barrels No. 1 and 3.

Table 17

DISSOLVED OXYGEN CONTENT OF INTERSTITIAL WATER CONTAINED IN SOILS USED TO CULTURE SAGO PONDWEED

Water sampler No.	Water sampler location, depth in soil, and soil type	Dissolved oxygen content of samples in parts per million on respective sampling dates. Samples were obtained between the hours of 9 a.m. to 1 p.m.						Mean values of all values determined over 2 mos., p.p.m. dissolved oxygen
		June 12, 1964	June 16, 1964	June 25, 1964	July 7, 1964	July 20, 1964	Aug. 11, 1964	
Culture water	Representative of total volume.	7.22	7.35	7.81	7.81	7.69	7.67	7.60
1B	2 inches in top soil	.54	0	0	0	0	0	.07
1A	6 inches in top soil	.36	.05	.11	0	0	0	.09
2	2½ inches in gravel-soil mix	.07	.27	.32	0	0	0	.07
3B	3 inches in top soil just above gravel.	Tr.	0	0	0	0	0	0
3A	6 inches in a gravel layer	.05	.36	0	0	0	0	0
4	4 inches in canal silt	1.86	.82	.33	0	0	0	.50

sample by excess soil disturbance during field sampling or the lack of vertical water movement through the soil in culture aquaria used in this laboratory study. The 55-gallon culture aquaria would not be much different than a very slow-moving or static water situation at the soil-water interface.

Alkalinity determinations indicated a general progressive increase with time of bicarbonate ion concentration in all soils. The deeper samples reflect a greater degree of alkalinity than the shallow samples. Likewise, the barrels containing topsoil or topsoil mixes (except the gravel-soil mixture) had a higher HCO_3^{-1} content than did the gravel or the silt soils. This was probably due to the higher mineral content of the topsoil. The calculated equivalent carbon dioxide content of the soil-water generally exhibited an increasing trend to the middle of the sampling period and then showed some decline toward the end of the study because of its inverse relationship to increases in pH. The various factors sampled in respect to soil type or texture, and sampling depths had no obvious relation to root or rhizome development. All soil values of alkalinity and equivalent CO_2 were very high. The reliability or significance of these data to other comparable situations is not apparent at this time.

The results of propagule production observations and determinations are summarized in table 19.

Tuber production data did not indicate any significant differences between soil types or depths at which they were produced in soil. The total numbers and mean tuber dry weights were quite comparable in all four culture aquaria. It is interesting to note that in the predominantly gravel environment of barrel No. 2, the tuber productivity was equal to the more nutrient rich topsoil and canal silt used in the other situations. This would suggest that either the plant nutrient source was primarily from the water medium or that the plant nutrient requirements were not limiting and the small amount of topsoil supplied in the gravel-soil mix was adequate. There was no particular depth selection of tuber-bearing rhizomes in any of the test aquaria, except for the gravel situation in barrel No. 2. All others were primarily random penetration of the soil media. However, general observations of the upper gravel layer in barrel No. 3 indicated a trend of selection of tuber-bearing rhizomes for the upper topsoil and gravel interface rather than through the whole gravel layer. This general impression was not supported by the tuber number data given in table 19.

Comparisons of tuber production data with the soil-oxygen and equivalent carbon dioxide data did not suggest any obvious relationship in this study.

Because of this study's exploratory nature and the numbers of limiting conditions existing in the

Table 18

ALKALINITY DETERMINATIONS AND CALCULATED CARBON DIOXIDE CONTENT OF INTERSTITIAL WATER CONTAINED IN AQUATIC SOILS USED TO CULTURE SAGO PONDWEED

Water sampler No. and location	Determinations	Respective determinations made from samples obtained on the following dates, between the hours of 1 p.m. to 2 p.m.					Means of values obtained over 2 months
		June 16, 1964	June 25, 1964	July 7, 1964	July 20, 1964	Aug. 11, 1964	
Culture water	pH	7.4	7.7	7.1	[1] 8.5	8.2	7.78
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	25.52
	Alkalinity, HCO_3^{-1}	33.86	40.63	28.22	----------	33.86	27.31
	Calculated equivalent Carbon dioxide, p.p.m.	2.13	1.30	3.56	----------	0.34	1.47
1B 2 inches below surface of topsoil.	pH	6.8	6.7	6.6	7.0	6.9	6.80
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	440.17	593.67	711.05	1,241.52	1,320.52	861.39
	Calculated equivalent CO_2, p.p.m.	110.92	188.19	283.71	197.40	164.10	188.86
1A 6 inches below surface of topsoil.	pH	7.1	6.9	6.5	6.9	7.1	6.90
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	620.76	993.21	1,636.54	2,212.15	2,302.45	1,553.02
	Calculated equivalent CO_2, p.p.m.	78.22	198.64	823.18	442.43	290.11	366.51
2 2½ inches below surface of gravel soil mix.	pH	7.2	6.7	6.7	6.9	7.0	6.90
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	180.28	237.02	406.31	543.04	577.61	388.85
	Calculated equivalent CO_2, p.p.m.	18.06	75.14	128.80	108.61	91.84	84.49
3B 3 inches below surface in topsoil.	pH	6.6	6.7	6.7	6.9	6.9	6.76
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	57.10	706.53	1,049.64	1,467.25	1,602.78	976.66
	Calculated equivalent CO_2, p.p.m.	227.87	223.97	332.74	293.45	320.56	279.72
3A 6 inches below surface in gravel layer.	pH	6.8	6.7	6.7	6.7	7.1	6.80
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	417.60	778.77	1,275.37	1,918.71	2,020.28	1,282.14
	Calculated equivalent CO_2	105.24	246.87	404.29	608.23	254.56	323.83
4 4 inches below surface in canal silt.	pH	6.1	6.2	6.8	6.7	7.0	6.56
	Temperature, °C	25.0	26.0	28.0	25.6	23.0	----------
	Alkalinity, HCO_3^{-1}	187.36	253.49	417.60	654.12	1,015.79	505.67
	Calculated equivalent CO_2 p.p.m.	236.45	254.25	105.24	207.36	101.51	192.96

[1] Samples not reported because the initial pH exceeded pH 8.25, the starting point determining bicarbonate alkalinity.

experimental layout of this test, no conclusions can be reached at this time. To adequately study the factors considered would require larger volumes and deeper areas of test soils and/or variable soil horizons, and larger flowing water volumes. However, the technique of a fixed sampling device utilized to obtain interstitial soil-water samples over extended periods for chemical analysis was successful. The use of the fixed site soil-water sampler might well be applicable to other situations where a soil-water sample would be required.

Further laboratory investigation of the potential relationship between the physical nature of aquatic soils, and the growth and propagule productivity of rooted aquatic weeds is not suggested by data obtained to date.

Table 19

TUBER PRODUCTION OF SAGO PONDWEED IN VARIOUS COMBINATIONS OF SOIL TYPES AND DIFFERENT SOIL DEPTHS

Barrel No.	Relative location, depth in soil (inches)	Primary soil type used in culture aquaria or soil horizon	Total number of tubers at a given soil depth	Total number of tubers produced per barrel	Tuber mean dry-weight (mg)	Remarks
1	Surface to 3 in	Topsoil	52	----------	0.0134	Tuber distribution random through total soil volume.
1	3 to 6 in	do	83	----------	.0217	
1	6 in. to bottom	do	23	158	.0315	
2	Surface to 3 in	Gravel	26	----------	.0148	Tuber distribution random through total soil volume. Greater productivity near the bottom.
2	3 in. to bottom	do	135	161	.0206	
3	Surface to 3 in	Topsoil	50	----------	.0108	Tuber distribution random through total soil volume, except a trend of larger tuber number right at the upper gravel and top soil interface.
3	Upper gravel layer 2 in. to 3 in.	Gravel and organic matter.	68	----------	.0203	
3	Lower gravel layer 4 in. to 6 in.	Topsoil and gravel.	47	----------	.0263	
3	6 in. to bottom	Topsoil	22	187	.0236	
4	Surface to bottom	Canal silt	138	138	.0173	Tuber distribution random through the total soil volume. A slight trend of increased numbers of tubers near the bottom.

Pelletized Aquatic Herbicides

Herbicides are not normally formulated specifically for application to aquatic soils in flowing water situations for aquatic weed control. They usually possess certain physical characteristics, such as rate of dissolution, that are not desirable for optimum effectiveness in aquatic soil treatments.

It was the intent of this study to evaluate the activity of certain herbicides coated with a resin on aquatic weeds. The principle of controlled release of a toxicant has worked very well in extending the activity of algaecides included in antifouling paints for inhibiting the attachment of algae to the surfaces of irrigation structures. Limited work performed on pelletized herbicide formulations has been made in an attempt to duplicate the formulation principle used in fouling prevention materials.

The resinous binder used in preparing the coated herbicide pellets is a vinyl resin solution of the vinyl chloride-vinyl acetate copolymer dissolved in solvents, and is referred to in Bureau paint specifications as VR–6 seal coat (14). Pellets are prepared by mixing the herbicide into the vinyl resin solution until the mixture reaches a thick paste consistency. The paste is transferred to a hypodermic syringe and extruded in a continuous small diameter extrusion onto a glass surface for drying. The air-dried formulation is broken into small pieces which are used for soil applications. Percentage of active ingredient (herbicide) in the pellets is computed from the weight of the ingredients.

Pelletized herbicides are evaluated for activity on sago pondweed by treating soil contained in 6-inch flower pots. Sago pondweed tubers are planted in the soil at a depth of about 2 inches prior to application of herbicide.

The pelletized material is applied to the top 1 inch of soil on a pound-per-acre rate based on active ingredient. Providing the herbicide treatment gives a complete kill of the initial crop of pondweed, the water is drained from the aquaria and the soil replanted with tubers. Fresh tapwater is used to refill the acquaria. This procedure is repeated following each complete kill.

The acid formulation of silvex (2- [2,4,5-trichlorophenoxy] propionic acid) was evaluated in the pelleted and powder forms. Both forms were used to treat the soil at rates of 10, 20 and 40 pounds per acre (ai) with two replications for each rate. Total number of sago pondweed crops completely killed by these treatments is shown in table 20. Also the average number of days required to produce a complete kill of each new planting for each test replication is given in this table.

The pelleted silvex treatments increased the average number of kills at the 20-pound rate from 2.5 to 4 and from 4 to 5 kills for the 40-pound rate. These results are in agreement with those obtained in 1963 (4) where monuron pelleted in a similar manner to the silvex showed some increased activity over the uncoated monuron. The data also indicate that the coated silvex produced kills in a shorter period of time during the latter part of the experiment. This would suggest that the coating furnished some degree of controlled release of the chemical to provide the more frequent periodic phytotoxic levels.

Other materials evaluated by the same procedure described above included pellets containing silvex and cuprous oxide (Cu_2O) and cuprous oxide alone. Coated pellets containing equal quantities of silvex and Cu_2O were tested at 10 and 20 pounds per acre (ai) rates for both materials. Addition of Cu_2O to the silvex pellet did not alter the effectiveness of the pellet to any extent from that obtained from the pellet containing silvex only.

Cuprous oxide in powder and pellet forms were applied to soil at 100 and 200 pounds per acre rates. These materials showed very little effect on the sago pondweed growth and produced no significant injury to the first crop of plants. These results indicate that copper compounds of low water solubility are not likely to show much activity on pondweeds when soil applied.

Table 20

TOTAL NUMBER OF CROPS OF SAGO PONDWEED ERADICATED BY SILVEX IN THE POWDER AND PELLET FORMS

Silvex formulation	Test No.	10 lb./A		20 lb./A		40 lb./A	
		Number of crops killed	Average number of days for 100-percent kill	Number of crops killed	Average number of days for 100-percent kill	Number of crops killed	Average number of days for 100-percent kill
Powder	1	2	69	2	55	4	57
			185		55		34
Do	2	2	—	3	[1] 92	4	54
							95
Pellet	1	2	75	4	59	6	57
			109	—	56	—	44
					70	—	44
Do	2	2	—	4	81	4	49
							[1] 28
							[1] 70

[1] Represents only 1 test.

Literature Cited

1. "How to Frustrate Weeds," Reclamation Era, Volume 50, No. 1, February 1964.

2. Unpublished.

3. Frank, P. A., N. E. Otto, and T. R. Bartley, "Techniques for Evaluating Aquatic Weed Herbicides," Weeds, Volume 9, No. 4, October 1961.

4. Otto, N. E., and T. R. Bartley, "Annual Progress Report of 1963 Laboratory and Field Studies on Aquatic Weeds," Report No. WC–13, U.S. Department of the Interior, Bureau of Reclamation, Division of Research, March 25, 1964.

5. Snedecor, G. W., "Statistical Methods Applied to Experiments in Agriculture and Biology," Fifth Edition, Iowa State College Press, 1956.

6. Hodgson, R. H., and N. E. Otto, "Pondweed Growth and Response to Herbicides under Controlled Light and Temperature," Weeds, Volume 11, No. 3, July 1963.

7. Bartley, T. R., "Physical and Chemical Properties Indicative of Good Hydrocarbon Solvents for Aquatic Weed Control in Irrigation Systems," Report No. SI–17, U.S. Department of the Interior, Bureau of Reclamation, Division of Engineering Laboratories, April 24, 1958.

8. Dimethyl Sulfoxide (DMSO), Technical Bulletin, Crown Zellerbach Corp.

9. Bartley, T. R., "Evaluation of Emulsifiers for Use with Aromatic Solvent Aquatic Weed Killers and Test Method Used for Evaluating Emulsifiers," Report No. W–1, U.S. Department of the Interior, Bureau of Reclamation, Division of Engineering Laboratories, October 31, 1961.

10. Unpublished.

11. Eriksen, Clyde H., "A Method for Obtaining Interstitial Water from Shallow Aquatic Substrates and Determining the Oxygen Concentration," Ecology, Volume 44, No. 1, 1963.

12. Rainwater, F. H., and L. L. Thatcher, "Geological Survey Water Supply Paper 1454," U.S. Department of the Interior, Geological Survey, 1960.

13. Ellis, M. M., B. A. Westfall, and D. E. Ellis, "Determination of Water Quality," Research Report 9, U.S. Department of the Interior, Fish and Wildlife Service, 1948.

14. "Specifications for Vinyl-resin Paint, VR–6," U.S. Department of the Interior, Bureau of Reclamation, July 6, 1960.

ABSTRACT

Progress of various Bureau of Reclamation laboratory studies concerned with submersed aquatic weed problems are covered. Results summarized are not considered conclusive and generally require further investigation. Low-rate, long contract period treatments with acrolein in a flowing water situation caused a significant reduction in the total plant dry weight and vegetative propagule production of pondweeds. Weekly injury and regrowth estimates for 4 weeks following acrolein treatments describe the trends of pondweed response to the acrolein treatments. Results of recent herbicidal evaluation tests did not reveal any compound of promise for aquatic weed control. Two formulations of endothal exhibited good algaecidal activity on filamentous green algae in laboratory tests. The phytotoxicity of xylene-type aquatic herbicides was not enhanced by the use of selected additives. Greenhouse tests show that the herbicidal activity of xylene was reduced when emulsifier concentrations of less than 1.0 percent, volume to volume, were used. Techniques for repeated sampling of soil-water in fixed sites of aquatic soils and subsequent microanalyses for dissolved oxygen and alkalinity were evaluated and found suitable. Exploratory studies on the location and extent of subterranean sago pondweed tuber growth in culture aquaria did not appear to bear any relationship to soil type or dissolved oxygen content and alkalinity of interstitial soil-water. Silvex acid coated with vinyl resin was superior to the uncoated acid in total number of crops of sago pondweed killed at the higher rates of soil application.

DESCRIPTORS—*algae/*aquatic weeds/*dispersing agents/*water quality/*emulsion/*aromatic solvent/*temperature/*herbicides/soil treatment/toxicity/weed control/cultures/*ecology/dissolved oxygen/*limnology/biology/aquatic life/vinyl plastics/irrigation O&M/*chemical analysis/plant/growth/botany.

IDENTIFIERS—Algaecidal and herbicidal evaluation/emulsion stability/pelletized herbicides.

U.S. GOVERNMENT PRINTING OFFICE: 1966 O—788-773