Elodea Control In Southeast Florida With Diquat

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ABSTRACT

Results are presented from a series of 25 field trials where 6,7-dihydrodipyrido-(1,2-a:2′,1′-c) pyrazidiinium salt (diquat) alone and in combination with copper sulfate was applied for control of Florida elodea (*Hydrilla verticillata*) in Southeast Florida. Where water was static and where heavy rainfall did not dilute the treatment within 48 hours after application, control of Florida elodea was achieved with diquat and diquat plus copper sulfate. Density of Florida elodea infestation was shown to be an important factor in the determination of chemical rates required for control. Water properties (hardness, nitrate concentration, pH and turbidity), method of application

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and algal and marl deposits did not appear to affect the activity of diquat or diquat combinations. Reinfestation of treated canals, free of Florida elodea stems and leaves, was observed. This reinfestation was found to occur from underground vegetative propagules of Florida elodea. No effects on the fish population were observed during the trial series. Successful practical application of these findings has been made in Dade County, Florida.

INTRODUCTION

In past years, the use of herbicides has been advocated for control of submersed aquatic weed problems in the drainage canals of Southeast Florida. Submersed weed growth has increased rapidly in these canals over the past decade. Blackburn (1) states that "as canals are completed, they are rapidly infested with submersed weeds." At this time, Florida elodea (*Hydrilla verticillata*), formerly identified as American elodea (*Elodea canadensis*) (2), represents the climax vegetation in the majority of these canals. In this paper, Florida elodea will be referred to as elodea. Southern naiad (*Najas guadalupensis*) is no longer a major problem in the large canal systems of Southeast Florida.

Elodea is a perennial, submersed aquatic plant which has become a major aquatic weed problem throughout Southeast Florida. The general shape of the elodea plant is elongate. A branched stem supports whorls of four to five lanceolate, translucent, dark green leaves (Figure 1). The density of these whorls increases towards the stem tips, particularly in female plants.

Where the elodea strands grow in deep water, the whorls at the base of the plant may be 6 inches apart (Figure 2). The individual leaf margin is serrated and there is a serrated ridge on the underside of the midrib. These serrations are visible to the naked eye and are prickly to the touch. The stem of elodea is cylindrical.

Elodea is reproduced vegetatively. Flowers appear at certain times of the year towards the tip of the elodea stem. A minute flower is supported on the end of a long, spindly peduncle. Seeds may be produced occasionally, but these do not represent a significant method of elodea reproduction.

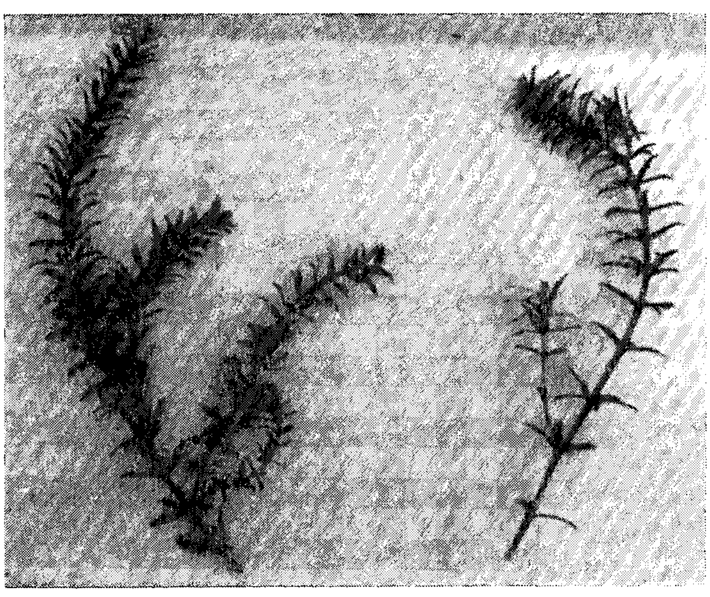

Figure 1. Apical section of stems of Florida elodea.

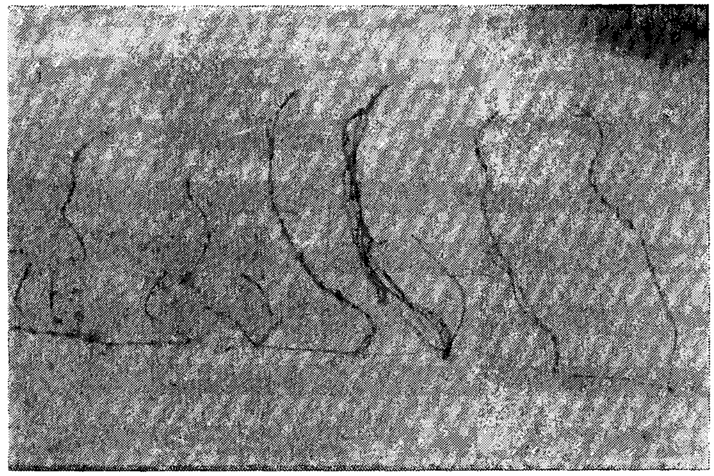

Figure 2. Florida elodea plant showing several strands joined by stolons.

It is assumed that spread of elodea infestations is furthered only by stolons (Figure 2) or by growth from the nodes of stem fragments of elodea.

The elodea plant is generally rooted by means of long, fine, white adventitious roots which anchor the plant firmly to the bottom of the canal or other body of water.

Elodea is capable of thriving in hard water. Where growing in hard water a precipitate of calcium carbonate often forms a dense coating or deposit on elodea leaves. This is the result of utilization of CO_2 from the surrounding water for photosynthesis.

Elodea forms dense mats. The portion of the plant towards the stem tips can completely occupy the top 12 inches of water. Lower portions of the plant are less dense due to the widely separated leaf whorls. Individual plants were observed to grow in 20 feet of water.

The primary canal system of Southeast Florida is under the control of the Central and Southern Florida Flood Control District (hereafter C&SFFCD). Secondary canals and fill canals are under the control of various county, municipal and private authorities. The C&SFFCD has approximately 1,150 miles of canal under its jurisdiction with more mileage planned. The Metropolitan Authority of Dade County, Department of Public Works, Water Control Section (hereafter Dade County) has approximately 200 miles of canal under its jurisdiction. The system has partly been constructed for drainage and has partly been created by the need for rock and land fill. In addition, there are many residential lakes with submersed aquatic weed problems.

The severity of submersed weed infestations in the primary drainage canals has necessitated the use of mechanical weed control devices. The ploughing of these canals by dragging a toothed, metal A-frame along the bottom behind an amphibious vehicle is an extremely expensive and inefficient method of weed control. Draglines are also employed. Maintenance and labor requirements are high. Annual cost per mile of canal cleaned amounts to a minimum sum of $500. In addition, the use of ploughs or draglines tends to assist the spread of submersed weeds throughout the canal system.

Crop Research Division, Agricultural Research Service, U.S. Department of Agriculture at Ft. Lauderdale, Florida, has evaluated many chemicals for the control of submersed aquatic weed problems in Southeast Florida. Promising candidate herbicides have been tested on a field scale. 6,7-dihydro-dipyrido (1,2-a:2', 1'-c) pyrazidiinium salt (diquat) was one of the herbicides found to have activity on submersed weeds. Control of Elodea with diquat in the laboratory was not as spectacular as control of southern naiad or coontail (*Ceratophyllum demersum*). Under Southeast Florida conditions, elodea was found to be less susceptible to diquat than naiad or contoontail (2) Research workers were sufficiently encouraged to utilize diquat in many field studies for the control of elodea.

Previous tests had indicated the diquat was generally not effective for elodea control in Southeast Florida. Research workers have advanced various hypotheses to explain why diquat, an efficient elodea control chemical in Northern areas of the United States (3, 4) was less effective under Florida conditions. The possibility of deposits on plant leaves interfering with diquat uptake by the plant and lack of adequate exposure time may have been the cause of poor elodea control (5).

It was noted that elodea control with diquat obtained by Dade County from 1963 to 1965 was erratic. Diquat was applied at 0.5 ppm in canals at Ludlam Glades, Coral Gables, and Melrose for control of elodea. Control was obtained for a minimum of one year at these sites. Application of the same rate of diquat, during 1965 in the Westwood Lakes and Carol City areas resulted in less than 3 months control.

These variations resulted in a lack in confidence in diquat for elodea control in Southeast Florida. The 1966 trial series and studies were established with the objective of discovering the reasons for the erratic results and establishing reliable control methods (6).

MATERIALS AND METHODS

The chemicals utilized in the 1966 trials for elodea control are found in Table 1.

TABLE 1. Chemicals Utilized in Elodea Control Trials—S. E. Florida, 1966.

Product	Chemical Name or Formula
ORTHO Diquat Water Weed Killer	6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazidiinium dibromide.
Copper Sulfate Crystals	CuSO4, 5 H_2O

Field Trials with Diquat and Copper Sulfate for Control of Elodea, Southeast Florida.

Thirty-four separate trials were established during 1966 in Dade County, Florida. Twenty-five of these trials will be referred to in this report. The other twelve trials involved chemical rates and combinations in an early stage of development. A description of each trial is given in Table 2. The canals varied in depth from five to twenty-five feet and in width from 30 to 80 feet. The length of canal which was treated varied from 220 to 3900 feet. Trial 10 was made cooperatively with C&SFFCD. All other trials were applied with Dade County spray boats and equipment. This equipment consisted of a 100 gallon spray tank with paddle agitation, a 5 gallon per minute spray pump and a hand held spray gun. In addition, injection equipment was devised from ½ inch iron piping. In Trials 4, 5, 9 and 10 a double pipe system was used. Two six-foot lengths of piping were connected to the regular spray hose by means of a single pipe with shut-off valve. In other injection treatments, a single open-ended ½" pipe with a right angle bend was utilized.

The chemicals were applied as dilute solutions. The 100 gallon spray tank was half filled with Diquat or Diquat combinations, agitated and then completely filled. The dilution factor was based on size of canal to be treated. In general, 100 gallons of spray solution were applied to a half acre of canal surface. The amount of chemical in ppm was calculated on the basis of weight of water in a given canal section and weight of chemical to be applied (ppmw).

In the first 19 of the 34 trials, water samples were taken at the time of treatment and in 14 of these trials at various intervals after treatment. Analyses for dissolved oxygen, turbidity and pH were carried out immediately after sampling on the canal bank using a portable water testing laboratory. Analyses for calcium hardness, total hardness, total alkalinity, nitrate and phosphate were made at a later date by the Applied Research Laboratories of Hialeah, Florida. Further reference will not be made to the results of analyses for dissolved oxygen, calcium hardness, total alkalinity and phosphate.

Water chemistry (pH, nitrate, total hardness, etc.) was measured as a factor that may influence the effectiveness of diquat on elodea. Hydrogen ion concentrations (pH) above 11 or extremely turbid water (4) could deactivate diquat. Total hardness has been considered as one of the reasons for poor results with diquat in this area. Nitrate was measured to determine water fertility and pollution (7). Water temperatures were taken at 1 foot below the water surface.

On the basis of practical experience and observations, control of elodea was considered commercially successful when 70% of the original infestation was eradicated. If the 70% level of control continued for 90 days or if the original infestation was eradicated, control was considered successful. Overall observation of the 1966 trials indicated that where over 70% control was maintained for more than 90 days, reappearance of elodea was due to reinfestation from underground, vegetative propagules.

Flow of water in canals or heavy rainfall within 48 hours after canal treatment can drastically affect diquat applications by lessening plant exposure time. Laboratory studies in Southeast Florida have shown that a 48 hour period of exposure of elodea plants to diquat is necessary to obtain maximum effect. This is particularly true of applications of diquat at 0.5 ppmw (5). Removal or dilution of applied diquat will result in poor elodea control. Flow could not quantitatively be measured in these trials. A visual estimate of flow was made at each treatment and was included in these comparisons. Rapid water movement through culverts or canals was observed by the movement of sand particles deposited in the canal by hand. Horizontal movement of these particles in the water at the point of application represented rapid flow. A vertical movement downwards through the canal represents no water flow. Deposits on the plants consist of marl (calcium carbonate) or algae (filamentous algae). These were evaluated visually on a 1 to 5 scale as zero, trace, slight, medium and heavy deposits.

In several canals higher submersed plants such as cabomba (*Cabomba caroliniana*), coontail, and pondweed (*Potamogeton illionoensis*) were present. Duckweed (*Lemna* spp.) was also observed at several trial sites.

TABLE 2. Details of 22 Field Trials Established in Dade County, Florida, 1966.

Month of Initiation	Trial No.	Trial Location	Rate Diquat cation ppmw	Application Method	Percent Elodea Infestation[a]	Deposits on Elodea		Previous History of Canal
						Calcium	Algae	
January	1	Andover "A"	0.5	Hose-on	30	Zero	Medium	No diquat cation
	2	Carol City "A8"	0.5	Hose-on	75	Slight	Heavy	No diquat cation
	3	Heftler Homes "N"	0.5	Hose-on	100	Medium	Heavy	1965—diquat cation 0.5 and 1.0 ppmw. Poor control.
February	5	Carol City "Realsite"	0.5	Inject in wake of boat	35	Zero	Slight	1965—diquat cation 0.5 ppmw. Poor control.
March	9	Heftler Homes "H"	0.5	Inject	90	Trace	Heavy	1965—diquat cation 0.5 ppmw. Poor control.
	3a	Heftler Homes "N"	0.5	Inject	20	Medium	Medium	1965—diquat cation 0.5 and 1.0 ppmw. Poor control.
	10	Tamiami Trail	0.5	Ploughed then Inject	10	Zero	Medium	No diquat cation
				Inject	50	Zero	Medium	
	11	Heftler Homes "M"	0.5	Inject	60	Zero	Slight	No diquat cation
	13	58th St. Canal	0.5	Inject	80	Medium	Medium	No diquat cation
April	14	Coral Gables Loop	0.5	Various	100	Trace	Medium	1964—diquat cation 0.5 ppmw. Good control.
	15	Heftler Homes "H"	0.5	Hose-on	60	Medium	Medium	No diquat cation
	16	Heftler Homes "H"	0.5 + 0.5 copper sulfate	50% Hose-on	70	Medium	Slight	1964—diquat cation 0.5 ppmw. Poor control.
			1.0	50% Inject	75	Medium	Slight	1965—diquat cation 0.5 and 1.0 ppmw. Poor control.
	17	Carol City "A9"	0.5 + 0.5 copper sulfate	50% Hose-on 50% Inject	95	Medium	Heavy	1965—diquat cation 0.5 ppmw. Poor control.
	2a	Carol City "A8"	0.5	Hose-on	35	Slight	Heavy	No diquat cation
April	19	117th Ave. Canal	1.0	Inject	80	Medium	Medium	No diquat cation
May	14a	Coral Gables Loop	0.5 + 0.5 copper sulfate	Hose-on	70	Trace	Slight	1964—diquat cation 0.5 ppmw. Good control.
June	21	Carol City "A5"	1.0 + 1.0 copper sulfate	Hose-on	70	Zero	Medium	1965—diquat cation 0.5 ppmw. Poor control.
	22	82nd Ave. Canal	0.25 + 2.0 copper sulfate	Hose-on	75	Medium	Zero	No diquat cation
July	24	Kendall Gardens	0.5 + 0.5 copper sulfate	Hose-on	40	Trace	Trace	No diquat cation
September	27	Westwood Lakes "B"	0.5 + 0.5 copper sulfate	Hose-on	80	Heavy	Heavy	No diquat cation

[a]Percentage of canal volume occupied by elodea.

Weather at Miami Airport, Miami, Dade County, Florida 1966.

Data from the Miami airport weather station was utilized as it was central to the trial sites. Examination of data from other sites within the general area did not reveal any large variation. In general, rainfall in 1966 was above average for this area (Table 3). This was particularly true in June, July, and August. June rainfall set a record for the month.

The influence of this high rainfall was very evident. For extended periods during the summer months, flood gates had to be left open for water flow. Despite this, widespread flooding occurred in many areas of Miami. Strong flow conditions occurred in the majority of canals during the summer and autumn months of 1966. The departure of the precipitation from normal as shown in Table 3 does not wholly reflect the great differences in rainfall when 1966 is compared to the early years of the 1960s, or to 1967.

Air temperatures were only slightly below normal in 1966.

TABLE 3. WEATHER AT MIAMI AIRPORT, FLORIDA, 1966

Month	Average Temp. (°F)	Departure From Normal (°F)	Rainfall (inches)	Departure From Normal (inches)	Days Over 0.1" Rain
Jan.	66.0	−0.9	3.97	+1.94	5
Feb.	68.9	+1.0	6.56	+4.69	3
Mar.	69.2	−1.3	3.25	+0.98	3
Apr.	72.8	−1.4	1.80	−2.08	3
May	77.6	0	5.53	−0.91	6
June	78.2	−2.6	21.37	+14.00	21
July	81.1	−0.7	8.50	+1.75	18
Aug.	81.7	−0.6	7.62	0.65	12
Sept.	81.2	−0.1	8.00	−1.47	17
Oct.	77.9	+0.1	10.88	+2.67	9
Nov.	70.2	−2.2	3.84	+1.01	4
Dec.	66.6	−1.5	0.74	−0.93	1

RESULTS AND DISCUSSION

Field Trials with Diquat and Other Chemicals for Control of Elodea in Dade County, Southeast Florida.

In the results, control is expressed as number of days when amount of elodea was less than 30% of original infestation. Evaluations of control were made from January, 1966 to January, 1967. The infestation of elodea represents the volume of canal filled with elodea plants.

Applications of diquat at 0.5 ppmw have been tabulated in Table 4. Examination of results achieved when 0.5 ppmw diquat was applied reveals the following:

1. Success was achieved where water was static.
2. At 0.5 ppmw of diquat elodea infestations lower than 70% were controlled effectively.
3. Control of elodea was achieved by diquat alone when calcium deposits were covering elodea leaves.
4. Algae deposits on leaves did not appear to interfere with control.
5. Hose-on treatments were as successful as sub-surface injection treatments.
6. Water quality did not appear to affect success or failure.

Comparisons of diquat-copper sulfate combinations are given in Table 5. The following statements summarize the results of these combinations:

1. The addition of copper sulfate did not minimize the effects of flow.
2. It was observed in Trials 16 and 17 that addition of copper sulfate to diquat accomplished quicked knockdown of elodea.
3. It cannot be said with certainty that quicker disintegration of the affected plants resulted from such combination treatments.
4. In Trial 16 complete control of a 95% infestation was achieved.

Further evaluation of diquat-copper sulfate combinations should be made. Blackburn (2) has not shown such excellent results with diquat-copper sulfate combinations.

Failures in his series of studies on Florida elodea have occurred where 100% infestation of elodea have been treated with single applications of diquat at rates generally higher than those used in the 1966 trials. Blackburn has always obtained some effect on elodea from diquat treatment. It is thought that, if retreatment of this reduced elodea stand were made before regrowth started, more successful results could have been obtained. Possibly if the 1.0 ppmw diquat cation used by Blackburn had been combined with 1.0 ppmw of copper sulfate and applied as a split application, superior control of elodea would have been achieved.

A final comparison has been made between the completely successful trials and the complete failures. In this comparison any "borderline" trials have been excluded. Only where clear-cut elodea control has been achieved has a trial been labeled a success. Only where a real failure to control elodea has been observed has the trial been included in Table 6.

It can be observed that success was characterized by the following factors:

1. Lack of water flow in canal or rainfall immediately after application.

TABLE 4. RESULTS FROM FIELD TRIALS WHERE 0.5 PPMW DIQUAT CATION WAS UTILIZED FOR ELODEA CONTROL, 1966.

Trial No.	Application Date	Rate Diquat cation ppmw	Application Method	% Elodea Infestn.	Days over 70% Control[1]	Deposits on Elodea: Calcium	Deposits on Elodea: Algae	Water Movement	Water Properties: pH	Conc. in ppm: Turbidity	Conc. in ppm: Total Hard.	Nitrate
A. *Success*												
1	January	0.5	Hose	30	295/300	Zero	Medium	None	8.0	10	230	0.58
2a	April	0.5	Inject	35	230/240	Slight	Heavy	None	7.7	15	175	0.31
11	March	0.5	Inject	60	310/320	Zero	Slight	None	7.8	11	220	0.18
15	April	0.5	Hose	60	220/240	Medium	Medium	None	7.6	23	250	1.05
B. *Failure*												
3	January	0.5	Hose	100	45/57	Medium	Heavy	Strong	7.4	2	165	0.23
9	March	0.5	Inject	90	0/37	Trace	Heavy	Strong	8.3	18	175	0.3
10	March	0.5	Inject	50	0/38	Zero	Medium	Strong	7.7	18	205	0.13
13	March	0.5	Inject	80	0/77	Medium	Medium	Strong	7.6	22	225	0.22

[1]This is expressed as a ratio of Days over 70% control to days from application to January 1, 1967.

TABLE 5. RESULTS FROM FIELD TRIALS WHERE DIQUAT-COPPER SULFATE COMBINATIONS WERE UTILIZED, 1966.

Trial No.	Application Date	Rate Diquat cation ppmw	Application Method	% Elodea Infestn.	Days over 70% Control[1]	Deposits on Elodea		Water Movement	Water Properties			
						Calcium	Algae		pH	Conc. in ppm Turbidity	Conc. in ppm Total Hard.	Nitrate
A. *Success*												
14a	May	0.5 + 0.5 copper sulfate	Hose	70	230/240	Trace	Slight	None	----	----	------	------
17	April	0.5 + 0.5 copper sulfate	Inject + Hose-on	95	215/220	Medium	Heavy	None	8.3	20	140	0.35
16	April	0.5 + 0.5 copper sulfate	Inject + Hose-on	70	105/135	Medium	Slight	None	8.1	8	165	0.26
24	July	0.5 + 1.0 copper sulfate	Hose	40	170/180	Trace	Trace	None	----	----	------	------
B. *Failure*												
126	June	1.0 + 1.0 copper sulfate	Hose	35	10/90	Slight	Medium	Heavy rain dilution	----	----	------	------
21	June	1.0 +1.0 copper sulfate	Hose	70	0/84	Zero	Medium	Heavy rain dilution	----	----	------	------
22	June	0.25 + 2.0 copper sulfate	Hose	75	56/108	Medium	Zero	Heavy rain dilution	----	----	------	------
27	Sept.	0.5 + 0.5 copper sulfate	Hose	80	20/60	Heavy	Heavy	Heavy rain dilution	----	----	------	------

[1]This is expressed as a ratio of Days over 70% control to days from application to January 1, 1967.

TABLE 6. COMPARISON OF COMPLETELY SUCCESSFUL AND COMPLETELY UNSUCCESSFUL TRIALS, 1966.

Trial No.	Application Date	Rate Diquat cation ppmw	Application Method	% Elodea Infestn.	Days over 70% Control[1]	Deposits on Elodea		Water Movement	Water Properties			
						Calcium	Algae		pH	Conc. in ppm Turbidity	Conc. in ppm Total Hard.	Nitrate
Successful												
1	January	0.5	Hose	30	295/300	Zero	Medium	None	8.0	10	230	0.58
2	January	0.5	Hose	75	300/320	Medium	Heavy	None	8.2	20	160	0.66
2a	April	0.5	Inject	35		Slight	Heavy	None	7.7	15	175	0.31
11	March	0.5	Inject	60	310/320	Zero	Slight	None	7.8	11	220	0.18
14	April	0.5	Hose	100	230/270	Trace	Slight	None	7.8	20	170	0.31
14a	May	0.5 + 0.5 copper sulfate		70								
15	April	0.5	Hose	60	220/240	Medium	Medium	None	7.6	23	250	1.05
16	April	0.5 + 0.5 copper sulfate	Inject + Hose	70	105/135	Medium	Slight	None	8.1	8	165	0.26
17	April	0.5 + 0.5 copper sulfate	Inject + Hose	95	215/220	Medium	Heavy	None	8.3	20	140	0.35
24	July	0.5 + 1.0 copper sulfate	Hose	40	170/180	Trace	Trace	None	----	----	------	------
Unsuccessful												
9	March	0.5	Inject	90	0/37	Trace	Heavy	Strong Flow	8.3	18	175	0.31
10	March	0.5	Inject	50	0/38	Zero	Medium	Strong Flow	7.7	18	205	0.13
13	March	0.5	Inject	80	0/77	Medium	Medium	Strong Flow	7.6	22	225	0.22
19	April	1.0	Inject	80	0/46	Medium	Medium	Strong Flow	7.5	24	210	0.35
21	June	1.0 + 1.0 copper sulfate	Hose	70	0/84	Zero	Medium	Heavy rainfall	----	----	------	------
22	June	0.25 + 2.0 copper sulfate	Hose	75	56/108	Medium	Zero	Heavy rainfall	----	----	------	------

[1]This is expressed as a ratio of Days over 70% control to days from application to January 1, 1967.

2. Failure of 0.5 ppmw diquat cation alone to control very dense infestations (above 70%).
3. Success of split applications of 1.0 ppmw diquat cation and/or diquat-copper sulfate to control such dense infestations. Trials 2 and 14 are examples.
4. Application method did not effect control.
5. Deposits of calcium and algae or both on elodea leaves did not interfere with success.

Lack of success was characterized by the following factors:

1. Presence of water flow in canal or dilution by heavy rainfall immediately after treatment.
2. Single applications of diquat alone at 0.5 ppmw cation on dense (above) 70% infestations.

Vegetative Propagules of Elodea in Southeast Florida

Control of elodea in the past has meant no more than control of vegetation present in the canal at the time of treatment. Observations in this study revealed that elodea found in Southeast Florida can reproduce not only from portions of the plant stem and by stolons, but also from vegetative propagules or tubers (Figure 4).

These propagules were found in the course of residue sampling activities in the bottom soil of the canals. It was thought that two types might exist. However, it now appears that one type of propagule is produced by the elodea plant. An underground stem produces this propagule initially (Figure 4).

This later becomes detached in the soil. A darkened portion of the propagule marks this point of attachment. The propagules are approximately 1/8" to 1/4" in length and half as broad as they are long (Figure 5). The end opposite the place of attachment is pointed. The propagule surface consists of a scale-like covering which varies from white to creamy-brown in color.

It is not known how long these propagules will remain dormant in the underwater mud of the canal. Neither is it known how long an elodea plant has to be established in an aquatic situation before it will produce such propagules. It is known that, after complete removal of the original elodea stand by diquat, reinfestation of the canal can occur from propagules. This reinfestation can be very rapid. It was observed in Trial 16, after complete eradication of elodea, that within one month after this eradication, strands of elodea were commencing to grow from the bottom of the canal towards the surface. Underwater investigations revealed that each strand emerging from the bottom had originated from a propagule. In other trials (1, 2 and 17) regrowth from propagules was much slower and confined to areas along the bank of the canal. Some propagules were found under rocks. The paragrass (*Panicum purpurescens*) and torpedograss (*Panicum repens*) growing along the banks appeared to restrict this growth. Retreatment of such new growth was necessary in Trial 1 eleven months after treatment. This treatment with diquat alone has been completely successful in control of elodea.

In the future, repeated treatment of new growth from propagules will be attempted in an effort to eradicate this source of reinfestation. It would appear that a treatment of elodea infestation should be practiced as early as possible in an effort to prevent propagule formation. This propagule formation appears to occur only after the elodea has become fully established in a particular body of water. Recent observations indicate that the establishment of propagules may occur in less than one year after invasion of a canal by elodea.

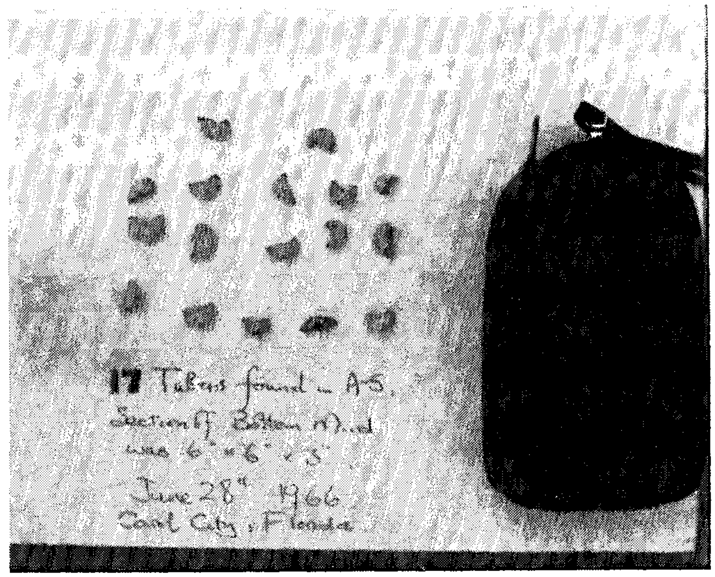

Figure 5. A collection of detached propagules of Florida elodea found in Dade County, Florida.

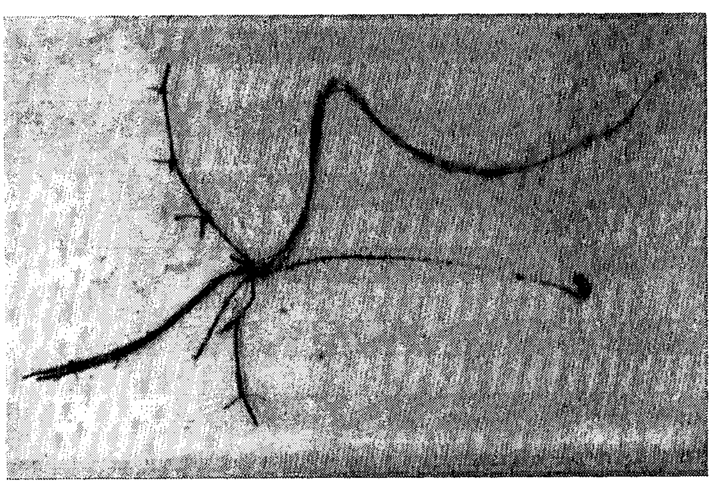

Figure 4. Propagule of Florida elodea shown attached to parent plant.

PRACTICAL APPLICATIONS OF DIQUAT PLUS COPPER SULFATE IN DADE COUNTY, FLORIDA

In November, 1966, Dade County carried out a series of canal treatments utilizing 0.5 ppmw diquat cation and 2.0 ppmw copper sulfate combinations. Results are presented in Table 7. Conditions of water movements were avoided and heavy rains did not occur. Under such conditions, successful control of Florida elodea has been achieved without deleterious effects to the fish population.

Corrosion of certain parts of the pump were observed with "in-tank" combination of diquat plus copper sulfate. Dade County has successfully applied copper sulfate by dragging the required quantity in a cotton bag behind the boat while applying the diquat solution through the pump. Corrosion due to diquat solutions was not noted in this test nor throughout the 1966 trial series.

TABLE 7. PRACTICAL APPLICATIONS OF DIQUAT PLUS COPPER SULFATE FOR ELODEA CONTROL, 1966.

Trial Number	Location	Days Over 70% Control[1]	Rate Diquat cation ppmw	Method	% Elodea Infestation	Deposits on Elodea Calcium	Algae
November							
27	Kendale Blvd. Canal	160/170	0.5 + 2.0 ppmw copper sulfate	Hose-on	25	Trace	Medium
29	Heftler Homes "L"	160/170	0.5 + 2.0 ppmw copper sulfate	Hose-on	60	Trace	Heavy
30	Heftler Homes "M"						
30	Heftler Homes "M"	160/170	0.5 + 2.0 ppmw copper sulfate	Hose-on	60	Trace	Heavy
31	Coral Park Estate	140/165	0.5 + 2.0 ppmw copper sulfate	Hose-on	50	Zero	Medium
November	(i and February (ii)						
32	Westwood Lakes Canals	140/160 (i)	0.5 + 2.0 ppmw copper sulfate	Hose-on	100	Heavy	Medium
		(ii)	0.5 + 2.0 ppmw copper sulfate	Inject	15	--------	--------

[1]As a ratio of Days over 70% control to days after application to May 1, 1967.

SUMMARY AND CONCLUSIONS

Control of elodea in Southeast Florida was achieved where water was static and where heavy rainfall did not dilute the treatment within 48 hours after application. Rainfall did not interfere with results as drastically as did rapid water flow in the canal. Even after 12" of rain had fallen in 24 hours, some knockdown of existing elodea was observed. Only where very rapid flow occurred was no effect recorded from a diquat treatment. This situation occurred in Trials 10 and 19. In every other case, some effect of diquat on elodea was noted.

Other factors did not affect success or failure as drastically as did flow or rainfall. Density of infestation is the one other factor which was shown to be of major importance. Diquat applications of 0.5 ppmw will affect a 100% infestation of elodea. "Follow-up' applications of 0.5 ppmw diquat or 0.5 ppmw diquat plus 0.5 ppmw copper sulfate, in Trials 2 and 14 respectively, did give complete control of vegetation remaining after the initial treatment. This split application technique was also utilized successfully in Trial 32. Infestations of elodea under 70% of the total volume of water were controlled by single diquat treatments even where deposits of calcium and algae occurred on the leaves of the elodea. Field observations tend to disprove the hypothesis that calcium and other deposits on elodea leaves interfere with the activity of diquat. No evidence in the "cleaned versus non-cleaned" study reported in 1966 (6) supported the hypothesis.

Water quality was not observed to affect diquat activity nor did method of application appear to drastically affect its activity.

Observations were made on the vegetative propagules of Florida elodea. These propagules were responsible for reinfestation of several canals where elimination of "above bottom" elodea stems had been achieved.

Observations of the field trials revealed that the chemical treatment did not effect fish present in the canals. The highest rates of chemical applied in 1965 were 2.0 ppmw diquat alone and 0.5 ppmw diquat plus 2.0 ppmw copper sulfate.

Practical applications of diquat plus copper sulfate as single and split treatments have been successfully made in Dade County.

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