Factors Affecting Control Of Florida Elodea With Diquat In Southeast Florida Canals

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ABSTRACT

Residues of 6,7-dihydrodipyrido[1,2-a:2',1'-c] pyrazidiinum salt (diquat) were found in three canals after treatment with 0.5 ppmw cation. Residue determinations were made on water samples taken at three depths in the profile, on whole plants of Florida elodea (*Hydrilla verticillata*) and on bottom soil samples. Residues varied with each canal and related to degree of control obtained. Successful control of Florida elodea with 0.5 ppmw cation was observed where plant density was low and water movement was absent. Differences in water chemistry were not responsible for the variation in degree of control of Florida elodea.

INTRODUCTION

Submersed aquatic plants have become a major problem in the maintenance of drainage canals in Southeast Florida during the past decade (1). Blackburn states (2) that "as canals are completed, they are rapidly infested with submersed weeds." A member of the Hydrocharitaceae family, Florida elodea (*Hydrilla verticillata*) has recently become the dominant submersed aquatic plant in these drainage canals. (3) This plant was formerly identified as American elodea (*Elodea canadensis* Michx.) Florida elodea is a perennial, submersed, aquatic plant. A branched, rounded stem supports whorls of four to five lanceolate, translucent drak green leaves. These leaves and stems may be coated with deposits of calcium carbonate and filamentous algae. The individual leaf has a serrate margin and a serrate ridge on the underside of the midrib. Florida elodea reproduces vegetatively from detached plant fragments, stolons or vegetative propagules. Dense infestations of this plant can completely occupy a canal. Growth of Florida elodea has been observed in water 20 feet deep. Lower portions of such growth have leaf whorls 6 to 8 inches apart, whereas at the surface leaf whorls are virtually contiguous. This terminal growth can form dense mats which completely covers the water surface.

Mechanical methods of control have been utilized with limited success in these canals. Results with diquat for submersed aquatic weed control in this area had been promising (4). In 1963, 1964 and 1965, 6,7-dihydrodipyrido-[1,2-*a*:2',1',-*c*]pyrazidiinium salts (diquat) was applied as a commercial treatment for elodea control in several canals.

This study was established in 1966 to determine the possible causes of the variations in control of Florida elodea with diquat. Field results of this study have been reported (3). The three trials, which represented part of the above study, were conducted to determine the inter-relationships between control of Florida elodea, disappearance of diquat residues and water quality.

MATERIALS AND METHODS

On January 18, 19, and 20, 1966, diquat was applied at 0.5 ppmw to three canals in Dade County, Florida. Diquat was applied as a dilute solution to the water surface in the test areas by means of a hand-held spray gun. A summary of trial details are listed in Table 1.

Residue Trial 1—This canal has steep soil sides and a sand bottom. Florida elodea was growing in dense mats along the edges of the canal. Filamentous algae was surrounding the elodea. No deposits of calcium carbonate were observed on the leaves. Water flow in this canal could not be detected.

Residue Trial 2—This canal has sloping marl rock sides and a sand bottom. Florida elodea was growing throughout the canal. Growth was less dense at the canal center. A dense covering of filamentous algae was associated with a slight sprinkling of calcium carbonate on the elodea plants. Water movement was not evident.

Residue Trial 3—This canal has steep marl rock sides and an organic-ooze bottom. This ooze is overlaid with a

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TABLE 1. Details of Residue Trials 1, 2 and 3, Dade County, Florida, 1966.

Residue Trial number	Canal Dimensions			Density of Elodea[1]	Location	Previous Diquat History
	Length	Width	Depth			
	feet	feet	feet			
1	2120	85	13	30	Andover "A"	No diquat
2	1500	45	6	75	Carol City "A8"	No diquat
3	1720	45	12	100	Hefler Homes "N"	Treated two times in 1965 without success

[1]Expressed as percentage of canal volume occupied by elodea.

clay. Florida elodea was growing throughout this canal. A dense covering of filamentous algae was associated with a heavy coating of calcium carbonate on the plants. Water movement was rapid for the duration of the experiment.

Sampling sites were established at three locations in each canal. Composite samples of water at three depths, bottom soil and Florida elodea were collected. Sampling dates were one day before treatment, one day after treatment, eight days after treatment, 15 to 16 and 22 to 24 days after treatment with diquat. Water samples were taken one foot below the surface, one foot from the bottom and at a point midway between these two locations. Water was collected with a Juday sampler. Bottom soil samples were collected by use of an Ekman dredge. Whole plant samples were taken by hand. Sampling was conducted at the same time of day in each individual trial. Water samples taken for diquat analyses were treated with 10 ml concentrated sulfuric acid to prevent loss of cation by hydrolysis. Plant and soil samples were frozen on the day they were collected. Pretreatment samples were used as a check and fortified samples in the diquat analyses. In Residue Trial 3, a pretreatment soil sample was obtained in a section of that canal system with a history of no diquat treatment.

Water, soil and plant samples were analyzed for diquat residues. A colorimetric method was used for water analysis.[1] In addition, water samples were analyzed for various characteristics. Dissolved oxygen content, pH, temperature, and turbidity were recorded at the time of sampling using a Hach Portable Field Kit. Alkalinity, total hardness, nitrate and phosphate determinations were measured by standard titration techniques at a later date. Control of Florida elodea was measured visually as percentage of original elodea infestation remaining after treatment.

RESULTS AND DISCUSSION

The 1966 study in Dade County, Florida, was established to investigate the reasons for the erratic behavior of diquat as a control agent for Florida elodea. Residue studies with diquat were established to determine whether the exposure of elodea to diquat was sufficient. Laboratory studies (5) have shown that a 48 hour exposure of Florida elodea to diquat is necessary for maximum phytotoxic effect. Field observations in Dade County (3) from a series of 25 trials indicated that static water (for at least 48 hours after treatment with Diquat) was necessary to achieve successful control of Florida elodea.

Examination of diquat residues over the water profile, (Table 2) reveals that in static water marginally infested with elodea (Trial 1) a rapid distribution of chemical occurred from water surface to canal bottom within 24 hours after application. Complete disappearance of residues in the water did not take place until after 14 days but before 21 days had elapsed. In the static, more densely infested Trial 2, diquat distribution was even and rapid. The diquat residues after 8 days were lower in trial 2 than in trial 1. At the 14 day interval no diquat residues could be detected. In contrast to Trials 1 and 2, Trial 3 was completely infested with elodea and water movement was rapid. A different pattern of diquat behavior can be detected in Trial 3. Stratification of applied chemical is shown at the 1-day sampling interval. A high concentration of chemical was found on the surface, but only a trace was detected at 12 feet. At eight days after treatment only a minute amount of diquat could be detected. No diquat residues were detected at the 2nd and 3rd week sampling dates.

[1]Chevron Chemical Company, Ortho Division, Richmond, California. Analysis of Diquat, Residue Method RM-5A.

TABLE 2. WATER SAMPLES—DIQUAT RESIDUES AS RELATED TO TIME AFTER TREATMENT AND DEPTH IN RESIDUE TRIALS 1, 2 AND 3.

Sample level in water profile	Residue Trial No.	Time After Treatment 1 day	8 days	2 weeks	3 weeks
		ppmw	ppmw	ppmw	ppmw
Top foot of water	1	0.28	0.10	0.06	0.00
	2	0.20	0.04	0.00	0.00
	3	0.24	0.00	0.00	0.00
Mid section of profile[1]	1	0.09	0.10	0.09	0.00
	2	0.26	0.03	0.00	0.00
	3	0.45	0.00	0.00	0.00
Bottom foot of water	1	0.27	0.11	0.07	0.00
	2	0.22	0.08	0.00	0.00
	3	0.01	0.01	0.00	0.00

[1]1 and 3—6 ft below surface
2—3 feet below surface.

Disappearance of diquat residues was slowest in Trial 1. This persistence was inversely related to the volume of weeds present at time of treatment. In trial 2, with its higher infestation (75% to 80%) of elodea, disappearance of diquat residues was more rapid. Distribution throughout the water profile of diquat applied to the surface was noted in both these static water canals. In Trial 3, poor distribution and rapid disappearance of diquat residues were observed. It is felt that the dense elodea infestation and rapid flow contributed to these results.

Diquat residues in elodea plants (Table 3) relate closely to the results discussed above for water samples with regard to diquat disappearance. In Trial 1, the elodea population had disintegrated completely by the two week sampling date. High levels of diquat were recorded for the one and eight day samples. It is reasoned that the quantity of elodea present was not sufficient to absorb all of the diquat applied to this canal. In Trial 2, although the diquat level in the plant reached 9.0 ppmw at eight days, plant knockdown was slower and complete disintegration never occurred.

TABLE 3. DIQUAT RESIDUES IN ELODEA BASED ON DRY WEIGHT AS RELATED TO TIME AFTER TREATMENT IN RESIDUE TRIALS 1, 2, AND 3.

Sample site	Time after Treatment 1 day	8 days	2 weeks	3 weeks
	ppmw	ppmw	ppmw	ppmw
Residue Trial 1 - treated area	9.08	11.55	Elodea eradicated	Elodea eradicated
Residue Trial 2 - treated area	6.58	9.23	6.63	4.90
Residue Trial 3 - treated area	0.17	0.06	0.04	0.04
Residue Trial 3 - area affected by flow from treated area	......	......	0.29	......

The difference in distribution of diquat in water between Trial 1 and 2 and Trial 3 is reflected in the elodea plant residue results from Trial 3. Very low (less than 0.2 ppmw) levels of diquat were detected in the plants at any sampling date. Uptake was limited although it is likely that upper plant sections contained a greater proportion of diquat. In an effort to evaluate the effect of rapid flow on chemical distribution in Trial 3, a plant sample was taken from outside the treated area. The highest residue level in Trial 3 was detected in this sample. Field observations confirmed this movement of diquat out of the treated area. Elodea knockdown was observed in an untreated section of the canal equal in length to that treated.

A relationship between diquat residues in bottom soil (Table 4) and in the water profile was noted. The soil samples were taken by a grab device. Depth control was not accurate and sampling variations did occur. Nevertheless, gross differences can be noted in the soil residue results. Diquat residues in Trials 1 and 2 increased after the one day sampling interval. By this time elodea plants were falling towards the canal bottom and were disintegrating. These data from Trials 1 and 2 are in quite close agreement with those reported from a Colorado pond by Frank (6). Results from Trial 3 indicate the short exposure time of the soil to diquat. Only at the two week sampling date was there any detectable residue in the bottom soil. It is possible that this residue was connected with elodea knockdown observed at that date.

Water chemistry analyses (Table 5) recorded during the course of the trials apparently do not follow any pattern connected with disappearance of diquat residues or elodea control. A turbidity increase would be expected to increase the rate of diquat disappearance from water (7). It is noted that in Trial 3 where turbidity was almost nonexistent that disappearance of diquat was most rapid. Nitrate and phosphate levels throughout the water profile decreased in each trial after treatment with 0.5 ppmw diquat. This result runs contrary to accepted belief that nitrate and phosphate levels will rise after aquatic weed growth decays or dies back (8). Other measures of chemical water quality shown in Table 6 did not vary from one trial to another. In summary, differences in diquat disappearance or elodea control between Trials 1 and 2 and Trial 3 could not be explained by water chemistry data.

TABLE 4. Bottom Soil Samples - Diquat Residues Based on Dry Weight as Related to Time after Treatment in Residue Trials 1, 2 and 3.

Residue trial number	Time after treatment			
	1 day	8 days	2 weeks	3 weeks
	ppmw	ppmw	ppmw	ppmw
1	0.33	3.52	6.84	3.98
2	0.85	3.68	2.60	3.14
3	0.00	0.00	1.74	0.00

TABLE 6. Water Samples—Range of Environmental Factors in Residue Trials 1, 2 and 3 Regardless of Depth or Time After Treatment.

Residue trial number	Temperature	pH	Total Alkalinity $CaCO_3$	Total Hardness $CaCO_3$	Ca Hardness $CaCO_3$
	°F		ppm	ppm	ppm
1	68-72	6.7-8.6	190-265	200-270	170-235
2	64-69	8.2-8.7	150-220	160-210	55-190
3	68-72	7.4-8.5	180-265	160-285	80-230

Control of Florida elodea with diquat has been discussed (3) previously. Field observations from a 25 trial series were utilized to draw certain conclusions with regards to factors which affect effectiveness of diquat application in Southeast Florida. Results from the diquat residue and water chemistry studies confirm these conclusions. It was concluded that major factors effecting control of elodea by diquat were water flow or rainfall and elodea density. Eradication of the existing stand of elodea was achieved in Trial 1 where density of infestation was low and water movement negligible. Residue data showed excellent distribution of chemical throughout the water profile associated with definite persistence over a 14-day period. In Trial 2 where elodea density was greater than in Trial 1 and water movement negligible, the same 0.5

TABLE 5. Water Quality Measurements for the 3 Trials.

Sample level in water profile	Residue trial no.	Dissolved Oxygen (ppm)					Nitrate (ppm)					Phosphate (ppm)					Turbidity				
		Pre	1 day	8 days	2 wks.	3 wks.	Pre	1 day	8 days	2 wks.	3 wks.	Pre	1 day	8 days	2 wks.	3 wks.	Pre	1 day	8 days	2 wks.	3 wks.
Top foot of water	1	8.0	7.0	5.0	7.0	8.0	1.32	1.28	0.44	0.27	0.22	0.58	0.48	0.30	0.32	0.31	10	20	10	25	32
	2	4.0	3.0	7.0	7.0	7.0	0.94	0.80	0.27	0.18	0.13	0.66	1.19	0.10	0.15	0.10	19	9	15	30	23
	3	10.0	6.0	6.0	7.0	6.0	0.14	0.51	0.20	0.11	0.10	0.20	0.26	T[1]	T	T	2	2	1	20	0
Mid section of profile	1	8.0	7.0	5.0	5.0	9.0	-----	2.00	0.33	0.35	0.35	0.40	0.46	0.20	0.30	0.20	11	22	22	22	33
	2	3.0	3.0	7.0	7.0	7.0	0.60	0.66	0.22	0.13	0.15	0.73	1.08	0.10	0.20	0.10	20	15	15	46	29
	3	6.0	4.0	4.0	5.0	6.0	0.29	0.22	0.27	0.09	0.11	0.21	0.16	T	T	T	0	0	0	19	0
Bottom foot of water	1	8.0	7.0	5.0	4.0	7.0	-----	1.19	0.27	0.33	0.35	0.70	0.55	1.00	0.20	0.20	13	25	21	25	37
	2	3.0	3.0	6.0	7.0	7.0	0.99	0.55	0.27	0.13	0.10	0.52	1.18	0.15	0.10	0.09	20	17	15	42	28
	3	5.0	2.0	4.0	4.0	2.0	0.30	0.30	0.20	0.11	0.20	0.25	0.17	T	T	T	2	0	0	20	7

[1]Trace amount

TABLE 7. FLORIDA ELODEA CONTROL—RESULTS IN RESIDUE TRIALS 1, 2 AND 3 TREATED WITH 0.5 PPMW DIQUAT, 1966.

Residue trial number	Infestation of Elodea	Deposits on Elodea Calcium carbonate	Algae	Control 1 wk.	2 wks.	3 wks.	6 wks.	8 wks.
	%			%	%	%	%	%
1	30 - marginal	None	Medium	75	99	100	100	100
2	75 - center open	Medium	Heavy	70	85	95	95	85[1]
3	100	Medium	Heavy	35	65	90	80	70[2]

[1]Retreatment with 0.5 ppmw diquat at 4 months gave 100% control for the remainder of 1966.
[2]Two retreatments at 0.5 ppmw diquat did not give saticfactory control in 1966.

ppmw rate of diquat resulted in less elodea control. Regrowth occurred two months after application. This regrowth of elodea was eradicated when a second treatment of 0.5 ppmw diquat was made. The more rapid disappearance of diquat residues in Trial 2 coupled with the lower levels of diquat in the plants relates closely to the higher density of elodea in the canal and hence, poorer control in comparison to Trial 1. In Trial 3, where elodea density was maximum and water flow was rapid, the slowest rate of elodea knockdown was observed. Regrowth commenced most rapidly at this site. These observations relate closely to the lack of persistence and low plant residue levels detected in the water and plants in Trial 3. Observations of elodea in an untreated section of the canal showed that knockdown was achieved to an equal degree by diquat moved from the treated area by water flow. Analysis of collapsing elodea plants from this untreated section (Table 3) showed a higher level of diquat present than in the treated section.

In conclusion, a relationship between persistence of diquat in the water profile and successful control was observed. Where density of plant infestation was greatest and where water flow was greatest, poor control of elodea was noted from 0.5 ppmw diquat. Where density of plant infestation was low and water movement was negligible, excellent control of elodea from 0.5 ppmw diquat was observed. In the former situation persistence of diquat in water were of a short duration and residues in plant and bottom soil were low. In the latter situation, persistence of diquat in water was longer and residues in plant and soil were at a higher level. Variations in water chemistry did not appear to affect elodea control with diquat.

ACKNOWLEDGMENTS

I acknowledge the assistance of Lamar Hall, Metropolitan Authority of Dade County, Florida; Robert Blackburn, A.R.S.—U.S.D.A., (Fort Lauderdale, Florida and their associates.

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