

Effects of Hydout and Aquathol K on Hydrilla in Gatun Lake, Panama

HOWARD E. WESTERDAHL

Research Ecologist,
Environmental Laboratory,
U.S.A.E. Waterways Experiment Station,
Vicksburg, Mississippi 39180

ABSTRACT

Three equivalent treatment rates of Aquathol K and Hydout were tested in the Frijoles Bay area of Gatun Lake, Panama, i.e., 27, 34, and 50 kg a.e./ha. Aquathol K and Hydout were effective at controlling hydrilla within the treatment plots. Aquathol K provided control within 24 to 72 hr posttreatment at each application rate. Hydout was much slower, requiring 14 to 21 days before hydrilla decline was evident at the two higher application rates. The 27 kg a.e./ha Hydout treatment showed only slight evidence of hydrilla defoliation and biomass reduction prior to plant regrowth to the water surface. Herbicide dispersion from the treated area was apparent during the first three days following treatment. Endothall was detected in the water from the buffer zones of plots treated with Aquathol K. Negligible endothall residues were found in the buffer zones surrounding the plots treated with Hydout throughout the 90 day posttreatment study period. Persistence of endothall in the water from plots treated with Aquathol K and Hydout was less than 7 days. Endothall persistence in sediment and plant tissue from plots treated with Aquathol K was approximately 3 and 7 days, respectively, and for more than 21 days from the Hydout-treated plots.

INTRODUCTION

Aquatic plant infestations of Gatun Lake have steadily increased since the Panama Canal was completed in 1914 to an areal coverage of more than 4900 hectares (ha). Hydrilla (*Hydrilla verticillata* (L.F.) Royle) and waterhyacinth (*Eichhornia crassipes* (Mart) Solms) are the major nuisance plant species. In April 1979, a cooperative field study involving Pennwalt Corporation, Panama Canal Commission, and the U.S. Army Engineer Waterways Experiment Station (WES) was initiated in the Frijoles Bay area of Gatun Lake, Panama. The objectives were to: evaluate the efficacy of two endothall formulations, i.e., Aquathol K and Hydout, for hydrilla control; evaluate the extent of herbicide dispersion in the test area; and, determine the persistence of herbicide residues in water, sediment and hydrilla.

Copper sulfate has been the principal herbicide for controlling hydrilla in these navigable waters primarily because it is inexpensive and readily available, although maintaining dry storage of this hygroscopic chemical has been a major problem in the tropical environment. Consequently, application of this chemical to infested areas of Gatun Lake

may have resulted in nonuniform application. Moreover, 200 to 800 kg/ha of copper sulfate have been required to achieve hydrilla control. These treatments must be repeated several times throughout the year in selected areas of Gatun Lake.

The two endothall formulations designated for this study were the dipotassium salt formulation and the dimethylalkylamine formulation of 7-oxabicyclo (2,2,1) heptane-2,3-dicarboxylic acid (Aquathol K and Hydout, respectively). The dipotassium salt formulation has a Federal registration for submerged aquatic plant control; the dimethylalkylamine formulation is registered in Florida, Georgia, and Texas under the 1974 Federal Insecticide, Fungicide, and Rodenticide Act's Section 24 (c). Results from operational use of these herbicides for controlling hydrilla suggested that these formulations may be cost competitive with copper sulfate for managing hydrilla in Gatun Lake.

The mode of action of endothall is not clearly defined. A summary of several studies (1) implicated inhibition of protein synthesis, retardation of lipid metabolism, and disruption of cell membranes. One of the most desirable characteristics of endothall is that it is rapidly and completely decomposed and no toxic intermediate compounds are known to form. The breakdown rate depends directly on water temperature and microbiological activity (2).

Specific objectives of this study were to: evaluate the efficacy of the dipotassium (Aquathol K) and dimethylalkylamine (Hydout) formulations of endothall for controlling hydrilla; evaluate the extent of herbicide dispersion in the test area; and, determine the persistence of herbicide residues in water, sediment, and hydrilla tissue within the test plots.

MATERIALS AND METHODS

Eight experimental plots, ranging in area from 1.2 to 1.8 ha and depth of 4 to 8 m, were selected in the Frijoles Bay area of Gatun Lake (Figure 1). Frijoles Bay water is considered soft with a hardness of 35-45 mg/l and alkalinity of 45-55 mg/l. Each plot was surveyed to ensure that approximately 90 percent of the water surface area was comprised of hydrilla. To minimize the chance of cross-contamination from plot to plot, the distance between each plot was maximized and, where possible, adjoining plots were separated by the river channel.

Water depth at each sampling station and water level elevation were recorded throughout the sampling program.

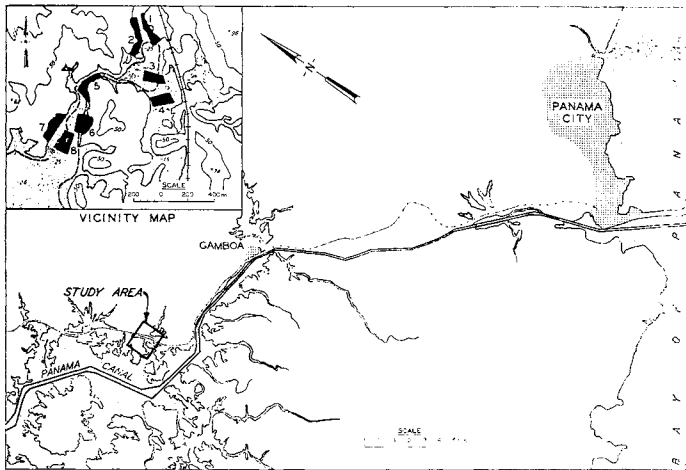


Figure 1. Area map of Gatun Lake, Panama, showing vicinity of Frijoles Bay and study area.

Throughout the sampling program, approximately 200 random water depth measurements per plot were made and isohyetal maps were drawn for each plot. The mean water depth for each of the eight plots was 3.9, 4.2, 3.5, 3.5, 5.0, 5.2, 3.9, and 3.5 m, respectively. The surface sediment was composed primarily of loose, organic detritus approximately 0.3 to 1.5 m thick. Below this layer was fine silt. Treatment plots 1, 2, 5, and 6 sloped toward the river channel, with maximum depths ranging from 10 to 15 m. The channel depth and bottom slope of each plot were defined since these influence the rates of endothall transport and dispersion in the water and subsequently affect the herbicide contact time with hydrilla (3). Gatun Lake water level fluctuations did not change more than ± 15 cm throughout the 6 month study period.

The specific endothall formulation and application rates were randomly assigned to six of the eight plots with the remaining two plots being reference or control plots. Specifically, TRT-1, -6, and -5 received dipotassium endothall at 27, 34, and 50 kg a.e./ha, respectively; and TRT-3, -7 and -2 received the dimethylaklyamine endothall at 27, 34 and 50 kg a.e./ha, respectively (Table 1). The reference plots were REF-4 and -8, although REF-4 was later discarded as a result of herbicide cross-contamination from an adjacent plot.

The liquid dipotassium endothall was applied approxi-

TABLE 1. COMPARISON OF ESTIMATED INITIAL ENDOTHALL CONCENTRATIONS (MG A.E./L) PRIOR TO AND FOLLOWING HERBICIDE APPLICATION OF 27, 34, AND 50 KG A.E./HA.

| | Dipotassium Endothall | | | Dimethylaklyamine Endothall | | |
|----------------------------|-----------------------|-------|-------|-----------------------------|-------|-------|
| | TRT-1 | TRT-6 | TRT-5 | TRT-3 | TRT-7 | TRT-2 |
| Pretreatment ^a | 1.0 | 1.5 | 2.0 | 1.0 | 1.5 | 2.0 |
| Posttreatment ^b | 0.7 | 0.7 | 1.1 | 0.6 | 0.9 | 1.1 |

^aThe concentrations and application rates were estimated following an operational site survey in which water depth, flow, and hydrilla infestation were assessed using visual observations and a few measurements of water depth and flow.

^bThe concentrations were computed based on plot surface area and approximately 200 water depth measurements obtained from each treatment plot during the posttreatment study period.

mately 1 m below the water surface using an airboat equipped with a conventional spray pump and four weighted trailing hoses. Dense hydrilla cover throughout the treatment plots prevented the trailing hose from delivering the herbicide near the sediment surface. The granular dimethylaklyamine endothall formulation was applied to the respective treatment plots using a blower-type spreader mounted on the bow of an airboat.

A simple randomized sampling program was selected for all measured parameters since the vegetation uniformly covered more than 90 percent of the surface area of all plots. The procedure for selecting a sampling site on each date required that a sequentially numbered and scaled 15 by 15 m grid overlay be placed on a drawing of each plot. The specific sampling grids for each date were selected from a random number table (4) and located in the field with a range finder and compass. Approximately 12 sampling grids per hectare were selected based on the estimated 12 plant biomass samples per hectare considered to adequately evaluate areal changes in standing crop or plant biomass.¹ Buffer zones, between the corner markers of adjacent plots, were sampled approximately 15 m perpendicular to the midpoint of each plot boundary to observe endothall drift and subsequent effects on vegetation.

The previously reported rapid uptake of endothall by hydrilla and its subsequent microbial decomposition in warm water (5, 6) required that frequent samples of water, sediment, and plants be obtained for herbicide residue analysis. These samples were collected at short intervals immediately following treatment and continuing throughout the study until the endothall concentration fell below detection limits (i.e. 0.01 mg a.e./l). Pretreatment sampling of each plot was completed immediately preceding treatment. Posttreatment samples were obtained on approximately day 1, 3, 7, 14, 21, 49, and 90.

A plant biomass sampler designed and developed by WES in cooperation with Allied Aquatics, Inc., was used to collect hydrilla at each sampling location (7). Each sample was removed from the bucket, washed to remove sediment, drained of free water. Each sample was weighed (accuracy: ± 45 gms) and recorded as wet weight.

Water samples from three randomly selected locations within each of the eight plots were collected using a 12-volt d-c Jabsco, Inc., pump attached to a weighted hose. Samples were taken at 0.3 and 2.0 m below the water surface and 0.5 m above the sediment. Each polyethylene sampling bottle was placed immediately in an ice-water brine solution and later frozen and stored until shipment to Pennwalt Corporation for endothall analysis (8).

Sediment samples were obtained by two divers who inserted an aluminum sampling tube (5-cm inside diameter) approximately 15 cm into the sediment at each sampling location within each plot. Contents of the sampling tubes were secured by placing plastic caps on each end. Each tube was placed immediately in an ice-water brine solution and subsequently frozen after returning from the field. The frozen sediment samples were packed on dry ice and shipped by air freight to Pennwalt Corporation for analysis (8).

¹Steward, K. K. 1979. Personal communication.

Approximately 1.0 kg wet weight of hydrilla tissue from each designated sampling location in each plot was collected using the biomass sampler as previously described. However, where the hydrilla growth was controlled effectively, an anchor attached to a dragline was used to obtain plant samples lying on the bottom surface. Plant samples were taken from a minimum of 10 locations within each plot on the specified sampling day. All samples were washed to remove sediment and drained of free water prior to storing on ice while in the field. Each plant sample was frozen immediately after returning from the field and packed in dry ice before shipment to Pennwalt Corporation for residue analysis (8).

RESULTS AND DISCUSSION

The results observed following treatment of TRT-1, -5 and -6 with the dipotassium salt of endothall were similar to those described in treated farm ponds in the United States (9). Rapid control of hydrilla was observed in each of the three plots within 3 days posttreatment (Figure 2). A statistically significant decline ($P < 0.008$) in hydrilla biomass occurred between posttreatment day 3 and 21 (Table 2). On posttreatment day 21, virtually no viable plant tissue could be obtained with the biomass sampler in these three plots. There was a statistically significant increase in endothall concentrations at the 2.0-m water depth in the

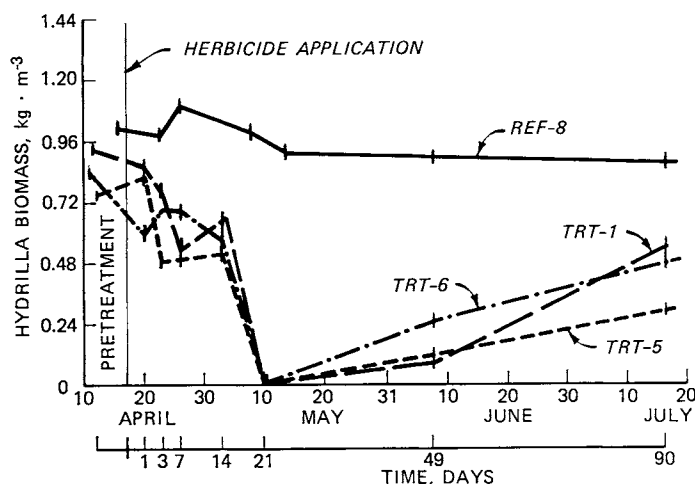


Figure 2. Effects of dipotassium endothall treatments on hydrilla biomass. Endothall application rates were: 0.7, 1.1, 0.6, and 0.0 mg a.e./l to TRT-1, -5, -6, and REF-8, respectively. Each point is the mean of approximately 15 replicate samples, i.e. 12 samples per hectare.

TABLE 2. LIST OF SIGNIFICANCE LEVELS (P) FROM THE T-TEST COMPARING TEMPORAL CHANGES IN HYDRILLA BIOMASS OF EACH TREATMENT PLOT TO REF-8.^a

| Plots Compared | Pretreat | Days-Posttreatment | | | | |
|----------------|----------|--------------------|--------|---------|---------|---------|
| | | 1 | 3 | 21 | 48 | 90 |
| REF-8 + TRT-1 | 0.329 | 0.234 | 0.238* | 0.001** | 0.001** | 0.002** |
| REF-8 + TRT-6 | 0.287 | 0.568 | 0.417 | 0.001** | 0.733 | 0.073* |
| REF-8 + TRT-5 | 0.145 | 0.202 | 0.098* | 0.001** | 0.004** | 0.000** |
| REF-8 + TRT-3 | 0.677 | 0.153 | 0.441 | 0.001** | 0.875 | 0.000** |
| REF-8 + TRT-7 | 0.439 | 0.768 | 0.517 | 0.001** | 0.058** | 0.000** |
| REF-8 + TRT-2 | 0.846 | 0.178 | 0.405 | 0.023* | 0.111* | 0.000** |

^a ** significant at $P < 0.008$ and * significant at $P < 0.10$.

buffer areas within 24 hr after treatment, providing evidence that endothall dispersed laterally as a density flow. These results are similar to those previously reported² based on approximately 100 field treatments of whole or partial bodies of water where the endothall concentration in the water decreased to less than 0.01 mg a.e./l within 48 to 72 hr posttreatment. One study investigated the disappearance of the dipotassium endothall formulation in farm ponds and found that endothall toxicity to plants was more rapid in soft water; water temperature did not affect endothall toxicity; and, the rate of endothall disappearance from the water column varied directly with the organic content in the water.

A maximum of 0.1 μg a.e. of endothall was found per gram of sediment from TRT-1, -5 and -6 during the first 72 hr following treatment (Figure 3). No detectable endothall residues were found thereafter. Hence, sediment endothall residues were considered to be very transitory.

Rapid absorption and concentration of endothall into plant tissue were observed in TRT-1, -5 and -6 followed by a gradual decline in concentration through post-treatment day 21 (Figure 4). The maximum endothall concentra-

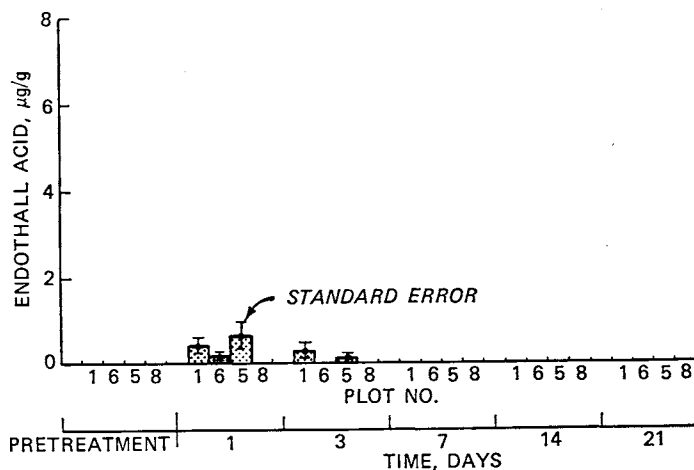


Figure 3. Endothall concentrations in sediment from TRT-1, -5, and -6 treated with the liquid dipotassium salt of endothall.

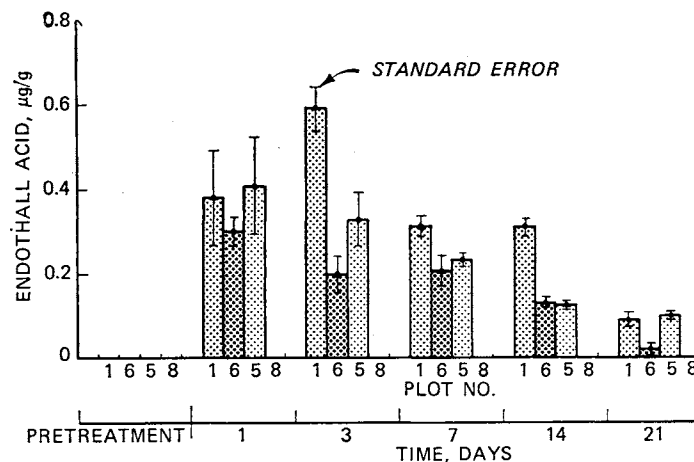


Figure 4. Endothall concentrations in hydrilla from TRT-1, -5, -6, and REF-8.

²Keckemet, O. 1980. Endothall and the environment. Presented at the Aquatic Plant Management Society, Annual Meeting, Sarasota, FL.

tions found in hydrilla tissue ranged from 0.4 to 0.6 μg a.e./g during the first 72 hr following treatment. Approximately 0.1 to 0.3 μg a.e. of endothall remained per gram of plant tissue through posttreatment day 21. These data suggest rapid endothall accumulation in hydrilla tissue followed by its slow metabolism in the plant, and a very slow release of endothall from decaying plant tissue. The original hydrilla biomass reappeared after 4 months had elapsed.

The granular, dimethylalkylamine formulation of endothall was also effective against hydrilla in TRT-2, -3, and -7, but control was much slower compared to dipotassium endothall (Figure 5). This formulation released endothall from the granule to the water at a very slow rate with subsequent rapid uptake by the hydrilla. A maximum endothall concentration in water of 0.18 mg a.e./l was detected in TRT-2, -3, and -7, representing less than 30 percent of the initial endothall concentration. By posttreatment day 14 endothall concentrations in all treatment plots were less than 0.05 mg a.e./l. The slow release of endothall from the granules minimized any potential for detecting transport and dispersion of this herbicide from the treated area, and provided longer contact time for absorption by hydrilla. The low endothall concentration available for plant absorption at a given time resulted in a much slower progressive plant kill.

Unlike the plots treated with dipotassium endothall, much higher endothall concentrations were found in sediment from the plots treated with the dimethylalkylamine formulation. Moreover, no statistically significant decrease ($P < 0.05$) in the mean endothall concentrations in sediment from each plot occurred throughout the 21 day post-treatment sampling period (Figure 6). The herbicide granules were observed embedded in the loose, amorphous organic sediments where they slowly decomposed and gradually released the endothall to the overlying water. The apparently slow release of endothall from the endothall granules embedded in the sediment may have been a result of endothall absorption to particulate organic matter in the

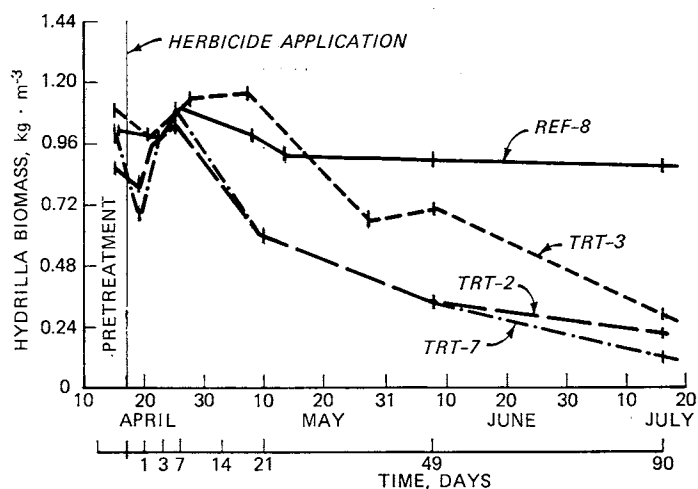


Figure 5. Effects of dimethylalkylamine endothall treatments on hydrilla biomass. Endothall application rates were: 1.1, 0.6, 0.9, and 0.0 mg a.e./l, respectively. Each point is the mean of approximately 15 replicate samples, i.e. 12 samples per hectare.

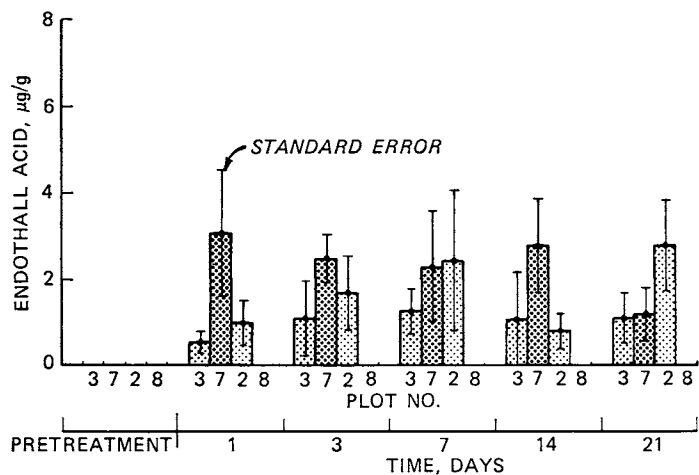


Figure 6. Endothall concentrations in sediment from TRT-2, -3, -7, and REF-8 treated with granular, dimethylalkylamine endothall.

sediment and diffusional transport into the overlying water or to the root surface where subsequent absorption would occur. Two observations support these assumptions. First, very low endothall concentrations remained in the water through day 21. Second, the gradual decline in hydrilla biomass over the entire 90-day posttreatment period suggested a much longer endothall persistence in this environment. The equivalent pretreatment hydrilla biomass did not reappear in the plots treated with dimethylalkylamine endothall until approximately 6 months following treatment.

High endothall concentrations in hydrilla tissue were measured within 24 hr following application to TRT-2, -3 and -7 and remained relatively constant through the 21-day posttreatment study period (Figure 7). The maximum endothall concentrations ranged from 0.4 to 0.7 μg a.e./g and occurred between posttreatment days 7 and 14. Likewise, approximately 0.1 to 0.3 μg a.e./g remained in the plant tissue on posttreatment day 21, although less than 0.01 mg a.e./l was found in the water. No statistically significant change in plant tissue endothall concentration occurred over the 21 day study period.

Endothall persistence exceeding 21 days in sediment and

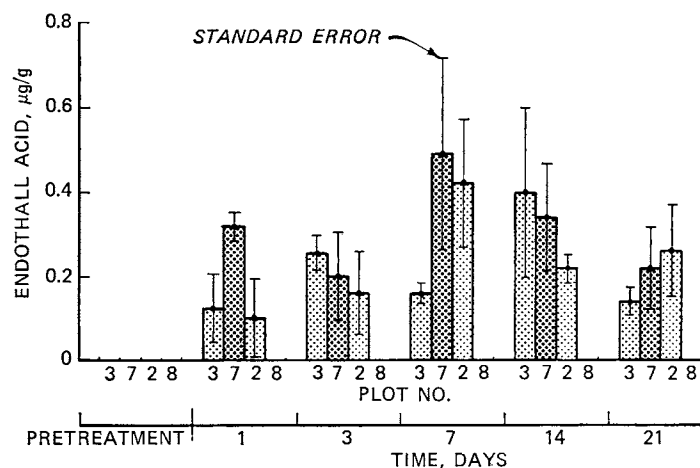


Figure 7. Endothall concentrations in hydrilla from TRT-2, -3, -7, and REF-8.

plant tissue was unexpected for this granular formulation based on previous field studies with endothall in the United States (9, 12). There are several possible explanations for endothall residue persistence in the sediment and hydrilla and the subsequent slow reduction of the hydrilla standing crop over the 3 month posttreatment period. One report² suggested that released endothall would be consumed or degraded by the microflora and fauna associated with the vegetation, resulting in no endothall accumulation in the water. However, results of this study suggest that any released endothall was rapidly adsorbed to the organic detritus and absorbed by hydrilla. Moreover, the gradual decline in hydrilla biomass suggests that the availability of endothall from the water for absorption by hydrilla was low, thereby minimizing plant uptake and subsequent microbial metabolism and decomposition of endothall (10, 11). Previous investigations (10, 11) have concentrated primarily on the microbial transformations of endothall in sediment with little emphasis placed on degradation by periphyton.

Based on this study, it appears that an initial application of the dipotassium endothall formulation to achieve rapid hydrilla control followed about one month later by a treatment with the dimethylalkylamine endothall formulation, could provide long-term hydrilla control exceeding six months duration.

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LITERATURE CITED

1. Simsimon, G. V., G. Chesters, and T. C. Daniels. 1972. Chemical control of aquatic weeds and its effect on the nutrient and redox status of water and sediments. Proc. 15th Conf. Great Lakes Res., pp. 166-180.
2. WSSA. 1979. *Herbicide Handbook*, 4th Ed. Weed Sci. Soc. of Amer., Champaign, Ill.
3. Serns, S. L. 1975. The effects of dipotassium endothall on the zooplankton and water quality of a small pond. Water Resour. Bull. 11(6):1221-1231.
4. Steel, R. G. D., and J. H. Torrie. 1960. *Principles and Procedures of Statistics*. McGraw-Hill Book Company, New York, New York.
5. Haller, W. T., and Sutton. 1973. Factors affecting the uptake of endothall — ¹⁴C by hydrilla. Weed Sci. 21:446-448.
6. Simsimon, G. V. 1976. Diquat and endothall: their fates in the environment. Residue Reviews 62:131-174.
7. Westerdahl, H. E. 1982. Field evaluation of two endothall formulations for managing (L.F.) Royle in Gatun Lake, Panama. Technical Report A- U.S. Army Engineer Waterways Experiment Station (In Press).
8. Carlson, R., R. Whittaker, and A. Landskov. 1978. Endothall. In: *Analytical Methods for Pesticides and Plant Growth Regulators*, Academic Press, Inc. pp. 327-340.
9. Yeo, R. R. 1960. Dissipation of endothall and effects on aquatic weeds and fish. Weed Sci. 18:282-284.
10. Sikka, H. C. and C. P. Rice. 1973. Persistence of endothall in aquatic environments as determined by gas-liquid chromatography. J. Agr. Food Chem. 25(5):842-846.
13. Jensen, H. L. 1964. Studies on soil bacteria (*Arthrobacter globiformis*) capable of decomposing the herbicide endothall. Acta. Agr. Scand. 14:193-204.