

Comparison of Two methods for Evaluating Growth of Hydrilla in Sediments Collected from Lake Okeechobee¹

DAVID L. SUTTON²

ABSTRACT

Sediments collected from Lake Okeechobee were processed in two ways prior to planting hydrilla (*Hydrilla verticillata* (L.f.) Royle). Hydrilla shoot dry weight was 1.6 to 2.7 times higher for plants cultured in sediments dried at 60 C, screened, and thoroughly mixed compared to similar plants cultured in sediment that remained moist and relatively undisturbed after collection from the lake. Mineral contents of the hydrilla tissue differed more due to plant section, shoots or roots, than due to the manner in which the sediments were processed after collection. The development of standard methods for the collection and processing of lake sediments will help provide uniformity among different research studies designed to evaluate the aquatic plant growth potential of various sediment types.

Key words: aquatic macrophytes, aquatic weeds, hydrosoil, nutrients, propagules, tubers.

INTRODUCTION

The role of sediment minerals in the growth of submersed aquatic plants has been the subject of discussion for many years (4, 5, 7), and it has become apparent that the concentration of certain minerals in the sediment plays a major role in their growth.

Barko (2) found open water to be the primary potassium source for growth of hydrilla, but the concentrations of nitrogen and phosphorus in the sediment were related directly to both growth and mineral tissue content of this plant. Likewise, hydrilla biomass was closely related to the concentration of phosphorus in rooting media differing in fertility and texture levels (9). Both of these studies (2, 9) stressed the need for additional research to evaluate the influence of sediment composition and sampling procedures on the growth of submersed plants.

Collection and storage of moist, undisturbed sediments is difficult, but sediments that have been dried are easy to

handle for use in growth experiments and for nutrient analyses, and they can be stored for a long time. Also, dry sediments which have been screened and mixed may be useful in comparative studies of plant growth with synthetic sediments composed of various soil types, nutrient levels, and clay and organic contents. Therefore, a study was conducted with the objective of comparing growth and mineral contents of a submersed plant in sediments collected from Lake Okeechobee and processed either "moist" or "dry," hereinafter referred to as moist and dry sediment, respectively. Hydrilla was chosen for culture on the sediments because it is a major weed problem and information on its growth in various sediments will be of interest to aquatic plant managers having problems with this aquatic plant.

MATERIALS AND METHODS

The core sampler described by Sutton (10) was used to collect sediment used in this study. The sampler allows for a core of 10.2 cm in diameter by approximately 20 cm in length. The length of the core depends on a number of factors such as the density and texture of the sediment which makes it difficult to obtain cores uniform in size.

The site chosen for collection of sediment was from Lake Okeechobee in an area approximately 200 m west and to the south of the bird watching tower located on the eastern berm of the Harney Pond Canal. Monocultures of hydrilla have grown in this area for over 20 years.

Cores of sediment were collected on May 9 and August 7, 1985, and January 30, 1986. At each sampling time, 16 cores were collected of which 8 were processed as moist sediment and 8 as dry sediment. Each core was randomly assigned a processing method prior to its collection.

Processing for the moist sediment condition consisted of slipping the sediment core from the sampler into a container constructed of standard irrigation polyvinylchloride (PVC) pipe with an inside diameter (ID) of 10.2 cm by 20 cm in length, the same dimensions as the core sampler, with one end of the pipe capped. Plastic wrap was secured over the open end of the container to prevent the sediment from drying and the samples were held at room temperature until hydrilla was planted. The sediments were held for 22, 34, and 32 days after collection on May 9 and August 7, 1985, and January 30, 1986, respectively.

Processing for the dry sediment condition consisted of placing a single core of sediment in a bucket with a lid and returning it to the Fort Lauderdale Research and Educa-

¹Contribution of the University of Florida's Fort Lauderdale Research and Education Center. Published as Journal Series Number 7757 of the Florida Agric. Exp. Sta. Primary support for this research supplied by the South Florida Water Management District. Partial support supplied by the Bureau of Aquatic Plant Research and Control of the Florida Department of Natural Resources, and the U.S. Department of Agriculture, ARS, under Cooperative Agreement No. 58-43YK-9-001. Received for publication July 14, 1989 and in revised form May 8, 1990.

²Professor, University of Florida, IFAS, Center for Aquatic Weeds, Fort Lauderdale Research and Education Center, 3205 College Ave., Fort Lauderdale, FL 33314.

tion Center (FLREC) where it was dried at 60 C. After drying, the sediments were sieved with a Number 10 mesh screen. Large debris such as rocks, sticks, and snail shells were removed. The screened material was thoroughly mixed and a 100-g sample removed for nutrient analyses. The remainder of the sediment was weighed and placed in PVC culture containers with dimensions the same as described for the sediments processed as moist.

Since the cores of sediments were assigned at random to the processing method, it is assumed the same amount of sediment was used for each processing method with the exception that 100 g was removed for nutrient analyses for the dry sediment. The average amount of dry sediment used for culture of hydrilla for the May 9 and August 7, 1985, and January 30, 1986 collection dates was $1,526 \pm 477$ g, $3,081 \pm 434$ g, and $4,141 \pm 203$ g, respectively.

Hydrilla was cultured in the sediments in an outdoor, circular, plastic-lined pool as described by Sutton *et al.* (13). Briefly, a pool with dimensions of 0.9 m in height by 3.6 m in diameter (which held 7,790 L of pond water at a depth of 76 cm) was used for culture of hydrilla in sediments from each collection period. Flow of pond water, from the same source as previously described (9), was sufficient to provide for an exchange of water every 24 hours.

Water temperature in the pool was recorded 5 days a week, generally at 4:00 p.m., with a maximum/minimum thermometer placed 30 cm below the surface of the water. Water temperature for a culture period was calculated as the mean of the maximum and minimum values obtained.

A total of 16 culture containers was used for each of three culture periods with an arrangement of two containers of each sediment processing type randomly assigned in each of four rows in the pool. Each culture container was planted with four sprouted tubers. Culture periods were as follows: May 31 to July 26, 1985; September 10 to November 5, 1985; and March 4 to April 29, 1986.

The sprouted hydrilla tubers were allowed to grow for 8 weeks after which the plants were removed from the culture pools and separated into shoot and root portions. The plant portions were washed with pond water to remove algae, sand, and other debris, and dried at 60 C to a constant weight. Plant material from the culture periods of May 31 to July 26 and September 10 to November 5, 1985 was ground to 40 mesh and digested with nitric and perchloric acids prior to nutrient analyses.

Digested plant material and dry sediment samples were analyzed by the University of Florida's Soil Testing Laboratory in Gainesville. The Kjeldahl method (1) was used to analyze the nitrogen in dry plant samples in our laboratory.

The Statistical Analyses System (SAS)³ software designed for use on Personal Computers was used to analyze plant dry weight, number of tubers and nutrient contents of plant material using Analysis of Variance (ANOVA) procedures, and MEAN procedures for the mineral contents of dry sediments. Hydrilla dry weights were converted to log values to stabilize the variance due to the wide differences in the values obtained for the three culture periods; however, the nontransformed values are presented. Count data for the tubers were transformed by adding 1 to each value and then taking its square root, a

standard transformation for count data (8), prior to analyses, but the nontransformed values are presented. Where appropriate, the Waller-Duncan Bayesian LSD Procedure was used for mean separation.

RESULTS AND DISCUSSION

The mean water temperature in the hydrilla culture pool was 30 C for the May 31 to July 26, 1985 growth period; 28 C during the September 10 to November 5, 1985 period; and 25 C for the March 4 to April 29, 1986 culture period. These temperatures are in the upper range for good growth of hydrilla and formation of tubers as suggested in the study by Van *et al.* (14).

The photoperiod was not conducive for tuber production (14) for the May 31 to July 26, 1985 culture period but tubers were produced during the other two culture periods. Numbers of tubers were analyzed using the ANOVA model to compare sediment processing and the two culture periods. No significant differences in the number of tubers were found due to sediment processing but the culture periods were different with an average of five tubers per culture container produced during the September 10 to November 5, 1985 period as compared to two per container during the March 4 to April 29, 1986 culture period. There was no interaction for the number of tubers between the sediment processing method and culture periods.

Dry weight values were analyzed using the ANOVA model to compare culture periods, sediment processing, and plant section (Table 1). Significant differences were found due to culture periods, sediment processing, and plant section. Also, a weak interaction was noted for culture periods and sediment processing, and a somewhat stronger effect for sediment processing and plant section. No interaction was observed for culture period and plant section, or for all three effects together. The interactions appear to be related to the magnitude in weight values for the roots as compared to the shoots and their differences for the culture periods. Shoot dry weights of plants in the sediments processed dry was 2.5, 1.6, and 2.7 times that of the shoots in the sediments processed moist. Differences in root weight for the two processing methods were less obvious than for the shoots.

It is difficult to compare the growth of hydrilla plants in the sediments processed dry with other published information. For example, Barko (2) obtained less than 2 g dry weight per container for hydrilla plants cultured for 8 weeks under conditions of 24 C with approximately $350 \mu\text{Em}^{-2}\text{s}^{-1}$ during a 14-hr photoperiod in sediments collected from Lake Kerr in East Oklahoma. Also, growth of hydrilla in the moist, relatively undisturbed sediments can not be compared because sediments from Lake Kerr were thoroughly mixed prior to culture of the hydrilla and the length of time from the collection of the Lake Kerr sediments until the culture of the hydrilla in them is not known.

Mineral content of hydrilla plant tissue cultured from the March 4 to April 29, 1986 period was not determined because not enough plant material was available for processing. Data for the two culture periods of May 31 to July

TABLE 1. DRY WEIGHT OF HYDRILLA CULTURED IN SEDIMENTS FROM LAKE OKEECHOBEE. SEDIMENTS WERE PROCESSED AS MOIST OR DRY AFTER COLLECTION. EACH VALUE IS THE MEAN OF PLANTS CULTURED IN EIGHT CORES OF SEDIMENT. THE STANDARD DEVIATION FOLLOWS THE MEAN. THE ANALYSIS OF VARIANCE IS BASED ON A LOG TRANSFORMATION OF THE WEIGHT VALUES; HOWEVER, THE DRY WEIGHT MEANS ARE THE NONTRANSFORMED VALUES.

Culture period and Sediment processing	Plant dry weight (g)	
	Shoot	Root
May 31 to July 26, 1985		
Moist	4.1 ± 2.3	0.8 ± 0.3
Dry	10.4 ± 3.8	1.3 ± 0.5
September 10 to November 5, 1985		
Moist	3.9 ± 1.2	0.7 ± 0.2
Dry	6.2 ± 1.0	0.9 ± 0.2
March 4 to April 29, 1986		
Moist	1.0 ± 0.4	0.2 ± 0.2
Dry	2.7 ± 0.8	0.4 ± 0.1

Analysis of Variance

Effects	Degrees freedom	Anova SS	Mean Square	F-value	(prop.>F)
Culture period (CP)	2	32.74	16.37	116.96	0.0001
Sediment processing (SP)	1	9.69	9.69	69.24	0.0001
Plant section (PS)	1	77.66	77.66	554.90	0.0001
CP*SP	2	0.91	0.46	3.25	0.0435
CP*PS	2	0.02	0.01	0.07	0.9331
SP*PS	1	1.09	1.09	7.78	0.0065
CP*SP*PS	2	0.08	0.04	0.31	0.7352

26, 1985 and September 10 to November 5, 1985 were pooled because no interactions were found among the combination of culture periods, processing method, and plant section. No differences were noted in the mineral content of the hydrilla tissue due to sediment processing; however, differences were noted for several minerals depending on their location within either the shoot or root tissue (Table 2).

The concentrations of nitrogen and sodium were found to be at the same level for both the shoot and root tissue. However, the concentration of phosphorus, potassium, and iron was 1.7, 2.2, and 11.9 times higher, respectively, in the roots than in the shoots. Calcium, magnesium, manganese, and zinc in the shoots tissue was 4.4, 2.5, 1.6, and 1.4 times higher in the shoots, respectively, than in the

root tissue. In the case of copper, the shoots of the plants cultured in the sediment processed dry contained a low amount as compared to a high amount in the roots for those plants cultured in the sediment processed moist.

Barko (2) suggests that the ratio of nitrogen to phosphorus in aquatic plant tissue needs to be 7 in order for effective mobilization of these nutrients from the sediments in a balanced fashion relative to the tissue requirements. However, analysis of aquatic plants in Lake Warniak indicate this ratio may vary considerably (6).

The ratio of nitrogen to phosphorus in hydrilla shoots collected from five sites in South Florida ranged from a low of 3 for plants from Lake Okeechobee to a high of 9 for hydrilla from the North New River Canal (12). For hydrilla plants cultured in four different sediment types including the sandy loam previously mentioned, ratios of 21 to 85 were determined by Steward (9). Likewise, the shoot tissue of hydrilla cultured in sand amended with various amounts of controlled release fertilizers contained a high of 44 for plants grown in only sand to a low of 37 for plants cultured in the highest level of fertilizer (11). Therefore, it is not surprising that a ratio of 21 for nitrogen to phosphorus in the shoot tissue for hydrilla cultured in the dry sediment from Lake Okeechobee was determined while this ratio was 16 for the roots of these same plants. It appears that the ratio of nitrogen to phosphorus in hydrilla tissue may depend to a large extent on the characteristic of the sediment in which it is growing.

Characteristics of the sediment collected from Lake Okeechobee and processed as dry for use to culture hydrilla are presented in Table 3. Since the interest of this study was to compare the manner in which the sediments were processed after collection and not any variability which might have occurred for the different collection dates, results from the 100-g samples for the eight cores from the three collection dates were pooled in order to calculate a mean, standard deviation, and low and high values for the various sediment parameters.

The ratio of nitrogen (ammonical nitrogen) to phosphorus in the sediments from Lake Okeechobee was found to be 0.4 as compared to 2.4 for a sandy loam (9) and 167 for Lake Kerr Sediments (2). However, the Lake Okeechobee sediments contained over three times the amount of iron as found in the sandy loam, but the amount of iron in the Lake Kerr sediments was not measured. The

TABLE 2. MINERAL CONTENT OF HYDRILLA CULTURED IN SEDIMENTS FROM LAKE OKEECHOBEE. SEDIMENTS WERE PROCESSED AS MOIST OR DRY AFTER COLLECTION.^a

Plant section and sediment processing	N (%)	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
<i>Shoot</i>										
Moist	1.4 a	583 b	6,830 b	50,250 a	2,773 a	2,065 a	983 b	41 a	53 a	4.3 ab
Dry	1.3 a	607 b	7,357 b	56,743 a	2,775 a	2,090 a	1,285 b	38 a	50 a	3.8 b
<i>Root</i>										
Moist	1.4 a	1,036 a	15,380 a	11,942 b	1,082 b	1,550 a	13,517 a	25 b	37 b	5.6 a
Dry	1.6 a	1,015 a	15,700 a	12,308 b	1,140 b	1,766 a	13,405 a	24 b	37 b	5.0 ab

^aValues are the means of nutrients determined in 1-g samples from plants grown on eight cores of sediments from each of the May 31 to July 26 and September 10 to November 5, 1985 culture periods. Means within a column followed by the same letter are not significantly different at the 5% level according to Waller-Duncan Bayesian LSD Procedure.

TABLE 3. CHARACTERISTICS OF SEDIMENTS COLLECTED FROM LAKE OKEECHOBEE AND PROCESSED DRY FOR USE TO CULTURE HYDRILLA.^a

Sediment characteristics	Mean	Standard deviation	Range	
			Low	High
pH	7.2	0.4	6.3	7.9
Organic matter (%)	1.2	±0.7	0.3	3.7
Soluble salts (mg/kg)	439	±82	350	728
Nitrate nitrogen (mg/kg)	0.5	±0.3	0.2	1.0
Ammonical nitrogen (mg/kg)	2.0	±0.9	0.8	3.4
Phosphorus (mg/kg)	5.1	±5.0	2.0	23.0
Potassium (mg/kg)	18.3	±6.2	9.6	32.8
Calcium (mg/kg)	750	±217	362	1,200
Magnesium (mg/kg)	50	±25	16	91
Sodium (mg/kg)	38	±13	21	64
Manganese (mg/kg)	1.0	±0.6	0.4	3.0
Zinc (mg/kg)	0.4	±0.4	0.1	1.8
Iron (mg/kg)	27	±6	20	40
Copper (mg/kg)	0.03	±0.02	0.0	0.08

^aValues are based on the analysis of a 100-g dry weight sample from each of eight sediment cores collected on three separate dates for a total of 24 cores.

organic content of the Lake Okeechobee sediments was 33% less than that reported for the Lake Kerr sediments.

The effect of sediment iron on growth of hydrilla is not known. However, Basiouny *et al.* (3) reported an increase in both the growth of hydrilla and the level of iron in the plant tissue when the amount of iron was increased in the nutrient solution for plants cultured under controlled conditions.

The reasons for the better growth of hydrilla in the sediments processed dry as compared to the relatively undisturbed moist sediments are not readily apparent in this study. The drying and thorough mixing of the sediments may have helped oxidize various compounds which resulted in making them more available for growth. Various chemical or physiological changes, or an interaction of these may have influenced the amount or availability of nutrients in the moist sediments. The nutrient content of the hydrilla tissue was the same regardless of the method of processing but differed with biomass yield.

An advantage of drying sediments after collection is they can be stored without the potential changes that might occur when the sediments are stored in a moist condition. Storing moist sediments after they are freeze-dried or under refrigerated conditions may be a way to prevent changes in them. However, additional studies are needed to evaluate the long-term effect of storing either dry or moist sediments. Additional studies are needed to deter-

mine the influence of collection and processing on the use of sediments to evaluate the aquatic plant growth potential for various types of sediments. And finally, the development of standard techniques for collecting and processing sediments would help provide uniformity to allow for comparisons of results from different studies.

ACKNOWLEDGEMENTS

Sincere thanks are due to Ms. Maria Bravo and Ms. Joanne Korvick for their excellent technical assistance with this study. The assistance of the Soil Testing Laboratory at the University of Florida in Gainesville under the direction of Dr. Ed Hanlon in the chemical analyses of the plant tissue and sediment samples for mineral content is gratefully acknowledged, and I thank Dr. Ken Portier of the Statistics Department for his assistance with the statistical evaluation of these data.

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