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Influence of Sediment Nutrients on Growth of Emergent Hygrophila

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ABSTRACT

Hygrophila (*Hygrophila polysperma* (Roxb.) T. Anderson) is a plants which forms serious aquatic weed problems. Both submerged and emergent growth forms occur. Nutritional studies with a controlled release fertilizer and sediments collected from hygrophila-infested areas were conducted with the emergent growth habit to provide insights into growth of this introduced plant. Plant dry weights for experimental 16-week culture periods with low average temperatures were associated with low amounts of hygrophila biomass as compared to culture periods with high average temperatures. Hygrophila cultured in sand rooting media with the controlled release fertilizer produced as much as 20 times more dry weight than plants cultured in sediments only. First-degree linear regression statistics showed hygrophila dry weights were highly related to ammonia nitrogen, magnesium, sodium, and pH values in the sediments. These findings show the close relationship of the emergent growth habit of hygrophila to sediment nutrients. Analyses for certain sediment characteristics may provide an indication of the potential growth that may be expected for weed infestations of this plant. Hygrophila grows year round in south Florida; however, visual observations of canals and other bodies of water indicate that lower amounts of hygrophila plants occur during the cooler months of year than during the summer season. These findings show the seasonal growth of emergent hygrophila occurs with biomass dependent on both sediment nutrients and temperature.

Key words: Hygrophila polysperma, invasive plant, aquatic weed, plant nutrition.

INTRODUCTION

Hygrophila (*Hygrophila polysperma* (Roxb.) T. Anderson) and hydrilla (*Hydrilla verticillata* (L.f.) Royle) were introduced to Florida during the 1950s (Gordon and Thomas 1997). Hydrilla quickly naturalized and became a major submersed plant problem in Florida, and gradually spread to other areas of the country.

It is not known when hygrophila naturalized in Florida, but dense, monocultures of plants were found in Miramar, Florida in 1980 (Vandiver 1980). The common name "Miramar weed" is sometimes used for hygrophila because of its first discovery as a weed problem in that area. Infestations of hygrophila have increased during the last decade to the point where the plant is now considered a serious weed problem in south Florida.

Hygrophila has the potential to spread to other warm water areas of the country. Recent problems with hygrophila in citrus groves and in the Withlacoochee River, Florida have been observed (Brian Nelson 1999, pers. comm.). The finding of hygrophila in the upper San Marcos River in Hays County, Texas (Angerstein and Lemke 1994) shows its potential to spread to other areas of the country. Although hygrophila has been reported (Schmitz and Nall 1984) to occur as far north as Virginia, presently it is causing problems only in areas with high summer temperatures such as in the southern portions of Florida.

A single endemic species, /Lake Hygrophila/ (*Hygrophila lacustris* (Schlecht & Cham.)), occurs in North America. Lake Hygrophila occurs sporadically as an emergent plant from northeast Florida west to east Texas (Godfrey and Wooten 1981).

The introduced hygrophila displays both submerged and emergent growth habits. Submerged plants may occupy the entire water column while emergent plants grow in shallow water areas and in saturated sediments along the shoreline. Also, emergent shoots form floating mats that may extend above the surface of the water.

Spencer and Bowes (1985) suggested, based on seasonal measurements of standing crop and photosynthetic temperature sensitivity, that hygrophila and limnophila (*Limnophila sessiliflora* (Vahl) Blume) did not pose the same weed threat as hydrilla. They suggested however that hygrophila appears to have more potential to cause weed problems than limnophila.

Problems with hygrophila may be more serious in canals than static water. Van Dijk et al. (1986) reported that water flow resulted in better growth of hygrophila than hydrilla when cultured under different flow rates. In these different flow rates however, hydrilla was growing at a faster rate than hygrophila.

The intent of this study is to provide additional information on factors influencing growth of hygrophila as little is known of the nutritional requirements of this invasive aquatic plant. We measured dry weights as an indication of growth for emergent hygrophila plants cultured either in sand with a controlled release fertilizer or in sediments collected from areas in which aquatic weed problems were known to occur.

MATERIALS AND METHODS

Plant material. Stock cultures of emergent hygrophila originally collected from plants growing in nearby canals were maintained at the University of Florida's Fort Lauderdale Research and Education Center (FLREC) in the plastic contain-

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ers with Sierra® fertilizer at the rate of 20 g per 330 cm^2. Apical shoots were periodically planted in newly fertilized containers to maintain the plants in an active state of growth.

Collection of sediments. Sediments were collected on two separate occasions from five different locations in canals near the FLREC designated as Sunflower, Royal Palm, Holloway, University A, and University B. The sediments were dried at 60C and ground individually with a Model 201 XL Holms Hammermill Crusher (Manufactured by Holms Bros., Inc., P.O. Box 707, 510 Junction Ave., Danville, Illinois 61834) with a mesh screen composed of holes 0.476 cm in diameter set 0.24 cm apart. Four dried samples from each site for each collection time were sent to the University of Florida's Soil Testing Laboratory in Gainesville for analyses. The analyses provided by the soil testing laboratory are those nutrients normally screened in samples to determine fertilizers requirements for crop production.

Experimental conditions. All experiments were conducted outdoors at the FLREC. Plastic containers with tapering sides (dimensions of 20.5 cm and 17 cm in diameter at the top and bottom, respectively, by 20.5 cm in height) with no drainage holes were used for stock and experimental culture of emergent hygrophila.

The containers were filled to a depth of 8 cm with coarse builder's sand. Sierra® 17-6-10 Plus minors controlled release fertilizer (Scotts-Sierra, Marysville, OH) formulated for an 8- to 9-month release rate at 21C was placed as a layer on the surface of the sand. An additional layer of sand covered the fertilizer to within 2.5 cm of the top of the container. The containers were placed on an asphalt surface to allow for growth of stock and experimental plants. Periodic watering by an overhead irrigation system maintained the containers in a flooded condition with water from a nearby pond.

Apical sections approximately 12 cm in length were selected from the stock plants for each experimental culture period. A single apical section was planted in each container by placing three to four of its lower nodes below the surface of the sand. For all culture periods, four apical sections similar to those planted were selected and dried to provide for an initial weight representative of those planted. Replications were arranged in four rows with treatments randomized within each row.

Temperatures were recorded Monday through Friday between 3:00 to 4:00 PM by placing a maximum/minimum thermometer on the surface asphalt close to each set of experimental containers for all culture periods except for the initial one in Experiment 1.

Experiment 1. Sierra® fertilizer was added in amounts of 0.5, 2, 8, and 32 g to each of four containers (four replications) in an attempt to provide base lines levels of fertilizers required for growth of emergent hygrophila. A total of 16 containers were used for each of four culture periods of December 9, 1993 to March 31, 1994, July 1 to October 21, 1994, November 21, 1994 to March 13, 1995, and April 17 to August 7, 1995.

Experiment 2. This portion of the study was an attempt to evaluate seasonal growth of emergent hygrophila with a constant amount of nutrients in the root zone. Sierra® fertilizer was added at the rate of 8 g to each of a set of 16 containers. A total of 192 containers were used with a set of 16 containers planted about the middle of each month for a 1-year period beginning July 12, 1994. For each set of 16 containers, plants were harvested from each of four containers after 4, 8, 12, and 16 weeks of growth.

Experiment 3. This experiment was conducted to compare growth of emergent hygrophila in sand amended with fertilizer and sediments collected from local canals where aquatic weed problems would be expected to occur.

Sierra® fertilizer was added in amounts of 1, 4, and 16 g to each of six containers (six replications), and sediments from each of the collection sites were added to each of six containers (six replications). A total of 48 containers were used for each of two culture periods of November 3, 1997 to February 23, 1998 and May 28 to August 18, 1998.

Growth of hygrophila. Growth was determined by dry weight differences. Plants were washed with pond water at the end of each culture period to remove sand, fertilizer, and any other debris. The washed plants were then dried to a constant weight in a forced-air oven held at 60C.

Statistical analyses. Values for dry weight were statistically analyzed using General Linear Models (GLM) procedures of the Statistical Analyses System (SAS Institute Inc., Cary, NC 27511) developed for personal computers. First degree linear regression statistics were generated for (1) dry weight means (dependent variable) of each 16-week culture period in Experiment 2 to temperature means (independent variable), and (2) dry weight means (dependent variable) of each culture period in Experiment 3 to means for sediments nutrients (independent variable) for each collection period using GLM procedures. Values for dry weight for each culture period in Experiments 1 and 2 are the means of plants from four cul-

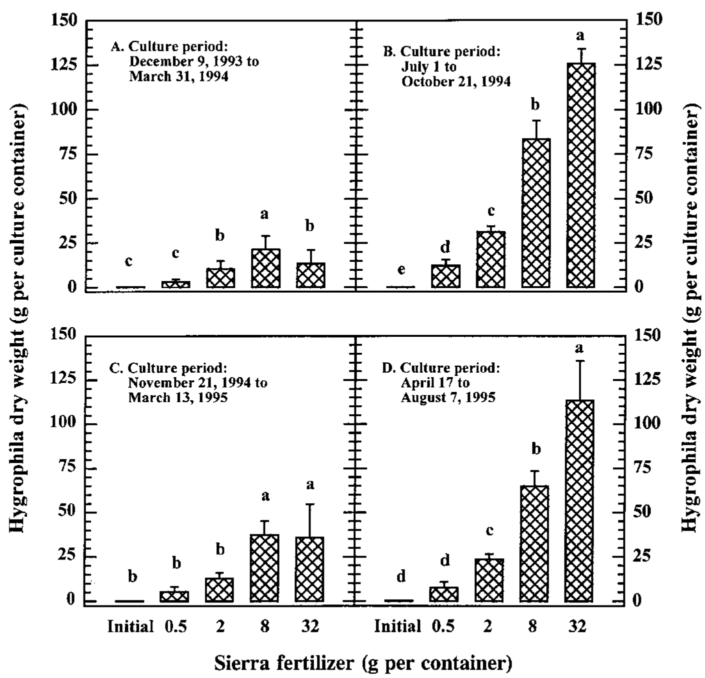

Figure 1. Dry weight of emergent hygrophila cultured under flooded conditions in sand rooting media amended with fertilizer for Experiment 1. Error bars are 1 standard deviation of the mean. Similar letters at the top of the bars for each culture period indicate no statistically significant difference for weight at P < 0.05 according to the Waller-Duncan Bayesian Procedure.

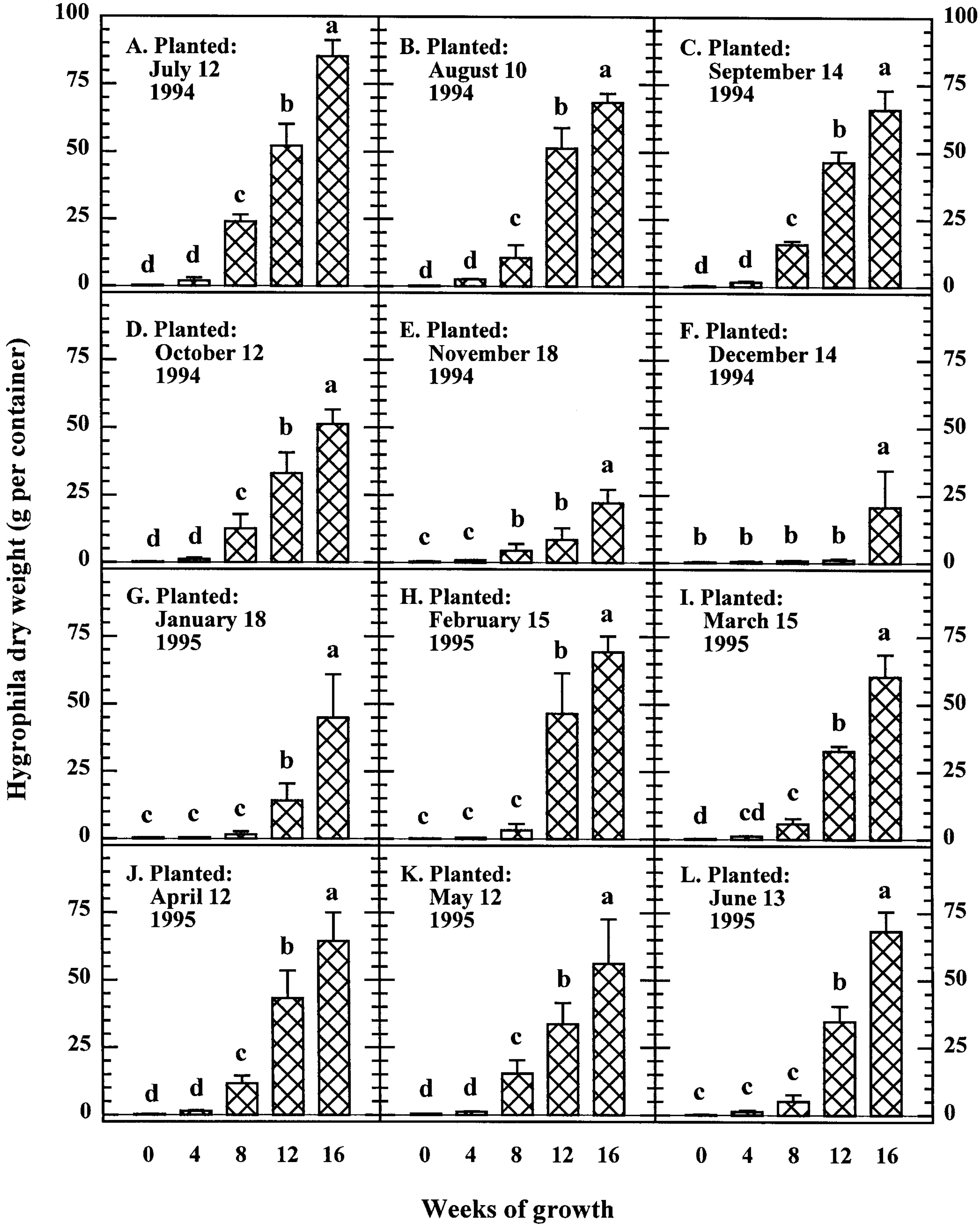

Figure 2. Dry weight of emergent hygrophila cultured under flooded conditions in sand rooting media amended with fertilizer for Experiment 2. Error bars are 1 standard deviation of the mean. Similar letters at the top of the bars for each planting date indicate no statistically significant difference for weight at P < 0.05 according to the Waller-Duncan Bayesian Procedure.

ture containers for each treatment, and six culture containers for each treatment for the two periods in Experiment 3. Nutrient values for sediments are the means of four samples from each collection period. Mean separation was accomplished with the Waller-Duncan Bayesian LSD procedure.

RESULTS

Plant dry weight. Hygrophila plants exhibited similar patterns of growth for the four culture periods in Experiment 1 (Figure 1). For the two winter Culture Periods of A and C, plant dry weight increased up to the 8-g fertilizer treatment rate during the 16-week culture period. But for these same two periods, dry weight for plants with 32 g was not higher than the 8-g rate. For the summer periods, B and D, dry weight differences were exhibited for all fertilizer treatment rates. Plants at the 32-g rate produced the highest dry weight of 125 and 115 g per container for Culture Periods B and D, respectively.

Dry weights for hygrophila planted at monthly intervals and harvested after 4, 8, 12, and 16 weeks of growth in Experiment 2 are presented in Figure 2. For hygrophila planted in November to February, dry weights after 4 weeks of growth were not higher than the initial weights. Furthermore, hygrophila planted in December did not show a significant increase in weight over the initial plantings until after 16 weeks of growth. For the other monthly plantings, dry weight differences were observed for all harvest periods.

The combined dry weight of hygrophila for all treatments were lower for Culture Period A (winter) than for Culture Period B (summer) in Experiment 3 (Figure 3). Plants cultured in sediments collected from University A and B produced the least amount of dry weight compared to all treatments for both culture periods.

For Culture Period A in Experiment 3, the highest dry weights were produced by plants grown in the 4- and 16-g fertilizer treatments and in sediments collected from the Royal Palm site. The highest dry weight was produced by plants cultured with 16 g of fertilizer for Culture Period B followed by a significantly lower amount at 4 g of fertilizer and an even lower weight for plants in the sediments from the Royal Palm site. No differences were observed in weight for plants cultured in the 1-g rate of fertilizer and the sediments either from Sunflower or Holloway collection sites.

Temperature. Temperatures for all culture periods except Culture Period A in Experiment 1 are presented in Table 1. A high average temperature of 32.1C was recorded for Culture Period B in Experiment 1. and a low average tempera-

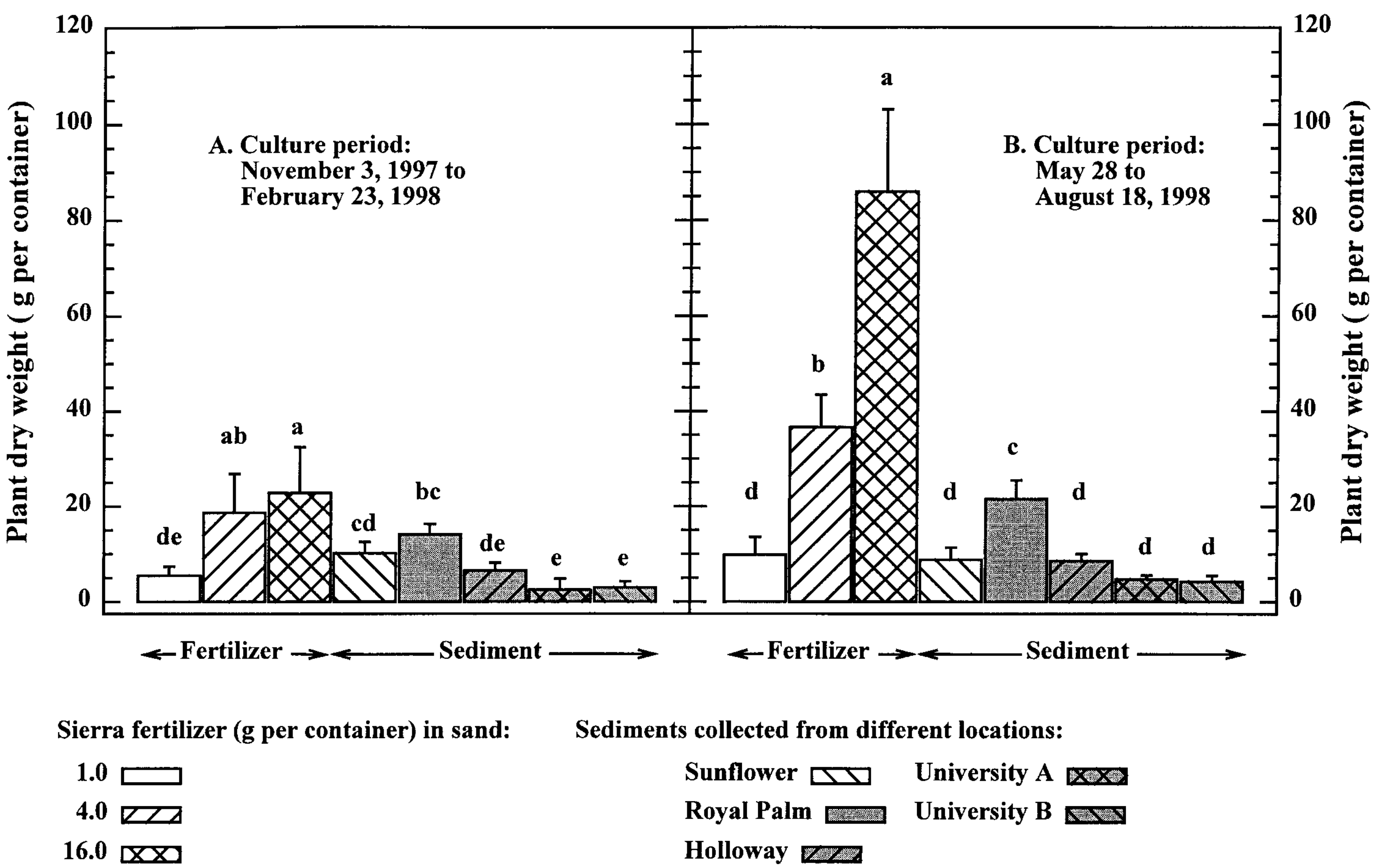

Figure 3. Dry weight of emergent hygrophila cultured under flooded conditions in sand rooting media amended with fertilizer and in sediments collected from canals in Broward County, Florida for Experiment 3. Error bars are 1 standard deviation of the mean. Similar letters at the top of the bars for each culture period indicate no statistically significant difference for weight at P < 0.05 according to the Waller-Duncan Bayesian Procedure.

TABLE 1. TEMPERATURES (C) FOR HYGROPHILA CULTURED IN SAND WITH FERTILIZER OR IN SEDIMENTS.

Culture period	Average	Minimum	Maximum
Experiment 1.			
Jul 01 to Oct 21, 1994	32.1	20.5	49.0
Nov 21, 1994 to Mar 13, 1995	20.8	4.0	38.0
Apr 17 to Aug 7, 1995	31.0	17.0	48.5
Experiment 2. Starting date of 16-week period			
Jul 12, 1994	31.9	20.5	49.0
Aug 10, 1994	30.2	16.0	46.0
Sep 14, 1994	27.1	8.0	43.0
Oct 12, 1994	23.5	4.0	43.0
Nov 18, 1994	20.9	4.0	38.0
Dec 14, 1994	21.6	4.0	40.0
Jan 18, 1995	24.5	4.0	46.0
Feb 15, 1995	28.5	8.5	46.5
Mar 15, 1995	30.3	13.5	46.5
Apr 12, 1995	31.2	17.0	48.5
May 12, 1995	31.1	19.5	48.5
Jun 13, 1995	30.9	19.5	48.5
Experiment 3.			
Nov 3, 1997 to Feb 23, 1998	20.3	8.0	37.0
May 28 to Aug 18, 1998	31.6	23.0	44.0

ture of 20.3C was recorded for Culture Period A in Experiment 3. The average temperatures for all culture periods were above the optimum release rate 21C for the fertilizer rates except for previously mentioned period, Culture Period B in Experiment 1, and the one period in Experiment 2 with a planting date of November 18, 1994.

Relationships of plant dry weights to temperature. For Experiments 1 and 3, dry weights of hygrophila in all treatments were low for the two culture periods with low average temperatures as compared to high dry weights for the other two periods with high average temperatures. For Experiment 2, a first-degree linear regression relationship was developed

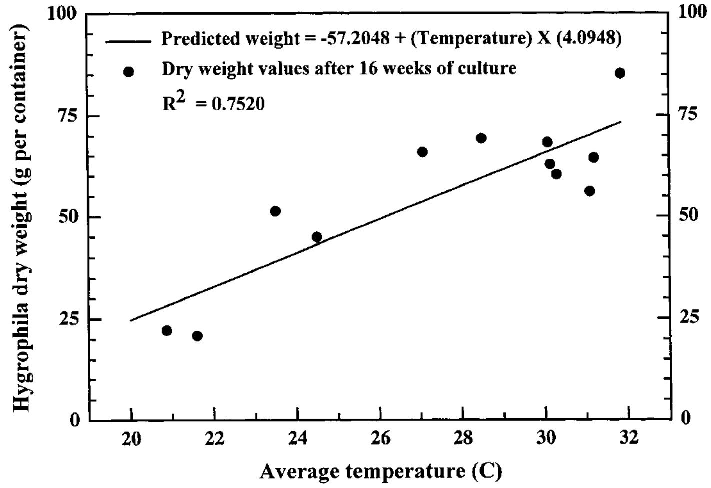

Figure 4. Relationship of dry weight of emergent hygrophila to temperature.

Sediment characteristics. Analyses of sediments collected from canals in Broward County used for culture of hygrophila produced variable results with regard to the measured characteristic for each collection time (Tables 2 and 3). Sediments from the Royal Palm site contained the highest amounts of ammonia nitrogen of all the sites while those from University A and B contained the least amount for both collection times. Measurements for nitrate nitrogen in samples from the first collection of sediment from Royal Palm were high, but low in samples from the second collection time.

Sediment from University B contained the highest level of phosphorus for Collection 1, but the amount for the second collection was similar to that in two of the other sites.

High amounts of potassium were measured in the Royal Palm site from both collections with low amounts in both University A and B and in Holloway. For sediments from the Sunflower site, the amount of potassium was lower than Royal Palm for the first collection, but similar for the second collection.

TABLE 2. CHARACTERISTICS OF SEDIMENTS COLLECTED FROM CANALS IN BROWARD COUNTY USED FOR CULTURE OF THE EMERGENT GROWTH HABIT OF HYGROPHILA. ALL VALUES IN MG PER KG OF SEDIMENT. SIMILAR LETTERS FOR VALUES IN EACH COLUMN FOR EACH COLLECTION PERIOD INDICATE NO STATISTICALLY SIGNIFICANT DIFFERENCE AT $P < 0.05$ ACCORDING TO THE WALLER-DUNCAN BAYESIAN PROCEDURE.

	Nitrogen							
Collection site	NH_4	NO_3	P	K	Ca	Mg	Fe	Na
Collection 1.—Used for Culture Period November 3, 1997 to February 23, 1998								
Sunflower	5.5 b	1.0 b	7.6 d	10.8 b	6885 a	49 b	2 d	33 b
Royal Palm	9.1 a	5.0 a	4.3 e	12.7 a	6455 ab	74 a	2 d	50 a
Holloway	2.1 c	1.1 b	11.2 c	8.8 c	5373 bc	36 c	11 c	19 c
University A	1.1 d	1.1 b	14.1 b	7.1 c	2220 d	24 d	23 a	24 c
University B	1.0 d	0.8 b	18.4 a	8.0 c	4520 c	31 c	15 b	23 c
Collection 2.—Used for Culture Period May 28 to August 18, 1998								
Sunflower	2.4 b	6.1 a	3.3 c	12.3 a	7408 a	32 c	4 c	23 b
Royal Palm	4.1 a	1.0 d	6.3 a	11.0 a	6795 a	95 a	1 d	48 a
Holloway	2.2 c	2.4 c	6.5 a	6.4 b	7035 a	36 bc	8 b	20 b
University A	0.5 c	3.4 b	5.6 ab	5.4 b	2478 d	20 d	19 a	21 b
University B	0.7 c	2.3 c	5.0 b	4.8 b	6798 a	41 b	6 c	20 b

TABLE 3. CONTINUATION OF CHARACTERISTICS OF SEDIMENTS COLLECTED FROM CANALS IN BROWARD COUNTY USED FOR CULTURE OF THE EMERGENT GROWTH HABIT OF HYGROPHILA. ALL VALUES IN MG PER KG OF SEDIMENT EXCEPT FOR PH AND CONDUCTIVITY (MS/CM).

Collection site	pH	Zn	Mn	Cu	Conductivity
Collection 1.—Used for Culture Period November 3, 1997 to February 23, 1998					
Sunflower	8.4 c	0.6 d	1.4 a	0.1 c	0.5 b
Royal Palm	7.6 d	11.8 a	0.8 c	0.2 bc	2.4 a
Holloway	8.6 b	2.7 bc	1.0 b	0.2 bc	0.3 bc
University A	8.6 b	2.2 c	0.7 c	0.3 b	0.2 c
University B	8.8 a	3.5 b	0.7 c	1.5 a	0.2 c
Collection 2.—Used for Culture Period May 28 to August 18, 1998					
Sunflower	8.6 b	0.4 c	1.2 a	0.1 bc	0.3 bc
Royal Palm	7.7 c	10.5 a	0.9 b	0.2 b	1.1 a
Holloway	8.6 b	2.5 b	0.7 c	0.2 b	0.3 b
University A	8.7 ab	2.4 b	0.6 d	1.76 a	0.1 d
University B	8.8 a	2.7 b	0.6 d	0.1 c	0.2 cd

For the other characteristics, sediments from the Royal Palm site for both collection times contained the highest values for magnesium, sodium, zinc, and conductivity, and the lowest pH of all the sites.

Relationships of plant dry weights to sediment characteristics. First-degree linear regression statistics for plant dry weights in relation to sediment characteristics were determined for hygrophila plants cultured in Experiment 3 (Tables 4 and 5). For both culture periods, plant dry weights were significantly related to amounts of ammonia nitrogen, magnesium, sodium, pH, and conductivity. Dry weight of hygrophila was related to phosphorus, potassium, and iron contents of sediments for Culture Period A, but not in Culture Period B.

DISCUSSION

Biomass of hygrophila in this study increased as expected. Higher dry weights were related to the higher levels of controlled release fertilizers added to the rooting media. Dry matter can not be related to a unit area because the shoots grew over the side of the culture containers; however, weights from the various treatments are comparable since the plants were cultured in containers of the same size.

Hygrophila grows all year round in south Florida. Visual observations of canals and other bodies of water indicate lower amounts of hygrophila plants occur during the cooler months of year than during the summer season. These observations agree with the dry weight findings for all three experiments. Dry weights of treatments for the culture periods with low average temperatures were associated with low amounts of biomass as compared to the culture periods with high average temperatures and high biomass.

Sutton and Latham (1996) found that interstitial concentrations of nutrients from the controlled release fertilizer did not rise as fast in culture containers during the winter season as compared to the summer season. Therefore, the release of nutrients from the fertilizer used for culture of hygrophila may have also contributed to the lower dry weights observed during culture periods with low average temperatures. However, this effect was probably minor compared to temperature effects on plant growth itself. For example in Experiment 3, growth of plants in both sediments and with the controlled release fertilizer was low during the cooler months of the year as compared to the warmer months.

TABLE 4. FIRST-DEGREE LINEAR REGRESSION STATISTICS FOR PLANT DRY WEIGHTS IN RELATION TO SEDIMENT CHARACTERISTICS FOR CULTURE PERIOD NOVEMBER 3, 1997 TO FEBRUARY 23, 1998 IN EXPERIMENT 3.

Nutrient	Mean square	F value	Pr > F	R-Square
NH_4—Nitrogen	92.77	66.52	0.0039	0.9568
NO_3—Nitrogen	59.99	4.87	0.1145	0.6188
P	86.72	25.42	0.0150	0.8944
K	95.00	146.13	0.0012	0.9798
Ca	67.59	6.91	0.0785	0.6971
Mg	91.66	51.96	0.0055	0.9454
Fe	83.45	18.55	0.0230	0.8608
Na	73.42	9.36	0.0550	0.7572
pH	77.82	12.21	0.0397	0.8027
Zn	38.58	1.98	0.2538	0.3979
Mn	10.24	0.35	0.5936	0.1056
Cu	31.25	1.43	0.3181	0.3223
Conductivity	69.90	7.75	0.0687	0.7209

TABLE 5. FIRST-DEGREE LINEAR REGRESSION STATISTICS FOR PLANT DRY WEIGHTS IN RELATION TO SEDIMENT CHARACTERISTICS FOR CULTURE PERIOD MAY 28 TO AUGUST 18, 1998 IN EXPERIMENT 3.

Nutrient	Mean square	F value	Pr > F	R-Square
NH_4—Nitrogen	175.03	24.96	0.0154	0.8927
NO_3—Nitrogen	37.14	0.70	0.4639	0.1894
P	24.09	0.42	0.5630	0.1229
K	87.53	2.42	0.2177	0.4464
Ca	24.27	0.42	0.5615	0.1238
Mg	169.51	19.15	0.0221	0.8646
Fe	85.27	2.31	0.2259	0.4349
Na	179.99	33.59	0.0102	0.9181
pH	193.70	246.20	0.0006	0.9880
Zn	21.09	0.36	0.5900	0.1076
Mn	44.19	0.87	0.4191	0.2254
Cu	21.09	0.36	0.5900	0.1076
Conductivity	190.52	103.23	0.0020	0.9718

Barko et al (1991) in their review of the literature on the importance of sediment and open water on growth of submerged plants reported that sediments are the primary source for nitrogen, phosphorus, iron, manganese, and micronutrients with the remainder supplied by the surrounding water. Emergent plants however, since they grow with their roots in the sediments and most of their shoots above water, obtain both macro- and micro-nutrients from the sediments.

Plants cultured with sand and fertilizer produced as much as 20 times the biomass as plants cultured with sediments collected from canals in Broward County, Florida. The sediments were lacking either in nutrient quality or quantity required for optimum growth even though the sediments were collected from areas with submerged hygrophila problems.

Standard soil analyses of sediments for nutrients generally considered important for crop production such as ammonia nitrogen, P, K, and Mg may provide an indication of the potential growth that may be expected for a particular body of water that would result in weed infestations of hygrophila. Seasonal growth will occur with biomass amounts dependent on sediment nutrients and temperature.

The influence of sediment nutrients and temperature on the growth potential of hygrophila needs to be taken into consideration when developing management methods for this noxious aquatic weed. For example, bodies of water with high sediments nutrients will probably require herbicide treatments than those with low nutrients. Herbicide treatments in the fall for low infestations may not be required since growth of the plants would expected to be slow due to low water temperatures.

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