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Influence of Spikerush Plants on Growth and Nutrient Content of Hydrilla[1]

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ABSTRACT

Shoots of spikerush plants, *Eleocharis cellulosa* Torr. and *Eleocharis interstincta* (Vahl) R. & S., collected from Lake Okeechobee, exhibited growth-retarding effects on hydrilla [*Hydrilla verticillata* (L.f) Royle] cultured for 8 and 16 weeks in outdoor tanks. The spikerush shoots were dried, ground, and added in amounts of 1, 5, 10, or 20 g to root culture containers filled with 2.2 kg of sand plus controlled release fertilizers. Statistical analysis of hydrilla dry weight indicated significant differences for species of spikerush and rate effects, and as expected, dry weight of hydrilla after 16 weeks of growth was higher than after 8 weeks. Rate effects within a species were predominantly linear with a high significance probability ($p>0.0001$). No differences in hydrilla tuber number were found between the two species of spikerush for the 10 and 20-g rates, but the number of tubers was reduced to an average of 82% compared to the control after 16 weeks of growth. Smaller tubers were associated with hydrilla plants that produced fewer numbers of tubers. A few differences were noted in the mineral content of hydrilla plants exposed to the dried spikerush compared to the control plants, but no definite trends were found to account for reduction in growth due nutrient levels found in the hydrilla tissue. This study suggests *E. cellulosa* and *E. interstincta* contain allelochemicals phytotoxic to hydrilla.

Key words: Allelopathy, nitrogen, phosphorus, potassium, tubers, *Eleocharis cellulosa, Eleocharis interstincta.*

INTRODUCTION

Allelopathy, biochemical interactions among plants due to one or more chemical compounds being produced by a plant, has been well documented for terrestrial systems (15, 16); but this form of interaction is not as well understood for aquatic plants. Information on allelopathic relationships of aquatic plants will help in the evaluation of their growth and development, and may result in the discovery of compounds which might eventually be used as growth regulators.

A reduction in growth after addition of residues of dried plants to living plants is generally assumed to be due to the presence of allelochemicals in the dry herbage (16). Although it is speculated that a reduction in allelopathic phytotoxicity may occur during the drying of plants (1), various studies have used drying temperatures of 60 to 90 C (5, 6, 11, 12).

In one of the first studies involving the interaction of aquatic plants to possible allelochemical effects, Oborn *et al.* (13) reported that pondweeds (*Potamogeton* spp.) were

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eliminated from cultures planted with least spikerush [*Eleocharis acicularis* (L.) R. & S.] during a 2-year period under greenhouse conditions. Further evidence for allelopathic effects of spikerushes was shown by the use of leachate from culture containers planted with dwarf spikerush [*Eleocharis coloradoensis* (Britt.) Gilly] which reduced the production of new shoots of American pondweed (*Potamooeton nodosus* Poir.) and sago pondweed (*Potamogeton pectinatus* L.) (8). Ashton, *et al.* (4) found this leachate contained a compound, or perhaps several compounds, with a molecular weight between 600 and 1000, that was phytotoxic to excised parts of sago pondweed and hydrilla.

Aqueous extracts from shoots of dried spikerushes, *E. cellulosa* and *E. interstincta*, reduced growth of duckweed (*Lemna paucicostata* Hegelm. 6746) cultured under axenic and controlled environmental conditions (20). Likewise, aqueous extracts of least spikerush showed growth inhibition in both lettuce seedling and duckweed assay systems (7), but this spikerush was not among the most phytotoxic of 17 aquatic plants evaluated with these assays.

To provide additional information on the possible allelopathic effects of spikerushes, a study was conducted with the spikerushes *E. cellulosa* and *E. interstincta*, and hydrilla. Although about 150 species of spikerushes occur throughout the world (10), these two species were selected because of their natural abundance in Florida. For example, over 3,400 ha of *E. cellulosa* were found during a survey in 1983 for aquatic plants in Florida (17), and the majority of plants of this species was present in Lake Okeechobee as a monoculture. *E. interstincta* was not found to be as abundant as *E. cellulosa* in the lakes examined during this survey.

To evaluate the influence of *E. cellulosa* and *E. interstincta* on the growth of hydrilla, a study was conducted that used dried shoots of these spikerushes placed in the root zone of hydrilla plants cultured under outdoor conditions. The hydrilla plants were monitored for dry weight, tuber production, and nutrient content of their tissues as indications of the allelopathic potential of the spikerush plants.

MATERIALS AND METHODS

Collection and preparation of spikerush herbage. Shoots of spikerushes, *E. cellulosa* and *E. interstincta*, were collected from populations growing in the northwest corner of Lake Okeechobee. The shoots were washed with pond water to remove algae and adhering debris, dried at 60 C, and ground to pass a 20 mesh screen. The ground material was stored at room temperature in an air-tight plastic container until used in the culture of the dioecious strain of hydrilla.

Culture of hydrilla with spikerush herbage. Experiments were conducted outdoors in cement tanks (6.2 m by 3.1 m filled with pond water to a depth of 0.8 m) at the Fort Lauderdale Research and Education Center (FLREC). The FLREC is located at coordinates 26°05'N and 80°14'W. Pond water, from the same source as described by Steward (18), flowed into the tank at the surface of one end and out the tank from a bottom drain at the other end at a rate which allowed for a complete exchange of water every 24 hours.

To study the influence of *E. cellulosa* and *E. interstincta* on growth of hydrilla, 1, 5, 10, or 20 g of the dried spikerush herbage was thoroughly mixed with 2.2 kg of sand amended with 10.8 g of Osmocote, 0.3 g of Esmigran, and 1.8 g of Dolomite[3]. Nutrient properties of the sand have been described by Langeland *et al.* (9). The mixtures were placed in polyvinylchloride (PVC) tubes with dimensions of 10 cm in diameter by 19 cm in height and capped at one end. The tubes were placed upright with the capped end down in a cement tank in rows, and each was planted with four sprouted hydrilla tubers. Tubers were collected from stock cultures of dioecious hydrilla maintained at the FLREC and allowed to sprout in pond water prior to use in the study (19).

For this study, a replicate consisted of a tube for each rate of dry spikerush and fertilizer and a control tube filled with sand amended with fertilizer only. The tubes were randomized by the amount of spikerush and placed in a row perpendicular to the flow of water. Of the four replicates used for each culture period, two replicates each were removed after 8 and 16 weeks after planting the sprouted hydrilla tubers.

Culture periods were (1) December 4, 1985 to March 26, 1986, (2) April 22 to August 12, 1986, (3) January 21 to May 13, 1987, and (4) May 22 to September 11, 1987. Water temperature was recorded during these culture periods as previously described by Sutton (19). To prevent damage to the hydrilla shoots after they reached the surface of the water by the feeding activity of the herbivorous moth, *Parapoynix diminutalis* Snellen, an emulsifiable concentrate of malathion (0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate) was added weekly to the tank to achieve a concentration of 1.0 ppm. Periodically, the tank was cleaned with a siphon to remove debris, or algae, or both which would build up on the bottom and sides of the tank.

For each culture period, hydrilla plants were harvested from two tubes of each spikerush rate and the control after 8 and 16 weeks of growth. Hydrilla plants were separated into shoots and roots at harvest time, washed with pond water, dried at 60 C, weighed, and ground to pass a 40 mesh screen. Hydrilla tubers were counted when present.

Nutrient analyses. The dried, ground hydrilla tissue, shoots or roots, from each tube was thoroughly mixed and a 0.5-g portion removed for nutrient analyses. The plant material was digested with nitric and perchloric acids at the FLREC, and the digest sent to the University of Florida's Soil Testing Laboratory in Gainesville for analyses of phosphorus, potassium, calcium, magnesium, sodium, manganese, iron, zinc, and copper according to standard methods (2). The Kjeldahl method (3) was used to analyze for nitrogen at the FLREC.

[3]Osmocote (18-6-12) with an 8- to 9-month release time is manufactured by Sierra Chemical Company, Milpitas, CA 95035; Esmigran by Mallinckrodt, Inc., St. Louis, MO 63147; and Dolomite (Soil Doctor) by Soil Doctor, Inc., Crystal River, FL 32629. Mention of a trademark or a proprietary product does not constitute a guarantee or warranty of the product by the University of Florida and does not imply its approval to the exclusion of other products that also may be suitable.

Statistical analyses. Dry weight, number of tubers, and mineral content of the hydrilla tissue were statistically analyzed using the general linear models in the Statistical Analyses System (SAS)[4] software located at the Northeast Regional Data Center (NERDC) in Gainesville, Florida. The effect of rate on response was examined both as a classification variable and as a continuous variable in separate analyses. In none of the analyses was culture period found to be important either as a main effect or in interactions, and hence analyses reported is for pooled culture periods. For classification variables, means separation of significant effects was accomplished using the Duncan-Waller Empirical Bayes LSD procedure (14). Regression analysis was used to examine the relationship between tuber weight and tuber number for the individual samples taken.

RESULTS AND DISCUSSION

Water temperatures were similar for the culture periods of December 4, 1985 to March 26, 1986 and January 21 to May 13, 1987; and April 22 to August 12, 1986 and May 22 to September 11, 1987 (Table 1). The mean water temperature for the two warmer culture periods was approximately 27% higher than for the two cooler culture periods.

The pooled shoot mean dry weight was 32 g for hydrilla plants cultured during the warmer culture periods of April 22 to August 12, 1986 and May 22 to September 11, 1987 compared to 12 g for January 21 to May 13, 1987, and December 4, 1985 to March 26, 1986. The difference in water temperature helps explain in part this difference in growth.

Statistical analyses of dry weight indicated significant differences for species of spikerush and rate effects, and as expected, the 16-week harvest weights for hydrilla were higher than those observed at 8 weeks (Figure 1). Rate effects within a species were predominantly linear with a high significance probability ($p>0.0001$). Due to the very different levels of variability between the 8 and 16 week harvests, no attempt was made to determine if trends were the same for the two periods within species of spikerush.

Shoot dry weight of hydrilla exposed to the 20-g rate of *E. cellulosa* was 89% and 77% lower than the control after 8 and 16 weeks of growth, respectively (Figure 1). Furthermore, after 16 weeks of growth, shoot dry weight of hydrilla exposed to the 20-g rate of *E. cellulosa* was 46% lower than the shoots of hydrilla plants exposed to the same rate of *E. interstincta*. Also, the 20-g rate of *E. cellulosa* resulted in the greatest reduction in shoot dry weight of hydrilla. The 1.0-g rates of neither spikerush species reduced hydrilla shoot growth below the control, but the shoot dry weight for plants exposed to the 5- and 10-g rates were lower than the control plants.

TABLE 1. WATER TEMPERATURE (C) IN OUTDOOR TANKS FOR HYDRILLA PLANTS CULTURED WITH DRIED SHOOTS SPIKERUSHES, *ELEOCHARIS CELLULOSA* AND *ELEOCHARIS INTERSTINCTA*, PLACED IN THE ROOT ZONE.

Cultured period	8 weeks			16 weeks		
	Mean	High	Low	Mean	High	Low
December 4, 1985 to March 26, 1986	22.0	27.6	13.5	22.8	31.0	13.5
April 22 to August 12, 1986	28.2	33.0	22.0	29.6	33.0	26.5
January 21 to May 13, 1987	23.2	30.0	16.0	25.5	31.0	15.0
May 22 to September 11, 1987	30.4	33.0	27.0	30.5	33.0	27.0

[4]SAS Institute Inc., Cary, NC 27511

No differences in hydrilla root dry weight were found between the two spikerushes for the 20-g spikerush rate with the hydrilla root weight for this treatment an average of 77% and 70% lower than the control plants after 8 and 16 weeks of growth, respectively. Root dry weight was lower than the control for the 10-g rate of the spikerushes after 8 weeks of growth but not after 16 weeks. The 1- and 5-g rates of spikerush did not reduce hydrilla root dry weight over that of the control.

Tubers were produced by hydrilla only during the December 4, 1985 to March 26, 1986 and January 21 to May 13, 1987 culture periods. These data agree with the study by Van, *et al.* (21) which showed that a photoperiod of short days and long nights stimulates tuber production for the dioecious strain of hydrilla.

The control hydrilla plants produced an average of 6 and 60 tubers per culture container after 8 and 16 weeks of growth, respectively. Only the 16-week tuber data are presented in Figure 2. No differences in tuber number were found between the control plants and the 1-g amounts of either species of spikerush and the 5-g amount of *E. interstincta* herbage. The 5-g rate of *E. cellulosa* spikerush reduced the number of tubers by 66% and 53% after 8 and 16 weeks of growth, respectively, as compared to the control. For the 10 and 20-g rates, no hydrilla tubers were found after 8 weeks of exposure, the number of tubers was reduced by 82% compared to the control plants after 16 weeks.

Smaller tubers were associated with hydrilla plants that produced fewer tubers ($P>0.0001$). Effects of both spikerushes on tuber production and development were similar. For the *E. cellulosa* treatments, regression analysis resulted in the equation: individual tuber weight = 0.0222 + 0.0009 × (number of tubers per culture container), and for *E. interstincta*: individual tuber weight = 0.0238 + 0.0009 × (number of tubers per culture container). Perhaps the smaller hydrilla biomass associated with the higher rates of spikerush produced less energy for propagule production which resulted in fewer and smaller tubers compared to the control treatments and low rates of spikerush.

Nutrient levels in the hydrilla tissue were similar to that reported by Sutton (19). No discernible simple trends were observed in hydrilla nutrient levels in relation to spikerush rates although some significant differences were noted in a means separation analysis (Tables 2 and 3). Shoots of hydrilla plants exposed to 1.0 g of *E. interstincta* for 8 weeks contained 39% less nitrogen than the control, but no differences were found after 16 weeks (Table 2). For phosphorus, roots of plants exposed for 8 weeks to 20 g of *E. interstincta* contained 38% less of this nutrient than the control; but interestingly, the shoots of hydrilla plants exposed to the 5- and 10-g rates of both spikerush for 16 weeks

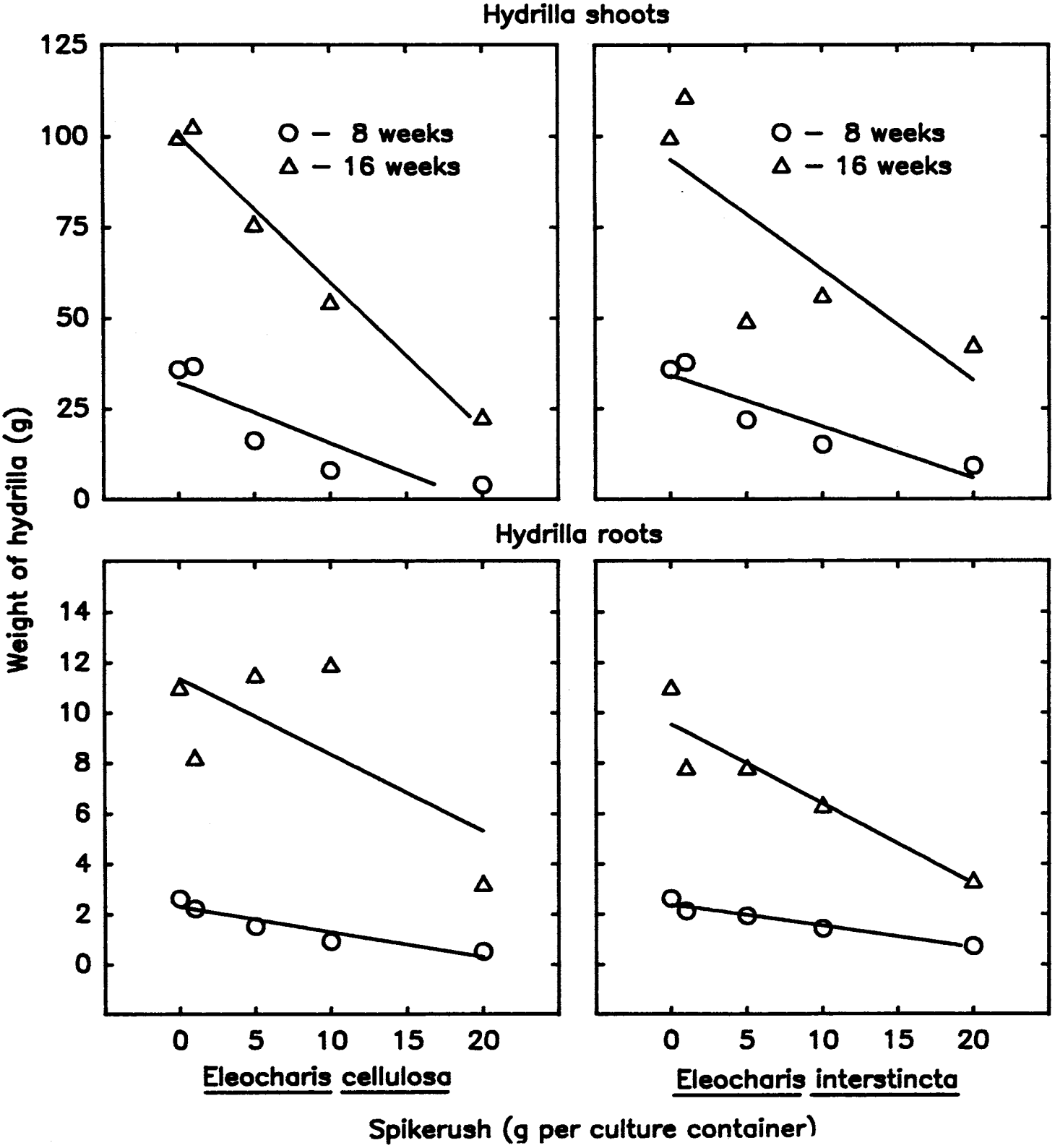

Figure 1. Dry weight for hydrilla plants cultured with dried shoots of the spikerushes, *Elocharis cellulosa* and Elocharis interstincta, placed in the root zone. Each value is the mean of plants from two containers for each of four culture periods.

contained an average of 24% more phosphorus than the shoots of the control plants. No differences were found for the amount of potassium in the control hydrilla tissue compared to hydrilla plants exposed to the various rates of spikerush.

When compared to the control hydrilla plants, no dif-

TABLE 2. NITROGEN, PHOSPHORUS, POTASSIUM, CALCIUM, AND MAGNESIUM CONTENT OF HYDRILLA TISSUE FOR PLANTS CULTURED WITH DRIED SHOOTS OF THE SPIKERUSHES, *ELEOCHARIS CELLULLOSA* AND *ELEOCHARIS INTERSTINCTA*, PLACED IN THE ROOT ZONE.[a]

		N(%)		P (μg/g)		K (μg/g)		CA (μg/g)		Mg (μg/g)	
Dry herbage	Amount	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks
	(g)	Shoots									
Control	–	1.51 ab	1.40 a	964 a	566 de	1637 a	10011 abc	36914 a	28040 a	2773 ab	2445 a
E. cellulosa	1	1.12 bc	1.24 a	949 a	551 e	18349 a	8000 c	39928 a	35250 a	2800 ab	2510 a
E. cellulosa	5	1.46 ab	1.45 a	1009 a	700 ab	15051 a	11435 ab	32800 a	33650 a	3086 a	3990 a
E. cellulosa	10	1.49 ab	1.45 a	974 a	716 a	13049 a	12390 a	29617 a	31650 a	3046 a	3360 a
E. cellulosa	20	1.86 a	1.59 a	955 a	684 abcd	16629 a	13190 a	27222 a	30000 a	3154 a	3345 a
E. interstincta	1	0.92 c	1.19 a	921 a	570 cde	14263 a	10033 abc	25057 a	30809 a	2234 b	2470 a
E. interstincta	5	1.19 bc	1.50 a	936 a	712 a	14663 a	10335 abc	35486 a	33900 a	2949 ab	3125 a
E. interstincta	10	1.30 bc	1.21 a	894 a	696 abc	13217 a	13096 a	32686 a	29775 a	3028 ab	3145 a
E. interstincta	20	1.43 ab	1.49 a	904 a	584 bcde	16577 a	8338 bc	34229 a	29557 a	3097 a	2555 a
		Roots									
Control	–	1.61 a	1.13 a	2118 a	1085 a	19822 a	15045 a	14053 a	12225 a	1125 a	821 a
E. cellulosa	1	1.69 a	1.33 a	1761 ab	1279 a	21934 a	18685 a	11326 a	12130 a	908 a	785 a
E. cellulosa	5	1.46 a	0.92 a	2000 ab	1087 a	21925 a	14875 a	13977 a	15955 a	1022 a	840 a
E. cellulosa	10	1.53 a	1.17 a	1707 ab	1015 a	26451 a	14180 a	9674 a	9383 a	981 a	779 a
E. cellulosa	20	1.28 a	1.27 a	1891 ab	966 a	21051 a	17200 a	16526 a	11875 a	1208 a	790 a
E. interstincta	1	1.43 a	0.99 a	2176 a	1085 a	19285 a	17225 a	14983 a	11935 a	1005 a	845 a
E. interstincta	5	1.43 a	1.18 a	1926 ab	1177 a	15874 a	17325 a	11263 a	14285 a	1117 a	850 a
E. interstincta	10	1.44 a	1.17 a	1602 ab	1134 a	25497 a	17685 a	11569 a	11540 a	964 a	865 a
E. interstincta	20	1.33 a	1.27 a	1311 b	1019 a	26773 a	18745 a	10309 a	12030 a	862 a	1020 a

[a]Values within a column for either shoots or roots followed by the same letter are not significantly different at the 5% level according to the Waller-Duncan multiple range test. Each value is the mean for nutrients measured in 0.5 g of plant tissue from two containers for each of four culture periods.

TABLE 3. IRON, SODIUM, MAGNESIUM, ZINC AND COPPER CONTENT OF HYDRILLA TISSUE FOR PLANTS CULTURED WITH DRIED SHOOTS OF THE SPIKERUSHES, *ELEOCHARIS CELLULOSA* AND *ELEOCHARIS INTERSTINCTA*, PLACED IN THE ROOT ZONE.[a]

		Fe(μg/g)		Na (μg/g)		Mn (μg/g)		Zn (μg/g)		Cu (μg/g)	
Dry herbage	Amount	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks	8 weeks	16 weeks
	(g)	Shoots									
Control	–	673 a	1450 a	2303 a	825 a	38 a	76 ab	139 a	35 a	5.8 a	3.9 a
E. cellulosa	1	753 a	1335 a	2314 a	855 a	37 a	71 a	39 a	33 a	4.7 a	3.7 a
E. cellulosa	5	654 a	1125 a	2249 a	1055 a	35 a	81 a	36 a	34 a	5.1 a	3.8 a
E. cellulosa	10	629 a	1100 a	2537 a	1215 a	35 a	77 ab	36 a	34 a	4.0 a	4.0 a
E. cellulosa	20	595 a	1150 a	2320 a	1305 a	33 a	76 ab	38 a	35 a	4.7 a	3.6 a
E. interstincta	1	691 a	1120 a	2022 a	933 a	38 a	62 ab	40 a	34 a	5.9 a	3.4 a
E. interstincta	5	555 a	1280 a	2097 a	1100 a	33 a	81 a	32 a	37 a	4.7 a	3.8 a
E. interstincta	10	527 a	985 a	2051 a	1155 a	33 a	71 ab	36 a	35 a	4.8 a	3.6 a
E. interstincta	20	1038 a	1065 a	2057 a	1165 a	38 a	60 b	36 a	34 a	4.9 a	2.9 a
		Roots									
Control	–	2491 a	8798 a	786 a	356 a	29 a	24 a	58 a	37 a	15.3 a	6.9 a
E. cellulosa	1	3474 a	8900 a	697 a	375 a	24 a	26 a	46 abc	28 a	9.0 bc	5.1 a
E. cellulosa	5	4411 a	8850 a	829 a	426 a	21 a	27 a	35 cd	29 a	6.2 cd	5.0 a
E. cellulosa	10	3920 a	9400 a	850 a	420 a	22 a	22 a	39 bcd	30 a	6.1 cd	4.7 a
E. cellulosa	20	6160 a	9575 a	990 a	350 a	25 a	25 a	39 bcd	26 a	5.7 b	5.7 a
E. interstincta	1	2777 a	11000 a	811 a	422 a	23 a	26 a	51 ab	51 a	10.6 b	5.7 a
E. interstincta	5	3925 a	10700 a	744 a	474 a	20 a	30 a	31 d	31 a	5.3 d	5.1 a
E. interstincta	10	2654 a	10600 a	658 a	354 a	18 a	29 a	25 d	29 a	5.9 cd	4.9 a
E. interstincta	20	3571 a	9700 a	731 a	374 a	17 a	28 a	25 d	30 a	3.8 d	4.3 a

[a]Values within a column for either shoots or roots followed by the same letter are not significantly different at the 5% level according to the Waller-Duncan multiple range test. Each value is the mean for nutrients measured in 0.5 g of plant tissue from two containers for each of four culture periods.

ferences were found either for the amount of calcium or magnesium (Table 2), or for iron or sodium (Table 3) in the tissue of hydrilla plants exposed to both species of spikerush.

Shoots of plants exposed for 16 weeks to the 20-g amount of *E. interstincta* contained 21% less manganese than the control shoots (Table 3). The concentration of zinc and copper in root tissue after 8 weeks of exposure to the spikerush herbages was lower than the control tissue but no differences were found after 16 weeks of growth.

In summary, based on the reduction in dry weight and production of tubers, this study suggests *E. cellulosa* and *E. interstincta* contain allelochemicals phytotoxic to hydrilla. The high phytotoxicity exhibited by *E. cellulosa* at the 20-g

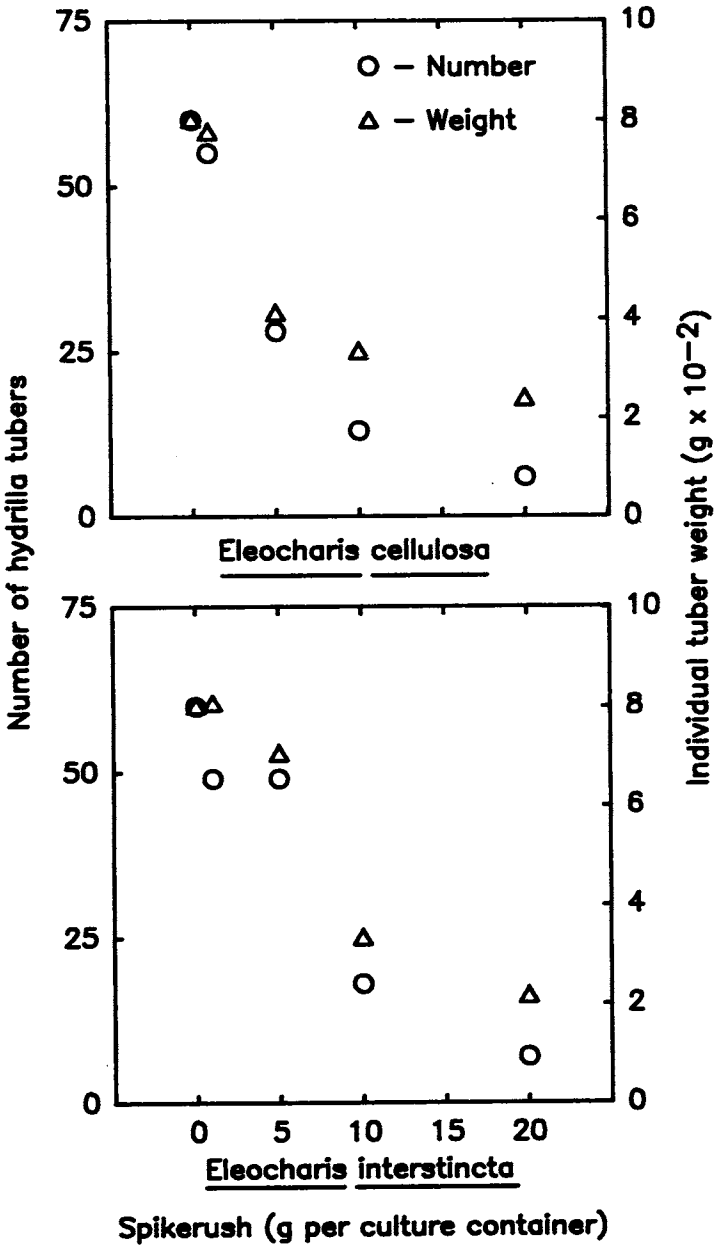

Figure 2. Number of tubers and individual tuber dry weight for hydrilla plants cultered with dried shoots of the spikerushes, *Eleocharis cellulosa* and *Eleocharis interstincta*, placed in the root zone. Each value is the mean of plants from two containers for the culture periods of December 4, 1985 to March 26, 1986 and January 21 to May 13, 1987 (16 weeks).

rate compared to *E. interstincta* supports the general observations that *E. cellulosa* resists invasion by other aquatic plants species resulting in monocultures of *E. cellulosa*.

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