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Growth of Hydrilla in Established Stands of Spikerush and Slender Arrowhead[1]

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ABSTRACT

Established stands of slender arrowhead (*Sagittaria graminea* Michx.) were more effective than spikerush (*Eleocharis geniculata* (L.) R. & S.) in reducing growth of sprouted tubers of hydrilla (*Hydrilla verticillata* (L.f.) Royle). During 8-week growth periods in culture pans held in outdoor plastic-lined pools with flowing pond water, shoot dry weight for sprouted hydrilla tubers planted with slender arrowhead was reduced as much as 95% compared to similar hydrilla tubers planted by themselves. Dry weight of hydrilla shoots from tubers planted with the spikerush was from 3 to 6 times lower than for tubers planted alone; however, in one growth period the spikerush did not reduce the shoot dry weight of hydrilla but the root weight was reduced. Treatments with hydrilla planted in established stands of slender arrowhead plants resulted in a 90% reduction in the number of tubers produced as compared to the control hydrilla plants; however, the reduction of propagules was less for hydrilla planted in established stands of spikerush plants.

Key words: Allelopathy, aquatic weeds, biomass, competition, native plants, propagules.

INTRODUCTION

Allelopathy and competition are two ways plants interact as they colonize and grow in an area. Rice (4) distinguishes allelopathy as biochemical interactions between plants, including microorganisms, which result in an inhibitory or stimulatory process, and competition as the removal or reduction of some factor, such as water, nutrient, or light, from the environment that is required by some other plant sharing the habitat.

Hydrilla appears to dominate a body of water primarily through competitive effects by its ability to photosynthesize under light conditions lower than that required by most other submersed plants (6). In this way, hydrilla begins to use carbon dioxide early in the morning when the supply is high, so that by the time the other plants receive enough light to begin to photosynthesize the carbon supply has

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been reduced. Also, hydrilla branches profusely near the surface producing a mat that blocks light penetration to submersed plants growing below it (3).

Allelopathic relationships have been associated with certain spikerush plants. For example, slender spikerush (*Eleocharis acicularis* (L.) R. & S.) and dwarf spikerush (*Eleocharis coloradoensis* Britt.) (Gilly) have been found to replace elodea (*Elodea canadensis* Michx.), American pondweed (*Potamogeton nodosus* Poir.), and sago pondweed (*Potamogeton pectinatus* L.) through non-competitive effects (2, 7). Extracts of materials from slender spikerush with a molecular weight between 600 and 1000 appear to be responsible for some of these allelopathic responses (1).

In order to provide additional information on the interaction of aquatic plants, a study was conducted allowing two species of plants native to Florida to grow and develop established stands. Once the plants were established, sprouted hydrilla tubers were planted in the hydrosoil of the stands to simulate the invasion of hydrilla in an area. Plant dry weight and tuber production after 8 weeks were the primary measurements of plant interactions.

MATERIALS AND METHODS

Two separate series of experiments were conducted allowing either spikerush (*Eleocharis geniculata* (L.) R. & S.) or slender arrowhead (*Sagittaria geniculata* Michx.) to grow and become established in culture pans after which sprouted hydrilla tubers were planted in the hydrosoil. After the hydrilla tubers were planted, all the plants were allowed to grow for an additional 8-weeks after which the plants were harvested.

Experiments were conducted outdoors in circular, plastic-lined pools, 0.9 m in height by 3.6 m in diameter, at the Fort Lauderdale Research and Education Center (FLREC). The FLREC is located at coordinates 26°05′N and 80°14′W.

Each pool contained 7,790 L of pond water at a depth of 77 cm. Pond water entered the pool at the top on one side and drained from the bottom on the opposite to provide for an exchange of water every 24 hr. Pond water was from the same source as described by Steward (5).

Plants were cultured in circular pans 19 cm in diameter by 20 cm in height. The pans were elevated 20 cm from the bottom of the pool. Each pan held 6.5 kg of coarse builders sand to which 15.17 g of Osmocote[3] (18-6-12) formulated for an 8 to 9-month release rate at a temperature of 21 C, 0.39 g of Esmigran, and 2.43 g of dolomite were added. The sand was air-dried and the fertilizers were thoroughly mixed in it.

Water temperatures were collected 5 days a week, generally between 3:00 and 4:00 PM, from a U-shaped maximum/minimum thermometer which was placed 30 cm below the surface of the water in the pool. Water temperature was calculated as the mean of the maximum and minimum values for the various growth periods.

The emersed form of spikerush plants was collected from wild populations growing in moist areas near the culture pools. Each pan received four individual clumps of spikerush plants. Slender arrowhead plants were from cultures maintained in a commercially available muck-sand soil held in the outdoor pools at the REC. Each pan received six individual plants of slender arrowhead. A stand was considered established after all spikerush or slender arrowhead plants covered the surface (284 cm^2) of the hydrosoil in the culture pans in which they were growing. Sprouted tubers were then planted in the established stands of either spikerush or slender arrowhead.

Sprouted tubers were obtained by first collecting ones which had not yet germinated from hydrilla plants that had been cultured for at least 1 year in plastic-lined pools at the REC. These tubers were then placed in pans located several centimeters below the surface in a plastic-lined pool with flowing pond water, and allowed to sprout and form shoots. Those tubers with shoots from 7 to 15 cm in length were selected for use in the study.

A single experiment consisted of 24 culture pans in a pool with four treatments of (1) native plants harvested at the time the sprouted hydrilla tubers were planted (Prior), (2) native plants plus hydrilla (With), (3) native plants alone, (4) hydrilla alone. The purpose of Treatment 4 was to use dry weight of these plants to determine any deleterious effects of the hydrilla on growth of the spikerush or slender arrowhead. In Treatments 2 and 3, four sprouted tubers were planted by pushing a tuber 2 to 3 cm below the surface of the hydrosoil in each culture pan. The pans for Treatment 3 were placed in the pool at the time of planting the native plants to account for any loss of fertilizer due to dissolution which might occur during the initial growth of the native plants. Each treatment was replicated in six culture pans. The treatments were randomized within rows perpendicular to the flow of pond water. The experiment was repeated three times for each native plant according to the time schedule presented in Table 1.

Harvest time for each experiment consisted of removing the plants in Treatment 4 at the time the sprouted hydrilla tubers were planted. Sprouted tubers were planted in Treatments 2 and 3 after which all the plants were removed after an additional 8 weeks of growth. The plants were separated into shoots and roots, and washed with pond water to remove algae, sand, and other adhering debris. Tubers were removed from those hydrilla plants which produced them. The plant material was dried to a constant weight at 60 C, and then 1.0-g samples of the dried material were placed in a 105 C oven. These samples were used to estimate the 105 C weight of the entire amount of plant material harvested.

Dry weight and tuber data were statistically analyzed using randomized block design procedures. Count data for the tubers were transformed by adding 1 to each value and then taking its natural log prior to analyses; however, the non-transformed values are presented.

RESULTS AND DISCUSSION

The emersed form of the spikerush readily adapted to growth in a submersed condition and formed a dense

[3]Mention of a trademark name 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.

TABLE 1. PLANTING AND HARVESTING TIMES FOR SPIKERUSH, SLENDER ARROWHEAD, AND HYDRILLA.

Plant and experiment number	Initial planting date	Planting date for hydrilla	Harvest of all plants
Spikerush:			
Experiment 1.	04 Aug 82	21 Sept 82	16 Nov 82
Experiment 2.	07 Jan 83	25 Feb 83	22 Apr 83
Experiment 3.	31 May 83	19 Jul 83	13 Sep 83
Slender arrowhead:			
Experiment 1.	02 Feb 83	14 Apr 83	09 Jun 83
Experiment 2.	21 Jun 83	26 Oct 83	21 Dec 83
Experiment 3.	12 Jan 84	25 Jun 84	20 Aug 84

growth of plants within 2 months after planting (Table 1). Growth of slender arrowhead was a little slower than the spikerush as up to almost 6 months were required for it to cover the surface of the container in which it was growing.

Osmocote is formulated to release nutrients when its temperature is 21 C or higher. Since the average water temperature was 20.6 C or higher for all the experiments (Table 2), release of nutrients from the Osmocote was adequate for the entire study. A high water temperature average of 30.8 C was measured during the 8-week period after planting hydrilla tubers in the established mat of slender arrowhead in Experiment 3.

Results from Experiment 1 gave dry weights of the spikerush and hydrilla differently than for Experiments 2 and 3 (Table 3). In Experiment 1, plant weight of the spikerush grown in combination with hydrilla was lower than for those plants grown alone. The reason for this difference among the three experiments may have been due to the difficulty in obtaining uniform spikerush plants for all the experiments. The root dry weights of spikerush

TABLE 2. WATER TEMPERATURES DURING ESTABLISHMENT OF SPIKERUSH AND SLENDER ARROWHEAD, AND DURING GROWTH OF HYDRILLA WITH THESE PLANTS.

Plant and experiment number	Water temperature (C)					
	During establishment of spikerush and slender arrowhead			During growth of hydrilla		
	Aver.	Min.	Max.	Aver.	Min.	Max.
Spikerush:						
Experiment 1.	28.7	26.0	35.0	25.4	19.0	31.0
Experiment 2.	20.6	14.5	26.0	22.6	15.0	29.0
Experiment 3.	28.6	23.0	33.0	30.1	25.5	34.0
Slender arrowhead:						
Experiment 1.	21.4	15.0	29.0	27.7	22.0	31.5
Experiment 2.	29.5	23.5	34.0	24.5	20.0	29.0
Experiment 3.	25.4	16.0	31.5	30.8	28.5	33.0

in all three experiments at the time the sprouted hydrilla tubers were planted were quite different. Also, based on the shoot dry weights in Experiments 2 and 3, the spikerush plants in Experiment 1 may not have had adequate time to develop an established stand prior to planting the tubers. Shoot weight of hydrilla was not reduced by the presence of the spikerush, but the root weight was lower as compared to hydrilla grown alone in Experiment 1 (Table 3). Decrease in root weight of the hydrilla cultured with the spikerush was also associated with a 41% reduction in the number of hydrilla tubers produced during the 8-week growth period.

In Experiments 2 and 3 both shoot and root dry weight of hydrilla was lower for plants cultured with the spikerush as compared to plants allowed to grow by themselves. The high water temperature, an average of 30 C, which occur-

TABLE 3. DRY WEIGHT AND NUMBER OF TUBERS OF HYDRILLA GROWN FOR 8 WEEKS IN ESTABLISHED STANDS OF THE SPIKERUSH.[a]

Experiment number and growth condition	Treatment number	Plant dry weight at 105 C (g)[b]				Number of hydrilla tubers
		Spikerush		Hydrilla		
		Shoots	Roots	Shoots	Roots	
Experiment 1:						
Prior	1	4.9 a	2.2 a	—	—	—
With	2	3.3 a	2.2 a	66.0 a	4.7 a	53 a
Spikerush alone	3	7.3 b	5.6 b	—	—	—
Hydrilla alone	4	—	—	79.0	7.4 b	90 b
Experiment 2:						
Prior	1	8.5 b	17.5 b	—	—	—
With	2	4.9 a	7.7 a	24.9 a	3.2 a	4 a
Spikerush alone	3	5.1 a	8.9 a	—	—	—
Hydrilla alone	4	—	—	64.6 b	7.2 b	12 b
Experiment 3:						
Prior	1	8.4 a	34.5 b	—	—	— c
With	2	12.3 b	13.5 a	23.7 a	2.7 a	—
Spikerush alone	3	13.6 b	9.5 a	—	—	—
Hydrilla alone	4	—	—	145.9 b	9.7 b	—

[a]Values within a column for each experiment followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test. Each value is the mean of six pans in one pool.
[b]A dash indicates no plants or tubers were harvested.
[c]The photoperiod was not conducive for tuber production during Experiment 3.

red during Experiment 3 after the sprouted tubers were planted probably accounted for the high amount of hydrilla shoot weight, 146 g, measured in this portion of the experiments.

All three experiments with the slender arrowhead and hydrilla produced similar results (Table 4). Dry weight of hydrilla shoots was 84 to 95% lower for plants cultured in the established stands of slender arrowhead as compared to hydrilla plants grown alone. Likewise, root dry weight of the hydrilla allowed to grow in the presence of slender arrowhead was 91 to 95% lower than comparable plants grown by themselves. Associated with this reduction in dry weight was a decrease in tuber production in Experiment 2 for those sprouted hydrilla propagules planted in the slender arrowhead culture pans as compared to the tubers planted alone. No tubers were produced in Experiment 1 and 3 because of the long-day conditions which occurred during the time the hydrilla was growing.

No growth of the slender arrowhead occurred during the 8-week period after the sprouted hydrilla tubers were planted as the dry weight of the plants was the same at the beginning of this period as compared to the end. This is not unexpected as the surface of the containers were covered with little room for new growth to occur.

Spikerush and slender arrowhead appear to compete effectively in the environment by forming dense stands of plants which restrict the ability of other plants to root into the sediment. Both of these species also form shallow, thick fibrous root systems which may further limit invasion by other plants. With the spikerush, almost 50% of the total plant weight was root material in this study. However, this spikerush does not appear to be nearly as effective as dwarf spikerush (*Eleocharis coloradoensis* [Britt.] Gilly) (8) as a management tool for use in displacement of weed species. Of the two native species from Florida used in this study, slender arrowhead appears to have the most potential for use in reducing the growth potential of hydrilla.

These data indicate that established stands of some native aquatic plants will help reduce establishment of hydrilla primarily through competitive effects. However, it is well known that hydrilla has the ability to replace many native submersed plants, and eventually this exotic plant will grow as a monoculture in many situations. Aquatic plant management strategies which seek to encourage growth of native submersed plants will help reduce the ability of hydrilla to invade and dominate a body of water. Additional studies are needed to evaluate ways to establish stands of native submersed plants concomitant with control methods to reduce the competitive nature of hydrilla.

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TABLE 4. DRY WEIGHT AND NUMBER OF TUBERS OF HYDRILLA GROWN FOR 8 WEEKS IN ESTABLISHED STANDS OF SLENDER ARROWHEAD.[a]

Experiment number and growth condition	Treatment number	Plant dry weight at 105 C (g)[b]				Number of hydrilla tubers[c]
		Slender arrowhead		Hydrilla		
		Shoots	Roots	Shoots	Roots	
Experiment 1:						
Prior	1	12.0 a	3.2 a	—	—	—
With	2	48.3 b	4.2 b	5.7 a	0.2 a	—
Slender arrowhead alone	3	48.3 b	4.6 b	—	—	—
Hydrilla alone	4	—	—	35.9 b	2.3 b	—
Experiment 2:						
Prior	1	29.7 a	3.5 a	—	—	—
With	2	53.1 b	6.5 b	2.4 a	0.4 a	5 a
Slender arrowhead alone	3	54.9 b	5.8 b	—	—	—
Hydrilla alone	4	—	—	42.4 b	7.3 b	55 b
Experiment 3:						
Prior	1	18.9 a	4.3 a	—	—	—
With	2	55.7 b	6.6 b	5.4 a	0.5 a	—
Slender arrowhead alone	3	55.5 b	5.1 a	—	—	—
Hydrilla alone	4	—	—	111.2 b	8.9 b	—

[a]Values within a column for each experiment followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test. Each value is the mean of six pans in one pool.
[b]A dash indicates no plants or tubers were harvested.
[c]The photoperiod was not conducive for tuber production during Experiments 1 and 2.

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