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Water Regimen and Depth Affect Hygrophila Growth and Establishment

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ABSTRACT

Hygrophila (*Hygrophila polysperma* [Roxb.] T. Anders.) was grown in outdoor mesocosms to determine the effect of water regimen and water depth on hygrophila growth. Water regimen treatments included water that was stagnant, flushed twice per week, aerated, or continuously circulated. Hygrophila growth was highest when water was flushed twice per week; plants in this treatment produced the highest root and shoot biomass and had the longest and widest leaves. Water depth treatments included hygrophila submerged deep (54 cm), submerged shallow (27 cm), emerged, or sub-irrigated. Sub-irrigated plants produced higher root and shoot biomass than plants from all other treatments. These results indicate that hygrophila must become established as a terrestrial plant in saturated or near saturated soils; furthermore, after establishment in a terrestrial environment it can encroach into nearby water and grow as a submerged plant.

Key words: East Indian hygrophila, Indian swampweed, hygro, *Hygrophila polysperma*, Miramar weed, root biomass, shoot biomass.

INTRODUCTION

Hygrophila (*Hygrophila polysperma* [Roxb.] T. Anders.) is an herbaceous, perennial, aquatic weed that grows submerged or partially emerged in fresh waters or as a terrestrial plant in saturated soils (Ramey 2001). Stems are creeping-ascendant, easily broken into fragments, and they root at the nodes; furthermore, leaves are opposite, simple, and acute and range from light green to brown to red in color (Anderson 1867). Plants reproduce asexually (from fragments) and produce seed; however, the contribution of seed to plant propagation is unknown (Sutton 1995).

Hygrophila is native to India and China (Sutton et al. 1994) and entered the United States in 1945 via the aquarium industry (Innes 1947). Reams (1950) noted that the species was able to establish quickly and survive in Virginia lakes. In 1965 hygrophila was observed growing in natural waters in Hillsborough County, Florida, and in 1979 it was discovered to be established and well-distributed throughout Lee County, Florida (Les and Wunderlin 1981). Shortly thereafter it was reported that hygrophila was a serious weed problem in south Florida canals (Vandiver 1980), and Spencer and Bowes (1985) reported the presence of hygrophila in Florida's Broward and Palm Beach counties. Sutton (1995) speculated that control of hydrilla (*Hydrilla verticillata* [L.F.] Royle) encouraged the establishment and spread of hygrophila throughout southern Florida by leaving large areas of water unoccupied by aquatic vegetation.

Results from previous research on hygrophila biology help explain the vigorous growth of hygrophila in Florida. Spencer and Bowes (1985) investigated the biology of hygrophila and concluded that a number of biological factors (e.g., vegetative reproduction, ability to photosynthesize in low and high light conditions) contribute to the persistence and seriousness of this species as a weed problem. Sutton and Dingler (2000) investigated the effects of temperature and sediment nutrients on hygrophila growth and concluded that although hygrophila grows year-round in Florida, growth was greatest during the warmer months of the year. Additionally, they found that when hygrophila was grown in sediment that contained 16 g of 17-16-10 fertilizer per 330 cm^2, plant biomass was nearly 20 times greater than that of plants grown in sediment with no fertilizer (Sutton and Dingler 2000). Van Dijik et al. (1986) conducted research to compare the growth of hydrilla and hygrophila in static versus flowing water and reported that hygrophila growth was greater in flowing water than in static water. Furthermore, they reported that hygrophila grown in flowing water had a greater number of emersed leaves and a healthier appearance than the plants grown in static water (Van Dijik et al. 1986). These findings suggest that the flowing water of rivers and canals in south Florida provides a favorable environment for hygrophila growth, which explains why hygrophila is predominantly found in these environments.

Although research has been conducted on the biology of hygrophila, very few papers have been published on hygrophila control. To conduct research on hygrophila control that will produce accurate, representative results, methods for propagating hygrophila sprigs and maintaining healthy actively growing plants in mesocosms for several weeks must be developed. The objective of this research was to determine which water regimen and water depth would result in optimal hygrophila establishment and growth.

MATERIALS AND METHODS

Experiments were conducted in 2005 and 2006 at the University of Florida Fort Lauderdale Research and Education Center (FLREC). Two 15-cm hygrophila sprigs were planted in 2-L plastic pots that contained pure sand amended with 15 g slow release fertilizer (Osmocote [15-9-20]). After sprigs were planted, pots were placed in 900-L vaults (219 by 76 by 54 cm).

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Water Regimen Experiments

Water regimen treatments included water that was stagnant, flushed twice per week, aerated, or continuously circulated. Water was completely replaced twice per week in the flushed twice per week treatment. In the aerated treatment water was aerated with the use of an aquarium aeration pump, and in the continuously circulated treatment water was circulated at a rate of 44 L min^{-1} with a submersible pump. In these experiments hygrophila was planted and allowed to establish under terrestrial conditions for approximately 60 days before experiment initiation. Experimental treatment conditions were maintained for approximately eight weeks until harvest. The first water regimen experiment (Experiment 1) was planted on November 15, 2005, initiated on January 5, 2006, and harvested on March 2, 2006. The second experiment (Experiment 2) was planted on January 29, 2006, initiated on April 4, 2006, and harvested on May 30, 2006. Plant data collected at harvest included root biomass, shoot biomass, internode length, leaf length, and leaf width. Each vault was considered one replication, and each vault contained three plants. Each plant within a replication was treated as a subsample, and each treatment had four replications. After collection, roots and shoots were dried and weighed. In addition to the plant data, water samples were collected from each mesocosm at harvest and analyzed for nitrogen (NO_3), phosphorous (PO_4), calcium, potassium, and magnesium concentration and pH. Samples were submitted to the FL-REC Chemistry Lab for analysis. A treatment by experiment interaction prevented pooling of the data across experiments; therefore, data from the two experiments are presented separately. Data were subjected to analysis of variance, and means were separated using Fisher's Protected LSD test ($\alpha = 0.05$).

Water Depth Experiments

Water depth treatments included plants submerged deep (54 cm), submerged shallow (27 cm), emerged (water level at the top of the pot), and sub-irrigated (water level approximately 5 cm deep in the mesocosm). The water in these treatments was stagnant because fresh water was only added as necessary to maintain the appropriate water depth, and there was no circulation. Hygrophila sprigs were planted and experimental treatment conditions were maintained for approximately 10 weeks until harvest. The first of the two water depth experiments (Experiment 3) was planted on December 30, 2005 and harvested on March 10, 2006. The second of the two water depth experiments (Experiment 4) was planted on March 28, 2006, and harvested on June 6, 2006. At harvest plant roots and shoots were collected, dried, and weighed. These experiments contained four replications with four subsamples per replication. Although trends in the data from the two water depth experiments were similar, differences in scale resulted in a treatment by experiment interaction; therefore, the two experiments were analyzed separately. Data were subjected to analysis of variance, and means were separated using Fisher's Protected LSD test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Water Regimen Experiments

In Experiment 1 (Table 1) and Experiment 2 (Table 2) hygrophila plants from the flushed twice per week treatment produced the highest shoot biomass and had the longest and widest leaves. Water from all treatments had nitrogen, phosphorous, and magnesium concentrations of 0, 0, and 1 ppm, respectively (data not shown).

In Experiment 1, root biomass did not differ among treatments. Internode lengths from the flushed twice per week, aerated, and continuously circulated treatments were similar to each other and lower than that of the stagnant treatment. Potassium content of water from the flushed twice per week treatment was lower than the other treatments, which did not differ from each other. Additionally, water pH was similar in the flushed twice per week and aerated treatments, which were lower than that of the other treatments.

In Experiment 2, root biomass of plants from the flushed twice per week treatment was higher than that of the other three treatments, which did not differ from each other. Furthermore, plants from the flushed twice per week treatment had lower internode lengths than those of the other three treatments, which were similar to each other. The pH of the continuously circulated water was higher than that of the other treatments, which did not differ, and no treatment differences were detected in potassium content of the water.

These results indicate that hygrophila growth was maximized when plants were grown in water flushed twice per week. In general, hygrophila plants from this treatment produced the highest amounts of root and shoot biomass and the longest and widest leaves. Sutton (1995) noted that hygrophila was a common weed of canals in south Florida. Our conclusion that maximum hygrophila growth occurred in the flushed twice per week treatment helps explain why canals favor hygrophila growth because the growing conditions of this treatment were very similar to those commonly found in canals. Van Dijik et al. (1986) concluded that hygrophila grew best in flowing water (water that was moving and was

TABLE 1. EFFECT OF WATER REGIMEN ON HYGROPHILA ROOT BIOMASS, SHOOT BIOMASS, INTERNODE LENGTH, LEAF LENGTH, LEAF WIDTH, CALCIUM AND POTASSIUM CONCENTRATION, AND PH[a] IN EXPERIMENT 1.

Treatment	Root biomass (g)	Shoot biomass (g)	Internode length (mm)	Leaf length (mm)	Leaf width (mm)	Ca (ppm)	K (ppm)	pH
Stagnant	1.45 a	6.78 b	22.3 a	20.3 b	6.8 b	22.3 b	1.0 a	7.8 a
Flushed twice per wk	1.88 a	10.14 a	19.3 b	33.5 a	9.0 a	51.5 a	0.3 b	7.0 b
Aerated	1.61 a	7.30 b	20.8 ab	19.0 b	6.8 b	26.0 b	1.0 a	7.0 b
Continuously circulated	1.79 a	7.47 b	19.8 ab	18.0 b	6.0 b	23.3 b	1.3 a	8.0 a

[a]Values followed by the same letter within each column are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

TABLE 2. EFFECT OF WATER REGIMEN ON HYGROPHILA ROOT BIOMASS, SHOOT BIOMASS, INTERNODE LENGTH, LEAF LENGTH, LEAF WIDTH, CALCIUM AND POTASSIUM CONCENTRATION, AND PH[a] IN EXPERIMENT 2.

Treatment	Root biomass (g)	Shoot biomass (g)	Internode length (mm)	Leaf length (mm)	Leaf width (mm)	Ca (ppm)	K (ppm)	pH
Stagnant	0.57 b	1.08 b	28.3 a	6.3 c	2.3 c	17.8 b	1.5 a	7.0 b
Flushed twice per wk	1.58 a	13.75 a	18.4 b	36.9 a	8.8 a	37.5 a	1.0 a	7.0 b
Aerated	0.18 b	2.08 b	31.2 a	21.0 b	5.9 b	18.0 b	1.3 a	7.0 b
Continuously circulated	0.15 b	0.50 b	28.7 a	7.8 c	2.5 c	14.5 b	1.0 a	7.5 a

[a]Values followed by the same letter within each column are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

TABLE 3. EFFECT OF WATER DEPTH ON HYGROPHILA ROOT AND SHOOT BIOMASS[a] IN EXPERIMENT 3 AND EXPERIMENT 4.

	Experiment 3		Experiment 4	
Treatment	Root biomass (g)	Shoot biomass (g)	Root biomass (g)	Shoot biomass (g)
Submerged deep	0.02 c	0.06 c	0.00 c	0.00 c
Submerged shallow	0.01 c	0.05 c	0.00 c	0.00 c
Emerged	0.58 b	3.71 b	1.43 b	7.78 b
Sub-irrigated	1.33 a	6.15 a	6.03 a	20.23 a

[a]Values followed by the same letter within each column are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

continuously being replaced with fresh water). Although our research did not include a treatment with flowing water, the water in the continuously circulated treatment was moving, and the water in the flushed twice per week treatment was replaced. Because hygrophila growth was higher in the flushed twice per week treatment than in the continuously circulated treatment, we speculate that hygrophila growth was greater in flowing water not only because the water was moving, but because it was constantly being replaced with fresh water.

Water Depth Experiments

Experiment 3 and Experiment 4 plants from the sub-irrigated treatment produced a higher amount of root and shoot biomass than the plants from the submerged deep, submerged shallow, and emerged treatments (Table 3). We concluded that when hygrophila was grown in stagnant water, maximum growth occurred when the water depth was maintained below the sediment surface. Several authors (Vandiver 1980, Kovach et al. 1992, Sutton and Dingler 2000) have stated that hygrophila can grow as both a submerged and emerged plant in rivers and canals. In our research hygrophila did not grow well when initially established as a submerged plant; however, the water was stagnant in the water depth experiments, contrary to the flowing water that would most likely be present in the rivers and canals where hygrophila is reported to grow as a submerged plant. Based on our results, we speculate that hygrophila fragments may become established first as a terrestrial plant on the banks of rivers and canals, and then expand to the deeper water where it becomes established as a submerged plant.

We concluded that to successfully grow hygrophila in experimental mesocosms, the water should be flushed at least twice per week, and that hygrophila can be grown in static water only as an emerged plant with the water level maintained below the sediment surface (sub-irrigated). Future research should be conducted to determine if flushing the water more frequently than twice per week results in a further increase in hygrophila growth. Because the water depth experiments were conducted in stagnant water, this research should be repeated in water that is stagnant, aerated, and continuously circulated to determine if submerged hygrophila growth is affected by both water depth and regimen.

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