ERDC/TN APCRP-EA-26
October 2011

Shade and depth effects on the growth of giant salvinia

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PURPOSE: To determine shade and depth-to-sediment effects on the growth of giant salvinia (*Salvinia molesta* Mitchell).

BACKGROUND: Giant salvinia (*Salvinia molesta* Mitchell), a free-floating aquatic invasive fern native to southeastern Brazil, is currently found worldwide in subtropical, tropical, and temperate regions. It has been reported in more than 20 countries including the United States, where it was most likely introduced through the aquarium or water garden trade (Room et al. 1981). An aggressive aquatic species, giant salvinia can completely cover water surfaces and form mats up to 1 m thick (Thomas and Room 1986). Giant salvinia has three growth forms; primary, which has small, flat leaves, approximately 10-15 mm wide; secondary, which has boat-shaped leaves with rounded apices ranging from 20-50 mm wide; and tertiary (mat-forming), which is the mature form, where plants are crowded together with short nodes and folded leaves (Harley and Mitchell 1981). Dense mats of giant salvinia can impede transportation, irrigation, hydroelectric production, flood, and mosquito control; destroy aquatic habitat; degrade water quality; and hinder rice cultivation and fishing (Oliver 1993, Mitchell 1979, Holm et al. 1977).

Giant salvinia has invaded several freshwater systems within the last decade in southern, southwestern, and Gulf coastal states of the United States where it has exhibited persistent and sometimes explosive growth (U.S. Geological Survey (USGS) 2004). Giant salvinia prefers still or slow-moving fresh water (Harley and Mitchell 1981), but can cover large areas of any water body if growing conditions are adequate. These conditions are generally found in backwater, shallow coves of reservoirs, lakes, and wetlands. Because many aquatic systems are tree-lined, backwater cove areas can be shady, reducing light availability to invading giant salvinia plants. Additionally, backwater cove areas tend to be shallow, positioning giant salvinia's rootlike third leaf closer to the sediments. This proximity to the sediments may provide giant salvinia increased opportunities for nutrient uptake and growth.

The objectives of this study were to document different shade and depth-to-sediment treatments on giant salvinia growth.

MATERIALS AND METHODS: Studies were conducted at the Lewisville Aquatic Ecosystem Research Facility located in Lewisville, Texas.

SHADE STUDY: In August 2008, 0.24 L of pond sediment was added to each of forty 19-L containers (33 cm height, 30 cm wide) to ensure that adequate trace nutrients were available to sustain growth of giant salvinia. Low pH (average 5.4 units, monitored weekly) was maintained by adding 0.8 L (30 g) of peat moss (Premier Horticulture, Quebec, Canada) to all containers to help maintain nutrient availability from pond sediment. Containers were filled with alum-treated water from Lake Lewisville, Lewisville, TX. Each container was amended with 20 ml of a 26.5-g NH_4NO_3/L and 8.26-g Na_2PO_4-H_2O/L solution to provide nitrogen and phosphorus for the duration of the study. Three five-leaf pair giant salvinia plants were added to each container. The plants were green, robust, and undamaged by herbivory. Six salvinia plants (five-leaf pair giant salvinia plants) were collected and dried for initial biomass weights. Shade treatments tested were full light (0% shade), 30% shade, 57% shade, and 80% shade (Lumite Fabric®, Chicopee, Cornelia, GA). Each treatment was replicated 10 times.

DEPTH STUDY: In June 2009, 0.48 L of pond sediment was added to thirty 19-L containers (33 cm height, 30 cm wide) to ensure adequate nutrients were available to sustain growth of giant salvinia. To obtain the various depths to sediment, sand was added below the sediment to ensure all plants were positioned at the same height in the research containers and thus they received equal light conditions. Containers were filled with alum-treated water from Lake Lewisville. No additional nutrient or pH amendments were made to the water to ensure growth was dependent on depth to sediment. One giant salvinia plant with five-leaf pairs was added to each container and allowed to grow for three weeks. The plants were green, robust, and undamaged by herbivory. Algal growth was controlled by adding 100 uL of Aquashade (Applied Biochemist, Germantown, WI) to the water and by floating Styrofoam plates on the water surface to limit light penetration into the water column. As giant salvinia grew, the plates were removed to minimize interference with spread. Six salvinia plants (five-leaf pair giant salvinia plants) were collected and dried for initial biomass weights. Depth-to-sediment treatments tested were: deep (30 cm of water), medium (15 cm of water), and shallow (2.5 cm of water). Treatments were replicated 10 times.

PLANT HARVESTING: In both studies, plants were collected from each container after 3 week's growth, dried to a constant weight at 55°C using a Blue M forced air oven (General Signal, Atlanta, GA), and weighed.

STATISTICS: Statistical differences between treatment dry weights were calculated using a one-way analysis of variance (ANOVA). Significant differences between means were ascertained using Tukey's level of significance at $p=0.05$. Statistics were performed using Statistix Analytical Software, Tallahassee, FL.

RESULTS AND DISCUSSION:

SHADE STUDY: Significant differences ($p=0.0000$, $F=94.68$) were found between control (0% shade) and all other shade treatments (Figure 1). After 3 week's growth, control dry weight was approximately three-fold greater than the highest shading (80%). Initial average biomass dry weight (DW) was 0.12g, indicating substantial increases in biomass in all treatments.

As shade levels increased, green leaf color appeared to deepen when compared side-to-side (Owens, pers observ). Lambers et al. (1998) reported that shade-tolerant plants can increase leaf area and chlorophyll concentrations (darker green color), while decreasing leaf thickness. No plants in this study reached tertiary form, probably due to the short duration of the growth period investigated. Control (0% shade) plants completely covered their containers after the three-week growth period and were generally in the secondary growth form. Plants growing in 30% and 57% shade also completely covered the surface of their containers and were represented by a mixture of primary and secondary growth forms. Giant salvinia plants in the 80% shade treatment containers remained in the primary growth form and loosely covered the surface. Harley and Mitchell (1981) observed that giant salvinia plants growing in shade tended towards the primary growth form especially during the early stages of invasion.

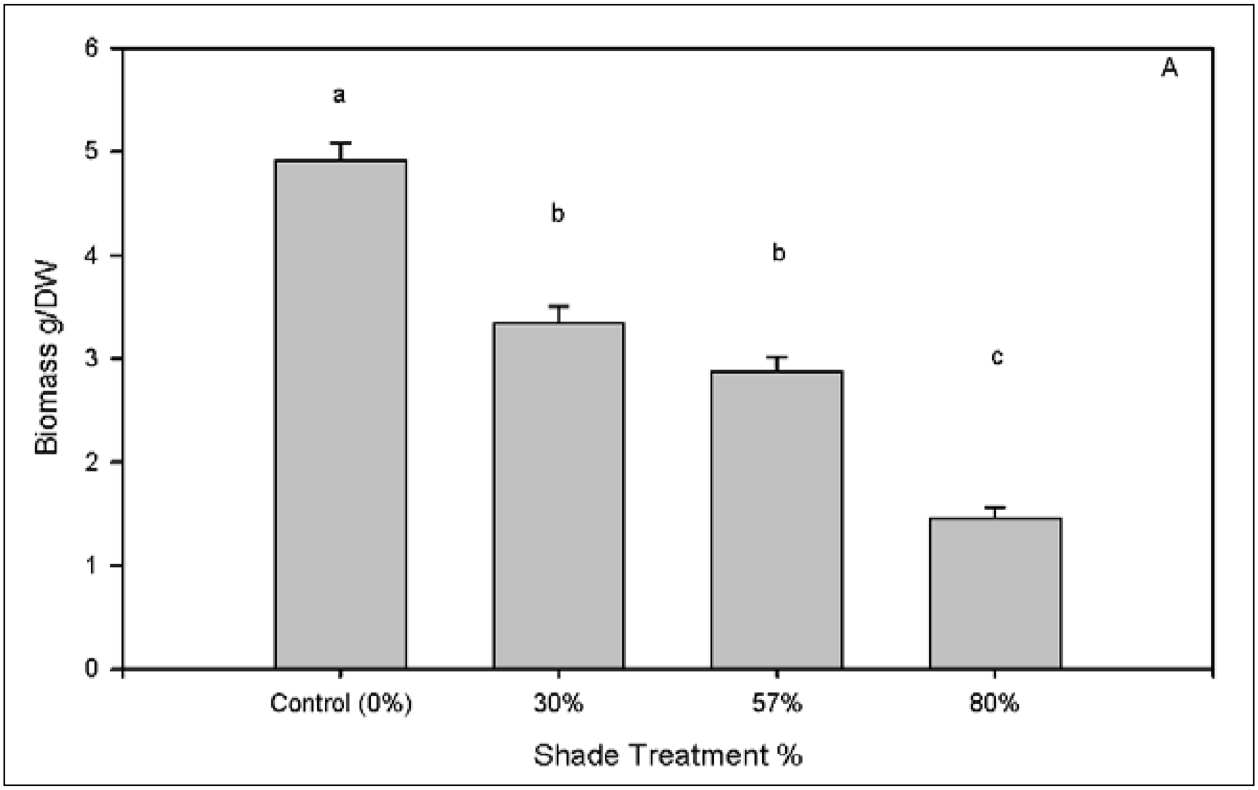

Figure 1. Giant salvinia dry weight biomass (g/DW) under different shade treatments (0% (control), 30%, 57%, and 80% shade), p=0.0000, F=94.68. Bars indicate average biomass and letters indicate significant differences between treatments according to Tukey's level of significance at p=0.05.

Compared to pre-treatment dry weights there was a 12.5-fold increase in biomass with 80% shading after just 3 weeks of growth, indicating that even under deep shade conditions, growth potential of giant salvinia remains slower but still good.

DEPTH STUDY: Significant differences (p=0.0000, F=14.64) occurred between the shallowest depth-to-sediment (2.5 cm) and other depth-to-sediment treatments (Figure 2). No significant differences were observed between medium and deep depth treatments. Biomass in the shallowest depth-to-sediment treatment averaged approximately twice as much as the other two treatments after 3 week's growth. Initial average biomass was 0.04 g. Because giant salvinia is a free-floating plant, nutrients must be obtained from the water column via the modified third leaf (Harley and Mitchell 1981). Additional nutrient and pH amendments were not added to the water in this study to ensure that differences in growth were a result of either nutrients in the sediment and/or those released into the water column from the sediment. Owens et al. (2005) demonstrated that low pH (less than 7.0 units) increased the growth potential of giant salvinia in 416-L tanks within 4 weeks compared to high pH (8.5 units+). Increased growth at lower pH was attributed to availability of certain nutrients in the water column. This depth-to-sediment study found that under high pH (greater than 8.5 units) in the water column, greater biomass was produced when the modified third leaf was close to the sediment interface. One possible explanation is that under high pH conditions, giant salvinia can grow substantially if the modified leaves (roots) are close enough to sediments to permit absorption of nutrients being released into the water column. Further research needs to be conducted.

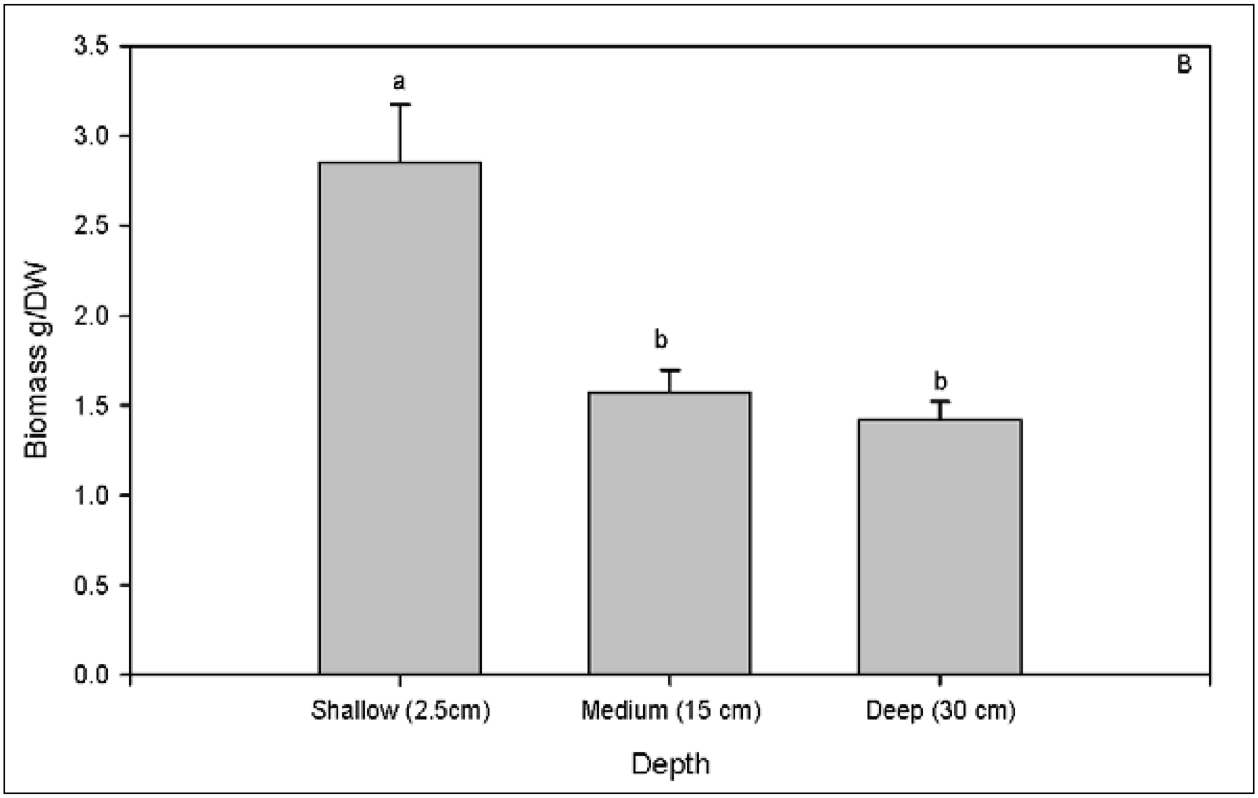

Figure 2. Giant salvinia dry weight biomass g/DW at varying depths to sediment (deep = 30 cm, medium = 15 cm, and shallow = 2.5 cm), p=0.0000, F=14.64. Bars indicate average biomass and letters indicate significant differences between treatments according to Tukey's level of significance at p=0.05.

SUMMARY: While increased shade or depth-to-sediment can limit growth, giant salvinia can still survive and expand under these less-than-perfect conditions. In many U.S. lakes, growing conditions may not be ideal for giant salvinia in the lake proper, but shallow, shaded backwaters may provide refuge for establishment of giant salvinia colonies. In these situations, commonly changing conditions such as falling water levels or increased nutrient inputs may be able to expand to problematic proportions. Recognized as "the world's worst weed" by the U.S. Fish and Wildlife Service Texas Coastal Program (*http://www.fws.gov/texascoastalprogram/giant_salvinia.htm*), the studies reported herein indicate that giant salvinia can easily survive until ideal conditions permit it to live up to this reputation!

ACKNOWLEDGEMENTS: This research was conducted under the U.S. Army Corps of Engineers Aquatic Plant Control Research Program, U.S. Army Corps of Engineers Research and Development Center under the program leadership of Dr. Al Cofrancesco. Permission to publish this information was granted by the Chief of Engineers. The authors would like to thank Dr. Judy Shearer and Julie Nachtrieb for review of this paper.

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This technical note should be cited as follows:

> Owens, C., R. M. Smart, and G. O. Dick. 2011. *Shade and depth effects on the growth of giant salvinia*. APCRP Technical Notes Collection. ERDC/TN APCRP-EA-26. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *www.wes.army.mil/el/aqua*.

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