J. Aquat. Plant Manage. 42: 91-94

Low Temperature Limits of Giant Salvinia

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ABSTRACT

Giant salvinia (*Salvinia molesta* D.S. Mitchell) growing in three outdoor research ponds survived two north Texas winters during 1999-2000 and 2000-2001. The first winter was mild, with only one major freezing event. The second winter had three major freezing events, but again small numbers of the plants survived. Acute low-temperature exposure of the plants in a controlled study demonstrated that formation of ice results in decreased survival of giant salvinia. All the plants exposed for 48 hours to air temperatures of -16C were killed while those exposed for 48 hours at -3C survived apparently due to incomplete ice formation in the water of the containers.

Key words: Salvinia molesta, temperature, freezing event, acute exposure.

INTRODUCTION

Giant salvinia is a floating aquatic fern native to southeastern Brazil, occurring between latitudes 24° and 32°S (Forno and Harley 1979). The plant is currently found worldwide in subtropical and tropical regions. It has been reported in more than 20 countries, introduced as an aquarium or water garden species (Room et al 1981). In Texas, plants were first observed in 1997 in a Houston, Texas schoolyard pond. In 1998, giant salvinia was reported from Toledo Bend Reser-

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Received for publication November 18, 2003 and in revised form March 1, 2004.

voir, and by year 2000, giant salvinia had been found in 4 reservoirs (Conroe, Sheldon, Texana and Toledo Bend), 5 rivers (or streams) and 20 ponds in Texas. It has also been reported in nine other states including AL, AZ, CA, FL, GA, HI, LA, MS, and NC. Located in the USDA hardiness zone 7b, the Lewisville (TX) Aquatic Ecosystem Research Facility (LAERF), at latitude 33°04'45"N, longitude 96°57'30"W, is one of the more northern locations at which giant salvinia is known to occur in the United States. Plants in three outdoor ponds at the LAERF, stocked with giant salvinia in August 1999 for research purposes were exposed to two north Texas winters during 1999-2000 and 2000-2001.

Giant salvinia exhibits different growth forms defined here as either the "colonizer" form which has flat, floating fronds due to growing on an open, uncrowded water surfaces or "mat" form which has erect fronds where surface conditions are crowded. In general, giant salvinia possesses pairs of floating light-green leaves attached to a branching stem that is submersed 1 to 2 cm below the water surface. At each node a third, finely dissected leaf with brownish root-like segments hangs below the stem to depths ranging from 4 cm in nutrient-rich water to 50 cm in nutrient-poor water (Room and Kerr 1983). Dense mats of giant salvinia can impede transportation, irrigation, hydroelectric production, flood and mosquito control, as well as destroy habitat, degrade water quality, and hinder agricultural endeavors such as rice cultivation and fishing (Holm et al. 1977, Mitchell 1979). An aggressive aquatic species, giant salvinia can completely cover water surfaces, forming mats up to 1 m thick (Thomas and Room 1986).

Whiteman and Room (1991) found that giant salvinia buds were killed when exposed to <-3C for a few hours, probably when ice formed within the tissues. Higher survival rates resulted when the plants were supplied with nutrients, although this nutrient effect was minor and leaves were found to survive freezing air temperatures if they were below the water surface. Harley and Mitchell (1981) state that giant salvinia can withstand infrequent frosts or freezes since buds are protected from freezing by larger leaves; however, giant salvinia is killed if low temperatures persist. Thicker mat production provides some protection for plants or plant parts below the mat surface. Buds are usually located under the water surface and are protected from the cold air temperatures unless the surface water freezes. Whiteman and Room (1991) suggest that giant salvinia will persist in areas that experience frost but not ice formation on water bodies. During heavy frosts, emergent growth may be killed back, but submersed stems, insulated by the water and the top portion of the mat, often survive. In the spring, populations can recover from many dormant lateral buds embedded deep in the mats.

The objectives of this two-part study were to 1) document survival of giant salvinia in relation to low temperature exposures under ambient pond conditions, and 2) determine survival of giant salvinia plants following controlled exposure to acute low air temperatures for various periods of time. This knowledge could be used in management to help evaluate the potential for persistent spread of this species into new geographic areas based on temperature zones, and the probability of a new infestation persisting beyond a single growing season.

METHODS

Field Exposure Study

The three LAERF unlined ponds are rectangularly shaped and range in size from 0.25 to 0.32 ha. The ponds are approximately 2.0 m at the deepest end and average about 1.0 m depths overall. Water chemistry for the LAERF ponds is suitable for giant salvinia growth. The LAERF ponds compare favorably with nutrient values from other eutrophic aquatic systems, and all exotic aquatic plants of national concern grow well at the LAERF (Smart et al 1995). Approximately five 114 L containers of giant salvinia were added to the ponds during the latter part of August 1999. After the first freeze at the LAERF on December 5, 1999, 50 giant salvinia plants were harvested from the ponds, placed into a container of 10 cm pond water and held in a heated greenhouse. The giant salvinia plants were held and observed for 4 weeks. The occurrence of new growth was taken as an indicator of viability. After four weeks, all living plants were counted and destroyed by drying, and the % survival was calculated. After each additional freezing event in the winter of 1999-2000, 50 giant salvinia plants were collected from the ponds and the procedure was repeated.

Samples of giant salvinia were again collected from the ponds during the succeeding winter season (2000-2001) following each freezing event although counts were not made. It was just noted if giant salvinia survival occurred after four weeks observations. Air temperature data for both winters were obtained from NOAA (National Oceanic and Atmospheric Administration) monthly summary for the Denton County Airport (NOAA, 1999- 2000, 2000-2001), which is approximately 20 km from the LAERF.[4]

Acute Exposure Study

During the fall of 1999, 475 giant salvinia plants were removed from the pond and separated into 18 treatments and controls. Treatments were established in a 6 by 3 factorial design of 1, 4, 8, 15, 24, and 48 hours' exposure at 4C, -3C and -16C temperatures. Controls were immediately placed in the heated greenhouse maintained at a minimum of 10C under natural light. Twenty-five giant salvinia plants were used for each temperature and exposure time, including controls. The plants were placed into 19-liter containers, each holding 10 cm of pond water. Upon completion of each exposure treatment, the containers were placed into the heated greenhouse and observed for 4 weeks to ascertain survival. The occurrence of new growth was taken as an indicator of viability. After four weeks, all living plants were counted and destroyed by drying, and the % survival was calculated.

RESULTS AND DISCUSSION

Fifteen freezes occurred over the winter of 1999-2000 with the first freeze occurring on December 5, 1999. Due to the late introduction of giant salvinia to the three outdoor ponds

[4]National Oceanic and Atmospheric Administration (NOAA), 1999-2001, Local Climatological Data Monthly Summary, P.O. Box 610086, Dallas-Ft. Worth, TX.

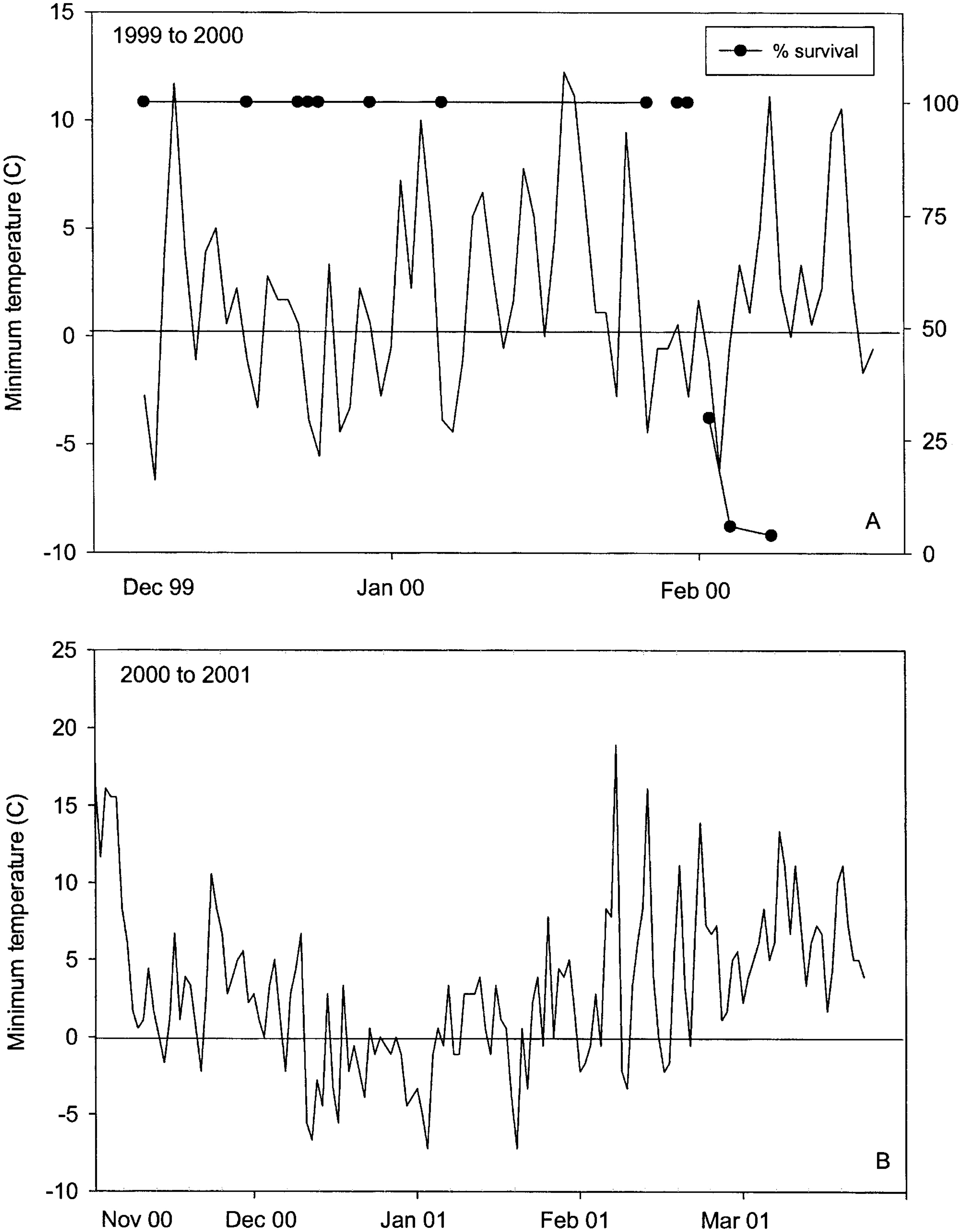

Figure 1. (A) Percent survival of giant salvinia from December 1999 through February 2000 and minimum air temperature for the Lewisville Aquatic Ecosystem Research Facility provided by the National Oceanic and Atmospheric Administration monthly summary for the Denton County Airport during 1999-2000, (B) Minimum air temperature for the Lewisville Aquatic Ecosystem Research Facility provided by the National Oceanic and Atmospheric Administration monthly summary for the Denton County Airport during 2000-2001 (See text for observations of giant salvinia survival).

in August 1999, the giant salvinia mats were single layer of plants with numerous visible open areas when the first freeze ensued. Most of the 15 freeze events over the winter of 1999-2000 were minor. Cold temperatures below freezing were not sustained for more than a few hours overnight. One major event with below freezing temperatures for 48 hours or more occurred over the time period of January 27 to 31, 2000. Three samples were collected over this 4-day temperature event. Ice formed across approximately half the pond. The temperature briefly rose above freezing in the afternoon of January 29, reaching 2C, but fell again that night to around -6C. The last date where 100% survival was counted was the January 30 sampling. By January 31, 2000, the percent survival had fallen to 30%. Following two additional minor freezes, percent survival fell to 4% on February 6, the date of the last freeze event of that winter (Figure 1A). Air temperatures increased as spring progressed, and as most of the giant salvinia mats were dead, decomposition escalated and the mats fell to the bottom of the ponds. No giant salvinia plants were observed in the three ponds until May 2000.

The first freeze of the 2000-2001 winter season occurred on November 13, 2000. Dense mats of giant salvinia completely covered all ponds. The 2000-2001 winter had 46 daily lows below freezing and three major events with 48 or more hours of freezing air temperatures. Ice completely covered the outdoor ponds during two of the three major events, and partially covered the pond during the other event. The last major freeze event happened over the time period of January 1 to 3, 2001, followed by several minor freezes through mid-February (Figure 1B). By the end of February, the majority of giant salvinia plants were brown and the leaves were flat and losing structure. No plants that were collected from the ponds and placed in the greenhouse after January 18, 2001 showed any viability although sampling continued throughout all freezing events. Nonetheless a few giant salvinia plants were found in one pond at the beginning of summer 2001.

In support of the field results, the acute-exposure study results demonstrated that a decrease in percent survival of giant salvinia requires an extended period of time below freezing, with ice formation. Total ice formation, surface to bottom, at -16C for 48 hours completely killed all giant salvinia plants in the containers, while the -3C for 48 hours treatment, did not, apparently due to incomplete ice formation in the container (Figure 2). The ice formation at -3C for 48 hours was approximately 1 cm in depth with unfrozen water beneath, thus providing an insulating effect for the giant salvinia. If the plants had been exposed for a greater period of time at the -3C and thicker ice had been produced, then viability might have been greatly reduced. Air temperatures for both winters in north Texas were recorded several times at -3C and below, but mortality only occurred when surface ice formation was observed. These findings correlate to those of Whiteman and Room (1991) who suggested that ice formation within plants is required for mortality.

In conclusion, the giant salvinia from a young colony survived the winter of 1999-2000. The winter of 2000-2001 was more severe, but the plants were larger and the mat thicker. By the last freeze on February 22, 2001, most of the giant salvinia had been killed; however, a few live plants were observed in one of the outdoor ponds at the beginning of summer. Acute-exposure studies found that -16C for 48 hours could destroy giant salvinia, with ice formation as an important factor in below-freezing temperature events.

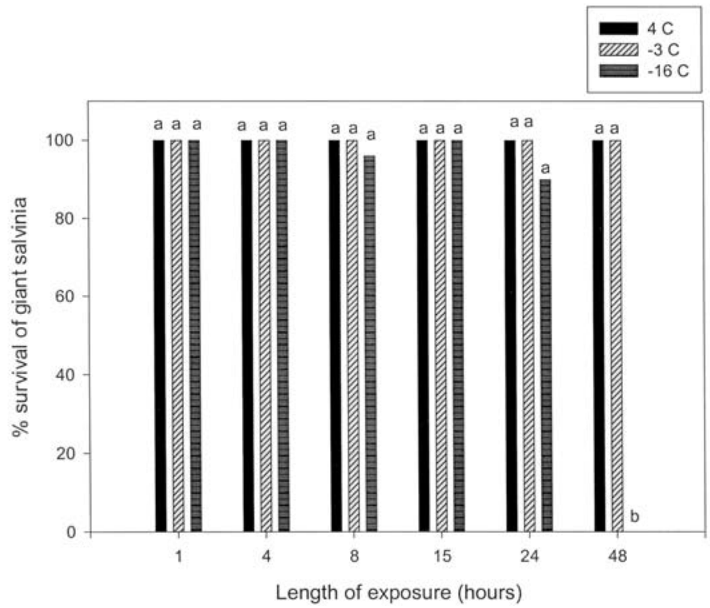

Figure 2. Percent survival of giant salvinia acute-exposure temperature study with exposure to three low temperatures (see legend) for six different time periods (x-axis).

ACKNOWLEDGMENTS

This research was conducted under the U.S. Army Corps of Engineers Aquatic Plant Control Research Program, U.S. Army Engineers Research and Development Center. Permission to publish this information was granted by the Chief of Engineers. We would like to thank Lee Ann Glomski and David Honnell for review of the paper and Joe Snow, Dian Smith and Gary Dick for technical and field assistance for this project.

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