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Low Temperature Limits of Waterhyacinth

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ABSTRACT

The range of waterhyacinth appears to be limited by cold temperatures to tropical or subtropical regions, although little experimental information exists on the cold-tolerance of the plant. Over the winters of 1992-1993 and 1993-1994, field and controlled laboratory experiments were conducted on the ability of waterhyacinth to withstand low air temperatures. Waterhyacinth withstood near-freezing temperature (<5C) for a limited period of time, but exhibited a steady decline in regrowth potential. Rooted plants appeared to resist the effects of cold temperature longer than free-floating plants.

Key words: Eichhornia crassipes, frost-resistance, cold-tolerance, hardiness.

INTRODUCTION

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is a mat-forming floating aquatic plant originating from tropical South America, but currently occurs worldwide in subtropical and tropical regions. In the United States, the plant is a problem in the South Atlantic and Gulf Coast states. It exhibits a distinct northern boundary for survival corresponding to a major limiting factor of low winter temperatures (Tyndall 1982, Aurand 1982). Repeated exposures to severe winters can limit waterhyacinth's range (Luu and Getsinger 1990).

Waterhyacinth was initially imported to the U.S. before 1890 for water gardens. Its vigorous growth and invasive characteristics have created nuisance problems for water quality, mosquito control and water-borne transportation (Rai and Munshi 1979, Penfound and Earle 1948). Once established in an area, the plant spreads through vegetative production of ramets (daughter plants) forming extensive mats which may slow or stop water flow.

Waterhyacinth stores carbohydrates in the stembase during the fall, from approximately mid-September through early October, to be used as energy reserves in times of stress (Madsen et al. 1993). Other than seed dormancy, waterhyacinth has not evolved the mechanisms necessary for surviving cold temperatures (Larcher 1980). Therefore, air temperatures below 0C significantly increase the mortality of the plant by killing portions of the waterhyacinth plant exposed above the water surface (Madsen et al. 1993).

The objective of this study was to determine waterhyacinth regrowth potential in response to cold or freezing air temperatures. This knowledge could be utilized in a management strategy, such as: 1) evaluating the potential for spread to new areas; 2) determining peak problem years of northerly populations and 3) utilizing freezing as an adjunct to drawdown as a management technique for waterhyacinth.

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METHODS

On 5 November 1992, the Lewisville Aquatic Ecosystem Research Facility (LAERF) near Dallas, TX (Latitude 33°04'45'N, Longitude 96°57'33'W) received its first freeze (daily minimum below 0C) of the winter season with an air temperature of -2C. At this time, sixty waterhyacinth plants rooted in sediment in approximately 30 cm of water were removed from an outdoor culture pond for use in regrowth experiments. Stembases from 10 randomly selected mature plants were examined for visible evidence of freeze damage to determine the effect of cold temperature upon these structures. The upper shoots of the remaining fifty plants were removed to determine regrowth of the waterhyacinth from stembases. The stembases with attached roots were placed in 200 L containers of water without added nutrients and placed in a heated greenhouse where minimum air temperature was 10C. These plants were examined weekly over a 4 week period for regrowth. All plants showing new growth were counted and removed. After each additional freeze, 60 more plants were removed from the outdoor culture pond and the sampling procedure was repeated over the winter months of 1992-1993. Outdoor air temperatures were continuously monitored using an Omnidata Easy Logger™ Field Data Recording System adjacent to the waterhyacinth pond. Missing temperature data was obtained from the NOAA (National Oceanic and Atmospheric Administration) monthly summary for the Dallas-Ft. Worth Regional Airport (NOAA, 1993-1994).

For three different dates, 60 free-floating waterhyacinth plants were collected from the outdoor culture pond, in addition to the 60 rooted plants used in the 1992-1993 field study. The same experimental procedure was followed as above.

On 30 October 1993, LAERF received its first freeze of the 1993-1994 winter season. One hundred twenty waterhyacinth plants were pulled from the outdoor culture pond for regrowth experiments. Sixty waterhyacinth plants collected from the outdoor culture pond were firmly rooted in the sediment in shallow water at approximately 30 cm depth. The remaining sixty plants were free-floating in approximately 91 cm of water. Replicate groups (60 per sample time per group) of free-floating and rooted waterhyacinth plants were collected during the 1993-1994 season in response to observed differences in mortality between these classes of growth forms. The same experimental procedure as the winter of 1992-1993 was followed.

Acute effect study. On 09 November 1992, 500 rooted waterhyacinth plants were removed from the outdoor culture pond and separated into 18 treatments and controls. Twenty-five plants were used for each treatment and the controls. Leaves were removed and stembases with attached roots were placed into 19 liter containers, which were filled with unamended water. Eighteen of the 19 containers were placed into the appropriate temperature treatment. Treatments were established in a five by three factorial design of 1, 12, 24, 32, and 48 hours exposure to 4C, 0C and -16C temperatures. One set was not exposed to low temperatures (≥10C), and was used as an experimental control. The controls were immediately taken to the greenhouse for regrowth. Following each temperature treatment, the 18 treatment containers were placed into a greenhouse with a minimum air temperature of 10C, and plants were allowed to regrow for four weeks.

Chronic effect study. On 05 January 1993, 400 rooted waterhyacinth plants were collected from an indoor culture raceway. Leaves were removed and stembases with attached roots were placed into 19 liter containers and filled with unamended water. One set was not exposed to low temperatures, and was used as an experimental control. Containers were placed in refrigerators and temperature was maintained at -1C or 5C. Weekly (for four weeks) 50 plants were removed from each temperature regime and placed in the greenhouse with a minimum air temperature of 10C to observe the regrowth of the plants.

For all experiments contained within this study, statistical differences were determined using a Chi-square Pearson index for 2 × 2 contingency table comparisons of the number of regrown and dead stembases for two treatments.

RESULTS AND DISCUSSION

Since 1988, there have been two freezing periods that have completely killed the entire outdoor waterhyacinth population at the LAERF. The last killing freeze occurred during the winter of 1990-1991, when there was a period of 11 days out of 12 with a minimum air temperature below freezing.

The winter of 1992-1993 was too mild for complete mortality of the waterhyacinth population (Figure 1a), and plants were able to regrow after the last freezing event, although at a significantly lower frequency (Figure 1b). We hypothesize that the portion of the plant found above the protected surface of the water was destroyed by freezing temperatures, but protected stembases with sufficient stored carbohydrates could regrow. As winter progressed and plants began to show a significant decrease in regrowth, stembases became necrotic and soft. If any area of the stembase remained firm and light-colored, regrowth generally occurred.

During the winter of 1992-1993, an apparent difference in mortality in the outdoor culture pond was noted between floating (91 cm depth) compared to rooted (30 cm depth) plants (Figure 1c). Plants collected on each of three dates consistently exhibited higher regrowth rates for rooted plants than free-floating plants. Our initial hypothesis was that rooted plants maintained active meristematic tissue lower in the water column than did free-floating plants, so the rooted stembases were better insulated from cold temperatures. Surface ice formation would freeze the floating stembases, but the rooted stembases would be unaffected.

Initial results for the 1993-1994 winter season indicated that mortality rates were significantly higher among floating rosettes than rooted stembases (Figure 2). The mortality levels in floating plants are initially two to four weeks ahead of the rate observed for rooted plants, which is consistent with hypothesis formed during the previous winter. Rooted stembases appeared to be protected from the colder air temperatures by a thicker layer of water than for the floating rosettes. Near the end of January, this relationship reverses, with floating rosettes having a higher regrowth rate than rooted stem-

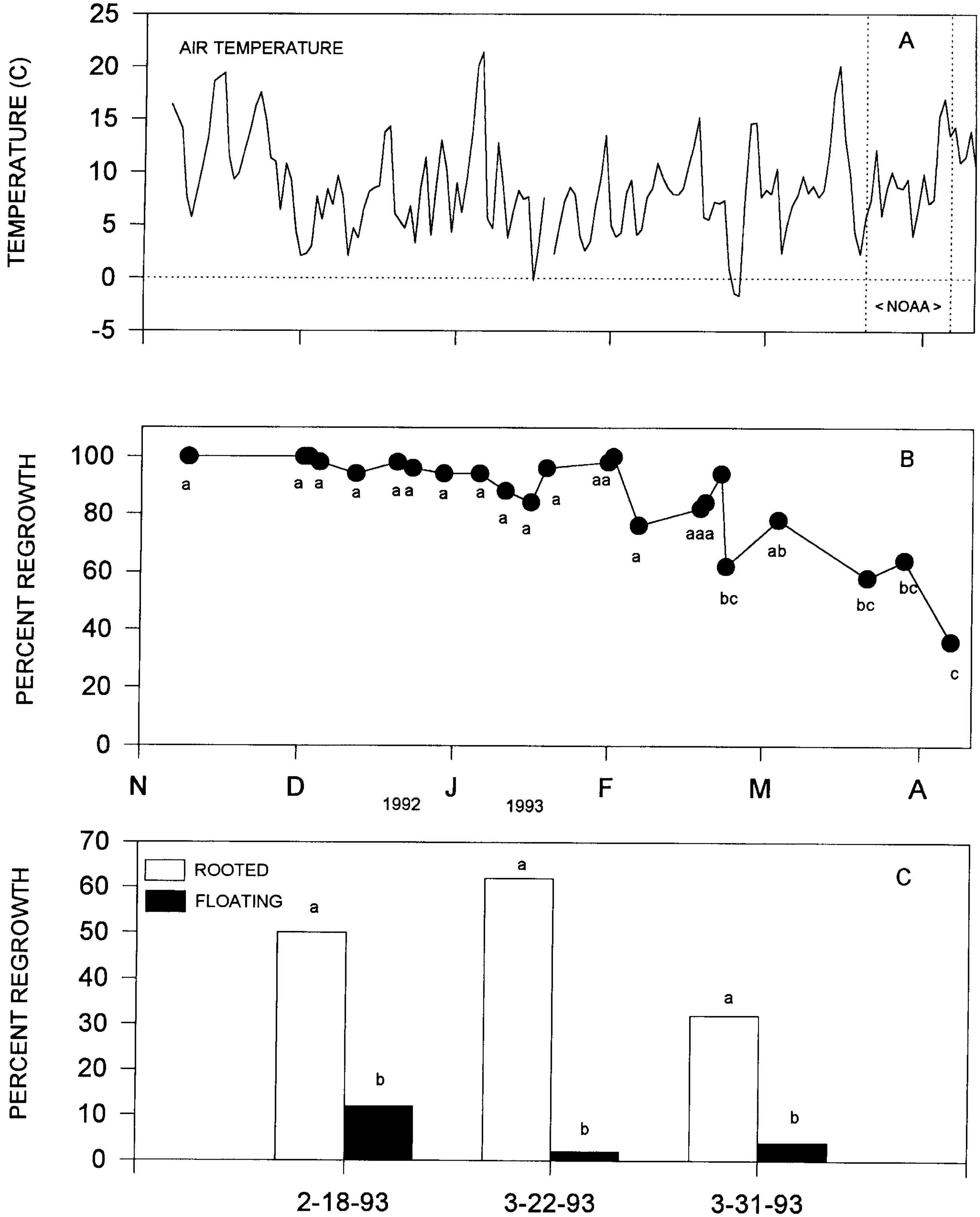

Figure 1. (a) Minimum daily air temperatures for the winter of 1992-1993; (b) Percent regrowth of waterhyacinth field study stembases collected on the indicated date; (c) Percent regrowth of rooted versus floating rosettes for 1992-1993.

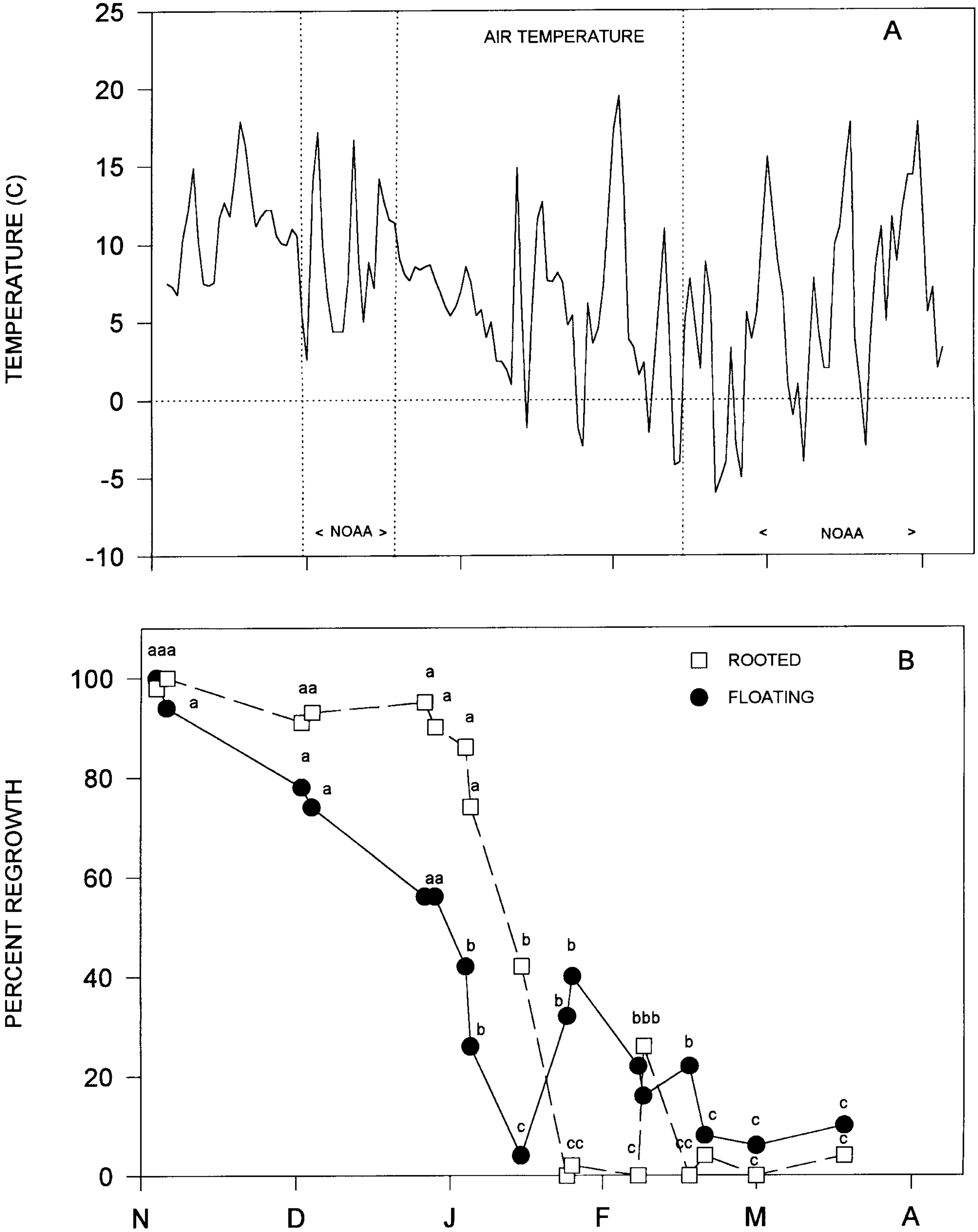

Figure 2. (a) Minimum daily air temperatures for the winter of 1993-1994: (b) Percent regrowth of waterhyacinth field study comparing rooted versus floating rosettes collected on the indicated date.

bases. Several possible mechanisms exist for this reversal, although it is not possible to attribute major responsibility to one of these mechanisms. First, there appears to have been a slight reduction in water level in the pond, which may have been sufficient to reduce the previous layer of protection from thermal stress. Second, the smaller rosettes were removed by mortality early in the season, selecting for the few remaining viable stembases. The rooted stembases could not move from the collection site, whether or not they had died. Last, the freeze of mid-January formed a thick layer of ice, which was sufficiently deep to affect the rooted stembases, but some floating stembases may have sunk sufficiently to avoid freezing. In the final analysis, the three hard freezes observed from January through February of 1994 were sufficient to cause over 90% mortality in stembases, from which essentially no waterhyacinth emerged. By the following spring, no differences between floating and rooted stembases were observed. In contrast, only one hard freeze was observed for the winter of 1992-1993, resulting in 40% viability in April, and a successful overwintering population of waterhyacinth.

A single hard freeze is not sufficient to kill the stembase, although it will kill exposed leaves. One critical factor for understanding the effects of cold temperatures is to differentiate between acute temperature stress and chronic temperature stress.

Acute effect study. The controlled laboratory studies provided specific data on the regrowth physiology of the waterhyacinth plant due to temperature and time of exposure for the specific treatment. The acute treatment consisted of a relatively broad range of temperatures over a 48 hour time period (Figure 3). Temperatures of 4C and 0C had no effect, but the -16C treatment significantly reduced regrowth ability of the plant. Exposure for 48 hours at -16C resulted in only 2% viability of the stembases.

Many aquatic plants have developed evolutionary mechanisms to survive cold or freezing temperatures. Although waterhyacinth can withstand lower temperatures for a short time period the plant does not possess the ability to withstand below zero temperatures for an extended time period. Near-freezing to freezing temperatures of up to 48 hours do not affect stembase survival, even with ice formation. Only a very severe freeze of 12 hours or more affects stembase mortality rates. While a severe overnight freeze may turn all of the waterhyacinth leaves brown, a single freeze generally will not affect the population regrowth potential by killing stembases. Stembase mortality requires longer-term chronic exposures to low temperatures.

Chronic effect study. Results of the chronic treatments were not as dramatic as the acute experiment, but give an indication why waterhyacinth is limited in its northern range (Figure 4). At 5C, by the end of the third week, there was a significant decrease in regrowth. Waterhyacinth has developed the ability to store carbohydrates in the stembase for short-term stress or disturbance (Madsen et al. 1993). However, in this study the stored carbohydrates in stembases were quickly used and therefore the waterhyacinth plants did not have sufficient reserves of carbohydrates to regrow. At 0C, regrowth potential significantly decreased each week. Chronic exposure to near-freezing temperatures of 2-3 weeks is required to inflict significant mortality on the stembase population to reduce overwintering potential. However, four weeks of exposure to 5C temperatures was not significantly different from the same exposure period of 0C. In addition, the effects of individual chronic exposures may be cumulative, such as the three freezing periods of the winter of 1993-1994. In addition to these freezing effects, subzero temperatures will result in ice formation that will result in direct physical damage to plants at both the organismal and cellular levels (Larcher 1980).

In summary, our field observations supported by laboratory studies indicate that longer-term chronic exposures to temperatures below 5C are required to produce measurable stembase mortality, and subsequently affect the overwinter-

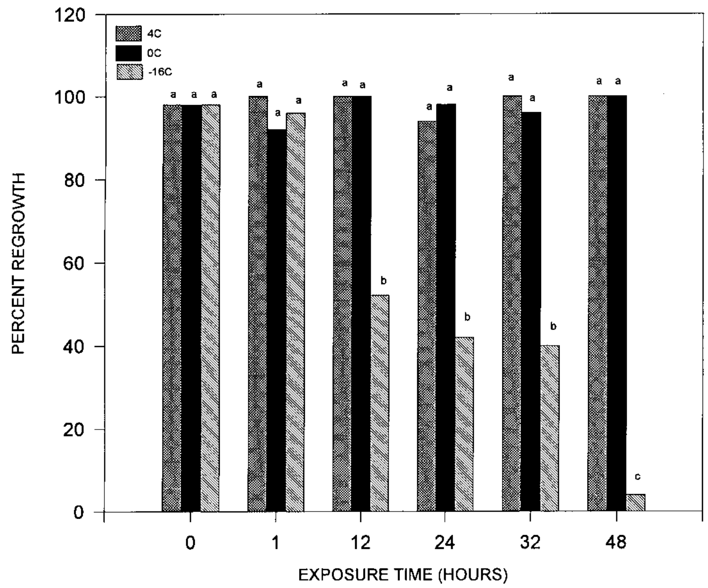

Figure 3. Percent regrowth of waterhyacinth acute effect controlled laboratory study.

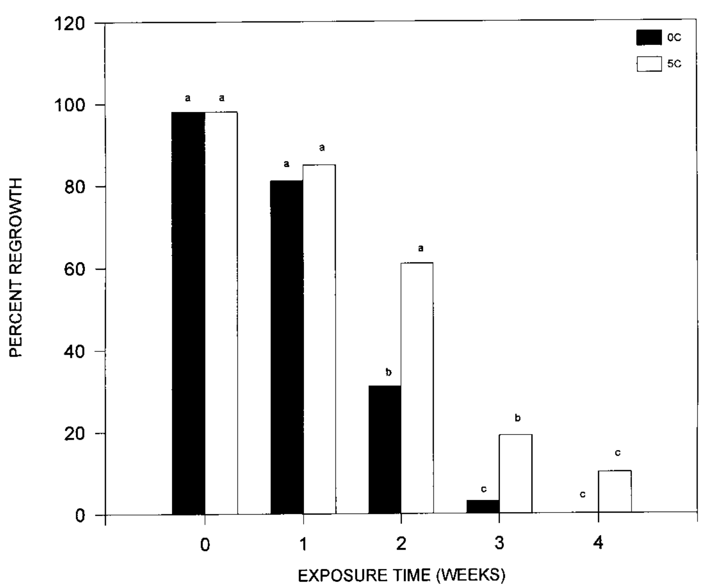

Figure 4. Percent regrowth of waterhyacinth chronic effect controlled laboratory study.

ing potential of a waterhyacinth population. Individual overnight freezes are rarely cold enough to result in stembase mortality, although aerial portions of the plant will be killed by exposure to freezing temperatures. This will not, however, affect the population in the long term. The effects of cold temperature can be increased by reducing the water layer over stembases. One appropriate management strategy would be to draw down water levels in waterhyacinth populations during cold weather periods, increasing the exposure of plant parts to air temperatures rather than buffered water temperatures.

As is common knowledge, moderate winters will result in higher overwintering survival and greater waterhyacinth problems the following growing season. Several severe freezes during the winter may result in lower populations of overwintering waterhyacinth the following season to such extent that nuisance populations may not form in areas along the northern edge of waterhyacinth's distribution. Further study may allow more precise estimates of overwintering potential based on winter temperatures.

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