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Note

The effect of temperature on waterhyacinth stem base regrowth

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INTRODUCTION

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is a perennial floating aquatic plant native to the Amazon region in South America. It is a monocot and a member of the Pontederiaceae family. In the United States, waterhyacinth has become invasive across the southeast, the Gulf Coast and in California. The first recorded introduction of waterhyacinth into the United States was prior to 1890 for use as an ornamental in ponds (Penfound and Earle 1948, Owens and Madsen 1995). It was first reported in California in Yolo County in 1904 (Bock 1968) and has become a widespread invasive species in the Sacramento–San Joaquin River Delta (hereafter the Delta). The rapid growth and ease of dispersal has led to intensive management operations for controlling waterhyacinth infestations. The California Division of Boating and Waterways treated 3,173 acres of floating aquatic vegetation, primarily waterhyacinth, in the Delta in 2017.

Waterhyacinth plants accumulate carbohydrates through photosynthesis during the summer growing season and store these carbohydrates in a stem base throughout the winter (Spencer and Ksander 2005, Luu and Getsinger 1990). During the fall and winter months, as temperatures decrease, most waterhyacinth leaves turn brown and die (Madsen et al. 1993). The stored energy reserves are used in the spring for the formation of new leaf and stolon growth (Madsen et al. 1993, Lyu et al. 2016). Ramets (daughter plants) grow from stolons originating from a parent plant. Vegetative reproduction occurs at a very high rate, with the number of ramets doubling in 7 d (Barrett 1992, Madsen 1993). As ramets grow, they cause the density of a waterhyacinth population to increase, pushing the outer edge of the population away from the bank, where forces such as tidal movement, wind, mass flow, or boats cause portions of mats to break away. These free-floating plants or groups of plants are then dispersed by the water or wind until they become entrained and found new populations. A waterhyacinth population will rapidly fill available habitat, forming dense mats on the water surface that decrease light availability below the floating mat. The dense monoculture formed can inhibit boating, wading, fishing, irrigation, and water access (Bock 1968, 1969, Williams 1980).

The distribution of waterhyacinth is limited by winter temperatures in the United States. It has been reported in 24 states and Ontario (U.S. Department of Agriculture, Natural Resources Conservation Service 2018), but it has become invasive in areas where temperatures do not extend below 0 C for sustained periods. Waterhyacinth can withstand short periods of temperatures down to 0 C, but will show increased mortality at longer periods of temperatures below 5 C (Madsen et al. 1993, Owens and Madsen 1995). North of 35°30′ in the southeast and 39°00′ in the Sacramento Valley in California, waterhyacinth populations are ephemeral or casual, with the exception of a population in Colorado that persists in water heated by a geothermal spring (Kriticos and Brunel 2016).

The objective of this study was to determine the temperature required to initiate stem base sprouting by comparing leaf and stolon growth from waterhyacinth stem bases exposed to different temperatures (5, 10, and 15 C) after they have overwintered. With a clearer understanding of the relationship between temperature and growth, managers should be able to measure temperature and use these measurements to focus their management efforts for waterhyacinth.

MATERIALS AND METHODS

Waterhyacinth stem bases were collected from sites in the Delta in February 2016. Any leaves present from the previous year's growth were removed. The stem bases were divided into nine groups of 10. Each group of stem bases was placed in a 38.7-L mesocosm filled with unamended water. Each of the mesocosms was randomly assigned one of three constant temperatures (5, 10, and 15 C), with a light regime of 14 h light : 10 h dark per day, with each temperature assigned to three mesocosms. Temperature and light conditions were maintained using Percival Intellus PGC-15[1] controlled environment incubators. Air and water temperatures were recorded using HOBO pendant®[2] temperature data loggers recording the ambient air temperature of the chamber and water temperature every 15 min.

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Table 1. Waterhyacinth morphological characteristics 54 d after initiating growth at 5, 10, or 15 C. Average number of leaves per stem base, cumulative length of leaves per stem base, average number of stolons per stem base, and cumulative length of stolons per stem base. Values are mean (standard error of the mean), with superscript letters representing mean differentiation ($P \leq 0.05$) using ANOVA.

Water Temperature (C)	5	10	15	*P* Value
n	30	30	30	
Number of leaves/stem base	0.23[a] (0.08)	0.30[a] (0.12)	2.80[b] (0.68)	1.14e-05
Cumulative length of leaves/stem base (mm)	4.80[a] (2.11)	4.37[a] (1.65)	124.07[b] (32.07)	6.51e-06
Number of stolons/stem base	0.00[a] (0.00)	0.00[a] (0.00)	0.43[b] (0.12)	1.63e-05
Cumulative length of stolons/stem base (mm)	0.00[a] (0.00)	0.00[a] (0.00)	6.00[b] (1.71)	1.58e-05

The number of leaves per stem base, cumulative length of leaves per stem base, the number of stolons per stem base, and the cumulative length of stolons per stem base were quantified twice per week for each stem base (n=90 for each character), beginning at 9 d after initiation of growth and continuing until 54 d after initiation of growth. Leaf length included the total length of the blade and petiole, measured from the apex of the blade to the point where the petiole separates from the stem. Stolons were measured from the apex to where the stolon separated from the stem base.

Each of these four growth characteristics were analyzed using an analysis of variance (ANOVA) to detect differences ($P \leq 0.05$) among means of plants growing at different water temperature 54 d after collection (R Core Team, 2016). The null hypothesis was that there were no significant differences among the temperatures for any the growth characteristics. Mean separations of significant effects were evaluated with Tukey's Honest Significant Difference (HSD) test ($P \leq 0.05$).

RESULTS AND DISCUSSION

For this population of waterhyacinth, leaf and stolon emergence from stem bases was initiated between 10 and 15 C. When the experiment concluded, 54 d after growth was initiated, the stem bases maintained at 15 C had produced 2.80 (± 0.68) leaves per stem base, whereas the stem bases at 10 and 5 C produced an average of 0.30 (± 0.12) and 0.23 (± 0.08) leaves per stem base, respectively. The stem bases maintained at 15 C also had a much greater leaf length [124.07 mm (± 32.07)], as compared to 10 C [4.37 mm (± 1.65)] and 5 C [4.80 mm (± 2.11)]. There was a small amount of leaf growth observed on some of 5 and 10 C stem bases at the beginning of the study, with both the number of leaves and leaf lengths leveling out and declining over the course of the study (Figure 1). This could be due to exposure to room temperature (24 C) for a short duration while the plants were sorted and placed in the growth chamber. Both the number of leaves and leaf length were variable ($P \leq 0.05$) when analyzed using ANOVA to detect differences among the plants growing at different temperatures (Table 1).

No stolons were produced at 5 or 10 C (Figure 1), whereas 10 of the 30 stem bases at 15 C produced stolons by 54 d [x=0.43 (± 0.12)]. The 15 C stem bases had a mean stolon length of 6.00 mm (± 1.71). Both the number of stolons and stolon length were variable ($P \leq 0.05$) when analyzed using ANOVA to detect differences among the plants growing at different temperatures (Table 1).

The different rates of growth observed between plants at 5 and 10 C, on the one hand, and 15 C, on the other, would impact the potential for invasion and spread of waterhyacinth. A higher rate of leaf growth, like that recorded at 15 C, would allow for more rapid carbohydrate storage. As the plants within a given mat grow more quickly because of increased leaf growth, the edge of the mat would expand away from the bank and into areas of higher water flow and more boat traffic. This would allow for the plants in that part of the mat to separate and disperse earlier in the year if temperatures increase because of climate change. The difference in stolon growth among the temperatures also has consequences for waterhyacinth dispersal and invasion. Ramets growing from stolons cause the density of a waterhyacinth population to increase in two ways. First, the increased density pushes the outer edge of the population to expand plant mats away from banks, where forces such as tidal movement, wind, water flow, or boats cause portions of mats to break away and disperse. Second, each ramet will ultimately break away from the parent plant and be able to disperse to new locations. Each ramet is capable of founding of a new population.

With greatly reduced leaf and stolon production at 5 and 10 C, waterhyacinth would disperse at a far lower rate, and would be easier to manage than the stem bases exposed to 15 C. It may also cause stolons, and therefore new ramets, to begin development earlier in the year. This understanding of temperature's effect on leaf and stolon production can help identify locations that may be susceptible to invasion and allow managers to allocate resources accordingly. It will also allow for better timing of management, before established populations begin rapid dispersal to new locations. By monitoring water temperatures at known nursery areas, managers can anticipate the timing of stem base sprouting and predict when preemptive management should occur. Additional studies could investigate temperatures between 10 and 15 C to further narrow down the temperature at which growth initiation occurs.

SOURCES OF MATERIALS

[1]Percival Intellus PGC-15 plant growth chamber, Percival Scientific, Inc., 505 Research Dr., Perry, IA 50220.

[2]HOBO pendant® temperature/light data logger, Onset Computer Corporation, 470 MacArthur Blvd., Bourne, MA 02532.

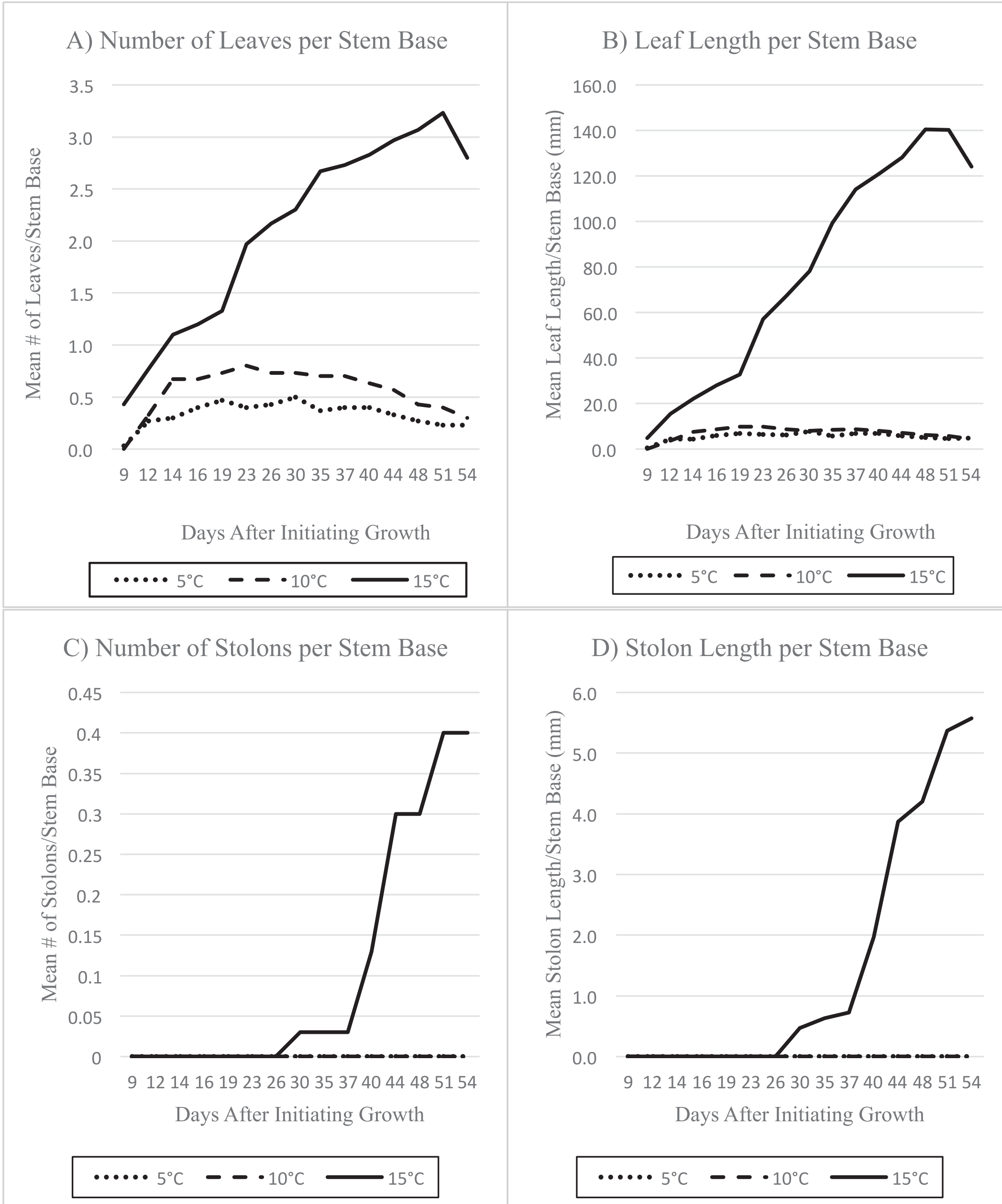

Figure 1. Morphological characters of waterhyacinth stem bases kept at three constant water temperatures (5, 10, and 15 C), measured from 9 through 54 d after initiating growth. (A) Number of leaves per stem base, (B) leaf length per stem base, (C) number of stolons per stem base, (D) stolon length per stem base.

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