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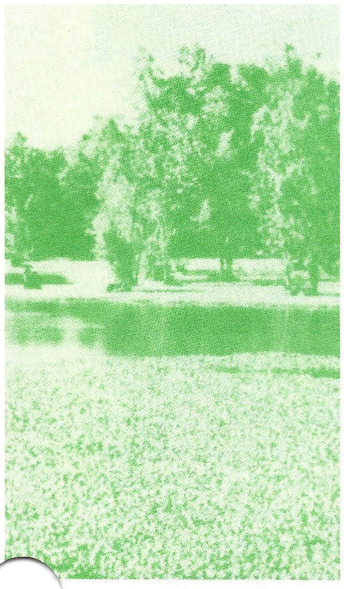

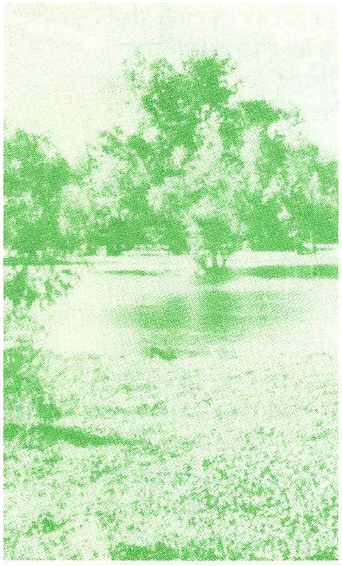

ENVIRONMENTAL LABORATORY

Aquatic Plant Control Research Program

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Outdoor growth experiments

Control Points in the Growth Cycle of Waterhyacinth

by
Kien T. Luu and Kurt D. Getsinger
Ecosystem Research and Simulation Division, EL

Certain macrophytes are highly successful competitors in aquatic systems, and populations of these plants frequently reach nuisance levels. The success and the aggressiveness of these macrophytes are related to their survival strategies. Survival strategies can enhance the success of a species by providing a competitive advantage over other species. Growth rate, photosynthetic efficiency, dispersal mechanisms, and energy reserves are among factors which influence this competitive advantage.

Knowledge of a nuisance plant's survival strategy can be used in managing that species by determining the factors which provide the plant's competitive advantage and identifying weak points in the plant's growth cycle. A weak point is a period during the growth cycle when a plant is least likely to recover following the implementation of a control method. Once weak points (or susceptible periods) are identified, they can be marked using growth-cycle events, morphological characteristics, or environmental cues. This determination will enable field personnel to predict the optimum time for applying control techniques. Used in this manner, weak points become "control points" in the growth cycle of a target plant.

Waterhyacinth (*Eichhornia crassipes*), hydrilla (*Hydrilla verticillata*), Eurasian watermilfoil (*Myriophyllum spicatum*), and alligatorweed (*Alternanthera philoxeroides*) are considered by the Corps of Engineers to be among the most troublesome aquatic macrophytes nationally. Although much information is available on these species, some aspects of the life history, physiology, and ecology of the plants are poorly understood.

A series of studies designed to elucidate the survival strategies and determine the control points of waterhyacinth, hydrilla, Eurasian watermilfoil, and alligatorweed are being conducted at the Waterways Experiment Station (WES). Both short- and long-term research on the growth cycle of these species will be conducted in controlled-environment systems and outdoors. Where appropriate, these studies will complement the ongoing research efforts of the Aquatic Plant Control Research Program (APCRP) Ecology Team. Results obtained from these small-scale studies will then be verified under field conditions. Following field verification studies, recommendations will be made for conducting small-scale evaluations of various control methods to take advantage of the target plant's weak points.

One method for determining control points in aquatic plants is to study the seasonal distribution and storage of energy reserves, such as carbohydrates, in the target species. This approach has been used to indicate physiological weak points in the growth cycle of terrestrial plants for effective control.

Carbohydrate Allocation

Carbohydrates are the most abundant organic constituents of plants, serving as important sources of chemical energy (for example, sugars and starches) and as major components of supporting tissues (for example, cellulose found in wood, cotton, and flax). Carbohydrates can be divided into two groups—total structural carbohydrates, which include permanent structural substances such as cellulose, and total nonstructural carbohydrates. Total nonstructural carbohydrates can be separated into two fractions—free sugars (such as glucose, fructose, maltose, and sucrose) and reserves (such as starch and fructan). Free sugars are readily available for metabolism, while reserve components are typically stored in structures such as stem bases, tubers, turions, rhizomes, and roots.

The terms "source" and "sink" are used in describing the mobilization of carbohydrates in plant systems. Carbohydrates always move from source to sink, hence the organs supplying or producing carbohydrates are sources and the organs that receive and use carbohydrates are sinks. Carbohydrate allocation involves the production of carbohydrates in

Two types of waterhyacinth inflorescences

photosynthetic organs (sources), loading into the sieve tubes of the phloem, and translocation to the growing parts (sinks), where unloading occurs.

The relationship between seasonal growth characteristics and carbohydrate allocation has been used to successfully control terrestrial nuisance species (Linscott and McCarthy 1962, Klingman 1965, and McAllister and Haderlie 1985). One technique has been to disrupt normal source-to-sink translocation of carbohydrates that precedes winter dormancy. For example, mowing of shoots in the fall prevents accumulation of belowground food reserves, making plants more susceptible to winter injury. As a consequence, spring growth is diminished. Spring growth (when below-ground food reserves are low) is also a critical period during which a control method, such as repeated mowing, is most effective for controlling perennial species (Klingman, Ashton, and Noordhoff 1975).

As with their terrestrial counterparts, perennial aquatic plants may rely on stored carbohydrate reserves for winter survival. In addition, recovery from periods of stress caused by fluctuating temperatures, drought, nutrient depletion, turbidity, and control tactics may be dependent on carbohydrate reserves. Linde, Janisch, and Smith (1976) identified a relationship between carbohydrate reserves and growth-cycle events in cattails (*Typha glauca*). When the pistillate spike was lime green in color and the staminate spike appeared dark green, carbohydrates were in their lowest level in the plant. This information allowed the timing of a control strategy to coincide with the color of the pistillate and staminate spikes.

Waterhyacinth Research

Small-scale, outdoor studies were implemented at the WES to clarify the growth characteristics of waterhyacinth and to determine the seasonal trends of carbohydrate distribution among plant parts. A better understanding of this plant's growth cycle and identification of physiological weak points is essential to improve the effectiveness of present control techniques. Interim results of the waterhyacinth study are discussed in the following paragraphs.

Experimental approach

Waterhyacinth ramets (daughter plants) of similar size and age were cultured outdoors in 1300-litre tanks, supplemented with a 20 percent Hoagland solution as a nutrient source (Hoagland and Arnon 1950). Growth measurements included growth rate, leaves per plant, leaf longevity, stolon length, ramets per plant, flowering frequency, and plant density.

Carbohydrate measurements included free carbohydrates, starch, and total nonstructural carbohydrates in stem bases, roots, membranes, inflorescences, leaves, and petioles (Figure 1). Separate samples of blooming and wilted inflorescences were obtained to determine the change in carbohydrates during and following blooming. Inflorescences were separated into three different parts—rachis, florets, and peduncles (Figure 2).

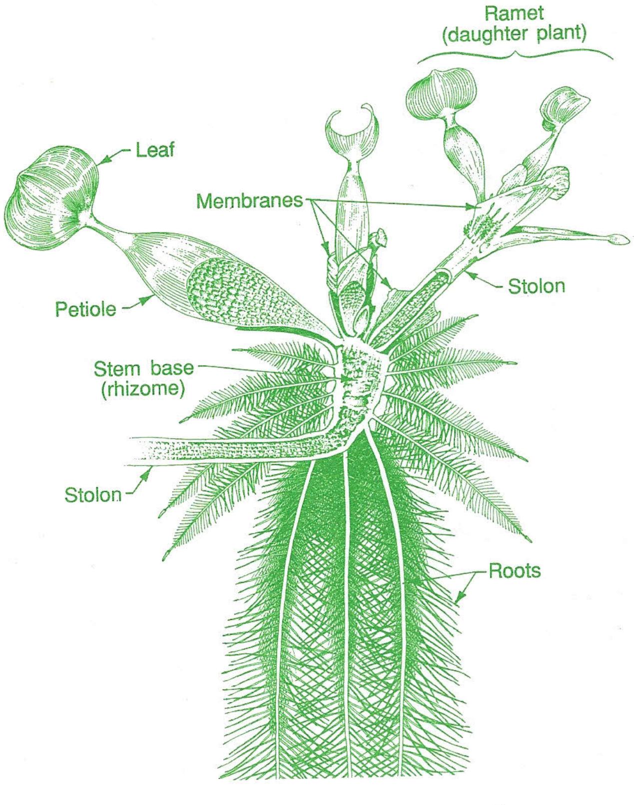

Figure 1. Major plant structures of waterhyacinth: stem bases, root, stolon, membrane, leaf, and petiole

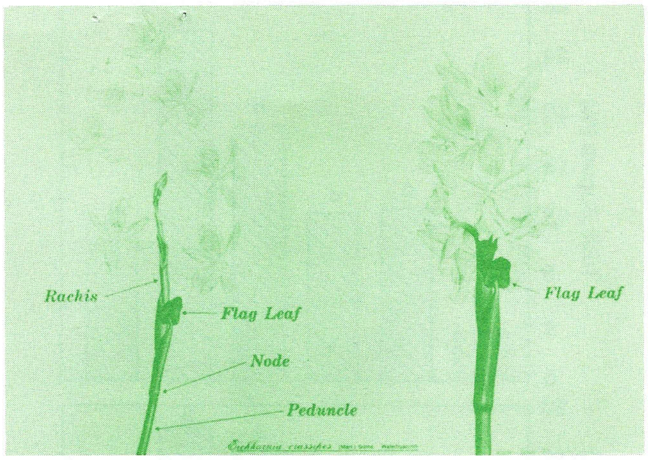

Figure 2. Different parts of waterhyacinth inflorescence: peduncle (stalk of inflorescence), rachis (supports florets), and florets (small, purple flowers)

Carbohydrate levels and distribution

Waterhyacinth carbohydrate levels fluctuated in most structures, with no clear trend. However, carbohydrate levels in stem bases gradually increased, beginning in July, and attained the highest concentration in October (Figure 3). The reduction of carbohydrate reserves in the stem bases after October resulted primarily from the production of new ramets in the waterhyacinth population.

During fall growth rate experiments, nonflowering plants produced over twice the number of ramets and nearly double the biomass, compared to flowering plants. This phenomenon has also been reported by other investigators, including Pieterse, Aris, and Butter (1976) and Watson (1984).

Because of the marked decrease in ramet and biomass production due to flowering, the distribution of energy among the inflorescence structures during the sexual reproductive phase of the plant was evaluated. Highest carbohydrate levels were found in the blooming rachis (26 percent total carbohydrate). Free and total carbohydrate decreased significantly in the rachis and florets after the inflorescences wilted. However, no change in carbohydrate content was found in the peduncles after the inflorescences wilted. This suggests that carbohydrates moved from the rachis to the stem via the peduncle, following flower wilt. This movement may act as a mechanism to conserve energy in the plant, whereby the remaining carbohydrates in the rachis were translocated to other energy-demanding sinks (growing tissue).

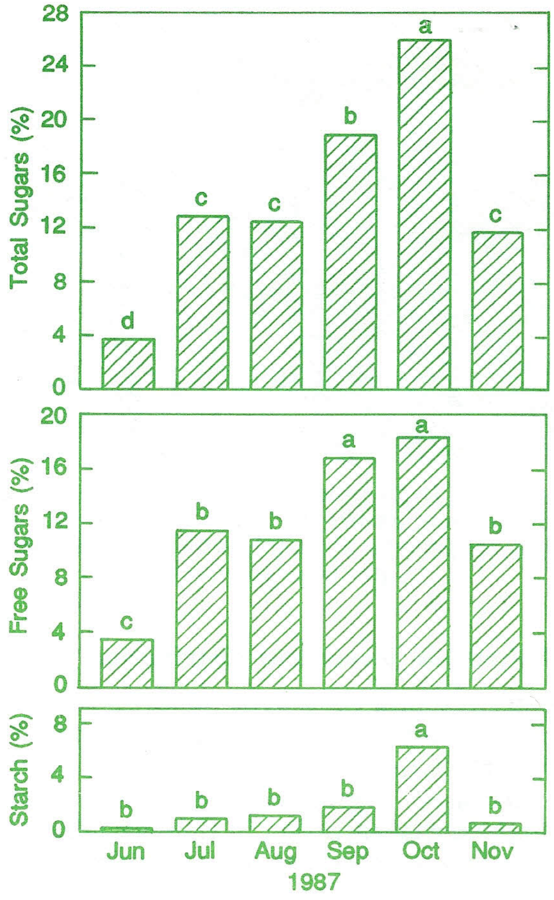

Figure 3. Carbohydrate contents in waterhyacinth stem bases during 1987 (Means with same letter are not significantly different according to Bayesian Least Significant Difference Test (K-ratio = 100).)

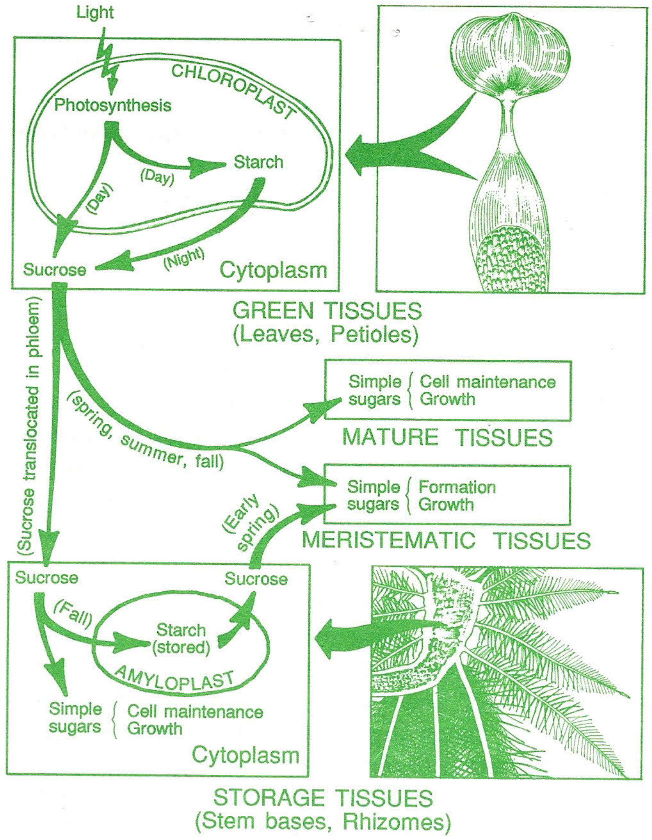

Figure 4. Simplified pathways of carbohydrate mobilization and utilization in waterhyacinth

The stem bases of waterhyacinths are sinks during the growing season, since they receive and store translocated carbohydrates from leaves and petioles (Figure 4). However, during the winter and early spring, the surviving stem bases act as sources. Stored carbohydrates within the stem bases are remobilized to support the surviving tissue and are moved to newly activated tissues for leaf, stem, and root development.

Conclusions

Based on results to date, mid-October (early fall) appears to be the time when waterhyacinth stores the maximum carbohydrate reserves in the stem bases. During blooming, the inflorescence appears to be a strong energy-demanding sink in the plant, with carbohydrates concentrating in the rachis.

The potential control points in the growth cycle of waterhyacinth occur shortly before mid-October, when the minimum night temperature is less than 20° C (68° F) and plants are actively translocating carbohydrates to the stem bases for accumulation of an energy reserve, and shortly before blooming, when inflorescences are actively developing, coinciding with the period of slowest ramet production.

Ongoing Studies

A two-year, small-scale, outdoor study on waterhyacinth is scheduled to be completed in the fall of 1988. This research has focused on the seasonal growth rate, ramet production, flowering, and energy (carbohydrate) allocation of the plant.

Studies on both monoecious and dioecious hydrilla, conducted in environmental chambers, are focusing on seasonal carbohydrate allocation in various plant structures, with special emphasis on reproductive and overwintering propagules. In addition, studies to determine carbohydrate depletion rates and estimates of biomass production from tubers have been initiated.

Studies to determine the control points for Eurasian watermilfoil and alligatorweed will be phased into the overall research effort in the near future.

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Request for Articles

Articles for the *Aquatic Plant Control Research Program* Bulletin are currently being solicited. If you have information concerning aquatic plant control research, please write Lewis Decell describing your work or send completed articles for consideration. Articles should run about 1,000 to 1,500 words and several black-and-white or color photographs (or slides) should be included. Address articles to Environmental Laboratory, ATTN: CEWES-EP-A, US Army Engineer Waterways Experiment Station, PO Box 631, Vicksburg, MS 39181-0631.

In this issue, a study to identify control points, or weak points, in the growth cycle of waterhyacinth, based on the relationship between growth characteristics and carbohydrate allocation, is reported. These findings will enable field personnel to predict and select the most appropriate time for optimum control. Preliminary results are presented.

AQUATIC PLANT CONTROL RESEARCH PROGRAM

This bulletin is published in accordance with Army Regulation 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Aquatic Plant Control Research Program (APCRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions are solicited and will be considered for publication so long as they are relevant to the management of aquatic plants as set forth in the objectives of the APCRP, which are, in general, to provide tools and techniques for the control of problem aquatic plant infestations in the Nation's waterways. These management methods must be effective, economical, and environmentally compatible. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: J.L. Decell, US Army Engineer Waterways Experiment Station, PO Box 631, Vicksburg, MS 39181-0631, or call AC 601/634-3494.

DWAYNE G. LEE
Colonel, Corps of Engineers
Commander and Director

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