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The Potential of a Summer Drawdown to Manage Monoecious Hydrilla[1]

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ABSTRACT

A summer drawdown to manage monoecious hydrilla (*Hydrilla verticillata* (L.f.) Royle) was investigated using a mesocosm system. The objectives were: to determine the length of drawdown required to kill vegetative biomass; to evaluate plant recovery in terms of regrowth and production of propagules following the drawdown; and to examine the influence of hydrosoil characteristics on plant response to drawdown. Hydrilla tubers were collected from the field, sprouted in the laboratory, planted in sand or silt loam soil, and placed in concrete tanks. A drawdown was simulated by taking plants out of the tanks, exposing them to ambient conditions for one to four weeks, and returning them to the mesocosms until the end of the growing season. A one-week drawdown was sufficient for killing hydrilla on sand; no regrowth or tuber production occurred. A one-week drawdown on silt loam was not effective in desiccating the root system and preventing regrowth; these plants produced the same amount of biomass and twice as many tubers as the reference plants. A drawdown of two weeks or longer, however, suppressed hydrilla regrowth and greatly reduced tuber numbers. Few turions were found on reference plants at the end of the season. Plants subjected to drawdown did not produce turions. These results suggest that a short-term summer drawdown on might be useful in monoecious hydrilla management; however, hydrosoil type may determine length of drawdown required for complete soil desiccation and plant kill.

Key words: aquatic weed, *Hydrilla verticillata* (L.f.) Royle, cultural control.

INTRODUCTION

Exotic aquatic plants quickly overrun shallow ponds and littoral zones of lakes (Wade 1993). These plants usually form dense monospecific stands that crowd out native vegetation which provide habitat for macroinvertebrates and fish populations (Wetzel 1983). Infested water bodies may become unusable for fishing, recreation, electrical power generation, domestic consumption, or industrial use.

One of the most competitive exotic species found in the littoral zone is a submersed macrophyte, hydrilla (*Hydrilla verticillata* (L.f.) Royle; Langeland 1996, Holaday et al. 1983). Monoecious hydrilla was first identified in North Carolina in 1980 (Langeland and Schiller 1983). It now occupies over 5800 acres and is the most rapidly expanding aquatic weed in the state (NCDEHNR-DWR 1996). If allowed to spread unmanaged, hydrilla has the potential to colonize over 130,000 surface acres of North Carolina waters (Kay 1990).

Production of propagules, subterranean turions (tubers) and axillary turions (turions), that persist in the hydrosoil allow hydrilla to survive many aquatic weed management practices including drawdowns (Haller 1976). The effects of drawdowns on monoecious hydrilla tuber production and tuber sprouting has not been well documented (Netherland 1997).

In North Carolina, a winter drawdown was investigated in a small piedmont impoundment to control monoecious hydrilla by freezing and desiccating tubers in the hydrosoil (Hodson et al. 1984). Tubers were collected monthly and sprouted in a dark laboratory at 26 C. Eighty to 100% of tubers sprouted proving the drawdown ineffective in preventing tuber sprouting due to a high amount of moisture retained in the clay hydrosoil.

A summer drawdown could be a successful management technique, however. Because monoecious hydrilla does not form many dormant tubers (Sutton and Van 1992), a drawdown carefully timed to kill new plants after the majority of tuber sprouting has occurred (usually mid- to late June in North Carolina), but prior to production of new tubers (late June to early July), might eliminate most of the hydrilla distributed in the drawdown zone.

The objectives of this study were to: 1) determine the length of drawdown required to kill shoots, roots, and rhizomes; 2) evaluate recovery in terms of vegetative regrowth and the development of tubers and turions following drawdown simulation; and 3) examine the influence of silt loam and sand hydrosoil characteristics on plant response to drawdown.

MATERIALS AND METHODS

Tests were conducted during the 1993 growing season in a flow-through mesocosm system located at the Unit 1 Research Farm at North Carolina State University in Raleigh, North Carolina, U.S.A. Eighteen concrete tanks (2.19 m length by 0.76 m width by 0.58 m depth) were filled to the top with water pumped from an adjacent irrigation pond by two Grainger 1 hp pumps. Each tank received three complete water exchanges daily.

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Turbidity, pH, and water temperature were monitored at midday near the water surface in five randomly selected tanks each week following the drawdown simulation. Turbidity was measured nephelometrically using a Monitek Model 21PE portable turbidimeter. Water temperature was measured with a YSI model 54 oxygen meter and pH with a Fisher Accumet model 220 pH meter. Air temperature using a maximum/minimum thermometer and rainfall using a rain gauge also were measured weekly.

Hydrosoils were collected from Lake Gaston, located on the North Carolina-Virginia border. Sediment was shoveled from the bottom of the lake, approximately 2 m from shore at a 0.5 m depth, sieved to remove rocks, shells, and plant fragments, and placed into separate boxes (30 cm length by 30 cm width by 9 cm depth). These boxes had wooden frames with screen bottoms which were lined with fabric to retard hydrosoil loss but allow drainage (YardTek Weed Shield, American Agrifabrics, Inc., Alpharetta, GA). Silt loam and sand were selected because they produce substantial hydrilla growth, yet have distinct physical and chemical characteristics and different drying properties (Coley 1993). Samples of these hydrosoils were analyzed and characterized by the NC Department of Agriculture, Raleigh, NC (Table 1).

Tubers were collected from Lake Gaston, placed into laboratory aquaria, and held under fluorescent light at 26 C for sprouting. When shoots reached a length of 10 cm, they were planted (five per box), placed in the tanks, and allowed to grow for seven weeks (3 June to 18 July) before the drawdown simulation was initiated on 19 July. Six replicates from each hydrosoil were harvested to determine if tubers were present at the time of drawdown. Except for reference plants, all plants were removed from the tanks and placed on the ground exposed to ambient conditions or under a rain shelter. This rain shelter was used to determine the length of exposure necessary to kill the vegetation in case rainfall influenced the outcome of the experiment. The top of the rain shelter was covered with clear plastic and built high enough to permit good air circulation. Landscape fabric was placed beneath all boxes to prevent interference from terrestrial grasses. Empty tanks were cleaned during the drawdown to remove any remaining plant fragments. After the appropriate time interval (one, two, three, or four weeks), boxes were returned to their respective tanks for the remainder of the growing season. Reference plants remained in the mesocosm system throughout the study for comparison of hydrilla growth and reproductive capacity in the absence of drawdown.

Table 1. Physical and chemical characteristics of hydrosoils used in the drawdown simulation.

VARIABLE	SOIL	
	Silt Loam	Sand
Organic Matter (%)	4.00	0.10
Humic Matter (%)	1.10	0.00
Cation Exchange Capability (meq)	6.70	1.70
pH	6.30	6.50
Nitrogen ($\mu g\ g^{-1}$)	2.00	1.00
Phosphorus ($\mu g\ g^{-1}$)	18.0	5.00
Potassium ($\mu g\ g^{-1}$)	55.0	24.0
Mechanical Resistance (MPa)	0.83	4.43
Bulk Density ($g\ cm^{-3}$)	0.04	1.32

Thirteen weeks after drawdown initiation, the hydrilla was harvested (25 October). Plants were clipped at the hydrosoil surface. Hydrosoils were washed and sieved to recover roots, rhizomes, and tubers. All plant materials were oven dried at 70 C to a constant weight to determine biomass production.

This study was a 2 (hydrosoils) x 5 (lengths of exposure—0, 1, 2, 3, or 4 weeks) factorial split plot design with three replicates per treatment. Lengths of drawdown (main plots) were randomly assigned to individual tanks. Each tank contained two boxes of each hydrosoil (subplots). For each hydrosoil type, one box was placed under the rain shelter and another was left exposed to ambient conditions. Data were transformed using log (n + 1) because values of zero were present. Data initially were subjected to an analysis of variance using a three-way interactive model at an alpha level of 0.05. No significant differences were found between plants placed under the rain shelter and those left exposed ($F = 0.0013$, $p = 0.9956$). Data then were lumped and re-analyzed using a two-way interactive model at an alpha level of 0.05. Transformed means of hydrilla regrowth and tuber production were separated using the LSD procedure at the 0.05 alpha level (Steel and Torrie 1980), however, the de-transformed geometric means are presented.

RESULTS AND DISCUSSION

Water temperatures in the tanks ranged from 27 C at drawdown initiation to 15 C at final harvest. The pH was slightly acidic (6.5 to 7.3). Although turbidity was generally low (between 1 and 5 NTU), one measurement of 90 NTU was recorded after a heavy rainfall. Air temperatures ranged from a minimum of 15 C to a maximum of 40 C. No rainfall occurred during the drawdown which probably accounts for no significant differences between plants that were under the rain shelter and those left exposed.

Hydrilla biomass, tuber numbers, tuber weights, average tuber weight, the ratio of tuber numbers per unit biomass, and the ratio of tuber weight per unit biomass were significantly affected by length of drawdown as well as hydrosoil type. There was also a significant interaction between drawdown and hydrosoil type. Means for hydrilla biomass, tuber numbers, and tuber weights are shown in Table 2.

Hydrilla Biomass and Tubers in Silt Loam

Biomass for reference plants grown in silt loam was similar to that observed in previous mesocosm studies with monoecious hydrilla (Coley 1993, Sutton et al. 1992). However, biomass in the mesocosms was three-fold higher than that reported for the field in North Carolina (Harlan et al. 1985).

Plants exposed to a one-week drawdown produced the same amount of biomass as the reference plants (Table 2). No tubers were recovered from the harvest at the drawdown initiation. Consequently, plant regrowth must have been generated by the root crowns. Monoecious hydrilla produces numerous root crowns and dense shoot growth near the hydrosoil surface (Van 1989). Therefore, a one-week drawdown was not long enough to desiccate root crowns and prevent regrowth.

TABLE 2. HYDRILLA BIOMASS, TUBER NUMBERS, AND TUBER WEIGHTS.[1]

Hydrosoil	Drawdown (weeks)	Total vegetative biomass (g DW m^{-2})	Tuber number per m^2	Total tuber weight (g DW m^{-2})	Average tuber weight (g DW)	Tuber number per g DW m^{-2} biomass	Tuber weight (g DW m^{-2}) per g DW m^{-2} biomass
Silt Loam	0	629 ± 92.6 **A**	1596 ± 194.8 **AB**	70.3 ± 10.3 **A**	0.05 ± 0.01 **A**	2.59 ± 0.59 **B**	0.11 ± 0.02 **A**
Silt Loam	1	527 ± 211 **A**	2985 ± 1325 **A**	74.4 ± 31.5 **A**	0.03 ± 0.01 **B**	6.19 ± 2.95 **A**	0.15 ± 0.07 **A**
Silt Loam	2	0 **B**	0 **C**	0 **C**	0 **C**	0 **C**	0 **B**
Silt Loam	3	7.35 ± 18.0 **B**	3.50 ± 8.57 **C**	0 **C**	0 **C**	0.48 **C**	0 **B**
Silt Loam	4	3.75 ± 9.19 **B**	0.50 ± 1.23 **C**	0 **C**	0 **C**	0.13 **C**	0 **B**
Sand	0	365 ± 98.8 **A**	910 ± 276 **B**	28.8 ± 11.2 **B**	0.03 ± 0.01 **AB**	2.57 ± 0.67 **B**	0.08 ± 0.03 **AB**
Sand	1	0 **B**	0 **C**	0 **C**	0 **C**	0 **C**	0 **B**
Sand	2	0 **B**	0 **C**	0 **C**	0 **C**	0 **C**	0 **B**
Sand	3	0 **B**	0 **C**	0 **C**	0 **C**	0 **C**	0 **B**
Sand	4	1.40 ± 3.43 **B**	0 **C**	0 **C**	0 **C**	0 **C**	0 **B**

[1]Means are shown ± 1 sd (n = 6). Different letters within a column denote significant differences between means (LSD procedure, alpha < 0.05).

Vegetative biomass and tuber production of monoecious hydrilla were suppressed by a drawdown of two weeks or longer (Table 2). Although negligible regrowth occurred on silt loam after a three-week drawdown and four-week drawdown, it was not statistically significant. The tubers produced from these plants were very small. Van and Steward (1990) speculated that tubers of this size did not contain enough starch reserves to survive overwintering.

Tuber numbers of reference plants were similar to those reported in previous studies (Coley 1993, Sutton et al. 1992) but two- and three-fold higher compared with field studies by Harlan et al. (1985). Plants subjected to a one-week drawdown produced the same number of tubers as the reference plants, but the average tuber weight was substantially smaller (Table 2). Stimulation of vegetative reproduction by sublethal stress is not unusual; *Elodea canadensis* Michx. and several other aquatic plant species reproduce prolifically when placed under stress (Sculthorpe 1967). The stress induced by one week exposure resulted in doubling the number of tubers produced per unit weight of biomass; however, the weight of tubers per unit biomass was similar to the reference plants. These results indicate that a drawdown which is not long enough to completely kill the shoot biomass and the associated root system in a silt loam hydrosoil could stimulate hydrilla tuber production. Increased tuber production would mean more plants sprouting and colonizing a given water body.

Only total tuber dry weights were significantly greater in silt loam than in sand (Table 2). The greater tuber weights in silt loam may reflect the difference in quantity and/or availability of nutrients found in that hydrosoil. Spencer et al. (1994) found that once vegetative reproduction was initiated, monoecious hydrilla allocated most of its carbon and nitrogen to tuber production at the expense of shoot and root production. In addition, increased tuber weights for monoecious hydrilla have been reported for substrates with higher organic matter (Coley 1993, Spencer et al. 1992).

Hydrilla Biomass and Tubers in Sand

Biomass and tuber numbers for reference plants grown on sand corresponded to field observations in North Carolina (Harlan et al. 1985) as well as previous mesocosm studies (Coley 1993). Vegetative biomass and tuber numbers of monoecious hydrilla were suppressed by a one-week drawdown (Table 2). The regrowth that occurred on sand after a four-week drawdown was not statistically significant. Regrowth from hydrilla root crowns in sand was probably inhibited by hydrosoil pore size. Not only does the larger pore size allow water to flow through it rapidly but it creates a mechanical resistance to root penetration (Daddow and Warrington 1983).

Turion Production

Each reference plant produced 13.3 ± 4.9 turions; however, no turions were produced by any plants exposed to the drawdown. Since turions were found in previous studies using the same mesocosm system (Coley 1993) and conditions were suitable to induce turion formation (Spencer and Ksander 1991), it is uncertain whether adverse conditions created by the drawdown halted turion formation (Spencer et al. 1994). Because most of monoecious hydrilla's nutrient supply is allocated for tuber production (Spencer et al. 1994), there may not have been sufficient nutrients for turion production. It has been suggested that axillary turions are adapted for dispersal by water movements to colonize new areas in a given water body because they are small and produced in the water column (Spencer et al. 1987). More evidence is needed to determine if a summer drawdown would limit the potential range of hydrilla by eliminating or reducing turion production.

This study demonstrated that a properly timed drawdown of only two to four weeks duration could suppress vegetative growth and inhibit tuber and turion production of monoecious hydrilla grown on two hydrosoils. Our results also suggest that the type of hydrosoil present in the drawdown zone may have a major impact on the success of a drawdown; insufficient exposure length potentially could stimulate tuber production on some hydrosoils. Another study to determine the desiccation rates of different hydrosoil types would provide additional information on exposure length required to kill monoecious hydrilla that could not be detected from the present approach. Moreover, additional research is needed to field validate the effectiveness of a short-term summer drawdown *in situ* before this management technique can be recommended for hydrilla control.

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