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Seed Production and Growth of Waterchestnut as Influenced by Cutting

BARBARA A. METHÉ,[1] R. J. SORACCO,[1] J. D. MADSEN[2] AND C. W. BOYLEN[1]

ABSTRACT

A major infestation of waterchestnut (*Trapa natans* L.) in a reservoir in New York State was studied to evaluate the efficacy of air boat cutting as a possible control measure. A measure of the status of the seed bank through sediment core analysis showed that deposition of new seeds in a treatment site was reduced to no net gain of seeds versus an average of 170 seeds/m^2 added to the seed bank in an untreated site. Results from seed-fall collection baskets placed in two untreated sites revealed new deposition of 180 seeds/m^2 and 143 seeds/m^2, respectively, which corroborated the results from sediment core data. Cut rosette fragments, produced by the cutting operation, were compared to undisturbed whole plants for vigor and seed production. Both vigor and seed production rates were less than those of intact plants.

Key words: aquatic macrophyte, water caltrop, aquatic plant control, *Trapa natans*, aquatic plant cutting.

INTRODUCTION

Waterchestnut is a floating leaf, aquatic plant introduced from Eurasia to New York State in the late 1800's and is now found throughout the Northeast (Countryman 1978). Major infestations exist along the shoreline of the Hudson and Mohawk Rivers and in Lake Champlain, as well as in numerous regional lakes and ponds.

In the Northeast, seed germination occurs in late May and by early June a dense canopy of rosettes is soon established on the water surface. Bud formation in the rosettes begins in late June followed by flowering in early July. The first fruits reach maturity by August and upon abscission, these negatively buoyant seeds fall to the sediment. Seed production continues until the senescence of the vegetative plant. As a true annual, waterchestnut overwinters entirely by seed (Smith 1955). A portion of seeds produced each year germinate the following spring while those remaining in the sediment accumulate to produce a seed bank[3]. Seeds have been shown to be viable in excess of five years (Kunii 1988).

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[1] Rensselaer Fresh Water Institute, MRC 203, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.

[2] U.S. Army Engineer Waterways Experiment Station, Lewisville Aquatic Ecosystem Research Facility, RR#3 Box 446, Lewisville, TX 75056.

[3] Madsen, J. 1990. Waterchestnut (*Trapa natans* L.) Research in the Watervliet Reservoir-1989 Report. Fresh Water Institute Report #90-8. Rensselaer Polytechnic Institute, Troy, New York. 29 pp.

Waterchestnut has become a nuisance plant largely due to aggressive growth habits. Native plant populations are adversely impacted creating a loss of biodiversity. Waterchestnut has less value as food and shelter to most fish and waterfowl than native plants and has a deleterious effect on water quality (Kiviat 1987). Its narrow, flexible stem supports rosettes which impede passage of boats or people by its extensive surface growth. The fruits possess sharp spines with recurved barbs which are capable of causing painful wounds.

Until recently, control programs have centered on two management forms: (1) physical, including hand pulling or mechanical harvesting and (2) chemical, primarily use of the herbicide 2,4-D [(2,4- dichlorophenoxy) acetic acid] (Smith 1955). In New York State, a control program in the 1970s using 2,4-D was successful in nearly eradicating waterchestnut. However, concerns about adverse chemical effects on fish and aquatic invertebrates lead to a discontinuation of the program in 1977 (Countryman 1978). Since that time, waterchestnut has reestablished to nuisance proportions.

One such infestation exists in the Watervliet Reservoir. A study was begun in 1989 to examine seed production and the effect of a cutting program that utilized a specially adapted air boat. This research was developed in conjunction with an ongoing operational program with the major objectives to: (1) confirm that interruption of the life cycle at flowering and during seed set would decrease mature seed production, (2) ascertain the existence of a decreasing relationship between lower seed production and disappearance of seeds in the sediment, and (3) examine if cut rosettes contain sufficient vigor and can remain viable to produce mature seeds.

MATERIALS AND METHODS

The Watervliet Reservoir is a 175-hectare, potable water supply located in Albany County, New York. Mean water depth for the entire reservoir is 3.5 m. In the western end where all sampling took place, mean water depth was 3 m. The design of the air boat and cutting blade allowed for more rapid movement and coverage of larger surface areas per unit time than traditional harvesters. A sharp V-shaped metal blade mounted in front of the bow was lowered approximately 10 cm below the water surface during cutting operations such that rosettes, once detached from their stems, were disrupted from normal growth and seed production cycles. Under the cutting program managed by the City of Watervliet, rosettes were not removed from the water after cutting.

Sample sites included a treatment area in the main body of the reservoir with a mean depth of 1.5 m where cutting was performed. An untreated reference site characterized by a mean depth of 1.5 m was maintained throughout the growing season in an embayment approximately 200 m from the treatment area (untreated site #1). A second untreated reference site with a similar mean depth of 1.5 m and 10 m from the treated site, located in the main body of the reservoir, was also maintained (untreated site #2).

The status of the seed bank was determined by analyzing 20 sediment cores (7.6 cm *i.d.*) removed from both the treatment site and untreated site #1 in June and November. Seeds from these cores were collected, counted, dried to a constant weight, and examined for the presence of an endosperm as a measure of viability. The core data obtained after senescence (November) represent existing seeds as well as those newly deposited to the bank (previous deposition plus current deposition). The difference between the two sampling periods (November minus June) provides a measure of new seed deposition.

A second method to estimate seed production was obtained by the use of seed-fall collectors which gathered newly produced seeds. The collectors consisted of wire mesh baskets (30 cm by 60 cm) placed directly underneath sections of the canopy in untreated sites #1 and #2. All baskets (10 baskets from each set) were retrieved in November after senescence.

Two transects in untreated site #1 were made every other week to examine seed production and selected phenological traits from early June through early October. The transects consisted of 20 0.1-m^2 quadrats in a straight line, each quadrat separated by a distance of 1 m. The total number of rosettes was counted in each quadrat with two rosettes per quadrat chosen at random for further observation. Phenological traits counted included leaves, buds, flowers, pollinated flowers, and seeds.

Vigor of cut rosettes was determined by collecting and labeling 100 of them with numbered tags to follow development of individual rosettes throughout the remainder of the growing season. Phenological traits as above were measured to provide data analogous to those collected from the transects. Ten cut rosette fragments were placed into each of ten nylon mesh enclosures. The dimensions of the mesh enclosures were 45 cm by 90 cm by 60 cm with 60-cm-long posts at each of the four corners of the enclosures serving to anchor them in the sediment. The ten enclosures were grouped in the center of untreated site #1 in two rows with approximately 1 m separating each enclosure. In the first six, each cut rosette was placed in an "upright" growing position. In the remaining four enclosures, extra untagged cut rosettes were mixed haphazardly with the ten tagged ones to better simulate the "crowded" position typical of the piling of cut fragments upon one another which normally occurred after cutting.

The presence of a significant difference between new seed deposition or loss values calculated from data obtained by the sediment coring method was determined. Calculation of the p value was made by first obtaining the sample variances of each mean data point. Next an estimate of variance between the differences (November minus June values) was determined followed by performance of the Student's t Test to obtain the actual p value. An analogous method was used to determine if the presence of significant differences existed between new seed deposition values obtained via the sediment coring and seed-fall collection techniques. All variance values calculated are 95% confidence intervals.

RESULTS AND DISCUSSION

The core data from the June sampling were obtained after germination of that year's cohort. Therefore, they represented seeds that remained in the bank from previous deposition and could potentially germinate in future years. In the untreated site #1 and the treatment site, the number of viable seeds averaged 40 seeds/m^2 and 80 seeds/m^2, respectively. This would indicate that a seed bank had accumulated at the sites through previous seed production (Table 1).

TABLE 1. AVERAGE NUMBER OF VIABLE WATERCHESTNUT SEEDS FOUND PER M^2 OF SEDIMENT AREAL COVER AND THE RESULTING SEASONAL SEED DEPOSITION OR LOSS. SEED DEPOSITION OR LOSS REPRESENTS THE DIFFERENCE IN VALUES BETWEEN NOVEMBER 1990 AND JUNE 1990.

	Sample date		Deposition or loss of new seeds/m^2/year (11/90-6/90)
Treatment	6/90	11/90	
Sediment cores			
Reference site #1	40 ± 0.2	210 ± 0.6	170 ± 2.8
Treatment	80 ± 0.3	20 ± 0.1	-60 ± 2.8
Seed-fall collectors			
Reference site #1	—	180 ± 4.1	—
Reference site #2	—	143 ± 4.3	—

In the treatment site, a net loss of 60 seeds/m^2 occurred from June to November. This is a significant loss when compared to the net deposition of 170 seeds/m^2 in untreated reference site #1 ($p < 0.001$). Consequently, less than half as many seeds were observed in the cut site after senescence than in the initial sampling. Similar loss of the number of seeds to the seed bank was observed in a treatment site from the previous year.[3] The loss of seeds in the treatment area may have resulted from several factors including seed transport due to water and sediment movement, and/or seed mortality. The disruption of the canopy by cutting could potentially shift environmental factors to favor germination of dormant seeds in the sediment, although light intensity, *per se*, is not a factor in seed germination of waterchestnut.[4]

Mean values of 180 and 143 seeds/m^2 from untreated site #1 and untreated site #2, respectively, were measured via the seed-fall collection method. No statistically significant differences were calculated when comparing the untreated site #1 value with the net deposition value of 170 seeds/m^2 obtained in that site by the sediment coring technique ($p = 0.22$). A statistically significant difference was obtained when comparing the seed-fall collection value in untreated site #2 with the sediment core value from site #1 (Table 1). This difference can be attributed to variability between the sites. However, a comparison of the seed deposition values obtained in the two untreated reference sites from each method reflects an overall homogeneity in seed production in this region of the reservoir.

The results of these experiments suggest two important conclusions. First, a significant amount of new seed production is prevented by the cutting program as evidenced by a reduction in seed production relative to untreated sites. Secondly, the use of sediment cores and seed-fall collectors to measure seed production are potentially effective methods for monitoring the success of waterchestnut management techniques.

Vigor of cut rosette fragments was less than that of whole plants growing *in situ* (Table 2). A decrease in vigor was observed in both leaf size and number, especially by fragments placed in crowded conditions. In addition, the number of buds, flowers and pollinated flowers decreased steadily throughout the experiment and were always less on fragments than those counted on plants *in situ*. Despite this, seed production by the cut rosettes did occur. At the final sampling,

TABLE 2. COMPARISON OF PHENOLOGICAL TRAITS BETWEEN WHOLE PLANTS AND CUT ROSETTE FRAGMENTS. DATA REPRESENT AVERAGES ± 95% CONFIDENCE INTERVALS OF MAXIMUM MIDSUMMER VALUES.

Phenological traits	Whole plants	Upright rosettes	Crowded rosettes
Leaves	35.5 ± 0.8	20.0 ± 1.3	15.0 ± 1.7
Buds	4.0 ± 0.4	1.4 ± 0.3	1.3 ± 0.3
Flowers	0.5 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
Pollinated flowers	4.4 ± 0.4	3.5 ± 0.5	2.0 ± 0.4
Seeds	10.2 ± 0.7	3.0 ± 0.5	3.5 ± 0.6

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[4] Madsen, J. D. 1990. Waterchestnut (*Trapa natans* L.) Seed Germination: Effects of Temperature and Daylength. Fresh Water Institute Report #90-16. Rensselaer Polytechnic Institute, Troy, New York. 12pp.

upright cut rosettes averaged 3.0 ± 0.53 seeds/rosette while crowded cut rosettes averaged 3.5 ± 0.63 seeds/rosette (Figure 1). Rosettes attached to plants examined along transects averaged 10.2 ± 0.74 seeds/rosette (Figure 1).

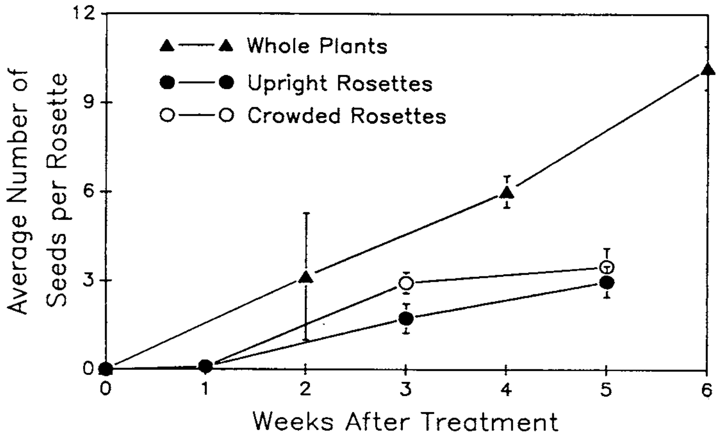

Figure 1. Average number of seeds produced per rosette along transects of uncut plants and cut rosettes arranged in upright and crowded conditions. Values represent the means of 80 repetitions for whole plants and 60 and 40 repetitions from the two cut rosette fragment studies, respectively. Error bars represent ±95% confidence intervals.

As a management practice, these results suggest that cutting minimized, but did not prohibit, seed production in waterchestnut. The final sampling showed the number of buds per fragment rosette was slightly less than one bud per cut rosette versus four buds per rosette of whole plants. Rosette fragments containing buds, flowers, and pollinated flowers present at the time of cutting were capable of continuing seed maturity. However, those rosette fragments without buds after cutting had greater difficulty producing new buds which have the potential for mature seed set. To decrease the number of seed forming components present leading to mature seed production, it would be necessary to cut original growth or regrowth as frequently and aggressively as possible, especially if rosette fragments are not being removed promptly from the water after cutting.

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