J. Aquat. Plant Manage. 23: 64-67

Density of Tubers and Turions of Hydrilla in South Florida[1]

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ABSTRACT

The mean number of tubers of hydrilla (*Hydrilla verticillata* Royle) in cores of hydrosoil in South Florida from 1977 to 1979 was in the descending order of North New River Canal > Lake Okeechobee > Loxahatchee National Wildlife Refuge = north end of Lake Trafford = south end of Lake Trafford, with a high of 207 per m^2 in the North New River Canal and 36 per m^2 in the south end of Lake Trafford. The number of turions was different for all the locations with the highest number, 90 per m^2, found in the North New River Canal and the lowest, 5 per m^2, in Lake Okeechobee. In the north end of Lake Trafford, cores collected in January 1979 resulted in an estimate of 882 tubers per m^2 while the number of turions was estimated at 37 per m^2. In January 1978, cores from the North New River canal resulted in an estimate of 273 turions per m^2 and 457 tubers per m^2. No seasonal trends were noted for these propagules; however, yearly differences in tubers for the North New River Canal and the Loxahatchee National Wildlife Refuge were observed. Also yearly differences were noted for turions collected from Loxahatchee and the south end of lake Trafford. These data suggest that management strategies must consider the high number of tubers and turions which may be present throughout the year.

Key words: Aquatic macrophytes, aquatic weeds, propagules, regrowth, survey, vegetative reproduction.

INTRODUCTION

Hydrilla, a submersed aquatic plant, is a major problem in the United States. Management of a hydrilla infestation is hampered by its production of special reproductive organs, tubers and turions. These, especially the tubers, are generally assumed to be a major source of regrowth of new shoots after winter die-back, or after herbicides, herbivorous fish, or other means are used to control the mature plants.

Information on the density of tubers and turions will be useful in formulating strategies for managing growth of hydrilla. However, little information is available on the number of them which may occur in various aquatic sites, although it is well known that day length governs the production of tubers (3, 10).

In a study of hydrilla growing in ponds Haller and Sutton (4) found an estimated 257 tubers and 65 turions per m^2 after 2.5 years of growth of hydrilla. After 70 weeks of growth of hydrilla in outdoor aquaria with a sandy loam sediment, Steward (7) found 4,240 tubers per m^2, but no mention was made if any turions were present. In another outdoor aquarium study (8), turions were produced during 16 weeks of winter growth of hydrilla; however, their density could not be determined because they fell to the bottom of the aquaria and their origin could not be related directly to the main or sub-plot treatments.

Mitra (5) reported that in India, tubers were present in amounts almost 10 times that for turions. In a survey of three lakes in Florida during 1977 (1), a high of 510 tubers per m^2 was found for the November sampling period in Orange Lake (Alachua County); however, apparently no turions were found in any of these lakes.

Pieterse *et al.* (6) suggested that turion formation is stimulated by low levels of nitrogen and phosphorus in the water. In their study, no turions were formed in nutrient solutions with 22.6 mg of nitrate per liter plus 148.8 mg phosphate per liter but 29 turions (expressed on a basis of 1.0 g dry weight of hydrilla) formed on plants cultured with 0.02 mg nitrate plus 0.15 mg phosphate per liter.

A better understanding of the production of hydrilla tubers and turions and their subsequent density will help in the timing of various management practices to control growth of this submersed, noxious weed. Therefore, a study was conducted to estimate tuber and turion density at five locations in South Florida during a 3-year period.

MATERIALS AND METHODS

Sampling Procedure. The sampler described by Sutton (9) was used to collect cores of hydrosoil from various locations. Cores were placed in separate containers, and transported to the Fort Lauderdale Research and Education Center for separation of the hydrilla tubers and turions from the hydrosoil. Each core was washed and sieved on a fine mesh screen with openings of 3 mm. This screen retained the tubers and turions but allowed the hydrosoil to pass through.

Study Locations. Cores of hydrosoil were collected from locations which had supported an abundant growth of hydrilla for a number of years. These locations were (1) the Harney Pond area of Lake Okeechobee, (2) the south side of the Loxahatchee National Wildlife Refuge (Loxahatchee) approximately 4 km west of the public boat launch area, (3) approximately 0.25 km west of the University Drive along State Road 84 in the North New River

[1]Contribution of the University of Florida's Fort Lauderdale Research and Education Center. Published as Journal Series Number 6142 of the Florida Agric. Exp. Sta. Agricultural Research Service (ARS), Southern Region, South Atlantic Area, USDA, cooperating. Supported in part by the Florida Department of Natural Resources, Bureau of Aquatic Plant Research and Control.

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Canal, and (4) from the north and south end of Lake Trafford. At each sampling time for each location, 25 cores of sediment were collected from the same general area, and always from beneath a surfaced growth of hydrilla. Each core was collected approximately 0.1 to 3.0 m apart during each sampling time.

Sampling began in January 1977 and continued at approximately 2 month intervals for a 3-year period. Because of the distance between locations and weather conditions, the cores were not always collected from each location on the same date.

For each location and date, the tubers and turions were separated into groups. Those propagules which had germinated, produced a recognizable shoot, were removed from the groups but were included in the total to estimate the number per m^2. Calipers were used to aid in the determination of tuber length, the distance from the apex to its base.

The water depth from which the cores were collected was difficult to determine because of the soft mucky bottoms in these locations but the initial approximate depth was 1.2 m for Lake Okeechobee, 1.1 m in Loxahatchee, 2.3 m in the North New River Canal, and 0.75 m in the south end and 1.2 m in the north end of Lake Trafford. During the course of the study, the water depth varied in these locations due to rain fall and water level regulation by the various water management districts.

Statistical Analyses. The Statistical Analyses System (SAS) software located at the North East Regional Data Center (NERDC) was used to analyze the data. The number of propagules plus 1 for each location and sampling date was transformed by the use of logarithms prior to analyses. However, the un-transformed average densities are presented.

Because of the large number of cores which contained no propagules, the following parameters were examined:

$$P = \frac{\text{Number of cores with at least one of either a tuber or turion}}{\text{Total number of cores for each sampling time at each location (=25)}}$$

m = average number of tubers and turions per core when at least one tuber or turion was present

RESULTS AND DISCUSSION

An analysis of variance for locations by year by months indicated highly significant main effects as well as a significant three-way interaction. The significant three-way interaction implies that differences among locations varied among years and months.

Most of the degrees of freedom are found in the error term mainly because of the 25 cores which were collected for each location at each sampling time. This gives a very good estimate of the pooled within location (error) variance, and because of the large degrees of freedom almost assures a statistical significance. For this reason, only the mean and its associated standard deviation for the number of tubers and turions per m^2 for the various locations are presented in Tables 1 to 4.

TABLE 1. DENSITY OF SPECIALIZED REPRODUCTIVE STRUCTURES OF HYDRILLA AND THE NUMBER GERMINATED AS A PERCENT OF THE TOTAL COLLECTED IN THE NORTH NEW RIVER CANAL. EACH VALUE PER m^2 REPRESENTS THE MEAN WITH ITS ASSOCIATED STANDARD DEVIATION FOR 25 CORE SAMPLES.

Date of collection	Number per m^2		Number germinated (%)	
	Tuber	Turion	Tuber	Turion
1977				
25 January	249 ± 274	111 ± 165	0	0
05 April	448 ± 441	143 ± 209	0	0
19 May	254 ± 287	55 ± 89	0	0
08 July	305 ± 264	79 ± 114	8	0
26 September	420 ± 427	92 ± 105	0	0
19 November	102 ± 150	222 ± 197	11	12
1978				
03 February	457 ± 559	273 ± 522	9	7
27 March	171 ± 203	176 ± 281	0	0
22 May	213 ± 165	69 ± 176	0	7
19 July	120 ± 165	14 ± 51	15	33
25 September	37 ± 86	51 ± 149	0	9
30 November	139 ± 183	92 ± 129	7	20
1979				
30 January	166 ± 238	6 ± 125	3	8
27 March	143 ± 171	0 ± 0	0	0
21 May	176 ± 216	152 ± 240	0	0
06 August	148 ± 215	42 ± 81	19	22
26 September	125 ± 218	37 ± 86	11	25
20 November	51 ± 125	0 ± 0	0	0

TABLE 2. DENSITY OF SPECIALIZED REPRODUCTIVE STRUCTURES OF HYDRILLA AND THE NUMBER GERMINATED AS A PERCENT OF THE TOTAL COLLECTED IN LAKE OKEECHOBEE. EACH VALUE PER m^2 REPRESENTS THE MEAN WITH ITS ASSOCIATED STANDARD DEVIATION FOR 25 CORE SAMPLES.

Date of collection	Number per m^2		Number germinated (%)	
	Tuber	Turion	Tuber	Turion
1977				
25 January	166 ± 188	0 ± 0	0	0
05 April	106 ± 137	0 ± 0	0	0
19 May	78 ± 140	9 ± 32	0	0
18 July	37 ± 80	14 ± 51	0	0
26 September	46 ± 163	0 ± 0	0	0
29 November	176 ± 192	0 ± 0	0	0
1978				
02 February	208 ± 163	28 ± 60	0	0
30 March	69 ± 120	0 ± 0	0	0
26 May	240 ± 205	5 ± 23	0	0
21 July	88 ± 121	5 ± 23	0	0
30 September	18 ± 43	5 ± 23	0	0
28 November	9 ± 32	0 ± 0	50	0
1979				
06 February	69 ± 167	5 ± 23	0	0
29 March	5 ± 23	0 ± 0	0	0
31 May	37 ± 86	0 ± 0	0	0
15 August	171 ± 164	0 ± 0	3	0
10 October	236 ± 230	5 ± 23	8	100
04 December	203 ± 168	14 ± 38	0	0

An analysis of variance testing only for differences between locations using month to month variability for the error term indicated that the mean density of tubers was in the order of North New River Canal > Lake Okeechob-

TABLE 3. DENSITY OF SPECIALIZED REPRODUCTIVE STRUCTURES OF HYDRILLA AND THE NUMBER GERMINATED AS A PERCENT OF THE TOTAL COLLECTED IN LOKAHATCHEE NATIONAL WILDLIFE REFUGE. EACH VALUE PER m^2 REPRESENTS THE MEAN WITH ITS ASSOCIATED STANDARD DEVIATION FOR 25 CORE SAMPLES.

Date of collection	Number per m^2		Number germinated (%)	
	Tuber	Turion	Tuber	Turion
1977				
15 January	111 ± 139	120 ± 151	0	0
05 April	79 ± 141	69 ± 111	0	0
19 May	74 ± 87	9 ± 32	0	0
18 July	74 ± 74	46 ± 75	0	0
26 September	51 ± 95	42 ± 81	0	0
29 November	14 ± 51	152 ± 191	0	0
1978				
01 February	28 ± 60	125 ± 120	0	0
31 March	23 ± 67	74 ± 115	0	0
22 May	23 ± 58	185 ± 231	20	2
21 July	0 ± 0	129 ± 147	0	4
29 September	0 ± 0	79 ± 114	0	0
27 November	0 ± 0	42 ± 42	0	0
1979				
22 January	0 ± 0	65 ± 100	0	14
22 March	9 ± 32	0 ± 0	0	0
17 May	106 ± 166	32 ± 85	0	0
06 August	0 ± 0	0 ± 0	0	0
28 September	51 ± 89	9 ± 32	0	0
06 November	46 ± 67	23 ± 67	0	0

TABLE 4. DENSITY OF SPECIALIZED REPRODUCTIVE STRUCTURES OF HYDRILLA IN LAKE TRAFFORD. EACH VALUE PER m^2 REPRESENTS THE MEAN WITH ITS ASSOCIATED STANDARD DEVIATION FOR 25 CORES.

Date of collection	Number per m^2			
	North end		South end	
	Tuber	Turion	Tuber	Turion
1977				
25 January	157 ± 176	14 ± 38	74 ± 120	9 ± 32
05 April	22 ± 57	5 ± 23	111 ± 162	5 ± 23
19 May	9 ± 31	14 ± 38	249 ± 324	9 ± 32
18 July	0 ± 0	14 ± 38	5 ± 23	0 ± 0
26 September	9 ± 46	0 ± 0	5 ± 23	0 ± 0
29 November	5 ± 23	0 ± 0	32 ± 97	5 ± 23
1978				
31 January	5 ± 23	0 ± 0	0 ± 0	0 ± 0
30 March	28 ± 84	55 ± 101	9 ± 32	42 ± 87
25 May	9 ± 32	60 ± 134	37 ± 64	203 ± 177
24 July	0 ± 0	9 ± 32	0 ± 0	83 ± 97
29 September	0 ± 0	0 ± 0	0 ± 0	23 ± 58
28 November	14 ± 51	97 ± 140	83 ± 127	74 ± 94
1979				
05 February	882 ± 701	37 ± 104	0 ± 0	28 ± 96
29 March	5 ± 23	18 ± 43	5 ± 23	65 ± 100
31 May	5 ± 23	23 ± 75	18 ± 55	18 ± 55
26 July	0 ± 0	9 ± 32	5 ± 23	0 ± 0
10 October	0 ± 0	0 ± 0	5 ± 23	5 ± 23
04 December	0 ± 0	0 ± 0	18 ± 64	18 ± 55

nee > Loxahatchee = north end of Lake Trafford = south end of Lake Trafford (Table 5). The number of turions was statistically different for all the locations with the highest number found in the North New River Canal and lowest in Lake Okeechobee.

TABLE 5. MEAN DENSITY OF SPECIALIZED REPRODUCTIVE STRUCTURES OF HYDRILLA COLLECTED FROM FIVE LOCATIONS IN SOUTH FLORIDA DURING 1977 TO 1979.

Location	Number per m^2[1]	
	Tubers	Turions
North New River Canal	207 a	90 a
Lake Okeechobee	109 b	5 e
Loxahatchee National Wildlife Refuge	38 c	67 b
North end of Lake Trafford	64 c	20 d
South end of Lake Trafford	36 c	33 c

[1]Values within each column followed by the same letter are not significantly different at the 95% confidence level as determined by Duncan's multiple range test. Each value is composed of the mean number of propagules found in 25 cores of sediments collected approximately every 2 months from each location.

The ratio of tubers to turions was not consistent for the various locations, although in general, more tubers than turions were found in the cores. However, cores collected for several of the sampling times from Lake Trafford contained more turions than tubers. Furthermore, cores collected during a few of the months from this lake contained turions but no tubers.

Tubers were always found in cores collected from the North New River Canal and Lake Okeechobee. Turions were found in the North New River Canal for all the sampling months of the 3-year study except for March and November 1979. Likewise in Loxahatchee, turions were present for all the sampling times except for March and July 1979.

The test for parameter P indicated yearly differences for tubers found in the North New River Canal and Loxahatchee, and for turions in Loxahatchee and the south end of Lake Trafford. No pattern emerges for differences due to abundance of tubers and turions collected for the various sampling months. These data suggest that the North New River Canal and Loxahatchee may provide additional information on density, if an intensive sampling study were conducted in these areas.

No significant differences were determined for the test on the parameter m. This test seems to suggest that when a core contains at least one specialized reproductive structure, be it either a tuber or turion, the expected number observed is not dependent upon the year or month in which it was collected.

Length distribution for tubers collected during this study are presented in Table 6. Haller *et al.* (3) found over 50% germination of tubers in the 7 to 11 mm size length of those collected from Rodman Reservoir. As shown in Table 6, the majority of the tubers collected during this study are in the 7 to 11 mm size class. This indicates that under optimum germination conditions many of these would sprout.

The number of germinated propagules found in the cores are presented in Tables 1 to 4. Values for Lake Trafford are not presented in these tables since sprouted tubers were found only twice during the 3-year study. In the north end of Lake Trafford, 43 germinated tubers were

TABLE 6. LENGTH DISTRIBUTION OF TUBERS OF HYDRILLA COLLECTED IN SOUTH FLORIDA DURING 1977 TO 1979. FOR EACH LOCATION, MEASUREMENTS WERE POOLED FOR EACH SAMPLING TIME. ALSO, THOSE TUBERS COLLECTED FROM THE NORTH AND SOUTH END OF LAKE TRAFFORD WERE COMBINED.

	Number of tubers in each length													
	Length (mm)													
Location	4	5	6	7	8	9	10	11	12	13	14	15	16	17
North New River Canal	0	4	24	55	108	168	194	117	66	25	13	6	1	0
Lake Okeechobee	0	4	12	20	50	56	143	68	40	13	5	1	0	0
Loxahatchee National Wildlife Refuge	0	7	8	18	22	40	32	14	0	0	0	0	0	0
Lake Trafford	0	3	7	15	30	36	63	79	52	32	6	2	0	0

counted out of 191 collected on 5 February 1979, and one sprouted tuber was collected from the south end of this lake on 10 October 1979.

No trend is apparent for the germination of tubers and turions found in this study. Rather, it appears that they sprouted at various time throughout the year.

These data provide little information to suggest a seasonal fluctuation in tuber and turion density for the locations sampled in South Florida from 1977 to 1979. This study supports the theory proposed by Bowes *et al.* (1) that germination of turions is inhibited in areas where a mat of hydrilla is maintained throughout the year such as that found in South Florida. They suggested that a mat of hydrilla results in a high CO_2 level in the hydrosoil, which in turn, reduces germination of hydrilla tubers.

Furthermore, density of tubers and turions may reach a steady state condition in which formation of new propagules equals those germinating with the maximum number for a body of water dependent on sediment type, type and concentration of nutrients in the sediment, water quality, and other factors. For example, Bruner and Batterson (2) found in small outdoor aquaria planted with hydrilla that soil fertility influenced the number of tubers produced and their sustained rate of production.

Future studies to evaluate seasonal production of hydrilla propagules under field conditions may need to focus attention on the ratio of newly formed immature to mature propagules at various times of the year. Research of this kind may provide more information on the production of tubers and turions than that explained on density alone.

Management strategies in South Florida must take into account the number of reproductive organs of hydrilla which exist throughout the year in some locations. These may serve as a source for reinfestation for a number of years. Therefore, successful management programs will need to eliminate completely all growth of hydrilla.

Complete removal of hydrilla would serve two purposes. First, the production of these specialized reproductive structures would be stopped. Second, perhaps by eliminating the mat of plants, more oxygen would reach the hydrosoil to encourage their germination. Of course, any new growth of hydrilla must then be prevented from having a chance to form additional tubers and turions.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Ms. Diane Johnston, Mr. Jay Gaus, and Mr. Terry Lott for their technical assistance during this study; and to M. Tom Martin, Refuge Manager, for allowing us to use the Loxahatchee National Wildlife Refuge as one of the sampling locations.

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