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Influence of Temperature and Light on Dwarf Spikerrush and Slender Spikerush Growth

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ABSTRACT

Pre-germinated two- to three-leaf seedlings of dwarf spikerush [*Eleocharis coloradoensis* (Britt.) Gilly] and slender spikerush [*Eleocharis acicularis* (L.) R. & S.] were transplanted into a soil mix and subjected to several submerged light-temperature conditions for 8 weeks. Rosette production, fresh weight, and dry weight were determined. Water temperatures were 3, 13, 19, 23, 25, 28, 30, 32, 35, or 37 C. Maximum growth for both species was relatively constant between 25 and 32 C and severely reduced at 13 and 37 C. Slender spikerush produced more rosettes than dwarf spikerush at 30 C or below, but the total biomass of slender spikerush was less than dwarf spikerush between 25 and 35 C. With light intensities of 360, 180, 60, 20, or 5 μE/m^{-2}/sec^{-1} (PAR), slender spikerush produced more rosettes than dwarf spikerush at the three highest light levels; at the lowest two light levels, growth was nil in both species. Although slender spikerush produced more rosettes than dwarf spikerush at each light intensity, the percentage decrease in population within each species was about the same as the light intensity was reduced. There was no interaction of light at 360, 180, or 60 μE/m^{-2}/sec^{-1} with temperature at 16, 22, or 29 C. Slender spikerush grew better at lower light-lower temperature conditions. Conversely, dwarf spikerush grew better at the higher light-higher temperature conditions. These results are discussed in relation to species selection to establish competitive stands on specific sites.

Key wcrds: Aquatic weeds, ecology, environment, competition, biological control.

INTRODUCTION

Dwarf spikerush [*Eleocharis coloradoensis* (Britt.) Gilly] and slender spikerush [*Eleocharis acicularis* (L.) R. & S.] are short-statured spikerushes that have been observed to "displace" undesirable aquatic plants which are usually taller in stature (Osborn et al., 1954; Yeo and Fisher, 1970; Yeo, 1980). Although there are undoubtedly several ecological factors involved in the successful establishment of a competitive stand of these spikerushes, water temperature and light intensity appear to be among the more important factors influencing submersed aquatic vegetation (Barko et al., 1986). Preliminary observations indicated the optimum temperature for the growth of both of these species is higher than that commonly found in local irrigation systems. Light reduction from turbid water and taller aquatic species found in the field also appear to suppress the growth of these low-growing species of spikerush. Anderson et al. (1986b) recently showed that herbicide suppression of American pondweed (*Potamogeton nodosus* Poir) resulted in increases in slender spikerush population in an irrigation canal. This study was conducted to determine the optimum and limiting water temperatures for dwarf spikerush and slender spikerush growth and investigate the influence of light intensity, water temperature, and the interaction of these two factors on their growth.

MATERIALS AND METHODS

General. Dwarf spikerush seed was from the USDA spikerush nursery at the University of California, Davis, and the slender spikerush seed was from "Leaky Acres", a ground water recharge facility in Fresno County, California. Pre-germinated two- to three-leaf seedlings, less than 1 cm high, of dwarf spikerush and slender spikerush were used in all experiments. The seeds of these species have a dormancy that must be broken and a light requirerment that must be satisfied for maximum germination (Yeo and Dow, 1978; Ashton et al., 1984; Yeo, 1986). Therefore, the seeds were scarified and stratified to break the initial dormancy and germinated in light for the light requirement as described below. The seeds were scarified by placing them in cold 5.25% hypochlorite (laundry bleach) for 10 hr at 21 C with occasional stirring. Following scarification, the seeds were rinsed with tap water and stratified in tap water for 4 weeks at 2 to 4 C. It was subsequently determined that the 10 hr scarification period with 5.25% sodium hypochlorite at 21 C was longer than optimal for slender spikerush; a 2 hr scarification period appears to be optimal for slender spikerush (Ashton et al., 1984; Yeo, 1986). The treated seeds were germinated in disposable petri dishes containing tap water that were placed in a growth chamber; 21 C, 46 μE/m^{-2}/sec^{-1} fluorescent light, and a 14 hr light/10 hr dark cycle. Under these conditions, the seeds germinate well but growth is slow.

Optimum and limiting water temperatures. For each group of treatments U.C. potting mix[2] was ground to pass a 2 mm sieve, autoclaved, moistened with water, and packed into 36 12.7 x 6.3 cm polyethylene trays. Half of these trays were planted with nine dwarf spikerush seedlings per tray and the other half with nine slender spikerush seedlings per tray. One tray of each species was placed in one of 18 plastic dish pans (32 x 27 x 31 cm). Six of these pans

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[2] U.C. mix: 50% sand, 50% peat, v/v; KNO_3 (0.124 g Kg^{-1}); K_2SO_4 (0.082 g Kg^{-1}); dolomite (1.95 g Kg^{-1}); gypsum (0.495 g Kg^{-1}); and superphosphate (0.879 g Kg^{-1}), (Anderson et al., 1986a).

were placed into each of three growth chambers and filled with tap water. The seedlings were under about 7 cm of water. The fluorescent-tungsen light intensity was 360 μE/m^{-2}/sec^{-1} with a 16 hr light/8 hr dark cycle. Adjustments were made to maintain the desired water temperature.

Each week the trays were manually cleaned of algae and refilled with fresh tap water. Water lost during the week by evaporation was replaced by addition of deionized water.

The plants were harvested at 8 weeks and washed with a spray of water to remove the U.C. mix from the root system and epiphytic algae from the shoots. The number of rosettes within each tray was counted, the plants blotted to remove excess water, and the fresh weight determined. After drying to constant weight at 80 C, the dry weight was determined for each tray. The experiment was conducted in three groups. The first group was run at water temperatures of 13, 19, and 32 C. The second group was run at 28, 32, and 35 C; and the third group was run at 25, 30, and 37 C. The standard errors were calculated and are shown on the figures. Differential response of these species to temperature between 13 and 32 C was analyzed by a one-way analysis of variance; the data was transformed to equalize the variance with an Ln(X+1) transformation.

Light intensity, water temperature, and their interaction. The materials and methods were similar to those described above with the following exceptions. Water temperatures of 16, 22, and 29 C were chosen as representative of low, moderate and near optimum temperatures for the growth of both species. The initial set of plants were grown with light being modulated by covering the pans with from 0 to 5 layers of a neutral density polycarbonate plastic (Tuffak; Rohm and Haas Co., No. 35100), which resulted in light intensities of 360, 180, 60, 20, and 5 μE/m^{-2}/sec^{-1}, respectively. Growth was severely reduced when 3 or more layers of the plastic was added; therefore, the data presented in the tables is from the next set of plants grown with 0, 1, or 2 layers of the plastic yielding 260, 180, or 60, μE,/m^{-2}/sec^{-1}. Measurements of both light and temperature variations indicated greater variations within chambers than among chambers; the arrangement of light treatments was, therefore, randomized by location within chambers, but held constant between chambers.

The plants were harvested at 8 weeks and the number of rosettes, fresh weight, and dry weight for each tray determined. The data were analyzed as a 3 x 3 factorial design with three replicates. Individual two-way analyses of variances were computed for each dependent variable for each species. An additional set of analyses were conducted on the differential data where the paired (within pan) dwarf spikerush results were subtracted from the slender spikerush results.

RESULTS AND DISCUSSIONM

Optimum and limiting water temperatures. The effect of water temperature on the number of spikerush rosettes per tray is summarized in figure 1. The rhizome spread was blocked by the tray boundary resulting in the densest growth for both species around the edge of the trays. The 8 weeks of growth was ample to give good plant densities for the near optimum temperatures without over-crowding the trays. Figures 2 and 3 summarize the effect of the water temperature on the fresh weight and dry weight per tray, respectively. The calculated differential responses of dwarf spikerush and slender spikerush relative to these parameters at these temperatures are presented in table 1.

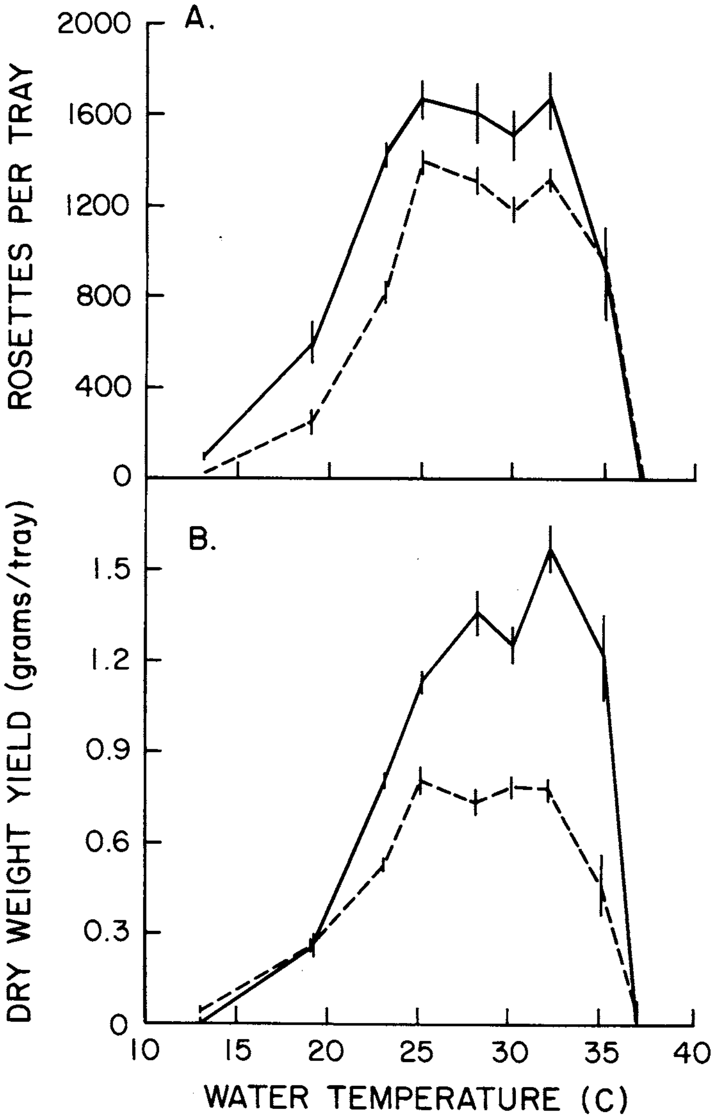

Figure 1. Response of dwarf spikerush (dashed) and slender spikerush (solid) to water temperature. Nine transplanted seedlings per tray were grown for 8 weeks; A = number of plants (rosettes), B = dry weight. ($\bar{x}$ ± std. error, n = 6).

The general shape of the temperature response curves for both species are similar, with maximum growth between 25 and 32 C (Figure 1). Growth declined more rapidly at temperatures above the optimum than below optimum. Growth was severely reduced at temperatures of 13 and 37 C. The decline of growth at water temperatures of 37 C is probably not of practical concern in most areas since this temperature is rarely reached in irrigation water. The reduction in growth at the lower temperatures is more important since irrigation water is frequently below 25 C and early season temperatures between 10 and 20 C are common. For spikerush to be an effective weed control

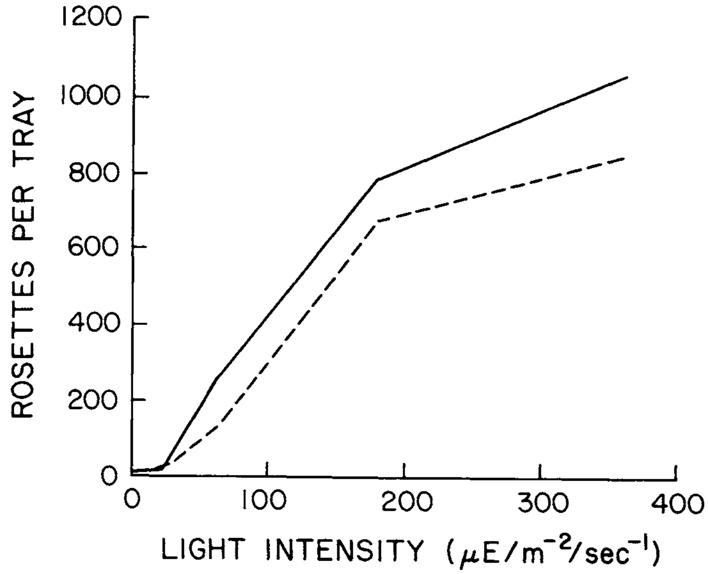

Figure 2. Response of dwarf spikerush (dashed) and slender spikerush (solid) to light intensity. Nine transplanted seedlings per tray were grown for 8 weeks.

agent, it is important to have the weeds controlled early in the season, but at this time low temperature is likely to limit the growth of spikerush.

Slender spikerush multiplied more rapidly producing more rosettes than dwarf spikerush at 30 C or below (Figure 1). However, the total biomass of the slender spikerush rosettes was less than that of dwarf spikerush between 25 and 35 C (Figure 1). These data indicate that slender spikerush may be more readily established than dwarf spikerush early in the season when the water temperatures are low. Differential species responses to temperature was examined more directly by subjecting the data to an Ln(X+1) transformation, to equalize the variance, and a one-way analysis of variance (Table 1). The results indicate that the difference in response, for all the dependent variables measured, was shifted toward more positive values at the lower temperatures of 13 and 19 C. This is interpreted to mean that at these lower temperatures slender spikerush grows better relative to dwarf spikerush than it does at higher temperatures. The data shows variable differences for temperatures between 23 and 32 C indicating that within this range of temperature, there are no differences either within or between the species.

TABLE 1. DIFFERENTIAL RESPONSE OF SLENDER SPIKERUSH AND DWARF SPIKERUSH TO TEMPERATURE. AVERAGE DIFFERENCE BETWEEN PAIRED POTS FOR THE VARIABLES INDICATED AFTER TRANSFORMATION[1,2]

Temperature (C)	Rosett count (per tray)	Fresh weight (g)	Dry weight (g)
13	1.846 a	0.459 a	0.0415 a
19	0.581 b	–0.081 b	0.0004 a
23	0.410 c	–0.626 cd	–0.1657 b
25	0.340 c	–0.471 c	–0.1689 b
28	0.179 c	–0.597 cd	–0.3032 d
30	0.237 c	–0.508 cd	–0.2354 c
32	0.234 c	–0.661 d	–0.3693 e

[1] Transformation: $Y = [\sum_{r=1}^{6} Ln(X_{a,t,r} + 1) - Ln(X_{c,t,r} + 1)] / 6$, where: 'a' is for slender spikerush, 'c' is for dwarf spikerush, 'r' is for the replicate (pair), and 't' is for temperature.

[2] Mean separations by Duncan's Multiple Range Test.

Light intensity, water temperature, and their interaction. The population data from the first set of plantings utilize pooled values from all three temperatures (Figure 2). There was a marked decrease in the number of rosettes produced as the light intensity was reduced with both species. At the three highest light intensities (360, 180, and 60 μE/m^{-2}/sec^{-1}1), slender spikerush produced more rosettes than dwarf spikerush, and at the two lowest light intensities (20 and 5 μE/m^{-2}/sec^{-1}) growth was essentially nil for both species. Relative to the maximum light intensity (360 μE/m^{-2}/sec^{-1}), the slender spikerush population was reduced 35% at 180 μE/m^{-2}/sec^{-1} and 81% at 60 μE/m^{-2}/sec^{-1}, while the dwarf spikerush population was reduced 31% 180 μE/m^{-2}/sec^{-1} and 88% at 60 μE/m^{-2}/sec^{-1}. Although slender spikerush produced more rosettes than dwarf spikerush at each light intensity, the percentage decrease in population within each species was about the same as the light intensity was reduced.

The tables give the light-temperature data for both species separately and the differences between the species. The cell means for each data set are given as well as the row means (temperature) and the column means (light). Table 2 gives the number of rosettes per tray after 8 weeks of growth from nine transplanted seedlings. Fresh and dry weights are given in tables 3 and 4, respectively. In general, the responses of these species to the light intensities and water temperatures they experienced in this combined factor study were similar to that which could have been predicted from the previously described experiments where each of these two factors was evaluated separately. That is, within the range of light intensities (60, 180, 360 μE/m^{-2}/sec^{-1}) and water temperatures (16, 22, and 28 C) used in this study both species showed a decline in growth as the

TABLE 2. PLANT POPULATION (ROSETTES PER TRAY) FOLLOWING 8 WEEKS OF GROWTH FROM NINE TRANSPLANTED SEEDLINGS. PLANTS WERE GROWN AT THREE TEMPERATURES AND THREE LIGHT INTENSITIES.[1]

Temperature (C)		Light intensity (μE/m^{-2}/sec^{-1}) 60	180	360	Mean
		Slender spikerush			
16		100	432	770	434 b
22		300	891	1128	773 a
28		275	1011	1299	862 a
	Mean:	225 c	778 b	1066 a	
		Dwarf spikerush			
16		21	112	252	128 c
22		112	616	833	521 b
28		266	1300	1457	1008 a
	Mean:	133 b	676 a	847 a	
		Slender minus dwarf			
16		79	276	518	291 a
22		188	58	295	180 a
28		8	–289	–138	–139 b
	Mean:	91 a	15 a	225 a	

[1] In no case was a significant (95% level) interaction between light and temperature found. Means were separated by Duncan's Multiple Range Test.

light intensity and water temperature was decreased. The influence of these two factors appeared to be additive; in no case was there an interaction between light and temperature at the 95% level of significance using an analysis of variance.

The paired data for dwarf spikerush and slender spikerush illustrate differences between these species that should be of practical importance in selecting the particular species to be used on a specific site (Tables 2, 3, and 4). Slender spikerush grew better than dwarf spikerush at the lower temperatures and lower light intensities. Conversely, dwarf spikerush grew better than slender spikerush at the higher temperatures and higher light intensities.

TABLE 3. FRESH WEIGHT YIELD (GRAMS PER TRAY) FOLLOWING 8 WEEKS OF GROWTH FROM NINE TRANSPLANTED SEEDLINGS. PLANTS WERE GROWN AT THREE TEMPERATURES AND THREE LIGHT INTENSITIES.[1]

Temperature (C)		Light intensity ($\mu E/m^{-2}/sec^{-1}$)			
		60	180	360	Mean
		Slender spikerush			
16		0.76	1.94	3.20	1.97 b
22		2.22	5.46	5.40	4.36 a
28		1.95	5.93	6.74	4.87 a
	Mean:	1.64 b	4.45 a	5.11 a	
		Dwarf spikerush			
16		0.15	1.69	3.01	1.62 c
22		1.52	7.99	9.16	6.22 b
28		3.07	10.59	14.77	10.76 a
	Mean:	1.58 b	6.76 a	8.98 a	
		Slender minus dwarf			
16		0.60	1.65	0.19	0.35 a
22		0.70	−2.52	−3.76	−1.86 b
28		−2.09	−8.77	−8.04	−5.89 c
	Mean:	−0.35 a	−3.18 b	−3.87	

[1] In no case was a significant (95% level) interaction between light and temperature found. Means were separated by Duncan's Multiple Range Test.

TABLE 4. DRY WEIGHT YIELD (GRAMS PER TRAY) FOLLOWING 8 WEEKS OF GROWTH FROM NINE TRANSPLANTED SEEDLINGS. PLANTS WERE GROWN AT THREE TEMPERATURES AND THREE LIGHT INTENSITIES.

Temperature (C)		Light inntensity ($\mu E/m^{-2}/sec^{-1}$)			
		60	180	360	Mean
		Slender spikerush			
16		0.016	0.140	0.248	0.150 b
22		0.175	0.432	0.432	0.346 a
28		0.161	0.497	0.559	0.406 a
	Mean:	0.132 b[3]	0.357 a	0.413 a	
		Dwarf spikerush			
16		0.014	0.117	0.785	0.305 b
22		0.093	0.515	0.624	0.411 b
28		0.299	0.918	1.094	0.770 a
	Mean:	0.135 b	0.517 a	0.834 a	
		Slender minus dwarf			
16		0.047	0.023	0.021	0.030 a
22		0.073	−0.078	−0.199	−0.068 a
28		−0.138	−0.421	−0.535	−0.365 b
	Mean:	−0.003 a	−0.158 b	−0.238 b	

[1] In no case was a significant (95% level) interaction between light and temperature found. Means were separated by Duncan's Multiple Range Test.

Field studies in northern California and northeastern Nevada have indicated that spikerush growth is frequently limited by low light and/or low temperature (Ashton et al., 1984). In this area low light is usually the result of water turbidity or shade produced by weed growth or algae mats. Most sites are dewatered from late fall to early spring, so light limitations are usually restricted to the rest of the year. Temperatures can be limiting at any time but least likely from July through September. Before dewatered sites are refilled in late winter, both light and soil temperatures are probably less limiting, and this condition may give both spikerush species a "headstart", compared to the truly submersed weed species. Both light and temperature are likely to be limiting in the spring after the systems are rewatered and before the water temperature increases. It is most desirable for spikerush to grow competitively during the late spring when aquatic weeds normally begin to cause problems.

The data presented here suggest that the growth of slender spikerush would be better than the growth of dwarf spikerush under the environmental conditions which occur in the spring in this area.

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