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# INFLUENCE OF WATER REGIME ON GROWTH OF DWARF SPIKERUSH AND SLENDER SPIKERUSH

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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 four water regimes for 56 weeks starting in June. These included: (1) continuously submerged, (2) continuously emerged, (3) submerged-winter emerged-submerged, and (4) submerged-winter drained-submerged under otherwise normal environmental conditions. Fresh weight and dry weight biomass was determined at approximately 4-week intervals. Both species increased in biomass with time, except during the winter months when growth of dwarf spikerush decreased but remained relatively constant with slender spikerush. Slender spikerush grew more rapidly than dwarf spikerush as the temperatures increased in the spring. Slender spikerush produced the most biomass at 56 weeks in treatment 4; about twice as much as in treatment 1 and about 1.4 times as much as in treatments 2 and 3. In contrast, there was little difference in the biomass of dwarf spikerush among the four treatments at 56 weeks. Slender spikerush produced about three times more biomass than dwarf spikerush in their respective best water regimes. These results, along with other data, indicate that slender spikerush would be better than dwarf spikerush for the competitive inhibition of undesirable aquatic species under our environmental conditions, and the growth of the former species can be optimized by manipulation of the water regime, whereas this does not appear to be the case for the latter species.

*Key words*: Aquatic weeds, ecology, environment, competition, biological control.

## INTRODUCTION

Dwarf spikerush [*Eleocharis coloradoensis* (Britt.) Gilly] and slender [*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 submerged aquatic vegetation (Barko et al., 1986). 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. (1986) showed that herbicide suppression of American pondweed (*Potamogeton nodosus* Poir) resulted in increases in slender spikerush population in an irrigation canal. Ashton and Bissell (1987) reported that with light intensities of 360, 180, 60, 20, or 5 $\mu E/m^{-2}/sec^{-1}$ (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. 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. There was no interaction of light at 360, 180, or 60 $\mu E/m^{-2}/sec^{-1}$ 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.

An additional important ecological factor involved in the establishment of these two spikerush species was suggested from field observations. It appeared that there was a differential growth response of these two species during the winter after dewatering a reservoir in the fall. This phenomenon was investigated by utilizing various water management regimes that reflect some typical situations that occur in the field in northern California throughout one growing season.

## 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 requirement 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 by Ashton and Bissell (1987).

*Cultural conditions.* The study utilized four cultural conditions: (1) continuously submerged, (2) continuously emerged, (3) submerged-winter emerged-submerged, and (4) submerged-winter drained-submerged. The sub-

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merged treatment was in 61 cm of water. The emerged treatment was in 2.5 to 6 cm of water, which kept the soil saturated with water with shoots emerged. The drained treatment was on sand, which allowed the soil moisture to vary with natural precipitation and humidity. The study was conducted from June 8, 1982 to July 26, 1983 (56 weeks) with the winter treatments being imposed from November 1, 1982 to April 15, 1983 (22 weeks). Details for obtaining these conditions are given below.

The experiment was conducted in the natural environment allowing the light, temperature, precipitation, and humidity to vary with changing climatic conditions. Two 91 × 274 cm fiberglass tanks 61 cm deep were divided into three (91 cm$^2$) compartments. The first tank received a continuous flow of tap water which overflowed into the first two compartments of the second tank. The water overflow depth in the first tank was set to 61 cm, and in the first two compartments of the second tank the overflow was set to maintain a water depth of from 2.5 to 6 cm (tank bottoms were not absolutely flat). The third compartment of the second tank was filled to a depth of 2.5 to 6 cm with river sand which was free draining, thus allowing the soil moisture to vary with changing climatic conditions.

U.C. potting mix[2] was autoclaved, ground to pass a 2.0-mm sieve, and firmly packed into 392 7 × 7, 8 cm deep, plastic pots. Half of these were planted with five dwarf spikerush seedlings and the other half planted with five slender spikerush seedlings. June 8, 1982, when the experiment was initiated, 132 pots of each species were randomly, placed in the submerged condition of tank 1, and 57 pots of each species were alternately placed in the emerged conditions of tank 2. November 1, 1982 the appropriate number of pots of each species were transferred from the submerged condition of tank 1 to the prescribed winter conditions (winter emerged or winter drained) of tank 2. April 15, 1983 the pots receiving the winter treatments were returned to the submerged conditions of tank 1. These pot transfers from one condition to another at the prescribed times resulted in the four water regimes indicated above.

At approximately 4-week intervals, four pots from each treatment were removed in a random pattern. The potting mix was washed away, and the fresh weight and dry weight (80 C) biomass of the plants within each pot was determined. Maximum and miniimum air temperatures were determined daily, and their monthly means are presented in Figure 1. The experiment was terminated after 56 weeks with the final harvest; July 26, 1983. The treatments were replicated four times and the data subjected to standard deviation analysis.

## RESULTS AND DISCUSSION

The seedlings of both species survived well following the initial transplanting. The plants generally appeared similar to naturally occurring plants growing under similar conditions, except that the surface biomass appeared to be somewhat larger than would have been expected under field conditions. Some of the slender spikerush rhizomes crept over the sides of the pots and were periodically trimmed back with scissors to prevent their invasion into adjacent treatments. The growth of slender spikerush rhizomes over the edges of pots is a typical response. Rhizomes of dwarf spikerush do not exhibit this behavior. Rhizomes of slender spikerush also grow closer to the soil surface than dwarf spikerush rhizomes. This differential behavior is more evident when the spikerush are grown in high-organic soil, eg. U.C. potting mix. When either species is grown without physical boundaries, they spread into unpopulated areas by rhizome growth. However, slender spikerush spread is primarily the result of relatively unbranched rhizome growth in contrast to the more branched growth of dwarf spikerush rhizomes.

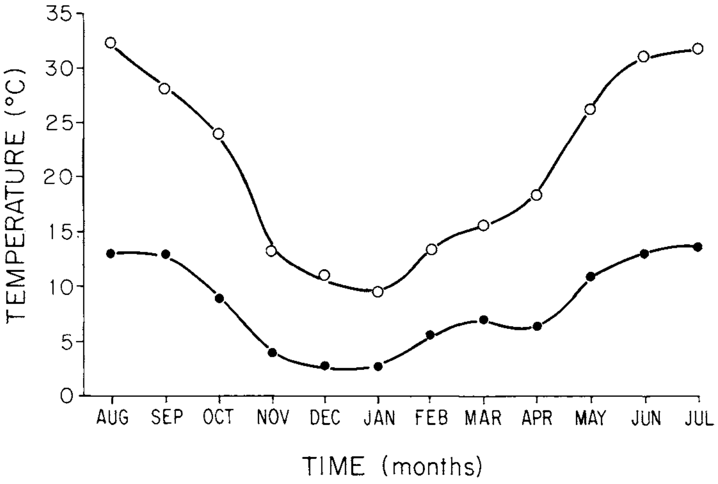

Figure 1. Maximum (○) and minimum (●) monthly mean air temperatures calculated from daily readings.

In general, both spikerush species increased in biomass with time under all four water regimes (Tables 1 and 2). However, they essentially stopped growing during the cold winter months. In fact, dwarf spikerush actually lost biomass during the winter and early spring (December 14, 1982 to March 8, 1983), whereas slender spikerush biomass remained relatively constant (December 14, 1982 to February 8, 1983). Slender spikerush grew more rapidly than dwarf spikerush as the temperatures began to increase in the spring. This differential temperature response favoring slender spikerush growth at low temperatures is in agreement with our previous report (Ashton and Bissell, 1987). During the first five months (June 8 to October 20, 1982) of the experiment, when the temperatures were relatively warm, both species produced more biomass when emerged than when submerged. This may be the result of increased light intensity, temperature, and carbon dioxide availability for the emerged plants relative to the submerged plants at this time of year and at this early stage of growth. This difference continued throughout the experiment but to a lesser degree for slender spikerush with time and disappeared completely for dwarf spikerush as the experiment progressed.

Slender spikerush produced the most biomass at the terminal harvest in the submerged-drained-submerged

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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., 1987).

TABLE 1. DRY WEIGHTS OF SLENDER SPIKERUSH GROWN UNDER FOUR WATER REGIMES.[1]

| Date | Submerged | Emerged | Submerged-Emerged Submerged | Submerged Drained Submerged |
|---|---|---|---|---|
| | ----------(g) | ---------- | ---------- | ---------- |
| 4-Aug-82 | 0.02 ± 0.01 | 0.15 ± 0.06 | —[2] | —[2] |
| 1 Sep-82 | 0.25 ± 0.02 | 1.17 ± 0.17 | — | — |
| 28-Sep-82 | 0.31 ± 0.09 | 1.62 ± 0.15 | — | — |
| 20-Oct-82 | 0.40 ± 0.08 | 2.25 ± 0.57 | — | — |
| 16-Nov-82 | 0.61 ± 0.07 | 2.75 ± 0.42 | 0.67 ± 0.09 | 0.68 ± 0.04 |
| 14-Dec-82 | 0.53 ± 0.05 | 2.77 ± 0.27 | 0.72 ± 0.10 | 0.75 ± 0.11 |
| 12-Jan-83 | 0.53 ± 0.09 | 2.80 ± 0.55 | 0.91 ± 0.17 | 0.89 ± 0.05 |
| 8-Feb-83 | 0.50 ± 0.08 | 2.48 ± 0.24 | 0.83 ± 0.06 | 0.91 ± 0.21 |
| 8-Mar-83 | 0.68 ± 0.08 | 2.68 ± 0.43 | 0.95 ± 0.14 | 1.28 ± 0.11 |
| 7-Apr-83 | 0.76 ± 0.24 | 3.49 ± 0.63 | 1.60 ± 0.15 | 2.61 ± 0.52 |
| 3-May-83 | 1.10 ± 0.12 | 4.73 ± 0.46 | 2.15 ± 0.68 | 3.45 ± 1.01 |
| 31-May-83 | 1.07 ± 0.10 | 4.94 ± 1.18 | 2.63 ± 0.64 | 2.73 ± 0.20 |
| 28-Jun-83 | 1.83 ± 0.21 | 6.05 ± 1.13 | 3.25 ± 1.12 | 5.96 ± 1.27 |
| 25-Jul-83 | 1.87 ± 0.20 | 5.10 ± 0.40 | 2.39 ± 0.28 | 4.43 ± 0.39 |

[1] Four water regimes: *Submerged* = continuously submerged (June 8, 1982 to July 25, 1983); *Emerged*= continuously emerged (July 8, 1982 to July 25, 1983); *Submerged-Emerged-Submerged* = submerged (June 8, 1982 to November 1, 1982), emerged (November 1, 1982 to April 15, 1983), submerged (April 15, 1983 to July 25, 1983); *Submerged-Drained-Submerged*= submerged (June 8, 1982 to November 1, 1982), drained (November 1, 1982 to April 15, 1983), submerged (April 15, 1983 to July 25, 1983). Each value is the mean and Std. deviation of four pots.

[2] The dry weights for these treatments would have been similar to the submerged treatment from August 4 to October 20, 1982 (column 2).

TABLE 2. DRY WEIGHTS OF DWARF SPIKERUSH GROWN UNDER FOUR WATER REGIMES.[1]

| Date | Submerged | Emerged | Submerged-Emerged Submerged | Submerged-Drained Submerged |
|---|---|---|---|---|
| | ----------(g) | ---------- | ---------- | ---------- |
| 4-Aug-82 | 0.02 ± 0.01 | 0.14 ± 0.04 | —[2] | —[2] |
| 1 Sep-82 | 0.19 ± 0.04 | 0.72 ± 0.22 | — | — |
| 28-Sep-82 | 0.38 ± 0.05 | 2.14 ± 0.55 | — | — |
| 20-Oct-82 | 0.50 ± 0.06 | 1.68 ± 0.24 | — | — |
| 16-Nov-82 | 0.62 ± 0.05 | 1.50 ± 0.16 | 0.71 ± 0.05 | 0.59 ± 0.17 |
| 14-Dec-82 | 0.63 ± 0.08 | 1.56 ± 0.15 | 0.59 ± 0.14 | 0.58 ± 0.05 |
| 12-Jan-83 | 0.60 ± 0.12 | 1.57 ± 0.23 | 0.71 ± 0.20 | 0.61 ± 0.13 |
| 8-Feb-83 | 0.45 ± 0.08 | 1.05 ± 0.29 | 0.45 ± 0.07 | 0.62 ± 0.09 |
| 8-Mar-83 | 0.41 ± 0.06 | 0.80 ± 0.67 | 0.60 ± 0.07 | 0.56 ± 0.09 |
| 7-Apr-83 | 0.51 ± 0.03 | 1.07 ± 0.56 | 0.55 ± 0.08 | 0.59 ± 0.10 |
| 3-May-83 | 0.68 ± 0.07 | 1.10 ± 0.53 | 0.70 ± 0.16 | 0.67 ± 0.17 |
| 31-May-83 | 0.73 ± 0.05 | 1.15 ± 0.31 | 0.98 ± 0.51 | 0.95 ± 0.29 |
| 28-Jun-83 | 1.38 ± 0.34 | 1.66 ± 0.87 | 0.97 ± 0.23 | 0.80 ± 0.21 |
| 25-Jul-83 | 1.19 ± 0.12 | 1.73 ± 0.47 | 1.10 ± 0.16 | 1.06 ± 0.13 |

[1] Four water regimes: *Submerged* = continuously submerged (June 8, 1982 to July 25, 1983); *Emerged*= continuously emerged (July 8, 1982 to July 25, 1983); *Submerged-Emerged-Submerged* = submerged (June 8, 1982 to November 1, 1982), emerged (November 1, 1982 to April 15, 1983), submerged (April 15, 1983 to July 25, 1983); *Submerged-Drained-Submerged*= submerged (June 8, 1982 to November 1, 1982), drained (November 1, 1982 to April 15, 1983), submerged (April 15, 1983 to July 25, 1983). Each value is the mean and Std. deviation of four pots.

[2] The dry weights for these treatments would have been similar to the submerged treatment from August 4 to October 20, 1982 (column 2).

treatment; about twice as much as in the continuously submerged treatment and about 1.4 times as much as in the continuously emerged or submerged-emerged-submerged treatments. The latter two treatments were essentially the same, but the biomass was about 1.5 times greater than in the poorest treatment, continuously submerged. In contrast, dwarf spikerush showed minimal differences in biomass among the four water regimes at the terminal harvest, even though the continuously emerged treatment was markedly superior to the continuously submerged treatment during the first few months of the study. Although the continuously submerged and continuously emerged treatments were somewhat superior to the submerged-emerged-submerged and submerged-drained-submerged treatments for dwarf spikerush, the data suggest that these differences are not of practical significance.

Although the biomass produced by these two species of spikerush was similar during the first few months of this study with the continuously emerged treatment yielding a greater biomass than the continuously submerged treatment, slender spikerush consistently produced more biomass in all four water regimes than dwarf spikerush during the second growing season. The best water regime (submerged-drained-submerged) for slender spikerush produced about three times as much biomass as the best water regime (continuously submerged) for dwarf spikerush.

The data presented here and complemented by our previous report (Ashton and Bissell, 1987) suggest that slender spikerush would be better than dwarf spikerush for the competitive biological control of undesirable aquatic plants under our environmental conditions, since slender spikerush produces more biomass and responds more favorably to low temperatures and low light than dwarf spikerush. The season-long growth of slender spikerush can be improved by manipulation of the water regime, but this does not appear to be the case for dwarf spikerush.

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