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The Effect of Dwarf Spikerush (*Eleocharis coloradoensis*) on Several Submersed Aquatic Weeds

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ABSTRACT

Dwarf spikerush [(*Eleocharis coloradoensis*) (Britt.) Gilly)] is a short-stature aquatic plant that displaces several species of submersed aquatic weeds in canals, ponds, lakes, and reservoirs. The extent to which dwarf spikerush influences the number of shoots and the dry weights of seven species of submersed aquatic weeds was determined in 1979 and 1980. Based on the dry weight of aquatic weeds planted at the same time as dwarf spikerush, the order of susceptibility of the different aquatic weeds, from most-to-least, was horned pondweed (*Zannichellia palustris* L.), Nuttall's elodea (*Elodea nuttallii* (Planch.) St. John), American elodea (*Elodea canadensis* Michx.), hydrilla (*Hydrilla verticillata* (L.f.) Royle), American Pondweed (*Potamogeton nodosus* Poir.), sago pondweed (*Potamogeton pectinatus* L.), and Eurasian watermilfoil (*Myriophyl-*

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lum spicatum L.). Dwarf spikerush reduced the production of subterranean turions of hydrilla and tubers of sago and American pondweeds by more than 50%.

Key words: Competition, displacement, turion, shoot number, dry weight.

INTRODUCTION

In 1954, Oborn (4) observed that slender spikerush (*Eleocharis acicularis* (L.) R. & S.) crowded out objectionable aquatic weeds, and he considered that the plant might be helpful in that respect in field situations. Yeo (11) reported that, during the period of 1966 through 1969, slender spikerush replaced a dense growth of American elodea and curlyleaf pondweed (*Potamogeton crispus* L.) in the first 1.7 km of a 36-km-long, earth-lined canal and has also replaced slender pondweed (*Potamogeton pusillus* L.) and leafy pondweed (*Potamogeton foliosus* Raf.) in other canals. He also reported that extensive growths of slender spikerush prevented the spread of aquatic weeds in two mountain reservoirs. Two other species of short-stature spikerushes, dwarf spikerush and barbed spikerush (*Eleocharis parvula* (R. & S.) Link, were found to have potential for displacing submersed waterweeds (10).

During the last 6 years, the senior author has observed increases in the distribution of the three species throughout California. The spread has been primarily due to the increase in the number of canals, drains, and water storage systems. It is thought that water-birds may have been mainly responsible for the movement of plants between the different water systems (1).

Relationships among specific aquatic plants that are naturally antagonistic have been reviewed (8). The following information concerning interactions between dwarf spikerush and aquatic weeds has been reported (9): (a) The undesired species must be a rooted plant, (b) the erect culms of spikerush mechanically prevent certain target species from rooting in the hydrosoil, and (c) a periodically fluctuating water level enhances the establishment and competitive effectiveness of spikerush. Johannes (3) also found that the upright culms mechanically prevent aquatic weeds from becoming established.

Frank and Dechoretz (2) demonstrated that the transfer of leachate from dwarf spikerush cultures to sago pondweed cultures reduces the number of sago pondweed shoots. When soil leachate from terraria containing dwarf spikerush were placed in tomato-cell suspension cultures, tomato-cell volume was reduced by 74% (6). Neither study identified or quantified an inhibiting substance in the leachate.

Apparently some aquatic weeds are affected more than are others by interference from spikerushes. The objective of this study was to determine the extent of dwarf spikerush interference with a selected number of submersed aquatic weeds that are economically important in California.

MATERIALS AND METHODS

To reduce the abundance of unwanted algae, the study was conducted outdoors under shade cloth that gave 55% shade. Soil with a texture composition of 19% clay, 40% silt, 40.6% sand, and 1.4% organic matter was placed 8 cm deep in ninety 75 L plastic tubs that had a surface area of 0.21 m^2. Then the tubs were filled with well water. After two weeks, viable plant parts of seven aquatic weeds, American pondweed, sago pondweed, horned pondweed, American elodea, Nuttall's elodea, hydrilla, and Eurasian watermilfoil, were planted in a total of 84 tubs, consisting of 12 for each of the seven aquatic weeds. The viable plant material used in the study included: nine germinated tubers of American pondweed and sago pondweed, nine 4-week-old seedlings of horned pondweed and nine freshly harvested, 8 to 15 cm-long shoot cuttings of each of the remaining species. After 4 weeks, when the waterweeds had begun to grow, dwarf spikerush tubers were sown, at a rate of 4,000/m^2 (840/tub), over the water surface of 6 of the 12 tubs in each group. Six tubs were planted with dwarf spikerush, only.

Well water was added periodically throughout the study to keep the water at maximum depth. The water contained 6.1 ppmw nitrate, 0.2 ppmw total phosphate, and 2.6 ppmw potassium and had a total hardness, total alkalinity, and pH of 160 ppmw, 180 ppmw, and 9.7, respectively.

To determine the competitive effects of dwarf spikerush on the growth of different weed species, we collected the following data: (a) The number of shoots of aquatic weeds grown with and without dwarf spikerush (counted in October 1979 and 1980), (b) the dry weight of each weed species grown with and without dwarf spikerush (dried at 24 C at the end of the study), (c) the number of rosettes formed in dwarf spikerush cultures (counted in October 1979 and 1980), and (d) the number of sago and American pondweed tubers and subterranean turions of hydrilla that developed in cultures with and without dwarf spikerush (counted at the end of the study). The subterranean turions were separated from the soil by washing them over a fine mesh screen. The number of shoots per unit area is important because that number represents plant density and is related to the resistance to waterflow and to the area occupied by vegetation. The dry weight is important because it represents the amount of plant material in a unit volume. The susceptibility of aquatic weeds to dwarf spikerush competition was calculated by dividing the dry weight of the number of shoots (in 1980) of plants grown with dwarf spikerush by the dry weight of the number of shoots (in 1980) of plants grown without dwarf spikerush and then multiplying by 100 to derive percentage of dry weight of the control or percentage of number of shoots of the control. The rosettes in six 6.45-cm^2 sections of sod from each culture were counted.

We analyzed the various data by comparing the means of treatments of aquatic weeds grown with dwarf spikerush with those of aquatic weeds grown in the absence of dwarf spikerush, using Student's t-test at the 1 or 5% level; or by comparing the mean number of rosettes formed in 1979 and 1980, using Duncan's multiple range test at the 5% level.

RESULTS AND DISCUSSION

American pondweed. Dwarf spikerush significantly reduced the number of shoots of American pondweed in both years of study (Figure 1). In 1979, the number was reduced

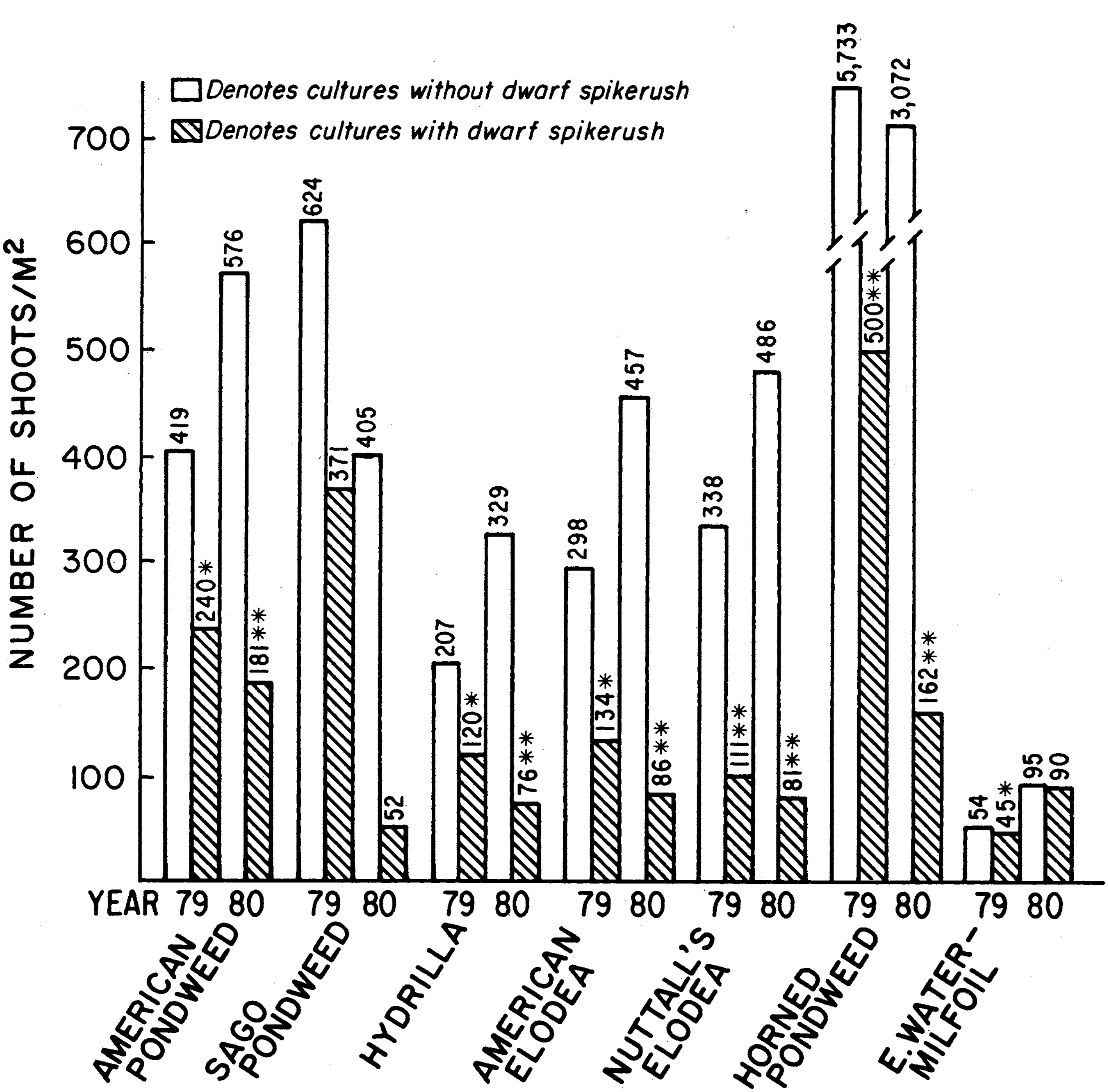

Figure 1. Number of shoots of aquatic weeds after one and two seasons of growing with and without dwarf spikerush. The values are the means of six replicates. (Significantly less amounts at the 1% level are indicated by ** and, at the 5% level, by *, as determined by Student's t-test.)

from 419 to 240 shoots/m^2; and in 1980, from 576 to 181 shoots/m^2. The dry weight of American pondweed plants cultured with dwarf spikerush (43 g/m^2) was also significantly less than in monocultures of American pondweed (168 g/m^2) (Figure 2).

The number of dwarf spikerush rosettes increased from 16,000 in 1979 to 19,000/m^2 in 1980 (Table 1). As many as 50,000 rosettes/m^2 have been reported to occur in aquatic environments where dwarf spikerush grew extremely well and was highly competitive (7). However, the senior author has observed that 10,000 to 20,000 rosettes/m^2 will displace waterweeds in certain aquatic situations.

American pondweed typically has two kinds of leaves, long, narrow submersed leaves, acute at both ends; and ovate floating leaves that form in clusters at the ends of erect stems. Stems with floating leaves on plants that were growing with dwarf spikerush were temporarily stunted for 2 to 3 months. They also had more leaves per stem than did stems on plants grown in monocultures. The stems on new growth appeared to be normal by August. The American

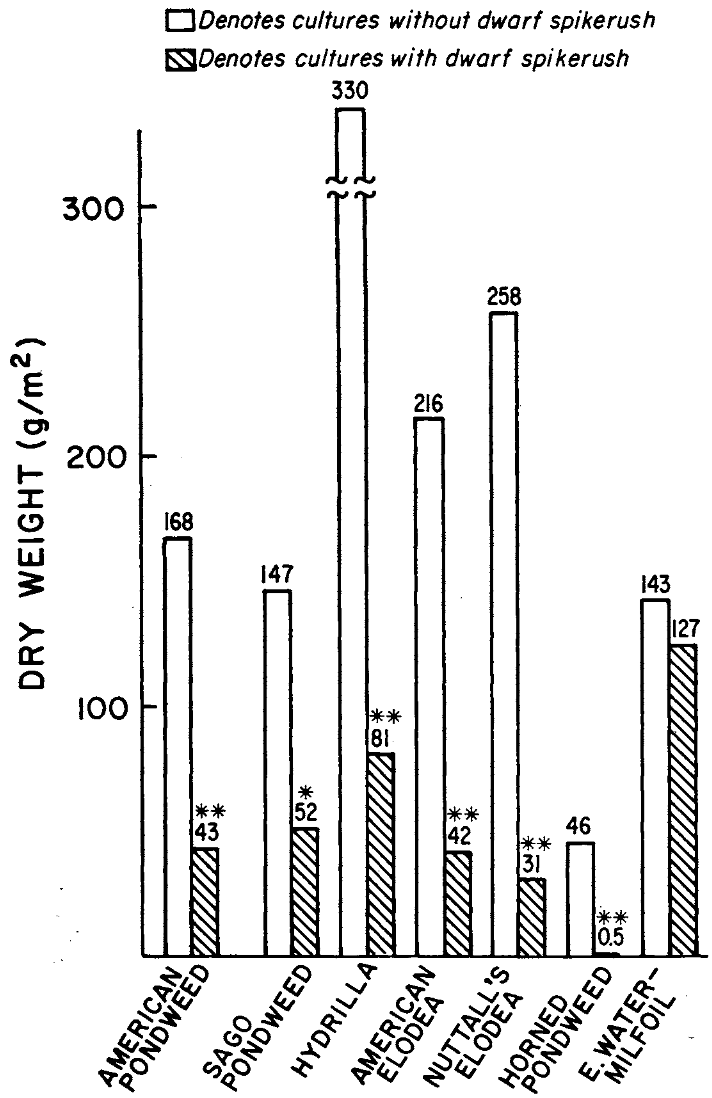

Figure 2. Dry weights of aquatic weeds after two seasons of growing with and without dwarf spikerush. The values are the means of six replicates. (Significantly less amounts at the 1% level are indicated by ** and, at the 5% level, by *, as determined by Student's t-test.)

pondweed plants that were grown without dwarf spikerush developed more tubers than did American pondweed plants grown in cultures with dwarf spikerush (Table 2). The effect of the competitive stress caused by dwarf spikerush reduced the number of tubers from 743 to 348/m².

Sago pondweed. Sago pondweed plants grown in cultures without dwarf spikerush developed 624 shoots/m², whereas those grown in cultures with dwarf spikerush developed only 371 shoots/m² in 1979 (Figure 1). Fewer shoots developed in sago pondweed monocultures in 1980.

Dwarf spikerush significantly reduced the dry weight of sago pondweed plants (Figure 2). Those grown in cultures with dwarf spikerush had a dry weight of 52 g/m², and those grown in monocultures had a dry weight of 147 g/m². The number of rosettes increased by only 1,000 during the study (Table 1). That small increase reflects the time it may take to establish a competitive stand of dwarf spikerush. Sago pondweed developed 59% fewer tubers in cultures with dwarf spikerush (1,430 tubers/m²) than in monocultures (3,524 tubers/m²) (Table 2). That result suggests that the complete displacement of some aquatic weeds, such as sago pondweed, may take several years.

TABLE 1. DENSITY OF DWARE SPIKERUSH ROSETTES DEVELOPED IN AQUATIC WEED AND DWARF SPIKERUSH CULTURES AFTER ONE AND TWO GROWING SEASONS.

Associated species	Number of rosettes formed[1,2] 1979	1980
American pondweed	16,000 bc	19,000 ab
Sago pondweed	19,000 b	20,000 ab
Hydrilla	11,000 c	26,000 a
American elodea	15,000 bc	24,000 a
Nuttall's elodea	16,000 bc	19,000 ab
Horned pondweed	13,000 c	6,000 b
Eurasian watermilfoil	12,000 c	9,000 ab
Dwarf spikerush (alone)	26,000 a	15,000 ab

[1]Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[2]Means of numbers of rosettes found in six 6.54 cm² samples and extrapolated to 1 m².

Hydrilla. When hydrilla was grown with dwarf spikerush, significantly fewer hydrilla shoots developed than when they were grown in monocultures (Figure 1). From 1979 to 1980, the number of shoots increased from 207 to 329/m² in monocultures of hydrilla and decreased from 120 to 76/m² in cultures with dwarf spikerush. The dry weight of hydrilla plants grown with dwarf spikerush was also significantly less than in cultures of hydrilla only (Figure 2). Dwarf spikerush grown with hydrilla developed 26,000 rosettes/m² in 1980, which was more than twice the number that developed in 1979 (Table 1). The reason for the large variability in rosettes is not known.

The number of subterranean turions that formed was significantly less in cultures of hydrilla grown with dwarf spikerush (176/m²) than in those grown in monocultures (405/m²) (Table 2).

American and Nuttall's elodea. Dwarf spikerush affected the number of shoots and dry weights of American and Nuttall's elodea similarly and significantly (Figures 1 and 2). From 1979 to 1980, the number of shoots in monocultures of American elodea and Nuttall's elodea increased from 298 to 457/m² and from 338 to 486/m², respectively. During that period the number of shoots of American and Nuttall's

TABLE 2. YIELDS OF SUBTERRANEAN PROPAGULES HARVESTED FROM AQUATIC WEEDS GROWING WITH AND WITHOUT DWARF SPIKERUSH.

Aquatic weed and culture condition	Propagules[1,2] (number/m²)
American pondweed	743
American pondweed + dwarf spikerush	348**
Sago pondweed	3,524
Sago pondweed + dwarf spikerush	1,430*
Hydrilla	405
Hydrilla + dwarf spikerush	176**

[1]Significant by less amounts at the 1% level are indicated by ** and, at the 5% level, by * as determined by Student's t-test.
[2]Means of numbers of propagules found in six 0.21 m² containers and then extrapolated to number/m².

elodea in the cultures with dwarf spikerush decreased from 134 to 86/m² and from 111 to 81/m², respectively.

The dry weights of both species were significantly less when the species were grown with dwarf spikerush than when they were grown in monocultures. American and Nuttall's elodea grown in monocultures weighed 216 and 258 g/m², but when they were grown with dwarf spikerush, they weighed only 42 and 31 g/m², respectively.

From 1979 to 1980, the number of dwarf spikerush rosettes in the cultures of American elodea increased from 15,000 to 24,000/m². Those in the Nuttall's elodea cultures increased from 16,000 to 19,000/m².

Horned pondweed and dwarf spikerush alone. The horned pondweed developed more shoots than any of the other aquatic weeds and was most affected by dwarf spikerush (Figure 1). In 1979 and 1980, the horned pondweed monocultures developed 5,733 and 3,072 shoots/m², respectively, whereas the cultures with dwarf spikerush developed only 500 and 162/m², respectively. The dry weight of horned pondweed was reduced 99% by dwarf spikerush (Figure 2).

The number of rosettes of dwarf spikerush grown with horned pondweed decreased from 13,000 in 1979 to 6,000 in 1980 (Table 1).

Eurasian watermilfoil. Dwarf spikerush did not affect Eurasian watermilfoil appreciably. When the plants were cultured with dwarf spikerush, they developed about the same number of shoots (90/m²) as in monocultures (95/m²) (Figure 1). The dry weight was slightly less when the plants were grown with dwarf spikerush (127/m²) than when they were grown in monocultures (143 g/m²) (Figure 2). The number of dwarf spikerush rosettes was less in 1980 (9,000/m²) than in 1979 (12,000/m²).

The susceptibility of the different aquatic weeds was classified, based on dry weights. The most-to-least susceptible were as follows: horned pondweed, Nuttall's elodea, American elodea, hydrilla, American pondweed, sago pondweed, and Eurasian watermilfoil (Table 3).

The number of aquatic weed shoots that developed in each of the aquatic weed cultures was less than when the plants were grown in cultures without dwarf spikerush. The dry weight of each aquatic weed species was also less when the plants were grown with dwarf spikerush.

The number of rosettes developed by dwarf spikerush in the different aquatic weed cultures ranged from 11,000 to 19,000/m² in 1979 and from 6,000 to 26,000/m² in 1980. The number of rosettes that developed were fewest in the horned pondweed and Eurasian watermilfoil cultures and in the monocultures of dwarf spikerush. The reduction in number of rosettes in the horned pondweed and spikerush monocultures could not be explained. Shading may have caused the reduction in the number of rosettes in the watermilfoil cultures. Eurasian watermilfoil was the least affected aquatic weed. It normally develops fewer shoots than the other plants studied and has roots that grow deeper in the hydrosoil and, therefore, may not be influenced by the shallow rooted dwarf spikerush. By not greatly affecting the growth of watermilfoil early in its development, the watermilfoil develops a dense canopy. The density of the canopies in the other aquatic weed cultures were less due to the influence of the dwarf spikerush early in their development.

Sago and horned pondweeds grown in monocultures may have developed fewer shoots in 1980 than in 1979 due to intraspecific competition within the different plant populations. Sutton et al. (5) utilizing plant dry weights, reported that intraspecific competition occurred between hydrilla plants. Sago and horned pondweeds were observed to have large shoot densities in 1979; however, the plants could not be sacrificed to obtain dry weights.

The numbers of tubers and subterranean turions of aquatic weeds that were formed were significantly less in cultures grown with dwarf spikerush than in monocultures. These reductions suggest that future population potentials could be reduced and the rate of displacement by dwarf spikerush enhanced.

TABLE 3. ORDER OF SUSCEPTIBILITY OF AQUATIC WEEDS TO DWARF SPIKERUSH COMPETITION AS BASED ON DRY WEIGHT IN 1980.

Aquatic weed	Percentage of dry weight of control[1]
Horned pondweed	1
Nuttall's elodea	12
American elodea	19
Hydrilla	25
American pondweed	26
Sago pondweed	35
Eurasian watermilfoil	89

[1]Values represent percentages of dry weight of aquatic weeds in monocultures.

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