J. Aquat. Plant Manage. 24: 11-16

Dormancy in Slender Spikerush Seed

RICHARD R. YEO[1]

ABSTRACT

Seed of slender spikerush (*Eleocharis acicularis* (l.) R. & S.) were found to have a pericarp- induced dormancy and a low temperature after-ripening requirement. Seed germinated best (60%) when they were scarified with sodium hypochlorite (NaOCl) for 2 hr and then incubated at 10 to 18 C. They germinated well (55 to 59%) when the seed were excised from the pericarps and then incubated at 30 to 35 C or chilled wet at 4 C for 2 months and then incubated at 15 C (53%). The best incubation temperature for seed stored dry for 2 months at 4 C was 10 to 18 C (11 to 20%). Dry-stored seed with the pericarps removed germinated the fastest, followed by seed treated with NaOCl seed chilled wet, and seed stored dry.

Key words: Excised, scarify, chilled-wet, pericarp, germination, after-ripening, incubation, temperature.

INTRODUCTION

Slender spikerush (*Eleocharis acicularis* (L.) R. & S.), dwarf spikerush (*Eleocharis coloradoensis* (Britt.) Gilly), and barbed spikerush (*Eleocharia parvula* (R. & S.) Link ex. Bluff) are short-statured spikerushes that will displace waterweeds (7, 10, 12). The germination of dwarf spikerush seed has been studied (9, 11, 13, 14). Freshly harvested seed (the term seed is used instead of "achene" for convenience) of dwarf spikerush were found to be dormant. Dormancy was removed by chilling seed wet and by scarifying the pericarps with sodium hypochlorite (NaOCl). This chemical has also been used to improve the germination of wild buckwheat, cow cockle, stinkweed, wild mustard, and wild oats (5). Bewley and Black (1) suggested that the improved germination may be due to enhanced entry of water or promotive chemicals, oxidation of inhibitory chemicals in the seed coat, or reduced mechanical rigidity. Mature seed of slender spikerush are also dormant. Because slender spikerush plants often grow in colder environments than dwarf and barbed spikerush plants, their seed may have different requirements for germination. Objectives of this study were to determine, (a) criteria for removing dormancy, (b) maximum percentage germination obtainable, (c) temperature required to germinate seed, and (d) effect of storage on viability. Knowing these factors will aid in developing methods for storing seed, seed preparation, seeding rates, and the establishment of spikerush on aquatic sites.

MATERIALS AND METHODS

General. Seed of slender spikerush used in the study were harvested in 1981 along the shore of a pond in Sacramento County and in 1981 and 1983 on a ground water recharge facility in Fresno, California. Each crop of harvested seed was air-dried, thrashed with a belt-roller to remove the seed from the flowers, and cleaned with a shaker table to separate the seed from the plant debris. The cleaned seed were stored in plastic containers at 4 C until needed for the experiments. Some treatments required chilling the seed wet or dry. Wet-chilled seed were stored submersed in distilled water at 4 C Dry-chilled seed were stored at 4 C.

The seed received various treatments and then they were either incubated in a controlled-environment chamber or at different temperatures on a thermogradient table to determine the effect of both the pre-incubation treatment and incubation temperature on germination. After treatment, the seed were placed in 10 by 38mm plastic petri dishes, 100 seed per dish, and covered with distilled water. Three replicates of each treatment were either placed in a controlled-environment chamber adjusted to 20 C and under a 14-hr daylength of 600 microEinsteins/cm^2/sec or in each cell of an 8-cell thermogradient table that supplied a temperature range of 4 to 35 C. During incubation on the thermogradient table, the seed were subjected to 80 microEinsteins/cm^2/sec of continuous light from 4 daylight fluorescent lamps set 0.6 m above the seed. Continuous light was used during preliminary tests. It was found that only about 4% of the seed would germinate in the absence of light and that continuous light did not have an adverse effect on germination. The germinated seed were counted each week for 4 weeks to obtain both the rate and total percent germination. Seed were considered germinated when the cotyledonary sheath emerged from the pericarp. The data were analyzed using Duncan's Multiple Range Test at the 5% level.

Effect of post-treatment chilling of scarified seed on germination. The seed used for this study were harvested in 1981 from a pond in Sacramento County. Eighty-one lots of 100 seed were placed in 12 by 75 mm dia plastic containers. Forty-eight of the containers were filled to 3/4 capacity with 5.25% NaOCl, placed in a rack, and then submersed in a 20 C water bath. Submersion in water kept the temperature of the chemical reaction from rising to a level lethal to the seed. The rack was periodically shaken to maintain a uniform temperature in the containers. After each 1, 2, 4, and 8-hr scarifying period, 12 containers were removed from the rack and the seed thoroughly rinsed over a fine-mesh screen to remove the excess NaOCl. These seed and the unscarified seed in 21 containers were placed in incubation dishes and covered with distilled water. Nine of the dishes had the storage water exchanged each week during the study period. The other 12 dishes had the storage water left unchanged during the study. The seed in the remaining 12 containers were placed dry in the incubating dishes. Three replicates of each treatment were incubated immediately, except seed from the weekly water exchange

[1]Research Botanist, Aquatic Weed Research Laboratory, USDA-ARS, Botany Department, University of California, Davis, CA 95616.

treatment. The seed were chilled at 4 C for l, 2, and 12 months. At the end of each of these periods, 3 replicates of each treatment were incubated on the thermogradient table.

Effect of scarification, chilling, and incubation temperature on germination. Two l groups of seed harvested in 1983 were measured. One qroup was placed in a 250 ml glass beaker and covered with 50 ml of NaOCl. The seed were allowed to soak for 2 hr at 20 C, then the seed were thoroughly rinsed with distilled water to remove the excess NaOCl. These scarified seed were put in a 20 ml plastic container and covered with distilled water. The untreated seed were placed dry in another container of equal size. Both containers were stored at 4 C for l month and then the seed were removed. Seed from each treatment were placed in incubating dishes, and incubated at 8 different temperatures on the thermogradient table. The total amount and rate of germination for each treatment and temperature were determined.

Effect of removing the pericarp on germination. The germination of seed that had their pericarps removed were studied using seed harvested in 1983 at Fresno, California. The percentage germination of seed that had been stored dry at 20 C for 2 months and had their pericarps removed were compared to the percentage germination of seed that had been chilled wet or dry for 2 months before incubating at different temperatures.

Two groups of seed, 1 g each, of freshly harvested seed were placed in 20 ml plastic containers. One group was covered with distilled water and the other left dry. A third group of seed had their pericarps removed by placing them on a flat metal plate and moving a 5 by 20 cm-long wood dowel over the seed. A "Y" frame was constructed with 2 legs holding the ends of the dowel and the third leg for a handle. Lead weights were added to the frame to give a total downward pressure of 2 kg, as measured on a weighing scale. The dowel was passed over the seed 10 times for the initial rolling and 20 times for each additional rolling. The pericarps on approximately 50% of the seed were crushed. Of these approximately 5% of the excised seed remained undamaged. Those that were unaffected by the initial rolling were rolled a second or third time. The excised seed were carefully separated from the trash using forceps, placed in a 20 ml container, and chilled dry. After 2 months of cold storage at 4 C, 24 lots of seed from each group of wet, dry, and excised seed were counted, placed in incubation dishes, covered with water and incubated on the thermogradient table. The total amount and rate of germination for each treatment at each temperature were determined.

Effect of excising seed chilled dry for 26 months on germination. Seed that had been harvested in 1981 at Fresno, California, and chilled dry for 26 months at 4 C were studied. Two l g groups of seed were removed from the storage container. One group of seed was treated (as above) to remove the pericarps and the other left untreated. Seed from each group were placed in incubating dishes, covered with distilled water, and incubated on the thermogradient table. The percentage germination of seed chilled dry for over 26 months and then their pericarps removed were compared to the percentage germination of intact seed treated similarly stored.

RESULTS AND DISCUSSION

Effect of post-treatment and chilling of scarified seed on germination. Soaking seed in NaOCl for 2 hr and chilling them wet for 2 or more months gave the best percentage germination, 17% (Table 1). Seed that had been scarified for 2 hr, but not chilled wet, germinated 7%. Chilling increased the percentage germination of scarified seed. The percentage germination of untreated seed chilled wet remained low throughout the 12-month chilling period and was only 4% at the end of the study. Exchanging the storage water every week did not improve germination, 3% after 12 months, indicating the absence of a germination inhibitor, as was found in dwarf spikerush (14). The germination of seed stored dry was poor, 3%. The highest percentage germination in this study was low compared to the 68% germination obtained by Rothrock and Waqner (8).

Effect of scarification, chilling, and incubation temperature on germination. The treatments of modification of them

TABLE 1. EFFECT OF POST-TREATMENT CHILLING OF SLENDER SPIKERUSH SEED SCARIFIED WITH NAOCL AND UNTREATED SEED CHILLED WET AND DRY ON GERMINATION.

Pre-incubation treatment[1]	Months of post-treatment chilling[2] 0	1	2	12
	(%)			
Scarified in NaOCL for 1 hr	2 c	7 b	6 bc	17 a
Scarified in NaOCL for 2 hr	7 a	11 a	12 a	17 a
Scarified in NaOCL for 4 hr	5 b	4 bcd	7 b	14 ab
Scarified in NaOCL for 8 hr	2 c	6 bc	4 bc	9 bc
Chilled wet, water unchanged	—	2 cd	3 cd	4 c
Chilled wet, water exchanged[3]	—	2 cd	3 cd	3 c
Chilled dry	0 d	0 d	1 d	3 c

[1]Seed incubated at 20 C.
[2]Values in each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.
[3]Storage water exchanged each week with fresh distilled water.

TABLE 2. PERCENTAGE OF GERMINATION OF SLENDER SPIKERUSH SEED THAT WERE SCARIFIED WITH NAOCL AND CHILLED WET AND SEED THAT WERE CHILLED DRY AND THEN INCUBATED AT DIFFERENT TEMPERATURES.

Incubation temperature (C)	Pre-incubation treatment[1] Scarified[2]	Chilled dry
	(%)	
4	0 f	0 c
10	48 b	20 a
14	60 a	19 a
18	51 b	14 a
23	42 c	8 b
27	28 d	6 b
31	23 de	6 b
35	18 ef	3 bc

[1]Values in each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.
[2]Seed scarified 2 hr with NaOCL.

used this study have been used to break the dormancy of other seed (2, 11, 14). The most notable result was the increase in the percentage germination that occurred when the incubation temperature was lower than 20 C (Table 2). The seed germinated best, 60%, when they were incubated at 14 C. A range of 10 to 18 C gave satisfactory germination of scarified seed and a similar range of temperature gave the highest range of germination for seed chilled dry at 4 C, 14 to 20%.

The percentage germination of both groups of seed gradually decreased as the incubation temperature was increased above 14 C. This suggested that an incubation temperature of 20 C was not satisfactory for optimum germination of slender spikerush seed. A temperature of 4 C prevented the seed from germinating.

The rate of germination for scarified seed was faster than the rate of germination for seed that had been chilled dry (Figure 1). The largest number of seed to germinate during any week occurred at 23 C in the first week. The rate of germination at this temperature decreased rapidly after the first week. Then, the rates of germination became at lower incubation temperatures, 10 to 18 C. Seed chilled dry germinated best during the fourth week of incubation. Both groups of seed germinated well at temperatures of

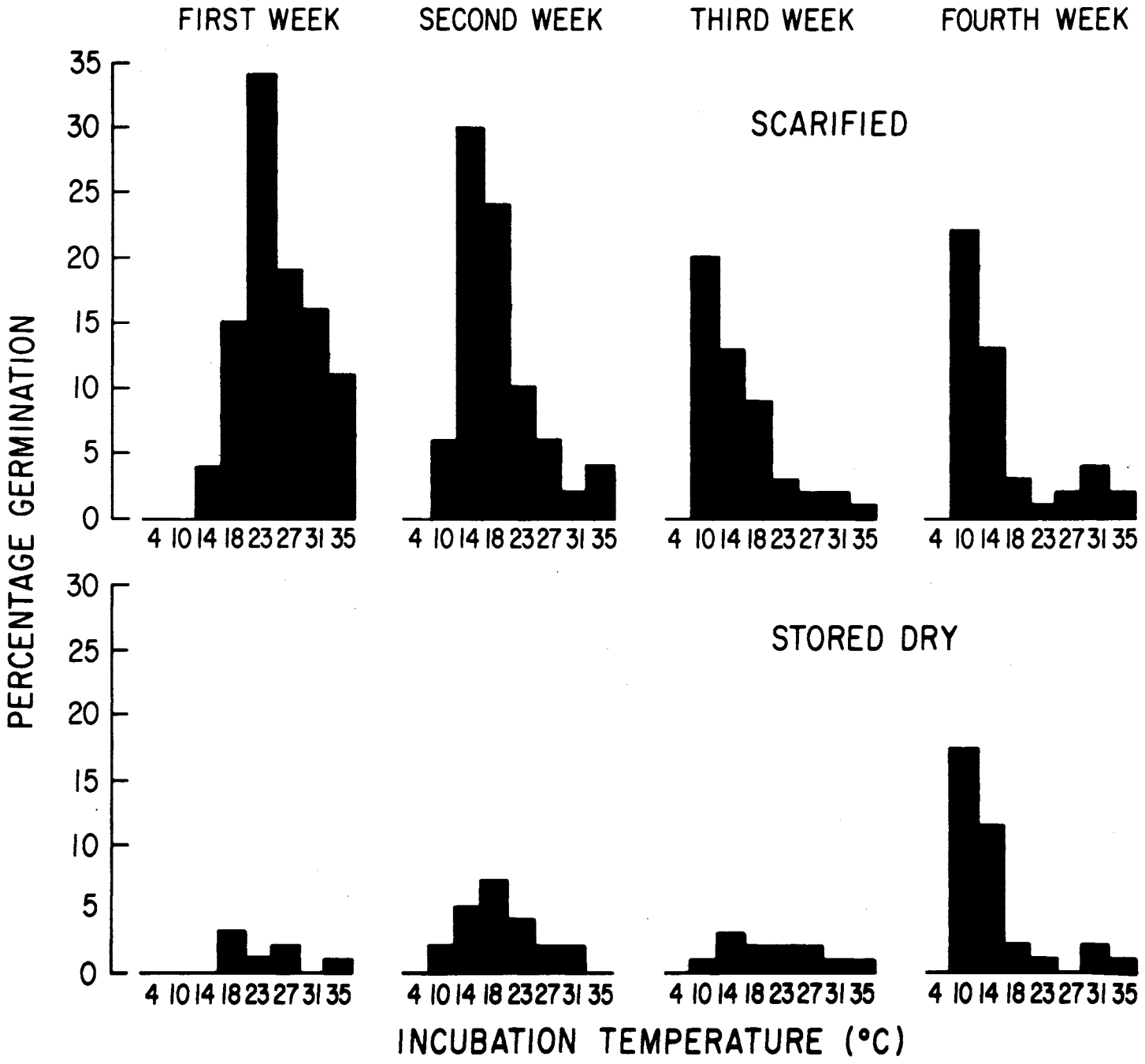

Figure 1. Rate of germination of slender spikerush seed scarified with NaOCl and seed stored dry at the end of 1, 2, 3, and 4 weeks of incubation at different temperatures.

TABLE 3. PERCENTAGE OF GERMINATION OF SLENDER SPIKERUSH SEED WITH PERICARPS REMOVED AND SEED CHILLED WET AND CHILLED DRY AND INCUBATED AT DIFFERENT TEMPERATURES.

Incubation temperature (%)	Pre-incubation treatment[1] Excised	Chilled wet	Chilled dry
	(%)		
8	0 e	0 d	0 c
11	11 d	27 b	12 a
15	24 c	53 a	11 a
18	35 bc	40 ab	11 a
22	47 ab	26 b	8 ab
26	49 ab	10 c	5 b
30	55 a	6 c	13 a
35	59 a	6 c	14 a

[1]Values in each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

TABLE 4. PERCENTAGE GERMINATION OF SLENDER SPIKERUSH SEED THAT WERE CHILLED DRY 26 MONTHS AND THEN HAD THEIR PERICARPS REMOVED AND SEED CHILLED DRY AND INCUBATED AT DIFFERENT TEMPERATURES.

Incubation temperature (C)	Pre-incubation treatment[1] Excised	Untreated
	(%)	
7	0 d	0 c
11	11 c	9 b
14	24 b	14 ab
19	23 bc	16 ab
23	21 bc	10 ab
27	23 bc	18 a
31	47 a	11 ab
35	49 a	14 ab

[1]Values in each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

10 to 14 C during the fourth week, suggesting that some after- ripening took place at these temperatures during the first three weeks of incubation.

Effect of removing the pericarp on germination. Seed with the pericarps removed germinated slightly better than intact seed chilled wet for 2 months (Table 3). Davis and Rose (3) found that the dormancy of *Crataegus mollis* Sarg. seed with intact pericarps was overcome by chilling seed 12 months at low temperatures, but with the pericarps removed, only 3 to 4 months of chilling was required. Removing the pericarps of Rosaceous seed, forced the seed to germinate (4).

The percentage germination of excised seed increased with an increase in incubation temperature, 59% at 35 C; whereas, seed chilled wet germinated better at a lower temperature, 53% at 15 C. The percentage germination of intact seed chilled dry for 2 months appeared erratic over a range of 11 to 35 C.

The rate of germination for excised seed was faster during the first week of incubation than for the other seed treatments (Figure 2). Seventy-four percent of all the excised seed that germinated did so at 26, 30, and 35 C during this period. The rate of germination at these temperatures decreased sharply after the first week. The overall rate of germination of seed chilled wet was low during the first week and highest in the second week, when most of the seed germinated at 15, 18, and 22 C. The rate of germination of seed incubated at 11 C increased during the second, third, and fourth weeks and decreased with seed incubated at 15 C during the same periods. Germination of seed chilled dry was slow and low. According to Mayer et al. (6), the seed of some plants do not after-ripened when they are stored dry. They must be imbibed and chilled to initiate the after-ripening process.

Effect of excising seed chilled dry for 26 months on germination. Twenty-six months of storage did not qreatly reduce the viability of seed. Seed chilled dry and then excised still germinated well, 47 to 49% at 31 to 35 C, respectively (Table 4). The percentage germinaticn of these seed increased with an increase in temperature. In contrast, intact seed chilled dry germinated poorly, 10 to 18%, over a temperature range of 14 to 35 C and was about the same percentage germination as in the other studies.

Discussion. Dormancy appears to be induced by both the pericarp and the embryo. Bewley and Black (1) and Crocker and Barton (2) quote cases where the combination of the pericarp and embryo induced dormancy. The embryo-induced dormancy was overcome by after-ripening the seed in water at low temperatures.

Removing the pericarp broke dormancy and gave a high percentage germination. The rate of germination for these seed was very rapid. The germination appeared "forced". However, the seedlings grew normally, which was in contrast to the abnormal seedlings that developed from "forced" seed plants (4).

Germination of seed treated with NaOCl was high. Breaking dormancy in this case appeared to be due to a combination of altering the pericarp and of after-ripening. Modifications of the pericarp will break dormancy either by enhancing the entry of water or promotive chemicals, oxidizing inhibitory chemicals in the coat, or reducing its mechanical rigidity (1). Only the latter may apply here, as the absence of an inhibitor was determined and removing the apex of seed to allow entry of water and promotive chemicals have not enhanced germination of spikerush seed in other studies (Unpublished data by author).

The rate of germination of scarified seed remained relatively high during the entire incubation period. The rate began high at 23 C in the first week, continued high in the second week, but at lower temperatures, 14 and 18 C. During the third and fourth weeks, the rate of germination remained high, but at a lower temperature, 10 C. This suggests that treating seed with NaOCl may have an effect on some seeds that is similar to excising (rapid germination at 23 to 35 C) and of after-ripening (germination at 10 to 14 C after 2 weeks of chilling wet during incubation).

The information shows that seed treated with NaOCl should be sown in the spring or fall when water temperatures are about 14 C. This also applies to seed that have been after-ripened by chilling wet at 4 C for one or more months. Seed that have been rolled or crushed to rupture the pericarps should be sown during the summer when the water/soil temperature is about 35 C. The excised seed will germinate rapidly at this time. The remaining intact seed will germinate later when the water temperatures have sufficiently cooled to allow the seed to after-ripen.

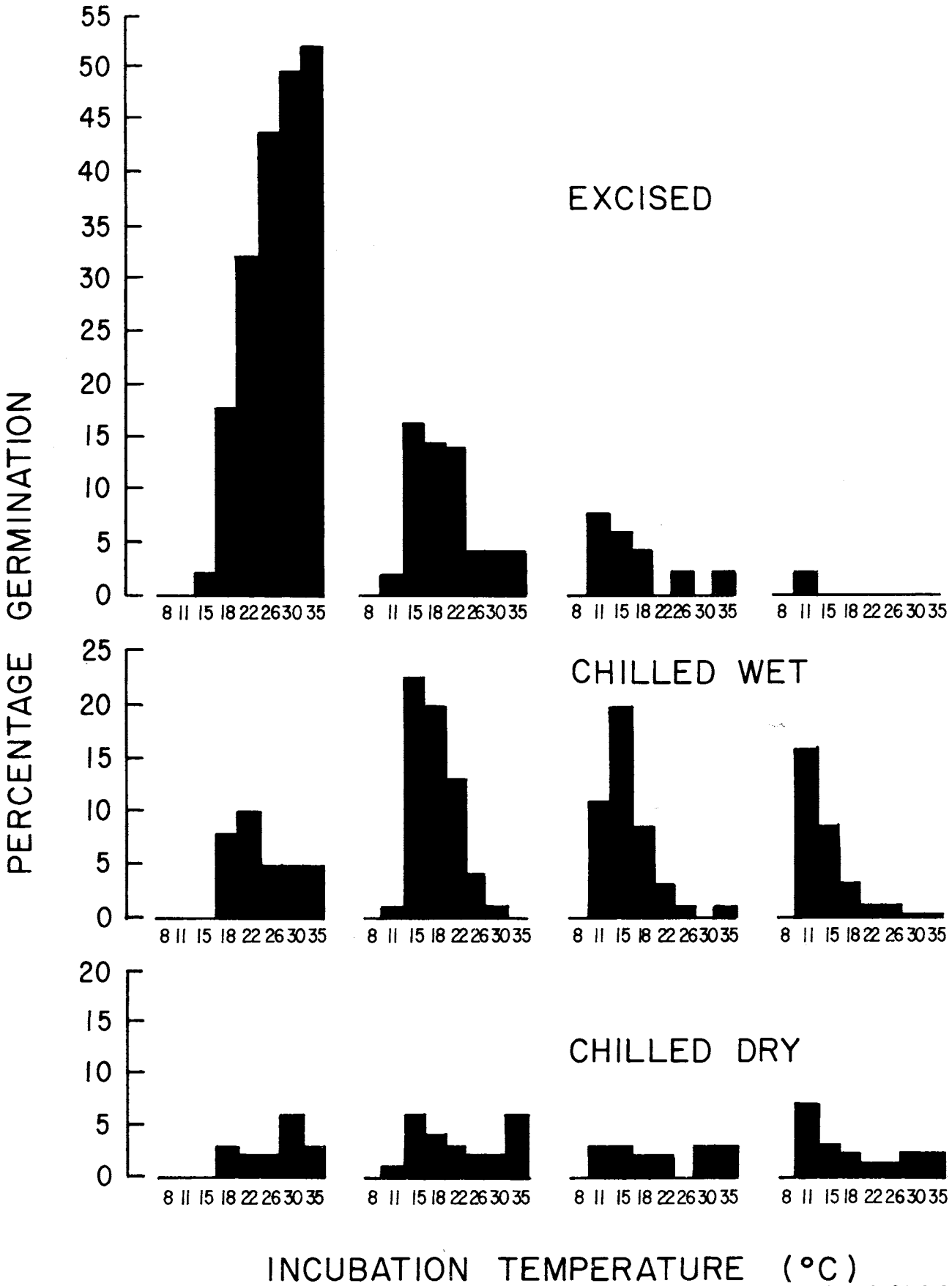

Figure 2. Rate of germination of slender spikerush seed with pericarps removed and seed chilled wet and chilled dry at the end of 1, 2, 3, and 4 weeks of incubation at different temperatures.

The percentage germination of seed influences the seeding rate. If a rate of 1 germinable seed per cm^2 is needed to establish a stand of slender spikerush in a relatively short period of time and only 50% of the seed treated with NaOCl will germinate, then 2 treated seed per cm^2 should be sown. When making a spring planting with seed that has been stored dry, and it is desirable to establish the spikerush the same year as it is planted, then a rate of 10 seed per cm^2 would be necessary to obtain 1 germinable seed per cm^2. The same seed could be sown in the fall at a rate of 2 seed per cm^2, as it would after-ripen during the winter and approximately 50% of the sown seed would probably germinate. Seed that have been stored in water at 4 C for more than 1 month and have a germination capability of 50%, should be sown in water with a temperature range of 11 to 22 C at 2 seed per cm^2.

LITERATURE CITED

1. Bewley, J. D. and M. Black. 1982. Physiology and biochemistry of seeds in relation to germination. V2, 1st Ed. Spring-Velag, Berlin, Heidelberg, New York, 375 p.
2. Crocker, W. and L. V. Barton. 1953. Physiology of seeds. Chronica Botanica. Waltham, Mass. 240 p.
3. Davis, W. E. and R. C. Rose. 1912. The effect of external conditions upon the after-ripening of the seeds of *Crataegus mollis*. Bot. Gaz. 54:49-62.
4. Flemion, F. and P. L. Prober. 1960. Production of peach seedlings from unchilled seeds. I. Effect of nutrients in the absence of cotyledonary tissue. Contr. Boyce Thompson Inst. 20:409-419.
5. Hsaic, A. I. and W. A. Quick. 1984. Actions of sodium hypochlorite and hydrogen peroxide on seed dormancy and germination of wild oats (*Avena fatua* L.). Weed Res. 24:411-419.
6. Mayer, A. M. and A. Poljakoff-Mayber. 1975. The germination of seeds. 2nd Ed. Perqammon Press. New York, N.Y. 192 p.
7. Osborn, E. T., W. T. Moran, K. T. Greene, and T. R. Bartley. 1954. Weed control investigations on some important plants which impede flow of western irrigation waters. Joint Lab. Rpt. SI-2, USDA, Bur. of Reclam. Eng. Lab. and USDA, ARS Field Crops Branch, 16-17.
8. Rothrock, P. E. and R. H. Wagner. 1975. *Eleocharis acicularis* (L.) R.& S.: The autecology of an acid tolerant sedge. Castanea. 40:279-289.
9. Yeo, R. R. 1980. Life history and ecology of dwarf spikerush (*Eleocharis coloradoensis*). Weed Sci. 28:263-272.
10. Yeo, R. R. 1980. Spikerush may help control waterweeds. Calif. Agric. 34:12-13.
11. Yeo, R. R. and R. J. Dow. 1978. Germination of seed of dwarf spikerush. Weed Sci. 26:425-431.
12. Yeo, R. R. and T. W. Fisher. 1970. Progress and potential for biological control with fish, pathogens, competitive plants, and snails. In Tch. Papers, First FAO Int. Conf. Weed Control. 450-463.
13. Yeo, R. R. and J. R. Thurston. 1979. Survival of seed and tubers of dwarf spikerush (*Eleocharis coloradoensis*) after exposure to extreme temperatures. Weed Sci. 27:434-436.
14. Yeo, R. R. and J. R. Thurston. 1983. Dormancy in seed of dwarf spikerush (*Eleocharis coloradoensis* (Britt). Gilly). J. Aquat. Plant Manage. 21:92-95.