The Effect of Salinity on Seed Germination and Seedling Growth of *Echinochloa crusgalli*[1]

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ABSTRACT. The purpose of this investigation was to determine the effect of salinity on germination and seedling growth of *Echinochloa crusgalli* collected from different populations. Germination studies with *Echinochloa crusgalli* indicated that each increase in salinity up to 1.5% NaCl caused a reduction in germination in both scarification and stratification + light treatments, with no seeds germinating at 2% NaCl. Stratified seeds without light did not germinate in any of the treatments. Seeds originating from parents growing at low, medium, and high salinity field sites differed in their response to salinity stress. At 2% NaCl, seeds originating from all three seed sources failed to germinate. Each increment in salinity caused a decline in seedling height, but the decrease was 61% at 1.5% NaCl for the low salt population, 77% for the medium salt population and only 38% for the high salt population.

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INTRODUCTION

Echinochloa crusgalli (L.) Beauv. (barnyard grass) is an annual grass usually found growing in nonsaline sites (Hitchcock 1950). However, a population of this species has become established in a wet saline area at Constitution, OH. Several studies have been carried out to determine the effect of environmental conditions on the germination of *E. crusgalli* seeds. The minimum, optimum, and maximum temperatures for germination of *E. crusgalli* were determined to be 13° C, 20-30° C, and 40° C, respectively (Brod 1968, Roche and Muzik 1964). Other germination studies of this genus by VanderZee and Kennedy (1981) report that the effects of anoxia on germination and seedling growth were not permanent, but rather were limiting and reversible.

Studies of salt tolerance in members of the genus *Echinochloa* have been reported infrequently. Shannon et al. (1981) found that *E. turnerana* has high tolerance to salinities of 1% total salts. Aslam et al. (1987) reported that seed germination and shoot yield of a population of *E. crusgalli* from Pakistan was depressed by treatments with saline solutions.

The goals of the present study were to determine the effects of salinity on the germination and seedling growth of *E. crusgalli* and to determine the responses to salinity of seeds collected at different sites along a salinity gradient. If natural selection for salt tolerance is taking place, germination of seeds from plants in the high salt habitat should be less inhibited by salt stress than that in seeds collected from low salt and medium salt sites.

MATERIALS AND METHODS

To study the germination responses of the seeds of *E. crusgalli* to environmental factors, several laboratory treatments were performed. The treatments included wet-cold stratification, scarification with sandpaper and salinity levels ranging from 0% to 2% NaCl. In stratification treatments the seeds of *E. crusgalli* were exposed to wet (distilled water)-cold conditions (5° C) for 30 days and then placed in a growth chamber with 30/20° C temperatures for 12 h light (50 $\mu E/m^2/s$, 400-700 nm) /12 h dark. In the wet-cold treatments, eight petri dishes were kept in a metal petri dish holder and placed in a refrigerator at a temperature of 5° C for 30 days. Subsequently, four petri dishes were exposed to light (50 $\mu E/m^2/s$, 400-700 nm) during germination, and the other four petri dishes were kept in a metal petri dish holder to maintain the dark condition in a 12 h-30 /12 h-20° C growth chamber. In the scarification treatment, the caryopses were rubbed with sandpaper, and the seeds were soaked in distilled water for three days and then placed at 20/30° C in a lighted incubator to study germination responses at different salinities. For this experiment, 25 seeds were placed in 5 cm diameter sterile plastic petri dishes containing two sheets of Whatman No. 2 filter paper. Filter paper was moistened with 5 ml of solution containing 0% NaCl, 0.5% NaCl, 1.0% NaCl, 1.5% NaCl, and 2.0% NaCl (w/v), respectively. Four replicates were used for each salinity treatment. The number of seeds germinating daily was recorded for 20 days.

Another set of germination experiments was conducted using three different seed sources. Seeds of uniform size were collected from low salinity (0.6% total soil salts), medium salinity (0.9% total soil salts), and high salinity (1.3% total soil salts) sites in the field during the 1986 growing season. These seeds were then scarified with sandpaper to break dormancy, soaked for three days and then used for experiments as described above. The number of germinating seeds was counted every two days for 20 days and the length of each seedling was measured.

Data in this investigation were analyzed using analysis of variance (ANOVA) to determine if there were differences between means of multiple samples (Sokal and Rohlf 1981). Where significant differences were found among the variables, multiple comparisons among the means were made using the least significant difference (LSD) test.

RESULTS

Seeds of *Echinochloa crusgalli* from both scarification and stratification + light treatments responded similarly to salinity treatments (Table 1). Highest germination percentages were found in the distilled water controls in both

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TABLE 1

The effect of salinity on germination percentages (mean SE) of Echinochloa crusgalli *seeds after scarification and stratification + light treatments. (Each value ± 1 SE).*

	Scarification	Stratification +light	Stratification -light
0.0% NaCl	85.0 ± 0.91	87.0 ± 1.47	0
0.5% NaCl	72.5 ± 1.04	74.5 ± 1.85	0
1.0% NaCl	57.5 ± 1.04	55.0 ± 0.82	0
1.5% NaCl	55.0 ± 0.91	53.5 ± 0.65	0
2.0% NaCl	0	0	0

the stratification + light and scarification treatments. Germination decreased in the 1.5% NaCl concentration by 33.5% and 30.0% from controls for each treatment, respectively. No seeds germinated in the 2.0% NaCl treatment. Percent seed germination in both treatments decreased significantly ($P < 0.05$) with increasing salt concentration from 0% to 1.5%. Stratified seeds incubated in darkness did not germinate in any of the treatments (Table 1).

The highest germination for seeds originating from the three locations was at 0% NaCl for seeds collected from the low, medium, and high salinity sites. Increased NaCl in the germination medium from 0% to 1.5% was correlated with decreased germination percentages for seeds of *E. crusgalli*. At 2% NaCl, seeds originating from all three locations failed to germinate (Table 2). When exposed to 1.5% NaCl, the germination of seeds from the low salt site was reduced to 46% of the control, while seeds collected from the high salt site had only a 32% reduction. A two-way ANOVA for these germination data indicated that both salt concentration and seed origin had a significant ($P < 0.05$) effect on seed germination.

TABLE 2

Percent germination (mean ± SE) of seeds originating from low, medium and high salinity areas, after 20 days exposure to NaCl treatments.

	Low salinity seeds	Medium salinity seeds	High salinity seeds
0.0% NaCl	89 ± 0.91	89 ± 0.91	84 ± 1.83
0.5% NaCl	76 ± 1.29	76 ± 0.82	79 ± 0.91
1.0% NaCl	50 ± 1.83	63 ± 2.45	52 ± 0.82
1.5% NaCl	41 ± 2.20	45 ± 2.19	57 ± 1.29
2.0% NaCl	0	0	0

Salinity also inhibited the growth of seedlings of *E. crusgalli*. Increasing salinity from 0% to 1.5% caused a decrease in the mean height of seedlings originating from collections made at low, medium, and high salinity field sites (Table 3). At 0% NaCl, seedlings originating from the low salinity site were significantly larger ($P < 0.05$) than those from medium and high salinity sites. Seeds originating from low and medium salinity sites produced seedlings that differed significantly ($P < 0.05$) when exposed to NaCl, with the tallest seedlings in 0% NaCl and the shortest seedlings in 1.5% NaCl (Table 3). The size of seedlings from high salinity sites was depressed less at 0.5% NaCl than was that of seedlings originating from low and medium salinity sites. In 0% NaCl and 0.5% NaCl treatments, seedling height did not differ, but both treatments were significantly different from those in 1% NaCl and 1.5% NaCl. Seedlings from high salinity sites were significantly ($P < 0.05$) smaller in size than those from the low and medium salinity sites. Plants from the high salt site treated with 1.5% NaCl reached a seedling size that was 62% of the control, while seedlings from the low salt and medium salt sites were 39% and 23% of the controls, respectively.

TABLE 3

The effect of salinity on the mean length (± SE) of 20 day old seedlings developing from seeds collected from plants at low, medium, and high salinity field sites.

	Low salinity	Medium salinity	High salinity
0.0% NaCl	11.68 ± 0.97	10.93 ± 0.63	6.86 ± 0.29
0.05% NaCl	8.52 ± 0.48	7.89 ± 0.76	6.33 ± 0.12
1.0% NaCl	5.44 ± 0.55	4.27 ± 0.13	4.31 ± 0.48
1.5% NaCl	4.51 ± 0.39	2.51 ± 0.29	4.29 ± 0.29
2.0% NaCl	0	0	0

DISCUSSION

The upper limit of tolerance for germination of *Echinochloa crusgalli* seeds from the saline site in Ohio was 1.5% NaCl. Aslam et al. (1987) reported that seeds from an *E. crusgalli* population from Pakistan did not germinate at salinity of 1.5% NaCl, indicating that the Ohio seed source from a saline habitat was more salt-tolerant at the germination stage than the seeds from Pakistan collected in a nonsaline location. The limits of salt tolerance of varied grass species have been reported to vary not only among populations, but also between species of glycophytic grasses. Horst and Taylor (1983) determined that the number of *Poa pratensis* seeds which germinated at the end of a 35-day test period was reduced by approximately one seed for every 0.1% increase in salt concentration. Francois et al. (1984) found that soil salinity up to 0.5% did not significantly inhibit germination of *Sorghum bicolor* seeds, but salt levels greater than 0.5% delayed germination. Francois et al. (1986) reported that germination of *Triticum aestivum* was little affected by soil salinity up to 0.25%, but at 0.5% and above germination was significantly delayed and the final germination percentage was markedly reduced. The tolerance limits of *E. crusgalli* at the germination stage were higher than the glycophyte *Triticum aestivum* and are closer to those of the moderately salt-tolerant halophyte *Hordeum jubatum* (Ungar 1974).

Many annual weed species have a light requirement for the induction of seed germination (Harper 1977, Baskin and Baskin 1977, Mayer and Poljakoff-Mayber 1975). A light requirement is of ecological significance to fugitive species and those plant species growing in rapidly-changing, high-stress environments because it provides for storage of seeds in the soil. Seed dormancy provides for a temporal distribution of seed germination, delaying germination until optimal conditions for seedling development occur (Ungar 1974).

The inhibitory effect of salinity was demonstrated by the reduction of mean seedling length for seeds collected at the low, medium, and high salinity field sites. Increasing soil salinity caused a decrease in the height of seedlings from all sources. Parental environmental conditions influenced the ability of *E. crusgalli* seedlings to respond to stressful environments. Plants growing in the high salinity habitat produced offspring that were less inhibited in highly saline environments, as indicated by the smaller reductions in germination and size of seedlings with increased salinity compared to plants from low salinity habitats. Ecotypic adaptation to microedaphic conditions has not been previously reported for nonhalophytes growing in saline habitats. However, similar germination and seedling growth responses could be obtained because of parental preconditioning (Ungar 1987). There is some evidence in the literature that selection may be taking place for greater salt tolerance at the germination stage for populations of *Prosopis farcta* and *Rumex crispus* growing in more saline sites (Cavers and Harper 1967, Bazzaz 1973).

Even though *E. crusgalli* seeds could germinate in NaCl solutions with up to 1.5% NaCl, seedlings survived for only twenty days at salinities above 1% NaCl. These data indicate that the seedling growth stage was more sensitive to the stress of salinity than the germination stage. Similar results were reported by Francois et al. (1984) for *Sorghum bicolor* and Ungar (1974) for *Hordeum jubatum*. However, Chapman (1960) and Mooring et al. (1971) determined that salt tolerance in some halophytic plants increases with development, but this was not the case for *E. crusgalli*.

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