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Germination behavior of common ragweed (*Ambrosia artemisiifolia*) populations across a range of salinities

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Common ragweed is a native annual that colonizes disturbed habitats including agricultural fields and roadsides. It is especially abundant along roadways receiving regular applications of deicing salt. Anecdotal evidence has suggested that the emergence of common ragweed seedlings often occurs before the emergence of other roadside species and at salinity concentrations as high as 400 mM L^{-1}, a level that can be found in roadside soils in early spring. However, the extent of this tolerance to salinity in common ragweed populations has not been quantified. The objective of this study was to assess the germination behavior of common ragweed seeds collected from three roadside and two agricultural populations across a salinity gradient. Seed germination of these five populations was monitored daily for 21 d across a sodium chloride gradient [0, 100, 200, 300, and 400 mM L^{-1}] under controlled conditions. Seeds from roadside populations showed consistently greater total germination and rate of germination than seeds from agricultural populations. Germination differences were most evident at the 300 and 400 mM L^{-1} salinity concentrations. Average germination at the 400 mM L^{-1} sodium chloride concentration was 31% for two roadside populations and only 3% for two agricultural populations. Germination of seeds placed in distilled water after the 21-d salinity exposure treatments (i.e., recovery rates) was also greater for the roadside vs. agricultural populations. Findings indicate that the germination behavior of common ragweed seeds to salinity for roadside populations may be locally adaptive and allows common ragweed to emerge relatively early in spring thus providing a competitive advantage over later emerging roadside plants.

Nomenclature: Common ragweed, *Ambrosia artemisiifolia* L., AMBEL.

Key words: Local adaptation, roadside vegetation management, ruderals, seed germination, sodium chloride.

Salinity is a major abiotic constraint for plants and can negatively affect important physiological processes (Greenway and Munns 1980; Lambers et al. 1998). Much research has been devoted to understanding how germination, plant growth, reproduction, and population dynamics are affected by hypersaline habitats such as salt marshes and salt deserts (Khan and Ungar 1984, 2001; Khan et al. 2002; Ungar 1995, 1996). Often, in these areas, the elevated saline conditions are present for at least several months of the year, and thus, the adaptive advantage of species capable of tolerating the high salinity conditions is clear (Forman and Alexander 1998; Ungar 1995). In contrast, fewer studies have examined the effect of the short duration of elevated salinity on plants. More specifically, the situation found along roadways that receive frequent applications of deicing salt (sodium chloride [NaCl]) during the winter months (Greipsson et al. 1997; Rothfels et al. 2002; Thompson et al. 1986; Westing 1969). Seed germination and growth of plants under these spatially and temporally more variable soil salinity conditions are not as well documented as that for halophytic species.

In many regions of North America, large quantities of deicing salt are applied during the winter months to roadways, especially in large metropolitan areas. An estimated 9.1 billion kg of deicing salt are spread annually on U.S. roadways for snow and ice removal (D'Itri 1992). Similarly, in the two most populated Canadian provinces of Ontario and Quebec, nearly 1.2 billion kg of deicing salt are applied to roadways in each province annually (D'Itri 1992). Concentrations of sodium in soil adjacent to these roadways are often temporally variable but can be high after snowmelt in spring and can accumulate over years. For instance, the sodium concentration in a roadside soil at a depth of 15 cm and at a distance of 0.5 m from the roadway in the Toronto, Ontario, area increased from 50 $\mu g\ g^{-1}$ soil before winter salt applications to 235 $\mu g\ Na^{+}\ g^{-1}$ soil after only 1 yr of salting (Hutchinson and Olson 1967). Sodium concentrations were found to be inversely proportional to the distance from the highway, with higher than normal sodium levels observed up to 9 m from the highway. However, NaCl may also be leached out of the root zone of most plant species during the spring, particularly in regions of eastern North America with high rainfall (Labadia and Buttle 1996; Westing 1969). Labadia and Buttle (1996) reported that in several southern Ontario sites, less than 15% of the total amount of deicing salt (i.e., 3 to 5 kg NaCl m^{-1} of highway) recorded before snowmelt in the spring remained in the soil after runoff and infiltration at these same sites (i.e., 0.45 to 0.75 kg NaCl m^{-1} of highway).

In addition to physiological processes in the plant, increases in the amount of deicing salt in soil can alter soil structure and fertility that also can negatively affect roadside plants (Bryson and Barker 2002; Jones et al. 1992). Soil structure and fertility can be altered when sodium replaces calcium and magnesium in the anion exchange process resulting in soils saturated with sodium and depleted of calcium and magnesium (Jones et al. 1992). This leads to decreases in soil permeability, poor aeration, nutrient and water deficiencies, and erosion. The application of deicing salt during the winter is suspected to be the prime cause of widespread mortality of roadside vegetation (Greub et al. 1985; Thompson and Rutter 1986) and the failure of some roadside revegetation projects (DiTommaso et al. 2002; Greub et al. 1985). Plant mortality is due primarily to the high soil salt concentrations although direct airborne salt spray accumulation on needles and branches can also injure and kill plants (Jones et al. 1992; Liem et al. 1985).

Seed germination is a critical phase in the life history of plants; therefore, salt tolerance during the germination phase may be especially critical for establishment of plants on roadsides that receive deicing salt during the winter months. Salt tolerance has been shown to be critical for the seed germination of coastal plants (Greipsson and Davy 1994, 1996). Thus, roadside plants whose seeds are capable of germinating during the relatively high saline conditions occurring in spring after snowmelt may be at a competitive advantage over other species whose seeds are inhibited or delayed from germinating or rendered nonviable under saline conditions. Common ragweed is one of several plant species that appears to have adapted to the stressful conditions of roadsides because it is often the first summer annual species to germinate in spring within the first 0.5 m of roadside verge (A. DiTommaso, unpublished data). In agricultural fields, common ragweed is also generally viewed as an early-germinating species in the spring (Bassett and Crompton 1975). Although summer annuals such as black medic (*Medicago lupulina* L.), spreading orach (*Atriplex patula* L.), and prostrate knotweed (*Polygonum aviculare* L.) are also commonly found along roadways, common ragweed is by far the most abundant, often forming monocultures within the first 0.5 m of roadside (DiTommaso and Massicotte 2002). This apparent tolerance in germination to elevated salinity levels in spring by roadside common ragweed populations may be a major reason for the dominance of this species along major roadways of northeastern North America (DiTommaso and Massicotte 2002; DiTommaso et al. 2000).

The objective of this study was to determine whether the seed germination behavior of common ragweed populations from roadsides receiving frequent deicing salt applications during the winter months was more tolerant of these temporally variable high salinity concentrations compared with the seed germination behavior of populations from agricultural fields. This local adaptation could be inferred if seed germination levels, rates of germination, and germination recovery rates (i.e., ability of viable seeds not germinating under saline conditions to germinate once returned to nonsaline conditions) were greater for the roadside populations than for the agricultural field populations at the higher salinity concentrations.

Materials and Methods

Seed Collection Sites

Mature seeds of common ragweed were collected in October 1999 from five sites in southwestern Quebec, Canada (45°25′N, 73°56′W). Two of the sites were located near Montreal, Quebec, Canada (Fields 1 and 2), and were agricultural fields that had been in fallow for 2 yr; one site was a secondary rural roadside near Montreal (Rural); and two of the sites were located along major highways near Montreal (Highway 1) and Quebec City (Highway 2), Quebec, Canada. The four Montreal region sites were at least 20 km apart, and the Quebec City site was about 240 km from the four Montreal sites. Seeds were collected randomly from approximately 20 plants from each of the five populations, and seeds from each population were mixed to obtain an adequate representation of genetic diversity within the population. These sites were selected because they represent the array of habitats where common ragweed is commonly found and because the roadside sites chosen provide a range of salinity concentrations that is typical of many roadside areas in northeastern regions of North America where deicing salt is applied. The two agricultural field sites had no history of deicing salt application. Soluble concentrations of NaCl in soil sampled after snowmelt in April 1999 from these sites averaged < 2 mg kg^{-1} soil in Field 1 and Field 2, 20 mg kg^{-1} soil in the rural roadway site (Rural), 250 mg kg^{-1} soil in Highway 1, and 350 mg kg^{-1} soil in Highway 2 (A. DiTommaso, unpublished data). To break dormancy, seeds were stored in moist sand at 4 C in the dark for 16 wk before the start of germination experiments.

Germination Experiments

One week before the start of the germination experiments, 25 seeds of common ragweed from each of the five sites were placed in 9-cm-diameter plastic petri plates on filter paper[1] moistened with 8 ml of either distilled water (control) or 100, 200, 300, or 400 mM L^{-1} NaCl solution. Five replicates of 25 seeds were used for each treatment. The petri plates were sealed with Parafilm[2] to prevent evaporation and placed in the dark at 4 C in a refrigerator. After this period, petri plates were transferred to a growth cabinet, under a 14-h photoperiod, 150 μmol m^{-2} s^{-1} photosynthetic photon flux and an alternating day/night temperature regimen of 30/10 C to simulate spring conditions at soil level in many areas of northeastern North America. All solutions were changed completely 10 d after the start of the germination trial. A completely randomized design was used with petri plate positions rerandomized every 2 d. The number of germinated seeds in each plate was recorded daily for a 21-d period, with all germinated seeds removed daily. Germination was assumed when the radicle was at least 2 mm in length. The viability of seeds not germinating after the 21-d period was determined by gently pressing the seeds using forceps. If the seed was firm, it was considered viable and was subsequently rinsed thoroughly with distilled water. If the seed did not resist the slight pressure, it was considered nonviable. Rinsed seeds from each of the five site by salinity-level treatment combinations were then placed on petri plates containing filter paper moistened with 8 ml of distilled water. The petri plates were returned to the growth cabinets under the same environmental conditions described above. Seed germination was recorded daily for another 14-d period, and viability of seeds at the end of this period was determined using the tetrazolium chloride test (International Seed Testing Association 1985). The 21-d germination and

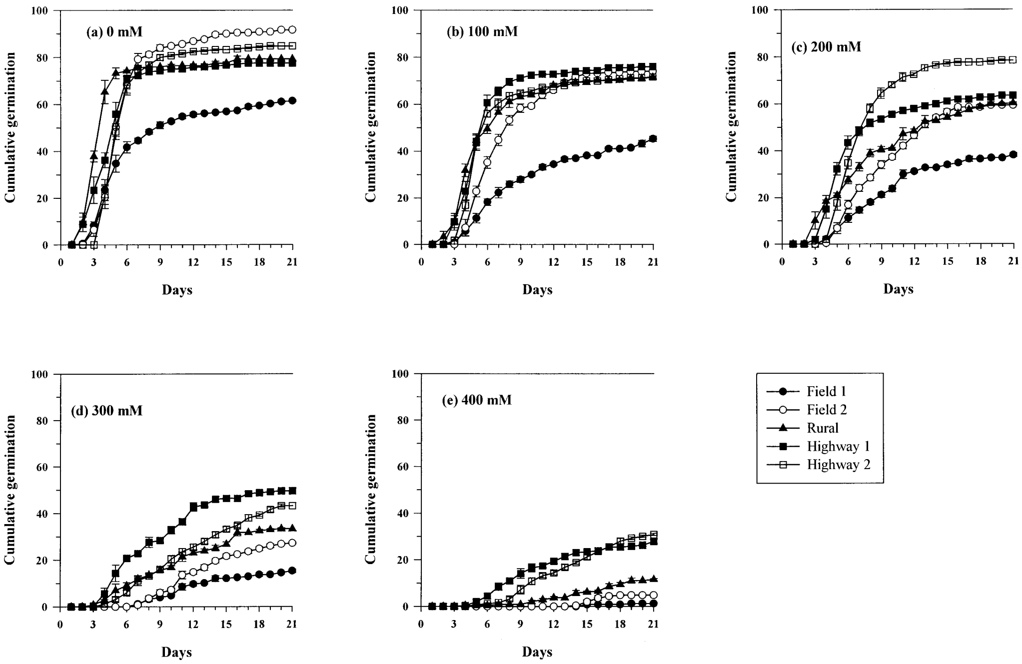

FIGURE 1. Cumulative percentage germination (± SE) over 21 d of common ragweed seeds collected from two agricultural field populations, a rural roadside, and two highway populations and subjected to salinity concentrations of (a) 0 mM L^{-1}, (b) 100 mM L^{-1}, (c) 200 mM L^{-1}, (d) 300 mM L^{-1}, and (e) 400 mM L^{-1}.

14-d recovery trials were repeated on another set of seeds collected from the same populations.

Statistical Analyses

The response variables for the 21-d germination trials were the percentage of seeds germinating at the end of the experiment and the rate of germination. Total germination percentage calculations did not include nonviable seeds. The rate of germination was expressed as:

$$\left(\sum n_t\right)/(n_f t) \qquad [1]$$

where n_t is the cumulative proportion of seeds germinating at each sampling time, n_f is the cumulative proportion of seeds germinating at the end of the experiment, and t is the number of sampling times (Noe and Zedler 2000). When no germination occurs ($n_f = 0$), the index value is defined to be 0. The index ranges from 0 to 1, increasing as germination occurs earlier in the experiment. Recovery percentages (the percentage of seeds not germinating in the saline solution but germinating after transfer to distilled water) after the 14-d trials were determined using the following formula:

$$(a - b)/(c - b) \times 100 \qquad [2]$$

where a is the total number of seeds germinating in both the saline solution and after being transferred to distilled water, b is the total number of seeds germinated in saline solution, and c is the total number of viable seeds.

The effects of common ragweed population and salinity concentration on the percentage total germination, germination rate, and the percentage of seeds germinating during the 14-d recovery trial were each analyzed with a two-way analysis of variance (ANOVA) with population source and salinity concentration as main factors. Percentage data were arcsine square root transformed to improve normality and homogeneity of variance. Data for the two runs of the experiments were pooled because variances were homogenous according to a Bartlett's test (Steel and Torrie 1980). All significant ($P < 0.05$) main effects were tested for differences between treatment levels using the LSD multiple range tests. In the case of significant interaction effects of population source and salinity concentration, simple effects were examined. ANOVAs were performed using SAS.[3] Regression analyses for percentage total germination and rate of germination data were carried out using the curve fitting procedure of SigmaPlot.[4]

Results and Discussion

Total and Germination Rate Under Saline Conditions

Total seed germination percentages in the distilled water control treatment at the end of the 21-d experimental period were above 78% for all common ragweed populations with the exception of one agricultural field population (Field 1), which had only 62% of seeds germinate by the end of the trial (Figure 1a). The number of nonviable seeds was negligible for all five populations (< 1%). Given that seeds from the five populations were subjected to a common 16-wk moist stratification period, it is not clear why seed germination levels for one of the field populations in the distilled water control treatment was low compared with the other four populations.

There was a significant interaction between common ragweed population and salinity concentration on the total percentage of seeds that germinated ($P = 0.002$) and on the germination rate ($P = 0.024$) during the 21-d trial period. Total germination was maximal in the absence of salt (distilled water) for all populations but decreased steadily with

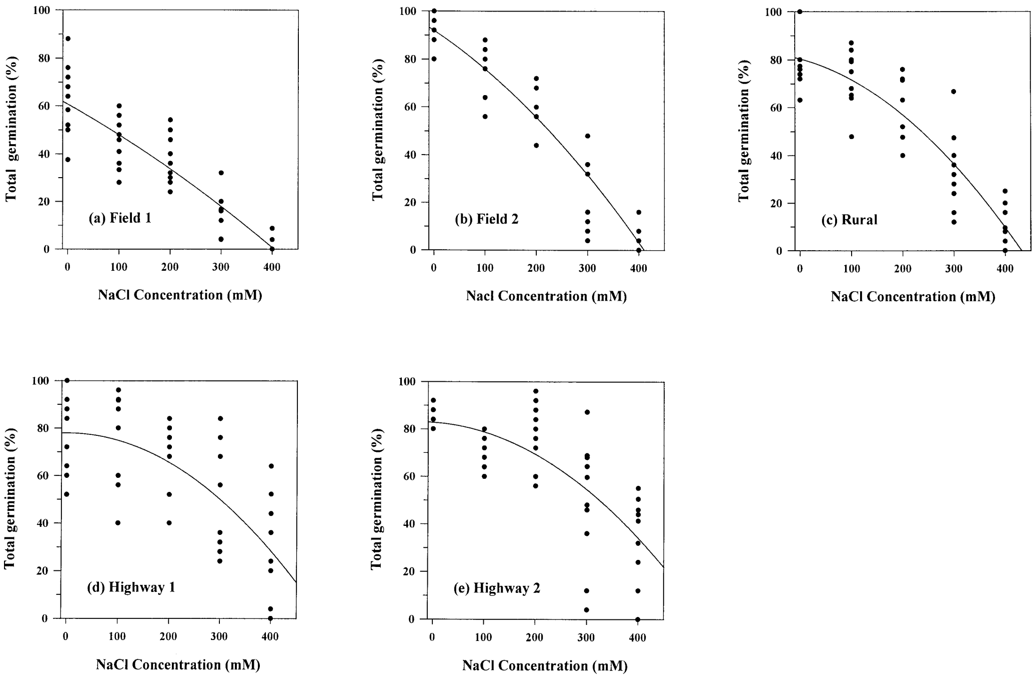

Figure 2. Relationship between total percentage germination and salinity concentration for common ragweed seeds collected from two agricultural field populations, a rural roadside, and two highway populations. Regression equations are (a) Field 1: $60.7 - 12.0x - 0.74x^2$, $r^2 = 0.82$; (b) Field 2: $91.9 - 13.9x - 2.1x^2$, $r^2 = 0.89$; (c) Rural: $80.3 - 5.7x - 3.0x^2$, $r^2 = 0.80$; (d) Highway 1: $77.9 - 0.1x - 3.1x^2$, $r^2 = 0.47$; (e) Highway 2: $82.8 - 1.3x - 2.7x^2$, $r^2 = 0.57$.

increasing salinity, especially for the two agricultural populations (Figure 2). These differential responses are most apparent when total germination is expressed as a proportion of germination in the absence of salt (Figure 3). Differences in total germination between the five populations were most important at the two highest salinity concentrations. For instance, at the 300 mM L^{-1} salinity concentration, germination of seeds collected along the two highway (62%) and the rural roadway (40%) sites was substantially greater than for the two agricultural sites (27%) (Figure 3). Relative to the distilled water control treatment, the total germination at the 400 mM L^{-1} salinity concentration was 2 and 5% for the two agricultural field populations Field 1 and Field 2, respectively, and 14, 36, and 41% for the rural roadside (Rural), Highway 1, and Highway 2 populations, respectively (Figure 3).

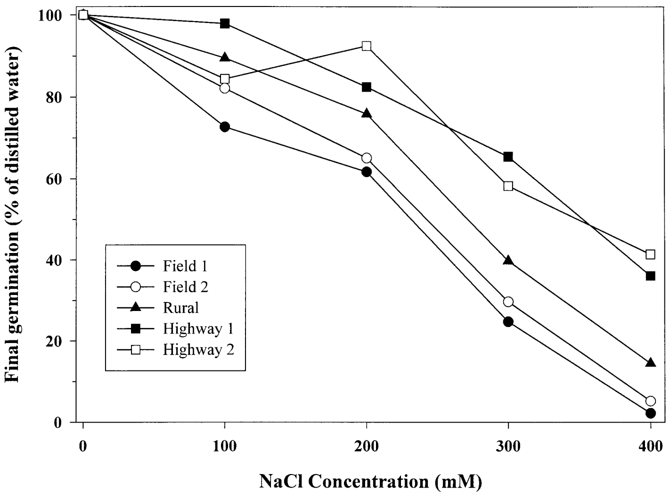

Figure 3. The response to salinity (NaCl) of total germination (over 21 d) of common ragweed seeds from two agricultural field populations, a rural roadside, and two highway populations, expressed as a percentage of seeds germinating in the absence of salt (in distilled water).

The sections of Highway 1 and Highway 2 where common ragweed seeds were collected receive annual applications of deicing salt of approximately 65,000 and 45,000 kg km^{-1} of roadway, respectively (DiTommaso and Massicotte 2002). The rural roadside site averages 10,000 kg of deicing salt km^{-1} of roadway whereas presumably no deicing salt was ever used on the two agricultural field sites. Thus, the gradient in soluble NaCl concentrations (i.e., < 2 to 350 mg kg^{-1} soil) obtained in soil samples after snowmelt from the five sites reflected the levels of deicing salt applied.

The germination rate decreased linearly with increasing salinity concentration and was steepest for the rural roadside population (Figure 4). The mean time to achieve 50% of the total germination also varied between the populations depending on salinity levels. At the 400 mM L^{-1} NaCl concentration, time to 50% total germination was 17, 14, 11 d for the agricultural field, rural roadside, and highway populations, respectively (data not shown).

Findings from this study suggest that common ragweed populations from roadsides receiving large and frequent applications of deicing salt during the winter months have a greater ability to germinate under saline conditions. The ability of seeds of some populations to germinate more rapidly or a greater percentage of the seeds to germinate under stressful environmental conditions provides an early competitive advantage to the more tolerant species (Harper 1977). Rahman and Ungar (1990) also reported greater reductions in total germination of seeds for the nonhalophytic annual plant barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] collected from a low-salinity site (0.6 % total soil

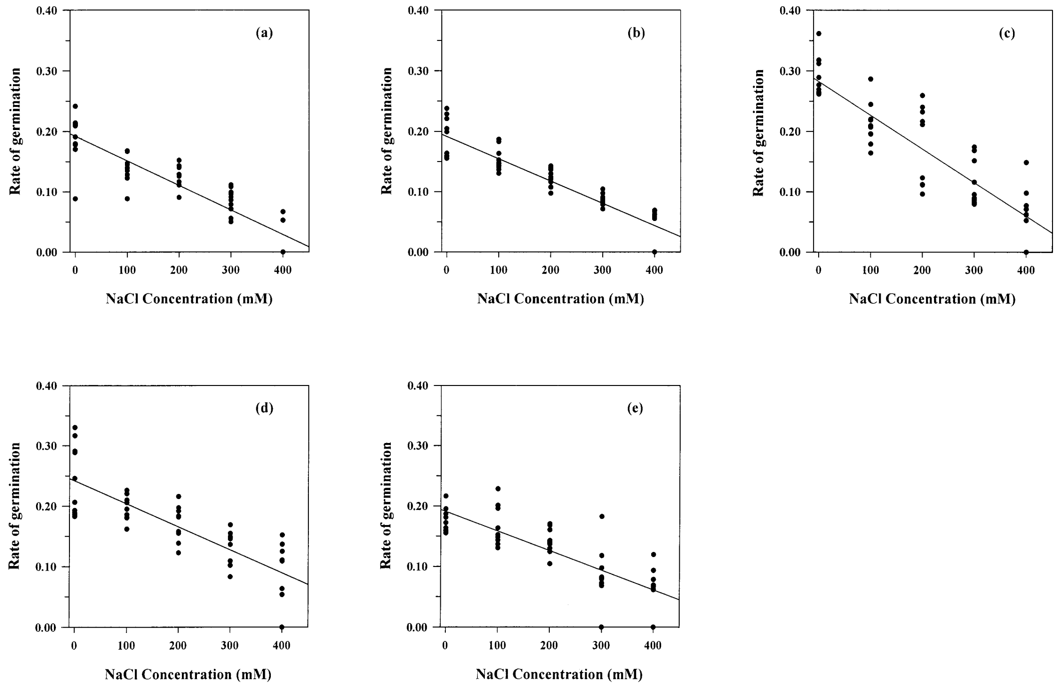

FIGURE 4. Relationship between rate of germination and salinity concentration for common ragweed seeds collected from two agricultural field populations, a rural roadside, and two highway populations. Regression equations are (a) Field 1: $0.192 - 0.0004x$, $r^2 = 0.80$; (b) Field 2: $0.192 - 0.0004x$, $r^2 = 0.84$; (c) Rural: $0.282 - 0.0006x$, $r^2 = 0.77$; (d) Highway 1: $0.242 - 0.0004x$, $r^2 = 0.65$; (e) Highway 2: $0.191 - 0.0003x$, $r^2 = 0.63$.

salts) vs. a high-salinity site (1.3% total soil salts) when subjected to different NaCl concentrations. Similarly, Kiang (1982) found increased germination tolerance to salinity of sweet vernalgrass (*Anthoxantum odoratum* L.) from a roadside vs. pasture population in New Hampshire, United States. Greipsson and Davy (1994) found that caryopses of coastal populations of lymegrass [*Leymus arenarius* (L.) Hochst.] in Iceland showed significantly greater total germination and more rapid germination in 100 and 300 mM L^{-1} NaCl solutions than inland populations.

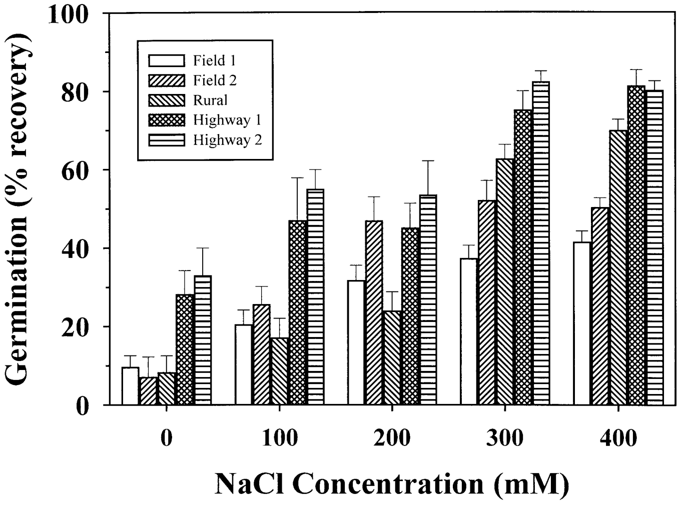

FIGURE 5. Percentage recovery of germination (± SE) in distilled water over 14 d for common ragweed seeds collected from two agricultural field populations, a rural roadside, and two highway populations after being subjected for 21 d to salinity concentrations of (a) 0 mM L^{-1}, (b) 100 mM L^{-1}, (c) 200 mM L^{-1}, (d) 300 mM L^{-1}, and (e) 400 mM L^{-1}.

Ability to Recover from Salinity Stress

Seeds in roadside soils may be subjected to high salinity concentrations soon after snowmelt but salt concentrations usually decrease as leaching or dilution of the saline solution occurs after precipitation events. Thus, the recovery germination trial simulated conditions typically found on roadside soils in early spring. Total germination after the 14-d recovery trial was significantly affected by common ragweed population, salinity concentration, and their interaction ($P = 0.023$). When viable, nongerminated seeds were transferred to the distilled water plates after 21 d of the salinity trial, the recovery germination percentages generally increased with increasing pretransfer salinity concentration (Figure 5). Mean recovery germination percentages increased to 62 and 64% at the 300 and 400 mM L^{-1} salinity concentrations for the five populations combined. Transfer of nongerminated seeds from the 100 through the 400 mM L^{-1} saline solution treatments to distilled water resulted in a 65% increase in germination of seeds for the two highway populations compared with seeds for the rural roadside (43%) and two agricultural field populations (38%). The greater percentage of seeds from the two highway sites to recover from elevated saline conditions after their transfer to distilled water relative to seeds from the rural roadside and the two agricultural field sites may also favor the early establishment of these plants in more saline habitats. The relatively rapid germination of seeds from the highway populations in the recovery trials suggests that the effect of NaCl on these seeds was not toxic but rather was a reversible osmotic effect that compromised water uptake into the seed (Bajji et al. 2002; Greipsson and Davy 1994).

During the 14-d recovery trial, the germination of additional seeds from the distilled water treatment during the germination trial indicates that the 21-d time frame for monitoring germination may have been too short, especially for the two highway populations (Figure 5). However, common ragweed seeds collected from Highway 1 and 2 had similar rates of germination under nonsaline conditions (distilled water) as seeds collected from the two agricultural fields (Figure 4). Thus, there is no apparent trade-off or loss of competitive advantage in roadside populations exposed to nonsaline conditions.

Despite the greater and faster germination of seeds from the highway populations at high salinity concentrations compared with the agricultural populations, increasing salinity did decrease total germination and germination rate for seeds collected from Highways 1 and 2. This inhibitory effect of salinity on seed germination has also been reported for numerous halophytes (Greipsson and Davy 1994; Lombardo and Saladino 1997; Ungar 1995). In contrast to more temporally stable saline environments such as salt marshes and salt deserts, it is plausible that selective pressure on plants in more transient salinity environments such as roadways may not be as long or intense as in hypersaline habitats. Therefore, any local adaptation to saline conditions found along roadways may be manifested only in the seed germination phase of the life cycle where maximum benefits may be achieved. Although seedling vigor or plant growth under different saline conditions was not examined, it is likely that the high saline conditions typically found near major roadways receiving deicing salt would be present for only a relatively short period of time (2 to 3 wk) because snowmelt water and precipitation move the saline solution out of the top layer of soil to lower soil depths in spring. Thus, at high salinity concentrations under these conditions, germination of seeds is likely a more beneficial adaptation than is later seedling tolerance to salinity. Early plant growth of common ragweed and other plants growing along roadways would likely be limited more by other abiotic factors such as drought, soil fertility, disturbance, and tolerance to heavy metals than necessarily by soil salinity concentrations (Vickers and Zak 1978; Ward et al. 1977). This view is consistent with preliminary findings showing that 2-wk-old common ragweed seedlings from Highway 1 did not exhibit greater survival or performance during a 21-d period across a salinity gradient (50 to 400 mM L^{-1}) relative to seedlings from agricultural field populations (S. Hyun Eom, personal communication). By contrast, Rahman and Ungar (1990) showed that at a 272 mM L^{-1} NaCl concentration, the height of barnyardgrass seedlings grown from seeds of a high salinity site was only reduced by 38% whereas the height of seedlings grown from seeds of a low salinity site was reduced by 72%. Cheplick and White (2002) reported that coastal populations of purple sandgrass [*Triplasis purpurea* (Walt.) Chapm.] did not exhibit local adaptation to airborne saltwater sprays. Similarly, Rothfels et al. (2002) found that 4-mo-old damesrocket (*Hesperis matronalis* L.) roadside plants near Hamilton, Ontario, Canada, did not show local adaptation to salinity (two 100-ml applications of 50 mM L^{-1} NaCl solution 1 mo apart) compared with old-field plants. These workers suggested that selection pressure for NaCl tolerance at the seedling stage might be more intense than at more mature plant stages.

Local Adaptation

The ability of some plant populations to adapt to heterogeneous environments can allow them to successfully colonize a wide range of habitats (Miller and Fowler 1994; Van Tienderen and Van Der Toorn 1991). Local selection pressure and genetic variation within populations will be important determinants of the ability of plant populations to adapt to a given habitat (Rice and Mack 1991; Slatkin 1987). The findings of this study are consistent with the hypothesis that observed differences in germination behavior of common ragweed seeds collected from roadside vs. agricultural populations are the result of local adaptation of roadside plants to the high salinity levels found along roadways. The substantially greater percentage of seeds from the highway populations germinating at the two highest salinity concentrations of 300 and 400 mM L^{-1} would be adaptive because it affords plants from these populations an early competitive advantage over later germinating seeds in roadside habitats. Timing of germination and emergence are critical factors influencing competitive hierarchies and competitive outcomes between plant species (Harper 1977).

Another possibility that cannot be ruled out from this study is that salinity stress experienced by roadside plants resulted in seeds with different germinabilities (i.e., maternal effects). Variations in the growing environment of parent plants from such factors as moisture and temperature stress have been shown to affect the ability of their seeds to germinate (C. C. Baskin and J. M. Baskin 1998; Gutterman 2000). Although such maternal effects have been shown to influence the overall seed dormancy level, few studies have demonstrated changes in the responsiveness of seeds to chemicals present in the germination medium. If maternal environment were found to be primarily responsible for the observed differences in seed germination behavior, then such a response would be considered a generalized adaptive feature of the species and not a local adaptation to a given habitat. To address this, future research should include the growing of plants from seeds collected in the roadside and agricultural field sites under a common environment and then testing their ability to germinate under the various salinity concentrations.

Implications for Roadside Vegetation Management

In vegetation surveys, DiTommaso and Massicotte (2002) found common ragweed to be the dominant plant species within the first 0.5 m of roadside and hypothesized that the ability of seeds from this plant to germinate under the high salinity concentrations in early to mid-spring may be responsible for the prevalence of this plant in these areas. Research by DiTommaso et al. (2000) showed that cultivars of several species considered suitable for roadside revegetation projects (white clover [*Trifolium repens* L.], perennial ryegrass [*Lolium perenne* L.], birdsfoot trefoil [*Lotus corniculatus* L.], and black medic) often have poor or delayed seed germination under moderate (200 mM L^{-1}) to high (300–400 mM L^{-1}) saline conditions. This reduced ability of seeds from groundcover species to germinate under elevated salinity concentrations may explain the reported failures of roadside revegetation projects in northeastern regions of North America (DiTommaso and Massicotte 2002; DiTommaso et al. 2002). Thus, more testing and selection of salt-tolerant low-growing perennials suitable for establishment along roadway verges is warranted. The inadvertent removal of established vegetation by snow-removal machinery during the winter months also favors the establishment of common ragweed along roadways because this species thrives in frequently disturbed habitats (Bazzaz 1974; Maryushkina 1991).

Findings from this study are consistent with the hypothesis that the germination behavior of common ragweed seeds from roadside populations is better adapted to the high salinity concentrations found in roadside soils than seeds from agricultural field populations. This greater ability of seeds from roadside plants to germinate at higher salinity levels and establish early may afford them a competitive advantage over other plant species and may explain why common ragweed is so abundant along roadside habitats in northeastern North America that receive large quantities of deicing salt each winter.

Sources of Materials

[1] Fisherbrand size P8 filter paper. Fisher Scientific Laboratory Equipment Division, 600 Business Center Drive, Pittsburgh, PA 15205.

[2] Parafilm. Pechiney Plastic Packaging Inc., 8770 West Bryn Mawr Avenue, Chicago, IL 60631.

[3] Statistical Analysis Systems (SAS) software, version 8. SAS Institute Inc., Box 8000, SAS Circle, Cary, NC 27513.

[4] SigmaPlot software, version 6.0. SPSS Inc., 233 Wacker Drive, Chicago, IL 60606.

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