Emergence and root growth of three pregerminated cool-season grasses under salt and water stress

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Abstract

Reclaiming salt-affected soils under semiarid conditions without irrigation is difficult. High salt concentrations both delay and decrease germination and emergence, which increases the time a soil must remain moist for germination and emergence to take place. Delayed germination can also affect a plant's capability to withstand summer drought because of limited root development. Cultural practices that encourage rapid growth at conditions suboptimal for germination should increase seedling emergence and reduce moisture requirements for emergence. We determined from greenhouse studies the effects of different levels of soil salinity and soil water on emergence and on root and shoot growth of 3 pregerminated cool-season grasses: 'Nordan' crested wheatgrass *(Agropyron desertorum)* (L.) Gaertn.), 'Flintlock' western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), and 'Vinall' Russian wildrye (*Psathyrostachys juncea* (Fischer) Nevski). Seed pregerminated prior to sowing resulted in more rapid emergence than untreated seed for all species at all levels of soil salinity and soil water. Salinity and water stress delayed and/or reduced emergence more in the untreated than pregerminated seed of Russian wildrye and western wheatgrass. Pregerminating seed before planting also resulted in greater root biomass for all species and greater root lengths for the 2 wheatgrass species than did untreated seed.

Key Words: germination, saline soil, seeding, seed treatment

Saltgrass meadows occupy an estimated 500,000 ha in Colorado and Wyoming (Osborn 1974). These meadows are frequently more moist than upland sites and have good production potential if low-value saltgrass is replaced by more palatable species (Ludwig and McGinnies 1978). However, reclaiming salt-affected soils under semiarid conditions without irrigation is difficult. Most grass seed are small and must be seeded at shallow depths. Seedlings are subjected to stress from extreme temperatures, strong winds, and excessive evaporation (Cook et al. 1974). Salt accumulation near the surface of saline soils can create an even harsher environment for germinating seed. High soluble salt concentrations decrease both germination rate and final germination percentage (Uhvits 1946, Millington et al. 1951, Dewey 1962). The longer it takes for a species to germinate, the longer the soil must remain moist, thereby increasing the amount of water required for germination and emergence. Delayed germination also delays root growth, which results in increased stress from summer drought.

Cultural practices which encourage rapid growth at conditions suboptimal for germination should increase seedling emergence and reduce moisture requirements during emergence. Hauser (1983) showed that grass seed that was germinated before sowing (pregerminated seed) emerged sooner and produced more plants than conventionally sown seed (untreated seed). Many plants are more sensitive to salinity during germination than in later stages of growth (U.S. Salinity Laboratory Staff 1954, Ross and Hegarty 1979). Two greenhouse studies were initiated under different levels of soil salinity (measured as electrical conductivity, EC) and soil water to compare emergence and root and shoot growth of plants grown from pregerminated and untreated cool-season grass seed: 'Nordan' crested wheatgrass *(Agropyron desertorum)* (L.) Gaertn.), 'Flintlock' western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), and 'Vinall' Russian wildrye (*Psathyrostachys juncea* (Fischer) Nevski).

Materials and Methods

The studies used seed which was pregerminated in a growth chamber and had radicles less than or equal to 3 mm in length. One-hundred seed per standard germination dish (32.5 × 33.8 × 7.5-cm) were germinated on Kimpac[1] and blotter paper soaked with 100 ml of distilled water. Crested wheatgrass and Russian wildrye were germinated in an 8-hr light period at 30° C alternating with a 16-hr dark period at 20° C. Western wheatgrass was germinated in the dark at temperatures that alternated between 15° C for 16 hr and 30° C for 8 hr [Association of Official Seed Analysts (AOSA) 1981].

Study I

The effects of 4 levels of salinity (0, 4, 8, and 16 dS/m) on the emergence of untreated, untreated + gel, and pregerminated seed were evaluated in Study I. The study design consisted of a randomized block with 4 replications. Approximately 2 ml of SGP[2] gel was applied to each pregerminated and untreated + gel seed before sowing. The gel prevents damage to the radicle during sowing of pregerminated seed (Searcy and Roth 1981). Fifty seed per treatment were planted 1.25-cm deep in 60 × 40 × 7.5-cm plastic lined flats in an Ascalon sandy loam soil, previously screened through 1.25-cm openings. The Ascalon sandy loam soil is a fine-loamy, mixed, mesic Aridic Argiustoll.

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[1]Mention of any trade name is for information only and does not imply endorsement.
[2]SGP Absorbent Polymer is a General Mills Chemicals' trade name for a "super" polymer composed of a natural polymer and a synthetic polymer made of acrylamids and sodium (or potassium) acrylate. SGP is manufactured under a USDA patent license and is available from the Henkle Corp., 4620 W. 77th Street, Minneapolis, Minn. 55435.

Table 1. Initial emergence (days) and emergence 17 days after planting (%) of crested wheatgrass, western wheatgrass, and Russian wildrye pregerminated and untreated seed at 4 soil salinity levels (EC).

Species	Emergence	Seed treatment	EC (dS/m) 0	4	8	16	Means
					days		
Crested wheatgrass	Initial	Pregerm	2.0	2.5	2.3	4.0	2.7x
		Untreated	5.0	4.8	6.3	8.8	6.2y
		Means	3.5a	3.6a	4.3a	6.4b	
					%		
	Seventeen days after planting	Pregerm	89.5	83.5	62.5	50.5	71.4y
		Untreated	77.0	75.3	36.8	33.9	55.8x
		Means	83.3b	79.4b	49.4a	42.2a	
					days		
Western wheatgrass	Initial	Pregerm	3.1	2.7	3.7	5.3	3.7x
		Untreated	8.3	7.2	9.8	11.5	9.2y
		Means	5.7ab	4.9a	6.8b	8.4c	
					%		
	Seventeen days after planting	Pregerm	89.5	87.5	78.5	70.0	81.4y
		Untreated	85.4	79.7	55.7	47.0	66.9x
		Means	87.4b	83.6b	67.1a	58.5a	
					days		
Russian wildrye	Initial	Pregerm	2.3a	2.3a	3.0a	3.3a	2.7
		Untreated	5.8a	6.0a	7.8b	10.5c	7.5
		Means	4.1	4.1	5.4	6.9	
					%		
	Seventeen days after	Pregerm	79.0b	68.5b	69.0b	49.0a	66.4a
		Untreated	80.3	79.0c	59.2b	21.7a	60.0
		Means	79.6	73.7	64.1	35.4	

[1]Means with the same letter are not significantly different ($P \leq 0.05$). The letters a through c are used for comparisons within rows and the letters x through y are used for comparisons within columns. Where there is a significant interaction, significant differences between main effects are not shown. Where there is no significant interaction, significant differences between just main effects are shown.

Salinity treatments were prepared using a solution of NaCl and $CaCl_2$ that gave the desired EC from a saturated extract (U.S. Salinity Laboratory Staff 1954). The saline solution was added to the soil before planting. Calcium chloride was used to keep the sodium adsorption ratio (SAR) below 3 (U.S. Salinity Laboratory Staff 1954). Electrical conductivity of the saturated extract was determined at the end of the study on soil samples randomly taken from the surface (0-2.5 cm) of each treatment. Treatment EC's at the end of the study period were 2.3, 3.8, 8.7, and 17.4 dS/m. Osmotic potentials calculated from treatment EC's obtained at the end of the study were approximately –0.27, –0.28, –0.63, and –1.27 MPa, respectively, at container capacity (CC) (U.S. Salinity Laboratory Staff 1954, Rawlins and Campbell 1986). Container capacity (Cassel and Nielson 1986) was maintained gravimetrically at 19% throughout the 17-day study period (13 June 1985 – 9 July 1985). Plastic linings prevented salts from leaching out the bottom of the flats. Greenhouse temperatures averaged 18° C at night and 33° C during the day. Emergence measurements were taken daily the first week and every other day the following 10 days.

Study II

The effects of 3 soil water treatments (wet, moderately dry, and dry), and 2 soil salinity levels (0 and 8 dS/m) on emergence and root and shoot weights and lengths of untreated and pregerminated seed were evaluated in Study II. Polyvinyl chloride cylinders measuring 20 × 60 cm were sealed at the bottom with redwood disks and silicon. Each cylinder contained the same screened Ascalon sandy loam soil used in Study I. The study consisted of a randomized complete block with 3 replications.

The wet treatment was maintained near CC by weighing water into each cylinder daily throughout the 24-day study period. Soil water contents for the moderately dry and dry treatments were obtained by bringing the cylinders to CC and then allowing them to dry 7 and 14 days, respectively, before planting. After planting no additional water was added to these treatments. Soil water was determined gravimetrically on planting day (12 July 1986) and 3, 7, 11, and 18 days after at depths of 0-2.5, 2.5-5.0, 5.0–7.5, and 7.5–18.75 cm. Soil water contents of 15.05, 10.13, 7.87, and 7.06% were determined for matric potentials of –0.03, –0.1, –0.3 and –1.5 MPa, respectively (Klute 1986). Soil water content at the surface (0–2.5 cm) during planting was 11% for the moderately dry and 9% for the dry treatment, which resulted in matric potentials of approximately –0.09 and –0.17 MPa, respectively. After 17 days, soil water content at the surface for the moderately dry and dry treatments was less than 1% (Fig. 1).

Each cylinder contained 16 seeds from a single seed treatment. Both pregerminated and untreated seed were planted 1.25-cm deep in holes that had been punched in the soil. A syringe was used to inject gel (2 ml/seed) into each hole containing a pregerminated seed. The seeds were then covered with soil.

Artificial lighting (569 uE/s/m^2) was set to come on at 0600 and go off at 2000 hr each day. Temperatures ranged from 38° C in the day to 19° C at night.

Emergence was measured daily the first week and every other day the following 17 days. The cylinders were split open at the end of the study period (24 days), the soil was washed away, and the root and shoot weights and lengths were measured.

For comparison with emergence from pregerminated seed, emergence from untreated seed was expressed as percentage of pure-live-seed (PLS). PLS determination was by AOSA (1981) methods.

The term 'initial emergence' is used throughout the discussion as

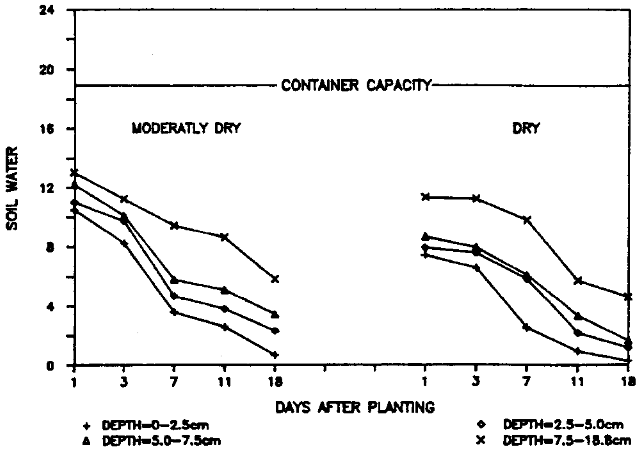

Fig. 1. *Relationship between percent soil water at 4 depths and number of days without supplemental water in both the moderately dry and dry treatments.*

the day emergence was first observed within a treatment and a species. The use of initial emergence makes it possible to determine whether treatment effects on rate of emergence are due to a change in emergence time.

Study I and II

Standard analysis of variance techniques were used in both studies to compare initial and total emergence. Duncan's new multiple range test was used for mean separation. There were no significant differences between untreated and untreated + gel treatments in Study I or between salinity treatments in Study II; therefore, these treatments were combined in the final statistical analysis after their variances were found to be homogeneous. Unless otherwise stated, all tests of significance were at $P \leq 0.05$.

Results

Study I

High salinity (8 and 16 dS/m) delayed initial emergence for untreated Russian wildrye seed. The 16 dS/m salinity level also delayed initial emergence for both pregerminated and untreated seed of crested and western wheatgrass (Table 1). Emergence for both seed treatments and all 3 species continued to be delayed by salinity after initial emergence had taken place (Fig. 2).

Total emergence for pregerminated crested and western wheatgrass seed was greater than total emergence for the respective untreated seed (Table 1). A significant seed treatment by salinity interaction ($P \leq 0.10$) was exhibited for western wheatgrass. Total emergence for untreated but not for pregerminated western wheatgrass seed was lowered by salinity levels of 8 and 16 dS/m (Table 1). A seed treatment by salinity interaction also occurred for Russian wildrye. There was a more rapid and a more pronounced decrease in total emergence with increasing salinity for the untreated than for the pregerminated seed (Table 1).

Study II

Salinity slowed and reduced emergence in both studies. However, salinity affects were not significant in Study II because of

Table 2. Initial emergence (days) and emergence 24 days after planting (%) of crested wheatgrass, western wheatgrass, and Russian wildrye pregerminated and untreated seed at 3 soil water levels.

Species	Emergence	Seed treatment	Water levels FC	Mod Dry	Dry	Means
			days			
Crested wheatgrass	Initial	Pregerm	2.5	2.8	2.8	2.7x
		Untreated	4.3	4.0	5.5	4.6y
		Means	3.4a	3.4a	4.1a	
			%			
	Twentyfour days after planting	Pregerm	59.4	34.4	42.2	45.3x
		Untreated	57.5	48.5	47.0	51.0x
		Means	58.4b	41.4a	44.6a	
			days			
Western wheatgrass	Initial	Pregerm	2.8a	2.5a	3.0a	2.8
		Untreated	7.3a	7.0a	11.0b	8.4
		Means	5.0	4.8	7.0	
			%			
	Twentyfour days after planting	Pregerm	79.7	56.3	46.9	61.0y
		Untreated	74.3	17.8	9.5	33.9x
		Means	77.0b	37.0a	28.2a	
			days			
Russian wildrye	Initial	Pregerm	3.0a	2.5a	3.3a	2.9
		Untreated	6.5a	6.5a	11.0b	8.0
		Means	4.7	4.5	7.1	
			%			
	Twentyfour days after planting	Pregerm	42.2b	48.4b	43.8a	44.8
		Untreated	49.3c	28.8b	17.8a	32.0
		Means	45.8	38.6	30.8	

[1]Means with the same letter are not significantly different ($P \leq 0.05$). The letters a through c are used for comparisons within rows and the letters x through y are used for comparisons within columns. Where there is a significant interaction, significant differences between main effects are not shown. Where there is no significant interaction, significant differences between just main effects are shown.

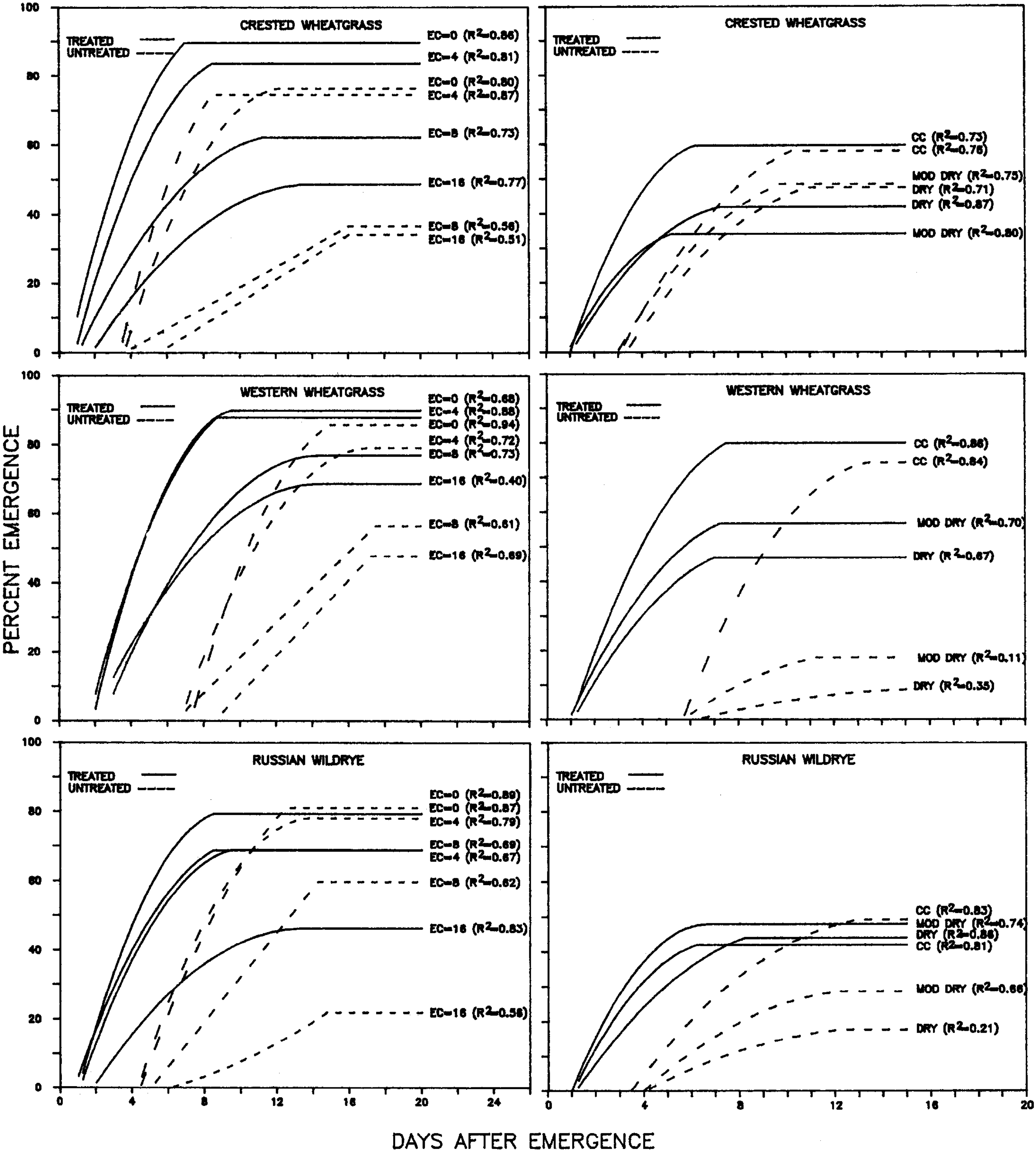

Fig. 2. *Relationship between time (days) and percent emergence of crested wheatgrass, western wheatgrass, and Russian wildrye from pregerminated and untreated seed at 4 salinity (EC) levels and 3 soil water (%) levels. Regression curves are discontinued at total emergence.*

Table 3. Root and shoot weight (mg) and length (cm) of crested wheatgrass, western wheatgrass, and Russian wildrye grown from pre-germinated and untreated seed at 3 soil water levels.

Species	Plant Measurement	Seed treatment	Water levels FC	Mod Dry	Dry	Means
			mg			
Crested wheatgrass	Root weight	Pregerm	34.3	25.7	20.3	26.8y
		Untreated	21.2	8.7	11.8	13.9x
		Means	27.8a	17.2a	16.1a	
			mg			
	Shoot weight	Pregerm	77.0	54.3	29.5	77.0y
		Untreated	49.0	30.0	35.8	38.3x
		Means	63.0b	42.2a	32.7a	
			cm			
	Root length	Pregerm	34.0	40.7	36.8	37.2y
		Untreated	28.2	23.0	30.8	27.3x
		Means	31.1a	31.9a	33.8a	
			cm			
	Shoot length	Pregerm	23.5	17.7	17.5	19.6x
		Untreated	21.8	13.2	17.3	17.4x
		Means	22.7b	15.5a	17.4a	
			mg			
Western wheatgrass	Root Weight	Pregerm	13.3	19.7	9.7	14.2y
		Untreated	13.2	7.8	6.5	9.2x
		Means	13.3a	13.8a	8.1a	
			mg			
	Shoot weight	Pregerm	51.0	45.0	36.0	44.0x
		Untreated	41.5	32.0	24.7	32.7x
		Means	46.3a	38.5a	30.4a	
			cm			
	Root length	Pregerm	28.2	29.6	31.0	29.6y
		Untreated	21.3	22.2	23.0	22.2x
		Means	24.8a	25.9a	27.0a	
			cm			
	Shoot length	Pregerm	19.3	17.0	15.7	17.3x
		Untreated	17.0	13.8	14.3	15.1x
		Means	18.2a	15.4a	15.0a	
			mg			
Russian wildrye	Root weight	Pregerm	26.5	23.5	6.8	18.9y
		Untreated	12.3	5.2	9.2	8.9x
		Means	19.4b	14.4b	8.0a	
			mg			
	Shoot weight	Pregerm	37.2b	46.7b	13.2a	32.3
		Untreated	25.5b	14.8a	16.2a	18.8
		Means	31.4	30.8	14.7	
			cm			
	Root length	Pregerm	25.0	33.5	20.8	26.4x
		Untreated	23.8	18.5	26.3	22.9x
		Means	24.4a	26.0a	23.6a	
			cm			
	Shoot length	Pregerm	17.3	17.2	11.8	15.4x
		Untreated	17.2	11.8	13.0	14.0x
		Means	17.3b	14.5ab	12.4a	

[1]Means with the same letter are not significantly different ($P \leq 0.05$). The letters a through c are used for comparisons within rows and the letters x through y are used for comparisons within columns. Where there is a significant interaction, significant differences between main effects are not shown. Where there is no significant interaction, significant differences between just main effects are shown.

variability in evaporation between cylinders, so those treatments were combined in Table 2.

Western wheatgrass and Russian wildrye failed to emerge from untreated seed in several of the moderately dry and/or dry treatment cylinders, which increased the variability between cylinders within these treatments. The increased variability obscured significant differences between western wheatgrass seed treatment correlation coefficients in the moderately dry and dry treatments, and between Russian wildrye seed treatment correlation coefficients in the dry treatment. However, a visual observation of the dry treatment regression lines for both species show that water stress delayed emergence from untreated seed more than pregerminated seed after initial emergence (Fig. 2). Water stress slowed emergence from untreated more than pregerminated Russian wildrye and western wheatgrass seed by delaying initial emergence from the untreated seed (Table 2). Decreasing soil water content had no effect on crested wheatgrass initial emergence (Table 2) or rate of emergence after initial emergence (Fig. 2).

Total emergence of western wheatgrass and Russian wildrye was lower for untreated than pregerminated seed for both the moderately dry and dry soil water treatments (Table 2). Crested wheatgrass grown from pregerminated seed gave the same total emergence as crested wheatgrass grown from untreated seed for all soil water treatments (Table 2).

Root weights of crested wheatgrass and Russian wildrye plants grown from pregerminated seed were 93, 54, and 112% greater, respectively, than root weights of plants grown from untreated seed (Table 3). Pregerminating crested and western wheatgrass seed before planting resulted in 36% and 33% greater root lengths than those obtained from untreated seed. Russian wildrye roots were much more fragile than the roots of the other species. Loss during separation of roots from the soil is believed to account for the lack of differences in root lengths between Russian wildrye seed treatments.

Shoot weights of Russian wildrye were lower for plants grown from untreated rather than pregerminated seed at the moderately dry soil water treatment (Table 3); however no differences between seed treatments were found at the dry soil water treatment. Although not statistically significant, root weights of Russian wildrye and root and shoot weights of western wheatgrass grown from untreated seed were lower at the moderately dry and dry soil water treatments than root weights of the same species grown from pre-germinated seed (Table 3).

Seed treatments did not affect shoot length in any of the species. Soil water treatments, however, did affect shoot lengths. Shoot lengths of crested wheatgrass and Russian wildrye were reduced by moderately dry and dry treatments (Table 3). Western wheatgrass shoot length was also reduced by lack of soil water ($P \leq 0.10$).

Discussion and Conclusions

Russian wildrye and western wheatgrass seed take longer to germinate than crested wheatgrass seed. Untreated seed began to germinate in about 4 days for Russian wildrye and 5 days for western wheatgrass. Surface soil water in the dry treatment dropped from 9% to approximately 5.4% in 4 days and from 9% to 4.2% in 5 days (Fig. 1). Matric potentials went from approximately −0.17 MPa to less than −1.5 MPa before seed began to germinate. Thus, a slow germination rate allowed the soil to dry at planting depth prior to and during the onset of germination, which progressively delayed and/or prevented emergence (Fig. 2). Growth leading to emergence from pregerminated seed begins almost immediately after planting. Therefore, plants grown from pregerminated seed were able to take advantage of the more favorable surface soil water conditions that existed at planting (9% for dry treatment) and send roots down into moist soil (Fig. 1 and 2).

Ludwig (1976) has shown Russian wildrye to be more sensitive to NaCl-induced osmotic stress during germination than other grass species, including crested wheatgrass. McGinnies (1960) attributed Russian wildrye's poor field establishment to water stress during germination. In both Studies I and II, Russian wildrye emerged more rapidly from pregerminated than untreated seed. Emergence of Russian wildrye and western wheatgrass from pregerminated seed was less affected by NaCl, water stress, and drying after planting than emergence from untreated seed. Therefore, planting pregerminated seed is a promising technique for establishing Russian wildrye and western wheatgrass under saline conditions. The greater root biomass in all 3 species and greater root length in crested and western wheatgrass should aid in establishment and survival of plants from pregerminated seed over those from untreated seed during critical early stages of seedling development. However, to insure successful field planting of pregerminated seed, cultural practices need to be developed that prevent and/or minimize desiccation of the radicle. The ability of seedlings from pregerminated seed to rapidly establish roots in deeper moist soil under high osmotic stress reduces the number of days the soil surface must remain wet for seedling establishment. Therefore, practices could include planting in wet soil and/or planting during predicted periods of extended rainfall (3 to 4 days). The use of irrigation may also become more economical with pregerminated seed because less water would be needed for initial establishment.

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