RESEARCH

Effects of Soil Texture, Watering Frequency, and a Hydrogel on the Emergence and Survival of Coated and Uncoated Crested Wheatgrass Seeds

by Jane M. Mangold and Roger L. Sheley

ABSTRACT

Revegetation of degraded shrub-steppe often fails due to intense competition from weeds, highly variable environmental conditions, and limited soil moisture. The objective of this study was to test whether a commercially available seed coating and a water-retaining acrylamide copolymer hydrogel would increase seedling emergence and establishment of crested wheatgrass (*Agropyron cristatum*) under three watering frequencies and two soil textures. Pots were filled with one of four soil treatments: field soil, two parts field soil mixed with one part sand, field soil plus hydrogel, or field soil plus sand plus hydrogel. We seeded the pots with coated or uncoated seed and placed them in a greenhouse for 66 days. The pots were assigned one of three watering treatments: 4.5 oz (150 ml) applied one time per week, 1.5 oz (50 ml) applied three times per week, or 0.9 oz (30 ml) applied five times per week. We recorded seedling emergence at three and six weeks. At the end of 66 days, the numbers of seedlings that survived were counted and above ground biomass was collected, dried, and weighed. We found that uncoated seed had 1.6 times greater seedling density than coated seed. Incorporation of the acrylamide copolymer hydrogel into the potting medium conferred some benefit to emergence, biomass, and survivorship of crested wheatgrass seedlings. However, it was watering frequency that produced the most consistent influence on seedling emergence, survival, and biomass. Watering three or five times per week increased emergence more than watering one time per week, but watering one time per week generally led to greater survivorship and biomass. This suggests that the use of water-retaining hydrogels may help to overcome soil moisture limitations and improve seedling establishment during revegetation of degraded shrub-steppe.

Keywords: revegetation, seed coating, seed conditioner, seedling emergence, Great Basin, shrub-steppe vegetation

Noxious weeds, improper grazing, frequent and intense wildfires, recreational activities, prolonged drought, mining, logging, and gas and oil exploration have degraded large areas within the Great Basin shrub-steppe of the western United States (Monsen and McArthur 1995). Shrub-steppe, which is typically populated by native, perennial species, may now be dominated by exotic, weedy, annual species. For example, much of the Snake River Plains in southern Idaho is vegetated by cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola iberica*), and tumble mustard (*Sisymbrium altissimum*). Dominance by exotic annuals can dramatically influence plant community composition, alter water, nutrient, and fire cycles, and decrease forage for wildlife and livestock (Mosley and others 1999).

In many cases, Great Basin soils, and the native vegetation they supported, have declined to the point where intense restoration efforts are now required to achieve a desired plant community. However, restoration of degraded shrub-steppe is challenging and fails more often than it succeeds (Pellant 1990, Allen 1995, Monsen and McArthur 1995). Instead, increasing emphasis is being placed on re-establishing perennial vegetation to restore properly functioning ecological processes, regardless of whether natives, native cultivars, or introduced species are used (Whisenant 1999). It is certainly true that properly functioning processes are critical to preventing further degradation and desertification of shrub-steppe. For example, cheatgrass dominance on shrub-steppe shortens the fire-return interval by creating more continuous fuel than perennial bunchgrasses. The shortened fire-return interval decreases species richness, with the dominant species being introduced annuals, thus perpetuating frequent fires (Whisenant 1990). One of the goals of the Bureau of Land Management is to establish perennial vegetation on shrub-steppe dominated by cheatgrass in an effort to restore the historical fire-return interval (J. Rose, personal communication).

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One restoration method that has been used to achieve this goal is assisted succession. Assisted succession is a technique designed to restore perennial vegetation on degraded shrub-steppe, especially areas dominated by invasive annual grasses and perennial forbs (Jones 1997, Roundy and others 1997). This two-step approach attempts to initially occupy the degraded site with an aggressive perennial, like crested wheatgrass (*Agropyron cristatum*), followed by niche opening and reinsertion of species native to the predisturbance plant community (Cox and Anderson 2004). Cox and Anderson (2004) found that native seedling emergence was greater in areas dominated by crested wheatgrass compared to areas dominated by cheatgrass and other annuals. However, seeding of crested wheatgrass and other introduced perennial grasses often results in poor establishment due to intense competition from weeds, highly variable environmental conditions, and limited soil moisture (Allen 1995).

Given these problems, researchers have begun to look to existing horticultural amendments, such as seed coatings and water-retaining polymers, as possible ways to achieve greater success in shrub-steppe plantings. Seed coatings have been developed that are purported to aid in the application and success of plantings. These coatings often contain mycorrhizal and beneficial algae and bacterial inoculums, fungicides, nutrients, vitamins, growth hormones, and/or absorbent polymers (Kaufman 1991). Polymers that absorb more than one hundred times their weight in water have been developed to reduce the necessity of frequent watering and to prevent plant losses due to drought and water stress (Johnson 1984, Wang and Boogher 1987, Callaghan and others 1988). Although these products have been primarily used in agronomic and horticultural settings, their application may help overcome factors that limit establishment of seeded species during restoration of shrub-steppe infested with exotic annual grasses.

The objective of this study was to test the effect of a water-absorbing hydrogel and a seed coating on the establishment of crested wheatgrass. We tested these two treatments under three watering frequencies and two soil textures. We hypothesized that the hydrogel and seed coating would increase establishment regardless of watering frequency and soil texture. Furthermore, we hypothesized that the beneficial effect of hydrogel and seed coating would be greater when the watering frequency was lowest and the soil texture was most sandy.

Materials and Methods

We conducted this study in a greenhouse at the Eastern Oregon Agricultural Research Center (EOARC) in Burns, Oregon from August 30, 2004 to November 3, 2004. Low and high temperatures and average humidity in the greenhouse were collected daily (Figure 1). No supplemental lighting was used.

In order to create our soil treatments, we collected field soil from a site about 15 miles (9 km) west of Burns. The soil was a clayey, montmorillonitic, frigid Lithic Argixerol. The soil was sieved to remove large fragments, but not sterilized because we wanted to retain the naturally occurring microbial component. A portion of the soil was mixed with sand in a ratio of two parts soil to one part sand, by weight. We then added a commercially available acrylamide copolymer hydrogel (93 percent potassium polyacrylamide acrylate copolymer, 7 percent water) according to package directions (one teaspoon of the crystals per one gallon of soil) and homogenously distributed it throughout half of the soil and half of the soil plus sand mixture. This resulted in four soil treatments: 1) field soil (F), 2) field soil plus sand (FS), 3) field soil plus sand plus hydrogel (FSH), and 4) field soil plus hydrogel (FH). We placed the four soil mediums in 5.9-inch (15-cm) wide x 4-inch (10.5-cm) deep pots and watered to pot capacity.

Pots were seeded with one of two seed treatments: 1) 20 pellets containing one to three crested wheatgrass seeds treated with a commercially available coating containing mycorrhizal, algae, and beneficial bacillus inoculums, vitamins, growth hormone, calcium carbon, calcium sulfate, and organic carbon chains that serve as an absorbent polymer or 2) 20 uncoated seeds. Seeds or pellets of crested wheatgrass seeds were placed

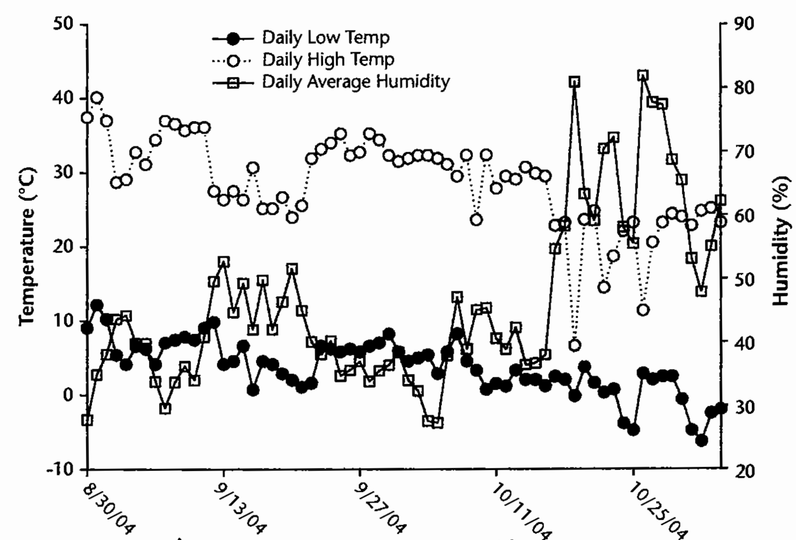

Figure 1. Daily low, high, and average temperatures and percent humidity in greenhouse during the study.

onto the soil surface of each pot and covered with 0.08 inch (2 mm) of the soil medium similar to that already in the pot. Most residual grass seeds were removed during sieving, but some may have emerged that could not be differentiated from crested wheatgrass.

We watered the pots for six weeks during which time they received one of three watering treatments that kept total water added per week at 4.5 oz (150 ml): 1) 4.5 oz, once per week; 2) 1.5 oz (50 ml), three times per week; and 3) 0.9 oz (30 ml), five times per week. Water was applied using a super-fine, 0.5-gallon (1.9-liter) per minute waterfog nozzle.

We replicated the treatments eight times, which resulted in 192 pots (four soil treatments x two seed treatments x three watering treatments x eight replications) arranged in a completely randomized fashion.

We recorded the number of seedlings at three and six weeks after planting. Survivorship percentage was based on the number of seedlings at six weeks. To test whether hydrogel improved seedling survival, we let the pots sit for two weeks following the second seedling count, and then watered them to pot capacity. Seedlings that appeared green and turgid one week after the final watering were considered survivors. We measured the aboveground biomass of survivors by clipping and placing it in paper bags, then drying it for 48 hours at 131° F (55° C), and weighing it.

We used an analysis of variance (ANOVA) to test for treatment effects and interactions on emergence at three and six weeks, survivorship, and aboveground biomass (SAS Institute Inc. 1990). Mean separations for significant ($p \leq 0.05$) main effects and interactions were achieved using Fisher's protected least significant difference ($LSD_{\alpha=0.05}$) comparisons (Peterson 1985).

Results

Seedling Emergence

The number of seedlings emerging three weeks after seeding was affected by the main effect of soil treatment ($p < 0.0001$) and the interaction between seed treatment and watering frequency ($p = 0.040$). Seedling density was highest in the FH treatment (20.4 ± 2.8 seedlings/pot), followed by the F treatment (17.6 ± 2.8 seedlings/pot). The two soils containing sand (FS and FSH) had the lowest seedling densities at 13.0 and 13.7 ± 2.8 seedlings/pot, respectively. Uncoated seed resulted in 1.6 times greater average seedling density than coated seed, regardless of watering frequency (Figure 2a). Coated seed watered three or five times per week resulted in 9.8 and 4.8 fewer seedlings/pot than uncoated seed watered three or five times per week, respectively. Coated seed watered once per week resulted in the lowest seedling density at about 10 seedlings/pot (Figure 2a).

Similar to the number of seedlings emerging three weeks after seeding, the number of seedlings after six weeks was influenced by the interaction of seed treatment and watering frequency ($p = 0.036$). Results were similar to those at three weeks with uncoated seed yielding higher seedling density than coated seed (Figure 2b). In contrast to results at three weeks, though, none of the coated seed densities were similar to any of the uncoated seed densities.

Soil treatment and seed treatment interacted to affect seedling density six weeks after seeding ($p = 0.003$). Uncoated seed yielded higher seedling densities than coated seed across soil treatments (Figure 3). Uncoated seed growing in soil treatments that did not contain sand (F and FH) resulted in seedling densities of 21.8 and 27.5 seedlings/pot, respectively, while coated seed growing in soil treatments that contained sand (FS and FSH) resulted in the lowest seedling density, 9.1 and 11.1 seedlings/pot, respectively (Figure 3).

Seedling Survivorship

Soil treatment and watering frequency interacted to influence seedling survivorship ($p = 0.048$). Survivorship ranged from about 80 to 100 percent (Figure 4). Most of the treatments resulted in survivorship near 100 percent, and two (FSH and FS watered once per week) resulted in survivorship slightly greater than 100 percent. This was due to a few seedlings that emerged after six weeks. The FS treatment watered five times per week, which resulted in 82.2 percent survivorship, was the low end of the range (Figure 4).

Aboveground Seedling Biomass

Seedling biomass was influenced by the interactions of seed treatment and

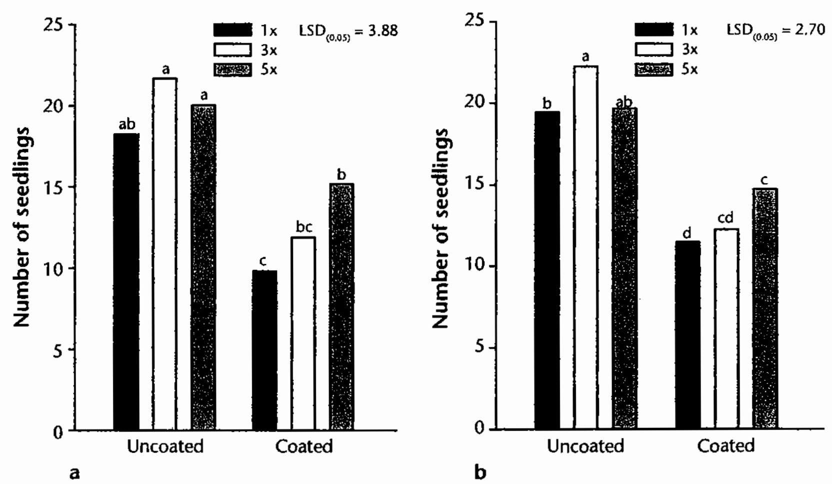

Figure 2. Effect of seed treatment and watering frequency on crested wheatgrass seedling density: a) three weeks after planting and b) six weeks after planting. Watering frequency is one time per week (1x), three times per week (3x), or five times per week (5x).

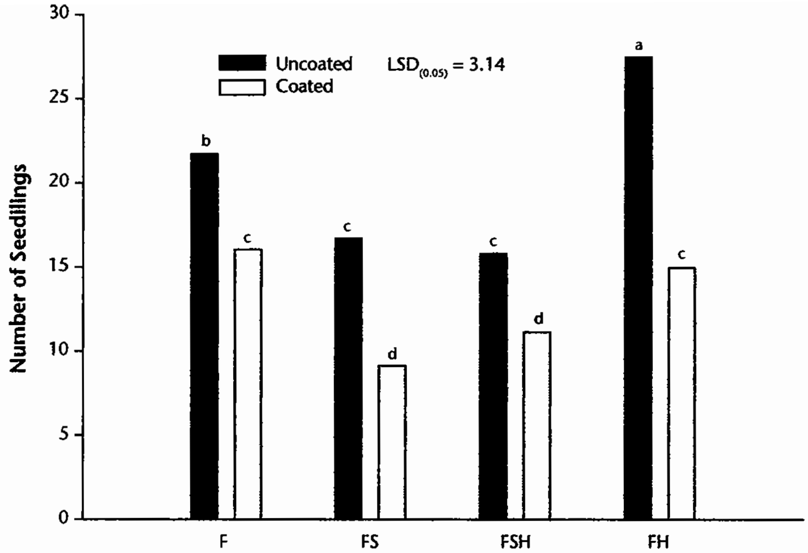

Figure 3. Effect of seed treatment and soil treatment on crested wheatgrass seedling density six weeks after planting. Soil treatments are field soil (F), field soil plus sand (FS), field soil plus sand plus hydrogel (FSH), and field soil plus hydrogel (FH).

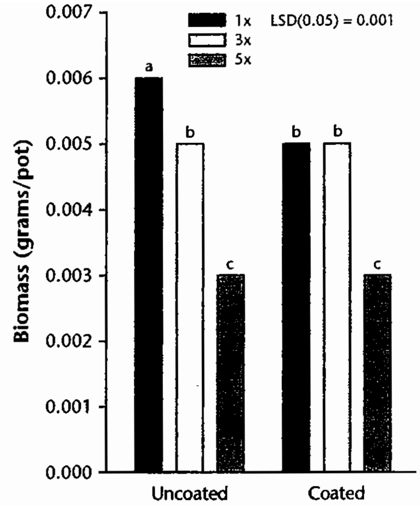

Figure 5. Crested wheatgrass seedling biomass of coated and uncoated crested wheatgrass seedlings. Watering frequency is one time per week (1x), three times per week (3x), or five times per week (5x).

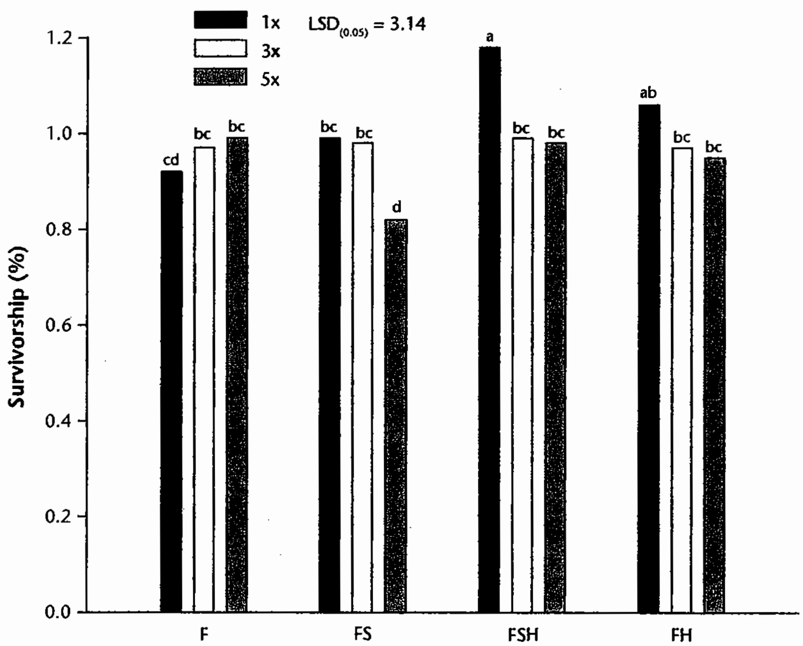

Figure 4. Crested wheatgrass seedling survivorship (%) as affected by soil treatment and watering frequency. Soil treatments are field soil (F), field soil plus sand (FS), field soil plus sand plus hydrogel (FSH), and field soil plus hydrogel (FH). Watering frequency is one time per week (1x), three times per week (3x), or five times per week (5x).

watering frequency (p = 0.001) and soil treatment and watering frequency (p = 0.0002). Watering five times per week generally resulted in the lowest biomass, regardless of seed treatment or soil treatment (Figures 5 and 6). The biomass of seedlings from uncoated seeds watered once per week (0.006 g/seedling) compared to five times per week (0.003 g/seedling) was doubled, and this trend was similar with coated seed as well (Figure 5). Biomass of seedlings watered three times per week was similar across all soil treatments, averaging about 0.005 g (Figure 6). The highest seedling biomass occurred in the FH treatment watered once per week (0.008 g/seedling), and the second highest biomass occurred in the F treatment watered once per week (0.006 g/seedling) (Figure 6).

Discussion and Recommendations

Coating crested wheatgrass seeds with a commercially available performance enhancement product did not appear to confer any benefits to crested wheatgrass establishment. In general, uncoated seed outperformed coated seed in the number of seedlings that emerged, while seedling survivorship and biomass was not affected by either seed treatment. Seed coating may ease handling and provide more precise placement in field situations, especially agronomic applications (Kaufman 1991). Our data suggests, however, that the inclusion of beneficial microbial inoculums, vitamins, hormones, and other chemical compounds to aid crested wheatgrass establishment may not be effective in the short term, and may even hinder emergence when seeding crested wheatgrass for rangeland restoration. Therefore, we failed to accept our hypothesis that seed coating would increase seedling establishment.

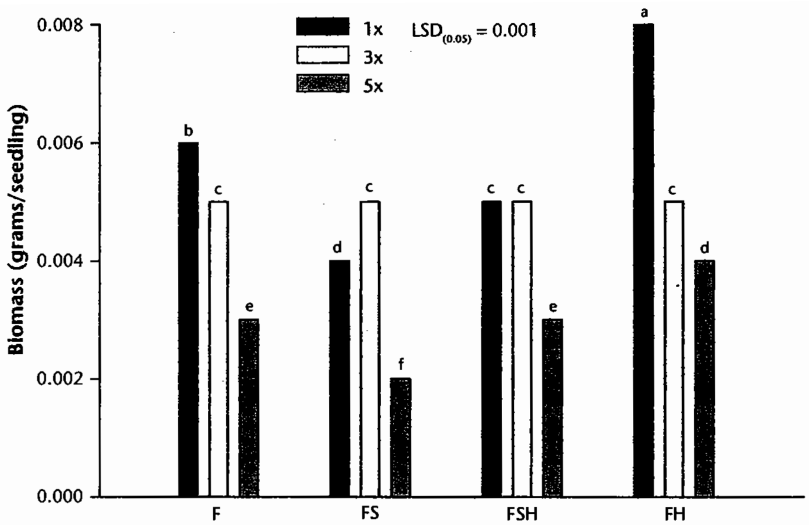

Figure 6. Crested wheatgrass seedling biomass as affected by seed treatment and watering frequency. Soil treatments are field soil (F), field soil plus sand (FS), field soil plus sand plus hydrogel (FSH), and field soil plus hydrogel (FH). Watering frequency is one time per week (1x), three times per week (3x), or five times per week (5x).

Our data suggest that the incorporation of the acrylamide copolymer hydrogel into the potting medium aided the emergence, biomass, and survivorship of crested wheatgrass seedlings. This is consistent with our first hypothesis. We further hypothesized that the beneficial effect would be greater when watering frequency was lowest and soil texture was sandier. The benefit of the hydrogel was most pronounced when watering occurred only once a week; however, the effect was greater in the pots containing field soil without any added sand. Al-Harbi and others (1996) found that a hydrophilic polymer improved cucumber seedling growth in sandy soil by increasing water-holding capacity and promoting aeration of the root medium. However, under the lowest soil moisture levels, a high concentration of the polymer decreased seedling growth. In their study and ours, the water-retaining hydrogel may have competed with the seedlings for water. While we used the application rate recommended on the packaging, we feel that further investigation into the ideal application rates for optimum benefits under different soil textures is necessary.

Watering frequency was the factor that most consistently influenced seedling performance. Similarly, Evers and Parsons (2003) found that watering frequency had a greater influence on growth and survival of switchgrass (*Panicum virgatum*) seedlings than soil texture. In our study more frequent, less intense watering increased emergence more so than that of less frequent, more intense watering. This probably occurred because seeds sitting within 0.08 inches of the soil surface experienced moist conditions from one watering event to the next, providing the developing seedling with consistent moisture necessary for germination metabolism and radicle emergence and elongation. As the seedlings grew and roots penetrated deeper into the soil, less frequent, more intense watering generally led to greater survivorship and biomass. Watering once per week may have wetted the soil more thoroughly than frequent, but less intense watering, and provided water to the deeper roots. Furthermore, watering deeply may have promoted root development deeper in the pot, which would be beneficial to survival. This suggests that under field conditions, frequent, less intense precipitation events may improve emergence, but less frequent, more intense precipitation events may be more conducive to establishment once seedlings have emerged.

Temporal patterns of daily precipitation in arid and semiarid regions are characterized by low-intensity (less than 0.2 inch [5 mm]), frequent (less than ten days between events) precipitation events (Loik and others 2004). While this pattern may be beneficial for seedling emergence, given our results, we speculate that seedlings do not become established under such precipitation. When spring precipitation events cease and the hot, dry summer ensues, which is a characteristic meteorological pattern for shrub-steppe (West and Young 2000), revegetation efforts likely fail because seedlings did not develop a root system deep enough to exploit moisture found further down in the soil profile (Frasier and others 1984). Therefore, a trade-off may exist between environmental conditions conducive to emergence or establishment. This paradox reiterates the complexity of conditions that lead to successful revegetation. The characteristics of precipitation events, and not simply precipitation events themselves, may strongly influence seedling emergence and establishment, and this effect may vary from species to species (Frasier and others 1984).

The use of water-retaining hydrogels may help to overcome the obstacle presented by precipitation patterns and improve seedling establishment while revegetating degraded shrub-steppe. In this greenhouse study, we were able to incorporate the hydrogel into the soil, but this may not be as easy in a field situation where seed is typically drilled. In addition to the effectiveness of hydrogels applied at various application rates and in diverse soils, methods for incorporating granular hydrogels into soil prior to or during seeding should be developed and tested in the field.

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