Can seed agglomeration technologies increase native species seeding success?

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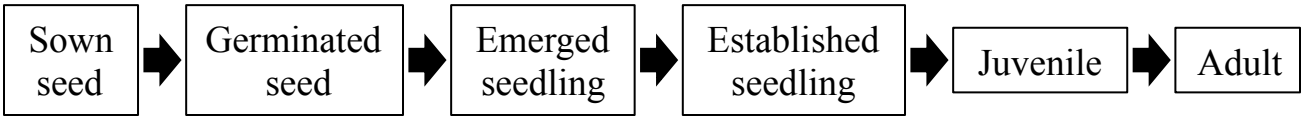
Background

Establishment of seeded species on rangelands is often low (Epanchin-Niell et al., 2009). Although most studies examining seeded species mortality have focused on how summer drought effects emerged plant survivability, stand-limiting mortality can occur at all life stages (James et al., 2011). Recent studies have shown that seedling emergence is a major developmental bottleneck in the progression from seed to adult plant (James and Svejcar, 2010; James et al., 2011; Boyd and James, In Review).

Plant life stages



A number of factors may influence pre-emergent seedling mortality. After seeds germinate they become susceptible to pathogens, especially when temperatures are cool and seedling growth is slow (Kirpatrick and Bazzaz, 1979). Newly germinated seedlings are susceptible to desiccation. Freeze-thaw cycles may cause physical damage to seedlings before emergence and can facilitate formation of physical crusts (Belnap 2003) that may impede seedling emergence.

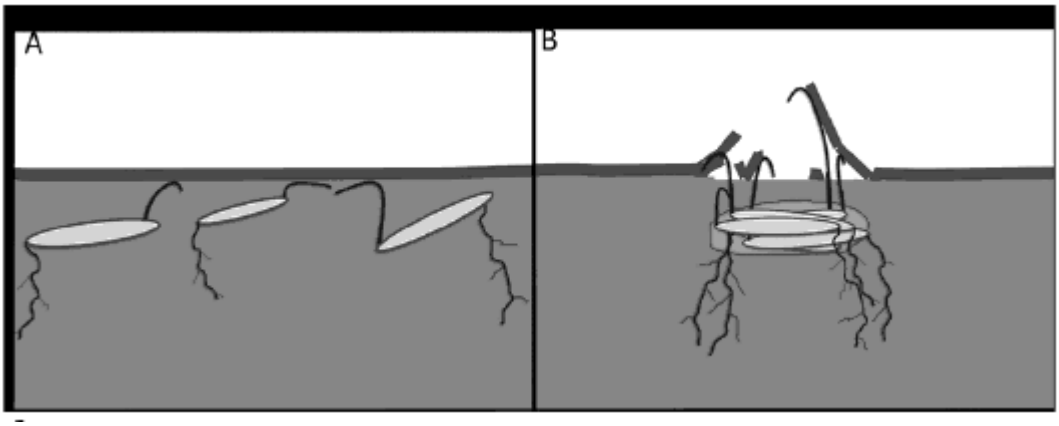
A few studies suggest that contiguous seeds of some species have greater germination rates and earlier emergence than seeds without neighbors (Ballard, 1958; Linhart, 1976). Rapid early emergence may increase survivability by allowing roots to precede drying fronts. Even minor differences in emergence timing can have a large influence on survivability and plant biomass (i.e. Bergelson and Perry, 1989).

The mechanisms responsible for enhanced germination of contiguous seeds are not well known and likely vary with species. Leachates from previously germinated seeds can accelerate germination (i.e. Bergelson and Perry, 1989) suggesting that biochemical transfer between seedlings and seeds may be important. Groups of seeds may retain moisture, and maintain a suitable environment for germination, better than individuals (Linhart, 1976). Soil bacteria can stimulate seed germination by breaking down seed coats and release of biochemicals (i.e. Gamalero and Glick, 2011). Groups of seeds may facilitate growth of more germination stimulating bacteria.

Localized dense stands produced from clustered seeding may have benefits to life stages beyond germination and emergence. Facilitation becomes more important relative to competition in harsh environments where resources are limited (Callaway and Walker, 1997; Fajardo and McIntire, 2011). Dense stands of plants may increase facilitation by providing wind shelter and reducing radiation, both of which influence evapotranspiration and soil water retention (Callaway and Walker, 1997 ; Fajardo and McIntire, 2011).

Nearby plants can alter interactions with microbial communities. Plant species cultivate their own unique microbial communities and conspecific neighbors may increase abundance of beneficial microorganisms. For example, neighboring plants could share the cost of maintaining symbionts such as arbuscular mycorrhizal fungi. However, similar to what occurs in crop monocultures (Shipton, 1977), conspecific neighbors may increase pathogen abundance. Plant neighbor influences can range from facilitative to competitive depending on the plant species involved, growth stage and environmental conditions. Although seeds and seedlings can inhibit germination of heterospecific neighbors (Linhart, 1976), little information is available about heterospecific seed neighbor interactions at early developmental stages.

Matthew Madsen and co-workers at the Eastern Oregon Agricultural Research Center in Burns, Oregon developed a technique for agglomerating multiple seeds into pellets to address seedling emergence problems associated with soil crusting. Their thought was that multiple germinating seeds may provide sufficient force to break through soil crusts.



Conceptual figure showing how multiple seeds can break through soil crust. **A.** Spaced seedlings being impeded by soil crust. **B.** Multiple seedlings can generate sufficient force to penetrate soil crust. (Figure adapted from Madsen et al., In Review).

In a proof of concept study (Madsen, Davies and Svejar, in review) they showed that seedling emergence was higher for agglomerated seeds in soils forming crusts. Biomass production of plants emerging from agglomerated seed was higher than for single seed, suggesting that benefits from having seedling neighbors outweighed the influence of increased competition. Interestingly, plants derived from single seeds coated with agglomeration materials exhibited greater biomass than uncoated single seeds, suggesting that agglomeration materials facilitated improved early growth conditions.

Matt claims that the seed agglomeration techniques he's developing allow soil microorganisms to be packaged with seeds. This may facilitate restoration of crested wheatgrass field and other areas containing low biodiversity. Bitterbrush seed is often found in rodent caches suggesting that the plant may benefit from conspecific seed neighbors. Agglomerating bitterbrush seeds with specific symbiotic nitrogen-fixing Frankia strains may improve establishment success.

Frost or freezing can injure emerged and pre-emerged seedlings. Matt is working on hydrophobic seed coatings to delay seed germination in the fall and winter when damage can occur. If successful, the technique may provide tighter control over when seeds of different species germinate. Although still in developmental stages, this technology may allow us to plant all species at a single time in the fall and increase seeding success.

Matt has agreed to collaborate with us on studies aimed at improving restoration seeding on the ranch. His involvement includes agglomerating seeds for us. Matt will visit the ranch on October 19 to talk about his research and the potential for collaboration.

The following pages describe two initial studies that could be put in the ground this fall.

Experimental site

Until recently the study area was used to produce Russian wildrye seed for distribution to other areas of the ranch. In 2010, the site was watered repeatedly to facilitate Russian wild rye and weed growth. Glyphosate (2 quart acre^{-1}) was applied and, after dieback, tilled to 4" and rolled to prepare the seedbed. Glyphosate was applied again in spring 2011 to control weeds and any Russian wildrye seedlings that may have emerged. We are again watering to encourage weed seed germination and will again treat the area with low amounts of glyphosate after weed emergence and prior to seeding.

Soil Properties

	Average (Stdev)
Soil organic matter	3.61 (1.5)
Sand	59.0 (7.7)
Silt	24.6 (6.7)
Clay	16.5 (2.6)

Aerial view of proposed study area

Background photo: area before conversion.

Experimental Design

3 species
- Snake river wheatgrass
- Idaho fescue
- Prairie coneflower

5 seed treatments
- Spaced single naked seeds
- Multiple naked seeds
- Drilled single naked seeds
- Drilled coated single seeds
- Coated multiple seeds

3 antibiotic treatments
- no-treatment
- fungicide
- nematicide

6 replicates

Seeds for drilled treatments will be sown using a Truax Roughrider seed drill. For other seed treatments seeds will be placed into furrows dug using a seed-drill and buried at a 0.4 inches by hand. An equal number of seeds per unit area (30 seeds per linear foot) will be sown for all treatments. Antibiotic treatments will be applied in the fall and twice in the spring across furrow rows.

Soil temperature will be monitored at three depths (surface, 0.4” and 1”) throughout the study using temperature buttons programmed to read temperature every four hours. We will monitor moisture immediately after seeding in the fall, when soil is thawed in the winter, and throughout the spring using a Theta Probe. Seedling emergence will be evaluated daily in the spring. Number of seedlings surviving to the juvenal stage will be documented in July. Biomass for each replicate will be evaluated by clipping, drying and weighing aboveground materials in July.

Depending on results, additional analyses may be warranted. We will collect soil cores for potential microbial community analyses. Aboveground biomass will be retained for potential foliar nutrient analysis.

Carrier (Nurse) Seed Study

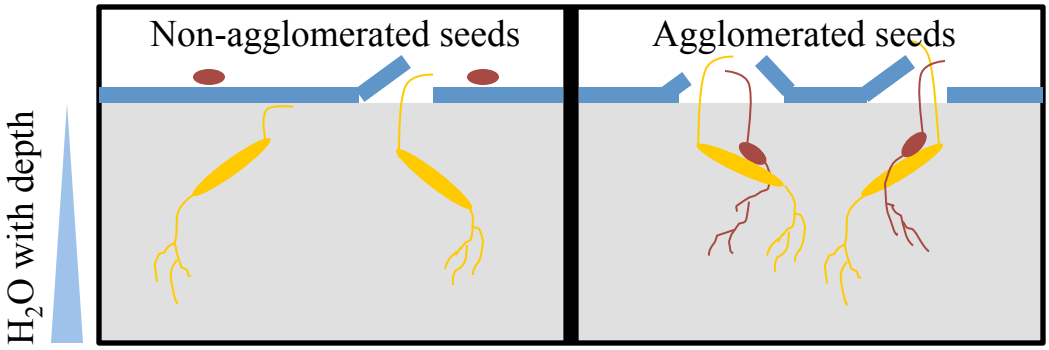
Broadcast seeding is recommended for many species. Some seeds require light for germination and others have low capacity to vertically penetrate soil. Since the soil surface is subject to extreme moisture fluctuations, broadcast seeding is more sensitive to climate conditions than drill seeding. Overall losses to seed predators are more likely when seeds are on the soil surface. If seeds could be buried, survivability may increase.

Agglomerating seeds that would normally be broadcast (target seed) together with seeds that can be buried (carrier or nurse seed) may allow emergence of the target seed after drill-seeding (see figure below). By agglomerating heterospecific seeds it may be possible to take advantage of potential facilitation relationships between species. For example, a nitrogen fixing carrier species may increase nutrient availability for the target species.

Competitive relationships may often outweigh facilitation. It may be possible to minimize competition after emergence by using carrier species that are poorly adapted to our climate conditions (i.e. a water-hungry agricultural species) as the carrier species. The carrier would be a poor competitor after facilitating emergence of the target.

As an initial "proof of-concept " test for emergence enhancement, we propose to pair Idaho fescue with prairie coneflower. Agglomerated seeds will be placed at two different depths (0.25 and 0.5 inches). Non-agglomerated seeds will be broadcast and buried at the same depths for comparison.

Conceptual figure showing potential benefits of carrier seeds for enhanced emergence of typically broadcast target seeds.



A. Broadcast seeds ( ) on the surface are exposed to climatic extremes and dessication. Individual buried seeds ( ) may not generate sufficient physical force to emerge. **B.** Agglomerated carrier and target seeds may generate sufficient force for emergence of both. Water relations are improved for target seeds placed under the soil surface. Carrier and target species root interactions can be positive or negative .

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