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Seedball Design to Optimize Germination

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Introduction

Successful seed-based arid land restoration is hard to achieve. Multiple challenges including infrequent precipitation, long-term drought, seed eating animals and poor soil conditions limit the effective germination of seeds and the establishment of desired plants. Seedballs (also called seed pellets and seed bombs) are emerging as a tool that directly address the limitations to restoration success in arid systems (Madsen et al. 2016).

Seedballs, which are structures generally composed of soil, seed, clay and water (Fig 1), are expected to protect seeds from desiccation stress, movement by granivores or wind and ultimately provide a small parcel of resources for growing seedlings. Although some papers have been published describing the utility of using seedballs for ecological restoration (Gornish et al. 2019), most formal studies do not explore best design techniques to optimize seedball success (Bleak and Hull 1958). This is slowly changing as seedballs (and their derivatives, including seed pucks, coins and pellets) become more commonly used. For example, research has investigated the effect of seedball ingredient type (Davies 2017), soil type (Madsen et al. 2021) and soil preparation (Jordan 1967) on restoration outcomes. Basic design strategies that optimize seedball success are critical for widespread use in aridland restoration projects.

We conducted two greenhouse experiments to explore the effect of fundamental components of seedball design on germination – an important bottleneck to aridland restoration success (James et al 2011). In the first study, we investigated several nutrient types that are commonly employed in seedball creation. In the second study, we examined singular and interacting effects of seed number, seed size and seedball size.

Figure 1. Seedballs

Methods

Both experiments were conducted in a greenhouse on the top floor of Tucson High School in Tucson, Arizona.

The first experiment examined different nutrient components of seedballs and their effects on germination. The nutrient types tested were: 1) organic potting soil (MiracleGro Nature's Care with Water Conserve); 2) mushroom compost (Garden Time); and 3) steer manure (Nature's Way). These nutrient types were selected based on typically used ingredients by land managers in our region. Seedballs were created using the following recipe: 1 part seeds of *Setaria vulpiseta* (Plains Bristlegrass; 70 seeds/ball), 3 parts nutrient, 5 parts clay (Lincoln 60 fireclay). For each replicate, the nutrient component in the seedballs included one of the following: only potting soil; only mushroom compost; only steer manure; ½ potting soil and ½ mushroom compost; ½ potting soil and ½ steer manure; ½ mushroom compost and ½ steer manure.

In January 2019 seedballs were randomly assigned to a pot in the greenhouse (a single seedball/pot). Pots were hand watered and checked for germinants daily. We evaluated the effect of nutrient type on germination rates.

In the second greenhouse study, we investigated the effects of seedball size, seed density per seedball and seed size on germination outcomes. Individual seedballs were created using 3 parts nutrients (MiracleGro Nature's Care with Water Conserve potting soil), and 5 parts clay (Lincoln 60 fireclay). Four different seedball sizes were created by hand, included 0.5in diameter, 1in diameter, 1.5in diameter and 2in diameter. In each of the seedballs, we inserted seeds of four different species at differing densities. The species used (from largest to smallest seed) included *Lupinus formosus* (Summer lupine; mean seed weight = 500mg), *Acaciella angustissima* (Prairie acacia; mean seed weight = 20mg), *Lotus purshianus* (Purshings lotus; mean seed weight = 4mg), and *Clarkia concinna* (Red ribbons; mean seed weight = 3mg). The four seed densities used were: 5, 10, 15 or 20.

In November 2019 seedballs were randomly assigned to a pot in the greenhouse. Pots were hand watered and checked for germinants daily. We evaluated the effect of seedballs size, seed density, and seed size on total germination.

Results

For the first study, germination was extremely low across all seedballs. Mean of total numbers of seeds germinated across treatments included: soil (2.37); mushroom (2.79); manure (3.45); soil+manure (3.25); soil+mushroom (2.81); and mushroom+manure (3.47). Despite this, we still found an effect of nutrient type on germination through time where the use of manure (either alone or mixed with another type of nutrient) resulted in higher germination than any other single or mixed treatment. Soil alone resulted in lower germination through time.

For the second study, we found that increasing seed density per seedball increases germination. However, there was no effect of seed density on germination (e.g. we did not see inhibition or facilitation of germination based on seed number). There was no relationship between seed size and germination. However, the two largest seeds had greater germination than the two smallest seeds (Fig. 2). Increasing seed ball size did not affect germination.

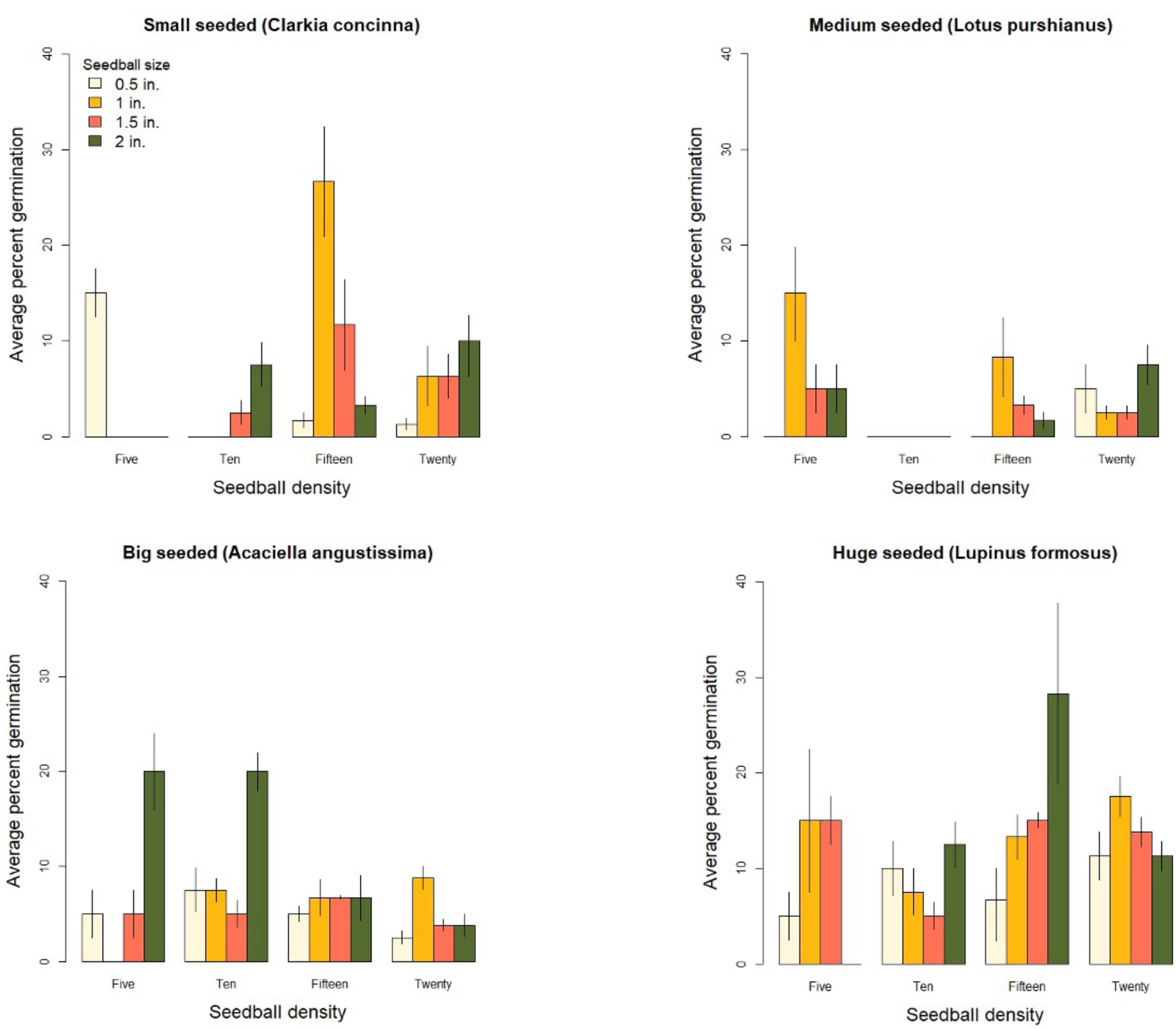

Figure 2. Mean±SD germination of the four species used in experiment 2 across seedball density and seedball size.

Discussion

In experiment 1, we documented relatively low germination (<10%), which is not unusual (Bleak, 1958). We found that seedballs created using manure as a nutrient base had slightly elevated germination rates, which might be expected as soil type (and thus nutrient content) is critical for driving germination success (Mangold and Sheley 2007). Manure is nutrient rich, with high levels of nitrogen, phosphorus, and potassium, all of which encourage plant growth (Shapiro 2016; Rurangwa 2018), which is why it is often used as an inoculant of eroded soils (Mikha, 2017). This outcome not only illustrates the value of prioritizing manure for seedball use, particularly in working landscapes where it can be procured for free or low cost, but also highlights the importance of critically considering ingredient type for seedballs.

We also found that common components of seedball design, including seedball size, seed density within the seedball, and seed size did not affect germination in experiment 2. Seed density is known to affect germination where inhibition can occur when many seeds are clumped together (Linhart 1976). Apparently, at the density levels chosen for this work, we did not reach inhibition levels, if they exist. The lack of an effect of seedball size (in the range we tested here) should be encouraging to practitioners who might create seedballs of various sizes depending on method of production.

This work should be helpful for the creation of best management practices in the design and deployment of seedballs for ecological restoration.

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