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What limits seed-based restoration: seeding methods or environmental constraints?

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Abstract

Drylands worldwide face severe degradation, requiring restoration efforts that often rely on native plant species. However, the small seed size of some species poses challenges for conventional seeding machinery. In Western Australia, the "Comm Veg" seeder is commonly used, creating furrows to improve seedling establishment.

To address limitations in seed distribution and sowing speed, seed pelleting technology was explored to increase seed size, enabling the use of a crop seeder (Aitchison). A field experiment in Eganu, WA (July 2024), compared seedling emergence and survival of four native species (*Eucalyptus oldfieldii, Melaleuca cordata, Eremaea pauciflora*, and *Acacia pulchella*) sown as bare seeds using the Comm Veg and as pelleted seeds using the crop seeder. Seedling emergence was measured in early (September) and mid-spring (November). A glasshouse experiment assessed germination rates of bare versus pelleted seeds.

Glasshouse results showed similar germination rates for bare and pelleted seeds across species. In the field, seedling emergence was higher with the Comm Veg seeder, likely due to greater soil moisture storage in the deep soil layer (7–15 cm) in furrowed areas. Alive *Acacia* seedlings exhibited significantly longer roots than dying seedlings, indicating deeper moisture access. However, seedling mortality was high for all species by mid-spring (<2% survival), likely due to late sowing and frequent droughts. Although crop seeder showed lower effectiveness in conserving soil moisture and supporting seedling survival, integrating agricultural machinery with seed pelleting technology remains promising for cost-effective, large-scale restoration. Refining sowing techniques and pelleting methods is essential to improve restoration success in degraded drylands.

Introduction

Drylands worldwide face severe disturbances from grazing, land-use changes, fire, and drought. Vast areas with low plant productivity making large-scale restoration in drylands costly and challenging. Direct seeding of native plants is widely regarded as a cost-effective and essential approach for large-scale restoration (Merritt and Dixon, 2011). However, less than 10% of seeds typically establish successfully due to various edaphic and biotic constraints (Ceccon et al., 2016). Additionally, handling and precision seeding of multispecies mixes with diverse seed sizes and shapes present logistical challenges, requiring specialized equipment and often resulting in low seedling establishment rates (Masarei et al., 2019).

In Western Australia, the "Comm Veg" seeder is commonly used for creating furrows during seeding. While effective, this approach could be enhanced with improved seed distribution and faster sowing speeds. Adapting agricultural machinery capable of sowing seeds over large areas at higher speeds and precise soil depths could benefit large-scale restoration efforts. However, the extremely small seed size of many native plants, such as gum trees, poses a significant challenge for using conventional crop seeders.

Seed enhancement technologies, initially developed for precision seeding in agriculture and horticulture, are increasingly being applied to ecological restoration (Madsen et al., 2016). One such technique, pelleting, involves adding materials to seeds to create an oval or spherical shape, making the original seed shape indiscernible (Pedrini et al., 2020). This process increases propagule size, enabling their use with agricultural machinery.

Effective restoration requires deep ecological knowledge to create restoration niches that support seed germination and seedling establishment, emphasizing the need for cost-effective, ecologically sound, and scalable methods. This research aimed to compare the effectiveness of two seed-based restoration methods: sowing bare seeds using the commonly used Comm Veg machine and sowing pelleted seeds of the same species with a crop seeder (Atchison). We hypothesized that the crop seeder would provide more precise seed distribution, while the slower-moving Comm Veg machine, which creates furrows, would offer more favourable recruitment restoration niches for seed germination and seedling establishment.

Methods

We tested seedling emergence and survival of four native plant species and a mixed-species treatment, comparing bare and pelleted seeds sown using two different seeder machines . The species included *Eucalyptus oldfieldii*, *Melaleuca cordata*, *Eremaea pauciflora*, and *Acacia pulchella* var. *pulchella* (DBCA 2024) (henceforth we refer to them using their genus names). Seeds of all species were pelleted using azomite as the coating medium and polyvinyl alcohol (PVOH, 8% solution) as the binder (Pedrini et al., 2020), resulting in pellets with a diameter of 1.5–2 mm, similar to canola seeds.

Bare seeds were mixed with perlite and sown using a Comm Veg direct seeder (North Stirling Pallinup Natural Resources). This seeder, designed for restoration applications in Western Australia, allows simultaneous sowing of fine and coarse seeds in four separate rows, while creating deep furrows to enhance rainwater catchment. Pelleted seeds were sown using an Aitchison drill seeder (Aitchison Seed Drills, New Zealand). This machine is optimized for sowing varying size crop seeds.

Seed sowing was conducted from July 22–24, 2024. Seedling emergence and survival were assessed 60 days after sowing (September 20, 2024) and 103 days after sowing (November 5, 2024). The final rainy week of the season occurred in early September, placing the assessments approximately three weeks and two months into the dry season, respectively. Soil moisture was measured by collecting soil samples from two depths: 0–5 cm (topsoil) and 7-15 cm (subsoil). Additionally, morphological growth parameters, including root and shoot biomass, seedling height, and maximum root distribution, were measured for six *Acacia pulchella* seedlings (both alive and dead).

The experiment followed a completely randomized block design with two seeding types (bare and pelleted) and four plant species as the main factors. Each seeding type was replicated in blocks, with each block containing five rows randomly assigned to one of the four species or a mixed-species treatment. This design resulted in 30 experimental units, encompassing two sowing types, five plant treatments, and three replicates. In a glasshouse experiment, seeds of the same species were sown as either bare or pelleted, and their emergence and survival were monitored over 45 days. This allowed us to confirm that observed differences in emergence between plant species in the field were attributable to factors other than seed pelleting and dormancy.

Results

Seedling emergence and survival in glasshouse

The glasshouse experiment showed species-specific differences in seedling emergence (Figure 1). *Acacia* (58%) and *Eremaea* (52%) had the highest emergence rates for bare seeds, while *Eucalyptus* (44%) and *Melaleuca* (23%) had lower rates. Pelleting reduced emergence in *Melaleuca* (8%) and *Eremaea* (29%) but did not affect *Eucalyptus* or *Acacia*. Seedling survival from day 20 to 45 was similar for both pelleted and bare seeds.

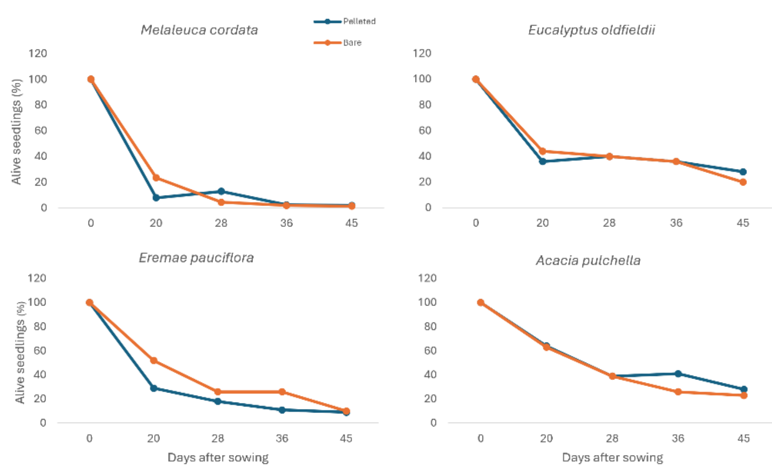

Figure 1: Seedling emergence and survival of four native species sown as bare or pelleted seeds under glasshouse conditions, means were compared by Tukey test at P<0.05).

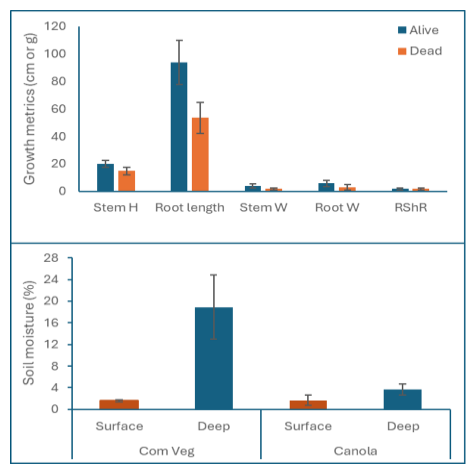

Figure 2: Comparison of growth metrics for Acacia seedlings (top) and soil moisture content across different seeding methods and soil depths (bottom), means were compared by Tukey test at P<0.05).

Soil moisture and growth metrics

Living acacia seedlings had root lengths approximately twice as long as those of dead seedlings, although their stem height and stem and shoot weights were similar. Soil moisture in the deeper soil layer (7-15 cm) was significantly higher in furrows created by the Comm Veg method compared to those created by the crop seeder, while no difference was observed in the topsoil layer (0–5 cm) between the treatments (Figure 2).

Seedling emergence and survival in field

For three of the four species (*Acacia*, *Eremae*, and *Melaleuca*), early seed emergence was significantly higher under the Comm Veg treatment, which used bare seeds sown in deep furrows, compared to the crop seeder treatment, which used pelleted seeds sown at the soil surface. In contrast, early seedling emergence for *Eucalyptus* was extremely low (<5%), with no clear difference between the methods. All species experienced severe mortality as drought intensified by mid-spring, with no difference in survival between the Comm Veg and crop seeder treatments.

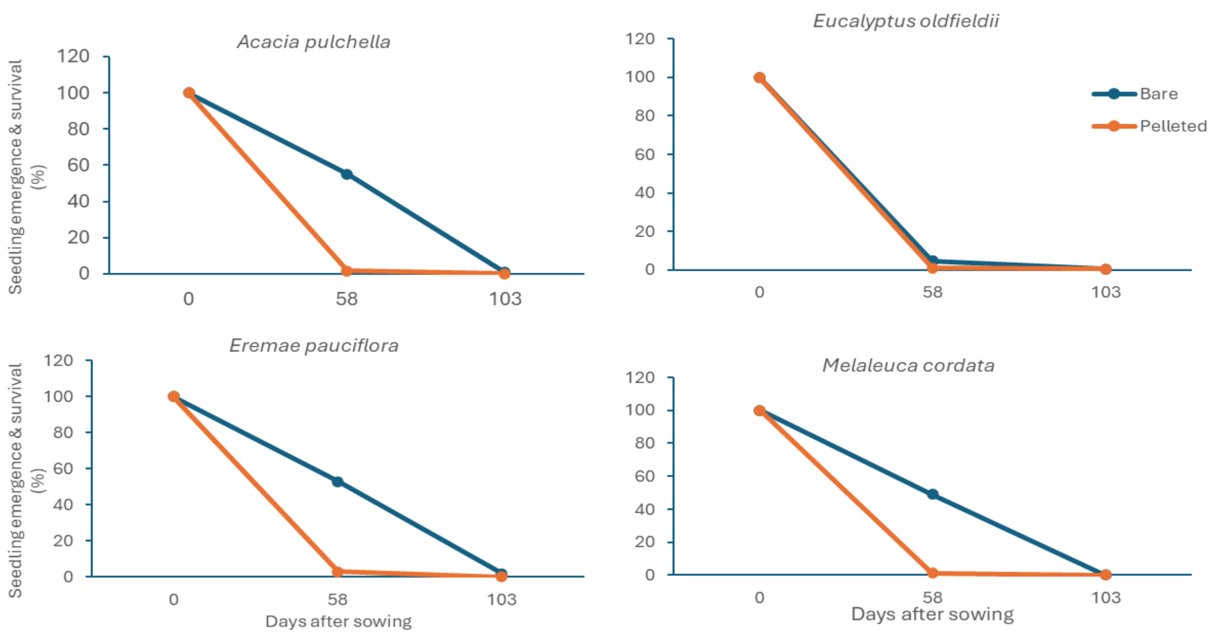

Figure 3: Seedling emergence and survival of native plant species sown as bare seeds in furrows using the Comm Veg method or as pelleted seeds using a crop seeder.

Discussion

Seed-based revegetation is widely regarded as a cost-effective and scalable solution for dryland restoration. Pelleting seeds into larger sizes offers the advantage of enabling the use of more sophisticated agricultural machinery in dryland restoration However, the results of this short-term trial highlight the pivotal role of major environmental factors—such as rainfall, soil moisture availability, and soil properties—in determining the success of restoration efforts. Late sowing and an unexpected 20-day drought in early September worsened moisture stress and led seedling mortality that was intensified by mid-summer.

Our glasshouse experiment corroborates previous studies (e.g., Pedrini et al., 2020) showing that seed germination rates were generally similar between pelleted and bare seeds. Therefore, the reduced seedling emergence observed in the field suggests that other factors, such as mechanical sowing methods, may have contributed to this outcome.

Field results demonstrated significant soil moisture retention in the deep soil layers of treatments using the Comm Veg machine, which creates deep furrows for seed placement. These furrows facilitated better moisture storage, which proved critical for seedling survival, especially under drought conditions. Morphological analysis showed that *Acacia* seedlings with longer root systems had a distinct advantage in accessing stored soil moisture within these furrows. This suggests that Comm Veg furrows, combined with the inherent root growth characteristics of *Acacia* species, enhance plant survival in water-limited environments.

In conclusion, our findings emphasize the critical importance of soil moisture storage around the root zone for seedling survival during dry seasons. Sowing techniques and timings that promote root elongation toward available moisture in the deep soil layers can significantly enhance seedling survival during dry seasons. While this small-scale trial indicated lower effectiveness of crop seeders in conserving soil moisture and improving seedling survival, the integration of agricultural machinery with seed pelleting technology remains a promising avenue for cost-effective, large-scale restoration. Further research and development on optimizing sowing techniques and machinery adjustments are warranted to enhance the efficiency and reliability of these methods.

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