Shrub Seedling Root Development, Establishment and Encroachment Potential

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Abstract

Taproot elongation increased linearly with both triggering event and watering frequency (P < 0.0001) and watering frequency was not significantly different between the two species (P = 0.4110). Slope of elongation rate against trigger duration was 43% higher in P. velutina than A. greggii (P = 0.1875). This suggests newly emerged P. velutina seedlings are more responsive to the magnitude of the rainfall event which triggers germination, thus reducing the time required to escape (to) topsoil denudation and (by) strong below-ground competition from shallow-rooted competitors, such as grasses. By contrast, A. greggii seedlings seem less able to take advantage of triggering events.

Methods

Site Description and environmental basis for treatments

• Greenhouse experiment conducted at University of Arizona Campus Agricultural Center in Tucson.
• Watering treatments based on summer precipitation (PPT) from the Santa Rita Experimental Range (SRER), 40 km south of Tucson (Table 1 and 2). Data sets were provided by the Santa Rita Experimental Range Digital Database (SRER 2007)

Experimental Design

• Prosopis velutina and Acacia greggii seeds were chemically scarified to break dormancy (Prosopis in 20% H₂SO₄ for 10 min; Acacia in 90% H₂SO₄ for 20 min), then soaked 24 h in distilled water in the dark.
• Seeds of each species (n=4) were planted into each of 72 pots (Zipset™) filled with a sandy loam soil (Fig. 1). Emerging seedlings were thinned to one per pot. Four pots of each species were randomly assigned within each block (tray of pots).
• Trays were allocated to one of two drip-line irrigation systems operated by manual valves with four liter and calibrated to determine the volume of water required for each tray to supply 1 mm per pot per event. Triggering events (5 mm H₂O in monsoon storms) were fixed effects. An additional regression on taproot elongation rate was included (vs root biomass) per day as an explanatory variable. JMP 5.0.1a software was used for all analyses (SAS 2002).

Analysis

• Measurements were corrected to 20°C per day of experiment to account for differences in experimental duration. Values for each species were averaged for each block (day), so watering treatments were applied at the tray level.
• Multiple linear regressions were applied to taproot elongation rate, in (root biomass), and rate of total biomass increase (root + shoot; mean used biomass). Block location (distance from zipee port) was a random effects variable, trigger duration and subsequent watering frequency were fixed effects. An additional regression on taproot elongation rate was included (root biomass per day) as an explanatory variable. JMP 5.0.1a software was used for all analyses (SAS 2002).

Results

• Taproot elongation increased linearly with both triggering event (P < 0.0001) and watering frequency (P < 0.0001). The increased due to triggering event was significantly greater than that due to subsequent watering frequency (Fig. 1: P = 0.0001). Slopes of elongation rate against trigger duration were 43% higher in P. velutina than A. greggii (P = 0.1875), and increased triggering event (2 to 5 days).

• Total biomass of A. greggii exceeded that of P. velutina (P = 0.0076). P. velutina responded more to increased triggering event than A. greggii (P = 0.0027, for ln(total biomass)].

Discussion

• This study investigated initial seedling establishment – the most vulnerable and tractable phase of the shrub life cycle. In arid and semiarid environments, rapid access to deeper soil moisture is likely a key factor in woody plant seedling survival and the spread of shrub and two species into grasslands. Within typical environmental limits, taproot elongation is stimulating P. velutina and, especially, P. velutina seedlings more responsive to triggering event duration than subsequent triggering, response to triggering event being less than expected due to lower seedling establishment and growth.

• Results suggest early rooting depth is driven more by the size of triggering event as the subsequent soil moisture dynamics. Deeper soil moisture is less available to grasses and herbs and limits access to the deeper soil, so achieving greater rooting depth early in the use of this conservation experiment is expected to translate into increased survival through the first dry season. Young P. velutina seedlings appear more able than A. greggii to capitalize on the water provided by larger triggering events. This may help explain why environmental conditions favoring shrub proliferation in grasslands have benefitted some woody species more than others and, in particular, why P. velutina has become a ubiquitous grassland invader in the desert southwest.

• It remains to be shown whether the trends shown in this study continue through the seedlings’ first year, and whether the root elongation differences between intraspecies and interspecies populations apply more generally to just these two species – the subject of continuing experiments. Preliminary results indicate that P. velutina, A. greggii and Parkinsonia floridia seedlings can attain root depths of 120 cm within 60 days of germination in controlled environments. However, seedling mortality in the field reached 100% in P. velutina and Larrea tridentata and 70% in P. floridia (seedling n = 337, 77, 42 respectively at the Santa Rita Experimental Range in 2007) (emergence from seed was below 1% in A. greggii). There is doubtless a complex interplay between germination, taproot elongation, rainfall and how these may be further modulated by other factors such as soil type and karsticity.

References

Santa Rita Experimental Range (SRR). 2007. http://srr.ars.usda.gov/SRR/precip/precip.xls, maintained by SRR, viewed 09/09/2007. Funding for the digitization of these data was provided by USDA Forest Service Rocky Mountain Research Station and the University of Arizona.

Acknowledgements

We are grateful for the support of NSF Ecological and NSF – JEST – programs, and for the help of Chad McMurry, Hairu Hox, Miranda Loring, Katie Lee and Adele Mold.

Table 1. Storm duration frequencies and average rainfall, SRR, July through September, 1922-2005; compared with experimental treatments (trigger duration).

<table>
<thead>
<tr>
<th>Santa Rita Experimental Range precipitation</th>
<th>Single monsoon storms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of consecutive days rain in 1922-2005</td>
<td>Event frequency (yr⁻¹)</td>
</tr>
<tr>
<td>5 days</td>
<td>0.33 ± 0.11</td>
</tr>
<tr>
<td>3 days</td>
<td>2.62 ± 0.35</td>
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</tbody>
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Table 2. Estimated mean daily rainfall at SRR, July and August, 1922-2005; compared with experimental treatments (follow-up watering frequency).

<table>
<thead>
<tr>
<th>Santa Rita Experimental Range precipitation</th>
<th>Means of peak rainfall months (mm/day)</th>
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<tr>
<td>July</td>
<td>August</td>
</tr>
<tr>
<td>Lower 95% limit</td>
<td>0.22 ± 0.15</td>
</tr>
<tr>
<td>Mean</td>
<td>2.60 ± 0.60</td>
</tr>
<tr>
<td>Upper 95% limit</td>
<td>4.90 ± 1.00</td>
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Figure 1. Experimental setup.

Figure 2. Root elongation responses to increased watering frequency (alternate days to every 5 days) and increased triggering event (2 to 5 days).

Figure 3. Plot of mean root elongation rate against triggering event, with daily subsequent watering. Dashed lines indicate 95% CIs for the means.