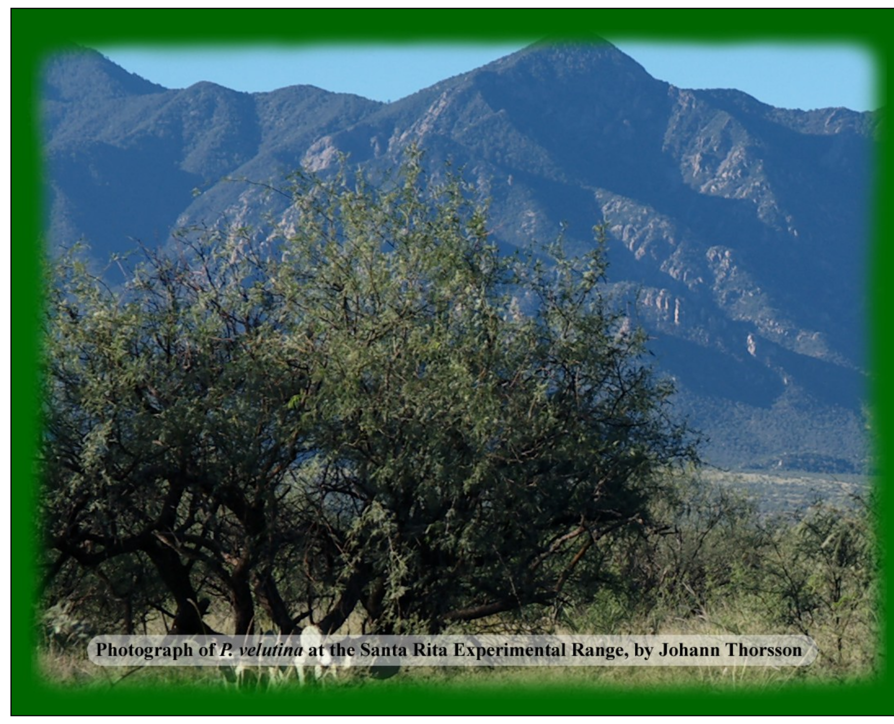

Seedling use of soil moisture: a factor in shrub encroachment potential

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Introduction

- Encroachment of woody plants into desert grasslands over the past century is well documented. Such encroachment has profound and lasting effects on the carbon, water and nutrient cycles.
- It is unclear why the abundance of some native woody plants has increased dramatically while the abundance of others has not.
- We sought to ascertain the potential basis for these discrepancies by comparing drought-tolerance of young seedlings of *Acacia greggii*, a shrub species whose historical abundance does not appear to have changed markedly, to that of seedlings of *Prosopis velutina*, a shrub whose density has increased dramatically over the past 100 years.
- This investigation concentrates on initial seedling establishment - the most vulnerable and tractable phase of the shrub life cycle.
- The primary aim is to understand why environmental changes favoring shrub proliferation in grasslands have benefited some species more than others.

Hypotheses

Each species' drought 'LD_{50}' was recorded (LD_{50} = time at which treatment survivorship was 50% of control survivorship). As *P. velutina* has been a more aggressive invader into arid and semi-arid grasslands than *A. greggii*, we hypothesized that its seedlings would be better adapted to drought, such that:

H_1: *P. velutina* time to LD_{50} > *A. greggii* time to LD_{50}.

H_2: Soil moisture in *P. velutina* LD_{50} treatments < Soil moisture in *A. greggii* LD_{50} treatments.

Fig. 1. Photo of experiment and irrigation set-up.

Fig. 2. *P. velutina* and *A. greggii* early in experiment.

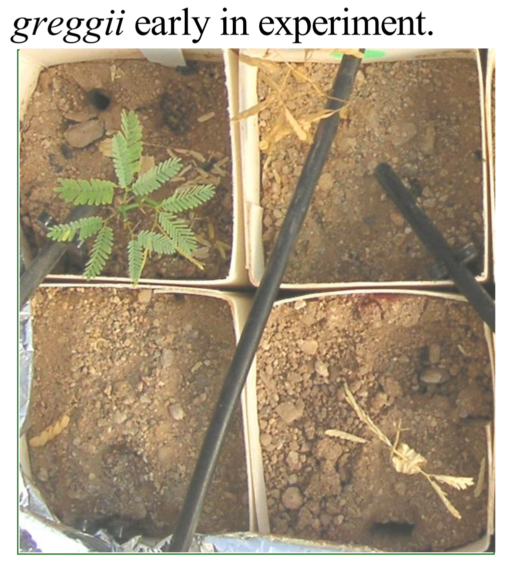

Fig. 3. Same seedlings as above after LD_{50} of each species.

Methods

- *P. velutina*, and *A. greggii* seeds supplied by Desert Seed Source, Tempe, AZ and prepared as follows:
  - *P. velutina* seeds were chemically scarified in 20% H_2SO_4(aq) for 10 minutes.
  - *A. greggii* seeds were scarified in 90% H_2SO_4(aq) for 20 minutes.
  - All seeds were soaked 24 hours in distilled water in the dark.
- For each species, four seeds were planted into each of 72 pots (Zipset™) filled with a sandy loam soil (fig. 1).
- Four pots of each species were randomly assigned within each block (tray).
- All pots received 5 mm of water in morning and 5 mm water in the evening on two consecutive days. Thereafter, pots received 5 mm every other morning. Emerging seedlings were thinned to one per pot (fig. 2).
- Watering was discontinued in 75% of the pots (dry downs) three days after peak emergence (day 7 for *P. velutina*, day 9 for *A. greggii*).
- Soil volumetric water content was estimated on a randomly selected subset of pots (TDR 100 Soil Moisture Probe) and seedling heights were measured periodically.
- Seedlings were assessed daily. A plant was considered dead once it had lost all hints of green and had become brittle.
- LD_{50} was calculated as the time (in days) at which the number of live seedlings in the dry-down pots was 50% of the number of live controls.
- Half of the seedlings classified as dead were randomly selected and re-watered to confirm mortality (fig. 3).

Results

- *A.greggii* seedlings typically survived 5 days more drought than *P. velutina* seedlings: *A.greggii* time to LD_{50} was 39 days whereas *P. velutina* time to LD_{50} was 34 days (fig. 4) after water was withheld. H_1 was not supported.
- Dry down soil moistures of the two species at LD_{50} were indistinguishable, both being 7.5% ± 0.1% by volume. H_2 was not supported.
- By day 29, *P. velutina* and *A. greggii* control soil moistures were significantly different ($P < 0.05$).
- At the end of the experiment, mean heights of the two species were not statistically significantly different (fig. 6).
- A previous experiment of similar design showed that under control conditions, *P. velutina* seedlings increased in biomass significantly more rapidly than *A. greggii* seedlings over their first 17 days (Table 1 and fig. 7).

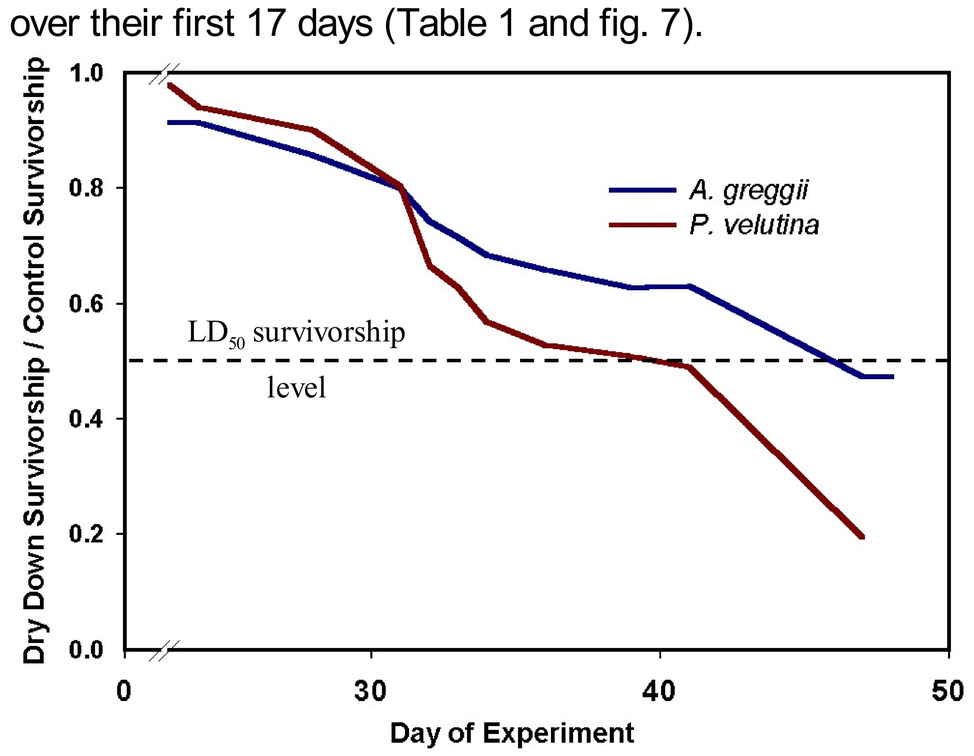

Fig. 4. Survival of *A. greggii* and *P. velutina* dry-down seedlings (watering ceased 3 days after peak emergence) as proportions of control survivorships (100% and 92% respectively over the whole experiment, with 5 mm water alternate days).

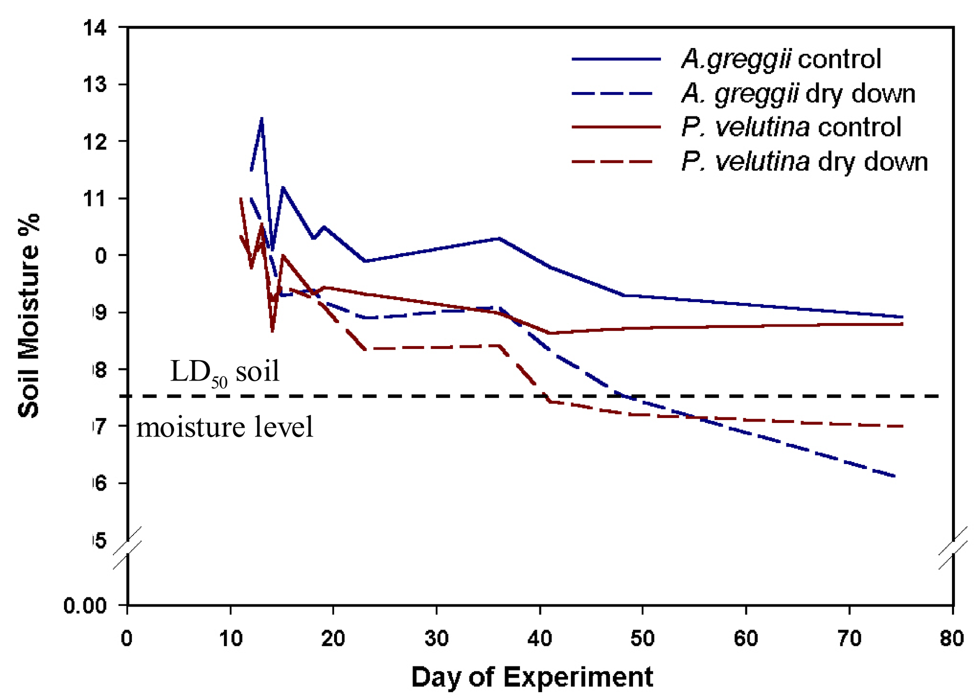

Fig. 5. Volumetric soil moisture content in control and dry down pots.

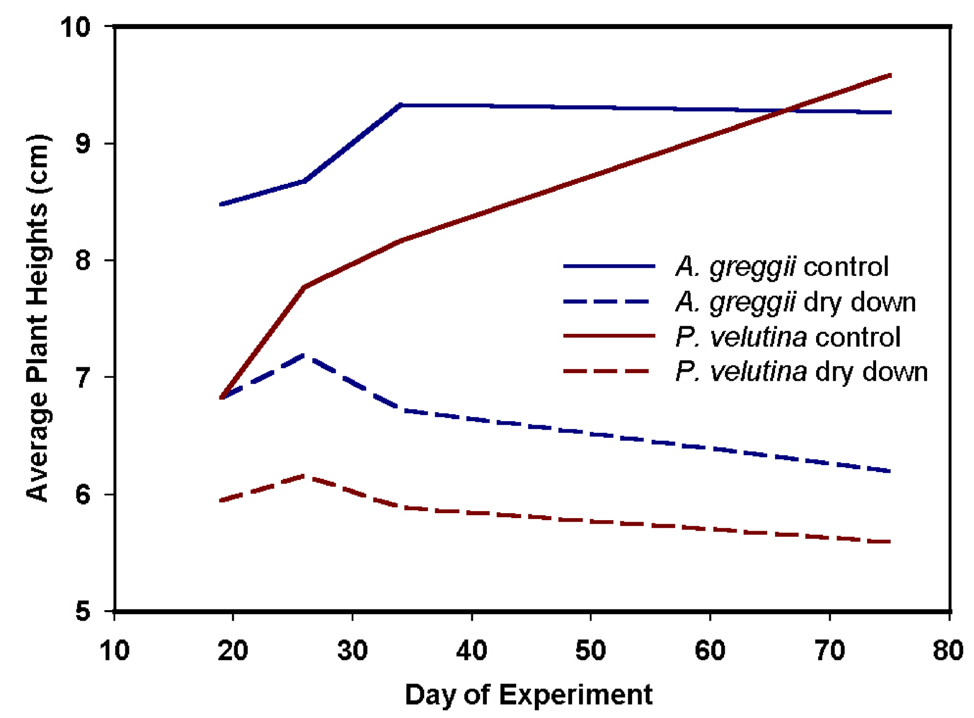

Fig. 6. *A. greggii* and *P. velutina* seedling height in control and dry down pots (watering ceased three days after peak emergence).

Results (continued)

Species	Seed mass (mg)	Seedling root mass (mg)	Seedling shoot mass (mg)	Net Biomass Gain (mg)
A. Greggii	158	63 ± 5	125 ±14	**30**
P. velutina	21	45 ± 6	63 ± 7	**88**
P-value	< 0.0001	< 0.02	< 0.001	

Table 1. Table comparing seed mass without coat and root and shoot mass at 17 days.

Fig. 7. Photograph illustrating differences in seed size (left) and in root and shoot size of 75 day old seedlings of *A. greggii* (above) and *P. velutina.*

Discussion

- *A.greggii* seedlings were able to tolerate a longer duration of drought than *P. velutina* seedlings (fig. 4). However, this was due to *P. velutina* utilizing soil moisture more rapidly than *A. greggii* (fig. 5) and accruing substantially more biomass (Table1; see also fig. 6).
- The greater biomass accumulation by seedlings of *P. velutina* was surprising, given that *A. greggii* seed mass was, on average, 7.5 X greater (Table 1, fig. 7).
- In drylands, rainfall events of sufficient magnitude to cause seedling emergence may or may not be followed rainfall events needed to sustain seedling survival. If *P. velutina* and *A. greggii* both germinate in response to a given rainfall event, and the probability of a subsequent rainfall event within 10 days is high, *P. velutina* seedlings would accumulate biomass more quickly, in particular extending its taproot rapidly. In so doing, *P. velutina* is more likely to persist by virtue of accessing deeper soil stores of soil moisture and experiencing less intense competition from grasses.
- The initial ability of *A. greggii* seedlings to survive drought longer than *P. velutina* comes at the cost of reduced growth. Thus, it may be less effective in competing with grasses for soil moisture, less likely to exploit deeper stores of soil moisture early in its life cycle; and hence, less likely to persist.
- Given that *P. velutina* has more successfully invaded desert grasslands than *A. greggii*, it appears that its 'competitor strategy' is ultimately superior to *A. greggii*'s 'stress tolerance strategy' (*sensu* Grime, P.J. 1979. *Plant strategies and vegetation processes*. John Wiley and Sons, New York) in that context. The observed differences in seedling performance may help explain patterns of species distribution on a more local scale.

Acknowledgements

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