Temporal fluctuations of *Parkinsonia aculeata* L. seedling germination and growth in three Australian rangelands habitats

Roger Lawes
CSIRO Sustainable Ecosystems, Davies Laboratory, Townsville, Queensland 4814, Australia
CRC for Australian Weed Management

Summary Rainfall in the Australian rangelands is highly variable and as a result, weed invasions and weed seedling recruitment are generally episodic. The amount and frequency of rainfall influence the extent of habitat and portion of the landscape that a weed species might invade. To define a weed's habitat it is necessary to determine the moisture requirements that will allow the weed to germinate and establish. These moisture requirements can be used to help define the extent of suitable habitat. A model of seedling survival was created for *Parkinsonia aculeata* L. using a combination of historical rainfall data and information on the growth and development of the weed. The growth data were obtained from glasshouse experiments. The model predicts whether *P. aculeata* seedlings would grow and survive for an 18 week period, given daily rainfall and climatic conditions for that period. The model was used to predict the frequency of seedling survival and habitat suitability for *P. aculeata* in Darwin, Charters Towers and Alice Springs using climate records from 1950 to 2000.

Keywords *Parkinsonia aculeata*, simulation model, habitat suitability.

INTRODUCTION

For a plant to be invasive, seedlings need to survive until maturity and produce seed to propagate the species. While an adult plant may survive extended dry periods, seedlings are arguably more vulnerable to short periods of moisture stress and seedling survival is generally episodic (e.g. Booth *et al.* 1996).

Rainfall varies from location to location and from season to season and affects the soil moisture regime of a habitat. The extent and duration of moisture stress defines many characteristics of a habitat, which in turn influences the suitability of a habitat for invasion by a weed. Variations in rainfall can be related to soil moisture availability across the landscape and this may influence the frequency of seedling survival. To quantify the likelihood of seedling survival in various environments it is essential to understand the effects of different soil moisture regimes on seedling survival and relate this to temporal fluctuations in rainfall. It is difficult to acquire this information quickly from field data. Consequently, data from glasshouse trials were used to determine the response of *Parkinsonia aculeata* L. seedlings to variations in rainfall (Lawes *et al.* 2004).

Parkinsonia aculeata currently occupies approximately 800,000 ha of rangelands in Western Australia, Queensland, and the Northern Territory, as well as small areas in New South Wales and South Australia. There are substantial variations in annual rainfall across these regions and it is likely that their vulnerability to invasion by *P. aculeata* also varies. In regions with low rainfall, *P. aculeata* may only survive in habitats such as the riparian zone where soil moisture levels are adequate and less dependent on annual rainfall.

The response of *P. acuelata* seedlings to rainfall in three soil types was previously determined by Lawes *et al*. (2004). Some of the data are presented here and used to construct a simple water balance model of *P. acuelata* growth during the first 18 weeks after germination. *Parkinsonia aculeata* is found near Darwin, Alice Springs and Charters Towers. The model is run using 50 years of historical rainfall records from these areas. The suitability and likelihood that *P. aculeata* could become invasive in each of these regions is discussed.

METHODS – GLASSHOUSE TRIAL

A sand, a loam and a cracking clay broadly represent the range of soil types found in the rangelands of Australia and these were used. It was hypothesised that these three soils would influence plant growth and development, particularly as water became limiting. *Parkinsonia aculeata* was sown into 36 plastic pots that were 75 cm in length and 23 cm in diameter. These pots were continuously watered for four weeks to simulate part of a wet season in the northern Australian rangelands. At the end of this period, four watering regimes were imposed. These were a non limiting water treatment (zero stress), soil moisture maintained at 30% above wilting point (low stress), soil moisture maintained at 10% above wilting point (mid stress) and a drought treatment (high stress), where watering ceased after four weeks of plant growth. All watering was carried out by hand and the only loses occurred as a result of evaporation and transpiration and this was defined as water use. The trial was concluded after 18 weeks. Above-ground biomass was measured at the conclusion of the trial and total water use (mm) was monitored by weighing pots weekly. Data were analysed using a grouped linear regression. See Lawes *et al.* (2004) for more detail.

RESULTS – GLASSHOUSE TRIAL

The soil and water treatment effects and their interaction had a significant influence on the production of above-ground dry biomass ($P < 0.001$). More above-ground dry matter was produced in the clay (51.2 g ± 2.9 g) than the loam (41.1 g ± 2.9 g) or the sand (7.9 g ± 2.9 g). The inclusion of the covariate, the log of water use (mm), accounted for the water treatment effects ($P < 0.002$) and influenced the soil effect. These relationships are best summarised by the equations derived from the linear regression in Table 1 and illustrated in Figure 1. The intercept of the x-axis from each of these equations effectively determines the minimum amount of water necessary to sustain the plant for 18 weeks and these equations were subsequently used in the model.

METHODS – MODEL CONSTRUCTION

Seedling model construction The growth simulation model is comprised of a simple daily water balance model for a clay soil. The soil was assumed to be 20 cm deep and hold a maximum of 42 mm of moisture. Each day the amount of water in the profile increased because of rainfall and decreased because of evaporation multiplied by a vegetation factor of 0.3. The vegetation factor accounts for the effect variables such as shading and leaf litter have on soil evaporation. The vegetation factor varies between species and has not been formally defined for *P. aculeata.* In this instance, the figure chosen was subjective.

Parkinsonia aculeata was assumed to survive for at least 18 weeks if the following three conditions were met. Firstly, *P. aculeata* germinated if the amount of moisture in the soil profile reached 80% of its capacity (i.e. 38 mm). Secondly, it survived for the next four weeks if some moisture remained in the profile every day for four weeks. Thirdly, it was then assumed to survive until 18 weeks of age if there was at least 166 mm of water available to the plant for the 18 week period. If any of these conditions were not met, then it was assumed that the seedling died.

Seedling model simulation This model was run using historical weather data from 1950 to 2000 for Darwin, Alice Springs and Charters Towers as input data. It was assumed that *P. aculeata* was growing on a clay soil.

RESULTS – MODEL OUTPUT

During the period of investigation, the requirements for seedling growth and survival were met in all three environments, even though average annual rainfall varied from just 284 mm in Alice Springs to 1717 mm in Darwin. Charters Towers averaged 656 mm.

The climatic conditions necessary for seedling survival occurred 305 times in Alice Springs, 1997 times in Charters Towers and 5062 times in Darwin. At the conclusion of the 18 week growth period these seedlings produced an average of 78 g, 111 g and 125 g of above ground biomass in Alice Springs, Charters Towers and Darwin, respectively.

Seedling survival was seasonal in Darwin. In January, February and March there was a 100% chance that conditions would suit the germination and survival of *P. aculeata* at some stage. By May there was only 4% chance that seedlings would survive and this declined to 0% in June and July. The likelihood of seedling survival did not increase again until October (Figure 2).

Table 1. Relationships between the log of water use and soil type for *P. aculeata* seedlings.

Soil	Constant term	Coefficient of log water use (mm)
Clay	−261.5 ± 16.3	51.2 ± 2.7
Loam	−183.4 ± 23.2	36.4 ± 3.8
Sand	−53.0 ± 25.3	11.1 ± 4.4

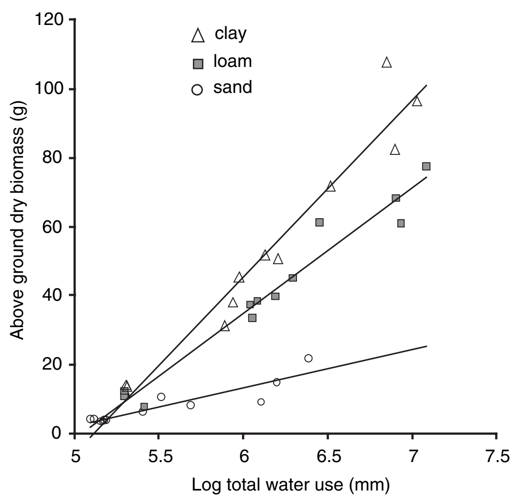

Figure 1. Relationship between the log of water used after 18 weeks, soil type and the above-ground dry biomass of *P. aculeata.*

Seedling survival was also seasonal in Charters Towers where there was an 80% chance that, at some stage during February, conditions suited the germination and survival of *P. aculeata*. This declined linearly until September and increased thereafter (Figure 2).

Seedling survival in Alice Springs was comparatively rare and a-seasonal. There was usually only one day in a month when the requirements for germination and growth of *P. aculeata* were met. In contrast, there were between 16 and 23 days within the month that suited seedling germination and survival in Darwin. In Charters Towers there were between 6 and 10 days within a suitable month where *P. aculeata* could have survived. Days that do not suit imply the prevailing climatic conditions would have resulted in seedling death.

DISCUSSION

The glasshouse trial enabled the growth and development of *P. aculeata* in relation to soil moisture availability to be quickly understood. These data were then used to build a relatively simple but informative model on habitat suitability for the weed.

P. aculeata is found in all three locations used in this study and is considered invasive in Charters Towers and Darwin. For a weed to proliferate in a habitat, seedlings must survive and thrive on a regular basis and the model suggests this rarely occurs in Alice Springs. Even if a seedling survives in Alice Springs, after 18 weeks it will, on average, have 40% less biomass than the equivalent plant in Darwin. Any reduction in the rate of biomass accumulation is likely to delay the onset of maturity and seed production, which in stressed environments would reduce the overall seed load. This would further reduce the likelihood of the weed becoming invasive. Furthermore, seedlings are more likely to germinate and die in low rainfall environments, further reducing the seed bank. In the other two environments, *P. aculeata* frequently survives for at least 18 weeks and has a greater potential to become invasive. This potential arguably reaches its peak in Darwin where the weed may grow and develop to an advanced stage over a 6 month period from October to March. The model therefore predicts that the invasiveness of *P. aculeata* varies markedly between the three locations.

The purpose of this model was to simulate the impact that variations in rainfall have on the germination

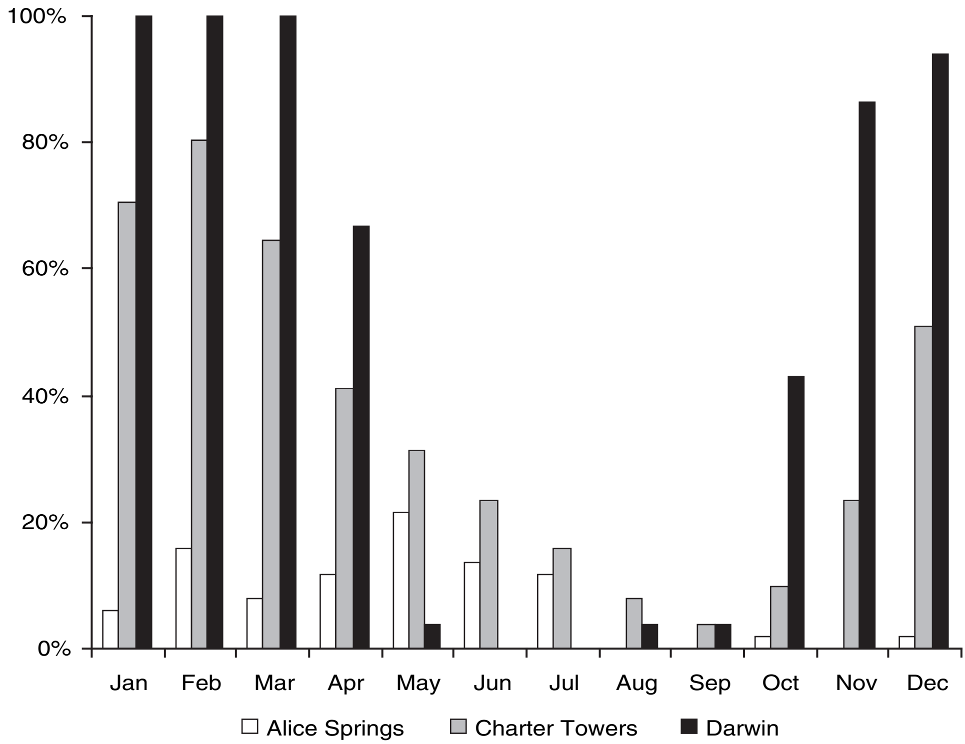

Figure 2. The probability that the rainfall conditions would enable *Parkinsonia aculeata* seedlings to germinate and survive in Alice Springs, Charters Towers and Darwin, based on data obtained from a glasshouse trial.

and survival of *P. aculeata*, which is one of the key processes that takes place in the field. More elaborate field based studies would provide further insights into the growth and development of *P. aculeata* and its interaction with the surrounding plant community. In the field, habitats are generally defined by a range of variables, including soil type and soil moisture, but also by other vegetation types. For a weed to proliferate it may have to compete with existing vegetation and this may reduce the potential for it to become invasive. Conversely, seedling survival may be higher in areas prone to flooding. The simple water balance model produced here is driven solely by rainfall. Flooded areas often harbour large populations of *P. aculeata,* particularly in drier climates such as Charters Towers. The likelihood of seedling survival in these flooded regions is greater because the required level of soil moisture necessary to germinate and propagate the seedling will be met more frequently. Furthermore, in flooded areas the entire soil profile would be saturated, thus increasing the soil depth and plant available water beyond the 20 cm used in the model. The current model is ideally suited to broadly differentiating between environments. It is not capable of precisely modelling small-scale ecological processes brought about by changes in vegetation structure or flooding. Obviously, with extensive fieldwork, a more capable predictive model could be produced that would determine the nature and extent of the habitat requirements of a weedy species.

ACKNOWLEDGMENTS

I thank Lindsay Whiteman from CSIRO Sustainable Ecosystems for the technical support in running the glasshouse trial.

REFERENCES

Booth, C.A., King, G.W. and Sanchez-Bayo, F. (1996). Establishment of woody weeds in western New South Wales. 1. Seedling emergence and phenology. *Rangeland Journal* 18, 58-79.

Lawes, R.A., Abbott, B. and Whiteman, L. (2004). Water relations of *Parkinsonia aculeata* seedlings in three soil types. *Weed Research* (under review).