Is *Retama raetam* (Forsskal) Webb a legitimate alert list species?

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Summary *Retama raetam* (Forsskal) Webb (white weeping broom) is a leguminous shrub from the Mediterranean basin that was first recorded in Australia in the 1840s. It has a history as a garden plant, but has escaped and naturalised at several locations around Perth in Western Australia and in various locations in South Australia. *R. raetam* has been placed on the Australian National Environmental Alert List, a list designed for species that pose a significant biodiversity threat, but which are restricted in distribution making control feasible.

Until now, there has been a scarcity of quantitative evidence to support the placement of *R. raetam* on the alert list. However, recent studies reported here demonstrate naturalised *R. raetam* has copious seed production, a high amount of seed dormancy and displays juvenile drought tolerance. These results along with the severity of a handful of current infestations suggest that *R. raetam* warrants control before eradication becomes infeasible.

Keywords Environmental weed, seed dormancy, seed production, root growth.

INTRODUCTION

Retama raetam (Forsskal) Webb (white weeping broom) is a woody leguminous shrub that is indigenous to much of the southern Mediterranean basin (International Legume Database and Information Service 2005). It is more common in the arid and semi-arid areas of its range. *R. raetam* is taxonomically a member of the Cytiseae tribe, which also includes major weeds such as *Cytisus scoparius* (L.) Link (Scotch broom) and *Genista monspessulana* (L.) L.A.S.Johnson (Cape broom).

Retama raetam was introduced to Australia as an ornamental, being first recorded as early as 1845 (Kloot 1986). It has continued to be used as a garden ornamental, prized for its profuse white perfumed flowers. Its ability to withstand drought (Mittler *et al*. 2001) may also make it popular in the recent trend of 'water wise' gardening. Garden plants are the major source of Australia's existing environmental weeds (Virtue *et al*. 2004) and the likely original source of most naturalised *R. raetam* populations. After being first recorded as naturalised in South Australia in 1906 (Kloot 1986), *R. raetam* has now naturalised around Perth in Western Australia and in various locations around South Australia (Council of Heads of Australian Herbaria 2005). In common with its distribution in its native range, Australian naturalised populations occur in low rainfall areas.

Retama raetam has been included on the National Environmental Alert List and thus considered to have the potential to become a significant threat to biodiversity if it is not managed (Department of the Environment and Heritage 2004). There has been a lack of quantitative evidence to suggest reasons for placing *R. raetam* on the alert list. The aim of this study was to provide some quantitative biological information on the potential threat of *R. raetam* as an environmental weed.

MATERIALS AND METHODS

Soil surface seed bank The production of a large number of seeds increases the probability that some progeny will land in a spot favourable for germination. It is one trait considered to be associated with weediness (Baker 1974).

Retama raetam pods dehisce from the parent plant during mid to late summer and accumulate on the soil surface. Sampling occurred in February, once all the seed were fully ripened and had a chance to dehisce from the plant. At the four sites studied, quadrats (50 cm^2) were placed at random in four locations in both 2003 and 2004 and five locations in 2005. Sites are listed in Table 1. Pods were sucked with a portable vacuum unit from the soil surface. Intact pods were threshed using corrugated rubber threshing boards to minimise damage to the seed. Samples were cleaned and then weighed. To calculate the number of seeds per sample, all seed from that location were bulked and seven lots of 100 seeds were taken and weighed to give a mean 100 seed weight. Where there were less than 700 seeds collected from a site, all seeds were counted and weighed and a 100 seed weight calculated.

Initial level of impermeable seed Legumes are commonly associated with possessing physical seed dormancy (Baskin and Baskin 1998). This provides the seed with temporal protection from germinating shortly after spring-summer ripening, a time with infrequent rain events and high temperatures.

During February 2004, ripe, intact pods of *R. raetam* were collected randomly at Kadina from one shrub. Four replicates of 50 pods were randomly selected to determine the initial level of impermeable seed. Seeds from these lots were removed from the pods, then placed in Petri dishes on moist filter paper and incubated for two weeks at a constant 20°C with 12 hour day and 12 hour night cycles. The number of seeds that had not imbibed were counted after 14 days.

Seedling growth Moisture is often a limited resource in Australian natural ecosystems. The ability of seedlings to grow in conditions of dry soil may be advantageous, especially in lower rainfall environments. Root system attributes may be important in allowing a species to achieve this.

An experiment was undertaken to study the growth of *R. raetam* seedlings in high and low soil moisture. The experiment was conducted in a north-facing glasshouse on Waite Campus during December 2004 and January 2005. Daily minimum and maximum temperatures fluctuated between 12°C and 20°C and 20°C and 29°C respectively. Plants were grown in 8.5 cm square pots measuring 18 cm in height. Pots were filled with University of California potting mix to a standardised weight before the commencement of the experiment.

As the objective was to investigate the species' seedling growth, not individual ecotype growth, seeds from several different locations were mixed together. Seeds were collected from wild plants at Kadina, Lipson and Robe (see Table 1 for details). Scarified seed were pre-germinated in Petri dishes before being planted into pots. Germinated seeds with 1 cm radicles were sown at a depth of 1 cm. Each pot contained one plant.

The randomised block design included two watering treatments, full water and no follow up water, and these were replicated nine times. All pots were watered from the day prior to planting with 10 mL water pot^{-1} day^{-1} until four days after the germinated seeds had been planted. On the day of planting, pots received 10 mL of Fongarid® fungicide mixture in place of straight water. The no follow up water treatment received no further water after the fourth day. On the fifth day after planting, two replicates of the full water treatment were weighed and then watered slowly until water drained from the medium. The pots were left to stand overnight before being weighed again and a mean weight calculated. The difference between this weight and the pre-water weight taken the previous day provided the amount of water that was given to each pot of the full water treatment. Every three days this process was repeated.

Plants were destructively harvested 29 days after planting and the shoots and roots separated. Leaf area was measured by the program WinDias 2.0. Root systems were first cleaned before being scanned and analysed using WinRhizo Pro version 5.0. Root and shoot material were dried separately at 60°C for 72 hours and then weighed.

Differences between watering treatments were assessed by the use of two sample t-tests. Shoot dry matter was *ln* transformed prior to analysis.

RESULTS

Soil surface seed bank Three of the four *R. raetam* populations studied accumulated a large amount of seeds on the soil surface (Table 2). The population at Kadina accumulated the largest soil surface seed bank and also possessed the smallest seeds (Table 3).

Table 1. Location of *R. raetam* populations studied.

Site	Mean annual rainfall (mm)	Land use
Blyth	424	Roadside
Kadina	388	Native vegetation
Lipson	394	Roadside
Robe	633	Roadside

Table 2. Mean soil surface seed bank (seeds m^{-2}) ± SE of studied *R. raetam* populations.

Site	2003	2004	2005
Blyth	–	968 ± 190	760 ± 122
Kadina	–	7165 ± 677	5877 ± 1301
Lipson	4932 ± 975	–	–
Robe	–	5556 ± 1479	3284 ± 749

Table 3. Mean seed mass (mg) ± SE of studied *R. raetam* populations.

Site	2003	2004	2005
Blyth	–	61.15 ± 0.08	68.39 ± 0.17
Kadina	–	55.56 ± 0.01	54.81 ± 0.02
Lipson	63.53 ± 0.37	–	–
Robe	–	78.81 ± 0.07	79.39 ± 0.15

Initial level of impermeable seed Seed collected from Kadina in 2004 possessed 79% impermeable seed. Viability of the seed was high with 92.5% able to germinate successfully once scarified.

Seedling growth The effect of drought significantly reduced the above ground traits, shoot dry matter ($P < 0.05$) and specific leaf area ($P < 0.05$) (Table 4). However, no root traits differed significantly between the two watering treatments.

DISCUSSION

The production of a large number of propagules increases the chance of successful recruitment. At all sites except for Blyth, *R. raetam* surface seed banks exceeded 3000 seeds m^{-2}. Large seed production also, along with suitable seed dormancy, contributes to the formation of large persistent seed banks. These are able to disperse the population in time and help guard against severe events to the parent population such as drought, fire or deliberate weed control. *R. raetam* appears to be well adapted to achieve this in the sites studied.

Retama raetam had a larger individual seed mass than other weedy temperate legume shrubs (unpublished data). Large seed mass has proved advantageous in establishing under dry soil conditions (Leishman and Westoby 1994) and may have aided *R. raetam* in naturalising in dry environments.

Retama raetam is a desert plant in its natural habitat (Davis 1953), so must have mechanisms to cope with moisture and heat stress. Mittler *et al.* (2001) found that the upper canopy stems of *R. raetam* enter a type of 'dormancy' under drought stress. The characteristics of the root systems of *R. raetam* may also contribute to its drought tolerance. Whilst above ground its growth was reduced by water stress, root growth and the proportion of biomass devoted to root growth were not affected by drought. Under water stress, a plant that reduces the amount of leaf area is advantaged through reduced transpiration (Lambers and Poorter 1992). However, maintaining or increasing the proportion of biomass invested into roots increases the plant's ability to find moisture. Species from stressful habitats often allocate extra resources to root growth (Lambers and Poorter 1992). The ability of a plant to explore and capture soil resources is critical, especially in situations where they are limiting.

It appears that *R. raetam* is climatically suited to much of southern Australia, but particularly to the lower rainfall regions with alkaline soils. It is most frequent in the Northern and Yorke Region in South Australia. Whilst *R. raetam* is at present confined predominately to roadsides, only 21% of native vegetation in the Northern and Yorke Region remains. Most of this is severely fragmented and small in area (<20 ha) (Graham *et al.* 2001). Small isolated remnants are much more vulnerable to increasing disturbance, which facilitates weed incursion (Hobbs and Atkins 1988). This particularly applies to roadside vegetation, a significant source of biodiversity in agricultural regions. The presence of threatened indigenous species in roadside vegetation in the Northern and Yorke region (Kenny *et al.* 2000) highlights the need to value and protect any remnant vegetation.

From the sites reported in this study and other opportunistic sightings, it is apparent that current herbarium records do not adequately reflect the true extent of the distribution of *R. raetam*. Of the known locations, most populations still appear to be limited to a handful of adult plants, except for three larger infestations. The largest one at Kadina occurs around the Wallaroo Mines site on Yorke Peninsula, which is of historic conservation significance.

As current herbarium records do not reflect the true extent of *R. raetam*'s distribution, adequate mapping will be needed to assess if eradication is still feasible. Considerable resources will be required for successful control of the three known significant infestations. Whilst *R. raetam* has been naturalised for around 100 years, it was not recorded in a native vegetation survey of the Yorke Peninsula in 1994 (Kenny

Table 4. Mean values ± SE of studied *R. raetam* seedling traits.

Trait	Drought	Water
Shoot dry matter (g)	0.039 ± 0.002	0.057 ± 0.007
Specific leaf area (g_{leaf} cm^{-2})	93.11 ± 4.2	117.44 ± 5.5
Root dry matter (g)	0.008 ± 0.007	0.009 ± 0.001
Root mass ratio (g_{root} $g^{-1}{}_{plant}$)	0.16 ± 0.01	0.14 ± 0.01
Root: shoot ratio (g_{shoot} $g^{-1}{}_{root}$)	0.20 ± 0.15	0.16 ± 0.01
Total root length (cm)	76.79 ± 8.51	74.43 ± 10.12
Root surface area (cm^2)	12.79 ± 1.27	12.75 ± 1.93
Specific root length (g_{root} $cm^{-1}{}_{root}$)	9893 ± 733	8032 ± 544

et al. 2000) or recognised as a pest plant of concern in the Integrated Natural Resource Management Plan for the Northern and Yorke Agricultural District (Northern and Yorke Agricultural District Integrated Natural Resource Management Committee Inc. 2003). This may indicate that these infestations are relatively recent and that *R. raetam* is nearing the end of its lag phase after which its range may increase substantially (Hobbs and Humphries 1995).

Awareness of the weed potential of *R. raetam* is low, especially in the regions where it is already established. Communication with nurseries is essential to avoid sale of the species and distribution of the existing White Weeping Broom Management Guide (CRC for Australian Weed Management 2003) would be a useful extension process to the community in general.

The inclusion of *R. raetam* on the alert list seems warranted. Naturalised *R. raetam* populations are characterised by producing large amounts of dormant seed. *R. raetam* seedlings are not significantly affected by dry soil conditions, providing advantages for establishment in drier areas. These areas comprise much of southern Australia's dryland agricultural landscape and the remaining native vegetation is of high biodiversity and conservation value. Environmental weeds have the capability to severely degrade these remnants. *R. raetam* does appear to pose a significant threat as an environmental weed and control actions need to be prioritised before eradication becomes infeasible.

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