Invasive potential and competitive ability of the Eurasian herb

*Centaurea solstitialis* L.

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Summary *Centaurea solstitialis* L. is a highly invasive weed in several Mediterranean ecosystems, but until now has shown minimal and spatially restricted invasiveness in Australia. However, *C. solstitialis* may be a sleeper weed with the potential to become highly invasive in Australia some time in the future. The aims of this study were to investigate whether *C. solstitialis* is a sleeper weed and the factors that may inhibit the species from becoming as invasive in Australia as it has elsewhere. Two glasshouse experiments are reported here that looked at differences between *C. solstitialis* from different locations and competition dynamics of the local plants. Results so far are inconclusive as to whether there are phenotypic differences between *C. solstitialis* plants sourced from various populations in Australia and overseas, but the competition experiments show that the common native grass *Austrodanthonia caespitosa* (Gaudich.) H.P.Linder competes strongly with *C. solstitialis* and we suggest that this may be a factor in preventing invasion of South Australia’s native grasslands.

Keywords *Centaurea solstitialis*, sleeper weed, competition, biotic and abiotic stress, invasive, *Austrodanthonia caespitosa*, *Avena fatua*.

INTRODUCTION

Invasive plants are a highly visible part of the landscape with well-documented costs to the Australian environment and economy (Martin 2003). Efforts to control weeds are predominantly concentrated on preventing entry of new pest species into Australia and controlling those species that cause the most harm. Other species worthwhile considering are those that have become naturalised in the Australian landscape but have not become invasive. Analysis of the history of invasions in Australia has shown that a minority (~10%) of introduced plants become naturalised and a similar proportion become invasive (Williamson 1996). Similarly, in Australia there are 343 species on the Noxious Weeds List and at least 2779 naturalised exotic species from more than 27,000 known introductions (Virtue et al. 2004).

This leaves more than 2400 species of exotic plants that have established in Australia without becoming strongly invasive, although many are minor problem weeds in some local areas. These exotics are likely to include some ‘sleeper weeds’, which are introduced plants that have naturalised in a region but not yet increased their population size exponentially (Groves 1999). This period of slow growth can be considered as a time lag between establishment and invasive spread, and can take a few decades, (e.g. for *Echium plantagineum* L.) (Piggin and Sheppard 1995) or more than 50 years for *Mimosa pigra* (Lonsdale 1993). A study of 184 European weeds gave average time lags of 131 years for shrubs and 170 years for trees to become invasive (Kowarik 1995). This amount of time might be necessary for a species to adapt to local conditions sufficiently to become invasive.

While many of the 2400 naturalised species will remain low impact weeds, a proportion of them are likely to become invasive at some point in the future. It is therefore important to define, identify and predict which species will become invasive. However, attempts to predict the invasiveness of a species or group of species is difficult, with most studies comparing attributes of invasive and non-invasive species (Perrins et al. 1992, Reichard and Hamilton 1997, Rejmanek and Richardson 1996, Williamson and Fitter 1996) or the invasability of various ecosystems (Maron and Connors 1996, Naem et al. 2000, Tilman 1997, Wardle 2001) with varying and inconsistent results. However, some of the best predictors of weediness are country of origin, history of invasion and taxonomy of the species (Kolar and Lodge 2001), but none relate specifically to the dynamics of time lags. Predictions of invasiveness are difficult, while prediction of ‘sleepiness’ is hitherto unknown.

Work in Australia on predicting sleeper weeds for early, cost-effective eradication uses AQIS protocols that include history of invasion and ecological amplitude (Brinkley and Bomford 2002) to identify potential threat species. Given the difficulties of assigning sleeper status to a species, the best method of assessment is...
to investigate possible factors constraining a sleeper weed. Our study looks at several potential factors that can influence sleeper weed status such as phenotypic and genotypic differences, as well as biotic and abiotic variables pertaining to the species’ new environment. These variables can include water and nutrient status as well as competition from local species.

The Eurasian annual *C. solstitialis* has been in South Australia (SA) for at least 125 years (herbarium specimen), and has a limited, sparse distribution here but is a declared species in parts of New South Wales. However, it is highly invasive in several other Mediterranean areas of the world, such as California, South America and Europe (DiTomaso 2001, Maddox et al. 1985). *C. solstitialis* is a deep rooted species that grows well in the degraded, perennial grasslands of North and South America, but not in similar areas of SA. Possible explanations of these different invasion dynamics might include different growth characteristics or competitive abilities of the local phenotypes.

We set up experiments to investigate whether there were phenotypic differences between plant populations as well as an experiment to see how *C. solstitialis* competes against native grass species, under different nutrient and moisture conditions.

We tested the hypotheses that phenotypes would differ between different locations, and that soil moisture and nutrients would be a major limiting factor in growth and competitive abilities of *C. solstitialis*.

**MATERIALS AND METHODS**

An experiment was set up to assess differences in growth between *C. solstitialis* plants from different origins. Seeds were sourced from *C. solstitialis* populations in several different locations including Australia (SA, Victoria, Queensland), Europe (Hungary, purchased from Herbiseed, UK) and USA (California) and grown in a glasshouse under different nutrient (high and low) and moisture conditions (high and low). Nutrients were added to half of the pots in the form of slow release fertiliser at the manufacturers recommended rate (50 g per 10 litres of potting mix). Low water treatments pots were watered once per week, while high water pots received water twice per week. Plants were grown for four months and shoots were harvested, dried and weighed for comparison between nutrient and water treatments and between locations.

A second glasshouse experiment was set up to assess how *C. solstitialis* competes with other species. *C. solstitialis* was grown either with a conspecific or in competition with another species, the common native grass *A. caespitosa* using four resource treatments. Two planting combinations were used: either two *C. solstitialis* plants (CC) or one *C. solstitialis* and one *A. caespitosa* (CD). Half of the pots were watered twice weekly and the other half once weekly, this gave Wet and Dry treatments, while nutrients were added to half of the pots which gave high nutrient (N) and low nutrient (n). The four combinations being WetN, Wetn, DryN and Dryn, with five replicates for each treatment combination. Plants were grown for six months at 25°C under natural light from late spring until autumn. Plants were harvested separately and dried at 70°C and shoot dry weights (DW) from both experiments were recorded. Shoot DW of plants from different locations were compared for the first experiment. For the second experiment, comparison was made between *C. solstitialis* shoots grown either with conspecifics or with *A. caespitosa*. All analyses used one-way ANOVA and were performed with JMP 4.0 (SAS Institute).

**RESULTS**

At high resource levels some differences were evident between plants from different locations. Above ground dry weights for SA types were significantly larger than the European types (Figure 1). There were no significant differences in dry weights between phenotypes grown in the other three resource treatments (WetN, DryN, Dryn).

At all nutrient levels in the competition experiment, shoot biomass was significantly lower when *C. solstitialis* was grown with *A. caespitosa* compared to those grown with a conspecific. Planting combinations were compared separately for each resource level

![Figure 1. Comparison of mean dry shoot weights (DW) for *C. solstitialis* under the high resource treatment between South Australia (SA); Victoria (Vic); Queensland (Qld); Europe (Euro); California (US). Significant differences are indicated by different letters above columns, P = 0.0042.](image-url)
There were also differences in the growth of *C. solstitialis* under the different resource treatments in the second experiment. There was higher shoot biomass when nutrients were added, whereas soil moisture generally made little difference to growth of *C. solstitialis*.

**DISCUSSION**

There were some differences in the growth of *C. solstitialis* between the five phenotypes, with the SA plants being the largest, which may be evidence of adaptation by the species to SA conditions. This does not support the hypothesis that *C. solstitialis* is a sleeper weed. *C. solstitialis* is known as a strong outcrosser with a selfing rate of 5% or less with corresponding high levels of genetic variability in any given population (Roche et al. 1997, Sun and Ritland 1998). This may explain how it has adapted to the endemic SA conditions. If it were a sleeper we would expect it to be no different or smaller than other phenotypes, particularly those from highly invasive populations such as California. This would suggest an ‘awakening’ would be possible following hybridisation with a secondary introduction.

However, a small garden trial, not reported here, suggests the plants from California exhibit different phenology and grow larger in field conditions with different allocation patterns between the rosette and the shoot leading to more seed production over a longer time. More extensive garden bed trials are needed to investigate potential differences between phenotypes from invasive and non-invasive populations.

The competition experiment was important for studying the characteristics of the local phenotypes, particularly in relation to resource responsiveness and competitive abilities. Our results show that *C. solstitialis* responds strongly to nutrient levels (Figure 2) in contrast to other studies that suggest soil water is of primary importance for this species (DiTomaso, 2001). *C. solstitialis* were significantly smaller at all resource levels when competing with *A. caespitosa* but particularly so at the lowest resource levels, under which they rarely set flowers during this experiment. Similar effects have been reported in competition experiments between *C. solstitialis* and the native American bunchgrass *Nassella puchra* (Morghan and Rice 2005). These results provide some evidence that competition from local species may be a factor in helping prevent invasions of the grasslands by *C. solstitialis*. This suggests further degradation of the native grasslands of SA could increase the probability of *C. solstitialis* invading. We are currently comparing competitive abilities of *C. solstitialis* sourced from South Australian and Californian populations, which should provide more relevant information regarding functional differences between these types.

The invasive potential of *C. solstitialis* in SA is limited by a combination of climate, agricultural use and suitable natural environments. Further, we suggest the competitive abilities of native grasses such as *A. caespitosa* and the low nutrient status of SA soils will act to reduce the likelihood of invasion of the grasslands by *C. solstitialis*. Given the amount of time *C. solstitialis* has been naturalised in Australia, it may be that the most likely mechanism for ‘awakening’ the species is through significant landscape degradation, although secondary introductions should not be ruled out.

The definitive test of whether a species is a sleeper can only be post hoc. If *C. solstitialis* becomes highly invasive in South Australia we can say it was a sleeper weed. Current evidence favours the hypothesis that it is not a sleeper weed but this is probably dependent on relevant timescales. However, it is not certain how long would be required to declare a non-sleeper. The possibility of changing management practices on potential growth for *C. solstitialis* populations also needs investigation.

**REFERENCES**


from garden plots in Italy. *Biological Control* 4, 149-56.


