CHARACTERIZATION OF THE REPRODUCTIVE BEHAVIOUR AND INVASIVE POTENTIAL OF PARThENIUM WEEd IN AUSTRALIA

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ABSTRACT
Genetic and environmental and reproductive factors can play a vital role in the invasion success of plant species. In fact, recent studies indicate that plant reproductive systems are an important determinant of invasion success. To test these hypotheses, this study used two independent introductions of Parthenium hysterophorus L. (Asteraceae), which differ in invasion success post-introduction into Australia. Using individuals from both Clermont and Toogoolawah populations in this study, we examined some significant differences in their pattern of morphological characters, the floral structures and the reproductive behaviour of the two different populations of parthenium weed in Australia and assessed if differences identified in these populations correlate with invasiveness.

Key words: Invasive Species, Parthenium weed, Reproductive biology, Self-compatibility.

INTRODUCTION
One of the most disturbing aspects of globalization is the movement of exotic plant species into virtually every ecosystem on earth (McNeely, 2001; Vitousek, 1997). Global trade has increased the opportunities for organisms to be spread widely and repeatedly introduced to new areas. Australia is facing weed invasions from within as well as from overseas. Every year new alien weeds are introduced into the country, and some that are already naturalized (including parthenium weed) extend their range to other parts of Australia (AWS, 2006). When species are transported across biogeographic barriers to dispersal, it may become invasive, endangering the native species in the invaded ecosystem, undermining agriculture, threatening human and animal health and/or creating other unwanted and often irreversible effects on human life.

Both genetic and ecological factors are thought to play a vital role in the invasion success of plant species (Saki et al., 2001). Furthermore, recent studies suggest that reproductive systems are important determinants of genetic variation in species, which in turn

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may have impacts on the invasiveness of a species. However, little empirical evidence is currently available to support these hypotheses. As a case study, we have used use Parthenium hysterophorus L. (Asteraceae), commonly known as parthenium weed, an invasive plant and agricultural weed in eastern Australia, to test these hypotheses. Parthenium weed is considered as a major weed of grazing land in central Queensland, where it significantly reduces the productivity of pastures (Navie et al., 1996). This species was first reported in the Toogoolawah district in south-eastern Queensland in 1956 and it has been suggested that this introduction occurred via machinery during the World War-II (Parsons and Cuthbertson- 1992). A second introduction is thought to have occurred in contaminated pasture seed lots in the Clermont district in central Queensland in 1958. The history of spread of the weed from these two introductions is quite different. The Toogoolawah population seems to be much less invasive, with its population size remaining small and isolated, while the Clermont population has spread to cover many millions of hectares in central Queensland.

It should not be assumed that all populations of an introduced species will demonstrate invasiveness, since the propensity for invasiveness may be a result of genetic factors as well as ecological factors (Sakai et al., 2001). There may be different biological characters (especially growth and morphological attributes, reproductive behaviour and competitiveness) that may make one genetically distinct population of a weed more invasive than another. Thus, the present study was undertaken in order to examine whether various morphological, physiological and reproductive characters may have played a crucial role in the process of invasion.

**MATERIALS AND METHODS**

Seeds of the Clermont population (Central Queensland) and Toogoolawah population (South-east Queensland) of parthenium weed were obtained from the UQ seed collection held at the School of Agriculture and Food Sciences (SAFS) in Brisbane, Queensland. The seeds were germinated and 25 replicate seedlings from each population were individually grown in pots (25 cm diameter) in a temperature controlled glasshouse (28 ± 5 / 18 ± 2 °C: day/night). Data were then recorded for several different phenological characters. To investigate any differences in the floral morphology, five flowers from each replicate plant were collected and photographed using a Nikon SMZ-D AFX-11A photo microscopic system with FX-35 camera and their floral structures measured using Image Tool for Windows version 3.0, an image analysis software product developed by the University of Texas. In order to determine the reproductive behaviour
of the plants, with respect to self-compatibility, five flowers from each plant were enclosed in small glassine bags. At the time of seed physiological maturity, the glassine bags containing flowers were collected and the seeds produced removed from the flowers. The bagged seeds were x-rayed to determine the percentage of seed filled in each population, and were compared with non-bagged flowers. The total percentage of filled seeds in each population was used as an indicator of self-compatibility.

**Statistical Analysis**

The data sets were subjected to two sample T-tests and one way ANOVA using the Minitab statistical package to determine if any of the measured parameters differed statistically between the Toogoolawah and Clermont populations.

**RESULTS**

**Growth Patterns**

The results clearly indicated that both the Clermont and Toogoolawah populations exhibited very similar growth patterns during the early rosette stage. However, as time progressed, the plants belonging to the Clermont population showed more vigorous growth attributes. The Clermont plants had produced significantly more leaves after both five and ten weeks of growth ($P < 0.001$). Both populations were also found to be significantly different from each other in some other morphological characters, such as average length of primary branch ($P = 0.003$) and height of plant ($P < 0.001$). It is also evident from the results that seeds produced by the Clermont population were statistically larger than those produced by the Toogoolawah population. Seeds from both the Toogoolawah and Clermont populations reached greater than 90% germination in 3 weeks under ideal conditions (ca. 20-25 °C and 12/12 day/night). However, seeds from the Clermont biotype had an increased rate of germination (Fig. 1).

**Floral Morphology**

The morphology of floral structures plays a vital role in the pollination biology of plant species. It is clear from the data analysis that flowers produced by plants of the Toogoolawah population were quite different in structure when compared with flowers produced by plants of the Clermont population. In particular, the flowers of Clermont plants had significantly longer stamens and involucre bracts than those of Toogoolawah plants ($P < 0.001$). It was also apparent that Toogoolawah plants initiated their first flowers earlier than plants of the Clermont biotype (Fig. 2).
Self-compatibility

The results of this experiment indicate that the two populations of parthenium weed have significantly different levels of self-compatibility. In the control treatments, both the Clermont and Toogoolawah biotypes produced above 80% filled seeds. However, in the treatment with glassine bagged flowers, 73% of seeds produced by the Toogoolawah plants were filled compared to only 28% of seeds produced by the Clermont plants.

Figure 1. Mean values of several growth and germination parameters recorded from two populations of parthenium weed: a) number of leaves; b) average length of primary branch; c) Plant height d) germination rate. Values are the means of 25 replicates. Clermont and Toogoolawah.
Figure 2. Mean values of several reproductive parameters recorded from two populations of parthenium weed: a) days to flowering b) stamen length c) self-compatibility levels. Values are the means of 25 replicates. Clermont and Toogoolawah populations.

DISCUSSION
Overall the results presented here show clear differences in morphological characters, seed physiology and reproductive systems between the two biotypes. While it would be nice to speculate which of these differences may be linked to increased invasiveness of the Clermont biotype, given that the biotypes differ in most attributes
examined this is not possible. Instead differences between the biotypes will be discussed and related to the current literature on biological invasions.

The results recorded for various growth attributes showed that plants of the Clermont population displayed faster growth when compared to plants of the Toogoolawah population, especially after the bolting (i.e. stem elongation) stage of their life cycles. This difference is most probably due to different level of metabolism at different life stages or to the expression of genetic differences.

After the bolting stage of their life cycles, the two populations exhibited differential priorities for their further development. Plants of the Clermont population required a much shorter period of time to initiate stem elongation than plants of the Toogoolawah population, and also produced a larger number of leaves and branches. This may be considered to be a useful competitive trait, especially when parthenium plants are becoming established in a new area or during their subsequent secondary spread. Invasive plants with a taller stature, larger leaves and branches, and a faster growth rate would have an architecture which may enhance their success when they are exposed to competition with other species in the field.

It is also apparent from the results that the two populations of parthenium weed in Queensland are employing comparatively different seed production strategies. Plants of the Clermont population produced much larger seeds along with accessories in comparison with Toogoolawah. Pandey and Dubey (1988) have analogous observations regarding variations in seed size. The larger seeds of the Clermont biotype could be a factor facilitating short to long dispersals by water, wind and other agencies. The seeds of both populations showed a relatively high level of germination (i.e. above 90%) under ideal conditions (ca. 20-25 °C and 12/12 day/night) for 21 days. However, seeds of the Clermont population proved more opportunistic by achieved 50% germination in only a few days while seeds of the Toogoolawah population took more than a week to complete 50% germination. This opportunistic and rapid germination behaviour may be one reason why the Clermont population produces such large stands of plants following significant rainfall events in Central Queensland. Such a rapid germination rate may be an important contributing factor for seedling establishment and provide a competitive advantage (Baker, 1972). The germination behavior of the two populations may be due to different dormancy mechanisms inherited in them (Dixon et al., 1995). It may also depend upon several climatic factors, including the pattern of rainfall and the timings of subsequent germination events at a site (Coffin and Lauenroth, 1989).
Keeping in mind the importance of floral morphology in the pollination biology of plant species, the reproductive structures of the Toogoolawah population were found to be reduced in size when compared to the Clermont population. The larger and broader floral structures of the Clermont plants may result in increased exposure and increased pollen capture from the surrounding plants. Such a reproductive strategy would likely favor cross-pollination, while the reverse is true for the Toogoolawah plants. Gupta and Chandra (1991) considered parthenium weed to be entomophilous or at most amphiphilous. The outcomes of the present research suggest that parthenium weed is not an obligate out-crosser, but it is capable of both pollination types, and that the level of self-compatibility varies from population to population. It was found to be as high as 73% in the Toogoolawah population and as low as 30% in Clermont population. A reasonable amount of self-compatibility is crucial to produce enough seeds during the secondary spread of parthenium weed into new locations. However, out-crossing is also important for maintaining genetic diversity in populations, which are then able to adapt to a wider range conditions and facilitate invasion.

Based on the very prominent differences observed in the physiology, morphology and reproductive systems of these two populations, future studies are planned to compare the competitiveness and genetic diversity of the Clermont and Toogoolawah populations. Furthermore, we will examine which traits are associated with invasiveness in the Clermont biotype, using crosses to introgress particular traits from the Clermont biotype into the Toogoolawah biotype and assessing their competitive ability in comparison to parental biotypes.

REFERENCES CITED


