Technical note

Allelopathic potential of the weed, *Parthenium hysterophorus* L., in Australia

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Summary
The effect of aqueous leachates of parthenium weed (*Parthenium hysterophorus* L.) leaves on germination and seedling growth of five test species was examined. Germination of climbing buckwheat (*Polygonum convolvulus* L.), liverseed grass (*Urochloa panicoides* Beauv.), buffel grass (*Cenchrus ciliaris* L.) and parthenium weed were significantly ($P < 0.05$) depressed (92, 95, 88 and 80% respectively) at the highest leachate concentration used (250 mg fresh leaf material mL^{-1}) while the lowest concentration (63 mg fresh leaf material mL^{-1}) significantly ($P < 0.05$) depressed germination of climbing buckwheat, liverseed grass and buffel grass (80, 80, 87% respectively) but not parthenium weed. Neither high nor low leachate concentrations significantly reduced the germination of sunflower (*Helianthus annus* L.). Seedling growth, as measured by biomass production of sunflower, liverseed grass, climbing buckwheat and buffel grass were all significantly ($P < 0.05$) depressed (22, 65, 26 and 76% respectively) at a medium leachate concentration (125 mg fresh leaf material mL^{-1}), while a slight stimulatory effect was observed on parthenium weed. The most sensitive species to the leachate applied at the seedling stage was buffel grass which exhibited significant ($P < 0.05$) reductions in shoot and root biomass as well as plant height.

Introduction
Parthenium weed (*Parthenium hysterophorus* L.) (Asteraceae) is an aggressive weed native to southern North America, Central America, the West Indies and central South America (Picman and Picman 1984) and through accidental introduction in Africa, India and Australia (Everist 1988). In many of these locations the weed has become a serious agricultural problem, invading new areas to the exclusion of all other species and greatly reducing the productivity of subtropical crops and pastures (Picman and Picman 1984). The weed is also toxic to some grazing animals (Ahmed *et al.* 1987) and is a medical hazard to humans causing hay fever and allergic eczematous contact dermatitis (Towers 1981).

Parthenium weed was first reported in Australia in 1955 and has since spread throughout the grazing areas of central Queensland. It has not yet emerged as a major weed of cultivation, although some annual crops have become infested (White 1994). Control of the weed has been difficult; physical methods are often ineffective, chemical control is generally uneconomical (Gupta and Sharma 1977) and biological control has, so far, been largely unsuccessful (McFadyen 1992). The successful spread of parthenium weed in India has been attributed to its allelopathic properties, which allows the weed to compete more effectively with otherwise strong crop or pasture species (Mersie and Singh 1987). Phyto-inhibitors are released from the mature plant to the soil through leaching from the leaves (Kanchan and Jayachandra 1980a, Picman and Picman 1984, Swaminathan *et al.* 1990) and/or shoots (Sarma and Subrahmanyan 1975, Mersie and Singh 1987, 1988), the roots (Kanchan and Jayachandra 1979a, Guzman 1988) and during decomposition of the residues in the soil (Rajan 1973, Kanchan and Jayachandra 1979a,b, Mersie and Singh 1987). Several sesquiterpene lactones and phenolics are thought to be the water soluble compounds involved in these allelopathic responses (Picman and Picman 1984, Swaminathan *et al.* 1990). The reasons for its rapid spread in Australia are unknown.

This present study was undertaken to provide information on the allelopathic potential of Australian parthenium weed plants, which are thought to have been introduced from North America. Specifically, the objectives were to:

i. detect the presence of any phyto-inhibitors produced by the leaves of parthenium weed, and

ii. investigate the allelopathic potential of parthenium weed on germination and seedling growth of a range of species commonly found in pasture and arable land in central Queensland.

Materials and methods

Plant materials

Five species: buffel grass (*Cenchrus ciliaris* L.), a common pasture grass, climbing buckwheat (*Polygonum convolvulus* L.), a common dicotyledenous weed of winter cereal crops; liverseed grass (*Urochloa panicoides* Beauv.), a common monocotyledenous weed of summer cereal crops; sunflower (*Helianthus annus* L.), a summer, dicotyledenous crop plant; parthenium weed (*Parthenium hysterophorus* L.), to observe any autotoxic effects; were used as test species in this study. Buffel grass seed was purchased in March 1993 from Heritage Seeds Pty. Ltd., Yeerongpilly, Brisbane. Climbing buckwheat seed was collected in September 1990 from sites around the Darling Downs. Liverseed grass seed was collected in December 1989 from sites around the Darling Downs. Sunflower seed was taken from the storage facility at The University of Queensland's Redland Bay property in March 1993. Parthenium weed seed was collected in 1992 from sites around Emerald in central Queensland. All seed samples were stored, dry, at 4°C before use.

Leachate production

Parthenium weed plants were grown in a controlled temperature glasshouse (day: 22 ± 2°C, night: 17 ± 2°C) in plastic pots (30 cm height by 20 cm diameter) containing a University of California potting mix moistened to field capacity. After approximately 90 days the plants flowered and all green leaf lamina material was removed and placed into 20 g freshweight batches. In each batch the leaf lamina material was cut into approximately 1 cm^2 sections and shaken gently with 80 mL of distilled water in a 500 mL flask for three minutes at approximately 25 ± 2°C, in the light. This procedure was repeated further to produce a total of 12 batches of leachate which were then decanted into a stock one litre Schott bottle. The undiluted leachate was, therefore, produced from the equivalent of 250 mg fresh leaf lamina material mL^{-1}. Some of this leachate was diluted to give three-quarters (190 mg fresh leaf material mL^{-1}), one-half (126 mg fresh leaf material mL^{-1}), and one-quarter (63 mg fresh leaf material mL^{-1}) strengths. All concentrations were stored in a darkened refrigerator at 4 ± 2°C and used within 30 days of preparation.

Leachate on seed germination

Seed of the test species was surface-sterilized by shaking in a 0.5% (v/v) sodium hypochlorite solution containing 0.1% (v/v) Tween 20 for three minutes followed by three washes in sterile water. Petri dishes (9 cm diameter) were lined with two layers of Whatman No. 5 filter paper and wetted (5 mL) with each of the leachate solutions or with distilled water. Five replications each having 20 surface sterilized seed, were placed on each of the five leachate concentrations. Each Petri dish with seed was closed with parafilm and incubated at 25 ± 1°C for a period of 14 days in a darkened germination incubator (Lindner and May Pty. Ltd., Brisbane, Queensland, Australia). Germination counts were taken at this time and any unusual morphological features of the seedlings recorded.

Leachate on seedling growth

Seed of the test species was imbibed in the tap water and germinated in vermiculite in a controlled environment glasshouse (25/20 ± 2°C, day/night with a photoperiod of 13 h). After 14 days, seedlings were removed and transplanted, one per cup, into 9 cm tall styrofoam cups containing 250 g of an acid washed, moist quartz sand. Following the transplantation step the seedlings were given three days of uninhibited growth before the leachate was applied. Twenty seedlings of each test species were individually treated with 40 mL of the appropriate leachate concentration diluted with an additional 40 mL of half strength Hoagland's nutrient solution. The plants were then incubated under the environmental conditions described above with the sand maintained in the cups at field capacity. After a further 14 days the height of each seedling was measured (soil surface to the tip of the tallest leaf), then carefully removed from the styrofoam cups, washed, sectioned and weighed as root and shoot samples, oven dried and weighed again.

Experimental design and statistical analysis

The experiment involving different concentrations of leachate applied to seed was conducted using a factorial arrangement of treatments in a completely randomized design where species and leachate concentrations were the major factors controlling germination. The experiment involving a medium concentration of leachate applied to seedlings was conducted using a factorial arrangement in a completely randomized design. Analyses of variance were carried out on arcsin-transformed data for germination percentage and natural logarithm transformed data for plant biomass and height.

Results

Germination

All leachate concentrations (250 to 63 mg fresh leaf material mL^{-1}) significantly ($P < 0.05$) inhibited germination of liverseed grass (95 to 80%), buffel grass (88 to 76%) and climbing buckwheat (92 to 80%) (Figure 1). Both the full and 0.75 strength treatment significantly ($P < 0.05$) inhibited parthenium weed germination (80 and 70% respectively), however the 0.25 and 0.5 strengths had no inhibitory effect (Figure 1). None of the leachate concentrations significantly inhibited germination of sunflower (Figure 1).

Seedling growth

A moderate strength leachate treatment (125 mg fresh leaf material mL^{-1}) significantly ($P < 0.05$) reduced total dry weight accumulation in buffel grass, climbing buckwheat, sunflower and liverseed grass seedlings (Figure 2). The total dry weight of parthenium weed was not significantly ($P < 0.05$) reduced by this treatment (Figure 2). Of the species where total dry weight accumulation was significantly reduced buffel grass and liverseed grass had both root and shoot growth significantly ($P < 0.05$) reduced (Figure 2). Climbing buckwheat, although not having its root biomass reduced by the

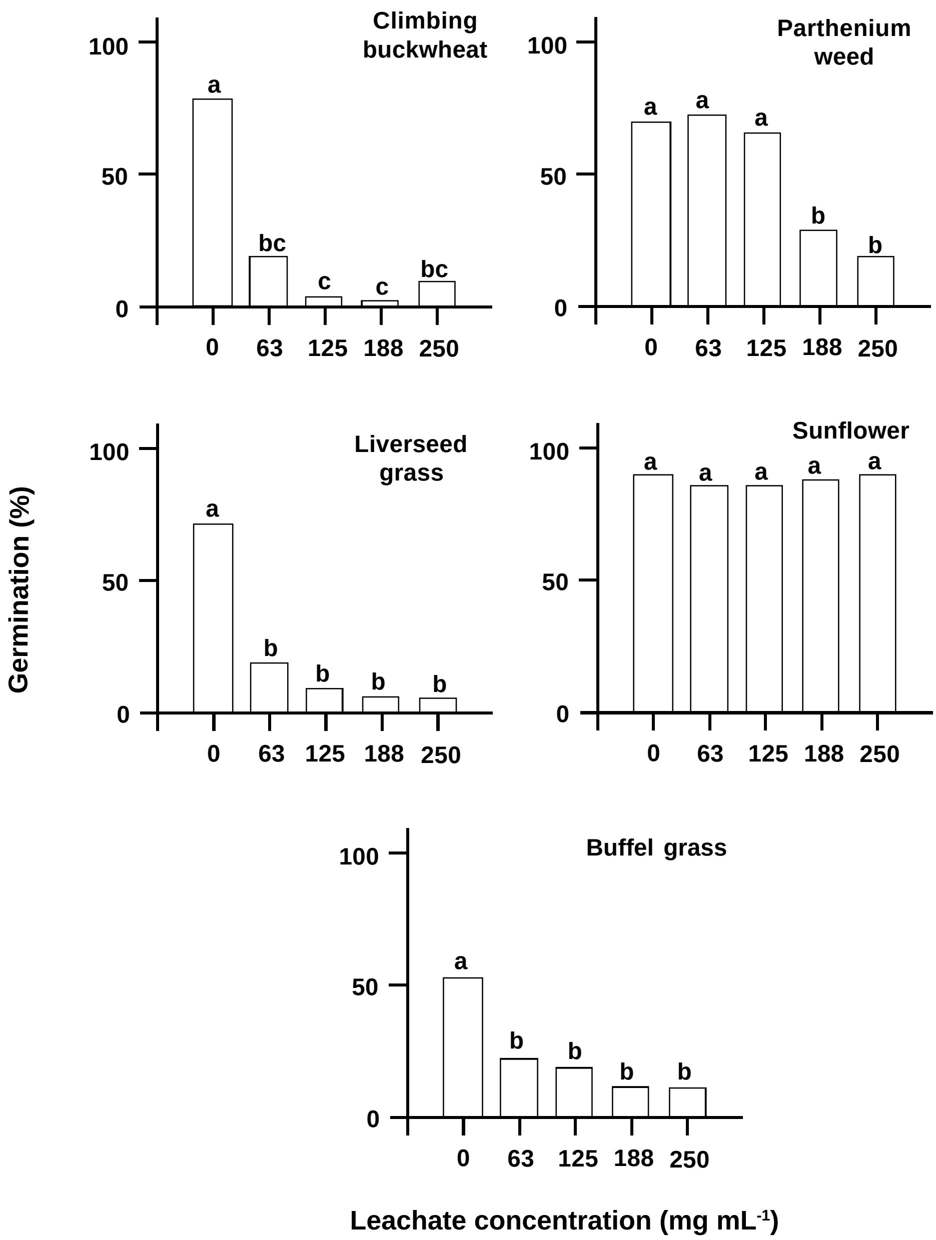

Figure 1. The influence of various leachate concentrations (250 to 0 mg fresh leaf material mL^{-1}) derived from parthenium weed leaves on the germination of five test species.

For each species there were 5 replicate samples of 20 seeds in each leachate treatment. Bars below letters that are the same are not significantly different ($P > 0.05$) between leachate treatments.

leachate treatments, did have its shoot growth significantly reduced (Figure 2). The moderate strength leachate treatment had a significant (P <0.05) inhibitory effect on height increase of buffel grass, climbing buckwheat and liverseed grass seedlings but not on parthenium weed or sunflower seedlings (Figure 2).

Discussion

With the exception of sunflower, all of the test species exhibited a significant (P <0.05) reduction in germination percentage when treated with the parthenium weed leaf leachate (Figure 1). In addition, seedling growth of all test species with the exception of parthenium weed, was significantly (P <0.05) reduced by the leaf leachate (Figure 2). These inhibitory effects are attributed to the phytotoxic nature of the parthenium weed leaf leachate and, in this regard, parthenium weed plants established from central Queensland populations had a similar allelopathic potential to that seen in plants isolated and studied in India (Kanchan and Jayachandra 1980a). The inhibitory effect of parthenium weed leaf leachate on germination of its own seed (Figure 1) indicates that parthenium weed phyto-inhibitors are autotoxic, providing a self-regulation of its own population size (Picman and Picman 1984). Interestingly, parthenium weed seedling growth was not significantly inhibited by its own leaf leachate (Figure 2). Thus, it appears that once germination has occurred, it is possible that parthenium weed seedlings will be unaffected by the presence of other parthenium weed plants. This would provide parthenium weed seedlings with a significant competitive advantage in a multi-species competition situation.

The significant reduction in germination percentage (Figure 1), shoot and root growth and height increase (Figure 2) of buffel grass by the moderate leaf leachate concentration shows this species to be highly susceptible to parthenium weed phyto-inhibitors. This suggests that buffel grass could be a susceptible species to parthenium weed allelopathic competition in the field. Early removal of parthenium weed from buffel grass pasture is highly desirable if productivity is to be maintained.

The response of climbing buckwheat and liverseed grass to the parthenium weed leaf leachates indicates that these weed species are also highly vulnerable to parthenium weed-derived phyto-inhibitors. Suppression of both root and shoot growth was the mode-of-action in liverseed grass seedlings, whereas inhibition of shoot growth alone was the principal mode-of-action in climbing buckwheat (Figure 2).

Sunflower was the only test species whose germination was not affected by the leaf leachate (Figure 1). This differs from an earlier report which indicated that parthenium weed phyto-inhibitors could reduce the germination of sunflower (Swaminathan *et al.* 1990). However, it should be noted that the concentration of leachates used in the earlier study (made from 500 mg fresh leaf material mL^{-1}) was twice that of the full strength treatment used in the present germination study. In response to a more moderate leaf leachate concentration (125 mg fresh leaf material mL^{-1}) sunflower seedlings exhibited a significant (P <0.05) reduction in total dry weight but not in height (Figure 2). Consequently, germination and seedling growth of sunflowers is less likely to be affected by parthenium weed phyto-inhibitors in the field.

There are a number of important limitations in the present experimental approach which have to be taken into account when conclusions relating to the field are drawn. Firstly, the concentrations of leachates used in the present study are likely to be greater than those produced following rain in the field. In addition, the observation that in the field phyto-inhibitors can become bound to soil colloids and that they are reduced in concentration through microbial decomposition (Kanchan and Jayachandra 1979b) were not duplicated in the present experiments.

In summary, parthenium weed plants produced from central Queensland populations undoubtedly produces water soluble phyto-inhibitors in their leaves which are capable of reducing germination percentages and seedling growth of a variety of crop, pasture and weed species coming from the same location as the central Queensland populations. The extent to which these phyto-inhibitors are active in the natural environment is, however, still to be established.

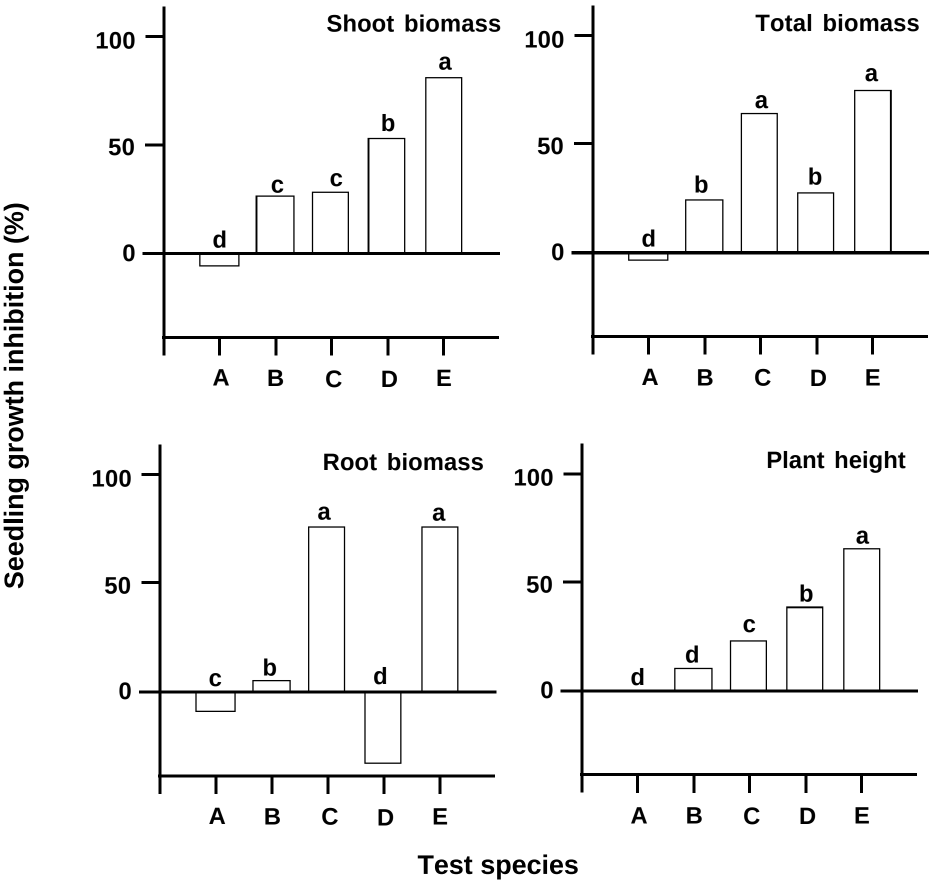

Figure 2. The influence of a medium strength leachate concentration (125 mg fresh leaf material mL^{-1}) derived from parthenium weed leaves on the seedling growth of five test species.
Fourteen-day-old seedlings from parthenium weed (A), sunflower (B), liverseed grass (C), climbing buckwheat (D) and buffel grass (E) were grown for a further 14 days with the leachate before harvest. For each species there were 20 individual replicate seedlings in each treatment. Bars below letters that are the same are not significantly different (P >0.05) between treatments.

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