Management of parthenium weed: enhancing the effectiveness of biological control through competition from beneficial plants

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Summary This study quantifies the combined effect of competitive pasture plants with biological control agents upon parthenium weed growth, first under shade-house then under field conditions at two locations in Central Queensland (Monto and Injune). The glasshouse study showed that the competitive ability of two test species (viz. bull Mitchell grass, *Astrebla squarrosa* C.E.Hubb. and butterfly pea, *Clitoria ternatea* L.) were significantly increased in the presence of the biological control agent *Zygogramma bicolorata* Pallister. In the field trial at Injune competitive plants were shown to suppress the growth of parthenium weed by 18–51% in the absence of biological control agents or by 60–86% in the presence of biological control agents. In addition, the presence of the biological control agents increased the productivity of the test plants by 6–21%. In the field trial at Monto two competitive plants (butterfly pea and buffel grass) were shown to suppress the growth of parthenium weed by around 33 and 50%, respectively, in the absence of biological control agents or by 62 and 69% in the presence of biological control agents. In addition, the presence of the biological control agents increased the productivity of the test plants by 15–30%. The early indications are that the use of competitive plants in the field where biological control agents have been released will increase their effectiveness and provide a source of fodder for grazing animals.

Keywords Parthenium weed, competitive plants, biological control.

INTRODUCTION

Parthenium hysterophorus L., commonly known as parthenium weed, is an invasive weed of global significance and has become a major weed in Australia and many other parts of the world. This noxious weed has been reported as a health hazard to people and domestic stock and is a significant threat to the viability of natural and agro-ecosystems through-out the world (Adkins and Navie 2006). To date, 11 biological control agents (nine insects and two rusts species) have been released in Australia in an attempt to manage this weed. Some of these agents have become well established and have had a measurable impact upon this weed (Dhileepan 2009), but the weed remains a concern to primary producers and for the environment. Other strategies have been recommended for the management of parthenium weed but each has its own limitations. Therefore, an integrated weed management (IWM) approach seems to be the only effective method that is likely to produce promising results. Competitive displacement of parthenium weed with other plant species (native or introduced) has shown potential in several parts of the world including India (Joshi 1991), Ethiopia, Pakistan and more recently in Australia (O'Donnell and Adkins 2005).

The present research aims to quantify the combined effect of competitive pasture plants with biological control agents upon parthenium weed growth under shade-house then under field conditions at two different locations in central Queensland (Monto and Injune). Once completed, these studies will provide an insight into how much more effective biological control agents may become in managing this weed in different environments in central Queensland.

MATERIALS AND METHODS

Shade-house study A shade-house study was undertaken at the Alan Fletcher Research Station, Sherwood, Brisbane, to quantify the combined effect of a parthenium weed biological control agent (*Z. bicolorata*) with two useful competitive pasture plants (viz. bull Mitchell grass, *Astrebla squarrosa* C.E.Hubb and butterfly pea, *Clitoria ternatea* L.) on the growth of parthenium weed. *Zygogramma* adults and larvae were collected from ragweed (*Ambrosia* spp.) plants growing in Fig Tree Pocket, Brisbane, and a colony of the insect was established on shade-house-grown parthenium weed plants. Seedlings of both competitive pasture plants and parthenium weed were raised, then transplanted into soil in pots (25 cm diameter) in the following two densities and combinations: low density (4:0, 3:1, 2:2, 1:3, 0:4; and high density (6:0, 4:2, 3:3, 4:2, 0:6), each with eight replicates for both test plants. The experiment was run as an addition series following Rejmanek *et al*. (1989). Pots of plants were distributed randomly on 20 bench tops within a shade house. There were two adjacent compartments (each size 5 × 7 m) to the shade-house separated by a net wall and both by a circulating water boundary. The trial consisted of 160 pots, placed at random onto steel benches inside each compartment. *Zygogramma* adults were transferred from the stock colony plants (6 week old stage) to the test plants at a ratio of two adults per pot, in just one of the shade-house compartments. At the end of the experiment, the dry biomass of the two test plant species and parthenium weed were determined for each pot. Competition was assessed using a competitive index as described by Spitters (1983) where values greater than 1.0 indicate greater competitiveness than parthenium weed.

Field studies Two field trials were undertaken, one at Injune and one at Monto (central Queensland), to quantify the combined effect of the biological control agents (those present at the field sites at that time) and six competitive pasture plants on parthenium weed growth. At Injune, a suitable site (12 × 24 m), evenly infested with parthenium weed, was selected in consultation with the local land owner. The selected site was ploughed and 90 plots (1 × 1 m) were created. The seeds of the test pasture plants, viz. bull Mitchell grass (*Astrebla squarrosa*), kangaroo grass (*Themeda triandra* Forrsk.), purple pigeon grass (*Setaria incrassata* (Hochst.), buffel grass (*Cenchrus ciliaris* L.), seca stylo (*Stylosanthes scabra* Vog.) and butterfly pea (*Clitoria ternatea*), were obtained from commercial seed merchants and broadcast by hand onto each plot using the standard seeding rate and a tyre roller was used to press the seed into the soil. All plots were laid out in a completely randomised design and each treatment plot was replicated five times. At Monto, a suitable trial site (24 × 80 m) evenly infested with parthenium weed, was also selected in consultation with the local land owner. It was then ploughed and 60 treatment plots (6 × 4 m) were created. The rest of methodology used for this study was the same as that mentioned above for the Injune trial, except that the number of competitive pasture species used was only two (viz. butterfly pea and buffel grass). Both trials were conducted using an 'exclusion approach' where a fungicide and an insecticide were used to remove all of the biological control agents from the control plots. The pesticides (dimethoate at 7.5 mL 10 L^{-1}) were applied on a monthly basis and the sites weeded of all other weeds, either manually or with herbicide (glyphosate at 500 mL ha^{-1}). The presence and frequency of the biological control agents at each site were monitored on a monthly basis. After 160 days, randomly thrown quadrates (1 m^2) were used to harvest both the test plants and parthenium. The samples were then dried in a dehydrator and weighed. Finally, percent dry biomass reduction of parthenium weed by the test species and biological control agents was calculated. Statistical analysis was done with one-way ANOVA using the MINITAB 15 software package.

RESULTS

In the shade-house trial (Table 1) both test species were competitive with parthenium weed in the absence of biological control agent *Zygogramma,* but their competitiveness increased further in the presence of the agent.

In the Injune field trial (Table 2) all test species were shown to suppress the growth of parthenium weed by 18–51% without biological control agents and 60–86% in the presence of the biological control agents. The biological control agents recorded at the site were stem galling moth (*Epiblema strenuana* Walker.), leaf defoliating beetle (*Z. bicolorata*), stem boring weevil (*Listronotus setosipennis* Hust.) and winter rust (*Puccinia abrupta* var. *parthiniicola* Jackson). It was also found that when biological control agents were present, the test plants grew better (by 6 to 21%; Table 2). The maximum competitive advantage in the presence of biological control agents was gained

Table 1. The competitive ability of test plants when studied with and without the biological control (BC) agent *Zygogramma* present.

Test species	No BC	With BC
Butterfly pea (introduced species)	Medium[A]	High
Bull Mitchell grass (native species)	Low	Medium

[A] Where low is a competitive index value of <1.0, medium is a competitive index of 1.1–1.5 and high is a competitive index of >1.6.

Table 2. Change in dry biomass (%) of the six test species and parthenium weed with or without biocontrol agents (BC) at the Injune field site.

	Test plants	Parthenium weed	
Test species	With BC	No BC	With BC
Butterfly pea	+6	−40 acd[A]	−79 c
Seca stylo	+6	−18 e	−60 f
Bull Mitchell grass[B]	+10	−43 ad	−76 a
Purple pigeon grass	+11	−49 bd	−86 e
Buffel grass	+21	−51 b	−83 b
Kangaroo grass[B]	+7	−45 d	−80 d
Parthenium weed	−	−	−35

[A] Means with the same letters are not significantly different at P ≤0.05. [B] Native species.

with buffel grass (+21%) followed by purple pigeon grass (+11%) and by bull Mitchell grass (+10%), which is a native Australian grass species.

In the Monto field trial (Table 3) both test species were shown to suppress the growth of parthenium weed by between 33 (buffel grass) and 50% (butterfly pea) in the absence and 62 and 69% in the presence of the single biological control agent found at the site (stem galling moth). It was also found that when biological control agents were present, the test plants grew better (by 15 and to 33%; Table 3).

Table 3. Change in dry biomass (%) of the six test species and parthenium weed with or without bio-control agents (BC) present at the Monto field site.

	Test plants	Parthenium weed	
Test species	With BC	No BC	With BC
Butterfly pea	+15	−33 a[A]	−62 a
Buffel grass	+33	−50 b	−69 a
Parthenium weed	−		−21

[A] Means with the same letters are not significantly different at $P \leq 0.05$.

DISCUSSION

It is known that plant competition and herbivory caused by specialised insects can act synergistically (Lee and Bazzaz 1980, Cottam *et al*. 1986) or can have no effect (Sheppard 1996, Suwa *et al*. 2010) on the growth and performance of a host plant. In the current study we have found a strong synergistic interaction between plant competition and biological control agents upon the growth of parthenium weed, and this was seen both in a shade-house and a field trial.

In the glasshouse experiment, the competitive ability of the test plants was increased significantly in presence of a biological control agent, *Zygogramma*. Bull Mitchell grass was converted from a low to a moderately competitive species, while butterfly pea was converted from a moderate to a highly competitive species.

In the field studies at Injune, plant competition alone reduced parthenium weed growth by an average of 41%, while in the presence of biological control agents the reduction averaged 77%. At Monto, plant competition alone reduced parthenium weed growth by an average of 41%, while the reduction averaged 65% in the presence of biological control agents (Table 2 and 3). This lesser effect of biological control agents at Monto may be due to the fact that only *E. strenuana* was present, while at Injune three insects (*Z. bicolorata*, *E. strenuana* and *L. setosipennis*) and one pathogen (*P. abrupta*) were present.

From the current studies, it can be concluded that biological control agents and competitive plants can be used in a complementary manner to achieve better management of parthenium weed and the result is better than either option alone.

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