CHAPTER II – INTERFERENCE POTENTIAL OF THE ALIEN INVADER PLANT *PARTHENIUM HYSTEROPHORUS* WITH THREE INDIGENOUS GRASS SPECIES IN THE KRUGER NATIONAL PARK

2.1 Introduction

From Central America, *Parthenium hysterophorus* has successfully invaded many parts of the world, often becoming a menace in disturbed areas, farmlands and natural biomes. Part of the ability of *P. hysterophorus* to successfully invade areas is attributed to its wide scope of ecological adaptation (Hedge & Patil, 1982), and different and challenging environments may lead to the expression of potentially beneficial genetic traits (Agrawal, 2001), some of which may promote invasiveness.

Parthenium competes strongly for soil moisture and nutrients and has been shown to be an efficient interferer with crop growth (Tamado *et al*., 2002a). Khosola & Sobti (1981) reported a yield decline of 40% for agricultural crops in India, and Nath (1988) reported that the weed can reduce forage production in grasslands by up to 90%. Parthenium has been observed to cause substantial yield loss in *Helianthus annuus* L. (sunflower) and *Sorghum bicolour* (sorghum) in Queensland, Australia (Parsons & Cuthbertson, 1992), in sorghum (Tamado *et al*., 2002a) and *Eragrostis tef* (tef) (Tefera, 2002) in Ethiopia, and is reported to be one of the most important weeds in *Coffea arabica* (coffee) in Kenya (Njoroge, 1986). In South Africa, *P. hysterophorus* is a ‘major nuisance’ in *Saccharum* spp. (sugarcane) and *Musa* spp. (banana) orchards (Bromilow, 2001). *P. hysterophorus* is a highly prolific seed producer right up to senescence and one plant is reported to potentially produce between 15 000 and 25 000 seeds (Haseler, 1976; Joshi, 1991b). *P. hysterophorus* seeds are capable of germination as soon as they have been released from the parent plant, although ‘seeds may be induced into a state of conditional physiological dormancy by the ambient environmental conditions’ (Navie *et al*. 1996). In India, Pandey & Dubey (1989) observed *P. hysterophorus* seedlings in three successive cohorts in a single season, with seedling density and survival to maturity declining with successive cohorts.

It is widely believed that allelopathy also plays an important role in the invasiveness of *P. hysterophorus*. Allelochemicals have been identified in all *P. hysterophorus* plant parts and several sesquiterpene lactones and phenolics have been identified and implicated as the principal allelochemicals in *P. hysterophorus* (Picman & Picman, 1984; Swaminathan *et al*., 1990; Reinhardt *et al*., 2004). Release of these allelochemicals from the plant into the environment can be achieved through leaching from above- or below-ground plant parts or through the decomposition of plant residues. *P. hysterophorus* potentially uses all these mechanisms to release allelochemicals into the environment. Ridenour & Callaway (2001) point out that root mediated allelopathy would depend on factors such as plant densities, root distributions, root densities and microbial activity; and that the mobility of compounds in the soil may be less due to buffering or immobilization. Phenolics can interfere with plant growth directly by interfering with metabolic processes, affecting root symbionts, and by affecting site quality through interference with decomposition, mineralization and humification (Van Andel, 2005). In grasses, *P. hysterophorus* extracts have been demonstrated to be phytotoxic to *Eragrostis tef* (Tefera, 2002; Belz *et al*. 2006), and pure parthenin was phytotoxic to *E. curvula* and *Echinochloa crus-galli* (Belz *et al*., 2006).

Few studies have been conducted regarding the interference of *P. hysterophorus* with other plant species. Joshi (1991b) studied the interference effects of *Cassia uniflora* on *P. hysterophorus* and found that *C. uniflora* seedlings could suppress *P. hysterophorus* weed seedlings. *C. uniflora* is a short-lived shrub believed to also have allelopathic potential. Joshi (1991b) further observed that *P. hysterophorus* height dropped from 1.75 m to 0.9 m when exposed to interference from *C. uniflora*. A reduction in plant dry mass and number of inflorescences produced was also noticed when compared to a nearby stand of pure *P. hysterophorus*. Five years following the introduction to a site infested with *P. hysterophorus*, Joshi (1991b) reported an 84% reduction in the population of mature *P. hysterophorus* plants.

Since the first appearance of *P. hysterophorus* in southern Africa, it has spread at a steady, alarming rate and occurs in the warmer regions of South Africa, Zimbabwe, Mozambique and Swaziland (Henderson, undated; Bromilow, 2001). In the Kruger National Park, it is possible that at least one of the introductions of *P. hysterophorus* occurred when propagules entered the reserve via service vehicles. Another source of infestation is the former dumpsite adjacent to Skukuza rest camp in the reserve – the site chosen for the field trial reported on in this chapter.

Interactions between plants are often the result of complex combinations of specific mechanisms (Welden & Slauson, 1986; Callaway *et al*., 1991; Chapin *et al*., 1994), and although the fundamentals of competition and allelopathy are generally understood as isolated mechanisms, less is known about the relative contribution of these two mechanisms in overall interference interactions between plant species (Ridenour & Callaway, 2001). Ecologists have identified the importance of defining the individual effects more precisely (Ridenour & Callaway, 2001), but difficulty in separating the effects experimentally has hampered better understanding (Fuerst & Putnam, 1983). The objectives of the current study were to investigate the interference of *P. hysterophorus* with three indigenous grass species under naturally occurring conditions. Keeping the grass density constant while varying the *P. hysterophorus* density may help to assess the importance of the weed's density on plant interactions. The use of three different grass species serves to screen for one or more species that can adequately interfere with *P. hysterophorus* growth, and potentially be used as an antagonistic species in an integrated control programme.

2.2 Materials and methods

2.2.1 2003/2004 growing season

A field trial was established on an old dumpsite which has been invaded by *P. hysterophorus* near Skukuza in the Kruger National Park (Lat: -24.9800 Lon: 31.6000 Height 263 m). The dumping of general refuse at the site had ceased around twelve years earlier, since when the site was used for the dumping of garden refuse only until the commencement of the trial when this too was stopped. The trial site was cleared of vegetation and debris and a total of 36 plots, each measuring 4 m^2, were demarcated in a completely randomized design.

Following failure to establish the grasses *in situ* from seed in December 2003, *E. curvula*, *P. maximum* and *D. eriantha* seedlings were raised in seedling trays in the

University of Pretoria glasshouses. Several seeds were sown into each tray cell to form a tuft consisting of several seedlings. Once the seedlings had attained a height of between four and seven centimetres, each species was transplanted into field plots at equal densities (16 tufts m^{-2}). Tufts were planted across from each other along dripper lines that spanned across the plots at 500 mm intervals. All three of the grasses chosen for the trial are indigenous to South Africa. Unless indicated otherwise, the following descriptions of the grasses are taken from the 'KYNOCH PASTURE HANDBOOK' (2004):

Eragrostis curvula (Weeping love grass): A tufted highly variable species which is a summer growing, perennial grass. Stem length varies from 600 mm to 1200 mm, and stems can be either slender or robust, growing upright or sideways. Leaves can be as long as 600 mm and 10 mm wide. Grass often droops (weeps) when it gets older. The inflorescence is an open panicle with many spikelets capable of bearing many seeds. It is the most cultivated grass on dryland in South Africa, preferring sandy soil and growing best in areas receiving more than 650 mm rainfall per annum. The growing season for *E. curvula* is from September to April. *E. curvula* is often observed in disturbed areas, especially on well drained, fertile soils and has been used for erosion control (Gibbs Russel *et al*., 1991; Van Oudtshoorn, 2002).

Panicum maximum (Guinea grass): A tufted, perennial grass which reaches a height of 1000 to 2000 mm. The grass has slender stems and is particularly leafy, with broad, highly palatable leaves. *P. maximum* prefers damp places with fertile soils (Van Oudtshoorn, 2002), often occurring under trees and in shrubs and bushes. The grass is well adapted to a variety of soil types but does not perform well on very sandy soils or on heavily structured soils. It can withstand frost, does well with a minimum of 500 mm rainfall and is suited to tropical and sub-tropical areas. Guinea grass forms a high density of roots in the upper soil layers, which may explain its quick reaction to even the lightest rains.

Digitaria eriantha (Smuts finger grass): A tufted, perennial grass with branched stalks which can attain a height of up to 1200 mm. Six to ten finger-shaped clusters of 70-130 mm long are developed on the inflorescence. The base of the leaf sheaf is hairy while the leaf blades are almost hairless. Leaves grow to about 600 mm long and 13 mm wide. The grass grows in a variety of conditions and thrives in areas with a rainfall higher than 500 mm per annum. It can be established on an extensive scale and has proved itself on a large number of low and medium potential soils. *D.*

eriantha has been used to improve conditions by direct sowing into the veld (Van Oudtshoorn, 2002).

P. hysterophorus seedlings growing in the immediate vicinity of the field trial were transplanted into the plots at 5 or 7.5 plants m^{-2} densities. *P. hysterophorus* plants were planted between grass tufts along the dripper lines for the 5 plants m^{-2} density, and additional plants were planted in rows between the dripper lines for the 7.5 plants m^{-2} density. Plots with zero *P. hysterophorus* served as control. The trial was fully established on 18 January 2004 (Figure 2.1). A wire fence was erected around the perimeter of the trial to prevent interference from any wild animals, such as grazers, in the experiment. A gravitational drip-irrigation system was installed in an attempt to reduce any negative impacts of the unreliable rainfall characteristic for the area.

Figure 2.1 Trial site on day of establishment in 2003/2004 growth season

After eleven weeks (7 April) eight representative grass tufts were harvested from each plot and the dry mass determined. Final harvesting for the 2003/2004 season took place after eighteen weeks (27 May) when eight previously unharvested grass tufts were harvested from each plot, and six representative *P. hysterophorus* plants were harvested from the plots containing the weed. Harvesting of the re-growth from the first set of harvested tufts occurred after fifteen weeks (8 May) and again after another eighteen weeks (27 May). At the final harvest any plants that were not harvested for dry mass determination were cut down to ground level. Data were expressed on a per plant dry mass basis for the grasses and *P. hysterophorus*. As grass data were not normally distributed, the logarithm of grass dry mass accumulation expressed as percentage of control was analyzed using SAS®. *P. hysterophorus* dry mass accumulation was analyzed without transformation. A general linear model (GLM) of ANOVA was used and least significance differences (LSD) at $P \leq 0.05$ was used to separate means when significant differences did occur.

2.2.2 2004/2005 growing season

The field trial was re-established for a second growth season on 22 February 2005. The trial plan was modified to include parthenium controls plots containing only parthenium plants at 5 and 7.5 plants m^{-2} densities. Some of the *E. curvula* and *D. eriantha* plots on which some of the plants died naturally were converted for this purpose. Several of the grass tufts removed from these plots where used to replace grass tufts on other plots of the same species where mortalities had occurred. The only grass species not requiring replacement of plants that died was *P. maximum*. Parthenium plants had to be re-established by transplanting seedlings from outside the fenced area into the plots. Only one harvest took place during the 2005 growth season, 14 weeks after planting (30 May). The fresh mass of samples was measured in the field and representative samples from each species were oven-dried at 60ºC and weighed in order to determine the moisture percentage, enabling fresh mass to dry mass data conversion for all the samples. For grass dry mass accumulation, percentages of control were logarithmically transformed (as distribution was not normal) and analyzed using SAS®. Parthenium dry mass accumulation data were analyzed without transformation. A general linear model (GLM) of ANOVA was used and least significance differences (LSD) at $P \leq 0.05$ was used to detect significant differences between treatment means.

2.3 Results and discussion

2.3.1 2003/2004 growth season

2.3.1.1 First harvest (7 April 2004)

From the first harvest it was clear that *P. maximum* performed the most favourably, with *E. curvula* and *D. eriantha* both growing very poorly (Figure 2.2). Although the latter two grass species did manage to become established, their relatively slow growth rates showed that these species were not adapted to the local environmental conditions. It is known that pH preferences for *E. curvula* are in the region of 5.4 (H_2O) [measured at 4.4 (KCl)], and 5.5 (H_2O) [measured at 4.5 (KCl)] for *D. eriantha* (Kynoch Pasture Handbook, 2004). The mean pH of two soil samples taken from the trial site in March 2004 was 7.7 (H_2O) (see Appendix for complete soil analysis results), suggesting that the soil was too alkaline for favourable growth of these two species. *P. maximum* was more suited for this alkaline soil with a pH preference of 5.5 – 7.5 (H_2O) [measured at 4.5 – 6.5 (KCl)] (Kynoch Pasture Handbook, 2004), thus reaffirming the importance of pH in grass performance. High temperatures and other environmental factors in Skukuza may also have influenced grass performance. Although an irrigation system was utilized during the growing season, *P. maximum* is known to tolerate a wider range of moisture regimes than the other two grass species (Agricol Product Guide, undated. Agricol, Eagle Street, Brackenfell).

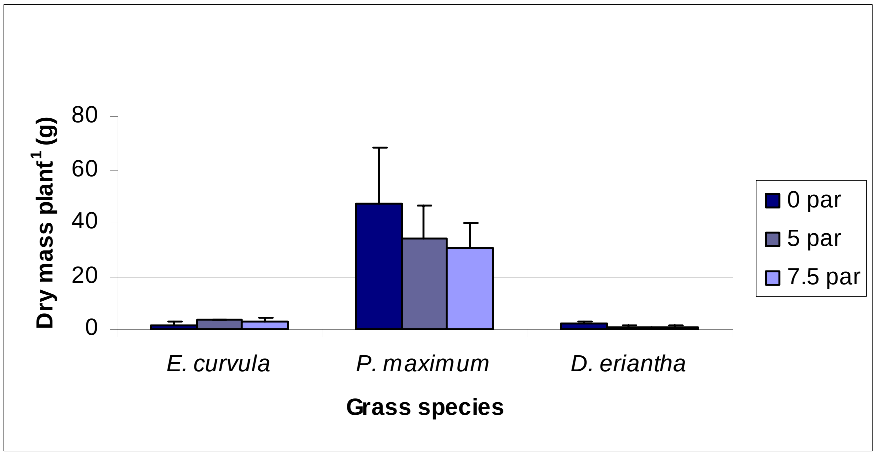

Figure 2.2 Grass dry mass accumulation over a period of 11 weeks on plots with 0, 5 or 7.5 parthenium plants m^{-2}

For percentage of control data, only the main species effect was significant, with *E. curvula* performing significantly better than *P. maximum* and *D. eriantha* in the presence of *P. hysterophorus* (Table 2.1). No significant differences between *P.*

maximum and *D. eriantha* occurred. However, the poor performance and extremely low growth rate of *E. curvula* and *D. eriantha* makes these results of limited practical relevance. Perhaps one reason for the increased growth rate of *E. curvula* on treatment plots could be the uptake of low levels of allelochemicals from *P. hysterophorus* plants resulting in growth stimulation as observed under controlled conditions for all three grass species (see CHAPTER V – 5.3) and for *E. curvula* as observed by Belz *et al*. (2006).

Table 2.1 Grass dry mass accumulation over a period of 11 weeks expressed as percentage of control (Appendix 2.1)

	Grass species		
	Dry mass percentage of control [%]		
P. hysterophorus density	*E. curvula*	*P. maximum*	*D. eriantha*
5 plants m^{-2}	211.4	72.7	55.7
7.5 plants m^{-2}	162.2	64.2	46.6
Mean	187.1a	68.4b	51.1b
LSDspp= 61.499			

Means followed by different letters differ significantly (LSD t –test, P=0.05)

2.3.1.2 Grass re-growth harvest (8 & 27 May 2004)

Although at this stage conditions were beginning to become less favourable for plant growth, *P. maximum* still had a much higher growth rate than the other two grass species; confirming that *P. maximum* has the best inherent adaptation for the site conditions (Figure 2.3). No significant differences for the main or interaction effects were observed for percentage of control dry mass data for the first re-growth harvest (Appendix 2.2).

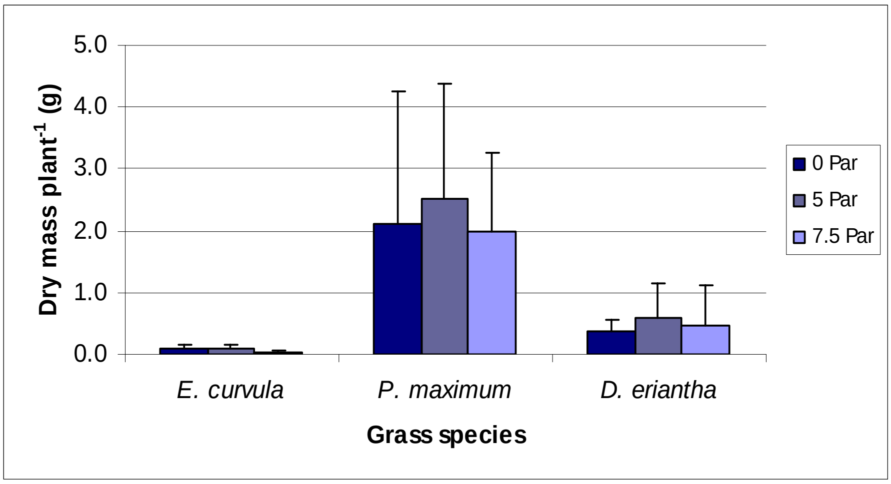

Figure 2.3 Grass re-growth dry mass accumulation over a period of 4 weeks on plots with 0, 5 or 7.5 parthenium plants m^{-2}

Grass re-growth was harvested for a second time three weeks later. By this time growth of *E. curvula* and *D. eriantha* had ceased almost completely on all plots. *P. maximum,* however, continued to grow. Mean percentage of control values for *P. maximum* showed a lower dry mass accumulation yield on plots with the higher parthenium density. Results were not significantly different however.

2.3.1.3 Final harvest (27 May 2004)

Grass data

Once again, harvesting of previously unharvested grass tufts which were allowed to grow for the entire duration of the field trial's growing season and determination of the dry mass accumulation of these plants showed very similar trends to previous data, with *P. maximum* performing by far the best of the three grass species (Figure 2.4).

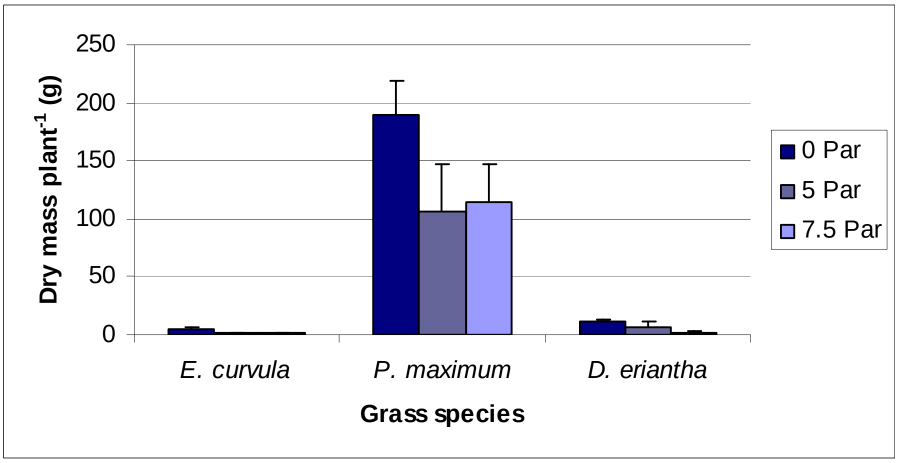

Figure 2.4 Grass dry mass accumulation over a period of 19 weeks on plots with 0, 5 or 7.5 parthenium plants m^{-2}

Analysis of dry mass accumulation expressed as percentage of control revealed that none of the main effects (species or parthenium density) were significant. At the $P<0.075$ significance level, however, the interaction effect was found to be significant (Table 2.2). Significant growth differences between the two parthenium densities were only observed for *D. eriantha*.

Table 2.2 Grass dry mass accumulation over a period of 19 weeks expressed as percentage of control (Appendix 2.3)

	Grass species Dry mass percentage of control [%]		
P. hysterophorus density	*E. curvula*	*P. maximum*	*D. eriantha*
5 plants/ m^2	28.8ab	56.4a	58a
7.5 plants/ m^2	37.7ab	60.2a	17.8b
LSD spp*par = 36.555			

Means followed by different letters differ significantly (LSD t –test, P=0.075)

Parthenium data

Per plant dry mass data for six representative parthenium plants indicated that only the main species effect was significant (Table 2.3). *P. maximum* was the most effective grass species regarding intereference with parthenium growth and significantly reduced the dry mass accumulation of the weed. Parthenium plants were further observed to be shorter and produced less seed relative to parthenium plants growing together with *E. curvula* and *D. eriantha*. *E. curvula* and *D. eriantha* did not perform well enough under the trial conditions to interfere significantly with parthenium growth. On *E. curvula* and *D. eriantha* plots parthenium yield on a per plant basis was higher on the plots with the lower parthenium density (5 plants m^{-2}) than on the plots with the higher weed density (7.5 plants m^{-2}), while the opposite occurred on *P. maximum* plots. Since *P. maximum* performed relatively better than the other two grass species it can be speculated that on the *E. curvula* and *D. eriantha* plots intra-species (parthenium-parthenium) interference dominated, while on the *P. maximum* plots inter-species (*P. maximum* – parthenium) interference was dominant.

Table 2.3 Parthenium dry mass accumulation over a period of 19 weeks (Appendix 2.4)

	Mean per plant parthenium dry mass (g)		
Grass species	5 plants m^{-2}	7.5 plants m^{-2}	Mean
E. curvula	62.9	46.5	54.7a
D. eriantha	49.6	43.9	46.8a
P. maximum	16.8	24.1	20.5b
LSDspp = 13.173			

Means followed by different letters differ significantly (LSD t –test, P=0.05)

1.3.2 2004/2005 growing season

Grass data

Similar to the previous season, *P. maximum* far outperformed the other two grass species in terms of growth (Figure 2.5), reaffirming that *P. maximum* is best suited to the environmental conditions of the trial site. *D. eriantha*, and to a lesser extent *E. curvula,* showed a noteworthy increase in growth rate for the 2004/2005 season, with aboveground dry mass increases on control plots of 406.8% and 233%, respectively from the 2003/2004 season. It can therefore be concluded that these species eventually became better adapted to the environmental conditions. In contrast, *P. maximum* showed a 26.8% reduction in dry mass accumulation from the 2003/2004 to the 2004/2005 growth season. This may be attributed to a shorter growth season and/or less favourable environmental conditions.

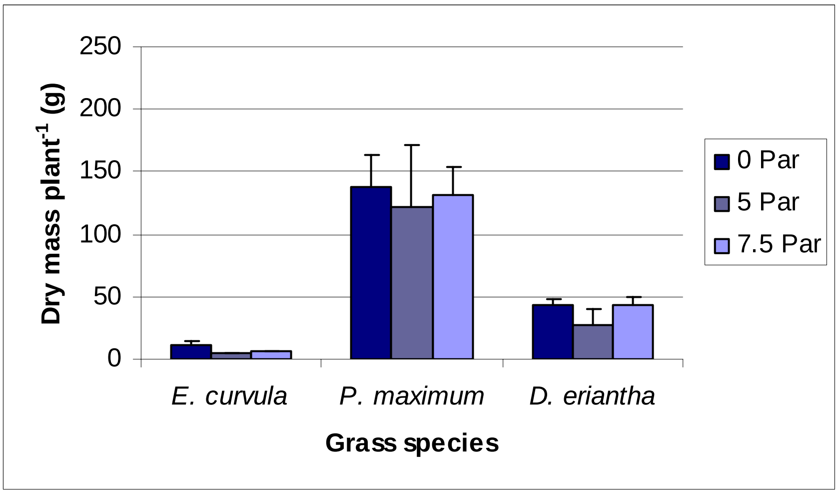

Figure 2.5 Grass dry mass accumulation over a period of 14 weeks on plots with 0, 5 and 7.5 parthenium plants m^{-2}

For percentage of control data, no significant differences were observed for the interaction effect. The main species effect was found to be significant ($P \leq 0.05$), however. Across the two parthenium densities, *P. maximum* was found to perform significantly better than *E. curvula* (Table 2.4).

Table 2.4 Grass dry mass accumulation over a period of 14 weeks expressed as percentage of control (Appendix 2.5)

	Grass species Dry mass percentage of control [%]		
Parthenium density	*E. curvula*	*P. maximum*	*D. eriantha*
5 plants m^{-2}	41.8	88.1	63.5
7.5 plants m^{-2}	59.6	95.3	98.5
Mean	50.7a	91.7b	81.0ab
LSDspp = 32.262			

Means followed by different letters differ significantly (LSD t –test, P=0.05)

Parthenium data

As expected, *P. maximum* again proved to be most effective in interfering with parthenium growth, with lowest parthenium yields occurring on *P. maximum* plots. Once again parthenium plants were observed to be smaller and produce less seed compared to plants growing on plots without *P. maximum*, and a large number of parthenium mortalities were observed on *P. maximum* plots. Analysis of parthenium dry mass data revealed that the interaction effect was highly significant (Table 2.5). *D. eriantha,* and to a lesser extent *E. curvula,* were only able to significantly interfere with parthenium growth at the 5 plants m^{-2} density. Parthenium per plant dry mass yield was observed to be higher at the lower weed density (5 plants m^{-2}) on all plots except on *P. maximum* plots. A similar trend was observed in the previous growth season (see 2.3.1.3).

Table 2.5 Parthenium dry mass accumulation over a period of 19 weeks (Appendix 2.6)

	Plant species Dry mass accumulation (g plant^{-1}) *P. hysterophorus*	*E. curvula*	*P. maximum*	*D.eriantha*
Parthenium density				
5 plants m^{-2}	32.3a	22.0b	0.23e	9.7cd
7.5 plants m^{-2}	14.5bc	12.2c	3.2de	7.2cde
LSDspp*par = 8.1024				

Means followed by different letters differ significantly (LSD t –test, P=0.05)

Buckley *et al*. (2004) mention that 'for successful [invasive plant] control, it may be necessary to change disturbance regimes or the succession trajectory of the community by creating favourable establishment opportunities for native competitors and unfavourable opportunities for weed regeneration'. It is important to mention that antagonistic species should be selected according to environment compatibility in addition to interference potential with the invader plant.

Significant differences for grass dry mass accumulation between the 5 and 7.5 parthenium plants m^{-2} were not always observed. No general statements can therefore be made on the effect of parthenium density. Cousens (1991) points out, that at low weed densities no significant differences most likely mean that the differences are too small to be detected because of variability. In hindsight it was observed that the selected weed densities employed in the field experiment were low relative to parthenium densities of as many as 96 mature plants m^{-2} which have since become established in the area. Relatively higher yields for both grasses and parthenium plants growing on the same plot in certain cases (= replications) may indicate that some plots within the trial were more favourable for plant growth and this may have contributed to experimental error, and hence, have made significant differences less detectable.

As *P. maximum* is a highly palatable grass, under natural conditions we can most likely expect a high grazing pressure on the grass which may influence its interference potential with parthenium. *P. maximum* is known not to tolerate intensive, frequent grazing (Fair, 1989). To the best of our knowledge, parthenium is not eaten by any herbivores. In the first growth season, all species were transferred into the trial as seedlings. It is not certain how the grasses would have performed in this parthenium infested area if seedlings had to develop from seed sown *in situ*. Allelochemicals from parthenium have been observed to inhibit germination and to stunt seedling growth of a wide variety of species. This must be considered and further investigated if the use of an antagonistic species in a biological control programme is considered.

2.4 Conclusions

P. maximum dominated with regard to overall performance in terms of dry mass accumulation as well as with suppression of parthenium growth. *D. eriantha* performed better than *E. curvula* but both of these species preformed poorly in comparison with *P. maximum*. The better performance of *P. maximum* is attributed to better adaptation to the environment conditions, probably especially due to soil pH and soil texture. *E. curvula* and *D. eriantha* performed better in the second growth season, indicating better adaptation to the environmental conditions after a longer establishment period. The suppression of parthenium growth, and even parthenium seedling mortality on *P. maximum* plots, together with good seed production by the grass when co-existing with parthenium, indicate that this species shows high potential for use as an antagonistic species in a biological weed control programme. There is also the possibility that *P. maximum* has an allelopathic effect on parthenium. Further research is required to progress our understanding of the interference mechanisms between parthenium and *P. maximum*.