Taiwania, 55(2): 128-138, 2010

Competitive Exclusion of *Parthenium hysterophorus* by Other Invasive Species - A Case Study from Andhra Pradesh, India

J. Asha kumari[1], P. Rama Chandra Prasad[2*] and K. B. Reddy[3]

1. *Department of Botany, Maris Stella College, Vijayawada, India.*
2. *Lab for spatial Informatics, International Institute of Information Technology, Gachibowli, Hyderabad- 500032, Andhra Pradesh, India.*
3. *S. G. H. R & M. C. M. R College of P.G. Studies, Mallareddy Nagar, Guntur -522 004, India.*

* *Correspondence Author. Tel: +91-9246109160; Fax: +91-40-6653 1413; Email: rcprasad@iiit.ac.in, rcp_ncmsl@yahoo.co.in*

(Manuscript received 2 November 2009; accepted 2 February 2010)

ABSTRACT: The abundance, dominance and growth performance of *Parthenium hysterophorus* in relation to its field associates in extensively large areas was investigated. The preliminary analysis of the data revealed that *P. hysterophorus* is a weak or poor competitor and hence it fails to grow in the company of any aggressive species. *Senna uniflora* and a few other plants were identified for the control of this pernicious weed. The ability of other species to control *P. hysterophorus* was attributed to allelopathy. In order to understand how *Hyptis suaveolens and Senna uniflora* are capable of arresting the growth of *P. hysterophorus*, pot culture experiments in de Wit replacement series, field experiments in experimental plots and experimental manipulation of the competitive species under natural conditions during different seasons were carried out for two years in 2004 and 2005. The results clearly revealed that both *H. suaveolens* and *S. uniflora* were highly effective in the management of *P. hysterophorus*. The results further showed that the physical dominance and the ability of the competitive species to deprive *P. hysterophorus* of light are mainly responsible for the decline of *P. hysterophorus*. Allelopathy doesn't seem to play any effective role under natural conditions.

KEY WORDS: *Parthenium hysterophorus, Hyptis suaveolens, Senna uniflora*, competitive exclusion, allelopathy, physical dominance.

INTRODUCTION

Parthenium hysterophorus L. commonly called congress grass or carrot weed is one of the aggressive, obnoxious, (Oudhia, 2000) invasive weeds that has made wide distribution globally affecting the growth of native species (King, 1974; Bhan et al., 1997). The weed shows a drastic impact on other plants as a strong competitor and creates health hazards in humans and animals (Narasimhan et al., 1977; Rajkumar et al., 1988; Evan, 1997; Handa et al., 2001, Muhammad Nadeem et al., 2005; and Sharma et al., 2005; Lakshmi and Srinivas, 2007). Different opinions were held regarding the entry of this species within the Indian sub-continent (Roxburgh, 1914; Rao, 1956; Bhan et al., 1997; Rabindra and Bhumannavar, 2005; Kohli et al., 2006). However the reports of National herbaria and institutes, recorded the species introduction into the country around 1810 (Bennet et al., 1978; Maiti, 1983; Kohli et al., 2006).

Though the weed remained uncommon and dormant during its early entry, sooner it attracted the researchers in the field of botany and ecology, being a strong competitor for native species and developed as an ecological threat (Singla, 1992, 2000; Mahadevappa, 1997; Oudhia, 2000). This exotic invasive species with deep penetrating roots and erect shoot, establishes itself rapidly in the alien environment suppressing the growth of other native species with its allelopathic effect (Kohli and Rani, 1994; Heirro and Callaway, 2003; Senthil et al., 2005). The species interferes with the growth of other species by producing and releasing chemicals like phenolic acids, sesquiterpenes (Picman and Picman, 1984; Kohli and Batish, 1994) and other residues (Singh et al., 2003) which seize the growth phenomenon of the coexistent species.

The species is capable of germinating and setting up itself at any time in the year and has a potential capacity to grow vigorously even in summer (Dhileepan, 2009). It inhabits in any kind of land apart from its proliferation in the waste lands, road sides, railway tracks, grave yards, back yards or any vacant site (Raju, 1998; Mahadevappa and Gautam, 2005). The species virtually invaded almost all the States of India (Brar and Walia, 1991; Mahadevappa, 1996) encroaching about five million hectare of land (Kohali and Rani, 1994; Mukhopadhyay, 1997). Initially the species was found to be grown mostly in wastelands but later encroached into pastures, agricultural lands (Kohli, 2004; Bhoumik and Sarkar, 2005) and forests too (Sushil kumar and Saraswat, 1999). The invasion of species into the forest areas thus altered the native species composition affecting the forest structure and diversity (Kumar and Rohatgi, 1999).

An extensive survey undertaken by the authors in different parts of Andhra Pradesh, India and the neighbouring States of Tamil Nadu and Karnataka during

Table 1. List of plant species identified for *P. hysterophorus* control in different States (based on Yaduraju et al., 2005).

State	Competitive plants
Andhra Pradesh	*Amaranthus spinosus, Cassia occidentalis, Cassia auriculata, Croton sparsiflorus, Hyptis suaveolens, Sida acuta, Stylosanthes scabra and Tephrosia purpurea*
Chattisgarh	*Cassia occidentalis, Cassia tora and Malva pusilla*
Haryana	*Chenopodium album*
Madhya Pradesh	*Achyranthes aspera, Alternanthera sessilis, Amaranthus spinosus, Cassia tora, Hyptis suaveolens, Sida acuta, Sida rhombifolia and Xanthium strumarium*
Karnataka	*Amaranthus spinosus, Cassia occidentalis, Cassia sericea, Hyptis suaveolens, Lantana camara, Ocimum canum and Sida spinosa*
Punjab	*Panicum maximum*
Tamilnadu	*Abutilon indicum, Aerva tomentosa, Cassia occidentalis, Cenchrus ciliaris, Cleome gynandra (Gynandropsis pentaphylla), Tagetus erecta and Tephrosia purpurea*
Maharashtra	*Cassia tora, Tephrosia purpurea, Xanthium strumarium*

2003 revealed a remarkable reduction in the dominance of *P. hysterophorus* wherever other plants were abundant and dominant (Asha Kumari, 2007). There were earlier cursory efforts to examine the bio-suppression of the spread of *P. hysterophorus* by other component species such as *Amaranthus spinosus, Cassia auriculata, Cassia ocidentalis, Cassia sericea, Cassia Tora, Croton bonplandianum, Hyptis suaveolens* and *Tephrosia purpurea*. In the grasslands dominated by perennial grasses such as *Cymbopogon coloratus* and *Heterpogon contortus,* the species acts as a weak or poor competitor (Reddy, 1986). Further, several workers (Jayakumar et al., 1989; Joshi, 1990, 1991; Baby Akula and Kondap, 1997; Singh, 1997; Mahadevappa, 1999; Sharma and Gautam, 2004) studied the role of *Cassia sericea* in controlling *P. hysterophorus* and described *C. sericea* as the best bet for the management of *P. hysterophorus*. Yaduraju et al., (2005) compiled a list of plant species from different parts of India, with potential competitive abilities for the biological management of *P.hysterophorus* (Table 1). Most of the investigators have finally concluded that the control of *P. hysterophorus* by others was mainly due to allelopathy.

The above observations inferred from the field work as well as from the literature survey formed basis for the present investigation to explore the chances of exclusion of *P. hysterophorus* in an ecosystem where other species succeed better in local adaptation, overgrow, dominate and lead to the suppression of *P. hysterophorus.* The present study mainly focuses on understanding the role of inter-specific and intra-specific competitive interactions between *P. hysterophorus*, *Senna uniflora* and *Hyptis suaveolens* and their possible exclusion impacts on *P. hysterophorus.*

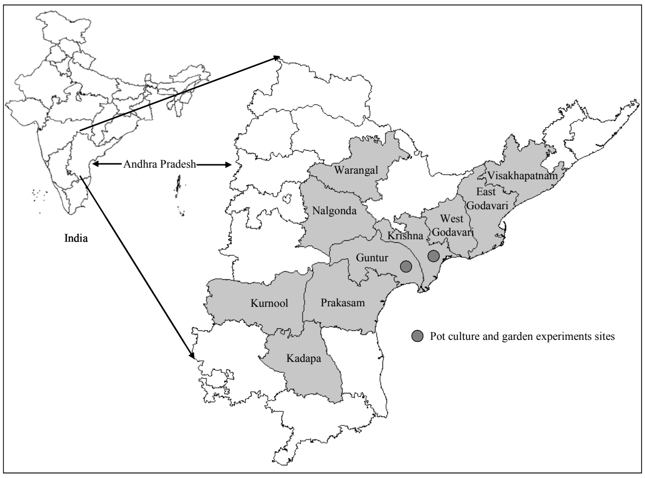

Fig. 1. Location map of the study area (both lab and field sites).

Study area

In order to illustrate the above research question, a series of laboratory experiments in pot cultures and experimental manipulations under field conditions during different seasons were carried out for two years in 2004 and 2005. The pot culture and garden experiments were carried out in and around the Acharya Nagarjuna University (ANU), Guntur, as well as at Maris Stella College, Vijayawada (Fig. 1). All laboratory experiments were conducted in the Ecology Research Laboratory of the ANU. Nursery level experiments were carried out in the nursery of the ANU and Maris Stella College, Vijayawada. Field experiments were carried out along the highways in Guntur, Krishna, Warangal, Prakasam, Kadapa, Kurnool, East Godavari, West Godavari, Visakhapatnam and Nalgonda districts of Andhra Pradesh State, India (Fig. 1).

MATERIALS AND METHODS

The materials chosen (Fig. 2) for the study includes the three most dominant, abundant, non-palatable exotic weeds *viz., Parthenium hysterophorus.* L. (a fast maturing annual of Asteraceae with deep tap root, erect stem, deeply lobed leaves and small white flowers), *Hyptis suaveolens.* L. (strong scented herb of Lamiaceae, with quadrate hairy stems and blue flowers in small cymes) and *Senna uniflora* (Mill.) H. S. Irwin & Barneby = *Cassia uniflora* Miller (annual, erect herb of Ceasalpinaceae growing up to 50 cm height with yellow color flowers in axillary racemes). *Senna uniflora* was found to form almost pure patches in areas where *P. hysterophorus* was the dominant. Similarly, *Hyptis suaveolens* was found to have driven out *P. hysterophorus* in many areas where the latter was the abundant.

The choice of these two weeds is justifiable due to their harmless nature compared to the drastic health impacts of *P. hysterophorus*. Further both are valuable sources of

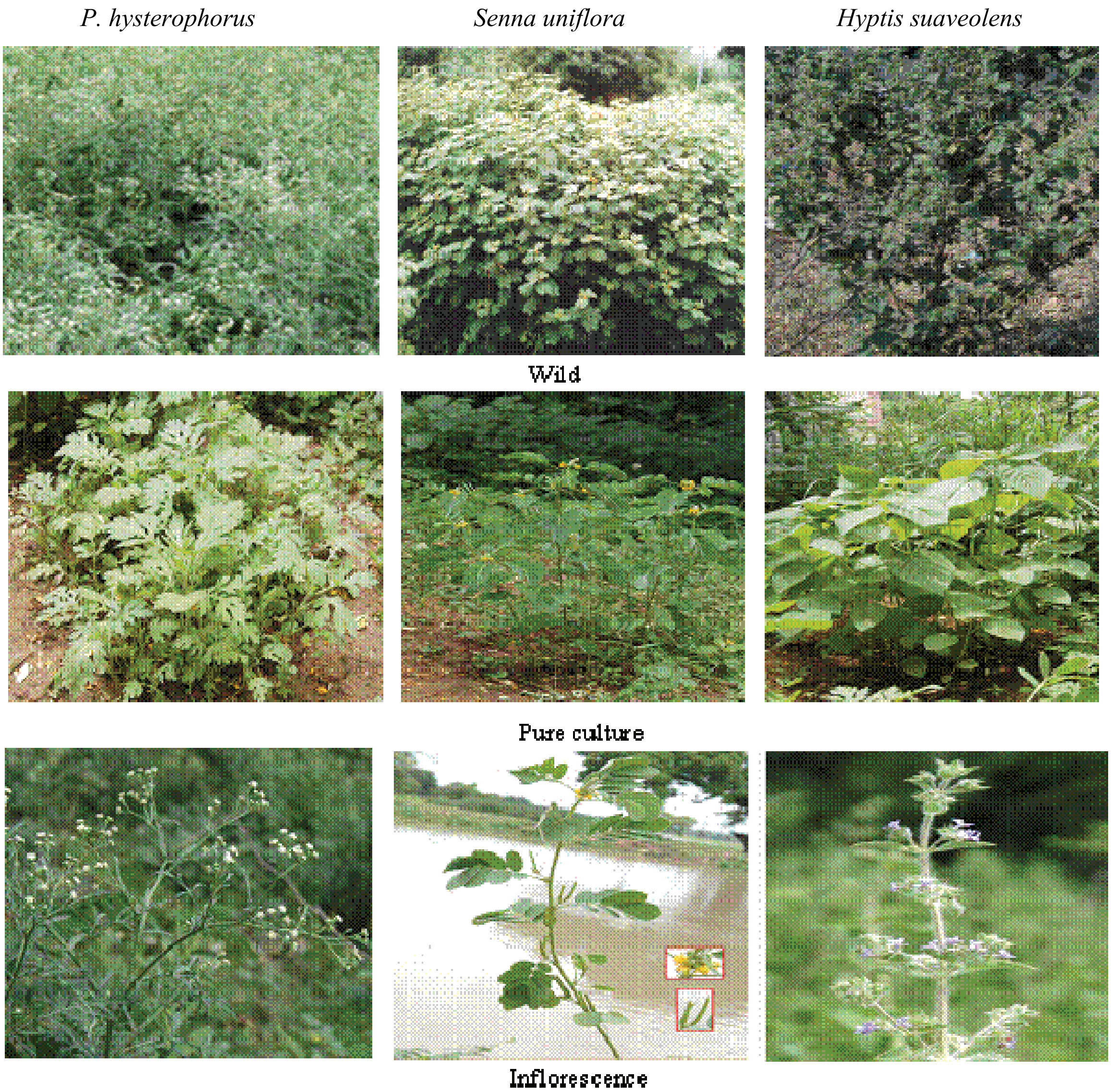

Fig. 2. Species used for the current study.

medicine though the utility of *S. uniflora* needs further works. The three species were made to compete both in pot cultures as well as under the natural field conditions. The plants were grown in deWit replacement series (deWit, 1960) in experimental plots, in a garden as well as under natural field conditions in different locations as mentioned in the study area. Standard error (SE), standard deviation (SD) and ANOVA were computed by using Minitab Programme.

Pot culture and garden experiments

A total of six plants / pot of 30 cm diameter were grown in pure cultures as well as in mixed cultures in replacement series. These experiments were designed mainly to monitor the impacts of inter and intra-specific interactions of the *H. suaveolens* and *S. uniflora* on *P. hysterophorus* and also to understand their mutual role in population regulation and inclusive or exclusive potentials. Care was taken to ensure that all pots contained the same soil in exactly same quantities.

Similar to pot culture experiments, in the deWit replacement series, the three test plants were grown either in pure cultures or in mixed cultures of two or all the three in plots of 50 x 50 cm with a constant total density of 30 plants / plot (Fig. 3). Thus in each plot there were either 30 plants of any one species or 15 each of any two species or 10 each of the three species. For each setup 12 replicates were maintained. The pots and plots were watered as and when required. A total of four harvests were made at the rate of three pots / plots per

Fig. 3. A: Experimental plots in the nursery of A.N.U. B: with seedling emergence.

month. Plant height, biomass production and seed output were measured to assess the impacts of interactions of the test plants in relation to their performance in pure cultures.

Field experiments

A special feature of the current investigation was the validation of the laboratory results of the present study and the earlier investigators under field conditions through a series of carefully planned and executed experiments in extensively large areas. Deliberately, *H. suaveolens* as well as *S. uniflora* were introduced into the areas that are under the total monopoly of *P. hysterophorus* in 10 districts of Andhra Pradesh (Fig. 1). The impact of the introduced species on *P. hysterophorus* was monitored for two years in 2004 and 2005 during the monsoon as well as during the post monsoon periods. Since the plants were non-palatable, it was presumed that the biotic and anthropogenic impacts would be more or less same under natural conditions on all the three species. In order to understand whether *P. hysterophorus* is capable of holding tenancy of its habitats, seeds of *P. hysterophorus* along with either *H. suaveolens* or *S. uniflora* or both at the rate of 1000 / m^2 were sown during the beginning of the rainy season in areas, which were dominated by *P. hysterophorus*. The performance of *P. hysterophorus* was monitored during the subsequent two years in different seasons by estimating the cover of *P. hysterophorus* with or without the other plants.

The following experiments were carried out during 2004 and 2005 under field conditions to understand how *S. uniflora* and *H. suaveolens* were capable of influencing *P. hysterophorus*. In each of the experiments described below, the size of the plot was 100 x 100 cm (1 m^2). Three replicates were maintained for each setup. Percentage germination, rate of survival of seedlings and growth performance of plants in terms biomass per plant were monitored.

Experiment involving fair competition: In this set of experiments, 1000 seeds each of the three plants of *P. hysterophorus* in combination with either *S. uniflora* or *H. suaveolens* were sown in Latin square design immediately after the monsoon cloud burst in June and covered with a thin layer of soil. This experiment was expected to provide information about the relative competitive abilities of the species under equal or fair competition. Simultaneously to understand how seasons can influence the outcome of interactions in a fair competition, 100 seedlings each of the three species of *P.hysterophorus* in combination with either *S. uniflora* or *H. suaveolens* were allowed to interact in each plot of 1 m^2 during the three different seasons.

Experiments involving unfair competition: Seeds of *S. uniflora* or *H. suaveolens* at the rate of 1000 / m^2 were sown in plots colonized by one to four fully grown *P. hysterophorus* plants. This experiment is a kind of simulation that occurs quite frequently under natural conditions where the fully developed summer populations of *P. hysterophorus* interact with the other species.

Light and litter impacts

Efforts were also made to understand the impact of light on the growth performance of the competing species in mixed cultures. The thickness of plant canopy and the density of plant foliage were determined by an indirect method, based on the percent interception of light by plant canopy. The light interception was calculated as an average of three measurements: the amount of light on the surface of plant canopy, beneath the plant canopy and near the ground and was measured with Lux Meter (Mastech Digital Lux meter MS6610). In order to describe how the litter of each species was capable of influencing the performance of competing species in pure as well as in mixed cultures, 1000 seeds each of the three plants were sown in March and covered with 1 kg litter of either of the plants. The experiments were repeated during the rainy, winter and summer seasons to understand the combined impact of litter and the seasons.

RESULTS

The results indicate that as the density of *H. suaveolens* or *S. uniflora* increased, *P. hysterophorus* was severely inhibited as indicated by an average height reduction by over 82% and 77% respectively at the end of fifth month. The data further reveals that inhibition of *P. hysterophorus* either by *H. suaveolens* or *S. uniflora* commenced in the very early stages. Tests of significance further indicate that the reduction in height of *P. hysterophorus* in the presence of *H. suaveolens* were significant to highly significant ($P>0.01$ to <0.05). When grown together in plots at a density of 15 each of *P. hysterophorus* and *S. uniflora* or *H. suaveolens* or 10 each of the three species per 0.25 m^2, highly significant reduction in the height of *P. hysterophorus* starting from the second month could be noticed. The reduction in height was 56.7%, 59% and 61% in the presence of *S. uniflora, H. suaveolens* and both respectively at the end of the fifth month. The results further indicate that the reduction in height began in the early stages but it was not very significant at the end of the first month. For instance, *P. hysterophorus* registered a reduction by 26%, 52% and 64% when grown together with *S. uniflora, H. suaveolens* and both respectively at the end of the second month. Also the biomass productivity of *P. hysterophorus* in combination were down by 47% in association with *H. suaveolens* and 38% in combination with *S.uniflora* at the end of fifth month. It was observed that the biomass production of *P. hysterophorus* was inversely related to the density of *H. suaveolens / S. uniflora* compared to its production in pure cultures.

P. hysterophorus produced seeds at the end of second month in pure cultures but it was delayed in mixed cultures. Flowering and fruiting in *P. hysterophorus* was delayed by almost a month in the presence of *H. suaveolens*. When both are in equal proportions, the seed output of *P. hysterophorus* had declined by 57.63% and as the density of its competitive species (*H. suaveolens*) increased, *P. hysterophorus* was severely inhibited and its seed production declined by about 82.2% at the end of the fifth month. It means that under competition with *H.suaveolens*, the seed output of *P. hysterophorus* represents a mere 17.8% of its average production. Similarly, S. *uniflora* had strongly inhibited the seed production in *P. hysterophorus* by 58.4% at the end of the fifth month.

When grown in equal proportions of 3:3 per pot, the seed output had declined by over 49% in *P. hysterophorus* when compared to the pure cultures. The reduction in seed output of *P. hysterophorus* was highly significant ($P>0.01$ to <0.05). The reduction of dry matter production under the aforesaid conditions was 9.3%, 34% and 52% respectively at the end of fifth month. The consequences of interspecific competition on seed output indicate that *P. hysterophorus* produced the first seeds in two months in monocultures but seed output was delayed by nearly a month on account of the impact of *S. uniflora* or *H. suaveolens*. The seed production in *P. hysterophorus* was lower by 51% with *S. uniflora*, 65% with *H. suaveolens* and it was further reduced to 73% by the combined impact of both the species. On the other hand, the seed output of *S. uniflora* or *H. suaveolens* was not inhibited by the presence of *P. hysterophorus.*

The results of interspecific competition of *H. suaveolens* on the seed output of *P. hysterophorus* and the impact of *S. uniflora* on *P. hysterophorus* in pure and mixed cultures clearly indicate that *H. suaveolens* had the potential to restrict the seed output. Between, *S. uniflora* and *P. hysterophorus*, the former could strongly inhibit the seed output than the latter. The seed output, germination, viable seed bank, seedling establishment, the reproductive and the aggressive capacity of a plant are the indicators of its success (Salisbury, 1961). The results clearly indicate that within two years, *P. hysterophorus* was replaced by *H. suaveolens* as well as *S. uniflora*. They became so dominant and abundant in the areas of introduction that little room was left for *Parthenium* especially during the rainy season. Thus *Parthenium* was virtually driven out of its strongholds by any one species after their deliberate introduction. But when both *S. uniflora* and *H. suaveolens* were introduced, the latter alone became dominant. *S. uniflora* could not establish in the presence of *H. suaveolens.* The results further indicate that in almost all places, *P. hysterophorus* could manage to survive during the post monsoon period.

The percent of light intercepted by the canopy of the three species ranged from a low of 71.17 *in P. hysterophorus* to a high of 95.18 in *H. suaveolens*. It indicates that *P. hysterophorus* intercepts less amount of light and *H. suaveolens* allows only a negligible fraction of light to reach the ground surface beneath the plant canopy.

Impact of application of whole plant litter to soil during different seasons, on seed germination (%), percent survival and dry matter production were studied under field conditions. During the rainy season, the litter of *P. hysterophorus* severely inhibited its own germination and survival, but it did not appear to have any significant impact on dry matter production in pure cultures. Litter of *S. uniflora* as well as *H. suaveolens* have also inhibited germination and survival of *P. hysterophorus*. But the litter of *S. uniflora* promoted dry matter production, while that of *H. suaveolens* significantly reduced dry matter production in *P. hysterophorus*. The Analysis of variance of the data reveals that the differences are highly significant and the probability of occurrence of such variations by chance or experimental errors was less than 0.005.

During winter as well as in summer the litter of *P. hysterophorus* inhibited its own germination, establishment and dry matter production. Much in the same manner *H. suaveolens* also inhibited *P. hysterophorus*. The impact of litter seems to have declined during winter season as indicated by the data when compared with the results of rainy season. During winter the inhibitory effect was less severe, but it was highly significant. Similarly, during summer the litter of *H. suaveolens*, exerted much lesser inhibitory effect on *Parthenium,* when compared with the rainy season. But the inhibition of *P. hysterophorus* by its own litter was more significant during the summer period than either the litter of *S. uniflora* or *H. suaveolens.*

Table 2. Final percentage of survival and dry matter production of different species when grown in mixed cultures at an initial density of 100 plants each per m^2 during different seasons.

Season	% Survival			Dry matter production(g)		
	Ph	Su	Hs	Ph	Su	Hs
Rainy	2.6	3.5	46.8	15.4	18.5	1612.2
Winter	8.8	2.3	6.5	142.6	3.3	24.2
Summer	52.4	0.6	1.4	168.8	0.2	1.1
% contribution to total density by different species				% Contribution to biomass by the different plants		
Rainy	4.9	6.61	88.4	0.93	1.12	97.8
Winter	50	13.06	36.9	83.8	1.94	14.2
Summer	96.3	1.1	2.57	99.2	0.11	0.646

DISCUSSION

A number of investigators (Singh, 1983; Jayakumar et al., 1989; Joshi, 1990, 1991; Singh, 1997; Senthil et al., 2005; Krishna Reddy and Bryson, 2005) from India have concluded that *C. sericea* (= *S .uniflora*) is an excellent candidate for biological control and management and can be used as a powerful tool in checking *Parthenium.* Although, *H. suaveolens* is also considered as a potential species for the control of *P. hysterophorus* it did not receive as much attention as it deserved until 2003 when the present work was undertaken. Recently, Senthil et al., (2005) recommended that *H. suaveolens* along with *C.sericea* could be used as bio-herbicide. The results of the study under report clearly prove that *H. suaveolens* is a much stronger and more powerful candidate than *C. sericea* in *Parthenium* elimination (Table 2). As far as Andhra Pradesh State is concerned *H. suaveolens* was highly successful in *Parthenium* control and *H. suaveolens* has become a ruler in the areas where *P. hysterophorus* was the dominant and was a strong and powerful competitor (Asha Kumari, 2007). It could eliminate both *P. hysterophorus* and *S. uniflora* in any fair contest.

Among the three species under consideration, *H. suaveolens* is not only physically dominant but it is also capable of holding tenancy of its micro site almost permanently, as a majority of individuals grow as perennials though the shoots are annuals. *S. uniflora* and *P. hysterophorus* on the other hand are strictly annuals and hence vacate their micro sites periodically. But those species that produce large quantity of seeds, capable of reaching the vacant micro sites, germinate and thrive during unfavorable conditions can effectively neutralize the disadvantage of annuals. Any annual that is capable of growing in any season (independent of seasons) like *P. hysterophorus* has an additional advantage of enjoying the free space without any competition and prepares itself for an offensive against its competitors, which arrive later in the rainy season. Thus a stage is set where adult plants of *P. hysterophorus* compete with the seedling and juveniles of *P. hysterophorus* or *S. uniflora*. In such an unfair competition *P. hysterophorus* could hold tenancy of its micro site at least for one season. It seems to provide the greatest opportunity for *P. hysterophorus* in its struggle for perpetuation.

In a fair competition between *P. hysterophorus* and *H. suaveolens* or *S. uniflora,* the first named species was the loser. When *H. suaveolens* and *S. uniflora* were given an equal opportunity to compete, the former proved to be the winner. In a triangular contest also *H. suaveolens* proved to be the captor. Thus the results clearly establish the dominance of *H. suaveolens.* Further, the results prove beyond doubt that *P. hysterophorus* cannot compete either with *H. suaveolens* or with *S. uniflora* if given an equal and fair opportunity. Neither *H. suaveolens* nor *S. uniflora* could bring down *P. hysterophorus* as long as it enjoyed the advantage of “head start”. It is evident from the fact that the introduction of *H. suaveolens* or *S. uniflora* in the adult populations of *P. hysterophorus* (which extended from summer to the rainy season) could not make any serious effect on *P. hysterophorus* as the initial occupier continued to flourish until the population completed its life cycle. Summer or pre-monsoon rains were found to promote germination and early establishment of *P. hysterophorus*. The seedlings of either *S. uniflora* or *H. suaveolens* that were to emerge later on under natural conditions could not exert any significant control on *P. hysterophorus* until the individuals completed their life cycle.

Hence it may be concluded that among the three species under consideration, *H. suaveolens* was the most powerful competitor while *P. hysterophorus* was the least competitive. When competition occurs between equally strong competitors, it results in a scramble type of competition but in the present case it may be classified as a contest type (Harper, 1977). Contest type of competition leads to the elimination of the weaker species by competitive elimination (Gause’s principle: Gause, 1934). But under the present circumstances, total elimination or complete control of *P. hysterophorus* by either *H. suaveolens* or *S. uniflora* or both may not be possible because of the extreme adaptability of the former to the local habitats. Therefore, it is expected that *P. hysterophorus* may continue to tolerate or escape the

Table 3. Impact of introduction of seeds of either *S. uniflora* (S.u) or *H. suaveolens* (H.s) or both at the rate of 1000/m^2 each in areas monopolized by *P. hysterophorus* (P.h) on the % cover of *P.hysterophorus* during the subsequent seasons and years. (All fractional values were rounded off to the nearest integer).

Experimental site (Districts of Andhra Pradesh)	Treatment	2004		2005	
		Monsoon	Post monsoon	Monsoon	Post monsoon
Guntur	*P. hysterophorus**	100	56	100	62
	P.h + S.u	48	52	12	26
	P.h + H.s	12	18	5	14
	P.h + S.u +H.s	14	20	8	16
Krishna	*P. hysterophorus**	99	43	100	74
	P.h + S.u	53	38	12	29
	P.h + H.s	9	19	5	13
	P.h + S.u + H.s	7	32	4	14
Prakasam	*P. hysterophorus**	100	74	100	74
	P.h + S.u	16	35	7	48
	P.h + H.s.	11	37	5	34
	P.h + S.u + H.s	12	42	9	42
Kurnool	*P. hysterophorus**	100	64	100	38
	P.h + S.u	24	60	15	39
	P.h + H.s	19	48	18	45
	P.h + S.u + H.s	16	36	17	42
Kadapa	*P. hysterophorus**	100	68	100	74
	P.h + S.u.	42	64	28	63
	P.h.+ H.s.	37	42	19	36
	P.h + S.u + H.s	35	44	29	32
EastGodavari	*P. hysterophorus**	88	56	92	74
	P.h + S.u	27	48	18	38
	P.h + H.s	13	26	11	28
	P.h + S.u + H.s	16	32	18	22
West Godavari	*P. hysterophorus* (control)*	92	68	100	74
	P.h.+ H.s.	14	37	8	22
	P.h + S.u + H.s	12	35	15	24
Visakhapatnam	*P. hysterophorus* (control)*	88	73	90	84
	P.h + S.u	27	48	18	47
	P.h + H.s	16	31	7	39
	P.h + S.u + H.s	15	31	8	37
Warangal	*P. hysterophorus* (control)*	94	62	98	67
	P.h + S.u	24	37	21	36
	P.h + H.s	8	26	6	21
	P.h + S.u + H.s	9	24	10	31
Nalgonda	*P. hysterophorus** (control)	100	56	100	61
	P.h + S.u	25	46	18	47
	P.h + H.s	12	29	10	28
	P.h + S.u + H.s	10	32	9	25

*Only *P. hysterophorus* was allowed to grow without any introduction

onslaught of both *H. suaveolens* or *S. uniflora* quite admirably for some years to come but it may not continue to be the structural species as its status is likely to get reduced to an interstitial species (Huston, 1994).

When all the three species were allowed to grow in a fair competition, *H. suaveolens* could more or less eliminate the other two species of *P. hysterophorus* and *S. uniflora*. Only in Prakasam and Kurnool districts *S. uniflora* exerted slightly stronger negative impact on *P. hysterophorus* than *H. suaveolens*. But when *H. suaveolens* was allowed to grow along with *S. uniflora* and *P. hysterophorus* the first mentioned species (*H. suaveolens*) was found to eliminate the latter two (Table 3). Thus it is apparent that S. *uniflora* could strongly compete and even control *P. hysterophorus* in its strongholds. But on the other hand, *H. suaveolens* proved to be much stronger, more powerful, and hence capable of eliminating *P. hysterophorus*. Thus the mere occurrence of *P. hysterophorus* within the colonies of the other species should not be taken as evidence either to indicate the competitive abilities of *P. hysterophorus.* But it may be viewed as an evidence of the absence of any strong allelopathic impacts of *H. suaveolens* or *S. uniflora*.

Establishment and growth of the species in the closed communities was found to depend upon the light availability and the light supply was found to be dependent on canopy density. The maximum amount of light that could diffuse through the canopy was 29% in *P. hysterophorus*, 16% in *S. uniflora* and 5% in *H. suaveolens.* It is clear that *Parthenium* allows more amount of light for others to grow under it s canopy, but *H. suaveolens* provides no such opportunity. This is because the leaves of *P. hysterophorus* are highly dissected

Table 4. Average areas of leaves (Cm^2) of *P. hysterophorus, H. suaveolens* and *S. uniflora* in relation to plant age both in pure cultures and mixed cultures.

Pot culture experiments

Name of the plant Speciess	Pure cultures Age of plants (days)					Ratio of largest/ smallest leaf	Mixed cultures Age of plants (days)					Ratio of largest/ smallest leaf
	60	90	120	150	180		60	90	120	150	180	
P.hysterophorus	14.15	38.15	28.3	18.73	*	3.49	9.78	24.66	23.17	14.27	*	3.39
H.suaveolens	48.20	71.2	38.6	7.30	6.15	11.57	49.86	73.5	39.36	5.79	5.2	14.13
S.uniflora	42.93	45.56	49.25	40.83	33.85	1.45	40.13	42.8	45.48	34.1	33.0	1.37

*Did not survive for 180 days

Under field conditions

Name of the plant Species	Pure cultures Age of plants (days)					Ratio of largest/ smallest leaves	Mixed cultures Age of plants (days)					Ratio of largest/ smallest leaves
	60	90	120	150*	180		60	90	120	150*	180	
P.hysterophorus	13.75	37.25	27.5	17.50	*	3.31	10.12	25.14	22.14	15.15	*	2.65
H.suaveolens	47.5	69.0	35.2	6.25	5.20	13.27	49.2	71.0	37.5	8.2	5.15	13.79
S.uniflora	43.7	45.0	48.75	40.75	32.50	1.50	41.50	43.0	41.75	35.21	31.2	1.38

* *P.hysterophorus* death commences after 150 days

and diffused. The amount of light intercepted or transmitted by any plant species is a measure of its canopy thickness. Canopy thickness seems to be a function of leaf area index, phyllotaxy, form and size of leaves and branching. From the data (Table 4) it is clear that *H. suaveolens* had the highest canopy thickness and *Parthenium* had the lowest. Any plant that intercepted more light deprives others of light, leading to a drop in production / respiration (P/R) ratio. From these observations it is clear that any species, which grows faster than others, produces thick canopy, becomes taller, occupies more space, becomes physically and ecologically dominant and is capable of inhibiting or even eliminating the other species (Bryson, 2003; Krishna reddy and Bryson, 2005). Similarly, a species that is capable of holding tenancy of its micro site longer gets an advantage over the others, which vacate their microhabitats periodically (Huston, 1994).

Application of litter along with seeds in nursery plots revealed that the *P. hysterophorus* was more severely inhibited by its own litter and the litter of *H. suaveolens*. But, these effects declined with time as the organic matter got degraded providing nutrients. The litter of *S. uniflora* seems to have stimulated the growth of all the three plants. It reveals that like other legumes, the biomass of *S. uniflora* could be used as a green manure without any deleterious effects. As the litter decomposed, it promoted plant growth irrespective of plant source. Thus, the adverse impacts of litter if any were only temporary. It means that in the long run, the litter of the earlier species may not be able to prevent the emergence of a different species. The decaying parts were found to be more toxic in certain cases than the live parts (Whittaker, 1970). However, in tropical countries with high temperature and rapid rate of decomposition such possibility can be discounted.

CONCLUSION

The results of the present study indicate that under normal circumstances, as long as the cultivated crops do not fail and as long as the pastures are not severely overgrazed, *P. hysterophorus* cannot invade and cause any damage to the crops or pastures. When relatively large gaps occur in the croplands, *P. hysterophorus* emerged as the dominant weed. Another feature noticed in parts of Kadapa district and some areas of Srikakulam district by the present investigator was the occurrence of a tall, relatively less branched biotype of *P. hysterophorus*, which is endowed with a potential capacity to compete strongly with the crop plants. When such biotypes emerge, crops losses are also likely to increase if the weed is not properly managed.

P. hysterophorus was found to be a poor or a weak competitor as evidenced by the simple fact that it failed to establish in any area where there was a dominant plant having close and compact canopy. Further, it was found to take advantage of severe grazing, which causes selective removal of palatable species, creation of gaps and a reduction in competitive pressure. It could also take advantage of the absence of the competitive species during summer. The rapid spread of *Parthenium* in India could be due to large-scale destruction of natural vegetation, severe overgrazing, frequent disturbances of high magnitude, which prevent the establishment and perpetuation of other palatable species (Reddy, 1986). Accordingly, the current trend of rapid urbanization and industrialization in India may create conditions for another explosion of *P. hysterophorus*. A search of the published literature indicates that present type of experiments in extensively large areas under field conditions was not made earlier. The conclusions drawn by earlier investigators were based either on laboratory or pot culture experiments or on circumstantial evidence. In order to test and verify whether it happens everywhere, further field level experiments in extensively larger areas in other States are recommended.

ACKNOWLEDGEMENTS

Authors are grateful to Prof. Reinhardt, Department of Plant Production and Soil Science, University of Pretoria, Pretoria, South Africa, for his compliments and constructive criticism as an adjudicator of Ph.D thesis.

LITERATURE CITED

Asha Kumari, J. 2007. Studies on the impacts of *Hyptis suaveolens* (L) poit and and *Senna uniflora* (Mill.) H. S. Irwin & Barneby on *Parthenium hysterophorus* (L) Ph.d Thesis, unpublished, Dept. of Botany, Acharya Nagarjuna University, Guntur, India.

Baby Akula and S. M. Kondap. 1997. Studies on Control of *Parthenium hysterophorus* L. by Allelopathy. In: Proc. First Int. Conf. on *Parthenium M*anagement, UAS, Darward: 136-139.

Bhan, V. M., Sushil Kumar and M. S. Raghuvamsi. 1997. Future strategies for effective Parthenium management, In: Proc. First. Int. Conf. on Parthenium Management. UAS, Bangalore. pp. 90-95.

Bennett, S. S. R., H. P. Nathani and M. B. Raizada. 1978. Parthenium L. in India – a Review and History. Indian J. Forest. **1**: 128-131.

Bhowmik, P. C. and D. Sarkar. 2005. *Parthenium hysterophorus*: its world status and potential management. In: Proc. Second. Int. Conf. on *Parthenium* management. UAS. Bangalore.

Brar, L. S. and V. S. Walia. 1991. Herbicidal control congress grass (*Parthenium hysterophorus*). Indian J. Weed Sci. **23**: 36-39.

Bryson, C. T. 2003. Weed Species. In: Plimmer, J. (ed.), Encyclopedia Agrochemicals, 3: 1571-1588. John Wiley & Sons, New York, USA.

De wit, C. T. 1960. On Competition. (repri. 1986) Evol. Monogr. **7**: 1-82.

Dhileepan, K. 2009. Managing *Parthenium* weed across diverse landscapes: limitations and prospects. In: Management of Invasive Weeds. S. Inderjit, ed. Springer Science. pp. 227-260.

Evans, H. C. 1997. *Parthenium hysterophorus*: A review of its weed status and the possibilities for biological control. Biocontrol News Information. **18**: 89-98.

Gause, G. F. 1934. The Struggle for Existence. Baltimore: Williams and Williams.

Handa, S., B. Sahoo and V. K. Sharma. 2001. Oral hyposensitization in patients with contact dermatitis from *Parthenium hysterophorus*. Contact dermatitis. **44**: 278-282.

Harper, J. L. 1977. Population Biology of Plants. Academic Press, London, UK.

Heirro, J. L. and R. M.Callaway. 2003. Allelopathy and exotic plant invasion. Plant and Soil **256**: 29-39.

Huston, M. J. 1994, Biological Diversity, The Coexistence of species on changing landscapes. Cambridge University.

Jayakumar, R., N. Kempuchetty, S. Subramanian. 1989. Allelopathic effect of *Casia sericea* on *Parthenium hysterophorus*. Madras. Agricultural Journal. **76**: 11641-647.

Joshi, S. 1990. An economic evaluation of control methods for *Parthenium hysterophorus* L. Biological – Agriculture and Horticulture. **6**: 4, 285-291.

Joshi, S. 1991. Biocontrol of *Parthenium hysterophorus* L. crop protection **10**: 429-31.

King, L. J. 1974. Boilogy and Control of Weeds. Wiley Eastern.

Kohli, R. K. and D. Rani. 1994. *Partheniumhysterophorus– a review*. Research Bulletin (Science) Punjab University **44**: 105-149.

Kohli, R. K. and R. Batish. 1994. Exhibition of Allelopathy by *Parthenium hysterophorus* in Agroeco system. J. Tropical Ecology. **35**: 295-307.

Kohli, R. K., D. R. Batish, H. P. Singh and S. D. Kuldip. 2006. Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. Biological Invasions **8**: 1501-1510.

Krishna Reddy, N. and C. J. Bryson. 2005. Why Rag Weed *Parthenium* is not a pernicious weed in the continental USA. In: Proc. Int. Conf. on *Parthenium* management, 2005. UAS, Bangalore.

Kumar, S. and N. Rohatgi. 1999. The role of invasive weeds in changing floristic diversity. Annals of Forestry. **7**: 147-150.

Lakshmi, C. and C. R. Srinivas. 2007. Parthenium: A wide angle view. Indian J Dermatol Venereol Leprol. **73**: 296-306.

Mahadevappa, M. 1996. *Parthenium*. Prasaranga. University of Mysore, Mysore, India.

Mahadevappa, M. 1997. Ecology, distribution, menace and management of Parthenium. In: Mahadevappa, M. and V. C. Patil (eds), Proc. Ist Int. Conf. On Parthenium Management, UAS, Dharwad, India.

Mahadevappa, M. 1999. *Parthenium* and its management. Publication center, Univ. Agri. Sci., Dharwad, India. p. 132.

Mahadevappa, M. and R. D. Gautam. 2005. Introduction of *Parthenium hysterophorus* L.: Status and Management. Proceedings of International symposium on Plant Interdictions: Achievements and Opportunities for South East Asia, held at National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi -12-5-17 February, 2005.

Maiti, G. S. 1983. An untold study on the occurrence of *Parthenium hysterophorus* L. in India. Indian J. Forestry. **6**: 328-329.

Md. Nadeem., Zahida Rani, Shahbaz Aman, Atif Hasnain Kazmi and Asad Shabbir. 2005. *Parthenium Weed*: a growing concern in Pakistan J. Pakistan Assoc. Derma. **15**: 4-8.

Mukhopadhyay, S. K. 1997. Present status of *Parthenium* weed in West Bengal and its management. In: Mahadevappa, M. and V. C. Patil (eds.), Proceedings of the first International conference on *Parthenium* Management, 32. University of Agricultural Sciences, Dharwad, India.

Narasimhan, T. R., M. Ananth, M. Naryana Swamy, M. Rajendra Babu, A. Mangala, P. V. Subba Rao. 1977. Toxicity of *Parthenium hysterophorus* L. Current Science. **46**: 15-6.

Oudhia, P. 2000. Medicinal Herbs and Insects of Chattisgarh India. Insect Environment. **6**: 138.

Pandey, R. K. and S. K. Saini. 2002. *Parthenium* threat to biological diversity of natural forest ecosystem in Madhya Pradesh: a case study in people's protected area of Baiga Chak, Dindori Forest division. Vaniki Saudesh. **26**: 21-29.

Picman, J. and Picman. 1984. Autotoxicity *Parthenium hysterophorus* and its possible role in control of germination. Biochem. System Ecology. **12**: 287-292.

Rabindra, R. J. and B. S. Bhumannavar. 2005. Prospects of Biological Control of *Parthenium* in India. In: Proc. Second. Int. Conf. On Parthenium Management, UAS, Bangalore.

Rajkumar, E. D., N. V. Kumar, N. V. Haran, N. V. Morthy, N. V. Ram. 1988. Antagonistic effect of *Parthenium hysterophorus* on succinate dehydrogenase of sheep liver. J. Environ. Biology. **9**: 231-7.

Raju, R. A. 1998. Prevelant Weed Flora in Peninsular India. Allied Publishers Ltd., Mumbai, 271pp.

Rao, R. S. 1956. *Parthenium* – A new record for India. J. Bombay Nat. Hist. Soc. **54**: 218-220.

Reddy, K. B. 1986. Studies on Phytosociology, Primary Production and Succession in Tropical Monsoonal Old – Field Grassland at Guntur, Ph.D. thesis. Nagarjuna University, Guntur, India.

Reddy, C. S., M. R. Bhanja and V. S. Raju. 2000. *Cassia uniflora* Miller: A New Record for Andhra Pradesh, India. Indian Journal of Forestry. **23**: 324-325.

Roxburgh, W. 1914. Hortus Bengalensis, Mission Press, Calcutta.

Salisbury, E. J. 1961. Weeds and Attens. Collins, London.

Senthil, A., C. Chinnusamy, R. Shanmugasundarum and O. S. Kandasamy. 2005. Identification of competitive/ allelopathic plant species for the management of *P. hysterophorus* In: proc. Second. Int. Conf. On *Parthenium* management. 5-7. 2005. UAS. Bangalore p. 256.

Sharma, R. and R. D. Gautam. 2004. Problems and management strategies for the control of congress grass. Indian Farming, **53**: 17-21.

Sharma V. K., G. Sethuraman and B. Rahdakrishna. 2005. Evolution of clinical pattern of *Parthenium* dermatitisia study of 74 cases. *Contact dermatitis.* **53**: 84.

Singh, N. P. 1983 Potential biological control of *Parthenium hysterophorus L.* current science 52: **13**: 644.

Singh, S. P. 1997. Prospectives in biological control of *Parthenium* in India. In: Proc. First. Int. Conf. on *Parthenium* Management, University of Agricultural Sciences, Dharwad, Oct. 6-8-1997, pp. 22-31.

Singh, P. K., Anil Dixit, V. P. Singh and A. K. Gogoi. 2003. On farm evolution of herbicide for the control of *Parthenium* and *Ipomea* species. Under non crop situations. Abstracts procs. National seminar on Alien invasive weeds in India.

Singla, R. K. 1992. Can *Parthenium* be put to use. The Tribune **112**: 6.

Singla, R. K. 2000. Congress Grass. The Scourge of India. The tribune on line edition. Chandigarh. India.

Sushil Kumar, M. and V. N. Saraswat. 2001. Integrated Management. The only solution to suppress *Parthenium hysterophorus.* In: Sankaran, K. V., S. T. Murphy and H. C. Evans. (eds.), Alien Weeds in Moist Tropical Zones; Banes and Benefits. Workshop proceedings, held at Kerala Forest Research Institute, India. pp. 150-168.

Sushil Kumar, M. 2005. Biological control of *Parthenium* through *zygogramma biocolorata*. Annual report of National Research Centre for weed science, Jabalpur, M. P. 89.

Yaduraju, N. T., M. Sushil Kumar, B. B. Prasad Babu and A. K. Gogil. 2005. *Parthenium hysterophorus* Distribution, Problem and Management Strategies in India. In: Proc. Second. In. Conf. On *Parthenium* management. Dec. 5-7, 2005, UAS, Bangalore.

Whittaker, R. H. 1970. Communities and ecosystems, Macmillan Co., Collier – Macmillan Ltd., London, UK.

入侵物種對銀膠菊 (*Parthenium hysterophorus*) 的競爭排除作用

J. Asha kumari[1], P. Rama Chandra Prasad[2*] and K. B. Reddy[3]

1. *Department of Botany, Maris Stella College, Vijayawada, India.*
2. *Lab for spatial Informatics, International Institute of Information Technology, Gachibowli, Hyderabad- 500032, Andhra Pradesh, India.*
3. *S. G. H. R & M. C. M. R College of P.G. Studies, Mallareddy Nagar, Guntur -522 004, India.*

* *Correspondence Author. Tel: +91-9246109160; Fax: +91-40-6653 1413; Email: rcprasad@iiit.ac.in, rcp_ncmsl@yahoo.co.in*

(收稿日期：2009 年 11 月 2 日；接受日期：2010 年 2 月 2 日)

摘要：我們在大面積的野外環境中，調查了銀膠菊 (*Parthenium hysterophorus*) 以及其所伴生的物種在野外的豐富度、優勢度以及生長情形。初步的分析顯示銀膠菊屬於弱勢的競爭者，無法與競爭力強的其他入侵植物共存，因此，單花決明 (*Senna unifora*) 以及其它幾個較為強勢的物種，被認為是可能控制銀膠菊的工具。為了瞭解優勢的入侵物種單花決明以及香苦草 (*Hyptis suaveolens*) 如何與具有毒他作用的銀膠菊共存，我們利用取代法 (DeWit replacement series) 設計物種種植在栽培盆中分布組合，並於自然環境下的野外的實驗樣區中進行為期兩年 (2004-2005) 並區分季節的競爭實驗。研究結果顯示，香苦草與單花決明對於銀膠菊來說，是相當有效的管理物種。主要的原因是因為這兩個物種對於光資源的競爭力與所產生的遮光物理機制導致銀膠菊無法生長，此外，銀膠菊的毒它作用在自然環境之下並沒有發揮作用也許也是其處於競爭弱勢的原因之一。

關鍵詞：銀膠菊、香苦草、單花決明、競爭排除、毒他作用、個體優勢。