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**In collaboration with IOBC working
group on biological control and
management of parthenium weed.**

Parthenium hysterophorus in Guangxi, China

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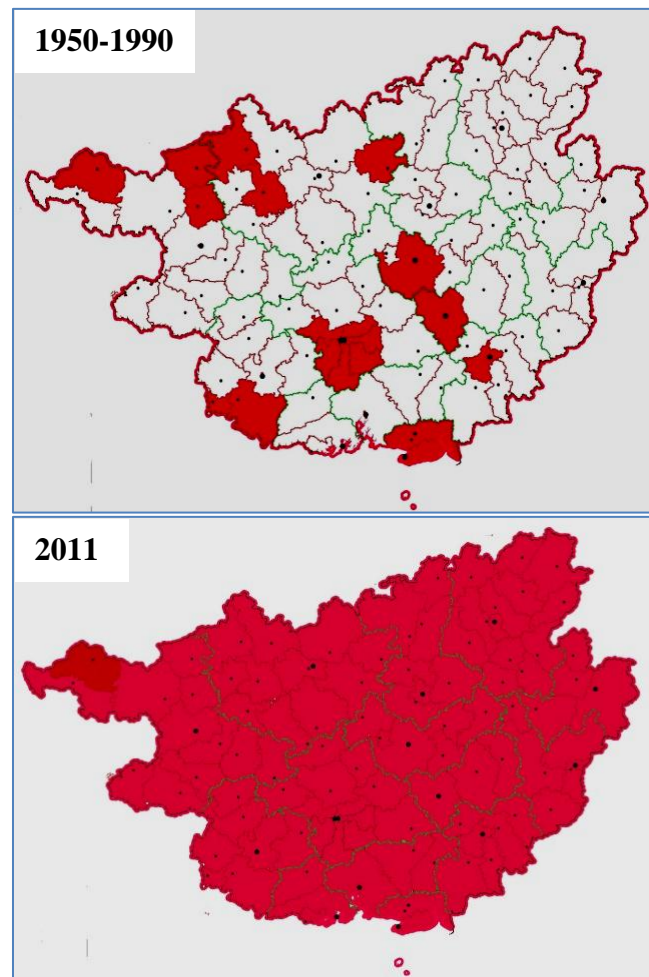
Parthenium hysterophorus L. (parthenium weed) is an aggressive colonizer of disturbed land and is spreading rapidly in China. Now it is distributed in Hainnan, Yunnan, Guangxi, Guangdong, Guizhou, Fujian and Shandong Provinces. Almost every district of Guangxi has been infested by parthenium weed. I will describe the invasion of this weed into Guangxi Province.

History in Guangxi Zhuang Autonomous Region of China

According to specimens kept in IBK, GXMI and KUN, during 1950s and 1960s, parthenium weed was only found in northwest of Guangxi, including Longlin and Lingyun county (Figure 1). In the 1970's, this weed was discovered in Nanning city, Guigang city, Beihai city, Hepu county, Luocheng county, Pingqiang city, Ningming county, Tiane county, Laibin City and Donglan county. In the 1980's, parthenium weed was

also found in Yulin city and Leye county. No references to this distribution are available except for a few examples stored in the herbarium. The plant checklist of Guangxi published in 1971 did not record this weed.

Figure 1. Spread of parthenium weed by 1950/90 and by 2011.



The weed was perhaps in its initial stages of invasion at that time and little attention was paid to its existence. Parthenium weed has now spread throughout the whole of Guangxi Province. A few scientists began to realize the dangers of this weed, but most people were not aware of its impacts upon human health.

Habitat for parthenium weed in Guangxi

Parthenium weed has mainly infested maize and sugarcane land, grasslands, sparse forest, vegetable land and roadsides in various districts (Figure 2). This has presented a wide range of problems, including traffic obstruction, destruction of road landscapes, low crop production etc. Farmers may apply herbicides on a number of occasions and also manually remove it by hand each year. The Government has not yet paid much attention and is not yet applying measures to control it. As a consequence, parthenium weed is still spreading throughout Guangxi Province. Parthenium weed seems to be adaptive to a wide range of soil nutrient levels. Stem branching and inflorescence number, the total biomass, flower mass and its ratio, and seed set all increased with increasing nitrogen level. Plant height and 1000-seed weight increased with increasing phosphorus levels. This weed adapted

to a wide range of nitrogen environments by increasing its seed production, which was achieved by enhancing branch and inflorescence number, flower mass and its ratio, as well as seed set. It also responded to phosphorous rich environments by increasing its seed quality. The addition of nitrogen and phosphorus to soils could therefore, promote the reproductive capacity of the weed, and increase its invasiveness in nitrogen- and phosphorus-rich environments. Parthenium weed was able to acclimate to different light conditions (22 to 100% of total light intensity) by changing its growth parameters, such as total biomass and biomass allocation, total leaf area and specific leaf area. However, it could not survive under low light conditions (5% of total light intensity).

Project: Guangxi Natural Science Foundation (2011GXNSFE 018005)

Figure 2. Habitats infested by parthenium weed in Guangxi Province, China



Progress towards biological control of parthenium weed in South Africa

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In South Africa, parthenium weed occurs in KwaZulu-Natal (KZN), Mpumalanga and North-West Provinces, with dense infestations in some parts leading to associated negative consequences on agricultural production and biodiversity conservation. It also invades the neighbouring countries of Mozambique, Swaziland and Zimbabwe, as well as further north in Africa. As a result, a biological control research program was initiated in South Africa, benefitting from the Australian experience of managing this weed.

Approval to release the rust fungus *Puccinia xanthii* var. *parthenii-hysterophorae* (Pucciniales: Puccinaceae) (Figure 1) in South Africa was granted by Government authorities in 2010, and initial releases of this biocontrol agent were made in the Kruger National Park (at Skukuza) in Mpumalanga Province during November 2010. Unfortunately this site was destroyed before establishment could be confirmed. Mass production of the rust fungus at the ARC-PPRI Stellenbosch laboratory was initiated during the winter months of 2011. Further mass rearing of this agent is currently also being conducted at the South African Sugar Research Institute (SASRI) in KwaZulu-Natal Province and at the Lowveld Pest, Disease & Variety facilities in Malelane, Mpumalanga Province (Figure 2). During December 2011, *P. xanthii* var. *parthenii-hysterophorae* was released at several sites in KwaZulu-Natal Province (two sites at Pongolapoort Dam (Figure 3), and one site each outside the towns of Hhluhluwe, Mkhuze and Jozini). These sites are situated in areas with dense infestations of parthenium weed. Additionally, the rust fungus was released at two sites along the Sabie River in Kruger National Park.

The rust fungus is being released by planting out rust-infected parthenium plants among healthy parthenium plants in the field. In early January 2012 it was reported that there was spread of the rust fungus to adjacent parthenium plants along the banks of the Sabie River. Unfortunately severe flooding of the Sabie River late in January 2012 destroyed both sites. During February 2012, all release sites in KwaZulu-Natal Province were

re-visited, but it was found that all rust-infected plants had died due to a dry spell a week after they were planted in December 2011. Further releases are planned for the forthcoming summer season, towards the end of 2012, and precautions will be taken to ensure that the rust-infected plants survive long enough in the field to give the rust fungus a chance to establish and spread.

Figure 1: *Puccinia xanthii* var. *parthenii-hysterophorae* symptoms on a *Parthenium hysterophorus* leaf



Figure 2: Mass-rearing of *P. xanthii* var. *parthenii-hysterophorae* at the Lowveld Pest, Disease and Variety Control facilities, Malelane.



During host range testing of the leaf-feeding beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) on 47 native and economically important members of the Asteraceae family at the ARC-PPRI quarantine laboratory at Cedara, significantly reduced feeding and oviposition was recorded on some non-target species. However, multiple-choice tests and assessment of larval development resolved results for most of the

affected non-target species. Finally, a risk analysis compiled to quantify the performance of *Z. bicolorata* on six cultivars of sunflower (affected in the series of tests) relative to that on parthenium weed, indicated that these cultivars had a negligible risk of supporting feeding or viable populations of *Z. bicolorata* in the field. This is confirmed by data from both the native and introduced range of the beetle. Based on these results, an application for permission to release *Z. bicolorata* in South Africa was submitted to the Department of Agriculture, Forestry and Fisheries in June 2012.

The stem-boring weevil *Listronotus setosipennis* (Coleoptera: Curculionidae) was exposed to 39 native and economically important members of the Asteraceae family in no-choice tests conducted in South Africa, but only seven non-target species and 12 sunflower cultivars received eggs. Multiple-choice tests resolved these results for several affected non-target species, and larval development trials were completed on eight sunflower cultivars that received eggs in no-choice and multiple-choice tests. Limited complete development occurred on two sunflower cultivars, but a risk analysis that was compiled indicated that the risk of these cultivars being able to support a viable population of *L. setosipennis* is negligible. Host range records from the native and introduced range of the weevil concur with the result of this analysis. Therefore, an application for approval to release *L. setosipennis* on parthenium in South Africa is being submitted to the Department of Agriculture, Forestry and Fisheries.

Promising results have been achieved so far during host range research on the seed-feeding weevil *Smicronyx lutulentus* (Coleoptera: Curculionidae), that was imported from Australia. Not a single egg was laid on any of the 18 native and economically important Asteraceae species and six sunflower cultivars that have been assessed so far in no-choice tests conducted in South Africa, indicating a high degree of host specificity, as also indicated by previous research conducted on this weevil in Australia. Further Asteraceae species are still to be assessed, but results so far indicate the strong likelihood of suitability of this agent for release in South Africa.

At a national weed biocontrol workshop in April 2012, a decision was taken to put on hold further host range research on the suitability of the stem-galling moth *Epiblema strenuana* (Lepidoptera: Tortricidae) for release in South Africa. This was decided due to the fact that there was significant larval feeding damage and development on five cultivars of *Guizotia abyssinica* (Asteraceae) (commonly called noog or

niger seed) from Ethiopia that were assessed in no-choice tests, as well as some feeding damage and larval development on these cultivars, even when parthenium weed was present in multiple-choice tests. Larval development trials will be conducted to conclude this aspect of research. Although *G. abyssinica* is not of concern for South Africa, it is native and of considerable economic importance to Ethiopia, where it is cultivated as an oil-seed crop. It is also utilised to some extent in other countries in Africa and Asia. Based on the laboratory results, and due to the broad native distribution of *E. strenuana*, its ability to also survive on *Xanthium* and *Ambrosia* species, and the moth's widespread, rapid establishment in Australia where it was introduced, in combination with the presence of parthenium weed in all countries linking South Africa and Ethiopia, a more conservative approach has been taken to not further consider *E. strenuana* at this stage, at least until the other biocontrol agents on parthenium weed have been established in South Africa, and their impact has been assessed.

This research program continues to be funded by the Department of Water and Environmental Affairs' Working for Water Program. We thank technical staff at ARC-PPRI Cedara and Stellenbosch for their contribution to the parthenium weed biocontrol research program.

Figure 3: Release of *P. xanthii* var. *parthenii-hysterophorae* by planting infected parthenium weed plants in a rosette-stage parthenium infestation at Pongolapoort Dam.



Occurrence and management of parthenium weed in Shandong Province, China

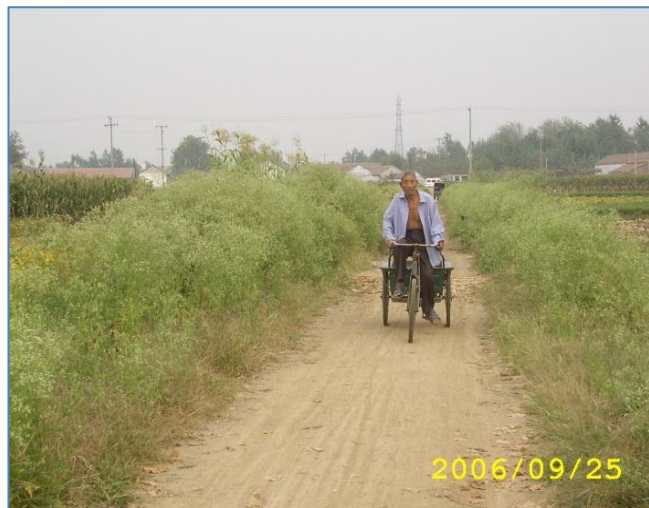
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Parthenium weed (*Parthenium hysterophorus* L.) is a member of the Asteraceae family, and native to Central America. It is an alien invasive weed in China, distributed from sea level to an altitude of 2,400m. Parthenium weed current distribution is mainly southern China, including the Provinces of Yunnan, Guangxi, Guangdong, Hainan, Hong Kong, and the south of Fujian, southwest of Guizhou, and also in Taiwan etc. It was introduced into Junan County and Linyi City, in Shandong Province very recently in July, 2004 through the importation of soybean seed from the United States of America.

Habitat and Biology

After its noticeable occurrence in 2004 in Junan County, it has already spread to other three other Counties, which are close to Junan. The total area is estimated to be about 400 thousand ha of land by 2010. Parthenium weed has become widely distributed in the wilderness, roadsides, riversides and wasteland in those regions. Earlier, it was not considered to be a weed of farmland but now it is also found in abundance in peanut, cotton, potato, and maize fields. It causes great yield loss in some infested farmlands.

Figure 1: Parthenium weed growing along the roadsides.



Parthenium weed is thought to have spread rapidly due to its high adaptability to the environment, its drought-tolerance ability, and its high seed production. It could germinate and grow very well from early spring to end of autumn (from mid-April to the end of October), in Shandong Province. In only 45 to 55 days it can grow from seed to the flowering stage. Flowering can last for several months, to the end of October. Taking about 15 days from flowering to fruit maturity, mature fruit automatically fall from the plant. Seeds production of parthenium weed is extremely large, about 2,000 per plant on average, with the number going up to 10,000 to 20,000. The seed dormancy is not uniform, and about 30 to 40 % of the seed could germinate in the same year. Seed germination rates are high when the seed is on the soil surface, and the germination rate reduces rapidly when the seed is 2 cm below the soil surface. As well as all of the above characters, parthenium weed has a strong allelopathic effect upon other plants. So, parthenium weed can suppress and crowd out other weed species, and could form a single dominant population in the invasion area, at the same time, cause serious threat to plant community biological diversity.

The rapidly spread of parthenium weed in Shandong Province is not only because of its characters but also due to other factors. For example, as the seed is very small and light, it can be spread easily within irrigation water, rain and river water; other farmer activities carry the seed into the farmland; long-distance distribution is mainly by farming machinery and vehicles carrying its seed from one place to another.

Figure 2: Parthenium weed growing in wastelands.



Management

It is known that mechanical and manual methods of management are unable to control parthenium weed efficiently in areas of high infestation. The parthenium weed seeds can germinate very quickly after the above ground parthenium weed plants have been removed. Uprooting or hoeing of the plants can only control the weed in areas where only a few parthenium weed plants are to be found. However, the farmer only cares about the weeds in the field, and not about the weeds along the road side or in the wasteland which soon causes re-infestations of the weed into the fields.

No viruses, fungi or insects, which can serious damage parthenium weed, have been found in Shandong Province. Chemical control of parthenium weed has been tested in the glasshouse, at the Institute of Plant Protection, SAAS, Shandong Province, China. The results showed that sulcotrione, mesotrione, and atrazine all control parthenium weed either when used as a pre-emergence or as a post-emergence herbicide. Rimsulfuron could also control parthenium weed when sprayed before parthenium weed emergence; metribuzin, glyphosate, topramezone, picloram could also control parthenium weed when sprayed at the 3 to 5 leaf stage. Field experiments using chemical control and competition with other plant are proceeding at this time. Integrated weed management approaches are likely to be the best for managing parthenium weed.

Figure 3: Physical control of parthenium weed.



Parthenium Research in Nepal: An Update

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Germination response

Germination response of 20 native and naturalized (alien) plant species growing in the five urban areas of Nepal (Kathmandu, Pokhara, Hetaunda, Chitwan and Butwal) were examined in the aqueous extracts of leaves and inflorescence of *Parthenium hysterophorus* L. (Poudel 2011). Out of the test species, six were sensitive species (i.e. high reduction in seed germination), three were moderately sensitive, and 11 were tolerant to the inhibitory effect of *Parthenium* extracts. Interestingly, the native plant species were found to be more sensitive to the allelopathic effects than the alien species. During the germination trials growth of the root appeared to be more sensitive to the allelopathic effect than shoots. Leaf extracts had higher inhibitory effects than inflorescence extracts on both germination and seedling growth. [This research work was for MSc thesis supervised by the author].

Puccinia abrupta: a new report to Nepal

Puccinia abrupta var. *partheniicola*, also called the parthenium winter rust, is one of two fungal pathogens that have been used as biocontrol agents against parthenium weed. In Nepal, this rust was first reported from the Kathmandu valley in May 2011 (Shrestha 2012a). There has been no report of its deliberate introduction to Nepal. Until now the rust has been limited only to a few places in the valley and the impact is insignificant. The rust has been observed during dry summer (March-May) when the population of parthenium weed is very small, and it disappears during the rainy season (monsoon) when the population and growth of parthenium weed is the highest. This rust has not been reported from other parts of the country. It is the second biocontrol agent of parthenium weed to be reported in Nepal; the Mexican beetle *Zygogramma bicolorata* is already established and has caused significant damage to parthenium weed in a few places (Shrestha *et al.* 2010).

From Roadside to Farmland

Until recent past, parthenium weed was mainly found on the roadsides, in fallow land, grazing land and abandoned lands. However, the weed has been expanding into new habitats such as non-irrigated

active farmlands. We observed parthenium weed growing in farmlands over various parts of the country (Figure 2). The farmland that is used only once in a year (during the rainy season) and is left fallow during the winter and summer appears to be the most vulnerable to parthenium weed infestation. During the fallow period, the weed gets a chance to grow and produce seed before the next cropping activities begin. Earlier, we reported the expansion of this weed into the Chitwan National Park which is the habitat of critically endangered one-horn rhino and a World Natural Heritage Site (Shrestha 2012b).

Public awareness

With the expanding distribution range and increased impact of parthenium weed, the common people are interested to know more about this weed and are searching for ways to control it. On March 23, 2012, Hetaunda Municipality organized a one day interaction program on the “Impact of Parthenium Weed on Environment and Health” for local community leaders (Figure 3). The author was invited as a resource person to that program and he highlighted various issues related to distribution, dispersal mechanisms, ecological and health impacts, and control measures of Parthenium in his lecture.

Figure 1. *Puccinia abrupta* var. *partheniicola* in Kathmandu, Nepal. A) An infected plant (March 2012), B) Upper surface of the infected leaf of parthenium weed May 2011).



Figure 2. Parthenium weed expanding into farmlands. A) Farmers were removing the weed to prepare the land for paddy plantation at Kirtipur, Kathmandu valley, B) The farmland heavily colonized by parthenium weed at Kohalpur, Banke district, western Nepal. C) Parthenium weed left intact after first round of ploughing at the same locality as B. All photographs were taken in May 2012.



Figure 3. Interaction program on parthenium weed organized by Hetaunda municipality (March 23, 2012)



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A Report on the 2nd Meeting of the International Parthenium Weed Network (iPaWN) June, 19th 2012, Hangzhou China.

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A second meeting of the International Parthenium Weed Network (IPaWN) took place at the New Century Grand Hotel, Hangzhou, on the 19th June 2012 in conjunction with the 6th International Weed Science Congress (IWSC). The meeting included brief country reports from several different countries that have problems with parthenium weed and discussed a number of emerging issues. More than 20 delegates from 15 countries attended the meeting.

Dr Steve Adkins, Chair, IPaWN, opened the meeting with a brief presentation summarizing what we know about the present distribution of parthenium weed around the globe highlighting the modes and the speed of its spread, the kinds of habitats that are becoming infested, the impact it is having upon crop and pasture production, and upon human and animal health. The presentation concluded with a summary of the research collaborations that are presently underway around the globe and an open invitation to others to join the network and to join in with the future activities.

Dr Asad Shabbir, Network Coordinator then gave a presentation on the objectives, past activities and future plans of IPaWN. He reported that since its initiation in 2009, IPaWN has expanded rapidly facilitating the exchange of information about parthenium weed and its management among 250 members from more than 30 countries. He explained about the 6-monthly International Newsletter produced by the network, and the other useful publications that are posted online to all network members. He also requested members to contribute on a regular basis to

the newsletter, and the next issue would be published in July/August 2012. All previous issues of the newsletter and information about the network are available at the website: <http://www.apwss.org/apwss-ipawn.htm>.

Dr Wondi Mersie, Professor of Weed Science at Virginia State University, USA, gave a brief overview of the East African project on parthenium weed management. He outlined the ongoing research that was underway on the host testing and release of biological control agents against parthenium weed in Ethiopia. Dr Mersie in his report pointed out that parthenium weed has been spreading rapidly over much of East Africa and the release of biological control agents and the implementation of integrated management strategies will be important in tackling this problem in the coming years.

Dr R.M. Kaithresan, Professor and Head of the Department of Agronomy, Annamalai University, India gave a brief report on the parthenium weed problem in the Indian subcontinent. He pointed out that further spread of the weed may be reduced, through a national awareness and eradication campaign. He pointed out that State Ministers are personally taking interest in parthenium weed awareness and management issue and are becoming actively involved in the eradication campaign for this noxious weed.

Dr Steve Adkins discussed the emerging problem of parthenium weed in Bangladesh and showed photos of parthenium weed invasion in different cropping and non-cropping areas. He also discussed about his recent visit to Bangladesh and the possibilities of developing an international collaborative project to manage this weed.

Figure 1: IPaWN meeting in Hangzhou, China.



Dr Anurudhika S. K. Abeysekera, a senior weed scientist from the Sri Lankan Rice Research and Development Institute shared an important observation that suggested that rice sterility could be caused by parthenium weed pollen. She pointed out that this is still an observation at the farmer level and needs to be further studied. If this turns out to be true, this will represent a great threat to food security in areas of south and south east Asia where parthenium weed is present in significant proportions.

Dr Carol Ellison from CABI-UK discussed the possibilities of biological control of parthenium weed in developing countries using rust pathogens. She pointed out that the search is on for new pathogens as well as old one with higher virulence and host-specificity.

Widespread establishment and the spreading of the Carmenta moth; a biological control agent for parthenium weed in Queensland, Australia

Dr Kunjitapatham Dhileepan: Biosecurity Queensland, Department of Agriculture, Forestry and Fishery Queensland Australia.

The parthenium weed clear-wing moth *Carmenta* sp. nr *ithacae*, a root feeding biological control agent for parthenium weed from Mexico was released in Queensland, Australia during 1998-2002. The larvae of the carmenta moth can bore through the stem-base into the root where they feed on the cortical tissue of the taproot (Figure 1). Evidence of field establishment was first observed in two of the release sites in central Queensland in 2004. Since then, their incidence remained low in and around four release sites, and four non-release sites, all in central Queensland. However, during a recent survey in the summer of 2012, widespread establishment of the carmenta moth was seen throughout central Queensland. It is expected that the spread of the moth will continue, and will have significant impact in complementing the already established other agents like the defoliating beetle (*Zygogramma bicolorata*), stem-galling moth (*Epiblema strenuana*), stem-boring weevil (*Listronotus setosepennis*) and the seed-feeding weevil (*Smicronyx lutulentus*). We will continue to monitor the spread and impact of the moth in the coming years.

Figure 1: Larvae infecting the lower portion of parthenium weed plants.



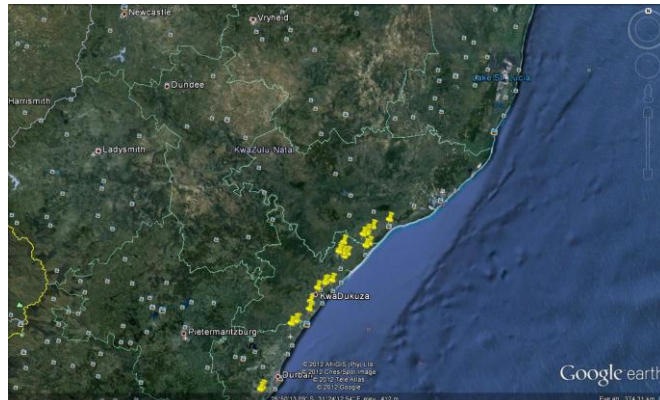
North American Parthenium biotype in Brazil

Dr Dhileepan along with Stefan Naser and Anthony King of Plant Protection Research Institute of South Africa, conducted surveys for weed biological control agents in South America (southern Brazil, southern Paraguay and the Misiones region of Argentina) in March to April 2012. During the survey, they found a large parthenium weed (*Parthenium hysterophorus*) infestation (all stages, including rosettes, and flowering plants) around a transport lorry depot on the outskirts of Foz do Iguacu (S 25° 30.531'; W 54° 33.585; Figure 2'). The flowers were whitish, similar to the North American parthenium weed race. No specialist insects were seen on the plant, except for polyphagous whiteflies, mealy bugs and mirids.

Figure 2. The North American race parthenium weed plants growing in Brazil.



Figure 1. Outlier populations of *P. hysterophorus* in KwaZulu-Natal cleared during 2012



Containment of Parthenium Weed spread in KwaZulu-Natal, South Africa

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The South African National Biodiversity Institutes' Invasive Species Program (funded by Natural Resource Management of the South African Department of Environmental Affairs) aims to detect invasive alien plants in South Africa at a relatively early stage of invasion. Although *Parthenium hysterophorus* does not fall within this mandate, the program has aided in its management in the KwaZulu-Natal Province in an effort to contain the species by clearing outlier populations during the 2010/2011 and 2011/2012 flowering seasons. The herbicide used was Access* 240 SL (0.375% for plants less than 1 m tall and 0.5% for plants > 1 m tall). Due to the late rains in 2012 and the warm climate of KwaZulu-Natal, *P. hysterophorus* continued flowering well into the winter season and the team were able to continue with chemical management for longer than would normally be possible. Over a period of a month and a half the Program employed 10 people to undertake chemical treatment of the plants. Chemical treatment of *P. hysterophorus* will continue during the 2012/13 flowering season while a long-term strategic management plan for *P. hysterophorus* is developed for South Africa.

PhD theses completed on parthenium weed at the University of Queensland

The invasive potential of parthenium weed (*Parthenium hysterophorus* L.) in Australia

Nguyen Thi Lan Thi

Abstract: Parthenium weed (*Parthenium hysterophorus* L.) belonging to the Asteraceae family is described as an aggressive herbaceous weed of tropical and subtropical environments and has been accidentally introduced into at least 30 countries around the world. It has the ability to dramatically reduce the productivity of pastures, as well as affect the welfare of both livestock and people. It has also become an important cropping weed and significantly disrupted native community biodiversity. The impacts of this species upon human and animal health haven't been well studied but it causes a range of allergy and respiratory diseases. In Australia, parthenium weed is currently one of the most important invasive weeds and is predominantly found in Queensland. In this state, it has been reported to cause a total habitat change, including that of native grasslands, open woodlands, river banks and floodplains and it is alarmingly replacing the native vegetation in many other countries including in India and Ethiopia. Clearly, there is a need to understand thoroughly the reproductive biology of parthenium weed, the mechanisms of the weed spread, seed persistence, and the impact of parthenium weed upon plant biodiversity. Insights into these aspects may allow us to model and hence, predict the invasion potential of parthenium weed in the

near future and thereby, to manage the weed more effectively and successfully.

Several experiments were conducted to determine the effects of several environmental parameters upon the reproductive capacity, seed quality and the longevity of its seeds in the soil seed bank. In addition, the effects of climate change variables such as CO₂ concentration, soil moisture and temperature on parthenium weed's early growth were considered. The species composition and dynamics of the soil seed banks during periods of active management were also investigated. The viable seed spread by vehicles was determined by examining the sludge samples collected from wash down facilities and viability in water bodies was also studied in order to develop a better understanding of the spread of this weed and methods for its prevention. Finally, the impact of parthenium weed upon a native pasture community biodiversity was investigated.

Warm (35/28 °C, day/night), as compared to cool growth conditions (25/18 °C, day/night), advanced the developmental process of parthenium weed, speeding up its life cycle (188 days as compared to 220 days), its time to flowering and fruiting commencement (49 days as compared to 57 days and 62 days as compared to 81 days for time to flowering and fruiting commencement) and promoting height attainment (118 cm as compared to 86 cm) and biomass accumulation (34 g as compared to 21 g per plant). Warm as compared to cool growing conditions, also promoted the reproductive ability of the plant, increasing its seed production capacity (24,421 seeds as compared to 18,512 seeds), the percentage of seed that was filled (64 % as compared to 57 %), promoting the proportion of dormant seeds (9.0 % as compared to 1.8 %) and producing seed with the capacity to live longer in the soil seed bank (more than 3 years as compared to less than 3 years).

Under an elevated CO₂ concentration (550 ppmv), coupled with a cooler (30/15 °C, day/night), wetter soil condition (field capacity), the early growth of the plant (including leaf production, leaf length development, leaf area and biomass) of two biotypes (Clermont and Toogoolawah) was greatly promoted over that seen under the same conditions but under an ambient CO₂ concentration (390 ppmv). The CO₂ enrichment increased leaf number (from 27 to 30 %), leaf length (66 to 89 %), leaf area (186 to 264 %) and dry biomass (206 to 305 %) for the two biotypes. However, growth was not significantly increased under elevated CO₂ conditions when the early growth was under warm conditions (35/20 °C, day/night). The CO₂ enrichment increased leaf number (7 %), leaf length (14 %), leaf area (32 %) and dry biomass (53 %) for Clermont plants.

In addition, the species composition and the dynamics of the soil seed bank following a 15 year period of active weed management were studied at two sites (Moolayember Creek and Clermont) in central Queensland. Parthenium weed represented 20 % and 80 % of the total seed bank community at the Moolayember Creek and Clermont sites, respectively. Parthenium weed was having a big impact upon these communities, and was significantly reducing the community diversity, the species richness, the Shannon-Weiner index and the evenness index. However, the impact of parthenium weed at the Moolayember Creek site was less than that seen at the two Clermont sites. When considered over a 15 year period, the initially declining parthenium weed seed bank at the Moolayember Creek site had more recently plateaued. The management program at these sites, involving biological control agents, had therefore reduced the parthenium weed seed bank (from ca. 33,000 to ca. 6,000 seeds m⁻²) in the first 8 years of management but no further reductions had occurred within the last 7 year period. During this time when the parthenium weed seed bank numbers had plateaued, the reduced parthenium weed seed bank had been replaced with seed from other annual weeds and unfortunately very little improvement in the overall size of the seed bank of the palatable fodder plants had occurred. At the Clermont sites, the parthenium weed seed bank was still increasing gradually in size. Furthermore, the seed bank of grass species remained extremely low and this site seemed to be unstable and undergoing a continued decline in biological quality.

The spread of weed seed (including that of parthenium weed) on vehicles was studied over a 3 year period. Material washed off vehicles at off-road wash down facilities, taken from five sites in central Queensland, in each of the four seasons of the year showed that the average total number of viable seeds t⁻¹ of dry sludge that collected in the bottom of the wash down facility was ca. 67,000. This included ca. 37,000 seed from grass and sedge species and ca. 30,000 seed from broadleaf species. There were ca. 146 species represented, coming from 34 families. Of these, 57 % were annuals, 51 % were forbs, 34 % were grass species, 34 % were weeds, and only 57 species were native (39 %) with the majority of seeds coming from the common cosmopolitan weed species such as *Cynodon dactylon* (L.) Pers., *Eleusine indica* (L.) Gaertn., *Eragrostis cilianensis* (All.) Vignolo ex Janch., *Portulaca oleracea* L., *Trianthema portulacastrum* L., *Oxalis corniculata* L., *Alternanthera denticulata* R.Br. and *Physalis lanceifolia* Nees. These species also represent the commonest weed species to be found along the roadsides and abandoned land in the central Queensland region. Most of the species

were annual forbs (50 %) with small or very small seed sizes (< 2 mm in diameter). A typical wash down facility was removing up to ca. 335,000 viable seeds from vehicles per week with 100,000 seeds coming from weed species. A typical vehicle might be carrying ca. 3,400 viable seeds, 1,200 of which are weed seeds. Parthenium weed was present in the sludge at all five facilities, with an average of 1,340 seeds t⁻¹ of dry sludge. A typical wash down facility was removing up to 4,000 viable parthenium weed seed per week. This clearly indicates that parthenium weed seed is commonly spread by vehicles and that vehicle transport must represent one of the most important vectors for its spread.

Moreover, the viability of parthenium weed seeds in water was measured in distilled, river, and sludge water at 10, 15, 20, 24, 27, 30 or 34 °C and in different pH solutions (4, 5, 6, 7, 8, or 9 of pH levels) at 15, 20, 24, 27, or 30 °C, for between 0 to 45 days. The viability of parthenium weed seeds was still high (ca. 90 %) after 45 days in distilled water and river water especially when the temperature of those solutions was low (10 or 15 °C). This viability of parthenium weed seeds was less (ca. 42 % after 45 days) in sludge water when the temperature was low (10 or 15 °C). The higher the temperature of the water and the longer the seeds were in the water, the lower the subsequent seed viability observed. Warmth elevated the rate of seed viability decline but even at 27 °C (a typical summer daytime temperature in Queensland) seed would be predicted to remain viable for up to 20 days in water. All seeds had died after 30 days in distilled and river water at 30 or 34 °C, and after 15 days in the sludge water. The viability of parthenium weed seeds decreased more rapidly when exposed to sludge water at all temperature treatments than to distilled water or river water. For the viability of seeds in different pH solutions, the higher the temperature of the solution and the longer the seeds were in it, the lower was their viability. The viability decreased drastically after 10 days in solutions at all pH level for most of the temperature treatments. All seeds died after 45 days in solutions at all pH levels kept at 27 and 30 °C. These outcomes did not depend upon the pH of the solution. The pH of the solution didn't seem to be the reason for the higher loss of seed viability in the sludge water, but other factors such as the lower dissolved oxygen content or the assumed higher microbial load in the sludge water could negatively affect viability more than that seen in river water.

Finally, the impact of parthenium weed upon the botanical diversity, both within the above-ground and below-ground communities, was assessed at a pastoral site in Kilcoy, Queensland, Australia. The effect on biodiversity was studied in areas infested with

different densities of the weed (i.e. high, low and no parthenium weed). There were 63 species and 101 species coming from 25 families and 33 families in the above-ground community and the below-ground community of the site, respectively. The native species represented 49 % of those present at the three sites while the introduced species represented 51 %, with 40 % of these regarded to be weeds. The importance value index and the relative density of native species were lowest at the high density of parthenium weed site and highest at the no parthenium weed site, both in summer and in winter, both in the above-ground and the below-ground communities. The species diversity (the Shannon - Weiner index) and the community evenness, both in the above-ground vegetation and in the soil seed bank, both in the summer and winter seasons, decreased as the parthenium weed infestation levels increased, even when the weed was present at a relatively low density of 2 plants per m².

Long term, sustainable management of parthenium weed (*Parthenium hysterophorus* L.) Using suppressive pasture plants

Naem Khan

Abstract: Parthenium weed (*Parthenium hysterophorus* L.) is a broad leaf herbaceous invasive weed of Asteraceae family of tropical and sub-tropical regions. This weed is imposing severe losses upon the pasture and crop production, livestock and plants biodiversity. It also putting the human and animal health at risk by causing various diseases such as allergy, hay fever, rhinitis and respiratory complications in human being and livestock. To address one of the issues 'pasture losses' due to this weed, certainly it is need of the day o find out sustainable management approaches such as the use of suppressive plants that could suppress the growth and reduce the existing huge soil seed bank of parthenium weed in central Queensland. This may permit us to model and thus, to identify plants with high suppressive ability upon the growth of parthenium weed, to sustainably and more effectively manage this weed on long-term basis in Australia and overseas.

A number of trials were undertaken investigating the suppressive ability of test species upon parthenium weed growth under glasshouse conditions. The selected suppressive plants were then tested in field conditions in Australia and in Pakistan and, under grazing regimes. Lastly, the suppressive ability of the selected species upon parthenium weed was studied under an elevated CO₂ concentration, the most important climate change variable. All these studies were aimed to develop parthenium weed management

approaches that could help minimize the pasture losses and to reduce its spread in the present as well as future climate change scenarios.

A good number of test plants including native and introduced pastures suppressed the growth of parthenium weed in the glasshouse conditions. Purple pigeon grass, guinea grass, and buffel grass were all strongly suppressive upon the growth of parthenium weed by producing > 1.5 suppressive index (SI) values. Other test species such as bull Mitchell grass, Indian bluegrass, Kangaroo grass, hoop Mitchell grass and pitted bluegrass and lablab showed moderate suppressive effects by giving ≥ 1.0 SI values. Silky brown top, red leg grass, centurion, curly Mitchell grass, cotton panic grass, forest bluegrass, weeping grass, desert bluegrass, Wallaby grass and black spear grass were all less suppressive by giving < 1.0 SI values.

The selected test species showed significant suppressive ability upon the growth of parthenium weed by reducing its biomass in the field conditions at two locations in central Queensland. Purple pigeon grass, buffel grass, Rhodes grass, creeping bluegrass and butterfly pea (all introduced) and bull Mitchell grass, Kangaroo grass and Queensland bluegrass (all native species) were all suppressive by significantly reducing the shoot biomass of parthenium weed in central Queensland. In addition, some of the selected species have also shown ability to suppress the growth of parthenium weed in two locations in Pakistan. In addition, all these test species produced higher shoot biomass for fodder purpose. In field conditions of Pakistan, Rhodes grass, Rhodesia sorghum and rice bean (all introduced) while buffel grass (native to Pakistan) greatly showed significant suppression ability upon the growth of parthenium weed in terms of shoot biomass reduction of the weed. The suppressive test species produced higher shoot biomass as fodder.

Furthermore, at the Injune, central Queensland site, six test species were studied for their suppressive ability over the growth of parthenium weed under four simulated grazing pressures no (0 %), low (25 %), moderate (50 %) and heavy (75 %). Parthenium weed growth was highly suppressed under 0 %, 25 % and 50 % simulated grazing pressure by purple pigeon grass and buffel grass. These two species have also produced good amount of fodder under these pressures of simulated grazing. Kangaroo grass, bull Mitchell grass and butterfly pea provided better suppressive abilities of parthenium weed growth at 0 and 25 % simulated grazing pressures. In addition, Kangaroo grass and butterfly pea have also yielded good amounts of fodder at these pressures, however, bull Mitchell grass did not. At 75% simulated grazing pressure, only purple pigeon grass was fairly

suppressive to the growth of parthenium weed probably due to its high shoot biomass, rapid and greater attainment of height and greater tussock diameter. All other test species exhibited less suppressive ability of parthenium weed at this simulated grazing pressure. Moreover, at each of the three simulated grazing occasions, higher amount of fodder was harvest for purple pigeon grass and buffel grass while moderate amount of fodder was harvested for Kangaroo grass, bull Mitchell grass and butterfly pea. The lowest fodder biomass was observed in case of Indian bluegrass in all cases.

The suppressive index values of the C4 test species (purple pigeon grass and bull Mitchell grass) reduced when grown under the elevated CO₂ condition (550 ppmv) with parthenium weed. Additionally, the growth of parthenium weed was found to increase under this condition of CO₂ when grown alone as well as when grown with the C4 grass species, while that of the C4 species remained unchanged when grown alone. However, growing with parthenium weed at different planting combinations, their growth decreased in the elevated CO₂ condition. This was probably due to the increase in the growth of parthenium weed. The suppressive indices values of the C3 test species (butterfly pea) greatly increased under the elevated CO₂ concentration when growth with parthenium weed. Both the suppressing opponents (i.e. butterfly pea and parthenium weed) growth promoted under the elevated CO₂ condition; however; butterfly pea being a C3 broadleaf legume was comparatively more increased under this CO₂ condition and hence promoted its suppressive ability upon parthenium weed by producing higher total biomasses.

Towards the improved management of parthenium weed: complementing biological control with plant suppression

Asad Shabbir

Abstract: *Parthenium hysterophorus* L., commonly known as parthenium weed, is an invasive weed of global significance that has become a major weed in Australia and many other parts of the world. Parthenium weed has been reported to be a significant weed of rangelands, crops, a disrupter of biodiversity in natural ecosystems and a health hazard to people and domestic animals. In Australia, parthenium weed is a 'Weed of National Significance' and is mainly found in Queensland where it has invaded c. 600,000 km² of prime pasture land reducing beef production by c. AU\$100 million annually and reducing stocking rates by up to 80 %. In Australia, integrated weed management approaches are built around a classical

biological control program onto which other strategies are added. To date, 11 biological control agents have been released with some of these agents becoming widely established, having a measurable impact upon weed populations. However parthenium weed remains a major weed of concern and improvements to the integrated weed management approach are necessary. The focus of this thesis was to investigate a new strategy for integrated weed management, then to assess the resilience of the strategy under a changing climate and finally to assess its applicability in another location.

To complement the biological control approach with other management tactics, appraisal of the impact of suppressive plant species (native or introduced) was undertaken under shadehouse conditions. The shadehouse studies involved two selected suppressive plants, the native Mitchell grass (*Astrebella squarrosa* CE Hubb.) and the introduced legume, butterfly pea (*Clitoria ternatea* L.) with two biological control agents, a leaf and seed feeding beetle (*Zygogramma bicolorata* Pallister.) and a stem galling moth (*Epiblema strenuana* Walker). The study showed the suppressive plants to significantly suppress weed growth (as assessed by height attainment, biomass production and seed production) in the absence of the biological control agents. However, this suppressive ability could be further enhanced in the presence of one of either biological control agents. In addition, x-ray analysis of the seed produced revealed that the plant growth suppression by the biological control agents and the suppressive plants together had a significant negative effect upon seed fill, indicating that management effects beyond the present generation was feasible. The interactive effects of the biological control agents and the suppressive plants upon parthenium weed growth also resulted in a greater production of biomass (fodder) by the suppressive plants.

The new combined integrated weed management approach was then tested under field conditions at two contrasting sites over a 2 years period in central west Queensland. In the first year, at the Injune field site, the six selected suppressive plants combined well with the biological control agents present in the field to synergistically reduce the growth of parthenium weed, by between 60 to 86 %. While in the second year the results were more variable with the suppressive plants reducing parthenium weed growth by between 23 to 67 % (when the biological control agents absent) or by 47 to 91% (when the biological control agents were present). When biological control agents were present, the corresponding biomass of the suppressive plants increased in comparison to that seen in plots where biological control agents had been excluded, by between 6 to 23 %. The maximum growth advantage

(in the presence of biological control agents) was achieved by buffel grass (+23 %), followed by purple pigeon grass (+19 %), then bull Mitchell grass (+17 %). Similar results were found at the Monto field site where the two selected test plants, buffel grass and butterfly pea acted with the biological control agents in a synergistic fashion to bring about the growth suppression of parthenium weed by ca. 65 %.

Parthenium weed plants when grown under an elevated CO₂ concentration (550 µmol mol⁻¹), produced a greater biomass, grew taller, produced more branches and seeds per plant, and photosynthesized at a greater rate, when compared to those grown at an ambient CO₂ concentration (380 µmol mol⁻¹). The winter rust (*Puccinia abrupta* var *parthenicola* Jackson Parmelee), under the elevated CO₂ concentration, induced a greater disease severity (20 % more pustules) on parthenium weed leaves than seen on plants growing under the ambient CO₂ concentration (380 µmol mol⁻¹). As a consequence of this increased disease severity, parthenium weed plants were shorter in stature, produced a lower biomass and a reduced number of branches. This was seen under both the elevated and the ambient CO₂ concentration. The stem galling moth (*E. strenuana*) significantly reduced the height, biomass and seed production of parthenium weed plants when grown under both the ambient and the elevated CO₂ concentration. In the presence of the stem galling moth, the total seed produced was 30 to 60 % less at elevated as compared to ambient CO₂ concentration. The stem galling moth had a significant negative impact upon the quality of seed with about 50 % of total seed produced at elevated CO₂ concentration, not filled. When grown under the ambient CO₂ concentration, together the stem galling moth and buffel grass had a strong negative effect reducing growth by as much as 65 % and seed production by 54 %. However, under an elevated CO₂ concentration (550 µmol mol⁻¹) growth was decreased by 38 % while there was no effect upon seed production. Alone the effect of the elevated CO₂ concentration (550 µmol mol⁻¹) had no effect on the growth of buffel grass.

A study on the distribution of parthenium weed in Pakistan revealed that the weed has rapidly spread from the northern districts to the southern districts of the Punjab Province, in the past 10 years. The persistence of parthenium weed in these hotter and dry districts suggests that the weed can survive under more extreme conditions than previously thought. The development of a CLIMEX distribution model that took into account this increased tolerance to drier and warmer conditions predicted that the weed could still spread into many other parts of Pakistan as well as south Asia. This increased range could include the

northern parts of Pakistan, parts of southern India as well as Nepal and most parts of Sri Lanka and Bangladesh. This CLIMEX distribution model satisfied the present distribution of parthenium weed both within Pakistan and also within Australia. When an irrigation scenario was added to the CLIMEX program, more parts of the southern districts of Pakistan (Indus river basin) became suitable for parthenium weed growth, as well as its biological control agent, *Z. bicolorata*. This expansion of the predicted range was due to irrigation producing extra moisture into the system. In addition to the weed moving north due to temperature increase, under irrigation the weed is likely to move into south of Pakistan. The CLIMEX model indicated that there are many more areas within Australia that are suitable for parthenium weed growth, both under the present and a future climate scenario. The predicted potential distribution of the suppressive plant, buffel grass (*Cenchrus ciliaris* L.) throughout the world was suggested to increase, showing considerable overlapping with parthenium weed indicating that the use of this grass as a suppressive plant in the integrated management of parthenium weed will be possible in Pakistan.

The importance of these finding in this study is that parthenium weed can be more effectively managed by complementing presently existing biological control strategies with suppressive plants in Australia, and this approach is likely to work in to the future under climate change, and in other locations around the globe where parthenium weed is becoming problem. In addition, the study has shown that parthenium weed is likely to expand its geographical distribution range, under both present and future climatic conditions. In Pakistan, the biological control agent, *Z. bicolorata* has not reached its full potential range and is likely to undergo range expansion in the future as well. Parthenium weed is likely to become more aggressive in Australia and around the world, but the combined use of biological control agents and suppressive plants is likely to work in many locations. Therefore along with the threats of future spread of the weed there are opportunities for better planning and management.

Upcoming Conferences on Weed Science and Invasive Species

18th Australasian Weeds Conference (18AWC)

Dates: 8-11th October 2012,
Venue: Melbourne, Australia
<http://www.18awc.com/>

Global Herbicide Resistance Challenge International Conference

Dates: February 2013
Venue: Perth, Western Australia.
<http://www.herbicideresistanceconference.com.au/>

18th International Conference on Aquatic Invasive Species

Dates: 21-25th April 2013
Venue: Niagara Falls, Ontario, Canada
<http://www.icaais.org/>

16th European Weed Research Society Symposium

Dates: 24-27th June 2013
Venue: Samsun, Turkey
<http://www.ewrs2013.org/default.aspx>

Recent Publications

Dhileepan K, Trevino M, Vitelli MP, Senaratne KA, McClay AS, McFadyen RE. 2012. Introduction, establishment, and potential geographic range of *Carmenta* sp. nr *ithacae* (Lepidoptera: Sesiidae), a biological control agent for *Parthenium hysterophorus* (Asteraceae) in Australia. *Environ Entomol.* 41(2):317-25.

Qian M, Li G, Tang S, Ou X, Lin Y, Yin J, van Klinken RD, Geng YP. 2012. Development of microsatellite markers for the invasive weed *Parthenium hysterophorus* (Asteraceae). *Am J Bot.* 99 (7):277-9.

Dhileepan, K.McFadyen, R.C. 2012. *Parthenium hysterophorus* L. - Parthenium: biological control of weeds in Australia, CSIRO Publishing p. 648.

Kumar S, Khandpu S, Rao DN, Wahaab S, Khanna N. 2012. Immunological response to *Parthenium hysterophorus* in Indian Patients with *Parthenium* sensitive atopic dermatitis. *Immunol Invest.*; 41 (1):75-86.

Shrestha BB. 2012a. *Puccinia abrupta* var. *partheniicola*: a biocontrol agent of *Parthenium hysterophorus* new to Nepal. *Biocontrol News and Information* 33:2N

Website: Information about iPaWN and all previous issues of International Parthenium Weed Newsletter are now available at the following website;
<http://apwss.org/apwss-ipawn.htm>