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Tropical & Sub-Tropical Weed Research Unit, The University of Queensland, Australia.

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

Parthenium weed research in Pakistan: An update

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The latter end of 2018 has seen an escalation of activities on *Parthenium hysterophorus* (parthenium weed) in Pakistan by CABI under its '*Action on Invasives'* program.

Monitoring parthenium weed using satellites

In a project led by the University of Manchester, CABI and local partners in Pakistan are looking into a novel approach to monitor the distribution and spread of parthenium weed using earth observation satellites and ground sensors.

In early October, the kick-off meeting in Pakistan with all the partners was organised by CABI in Islamabad. Here the project team outlined future activities and by engaging with local partners, were also able to understand more about how they could incorporate an inter-sectoral approach on the ground in Pakistan. It is vital to the project that key decision makers from a variety of sectors are involved in order to create a more universal approach to controlling invasive species like parthenium weed.

Current work is concentrated on:

- Collecting parthenium weed distribution and habitat data across the Punjab and Khyber Pakhtunkhwa Provinces
- Developing new and cost-effective sensors that could be using during field work validation
- Building the pipeline and retrieving imagery from Sentinel sensors to test preliminary algorithms

By monitoring parthenium weed using satellite imaging, the project aims to quantify the spread on a large scale, particularly in remote areas, in order to assess economic and environmental impacts, and monitor landscape level biological control solutions (Fig.1-3).

Fig. 1 CABI researchers checking insect damage on Parthenium weed (Rawalpindi, Pakistan).

Biological control research

Ongoing research on biological control includes work on *Listronotus setosipennis*, a stem boring weevil native to Argentina and Brazil. Already released in Australia, South Africa, Uganda and Ethiopia, larval feeding can kill parthenium seedlings and rosettes.

Modelling of the climatic requirements (CLIMEX) is underway for this species to determine the most likely areas where it will establish well and cause immediate damage in Pakistan.

Fig. 2 Mating couple of *Zygogramma bicolorata* beetles, a biological control agent already present in Pakistan (Rawalpindi, Pakistan)

Zygogramma bicolorata

More work is ongoing with *Zygogramma bicolorata* a biological control agent already present in the field.

Based on Dr Asad Shabbir's work using CLIMEX modelling, climatically suitable areas in Pakistan for *Z. bicolorata* are being identified for the relocation of this biological control.

Redistributing *Z. bicolorata* to these suitable, but yet not occupied areas, will mean that the biological control agent will become present throughout parthenium weed's range in Pakistan. In late October small, experimental releases were carried out at various sites at Hyderabad, Sindh.

However, one big limitation in relying on *Z. bicolorata* as a biological control agent in Pakistan is the asynchrony between the field activity and the emergence of the weed. By early spring (February-March), parthenium weed is already starting to grow, but *Z. bicolorata* emerges from diapause as late as June, giving the weed plenty of time in the interim to develop and produce seeds unhindered.

That said, research has begun attempting to break diapause early in order to allow *Z. bicolorata* to be more active in spring. This research will also assess the impact of early seasonal releases of the beetle on parthenium weed growth and reproduction to determine whether it is indeed an effective strategy.

Capacity building

Running and participating in training courses is a key component of CABI's work in *Parthenium weed*.

Fig. 3 Assessment of the biological control agent *Zygogramma bicolorata* on its ability to defoliate parthenium weed (Pakistan).

Short course: Classical weed biological control

A short course on invasion biology and classical biological control of weeds was delivered by CABI scientists Philip Weyl, Corin Pratt, and Nikolai Thom in Islamabad in November 2018. Dr. Asad Shabbir, University of Sydney, Australia, gave a guest lecture on invasive species and management in Pakistan.

A total of 35 participants attended the workshop, of which 28 were from organisations outside of CABI. They represented all Provinces of Pakistan and ranged from PhD students and University researchers, to extension officers working on the ground.

The workshop offered a valuable opportunity for Pakistani scientists and professionals to gain awareness of the efforts on a regional scale, as well as country-driven biocontrol activities to address not only parthenium weed but other invasive weeds in Pakistan. By the end of the course there was a marked difference in opinion with most participants willing to conduct weed classical biological control.

Training course: *Listronotus*

A select group of scientists from Pakistan attended a training course held in South Africa on *Listronotus*, conducted by leading parthenium weed expert, Lorraine Strathie from the ARC-PPR (Agricultural Research Council-Plant Protection Research). The training was both practical and theoretical and covered aspects such as: growing healthy parthenium weed plants for maintaining a culture of *Listronotus*, dissection of larvae from attacked plants, procedures for working in a quarantine facility, and more.

Reports from the attendees is that the course was very useful and equipped them with knowledge they could bring back to Pakistan.

Parthenium weed threatening the biodiversity of protected areas of Pakistan

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Plant invasions are a leading cause of degradation of ecosystems and loss of biodiversity on global scale (Mack *et al*. 2000). Invasive alien plants not only invade and reduce the productivity of agroecosystems, but they also negatively affect the natural ecosystems including Protected Areas (PAs). Plant invasions have serious negative effects upon aboveground vegetation and below ground soil seed banks of forest ecosystems (Gioria and Pysek 2016).

The PAs in Pakistan are also threatened by several alien woody and herbaceous species. *Parthenium hysterophorus* L. is an alien invasive weed in Pakistan that reduces the species richness and diversity of riparian habitats (Shabbir 2015). Jhok Reserve Forest of Lahore (1,243 ha), PA in the Punjab Province is invaded heavily by parthenium weed. Ecological studies were carried out at multiple locations in this PA during 2014-2015 (Fig. 1). We investigated the impact of parthenium weed on the above ground vegetation as well as on the composition and structure of the soil seed bank of this reserve forest (Fig. 4 and 5). Three different sites based on parthenium weed infestation (high, medium and low) were selected for sampling in the forest.

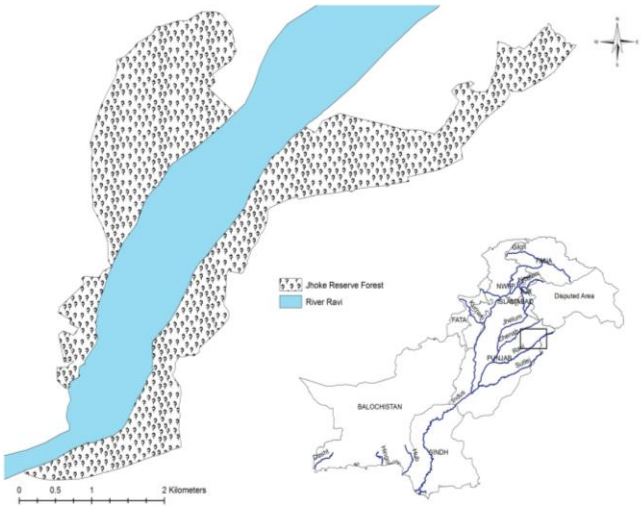

Fig. 4. Location of the Jhok Reserve Forest along the river Ravi, Lahore.

Fig. 5. Sampling and data recording activities in the field.

The plant species diversity of the forest decreased with an increase in the abundance of parthenium weed. The plant species diversity and cover (%) of grasses was lower in the high invaded sites as compared to low invaded site. The total germinable soil seed bank was found to be large at all sites (Fig. 6). The soil seed bank of parthenium weed was the highest as compared to native or other introduced species. The top soil layer accumulated a maximum number of seeds as compared to the subsoil, however the abundance of seed of all species decreased with an increasing soil depth.

The species richness and species evenness in soil seed bank decreased from low to high weed invasion. Many native species were absent on above ground vegetation however they were found to emerge from the soil seed bank. It appears that these native species didn't get a chance to germinate due to competition or allelopathic effects of parthenium weed. Parthenium weed negatively affected the plant species diversity of the PA.

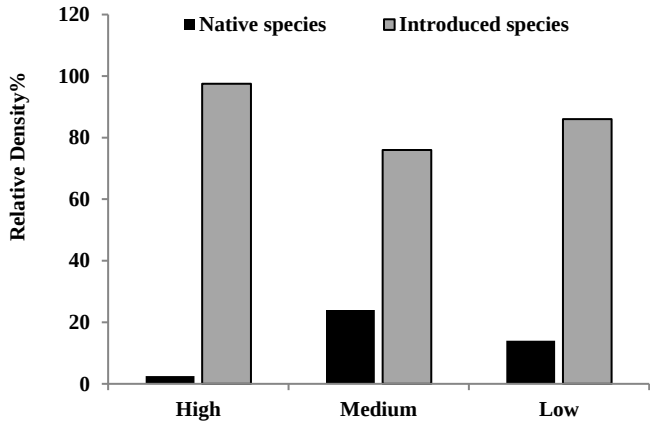

Fig. 6. The relative density of native and introduced species present in the aboveground vegetation of Jhok Reserve forest.

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Biocontrol efficiency of *Zygogramma bicolorata* at different growth stages of *Parthenium hysterophorus*

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Parthenium weed is a highly invasive weed in Pakistan. After a slow early spread, this weed has been devastating over the last two decades. Control of parthenium weed has been attempted by various methods, but successful management of this weed can only be achieved by an integrated approach with biological control as a key element.

In Australia, South Africa, Ethiopia and India, several biological control agents have been released against parthenium weed to manage its spread. Some important agents include leaf feeding beetle, stem boring weevil, stem-galling moth and rust pathogens. The leaf feeding beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera) was first released and established in India in the 1980s. From there, this beetle is thought to have travelled to Pakistan, probably around 2002.

The damage potential of *Z. bicolorata* was assessed against parthenium weed. *Zygogramma. bicolarata* was applied in different ratios (1, 2 and 3-pairs), at three different growth stages (rosette, pre-flowering and flowering) of parthenium weed. The experiment was carried out in a glasshouse and potted plants were caged (Fig. 7).

The damage (defoliation %) recorded was between 44-57% at flowering, 40-54% at pre-flowering and 100% at young stage of the weed (Fig. 8). The defoliation significantly reduced the weed biomass, height and seed production of parthenium weed. The damage inflicted by *Z. bicolorata* was more pronounced when it was applied at higher densities and at the early growth stages of the weed. This study indicated that parthenium weed can be more effectively managed if *Z. bicolorata* is able to attack at the early growth stages of parthenium weed.

Fig. 7*: Zygogramma* adults released inside the caged plants.

Fig. 8: Defoliation at flowering, pre-flowering and rosette stage of parthenium weed.

Parthenium weed steps forward in China

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Parthenium weed (*Parthenium hysterophorus* L.) is one of the most problematic weeds in the world. Known to be invasive in over 40 countries, the weed has been present in China since 1926 (Tang *et al*. 2009). In previous issues of IPN (No. 2 and 6) the situation up to early 2010s has been presented. However, since then the weed had found its way into previously unoccupied areas. New reports have appeared, a decade after the discovery of a separate introduction in Shandong, but all of them seem not to be close to the Shandong population, suggesting that they are probably

populations expanding from the earlier introduction into southern China.

The weeds movement north has been relatively slow for close to 100 years. However, now it's beginning to move north more rapidly. Multiple reasons may be contributing to this event, including intrinsic factors such as outcrossing and gene drift, or extrinsic reasons such as global warming and increasing human activity (road construction and/or trade). No research has been conducted in China so far on this specific aspect of weed movement.

Report from Jiangxi Province (Zeng and Qiu 2012)
During a recent survey, a population of parthenium weed was found in Nanqiaozhen, Xunwu County, Jiangxi Province. The plants were growing in wasteland next to road G206 in April 2012, at an elevation of 240 m above sea level. The County is located near the border of Fujian and Guangdong Provinces, both known to be infested by the weed. The proximity, as well as the road connection to both Provinces, could be the reason for its spread to this location. A plate of parthenium weed in the report shows several inflorescences with up to eight ray florets. This is taken as an indication that these plants come from the southern population where multiple ray florets are commonly found on plants

Report from Zhejiang Province (Lai *et al*. 2014).
Parthenium weed was found in Guoxizhen, Ouhai District of Wenzhou City, Zhejiang Province in June 2012.

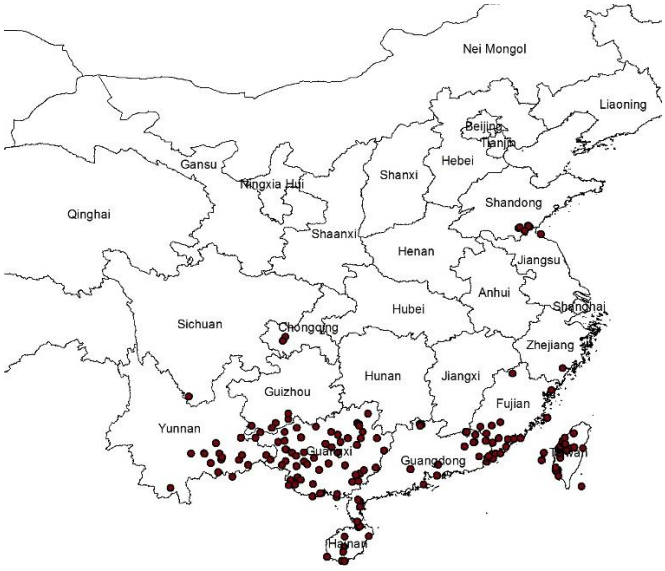

Fig. 9. The occurrence of parthenium weed in China. Dots represent herbarium records found in the Chinese Virtual Herbarium or sites derived from research publication (*Map prepared by Asad Shabbir*).

The plants were growing in wastelands and along the roadside, along with grasses in this outer suburb of the city. The Wenzhou South Railway Station is located in this District. There are also multiple canals connecting to the inner city and the Oujiang river.

Report from Chongqing municipality (Chen *et al*. 2016).
Parthenium weed was found at Zhongba Dam near the Yangtze river, and in a suburb of Chongqing municipality in September 2015, at an elevation of 182 m above sea level. Occasionally this site is an island in the river where local farmers grow vegetables on cleared land. They said that in 2014 there were a few weed plants, but by 2015 it had already occupied many canal banks, on wastelands, roadsides as well as their farmland. The vegetable production was then affected, and some farmers developed allergic skin reactions. The authors noticed that the infested area was close to water, also that weed fragments were being used as packing for the vegetables that were being transferred to market. Close monitoring of the site was suggested, as well as the eradication of any new plants that appeared, preferably in April when plants will be young and in the vegetative stage of development.

Fig. 10. Parthenium weed in Chongqing. Photo by Jun Zhang.

Herbarium records from Sichuan and Jiangsu Provinces (CVH 2018).

In addition, herbarium record show parthenium weed to be present in Panzhihua City, Sichuan Province in 2010, and Liandao Island, Lianyungang City, Jiangsu Province in 2001. The former was found near the border of Yunnan Province while the latter was found in a port area *c.* 150 km from Linyi County, Shandong Province. This population was recorded 1 year earlier than the 2002 outbreak in Shandong Province and therefore could be the precursor to that outbreak.

Records in Hunan Province (Qi and Yu 2001)
A record noticed in a published book entitled 'Overview of Seed Plants in Hunan Province' by Qi and Yu (2001) indicates that parthenium weed was once cultivated in gardens or parks in Hunan Province. However, there was no herbarium records available, nor any further reports of established field populations in that Province.

Acknowledgement
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Biodiversity occurrence data provided by: Chengdu Institute of Biology, Chinese Academy of Sciences; Wuhan Botanical Garden, Chinese Academy of Sciences; Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences; Northwest Institute of Plateau Biology, Chinese Academy of Sciences; Guangxi Institute of Botany, Chinese Academy of Sciences; South China Botanical Garden, Chinese Academy of Sciences; Institute of Applied Ecology, Chinese Academy of Sciences; Kunming Institute of Botany, Chinese Academy of Sciences; Lushan Botanical Garden, Chinese Academy of Sciences; Institute of Botany, Jiangsu Province and Chinese Academy of Sciences; Chinese National Herbarium, Institute of Botany, Chinese Academy of Sciences; WUK Herbarium, Northwest Agriculture & Forestry University (Accessed through Chinese Virtual Herbarium (CVH) Data Portal, www.cvh.ac.cn, 2018-09-23).

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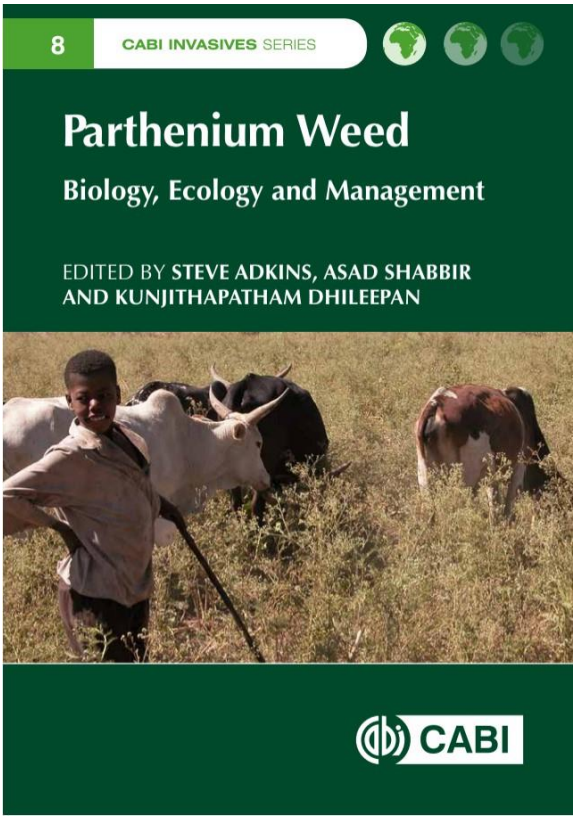
Parthenium Weed: Biology, Ecology and Management

Edited by S.W. Adkins, A. Shabbir and K. Dhileepan



This book is part of the CABI Invasives Series which addresses all topics relating to invasive species, including biosecurity surveillance, mapping and modelling, economics of invasive species and species interactions in plant invasions. Aimed at researchers, upper-level students and policy makers, titles in the series provide international coverage of topics related to invasive species, including both a synthesis of facts and discussions of future research perspectives and possible solutions.

In *Parthenium Weed: Biology, Ecology and Management* we ask the question, in parthenium weed do we have the 'worst weed the world has ever encountered'? The conclusion we have reached is, if not yet, then we soon will have! As this phenomenal 'demon plant' spreads around the world at a remarkable rate, causing such devastating outcomes to all aspects of agriculture, horticulture, forestry and the natural environment, as well as being a significant health concern, it is coming under unparalleled scientific and public scrutiny.

Parthenium Weed: Biology, Ecology and Management has been a collective effort by 26 members of the International Parthenium Weed Network. The book builds on a fundamental understanding of invasive plant biology and weed science that can be acquired from the many good texts available. Given such grounding, our broad aim in this book is to emphasize the practical relevance of understanding biology and ecology to enable effective and sustainable management, hence our subtitle – biology, ecology and management.

Parthenium Weed: Biology, Ecology and Management has a conspicuously world focus, drawing on examples from 48 countries which have found themselves with the misfortune of being invaded by this phenomenal weed. The journey through the biology and ecology reveals the very special nature of this quite amazing plant, as well as the general principles that apply universally within invasive weed science.

Our narrative is to build on credible observations and experiments and is abundantly illustrated with original data and well-selected images. Numerous summary sections provide a clear background to the new knowledge that is readily accessible and structured for easy reading. Within the book, one key theme that has been used to impart coherence through the specialized contributions from the 26 authors has been the integrated thought process to initially understand the weed and then to manage it. This theme refers to a constant interplay between internal (genetics) and external (environment) factors that drive every facet of the weed's existence.

Knowing which traits confer weedy status, and which stages of the life cycle are best to target to achieve meaningful management, continue to be major challenges for weed science – *Parthenium Weed: Biology, Ecology and Management* rises to these challenges. To order a copy of this newly released book, visit
https://www.cabi.org/bookshop/book/9781780645254

Looking into the future of an invasive giant, parthenium weed (*Parthenium hysterophorus* L.)

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Invasive alien species have always been a serious problem for agriculture and the environment around the globe. Climate change has been suggested to be a major driver for the range expansion of many invasive plant species mainly through increasing their growth, reproductive potential and dispersal ability. However, studies investigating the impact of climate change elements on the biological behaviour of invasive weed species are lacking. As part of my PhD project, I am studying the impact of two atmospheric carbon dioxide (CO_2) concentrations (ambient, 400 ppm and elevated, 700 ppm) and two soil moisture levels (100 and 50% of soil water holding capacity, WHC) on the growth and biomass production of two Australian parthenium weed biotypes (Clermont and Toogoolawah). The two biotypes chosen for this study are known to have a contrasting invasion history, Clermont is highly invasive while Toogoolawah is non-invasive.

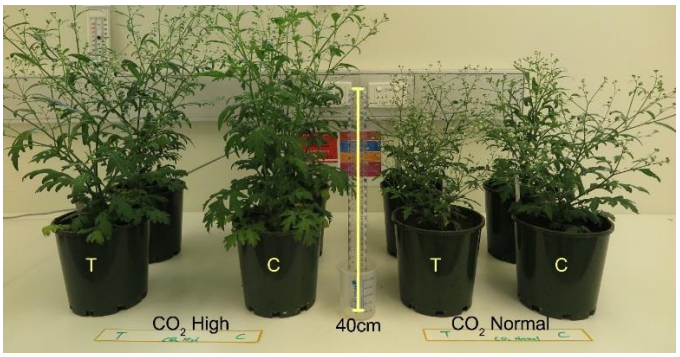

Fig. 11 The Toogoolawah (T) and Clermont (C) biotypes of parthenium weed grown at normal (400 ppm) and elevated (700 ppm) CO_2 levels in controlled conditions growth chamber.

The study is being conducted in two identical controlled environment growth chambers operating at 25/15°C day/night temperatures, 12/12-hour photoperiod and a 50% relative humidity with a continuous supply of CO_2. Results show Clermont to produce significantly more branches, leaves and flowers and attained greater height and biomass as compared with Toogoolawah, across all the moisture and CO_2 levels applied. This is consistent with its high invasiveness. Elevated CO_2 significantly increased all measured parameters for both biotypes at both moisture levels as compared to the ambient CO_2 treatment. A 50% WHC reduced the parthenium weed growth and biomass production as compared with the 100% WHC treatment. However, the extent of decline was significantly less for Clermont than for Toogoolawah, and at the elevated CO_2 than at ambient CO_2 concentration. In conclusion, future projected levels of atmospheric CO_2 and increasing droughts may enhance the growing and dispersal ability of parthenium weed in the sub-tropical and tropical environments of Australia and presumably in other locations around the world.

Upcoming Conferences on Weed Science and Invasive Species

27th Asian-Pacific Weed Science Society Conference

Dates: 03-06 September 2019
Venue: Kuching, Sarawak, MALAYSIA
Website: https://www.apwss2019.org/

XIX International Plant Protection Congress

Dates: 10-14 November 2019
Venue: Hyderabad, INDIA
Website:
https://www.plantprotection.org/Meetings/InternationalCongress%28IPPC%29/XIXIPPC,Hyderabad,1014November2019.aspx

Recent Publications

Bajwa, A. A., A. Ullah, M. Farooq, B. S. Chauhan, and S. Adkins. 2019. Chemical control of parthenium weed (Parthenium hysterophorus L.) in two contrasting cultivars of rice under direct-seeded conditions. Crop Protection 117:26-36.

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