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

Parthenium hysterophorus, an invasive weed in southern Oman

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Parthenium hysterophorus L., a serious alien invasive species, was first recorded in Oman in 1998 by myself as a roadside weed found in one locality in Dhofar, the southern region of Oman. This weed is commonly known as ‘hableem’ in western part of Dhofar. I noticed it on the Salah–Ayun road, and it took me some time to fully identify the plant (see Fig. 1 for locations). I had not included it in my checklist of the vascular plants of Oman (Ghazanfar 1992), and it was also not recorded earlier in plants of Dhofar (Miller & Morris 1988). It was most likely introduced with agricultural produce (fodder or food grains), imported into Oman at some earlier time. I found it again in 2002 in Wadi Darbat where it had spread to and was common, but had not spread to other parts of the escarpment Dhofar mountains. Twenty years on, my observations in September 2017 confirm that *P. hysterophorus* has spread to almost all parts of the mist-affected mountains and summit plateaus, and associated wadis of Dhofar and should be considered

as a serious invasive species that is now naturalised in Oman. *Parthenium hysterophorus* is native to Mexico, Central and South America and the Caribbean, and is a serious pantropical invasive species. It is an annual plant, deep rooted and flowers and fruits profusely in subtropical climate. The Province of Dhofar lies in the extreme SW Oman, and for most part consists of sparsely vegetated low hills and plains. Along the south coast a range of arc-shaped limestone mountains extend eastwards for about 290 km averaging 800–900 m in altitude (Fig. 1). Inland the mountains gradually from low hills and eventually form part of the central desert gravel plains, but on the seaward side the mountains fall sharply forming steep escarpments. For almost three months of the year, from mid-June to mid-September, during the SW monsoon, these mountains are covered in moisture-laden clouds and mists because of particular wind patterns that prevail in the monsoon belt (Fisher & Membery 1998).

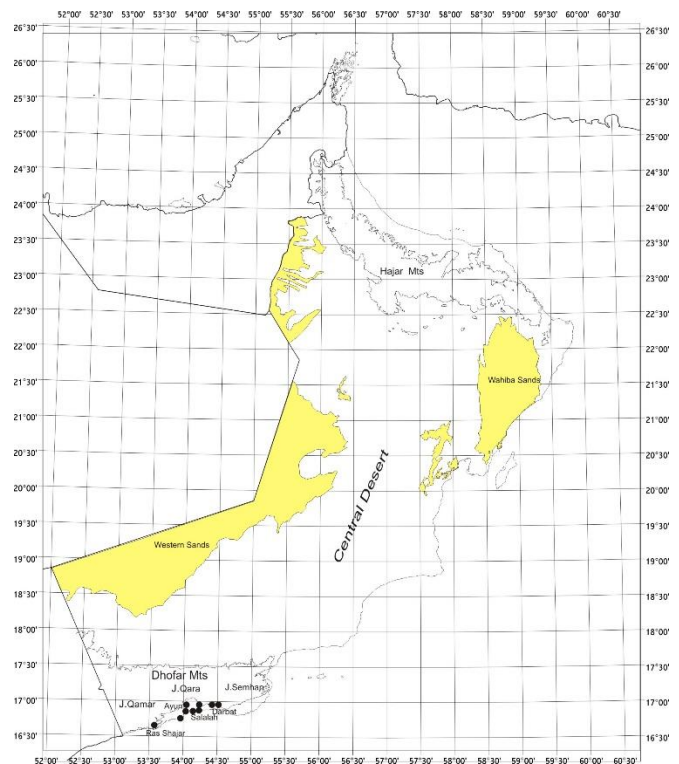


Fig. 1. Distribution of *P. hysterophorus* in Dhofar, southern Oman, based on observations. Each black dot represents presence in 10 × 10 km²; contours of Dhofar and Hajar mountains at 500 m.

Rainfall is scarce in Dhofar, and a few springs are the only source of water. But every monsoon, the moisture-laden clouds supply enough water for a subtropical vegetation to flourish on the mountains which is unique to southern Oman and the adjacent Mahra region in Yemen. The vegetation is rich in species with many endemic and regionally endemic species (Ghazanfar 1998, Patzelt 2015). The escarpment mountains and associated gorges and plains are covered with a dense deciduous woodland, thick scrub and ground vegetation. Several species such as those of the succulent Apocynaceae (*Desmidorchis* spp.) and Euphorbia are unique to these mountains, as are the many annuals and grass species that form the thick undergrowth. The rich annual herb community which includes many legumes and grasses, forms the fresh nutritious food on which livestock and other fauna thrive on the escarpment mountains and its associated wadis.

Parthenium hysterophorus is unpalatable to goats, camels and cattle, flowers and seeds profusely, with the result that its spread is greatly accelerated. It has taken over large areas of the mist affected grasslands of the Dhofar mountains which has affected the abundance of several native species of annuals. For example, on my recent visit I observed that several common annuals such as *Dyschoriste dalyi*, *Justicia diffusa*, *Heliotropium calcareum*, *Ipomoea dichora*, *I. turbinata*, *Boerhavia diffusa* that were abundant and found commonly earlier were rarer and difficult to locate (pers. obs. 2017). As *P. hysterophorus* is taller than many of the annuals, its thick, tall habit limits light to the low dwelling species (Fig. 2). It produces allelopathic chemicals that prevent other plants from germinating and growing near it. In some parts of Jabel Qamar and in areas of Wadi Darbat, it appears to dominate the under storey in open woodland (Figs 3, 4, 5).



Fig. 2. Tall plants of *P. hysterophorus* forming thickets on the mist-affected plateau of Jabel Qamar (Dhofar mountains). Ras Shajr, 850 m. Photo © S.A. Ghazanfar, Sept. 2017.



Fig. 3. *Commiphora* scrub on Jebel Qamar (Dhofar mountains) with *P. hysterophorus* in foreground. Ras Shajr, 850 m. Photo © S.A. Ghazanfar, Sept. 2017.



Fig. 4. *Acacia-Delonix-Anogeissus* deciduous woodland on Jebel Qara, Dhofar mountains. Wadi Darbat, 650 m. Photo © S.A. Ghazanfar, Sept. 2017.



Fig. 5. *Parthenium hysterophorus* growing with grasses and other annuals. Wadi Darbat, Dhofar mountains, 650 m. Photo © S.A. Ghazanfar, Sept. 2017.

Parthenium hysterophorus is already included in the Global Invasive Species Database (GISD 2010) and is reported to be a serious invasive species in Australia, South Asia, Ethiopia, East Africa and South Africa. Its status in Yemen and Saudi Arabia is not known, but in Oman it should be considered a serious invasive species and must be managed before it spreads entirely on the mountains of Dhofar and affects the rich biodiversity of these mountains.

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Parthenium weed in Pakistan: knowledge sharing workshop

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CABI - UK

A knowledge sharing workshop on parthenium weed in Pakistan was organised by CABI in May 2017 and sponsored by the UK's Department for International Development (DFID). CABI's new invasive species programme, Action on Invasives, dedicated to developing regional, national and local coordinated approaches to invasive species, delivered various background materials. The workshop's objectives were to share experiences and information on parthenium weed's invasion and impacts in the country and finalise an initial comprehensive action plan in the short, medium and long term. It is worth noting that parthenium weed was chosen as a proof of concept: the invasive species programme will aim to consult with all stakeholder to assess which other invasive species should be included in the future as the programme develops. The Executive Director of the Inspectorate General of Forests and representatives from Quarantine Departments, Research Institutes (including National Agricultural Research Centre and Natural History Museum of Pakistan), Universities (University of the Punjab, Lahore and University of Agriculture, Faisalabad) and the FAO were invited to discuss and contribute towards a national response to the invasive weed *Parthenium hysterophorus*.



Fig. 1. The participants of stakeholders' workshop Islamabad May 2017.

The Executive Director of the Inspectorate General, Syed Mahmood Nasir from the Global Change Impact Studies and the workshop facilitator, Abdul Rehman of CABI Pakistan, urged the participants to be motivated and creative in their efforts to develop a well-coordinated approach plan that considers the latest research and the needs of communities that are or will be affected by this devastating invasive weed. Dr Arne Witt of CABI presented parthenium research and development activities from a global perspective.

Parthenium weed invaded the Kingdom of Saudi Arabia and Thailand

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In the Middle East, parthenium weed is reported from Oman, Yemen, the UAE and the most recent addition is the Kingdom of Saudi Arabia. Parthenium weed was recently found in surveys carried out in south western regions of the Kingdom (Thomas, 2015). Parthenium weed is reported from the Jizan Province in the SW (Fig. 1). The occurrence of parthenium weed in the Kingdom is highly restricted and occasional (Dr. Jacob Thomas, Per. Comm. March, 2018; King Saud International University, Riyadh). The most likely source of introduction of parthenium weed into Kingdom could be naturally through north western parts of Yemen where this is already present. Since parthenium weed is currently highly restricted in SW parts of the Kingdom and at its initial stages of invasion, eradication of the weed may be possible if concerned authorities take quick notice and action.



Fig. 1. Distribution of parthenium weed in the south-western parts (red) of the Kingdom of Saudi Arabia.

In East and South-East Asia, parthenium weed is reported from China, Taiwan, South Korea, Japan, Malaysia, Vietnam and the most recent addition is Thailand in 2016. Dr Siriporn Zungsontiporn (M. Day, Australia, personal communication) has discovered parthenium weed in Thailand in 2016 and her team members are attempting eradication. Keeping in view the devastating effects of this weed in the region, parthenium weed has been a quarantine weed in Thailand since 2008. The leadership of a surveillance program for parthenium weed was given to Dr Siriporn Zungsontiporn in 2011-2012. In 2016, parthenium weed detected in a vegetable and maize going area in Lamphoon Province, northern Thailand. The weed was sprayed with paraquat and removed and set to fire outside the field. Since the weed had set seed, a follow up eradication program is in progress.

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Fig. 2. Parthenium weed along the margins of crop field in Thailand.



Fig. 3. Eradication of parthenium weed from agricultural area in Lamphoon Province, Northern Thailand using chemical (above) and physical (below) management. (Photo credit: Dr Siriporn Zungsontiporn, Thailand).

Mass rearing of *Zygogramma bicolorata* at TPRI, Arusha, Tanzania for the release against parthenium weed

Arne Witt & Julien Godwin

CABI

Parthenium weed disrupts the ecology of grasslands, invades woodlands, and generally disturbs native vegetation through aggressive competition (Evans, 1997). Being allelopathic, it inhibits the germination and growth of other plants, reducing crop yields and displacing palatable species in natural and improved pastures. Parthenium weed is now considered, by 90% of the farmers in the lowlands of Ethiopia, to be the most serious weed of croplands and grazing areas (Tamado and Millberg, 2000). There, in experimental fields infested with high densities of parthenium weed, sorghum yields were reduced by 97% (Tamado *et al.*, 2002). In India, parthenium weed infestations have resulted in yield losses of up to 40% in several crops (Khosla and Sobti, 1979). Parthenium weed is also a secondary host for a range of crop pests. In terms of pasture production, this noxious weed has been found to reduce livestock carrying capacities by as much as 90% (Jayachandra, 1971). It poses serious health hazards to livestock, and can cause severe allergic reactions in people who regularly encounter the weed.

Management efforts aimed at controlling parthenium weed include chemical control, use of manual and or physical removal, as well as biological control. Biological control agents against parthenium weed include, among others, beetles, stem-galling moths, and fungi. Of these agents, *Zygogramma bicolorata*, a leaf-feeding beetle, has been released and is now established in Australia, India, Pakistan, South Africa and Ethiopia. Due to its host specificity and impact it was also considered for release in Tanzania. After a Risk Assessment was submitted a permit was granted by the Regulatory Authorities in Tanzania for introduction and release.

Some 1,000 *Z. bicolorata* adults and 1,000 larvae from lab-reared cultures in South Africa were supplied in 2013, for direct release at five field sites in and around Arusha, Tanzania (ARC-PPRI and CABI, unpublished data). Subsequently, 200 adults and 1,000 larvae were supplied in late March 2014 for release into field cages, and another 1,000 adults in early February 2015 (ARC-PPRI and CABI, unpublished data). However, despite extensive surveys no establishment could be confirmed.

In 2016 funding was received from USAID and a mass rearing centre established at the Tropical Pesticides Research Institute (TPRI) in Arusha, Tanzania. *Zygogramma bicolorata* adults and larvae were imported from South Africa in March 2017. Unfortunately, due to delays during shipment only 444 beetles survived the journey from southern Africa. A large number also subsequently perished due to stress and fungal infections. The surviving adults (Fig. 1) and larvae (Fig. 2) were placed on potted plants in a laboratory.



Fig. 1. *Zygogramma bicolorata* adults (top left), larvae (top right) and feeding damage (below).

Under these conditions numbers rapidly built-up causing significant damage to plants (Fig. 1). Once a stable culture had been established adults and larvae were placed on plants in larger walk-in cages (Fig. 2 and 3). Encouragingly, favourable conditions have allowed the culture to grow. We currently have about 8,000 larvae and adults in culture. These will be released in January 2018 once field conditions have improved.



Fig. 2. Walk-in cage at TPRI, Arusha, Tanzania. *Zygogramma bicolorata* larvae and adults were reared on *Parthenium hysterophorus* seedlings which were planted directly in the soil.

Rearing of *Zygogramma bicolorata* for redistribution to new parthenium invaded areas in Pakistan

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At CABI Pakistan, work on the rearing of a biocontrol agent (a leaf defoliating beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera) for the management of parthenium weed has been initiated. This beetle was first reported in Pakistan in 2007 from the adjoining areas of Lahore. To rear this beetle, a nursery of parthenium weed has been established at the CABI Pakistan farm area. An open field and a tunnel have also been established (Fig. 1). Parthenium has been grown on both areas and sites were fenced with a cloth.

The larvae and adults of this beetle have been collected from the peri urban areas of the Islamabad. Once parthenium weed plants were matured, adults were released inside the enclosed and open sites for the multiplication (Fig. 2). The population of released *Zygogramma bicolorata* beetles increased to a large quantity in the open field as well in the tunnel. This growing population completely defoliated the parthenium weed plants. The rearing of beetles continued from May to September 2017. During the month of October most of the adult population entered

diapause. The populations of beetle were regularly observed. The adults of the beetle were collected and released to new areas in Islamabad.



Fig. 1. Establishment of parthenium weed in a tunnel (above) and open field (below) at CABI -Rawalpindi, Pakistan.



Fig. 2. Collection and multiplication of *Zygogramma* beetle at research facility.

Eco-management of Parthenium - an invasive weed in agro-ecosystems of Pakistan

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Over the last few decades, *Parthenium hysterophorus* L., which is known as parthenium weed in English (locally called *gajjar booti*) has become a threatening weed in Pakistan. Firstly, it was considered only to be a wasteland weed observed mainly along roadsides and paths, railway sides and around agricultural fields. But now, it has become a serious weed of summer and spring season arable crops, vegetables and orchards in Pakistan. It is thought to have invaded Pakistan from India through the importation of ornamental nursery seed/seedlings in late nineties. It has now become a weed of national significance. Parthenium weed has invaded about 48 countries around the world including Pakistan. In addition to its competitive nature, it is highly allelopathic in nature. That is why, it not only reduces crop yields but also affects the integrity and biodiversity of native ecosystems through replacing all other natural flora of grazing or therapeutic importance. In various countries, parthenium has already been reported to cause significant yield losses (up to 90%) in various crops.

In Pakistan, currently, this weed has been found to spread throughout both irrigated and rain-fed regions of the Punjab and Khyber Pakhtunkhwa. The major crops infested by parthenium weed are maize, cotton, sugarcane, and most summer season vegetables. The studies previously conducted in Pakistan on this weed were mostly related to its ecology and phytosociology nature. Therefore, there was a dire need to assess the yield loss and undertake management studies of parthenium weed in major crops. For studying allelopathic effects of parthenium weed against maize crops and estimating probable yield losses, economic threshold, critical period of competition and management options of this weed in maize crop, laboratory and field studies were conducted in Pakistan during years 2012 and 2013.

The allelopathic effect of parthenium weed extracts and rhizospheric soils of this weed was studied against germination and seedling growth of maize. Results

showed that up to 67% reduction in germination and 100% in seedling growths of maize occurred due to presence of phenolic compounds gallic, caffeic, 4-hydroxy-3-methoxy benzoic and *p*-coumaric acids in these extracts. However, parthenium weed rhizospheric soils caused up to a 35% decline in seedling biomass of maize as phenolic acids *m*-coumaric, vanillic, syringic and ferulic acids accumulated in these soils.

For biochemical control of parthenium weed, herbicidal potential of commonly growing herbaceous plants and leaves of tree species were explored and tested against the germination and seedling growth of parthenium weed. It was revealed that the maximum suppression of germination (95 and 79%) and seedling biomass (96 and 97%) of parthenium weed was caused by a 5% leaf extract of *A. aspera* and *R. communis*, respectively, possibly due to phenolic compounds (gallic, caffeic, chromatotropic, *p*-coumaric, *m*-coumaric, syringic and 4-hydroxy-3-methoxy benzoic acids) detected in them. The competition studies conducted in field showed that significant reduction in grain yield of maize was observed with parthenium density of five plants per m² and parthenium competition period of 5 weeks after crop emergence, therefore considered to be critical for control of this weed.



Fig. 1. Parthenium growing in maize experimental field in Faisalabad, Pakistan.

Economic thresholds of parthenium weed in maize crop through rectangular hyperbolic non-linear regression model were estimated to be 1.2 and 1.3 plants per m² during year 2012 and 2013, respectively. Herbicide screening field experiments revealed the highest parthenium weed control efficiency (100%) was achieved by bromoxynil + MCPA + metribuzin @ 470 g a.i. ha⁻¹ followed by dicamba @ 304.5 g a.i. ha⁻¹ (90 and 96.8%) during years 2012 and 2013, respectively. The best performance in terms of grain yield increase over weedy check was shown by the bromoxynil + MCPA + metribuzin @ 470 g a.i. ha⁻¹ (138%) followed by dicamba @ 304.5 g a.i. ha⁻¹ (74%). The highest benefit: cost ratio (6.87 in first year and 7.17 in second year) and marginal rate of return (2858 in first year and 2030 in second year) was attained by bromoxynil + MCPA + metribuzin @ 470 g a.i. ha⁻¹. It was therefore suggested that maize growers should use bromoxynil + MCPA + metribuzin @ 470 g a.i. ha⁻¹ for the effective and economical control of parthenium weed in maize.



Fig. 2. Severe infestation of Parthenium in cotton field at Sargodha.



Fig. 3. Parthenium infested citrus orchard in Sargodha.

Further, it is proposed for future researchers that competition studies of parthenium with other crops such as sugarcane, cotton and vegetables should be conducted to ascertain their yield loss and to find out its critical density and competition period in them. Moreover, further allelopathic studies should be carried out with respect to various growing conditions of parthenium weed in response to other ecological factors such as temperature, light, pH, moisture and salts under laboratory conditions to validate its allelopathic behavior. Allelopathic potential of various crops, weeds and trees should be tested against parthenium weed to evaluate their bio-herbicidal activity against this weed. Liquid extracts of allelopathic plants *A. aspera*, *A. philoxeroides*, *R. communis* and *Z. mauritiana* should be tested alone or in combination with existing synthetic herbicides for sustainable management of parthenium in different crops. Being a highly allelopathic weed, phytotoxic compounds and extracts of parthenium should be evaluated for their herbicidal, insecticidal and anti-pathogenic properties.

Parthenium weed problems, legislation and research in Malaysia

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Status of Parthenium Weed Problem

Parthenium weed (locally known as Rumpai Miang Mexico) is an invasive alien species in Malaysia, which has first been detected by Prof. Dr. S. M. Rezaul Karim, Universiti Malaysia Kelantan (UMK) in 2013 (New Straits Times, 25 October 2013). After his discovery, the division of Plant Biosecurity of Department of Agriculture (DOA), Malaysia took the issue as a national agendum and started survey throughout the country. Finally, ten States of the country were detected to be infested with the weed (Fig. 1). Due to the well-planned herbicide treatments in the infested areas of the country, the infestation of the weed is now under control and no significant increase in infested area has been found (The Star, 21 Nov. 2016). However, the problem of parthenium weed hazards has not been solved yet. A big number of weed seed are to be found in the soil seed bank (Karim et al. 2017a) and some people are being infected with parthenium allergy, especially in Kedah and Johor (Karim et al. 2017b). Most of the people of the country are still not aware of the hazards of parthenium weed and its correct identification. However, the Malaysian Government has made an act to control the

spread of this weed within the country. According to this act, any person found carrying the plant from one place to another without the permission of concerned authority is liable to a penalty of RM10,000 USD 2,500) or two year's imprisonment or both. Recently, the DOA has developed a Standard Operation Procedure (SOP) for controlling the spread of the weed, under which the people with parthenium infestation within his/her premises will be given the notice to control it or to take help from the nearby local Agricultural Office for its control. If no action is taken after giving two notices, he/she will be punished financially. The parthenium weed issue is now included in three different big agenda viz, management of invasive alien species (IAS), biocontrol of invasive weeds, and management of parthenium weed in Malaysia



Fig. 1. Parthenium weed infestation in peninsular Malaysia (Red dots indicate the infested areas).

Status of Parthenium Weed Research

Parthenium research in Malaysia started in June 2014 with an approval of the fundamental research grant (FRGS) of Ministry of Education, Malaysia in favour of Prof. R. Karim and his team to study the “Risk assessment of parthenium weed in Sungai Petani, Kedah, and Batang Kali, Selangor”. Under this project, we have surveyed the research sites two times to record the infestation status and changes in severity of infestation. Growth performance of the weed in different soil types and soil moisture regimes under the agro-ecological conditions of Malaysia and the weed seed bank under two research sites were studied. Socio-economic surveys were also done to know the knowledge and perception of the local people about this allergenic weed. We have recorded some new areas of

infestation in our research sites during the second survey. Despite herbicide sprays by the personnel of DOA, the vigorous growth of the weed was noticed in the areas of infestation. The weed has occupied their homes at the playground, home gardens, Muslim cemetery, premises of mosques and temples, vegetable gardens, sugarcane fields, near livestock farms, school premises, roadsides, and wastelands. In some places of Kedah, the weed density of 24 plants/m² was recorded. The weed favored the loamy soil with soil moisture of 30% of field capacity at a soil pH of 5.0 to 6.5.

More than 80% of rural people of Kedah do not have proper knowledge of the parthenium weed problem but about 40% of urban people of Seremban have a good knowledge of the weed. Under the final year research projects (FYP), the effects of parthenium weed on the growth of Gurami fish (*Trichogaster fasciata*) and broiler chicken were investigated. We have noticed the negative impacts of parthenium weed on the growth performance of fish and chicken. The plant extracts of Drumstick plant (*Moringa oleifera*) and Cogon grass (*Imperata cylindrica*) were found to reduce the seedling emergence of parthenium by 60%. The aqueous solution of table salt (NaCl) at 50% concentration was also found to kill the weed effectively at the early vegetative growth stage. As a biological control method, we have recorded two leguminous plants e.g. Mucuna plant (*Mucuna bracteata*) and Coffee weed (*Cassia occidentalis*), and two non-leguminous plants e.g. Deadnettle (*Lamium album*) and Croton plants (*Croton bonplandium*) as more competitive than parthenium weed. All these are preliminary studies; therefore, detailed studies are needed to make valid recommendations.



Fig. 2. Professor Dr. S. M. Rezaul Karim is receiving the best award in research and innovation on parthenium weed research at UMK (Left: Prof. Dr. Jasni Bin Sabri, Director of Research Management Office, UMK, and Middle: Prof. Dato Dr. Hj Ibrahim Bin Che Omar, Deputy Vice-Chancellor, Research & Innovation, UMK).

With the approval of the higher authority of UMK, recently we have established a research group named as Parthenium Weed Research Group (PWRG) headed by Prof. R. Karim, the members of the group will be putting their efforts in to combating the ill effects of this environmental pollutant in Malaysia. In 26th International Innovation Exhibition held at Kuala Lumpur Convention Center (KLCC) during 21 to 23, May 2015 Prof. Karim and his team won a silver award for discovering this "Killer Weed" in Malaysia. Recently on 26 October 2017, Prof. Karim has been awarded the best Research & Innovation Award at UMK for his contributory research on parthenium in the country (Fig. 2).

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Upcoming Conferences on Weed Science and Invasive Species

18th EWRS International Symposium "New approaches for smarter weed management"

Dates: 17-21 June 2018

Venue: Ljubljana, Slovenia

Website: <http://www.ewrs2018.org>

XV International Symposium on Biological Control of Weeds

Dates: 26-31 August 2018

Venue: Engelberg, Switzerland

Website: https://isbcw-2018.com/index.php?cat=show_start

Neobiota 2018 - 10th International Conference on Biological Invasions

Dates: 4-7 September 2018

Venue: Dublin, Ireland

Email: <http://www.neobiota2018.org>

21st Australasian Weeds Conference

Dates: 9-12 September 2018

Venue: Sydney, NSW, Australia

Website: <http://www.21awc.org.au/>

1st International Conference on Biological Control (IOBC Parthenium Working Group Workshop)

Dates: 27-29 September 2018

Venue: Bengaluru, India

Website: <http://www.icbc2018bengaluru.com/>

Invasive Alien Plants in Rangelands: Situation, Progress, Challenges

Venue: American University of Central Asia, Bishkek, Kyrgyz Republic

Dates: 6 - 10 August 2018

Website: <https://conbio.org/>

ISWS Golden Jubilee International Conference

Venue: ICAR-Directorate of Weed Research at Jabalpur, India

Dates: 21-24 November, 2018

Website: <http://isws.org.in/>

Recent Publications

- Shabbir, A., *et al.* (2018) Integrated use of biological approaches provides effective control of parthenium weed. *Archives of Agronomy and Soil Science* (in Press)
- Cowie, B. W., *et al.* (2018). "Physiological response of *Parthenium hysterophorus* to defoliation by the leaf-feeding beetle *Zygogramma bicolorata*." *Biological Control* 117: 35-42.
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