Prospects of classical biological control of weeds in Pakistan: challenges and opportunities

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Abstract

Alien invasive weeds are recognized as a global threat to natural and agro-ecosystems. The list of alien weeds of Pakistan is extensive, with many of these having become invasive posing a serious threat to agricultural production, biodiversity and human and animal health. Some of the worst affected environments are forest ecosystems, where woody invaders have transformed the native vegetation by altering native species composition and diversity. *Lantana camara*, *Prosopis juliflora*, *Broussonetia papyrifera*, *Eucalyptus* spp. and *Leucaena leucocephala* are considered the worst woody invaders while *Parthenium hysterophorus*, *Conyza bonariensis* and *Soliva anthemefolia* are some examples of problematic herbaceous invasive weeds. Aquatic weeds such as *Salvinia molesta*, *Pistia stratiotes*, *Alternanthera philoxeroides* and *Eichhornia crassipes* have established in many wetlands in the Sindh and Punjab provinces. Despite the number of invasive weeds in Pakistan, management has lagged behind, with the only classical biological control example being *Cactoblastus cactorum* released against *Opuntia* cacti in the 1990s. CABI has a long history and contribution in global efforts for the biological control of weeds in different parts of the world and now, with the help of key stakeholders, has recently started the “Action on Invasives” program which in Pakistan is focused on management of *P. hysterophorus* (parthenium weed) as a pilot project. This program includes awareness campaigns about the weed as well as the initiation of classical weed biological control projects against parthenium weed. Classical biological control offers a sustainable, long term control strategy against invasive weeds that needs to be employed, especially in developing countries such as Pakistan.

Keywords: Alien invasive weeds, spread, biological control, insects, management, developing country

Introduction

Pakistan occupies a wide biogeographic region with a diversity of landscapes. The elevation ranges from sea level to 8,611 m (K-2, world's second highest peak). This natural elevation gradient, running from south to north, provides some of the most diverse environments, each with a unique flora and fauna. There are more than 6,000 species of vascular plants reported from Pakistan with a high degree of endemism, especially in the northern regions of the country. Many alien plant species are also reported from Pakistan (Shehzadi, 2018), of which at least 30 are considered invasive. Despite the high number of invasive species, there is a scarcity of scientific data available on economic losses caused by invasive alien species in Pakistan; however, they are expected to be extensive.
Invasive weed species are difficult to manage, mainly because they are occupying large geographic areas and because of a limited availability of resources for management, especially in developing countries. A lack of awareness about invasive species and their impacts among the general public as well as a non-existent policy on invasive species at a national level are important reasons for their introduction and subsequent spread. In Pakistan, there is some good basic research, mainly done by universities, on the ecology and management of some invasive species, but research on invasive species is not a priority for national and provincial research organizations. For this reason, CABI has initiated the “Action on Invasives” program funded through UK Aid (DFID) and the Directorate-General for International Cooperation (DGIS, Netherlands), as well as CABI’s national and international partners. This program is coordinated by CABI but has joined with partners in Pakistan in a collaborative effort to control invasive species through an integrated pest management approach in which biological control will play an important role. The program will create a truly integrated and sustainable framework for tackling the problem of invasive species to generate growth, create jobs and help reduce poverty. The program’s goal is to protect and restore agricultural and natural ecosystems, reduce crop losses, improve health, protect trade and reduce degradation of natural resources and protected areas. This will be done by supporting local, national and regional activities for prevention, early detection, and control of invasive species. The control and management of parthenium weed in Pakistan is the first pilot study to create awareness through large scale campaigns and build capacity through training courses.

Invasive alien weeds in Pakistan

A large number of alien weeds are reported in Pakistan with some of these becoming invasive and threatening natural and agricultural ecosystems (Nasim and Shabbir, 2012; Shehzadi, 2018). Lantana (Lantana camara L.), mesquite (Prosopis juliflora [Sw.] DC.), paper mulberry (Broussonetia papyrifera [L.] L’Hér. ex Vent.), Eucalyptus spp., and leucaena (Leucaena leucocephala [Lam.] de Wit) are considered the worst woody invaders, while parthenium weed (Parthenium hysterophorus L.), fleabane (Conyza bonariensis [L.] Cronquist) and Soliva spp. are problematic herbaceous invaders (Table 1). Invasive vines or woody climbers, such as cat’s claw creeper (Dolichandra unguis-cati [L.] L.G. Lohmann) and ivy gourd (Coccinia grandis [L.] Voigt.) are threatening forest trees in protected areas and parks. Finally, aquatic invasive weeds such as giant salvinia (Salvinia molesta D.S. Mitch), water lettuce (Pistia stratiotes L.), alligator weed (Alternanthera philoxeroides [Mart.] Griseb.) and common water hyacinth (Eichhornia crassipes [Mart.] Solms) are rapidly invading wetlands in Sindh and Punjab provinces (Table 1).

Among the herbaceous plant invaders, parthenium weed is considered one of the worst weeds in Pakistan, threatening diverse ecosystems. Parthenium weed is an annual herb of the Asteraceae family, originating from the tropical Americas. It has since become a weed of global significance with as many as 48 countries invaded around the world (Shabbir et al., 2018). Parthenium weed significantly reduces crop and pasture productivity, impacts native plant communities and biodiversity and negatively affects human and animal health (Adkins and Shabbir, 2014). In Pakistan, this weed was first reported from the Gujarat district of Punjab province in the 1980s (Razaq et al., 1994); since then it is rapidly spreading throughout the province of Punjab, the Islamabad Capital Territory (ICT) and parts of Khyber Pukhtunkhwa (KP) province (Shabbir et al., 2012).

The spread of this weed was initially limited to wastelands and along roadsides, but it is now infesting field and horticultural crops and native forests. If not controlled, parthenium weed is responsible for significant yield losses in maize and sorghum crops grown in Punjab, Pakistan (Asif et al., 2017; Safdar et al., 2015) and is responsible for transforming the native vegetation and community structure of some protected areas in the Punjab region (Mujahid, 2015). Human allergy problems due to parthenium weed are on the rise in Pakistan (Nadeem et al., 2005). Similarly, livestock feeding on the weed may develop severe allergenic reactions, their meat and milk become tainted (Tudor et al., 1982) and it could be fatal for young calves (Ahmed et al., 1988). In spite of the significant impacts of parthenium weed in Pakistan, the levels of awareness in the general public are low.
### Table 1. Common invasive plant species of Pakistan.

<table>
<thead>
<tr>
<th>Category</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Origin</th>
<th>Invaded Habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woody</td>
<td>lantana</td>
<td><em>Lantana camara</em> L.</td>
<td>South America</td>
<td>Forests, protected areas and national parks in Punjab, Khyber Pakhtunkhwa (KP) Islamabad Capital territory (ICT) and Kashmir</td>
</tr>
<tr>
<td></td>
<td>mesquite</td>
<td><em>Prosopis juliflora</em> (Sw.) DC.</td>
<td>Mexico, South America and the Caribbean</td>
<td>Forests, protected areas and wastelands in Sind, Punjab and KP</td>
</tr>
<tr>
<td></td>
<td>paper mulberry</td>
<td><em>Broussonetia papyrifera</em> (L.) L’Hér. ex Vent.</td>
<td>South East Asia</td>
<td>Protected areas and urban forests in ICT, Punjab and KP</td>
</tr>
<tr>
<td></td>
<td>eucalyptus</td>
<td><em>Eucalyptus</em> spp.</td>
<td>Australia</td>
<td>Forest areas in KP</td>
</tr>
<tr>
<td></td>
<td>leucaena</td>
<td><em>Leucaena leucocephala</em> (Lam.) de Wit</td>
<td>Southern Mexico and Northern Central America</td>
<td>Protected areas and along roadsides and motorways</td>
</tr>
<tr>
<td></td>
<td>farnese wattle</td>
<td><em>Vachellia farnesiana</em> (L.) Wight &amp; Arn.</td>
<td>Southern USA, Mexico, Central America</td>
<td>Forests and protected areas in Punjab</td>
</tr>
<tr>
<td></td>
<td>cactus</td>
<td><em>Opuntia</em> spp.</td>
<td>South America</td>
<td>Most of arid parts of Punjab and KP</td>
</tr>
<tr>
<td>Climbing</td>
<td>cat’s claw creeper</td>
<td><em>Dolichandra unguis-cati</em> (L.) L.G. Lohmann</td>
<td>Mexico, Central America and Tropical South America</td>
<td>Protected areas in Punjab and ICT</td>
</tr>
<tr>
<td></td>
<td>ivy gourd</td>
<td><em>Coccinia grandis</em> (L.) Voigt.</td>
<td>South East Asia</td>
<td>Forests and parks in Lahore</td>
</tr>
<tr>
<td>Herbaceous</td>
<td>Parthenium weed</td>
<td><em>Parthenium hysterophorus</em> L.</td>
<td>Mexico, South America</td>
<td>Wastelands, roadsides, agricultural lands, protected areas in Punjab, KP, ICT and Kashmir</td>
</tr>
<tr>
<td></td>
<td>fleabane</td>
<td><em>Conyza bonariensis</em> (L.) Cronquist</td>
<td>South America</td>
<td>Wastelands, roadsides, urban areas</td>
</tr>
<tr>
<td></td>
<td>Button burweed</td>
<td><em>Soliva anthemfolia</em> (Juss.) Sweet</td>
<td>South America</td>
<td>Weeds of turf as well as recreational parks</td>
</tr>
<tr>
<td></td>
<td>roundleaf bindweed</td>
<td><em>Evolvulus nummularius</em> (L.)</td>
<td>South America</td>
<td>Grasslands, turf areas in Punjab</td>
</tr>
<tr>
<td></td>
<td>giant salvinia</td>
<td><em>Salvinia molesta</em> D.S. Mitch</td>
<td>Southeastern Brazil</td>
<td>Ponds, waterways in Punjab</td>
</tr>
<tr>
<td>Aquatic</td>
<td>water lettuce</td>
<td><em>Pistia stratiotes</em> L.</td>
<td>Southeastern North America</td>
<td>Waterways in Punjab</td>
</tr>
<tr>
<td></td>
<td>alligator weed</td>
<td><em>Alternanthera philoxeroides</em> (Mart.) Griseb.</td>
<td>Temperate regions of South America</td>
<td>Water bodies in Punjab</td>
</tr>
<tr>
<td></td>
<td>common water hyacinth</td>
<td><em>Eichhornia crassipes</em> (Mart.) Solms</td>
<td>South America</td>
<td>Water bodies in Punjab, Sind and KP</td>
</tr>
</tbody>
</table>

### Management options

Several control strategies have been suggested to manage invasive weeds; however, each has limitations. Chemical control of invasive weeds under certain circumstances can be effective, but it is usually expensive and can only be used in specific situations. Mechanical control involving slashing or uprooting is labor intensive and may not be effective, creating massive regrowth and/or germination due to disturbance, and exposure to some weeds such as parthenium weed increases health concerns due to their allergenic nature (Adkins and Shabbir, 2014). Classical biological control, although usually slow,
is an effective, safe and sustainable control strategy against many alien invasive weeds. For example, the biological control program against parthenium weed released nine insects and two pathogens (rusts) in Australia. Most of these agents are now well established in Australia and have a measurable impact on the growth and spread of parthenium weed (McFadyen, 1992).

There are several common problematic weeds across geographic regions for which some effective biological control agents are available at a fraction of the cost of a typical classical biological control initiative. Successful management of parthenium weed through biological control has been achieved in Australia and South Africa. This provides a great opportunity for developing countries like Pakistan to benefit from these successes.

**Biological control of weeds in Pakistan**

Under the Pakistan Plant Quarantine Act of 1976 and Plant Quarantine Rules of 1967, importation of insects and other organisms are allowed for scientific and allied purposes. Once a request for an import permit is lodged, the Plant Protection Department may issue the import permit after a review process. Additional approvals may be required from the Ministry of Environment and Climate Change for the release of an agent. However, the whole procedure is sometimes lengthy.

Several biological control agents have been released against insect pests in Pakistan; however, only one deliberate introduction of a biological control agent has been made against an alien weed. The cactus moth (*Cactoblastis cactorum* [Berg.]) was released against *Opuntia* spp. in Rawalpindi and Chakwal districts of the Punjab province in 1994. Egg sticks of the agent were sourced from Australia, and a culture was established in the laboratory before larvae were released in the field. However, it is not certain if the agent has established after its release (Zimmermann et al., 2000).

Despite the lack of deliberate introductions in Pakistan, classical biological control agents such as *Zygogramma bicolorata* Pallister (a leaf-feeding beetle) have fortuitously arrived in Pakistan. It is believed that *Z. bicolorata* arrived from India where it was released as a classical biological control agent against parthenium weed in 1984 (Javaid and Shabbir, 2006). The beetle is very effective and can curtail parthenium weed populations in its introduced range by reducing its growth and seed production. Most of the central and northern parts of Pakistan are climatically suitable for *Z. bicolorata* (Dhileepan and Senaratne, 2009).

CABI, under the program “Action on Invasives,” is considering the release of *Listronotus setosipennis* (Hustache), a new biological control agent against parthenium weed in Pakistan. *Listronotus setosipennis* is a small nocturnal stem-boring weevil native to Argentina and Brazil that only feeds on parthenium weed. This agent was already released in Australia, South Africa, Uganda and Ethiopia. Adult weevils feed on leaves and flowers while newly emerged larvae tunnel directly from the peduncle into the stem to feed. Larval feeding can kill parthenium weed seedlings and rosettes.

A proposal to the Plant Sciences Division (PSD) of the Pakistan Agricultural Research Council for the import of *L. setosipennis* from South Africa was submitted on 24 August 2017. The PSD committee recommended the importation of the agent for small-scale testing on parthenium weed and other non-target plants. In light of the committee’s recommendations, a request for an import permit was lodged with the Plant Protection Department under the Plant Quarantine Act. The competent authority approved to issue an import permit subject to the condition that the agent will be kept in a quarantine facility. CABI is currently building such a facility at its regional office in Rawalpindi in order to commence work on the host-range testing of *L. setosipennis* in 2019.

**Conclusions**

Many alien invasive plants are reported in Pakistan; however, the problem of alien invasive weeds is not well recognized due to lack of awareness in the general public and effective policies. Biological control is a safe and sustainable option for the management of invasive weeds in Pakistan. We believe once implemented successfully, CABI’s program “Action on Invasives” will pave the
way and remove barriers for the commencement of new biological control programs against other problematic weeds in Pakistan.

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References


