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Insect-mediated biological control of invasive weeds in India: success stories

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ABSTRACT

Invasive plants like weeds are a serious threat to agriculture and over the six decades in India the monetary losses from invasive weed species exceed $127 billion. They not only mitigate the crop yield but they also severely affect biodiversity and damage aquatic ecosystems. Though to control them we have a heavy reliance on chemical herbicides that has led to resistance development and environmental toxicity that emphasizes the need for ecofriendly management practices. Biological control emerges as a safer and environmentally sound option. In India insect-based biocontrol programs such as cochineal insects for prickly pear, salvinia weevil for water fern and mexican beetle for parthenium are some successful biological control programs that achieved great success. These cases highlight not only the effectiveness of ecofriendly biocontrol methods in managing invasive weeds but also the emergence of a new environmentally safe trend in weed management. Biological control has proven to be a successful and promising alternative to the heavy reliance on chemical herbicides.

***Keywords*:** Biocontrol, macrobials, weed killers, ecofriendly

INTRODUCTION

Plants existing out of place or proliferating where they are unwanted and undesired and competing with preferred crop plants for resources like water, sunlight, space and nutrients serving as alternate hosts of pests and insects thus adversely impacting crop production and human welfare such plants are known as weeds. Weeds comprehend all categories of plants like grasses, monocot plants, dicot plants, aquatic plants, trees, parasitic weeds etc. Weeds account for about one-third of the total losses caused by agricultural pests (DWR, 2015). Weeds obstruct the standard growth, development, yield of the desired crop and also interfere with the intercultural operations of the desired crop. Aquatic weeds block the irrigation canals and channels thus hindering the irrigation and also proliferate in water bodies thus degrading the water quality and disrupting aquatic life. Weeds cause 36.5% average losses in the Kharif season and around 22% in the Rabi season. Over the six decades in India, the monetary losses from invasive weed species exceed $127 billion, with key problematic weeds comprising *Parthenium hysterophorus*, *Lantana camara*, *Eichhornia*

crassipes, and *Salvinia molesta* (Saicharan et al. 2025). In severe conditions, weeds can have a more baleful effect than fungi, nematodes or any other insect pests on the crop (Gharde et al. 2018).

Weeds are usually controlled by herbicides (chemicals) also referred to as weed killers. Due to the continuous and excessive usage of chemical herbicides, resistance is being developed among the already existing weed population (Rao and Nagamani, 2010). Indiscriminate use of poisonous herbicide causes pesticide residual effect in the environment and hence continuously devastates the ecosystem and environment. Certain herbicides can be vulnerable to volatilization, leaching, and runoff which may cause them to accumulate in soils, water bodies, and tissue (Ghazi et al. 2023). To protect the environment and human beings from the catastrophic impact of these herbicides an ecofriendly method i.e. the use of biocontrol agents can be used to control both native and invasive species of weeds. Biocontrol or biological control is a method of controlling the population of pests (insects), plants (weeds) etc. using other living organisms that feed on these insects and weeds.

The living organisms that are used as a control are known as biocontrol agents. These biocontrol agents are comprised of macrobials (insects, nematodes and mites) and microbials (bacteria, viruses, fungi). Here are some of the most important weed biocontrol agent orders: Coleoptera (Family: Chrysomelidae, Curculionidae, Cerambycidae, Galeuricidae), Lepidoptera (Family: Phycitidae, Tortricidae), Diptera (Family: Agromyzidae, Trypetidae), Hemiptera (Family: Coreidae, Tingidae, Coccidae) (Kumari et al. 2022).

History of successful biological control programs for control of weeds by insects

The first unintentional outstanding success of biological control of prickly pear in India during 1795 by the cochineal insect led the world to use natural enemies against exotic weeds (Singh, 2004).

A red flower plant named prickly pear (*Opuntia sp.)* introduced in India during the 1800s as an element of the cochineal trade and it spread like a weed across North and South India. Numerous attempts were made to control this weed using its biocontrol agent i.e *Dactylopius ceylonicus* but it failed to establish and achieve the control.

But during the colonial period attempts were made to introduce a red colour dye producing insect *Dactylopius cacti* to set up a cochineal dye industry in India. But mistakenly, from Brazil *Dactylopius ceylonicus* a wild cochineal insect was introduced in place of *D. cacti*. And then the attack of *D. ceylonicus* is reported in *Opuntia vulgaris* which leads to unintended control over this weed in 1795 (Kumar, 2015). Hence, it is considered the first successful classical biological control example in the world.

Dactylopius ceylonicus showed host specificity and was effective only against *Opuntia vulgaris*, failing to suppress *Opuntia stricta*, which subsequently emerged as a serious weed in the southern part of India. To overcome this *Dactylopius opuntiae* was introduced from Sri Lanka in 1926 (Muniappan et al. 2026). This cochineal insect successfully established itself under Indian conditions and brought about remarkable control of *O. stricta* and *O. elatior*. Due to their sustained and effective feeding activity, these cactus species are no longer considered major weed problems in India.

Successful examples of biocontrol of weeds by insects in India

1. Invasive Weed - *Lantana camara*

Controlled by - Tingid lace bug, *Teleonemia scrupulosa*

History – In 1809 lantana was introduced as an ornamental plant in India from Central and South America but it proliferated and became a major weed across the country and caused great loss. Control was achieved in 1941 by the use of a Mexican insect named the tingid lace bug (*Teleonemia scrupulosa*) introduced in India from Australia. Regardless of good defoliating capacity it leads to partial success only.

2. Invasive weed – Water fern, *Salvinia molesta*

Controlled by – Salvinia weevil, *Cyrtobagous salviniae*

History – This weed was introduced in India (Kerala) from southeastern Brazil, and it invades the water bodies and rice fields of Southern India. It was first observed in Vole Lake of Kerala in 1955 (Ballal, 2022). The biocontrol agent of this weed is the Salvinia weevil (*Cyrtobagous salviniae*) which is native to Brazil and was intentionally introduced in India from Australia to control this weed in 1982. Its introduction leads to great success in the control of this aquatic weed.

3. Invasive weed – Congress Grass, *Parthenium hysterophorus*

Controlled by – Mexican beetle, *Zygogramma bicolorata*

History – In 1955 this weed was first noticed in India (Patel et al. 2024). It leads to many health problems to man and animal including respiratory problems and skin allergies. Hence it is considered an important weed in India. In 1983 its biocontrol agent a leaf feeding beetle (*Zygogramma bicolorata)* was introduced from Mexico. It leads to good control over this weed but still the seasonal resurgence is a problem.

Table 1. Some other successful examples of biocontrol of weeds by insects in India.

Sr.No.	Invasive weed	Biocontrol agent	Source country	Year	Current status
1.	**Crofton weed** (*Ageratina adenophora*) native of Mexico.	Gall fly, (*Procecidochares utilis*) native to Mexico.	New Zealand	1963	This weed proliferates in hilly region of Northern and Southern parts of India. The control is achieved initially but later due to *Bracon* spp. parasitism proper control has not achieved by this insect.
2.	**Water hyacinth** (*Eichhornia crassipes*)	Hydrophilic weevils (*Neochetina bruchi, N. eichhorniae*)	USA	1982	It is an aquatic weed so cause destruction in water tanks and rice fields. Great control is achieved by these natural enemies, around 40% of

	native of south America.	native to Argentina			cover reduction in weed was noticed in a month.
3.	**Siam weed** (*Chromolaena odorata*) native of West Indies and America.	*Pareuchaetes pseudoinsulata* native of Trinidad.	Sri Lanka	1984	*P. pseudoinsulata* was introduced in southern part of India and initially control is achieved to some extent but due to heavy parasitism at present it is not used for control.

CONCLUSION

From the unintentional introduction of *Dactylopius ceylonicus* (1795) to the deliberate release of *Dactylopius opuntiae* (1926) the reduction of Opuntia species in India demonstrates the effectiveness of insect-based biological control. These examples support the use of host-specific compounds as the main strategy for long-term weed control, providing a focused and sustainable substitute for chemical herbicides. These past operations set a technical and ecological standard for future invasive species efforts in the area by using biological methods to achieve long-term control.

Despite its shown effectiveness, local farmer's lack of technical knowledge is currently impeding the practical adoption of this biocontrol technique. Due to a lack of formal training and simplified field guides, many agricultural practitioners find it challenging to conduct ground-level control of these insect agents. This gap is further complicated by climate instability, as shifting temperatures and erratic weather patterns destabilize the natural life cycle of these biocontrol agents. Future initiatives must concentrate on closing this knowledge gap and modifying management techniques to fit a changing environment in order to maintain these advantages.

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