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A Review on Ecological Impact and Ecofriendly Control Methods of *Parthenium hysterophorus*: An Exotic Troublesome Weed in India

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Abstract

Parthenium weed (*Parthenium hysterophorus* L.) is a noxious environment pollutant weed under the family Asteraceae (tribe: Heliantheae). It is known for its notorious role as environmental, medical, and agricultural hazards. It is believed to have been introduced into India from North America. In the last few years it has emerged as the most devastating and troublesome weed in India. The main aim of this review is to provide general information about the Ecological impact, ill effects, and management of Parthenium weed through Biological control. Control of Parthenium weed has been tried by various methods including Integrated Pest Management (IPM), but no single management option would be adequate to manage Parthenium, and there is an urgent need to integrate various management options. Successful management of this weed can only be achieved by an integrated approach with biological control as the key element.

Keywords : Parthenium weed, *Parthenium hysterophorus,* IPM, Biological control.

1. Introduction

Parthenium hysterophorus L. (2n=18) commonly known as congress grass; carrot grass; bastard feverfew; broomweed; congress weed; dog flea weed; is a noxious plant, that inhabits many parts of the world, in addition to its native range in North and South America and the West Indies. This is a weed of global significance responsible for severe human and animal health issues, such as dermatitis, asthma and bronchitis, type I hypersensitivity and agricultural losses besides a great problem for native biodiversity. *P. hysterophorus* is presumed to have entered in India along with food grains imported from the USA under the US PL 480 scheme, also known as “Food for Peace” which is a food assistance programme of the US government (Vartak, 1968). It was first identified and described by Rao (1956) in Pune, in the Maharashtra district, where it was first observed in 1955 (Vartak, 1968), and has since spread to most of the sub-continent (Nath, 1988). Ever since the weed have become a menace around the globe including India, efforts have been made to manage the weed employing different methods such as mechanical, competitive replacement (allelopathy), chemical, and biological control methods. However, the weed has defied all human efforts to control it due to one or other disadvantages. Biological control, the intentional manipulation of natural enemies, insects, bioherbicides, nematodes, snails, and competitive plants to control harmful weeds, is gaining momentum as it is an effective and ecofriendly alternative to conventional methods of weed control.

Parthenium weed reproduces by seeds formed through sexual reproduction. In its neotropical range it grows to 30-90 cm in height (Lorenzi, 1982; Kissmann and Groth, 1992), but up to 1.5 m, or even 2.5 m, in exotic situations (Haseler, 1976; Navie et al., 1996). Shortly after germination the young plant forms a basal rosette of pale green, pubescent, strongly dissected, deeply lobed leaves, 8-20 cm in length and 4-8 cm in width. The rosette stage may persist for considerable periods during unfavorable conditions (such as water or cold stress). As the stem elongates, smaller, narrower and less dissected leaves are produced alternately on the pubescent, rigid, angular, longitudinally-grooved stem, which becomes woody with age.

Parthenium: seedlings

Parthenium weed: rosette stage.

Parthenium weed: of capitula (flower).

Parthenium weed: a single mature plant.

Flower heads are both terminal and axillary, pedunculate and slightly hairy, being composed of many florets formed into small white capitula, 3-5 mm in diameter. Each head consists of five fertile ray florets (some times six, seven or eight) and about 40 male disc florets. The first capitulum forms in the terminal leaf axil, with subsequent capitula occurring progressively down the stem on lateral branches arising from the axils of the lower leaves. Thousands of inflorescences, forming in branched clusters, may be produced at the apex of the plant during the season. Seeds (achenes) are black, flattened, about 2 mm long, each with two thin, straw-coloured, spathulate appendages (sterile florets) at the apex which act as air sacs and aid dispersal.

2. Habitat

P. hysterophorus occurs in the humid and subhumid tropics, typically favouring heavier fertile soils, such as black, alkaline clay loams, but is able to grow on a wide variety of soil types from sea level up to 2400 m (Evans, 1987a; Taye et al., 2002). Areas receiving less than 500 mm of rainfall annually are probably unsuitable, although the weed has strong adaptive methods to tolerate both moisture stress (Kohli and Rani, 1994) and saline conditions (Hedge and Patil, 1982; Khurshid et al. 2012). It is especially prolific in disturbed habitats, such as along roadsides and railway tracks, river and creek banks, in stock yards, around buildings and on wasteland, from where it spreads and invades agricultural systems. It is also present in rangelands, villages, gardens, along streams, rivers, plant nurseries and crop fields. Rashmi et al. (1999) reported that it is also present in wetlands.

Habitat List

Category	Habitat	Presence	Status
	Cultivated / agricultural land	Principal habitat	Harmful (pest or invasive)
	Disturbed areas	Principal habitat	Harmful (pest or invasive)
	Industrial / intensive livestock production systems	Secondary/tolerated habitat	Harmful (pest or invasive)
	Managed forests, plantations and orchards	Principal habitat	Harmful (pest or invasive)
	Managed grasslands (grazing systems)	Secondary/tolerated habitat	Harmful (pest or invasive)
	Protected agriculture (e.g. glasshouse production)	Present	Harmful (pest or invasive)
	Rail / roadsides	Principal habitat	Harmful (pest or invasive)
	Urban / peri-urban areas	Principal habitat	Harmful (pest or invasive)
Terrestrial-natural/ semi-natural	Natural forests	Present	Harmful (pest or invasive)
	Natural grasslands	Principal habitat	Harmful (pest or invasive)
	Riverbanks	Secondary/tolerated habitat	Harmful (pest or invasive)
	Wetlands	Secondary/tolerated habitat	Harmful (pest or invasive)

3. Ecological Impacts

3.1 Impacts on human health:

The pollen grains, airborne dried plant parts, and roots of parthenium causes various allergies like contact dermatitis, hay fever, asthma, and bronchitis in human beings. The common allergens found in this weed are parthenin, coronopilin, tetraneuris, and ambrosin. Pollens of parthenium causes asthma (allergic bronchitis), especially in children playing outdoors and in adults and old-age persons. Contact of plant with the body causes dermatitis and the spread of the problem all over the body causes great systemic discomfort. Pollens in contact with body causes swelling and itching of mouth & nose; also causes constant coughing. Consumption of weed roots causes excessive water loss from the body (Oudhia & Tripathy, 1998)

3.2 Impacts on livestock production:

Parthenium weed is toxic to animals causing dermatitis with pronounced skin lesions on various animals. If eaten, it is responsible for mouth ulcers with excessive salivation. Significant amount (10–50%) of this weed in the diet can kill cattle . In addition, it causes anorexia, pruritus, alopecia, diarrhea, and eye irritation in cattles. It's Contact causes inflamed udder, fever and rushes in cows. It also causes allelrgic inflammation in the mouth & digestive tracts of cattles. It destroys quality of dairy milk if cows are feed on the weed.

3.3 Impacts on crops production

Parthenium produces enormous numbers of pollens (on an average 624 million/plant), which are carried away at least to short distance in clusters of 600–800 grains, and settles on the vegetative and floral parts, including stigmatic surface, inhibiting fruit setting in crops like maize, tomato, brinjal, capsicum and beans.

Parthenium plant contains chemicals, like parthenin, hysterin, hymenin, and ambrosin, and due to the presence of these chemicals, the weed exerts strong allelopathic effects on different crops. Parthenin

has been reported as a germination and radical growth inhibitor in a variety of dicot and monocot plants.Yield loss may occur up to 40% in Rice & others through competition (Khosla & Sobti, 1979). Chickpea, mustard & linseed are killed due to allelopathy through root exudation. Grain filling in maize reduced by 50% due to allelopathic effects of pollens on floral parts. Seed germination is reduced in tomato, brinjal & chilli by weed allelopathy.*P. hysterophorus* is now being reported from India as a serious problem in cotton, groundnuts, potatoes and sorghum, as well as in more traditional crops such as okra (*Abelmoschus esculentus*), brinjal (*Solanum melongena*), chickpea and sesame (Kohli and Rani, 1994), and is also proving to be problematic in a range of orchard crops, including cashew, coconut, guava, mango and papaya (Tripathi et al., 1991; Mahadevappa, 1997).The growth and nodulation of legumes are inhabited by parthenium weed because of the effect of allelochemicals on nitrogen fixing and nitrifying bacteria (Kanchan and Jayachandra, 1981; Dayama, 1986).

3.4 Impacts on Natural Ecosystem

Infestation of Parthenium weed can degrade natural ecosystem because it has a very high invasive capacity and allelopathic properties which has the tremendous potential to disrupt any type of natural ecosystems.

The noxious *P. hysterophorus* grows in a wide variety of habitats and causes changes in above ground vegetation as well as in below ground soil nutrients. It is capable of out-competing native and introduced palatable plants that are important to livestock consumption. Furthermore, the changes in vegetation and soil nutrients could lead to ultimate changes in other trophic levels and alter the functioning of the ecosystem. Parthenium weed lacks natural predators, and cattle and livestock usually do not like to feed on it. As a result, the food chain is disturbed and the trophic structure changes, leading to an ecological imbalance in the invaded area. Parthenium weed is also an environmental weed that can cause irreversible habitat changes in native grasslands, woodlands, river banks and flood plains in both India and Australia (Jayachandra 1971; McFadyen, 1992; Evans, 1997a; Kumar and Rohatgi, 1999). Huge stands of parthenium weed are common in almost all open areas. Parthenium weed, due to its allelopathic potential, replaces dominant flora and suppresses natural vegetation in a wide range of habitats and thus becomes a big threat to biodiversity. Wherever it invades, it forms a territory of its own, replacing indigenous grasses and weeds which are supposedly useful for the grazing animals (De and Mukhopadhyay, 1983). Parthenium weed has an adverse effect on a variety of natural herbs which are the basis of traditional systems of medicines for the treatment of several diseases in various parts of the world (Mahadevappa et al., 2001; Shabbir and Bajwa, 2006).

The weed invades natural ecosystems, and has caused total habitat changes in native grasslands and open woodlands (McFadyen, 1992). It is an aggressive colonizer of wasteland, road sides, railway sides, water courses, cultivated fields, and overgrazed pastures and has invaded 14.25 million hectares of farm land during 2001–2007, compared to 2 million hectares in 1991–2000. Physiological studies have shown that parthenium weed has a low photo respiratory activity and has the C_3 photosynthetic pathway but with positive C_4 tendencies (Patil and Hedge, 1983). Thus the weed has higher photosynthetic potential. Parthenium weed has also invaded forest land (Towers et al., 1977). It has become a menace in forest nurseries (Chandras, 1970). Swaminathan et al. (1990) reported its allelopathic effect on the multipurpose tree species *Acacia leucocephala, Casuarinaequisetifolia, Eucalyptus tereticornis* and *Leucaena leucocephala*.

3.5 Impact on Biodiversity

In Parthenium infested areas, there is a sharp decline in the native biodiversity index, species

evenness and species richness over the time, clearly indicating the threat of Parthenium on native biodiversity of other weeds. According to McFadyen (1992), Chippendale and Panetta (1994), Parthenium has been reported to cause a total habitat change in native Australian grassland, open woodlands, riverbanks and food plains. Its allelopathic effect coupled with absence of natural enemies like insects and diseases are the two important factors responsible forits spread in India. According to Picman and Picman (1984), two sesquiterpene lactones such as parthenin and coronopilin present in large quantities have been reported to be autotoxic to seed germination and seedling growth and because it exerts strong allelopathic effect, it suppresses the growth and productivity of surrounding crops.

3.6 Impact on Soil Microflora

Parthenium weed inhibits the growth and activity of nitrogen fixing bacteria like *Rhizobium* and *Azotobacter* and nitrifying bacteria like *Nitrosomonas*. Sukhada et al., (1981) reported the inhibitory effect of root and leaf extract of *Parthenium hysterophorus* L. on the growth of Nitrogen fixingbacteria *Rhizobium phaseoli* and *Azotobacter vinelandii* and a decrease in the *Nitrosomonas* activity. Leghaemoglobin content in the root nodules of bean plants grown in soil mixed with Parthenium leaf was reduced significantly. Leaf and root leachates, parthenin, anisic acid, vanillic acid and fumaric acid inhibited nitrate production (Sukhada etal., 1981). The native soil algal flora was found to be inhibited by the addition of powdered air dried leaves, inflorescence and roots of Parthenium (Megharaj et al., 1987).

4. Ecofriendly control Methods:

4.1 Biological Control

Biological control is an ecofriendly and most effective means of reducing or mitigating pests and pest effects through the use of natural enemies. In the last three to four decades, a great deal of emphasis has been given to control parthenium through various biocontrol agents like microbial pathogens, insects, and botanicals. Of the various biocontrol strategies, biological control of weeds by plant pathogens has gained acceptance as a practical, safe, and environmentally beneficial method applicable to agro ecosystems. Biological control has been, and continues to be, considered the best long-term or sustainable solution to the parthenium weed problem in Australia (Haseler, 1976; McFadyen, 1992) and because of the vast areas and the socio-economics involved, this approach has also been proposed for India (Singh, 1997). Singh (1997) considered use of biocontrol agents (insects and fungal pathogens) and exploitation of competitive plants (allelopathy), the most economic and practical way of managing parthenium.

Searches for, and evaluation of, coevolved natural enemies have been conducted in the neotropics since 1977. So far, nine insect species and two fungal pathogens have been introduced into Australia as classical biological control agents (Julien, 1992; McClay et al., 1995; Navie et al., 1996; Dhileepan and McFadyen, 1997; Evans, 1997a). The rust fungus, *Puccinia abrupta* var*. partheniicola*, is a prominent natural enemy in the semi-arid uplands of Mexico (Evans, 1987). Screening of another rust species (*Puccinia melampodii*) from Mexico was carried out (Evans, 1997b; Seier et al., 1997) and released in the summer of 1999/2000 (PAG, 2000). Whereas, in India, the mycoherbicide potential of plurivorous fungal pathogens belonging to the genera *Fusarium, Colletotrichum, Curvularia, Myrothecium* and *Sclerotium*, has and is being evaluated (Mishra et al., 1995; Evans, 1997a). Parthenium phyllody disease caused by the phytoplasma of faba bean phyllody group (FBP) was reported to reduce seed production by 85% (Taye et al., 2002b) and is being evaluated for use as a biological control agent in Ethiopia.

Among the established insect biocontrol agents, the leaf-feeding beetle, *Zygogramma bicolorata*,

the stem-galling moth, *Epiblema strenuana*, the stem-boring beetle, *Listronotus setosipennis*, and the seed-feeding weevil, *Smicronyx lutulentus*, are proving to be the most successful when climatic factors are favourable (McFadyen, 1992; Dhileepan and McFadyen, 1997; Evans, 1997a). Some control of parthenium weed has also been achieved in India with *Z. bicolorata* (Jayanth and Visalakshy, 1994; Singh, 1997; Sarkate and Parwar, 2006), although there has been controversy concerning its taxonomy and host specificity (Jayanth et al., 1993; Singh, 1997).

4.2 Natural Enemies

There is a considerable amount of literature concerning the natural enemies of parthenium weed, as the weed has been a target for biological control for more than 30 years. Between 1977 and 1991, extensive surveys of phytophagous arthropods were undertaken in its North American native range. Over 250 species were recorded during this period, and these have been assessed for specificity. The results of these studies have been summarized (McClay et al., 1995; Cock and Seier, 1999; Seier and Djeddour, 2000). Six stenophagous insect species, including a leaf feeder, leaf miner, stem borer, stem galler and seed feeder, were released in Australia as biological control agents, and an additional two species from Argentina were released later (Navie et al., 1996; Evans, 1997a). The pathogens associated with *P. hysterophorus* in the neotropics have also been surveyed and evaluated as biocontrol agents (Evans, 1987b; 1997b). All the insect species released in Australia are coevolved natural enemies, as are the pathogens currently being assessed, however, numerous surveys and studies of both the arthropods and pathogens associated with parthenium weed in India (Kumar, 1998) and Ethiopia (Taye, 2002) have also been undertaken. These all represent adaptive or opportunistic natural enemies, most probably polyphagous or from related genera of Compositae. Larvae and adults of the stem-boring scolytid *Hypothenemus eruditus* (Westw.) caused widespread wilting of the weed, leading to good natural control; however, this beetle is known to attack several crops in different parts of the world. A cerambycid borer*, Oberea sp*., was also found to kill the plant. Unidentified natural enemies included a cerambycid and a dipteran stem-borer. Most of the natural enemies were known to attack crops; hence, the weed may serve as an alternative food-plant for most of them.

4.3 Allelopathic Control

The term allelopathy was coined by Molisch (1937), which generally refers to the detrimental effect of one plant species on seed germination, growth, and reproduction of another plant species. Numerous plants are reported to possess allelopathic potential and efforts have been made to use them in weed control. Competitive replacement of parthenium can be achieved by planting plants like *Cassia sericea*, *C. tora, C. auriculata, Croton bonplandianum, Amaranthus spinosus, Tephrosia purpurea, Hyptissua veolens, Sida spinosa,* and *Mirabilis jalapa* which are capable of effectively suppressing partheniumin natural habitats . A study in India revealed that Cassia sericea reduces the accumulation of parthenium by 70% and parthenium population by 52.5%. Another study showed that aqueous extracts from *Imperata cylindrica*, *Desmostachya bipinnata*, *Otcantium annulatum*, and *Sorghum halepense* markedly suppressed seedling growth and germination of parthenium . In India, crop rotation using Marigold (*Tagetes spp.*) during the rainy season, instead of the usual crop, has been found effective in reducing parthenium infestation in cultivated areas.

Both the root and shoot extracts of three allelopathic grasses, namely, *Dicanthium annulatum*, *Cenchrus pennisetiformis*, and *Sorghum halepense*, reduce germination and suppress early seedling growth of exotic weed *P. hysterophorus*. Aqueous foliar extracts of *Azadirachta indica, Aegle marmelos*, and

Eucalyptus tereticornis totally inhibited the seed germination of parthenium and may be exploited for controlling parthenium weed.

4.4. Integrated Pest Management (IPM)

In many locations parthenium weed is able to survive individually-applied management measures, and a more effective integrated approach is therefore required in these locations. A holistic IPM approach is propounded in India to achieve sustainable management of parthenium weed (Mahadevappa, 1997), and implemented in Australia through improved extension strategies (Navie et al., 1996; Chamala et al., 1997). Nav-Bahr and Bahar (2000) proposed ploughing before flower set and burning when the plants are dry and mature, application of atrazine or other herbicides like 2,4-D, paraquat, glyphosate, diuron and dalapon, using *Cassia sericea* to displace parthenium weed, and biocontrol using *Zygogramabicolorata.* Under IPM, two insects *Z. bicolorata*and *E. stenuana,* and two rust fungi*, Puccinia abrupta var. partheniicola* and *Puccinia xanthii var. parthenii-hysterophorae,* have shown potential and are being used to control this weed.

5. Conclusions

Awareness must be created among the inhabitants of the countries about the ill impacts of Parthenium. How this weeds look like, how the seeds are spread from one place to another and the possible methods of control should be taught to all of the peoples so that all the members of the community can be involved in combating the weed.

Appropriate methods for the management of *P. hysterophorus* are necessary to avoid potential threats to biodiversity and economic losses. The efficient and environment-friendly alternative to other time-consuming, costly, toxic, physical, and chemical methods is the use of biological control through allelopathy, insects and fungal pathogens. Till date the weed is not been completely checked and is still creating nuisance in India, and more needs to be done by scientists, agriculturists, and government to work jointly for managing this troublesome weed.

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