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Parthenium hysterophorus L.: A Major Threat to Natural and Agro Eco-Systems in India

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ABSTRACT

Parthenium hysterophorus is an aggressive annual herbaceous plant native to the Tropical America. It is now widely distributed in a number of tropical and sub-tropical countries. The weed has achieved major weed status in India only within the last few decades. The weed is very common along with the road sides, around the agricultural fields and on waste lands. *P. hysterophorus* is considered as a noxious weed because of its prolific seed production and fast spreading ability, allelopathic effect on other plants, strong competitiveness with crops and health hazard to human as well as animals. The infestation of the weed causes yield losses up to 40% in several crops and reduces forage production by up to 90%. The rapid spread of parthenium in India would be a bigger risk to the expansion and sustainable production of many crops. Control of parthenium is therefore crucial to boost the productivity of agricultural crops in the country. It is reported that for better management of the weeds, knowing the habitat, morphology and biology of the weeds are also important. Hence, an attempt has been made to review the habitats and adaptability, morphology and biology, allelopathic properties of *P. hysterophorus* and its impact on agriculture and human and animal health and management of the weed.

Key words: *Parthenium hysterophorus*, habitats and biology, allelopathic properties, impacts, management

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INTRODUCTION

Parthenium hysterophorus L. (Heliantheae: Asteraceae) is a poisonous and problematic weed, is now posing a serious threat to crop cultivation and also to human and animal health. It is commonly known as congress grass, feverfew, ragweed, parthenium or white top. It is a noxious weed native to Tropical America. It has now naturalized in several tropical and subtropical parts of the world[1]. Parthenium is one of the most troublesome weeds and figures among the list of invasive species in the GISD[2]. The plant is now widely distributed in India, Africa, China, Vietnam, Pacific Islands and Australia. In India, it was first recorded in 1810 in Arunachal Pradesh and Nagaland and in Pune in 1955. By 1972, it had spread into the majority of the western states from Kashmir in the north to Kerala in the south. Continuing to spread it was found in Assam in 1979 and is now present almost throughout the subcontinent and is probably the dominant weed in Karnataka State where it infests about 5 million ha. Parthenium weed has been reported from all states of India. In general, the overall spread in terms of density and infestation level is that it is highest in Andhra Pradesh, Bihar, Chhatisgarh, Delhi, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Tamil Nadu and Uttar Pradesh. The spread and infestation level is medium in Assam, Gujarat, Himachal Pradesh, Jharkhand, Jammu and Kashmir, Uttarkhand, Orissa, West, Bangal and Rajasthan states while spread is low in Andaman and Nicobar, Arunachal Pradesh, Daman and Diu, Goa, Kerela, Manipur, Mizoram, Mehgalaya, Nagaland, Pondicherry and Sikkim. So, at present, parthenium weed has become widely distributed throughout India and no state is able to say that they of free of parthenium weed[3]. Now it has achieved the status of the countries "Worst Weed" owing to its allelopathic effects on agricultural crop production and harmful effects on people and animals. During the 1980s, parthenium weed used to be considered a weed of rainfed fallow and wasteland but now it has become a weed of every crop and also into the forested land. The severity of the parthenium weed problem has compelled researchers and people from various action groups and societies to provide a forum for those in need and affected by parthenium weed. Based on the above facts in view, habitats and adaptability, morphology and biology, allelopathic properties and impacts of parthenium weed and its control are reviewed here.

HABITATS AND ADAPTABILITY

P. hysterophorus is a pioneer species which can invade grazing land, disturbed and cultivated areas, roadsides, recreation areas, as well as river banks and floodplains.

According to the Corine Land Cover nomenclature, the following habitats are invaded; arable land, permanent crops (e.g., vineyards, fruit tree and berry plantations, olive), pastures, banks of continental water, riverbanks or canal sides (dry river beds), road and rail networks and associated land, other artificial surfaces (wastelands). Parthenium is a drought-tolerant plant and can grow in almost all soil types[4]. This weed can grow over a wide range of moisture and temperature conditions but requires high soil moisture for seed germination[5]. It is reportedly photoperiod and thermoperiod insensitive and can flower year-round[4]. Seed germination can take place over a wide range of temperatures[6] and soil pHs[7]. Further, ragweed parthenium is very competitive and has been reported to gain an advantage over a C_4 pasture grass (*Cenchrus ciliaris*) as atmospheric CO_2 concentrations increase, despite being a C_3 plant[8]. This is fairly typical of the response of C_3 and C_4 plants when grown in enriched CO_2 atmospheres.

MORPHOLOGY AND BIOLOGY OF WEED

Parthenium weed is an annual herb with a deep tap root and an erect stem that becomes woody with age. As it matures, the plant develops many branches in its top half and may eventually reach a height of 2 m in good soil conditions. Its leaves are pale green, deeply lobed and covered with fine soft hairs. It is light green with branching stems, finely lobed leaves, 3-20 cm long, 2-10 cm wide. Once stem elongation is initiated, smaller leaves are produced and the plant becomes multi-branched in its extremities. The plant flowers 4-8 weeks after germination and flowering continue until drought or frost kills the plant. Small creamy white flowers occur on the tips of the numerous stems. Flower heads are small (4 mm across) and numerous in open panicles. Achenes are black, obovate, 2-2.5 mm long and light weight. Each flower contains 4-5 black seeds that are wedge-shaped, 2 mm long with white scales. The concept of "one year seeding, seven years weeding" is true for parthenium. Large plants can produce up to 15,000 seeds on average and up to 100,000 seeds[9] which can be distributed by floating on still or flood waters or in mud adhering to animals, vehicles and machinery[10]. It was reported densities as high as 200,000 seeds m^{-2} in the soil in India[11]. In some areas, more than 340 million parthenium seeds can be present per hectare in the surface soil, compared to 120,000 native grass seeds. Parthenium weed normally germinates in spring and early summer. It is thought that most seed germinate within two years if conditions are suitable, although a portion of buried seed may remain viable for several years[12]. Research shows that parthenium weed achieves highest germination rates at temperatures ranging from 12-27°C, the optimum germination temperature being 22-25°C. Buried seeds have been found to last longer than seeds on the soil surface and a significant proportion can still germinate after 8-10 years. In addition, the species is an opportunistic germinator and seeds can germinate at any time of the year provided moisture is available but require bare soil Naturally dispersed seeds required about 60 days, at a hot lowland site, to start emergence despite the presence of adequate rainfall and higher number of seedlings emerged in undisturbed plots than in hand hoed plots[6]. Under favorable conditions, four or five generations per year can be completed.

SEED DORMANCY AND SEED-BANK LONGEVITY

The parthenium seeds have the ability to undergo dormancy. The seed banks are persistent, with seed viability greater than 50% after more than two years in the soil. Seed near the soil surface is rarely viable beyond 2 years. However, undisturbed, buried seed will stay dormant for a longer period. It has been recorded as viable for up to 6 years and anecdotal evidence suggests even longer. In climates where rainfall is irregular, dormancy mechanisms prevent untimely germination. The size and persistence of the seed bank has implications several years beyond a reduction in parthenium weed populations. The germination of the seeds declined from 66% after 1 week of burial to 29% after burial for 2 years[12]. However, it was reported 74% seed viability after 2 year's burial and the predicted half-life of the seeds to be about 6 years[13]. The absence of a primary dormancy mechanism was found in the seeds[14], but the initial inhibition of germination was shown in freshly shed seeds[13].

INVASIVE AND ALLELOPATHIC PROPERTIES OF *P. hysterophorus*

- It is an aggressive colonizer that gets established in natural and manmade ecosystems, grassland habitats, open woodlands, river banks, flood plains, wildlife parks, open fields of settlements areas, bare areas along roadsides, crop fields, gardens heavily stocked areas around yards and watering points etc.[15]
- It produces large amounts of seeds and thus, it has the potential to become widespread
- The allelochemicals released directly from the weed or from seed leaching inhibit germination of other plants and the growth of pasture grasses, legumes, cereals, vegetables, other weeds and even trees[16]
- It induces changes in the physical and chemical properties of soil such as soil texture, soil pH, soil organic matter, soil nitrogen, soil potassium, soil phosphorus etc[17]
- It is noxious and unpalatable to herbivores

- It replaces rangelands palatable grasses and adversely effecting animals health damaging milk and meat quality[18]
- Manual removal is difficult because it may cause dermatitis, hay fever, asthma, allergic and even death in humans[17]

IMPACT OF WEED ON AGRICULTURE

- *P. hysterophorus* aggressively colonises disturbed sites and causes major negative impacts on pastures and crops. It competes strongly with crops such as sunflower and, in infested sorghum; *P. hysterophorus* suppresses yield, as well as contaminating the grain samples
- It affects nodulation in legumes due to inhibition of activity of nitrogen fixing and nitrifying bacteria viz., *Rhizobium*, *Actynomycetes*, *Azotobactor* and *Azospirillum*
- It was reported to cause yield losses of up to 40% in several crops[19] and is reported to reduce forage production by up to 90%[20]. *Parthenium* produces enormous quantity of pollen (on an average 624 million/plant), which is 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 tomato, brinjal, beans, capsicum and maize when its pollen grains are deposited on the stigmatic surfaces[21]
- The weed acts as an alternate host for many diseases caused by viruses in crop plants
- It also acts as an alternate host for the insect mealy bug
- In Ethiopia, the yield in *Sorghum bicolor* grain was reduced from 40-97% when *P. hysterophorus* was left uncontrolled throughout the season
- In Queensland (Australia), the species has invaded 170,000 km² of high quality grazing areas and losses to the cattle industry 8. Parthenium weed seed is also a contaminant of grain, pasture and forage seeds. Hence, it results in restricted sale and movement of these produces[22]

IMPACT OF ALLELOCHEMICALS PRESENT IN *P. hysterophorus* ON OTHER CROP PLANTS

P. hysterophorus is reported to exert negative allelopathic influence to its neighbouring plant species [23]. The chemical analysis has indicated that all the plants parts including trichomes and pollen contain toxins called parthenin of sesquiterpene lactones group. Other compounds include phenolics such as caffic acid, vanilic acid, ρ-cumaric acid, anisic acid, ρ-anisic acid, ferulic acid and chlorogenic acids[24]. Parthenin, caffeic acid and ρ-coumaric acid are the primary inhibitors present in this plant; other chemicals are hysterin, hymenin and ambrosin[25]. The sesquiterpene group includes parthenin, coronopilin, 2-β hydroxy coronopilin, tetraneurine A, hysterones A-D[26] and seco-pseudoguinaloides found in the form of charminarone[27]. The leaves and inflorescence of *Parthenium* have higher level of allelochemicals than the stem and roots[17]. These allelochemicals affect other plants either directly by leaching, root exudation and residue decay[24] or indirectly, ultimately leading to loss of native flora. The allelochemicals released from parthenium inhibit the growth of pasture grasses, legumes, cereals, vegetables, other weeds and even trees[28]. Several studies[29] investigated the effect of parthenium allelochemicals on other plants. It was found that the plant residue of parthenium was toxic to aquatic flora and fauna[30]. The allelochemicals released from parthenium affecting many plant species are sesquiterpene lactones and phenolics[31]. Parthenin is the major sesquiterpene lactone whereas caffeic, vanillic, ferulic, chlorogenic and anisic acids are the major phenolics[32]. These two synergistically acting groups of allelochemicals significantly decrease the seed germination and subsequent growth in many crops[33].

IMPACT WEED ON HUMAN AND ANIMAL HEALTH

The major components of toxic being parthenin and other phenolic acids such as caffeic acid, vanillic acid, ansic acid, ρ-anisic acid, chlorogenic acid and parahydroxy benzoic acid are lethal to human beings and animals[34]:

- Because of sesquiterpene lactone compounds, parthenium induce severe dermatitis and often allergic symptoms in human beings
- Parthenium pollen causes nasobronchial allergy with 42.5% of a large population in Bangalore, India showing sensitivity to pollen
- It is also reported to cause itching, popular erythmatous eruptions, loss of hair, marked depigmentation of skin, development of oedema ulceration and lesions in the mouth and intestine[35]
- Parthenium causes general illness, asthmatic problems, irritations of skin and pustules on hand balls, stretching and cracking of skin and stomach pains on human[36]
- It is a major cause of Trinities and Sinusitis, affecting about ten percent of the people who live near it[21]
- Due to its irritating odour, taste and presence of trichome hairs, parthenium weed is unpalatable, but cattle and sheep will eat it when feed is scarce. Consumption of large amount will cause clinical signs such as those of sanitation anorexia, pruritus and alopecia and gastro-intestinal irritation may result in diarrhea

Table 1: Effect of *P. hysterophorus* on human health and livestock

Disorder	Reaction
Contact dermatitis	Seasonal eruption of the exposed skin surface
Eczema	Chronic lichensified eczema of the exposed skin surfaces
Eczematoid dermatitis	Skin eruptions and itching
Dermatitis	Skin eruptions and itching
Allergic reaction	Cracks all over the sole
Allergic papules	Sore throat, bubbles in the mouth
Fatigue	General weakness, skin eruptions
Severe dermatitis	Loss of scalp, body hair, ridging on nails
Fever in cows	Inflamed Fever in cows udder and rashes
Hypersensitivity in rabbit	Restlessness, natural falling of hairs from the dorsal region of the neck and back, small boils and oozing of boils.
Ulcerations in buffaloes, horses donkeys, sheeps and goats kidney and liver	Acute and chronic toxicity, ulcers both in the mouth and digestive tract, oesophagus and abnormal folds, necrosis of

- Being toxic to livestock, causing both acute and chronic toxicity, a noticeable reduction in milk yield, tainting of milk with parthenin, depigmentation of skin, tainting in mutton and bitter taste in milk have been reported[37]
- Frequent contact with the plant stock or its pollen can produce serious allergic reactions such as dermatitis, hay fever and asthma in live especially horses (Table 1)

MANAGEMENT OF *P. hysterophorus*

It is necessary to control the problematic weed *P. hysterophorus* in time before spreading, because of its negative impact on natural and agro eco-systems. There are several methods available for controlling the parthenium weed. The methods are; manual and mechanical control, chemical and biological control and managing the weed by proper utilization.

Manual and mechanical methods: This is one of the most common methods for management among the rural population of India. Farmers manage parthenium weed within their crop field by uprooting or hoeing the plants out. Uprooting the weed manually when the soil is wet and slashing with sword, collecting and burning the weed before flowering are some of the effective means of control. However, they don't care to manage the parthenium weed along the adjoining road side, wasteland or fallow land which soon causes re-infestation of the weed into their fields. Uprooting the weed after seed setting will increase the area of infestation. The manual removal is usually neither very effective nor economical, because of the rapid re-growth requiring repeated removals for season-long control. Moreover, it is hard to get labour solely for parthenium weed uprooting as labours fear the ill effects caused by this plant. Pulling a plant in flower will aid in the dispersal of pollen grains, resulting in allergic reactions. Ploughing the weed in before the plants reach the flowering stage and establishing pastures or other plants may be effective.

Table 2: List of herbicides used for successful control of *P. hysterophorus*

Herbicides	Doses (kg a.i. ha^{-1})	References
Non-cropped areas		
Diquat	10 ppm	38
Paraquat	0.5	39
Glufosinate ammonium	2.5	40
Glyphosate	2.5	40
MON-8793	2.7	41
MON-8794	2.7	41
Common Salt	20%	42
Land-commercial, industrial, pastures, rights-of-way		
Metribuzin	0.7	43
Atrazine	6.0	44
Metsulfuron methyl	0.007	44
2,4-D	1.0	39
Tordon 75-D (2,4-D+Picloram)	3.0	44
Hexazinone	3.5	44
Gesaprium Combi	5.5	45
Chlorimuron	0.0013	43
Trifloxysulfuron	0.008	43
Halosulfuron	0.07	43
MSMA	1.12	43
Bromoxynil	0.56	43
Flumioxazin	0.09	43
Norflurazon	2.24	43
Clomazone	1.12	43
Fluometuron	2.24	43
Quinclorac	0.560	43
Grass pastures		
Dicamba	2.8	44

Chemical control: Chemical control of parthenium weed in India is gaining popularity. Because, this method of weed control is being used to eradicate the weed in time. The timing of chemical application is also important. The plants should be treated before flowering and seed setting and when other plants, especially grass, are actively growing and can re-colonize the infested area. Maintaining competition is important for control of parthenium weed, so spraying with a selective herbicide that will not kill other species is recommended. In open wasteland, non-cropped areas and along railway tracks and roadsides, the spraying of a solution of common salt (Sodium chloride) at 15-20% concentration has been found effective. Parthenium is found mostly in no man's land use of chemicals in such areas need community efforts. There are many herbicides available in the market for controlling the weed. With the onset of monsoon, emerged seedlings of sufficient height can be controlled by spraying of glyphosate at 1% solution. This application should be made at any cost before blooming. The list of herbicides is given in the Table 2 for controlling the weeds effectively.

Biological control: Even if the various chemicals control the weeds effectively in time, the continuous use

of the same causes the pollution hazards in the eco-systems. Therefore, weed management strategy needs to be shifted towards non chemical methods. Managing weeds using biological means is less expensive, permanent and pollution free. Biological control is the intentional manipulation of natural enemies by man for the purpose of controlling harmful weeds. Biological control seldom means complete eradication of the unwanted organism, but rather maintaining its population at lower than average that would occur in the absence of the bio-control agent. Parthenium is mainly a weed of waste and fallow land; hence bio-control is the most economical and practical way to keep the weed under check. Biological control of parthenium is the most cost-effective, environmentally safe and ecologically viable method. Several insects and pathogens have been tried from time to time for controlling the weed. The leaf-feeding beetle *Zygogramma bicolorata* and the stem-galling moth *Epiblema strenuana* are widely used in several countries to manage Parthenium. *Z. bicolorata* is now widely used in India to control Parthenium. The moth significantly reduces flower and seed production of the weed, especially at a young age. It has a relatively high reproduction in a short period of time. In 1983, a chrysomelid beetle *Z. bicolorata* was imported from Mexico for the management of parthenium. Host specificity tests were conducted with 40 plant species belonging to 25 families and the insect was declared to be safe to economic plants. Adults and larvae of *Z. bicolorata* feed on Parthenium leaves. The early stage larvae feed on the terminal and auxiliary buds and move on to the leaf blades as they grow. The full-grown larvae enter the soil and pupate. An insect density of one adult per plant caused skeletonization of leaves within 4-8 weeks provided this density is achieved early in the rainy season. In India, *Z. bicolorata* became abundant within three years after introduction, resulting in a significant reduction in parthenium density in local areas[46,47]. Other major biocontrol agents used are *Listronotus setosipennis,*(stem-boring weevil), *Smicronyx lutulentus* (seed-feeding weevil), *Bucculatrix parthenica* (leaf-mining moth), *Platphalonidia mystica* (stem-boring moth), *Conotrachelus albocinereus* (stem-galling weevil) and *Carmenta ithacae* (rootboring moth).

In the past several attempts have been made to control weeds with fungal products or mycoherbicides[48]. Several mycoherbicide products are now available in the market. A rust fungus, *Puccinia abrupta var. partheniicola* have been used as a biological control agent. Uredospore suspensions from 3 week old pustules of the rust have been applied to the foliage of parthenium and a consistent control effect has been achieved. This fungus is now being evaluated for development as a mycoherbicide. Pathogens like *Fusarium pallidoroseum*, *Puccinia melampodii* and *Oidium parthenii* also show good potential as biocontrol agents. The fungus *Cladosporium* sp. (MCPL-461) is regarded as an equivalent to a bio-control fungus. Some of the important disease-causing microorganisms reported on parthenium weed are *Alternaria alternata. A. dianthi, A. macrospora, Colletotrichum gleosporioides, C. capsici, Rhizoctonia solani, Fusarium oxy-sporum, F. moniliforme, Oidium parthenii, Myrothecium roridum, Phoma herbarum, Sclerotium rolfsii, Phyllody phytoplasma* and *Sclerotinia sclerotiorum.*

Allelopathic potential of plant species in controlling *P. hysterophorus:* The use of plants with allelopathic effect is an important component of biological control of parthenium. Competitive replacement of parthenium can be achieved by planting species like *Croton bonplandianum, C. sparsiflorus, Amaranthus spinosus, Sida acuta, Tephrosia purpurea, Stylosanthes scabra and Cassia auriculata*, which will compete with the weed and reduce its population. Similarly, planting *Cassia tora* will help to cover and suppress the growth of parthenium. In certain parts of India, crop rotation using marigold (*Tagetes* spp.) during rainy season, instead of the usual crop, is found effective in reducing parthenium infestation in cultivated areas. Growing competitive crops (fodder sorghum, sunflower and maize) or self-perpetuating competitive plant species and *Abutilon indicum* in non-crop areas is also recommended for effective management of parthenium. A recent botanical survey across India has shown that species such as *Cassia sericea, Cassia tora, Cassia auriculata, Croton bonplandianum, Amaranthus spinosus, Tephrosia purpurea, Hyptis suaveolens, Sida spinosa and Mirabilis jalapa* are capable of effectively suppressing parthenium in natural habitats[49]. Another study in India revealed that *Cassia sericea* reduces the accumulation of parthenium by 70% and parthenium population by 52.5%[50].

Both the root and shoot extracts of the three allelopathic grasses viz., *Dichanthium annulatum, Cenchrus pennisetiformis* and *Sorghum halepense* reduced germination and suppressed early seedling growth of *P. hysterophorus.* Aqueous extracts of *D. annulatum* and *C. pennisetiformis* were more inhibitory than extracts of *S. halepense*[51]. The aqueous shoot leachates of *Cassia occidentalis* have significant activity against *P. hysterophorus* and offer an alternative tool for the control of this obnoxious weed thus proving the concept of allelopathic or biomolecular interactions amongst the plant species as a natural replacement method, which was followed by *Rumex dentatus*[52]. The occurrence of allelopathy has been widely reported in aqueous extracts from *Imperata cylindrica, Desmastachya bipinnata, Otcantium annulatum, Eragrostis poaioides, Cenchrus ciliaris, Panicum antidotale* and *Sorghum halepense* markedly suppressed seedling growth and germination of parthenium[53,54]. Many other grasses have

also been reported to exhibit allelopathy to preclude the associated species through reducing their regeneration, growth and yield.

Management by utilization: Parthenium weed extracts have been well documented for their insecticidal, nemticidal and herbicidal properties by many researchers. However, there are no reports of these characteristic properties being used and any utilization taking place. The most practical use of parthenium weed in India so far has been through the production of compost and in vermicomposting along with other weeds. This method is being rapidly adopted by the farmers due to its simplicity[3].

Vermicompost preparation: Cut the parthenium weed into small pieces by using knife or chaff cutter and spread the material on the ground to a thickness of 10 cm layer. Over this spread *Tricoderma viridi* and spray urea at 0.5% solution (Generally 5kg urea/ ton of weed material). This sequence of layers is repeated up to a metre high and finally plastering should be done by with mud or clay soil. Keep the moisture level at 50-60%. After two weeks, a thorough mixing has to be given. The compost will be ready for field application after 40-45 days. It is a good source of nutrient and helps to maintain soil properties through aggregate formation. The `Parthenin' content acts as a growth regulator and so the next crop comes up well[42].

Mulching: Mulching has smothering effect on weeds by restricting the photosynthesis. It also conserves moisture, lower surface temperature, fertilize the soil, protect from rainy season and improve the soil quality.

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