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# Impacts and Management Strategies for *Parthenium hysterophorus*: A Weed of Global Importance

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**Abstract**

This paper explores the challenges and strategies in managing the invasive weed Parthenium hysterophorus. The use of chemical herbicides, such as glyphosate and atrazine, presents significant environmental hazards and has led to the development of resistant weed species. Alternative methods, including allelopathic control, have shown promise; specific plants like Cassia sericea and Imperata cylindrica effectively suppress Parthenium through natural chemical interactions. Biological control methods, leveraging natural enemies like microbial pathogens and insects, offer an environmentally friendly approach but require careful implementation. Integrated Weed Management (IWM) combines these biological controls with the use of suppressive plants to enhance effectiveness. Studies in Australia demonstrate that combining biological agents with suppressive plants like Mitchell grass and butterfly pea significantly reduces Parthenium growth, highlighting the potential for IWM as a sustainable solution for long-term weed control.

**Key Words:** Parthenium, Allelopathic, Weed Management

## Introduction:

Parthenium hysterophorus L. (Asteraceae), a notorious invasive plant, has spread across many regions of the world beyond its native range in North and South America and the West Indies. According to Holm et al. [2], this highly invasive species ranks among the most troublesome weeds known today. It poses significant global challenges, causing severe health issues in humans and animals, such as dermatitis, asthma, and bronchitis, as well as agricultural losses and threats to biodiversity. It is widely believed that the seeds of this weed

were introduced to India through grains imported from the USA under the US PL 480 scheme, also known as "Food for Peace," a food assistance program of the US government. The weed rapidly spread across nearly all states in India, becoming a naturalized species. In India, Parthenium was first identified in Pune (Maharashtra) by Professor Paranjape in 1951, as stray plants on rubbish heaps, and was later reported by Rao [3] as a new species in the country. However, the earliest record of this species in India dates back to 1814, when it was documented by Roxburgh, the father of Indian Botany, in his book Hortus Bengalensis [3, 4]. Since the weed became a global menace, including in India, various control methods have been employed, such as mechanical, competitive replacement (allelopathy), chemical, and biological control. Despite these efforts, the weed has proven difficult to manage due to various limitations. Biological control, which involves the deliberate use of natural enemies like insects, bio-herbicides, nematodes, snails, and competitive plants, is gaining traction as an effective and environmentally friendly alternative to conventional weed control methods [5].

The genus name Parthenium is derived from the Latin word parthenice, referring to the plant now known as Tanacetum parthenium (L.) Bernh., or "feverfew;" hysterophorus comes from the Greek words hystera (womb) and phoros (bearing), alluding to the plant's prolific seeding habit [8]. Commonly referred to as bitter weed, carrot weed, broom bush, and congress grass in India, it is also known as whitetop, escobar amarga, and feverfew in the Caribbean, and false ragweed and ragweed parthenium in the USA. Parthenium hysterophorus L. belongs to the tribe Heliantheae of the family Asteraceae, a highly diverse family with a cosmopolitan distribution [6].

In India, Parthenium hysterophorus L., also known as carrot weed, white top, or congress grass, is a herbaceous, erect annual plant of the family Asteraceae. It is commonly referred to as "gajar ghas" due to its resemblance to the carrot plant. The plant is believed to have originated from Mexico, America, Trinidad, and Argentina. After its noticeable presence was first recorded in Pune (Maharashtra) in 1956, Parthenium has spread like wildfire throughout India. Initially, Parthenium was primarily a problem in waste and vacant land, but it has since become a significant weed in crops as well. In forested areas, it poses a serious threat in grasslands, particularly in national parks, where it disrupts the herbivore-carnivore food chain. Currently, approximately 35 million hectares of land are estimated to be infested with Parthenium, and its spread into crop areas in recent years is particularly alarming.

**How Parthenium Spreads:**

Parthenium primarily spreads through its seeds, with the potential to produce up to 154,000 seeds per square meter. A single plant can yield between 15,000 to 25,000 seeds. These seeds are extremely lightweight and can be easily dispersed by wind, water, or various human activities. Additionally, Parthenium can regenerate from cut or broken parts, further aiding its spread. Its rapid proliferation in India is largely due to its allelopathic properties and the absence of natural enemies such as insects and diseases.

**Why Parthenium is a Dangerous Weed:**

Parthenium is a poisonous, invasive, problematic, allergenic, and aggressive weed that poses a significant threat to both humans and livestock. In India and Australia, it is recognized as a leading cause of dermatitis, asthma, and various nasal-dermal and naso-bronchial conditions. Beyond its health impacts, Parthenium also causes issues like blocking pathways and diminishing the aesthetic value of parks, gardens, and residential areas.

**Morphology of the Plant:**

Parthenium hysterophorus L., belonging to the family Asteraceae (tribe: Heliantheae), is a fast-growing, erect, and highly branched annual or ephemeral herb. The plant's life cycle consists of two distinct phases: the juvenile or vegetative stage, and the adult or reproductive stage. During the juvenile stage, the plant forms a rosette of large, dark green, simple, radicle, and pinnatisect leaves, which are small and non-flowering. These large lower leaves spread out flat on the ground like a carpet, preventing any other vegetation from growing underneath them [9]. In the adult stage, the plant becomes erect and extensively branched, with a deep taproot system that can reach up to 2 meters in height. The stem is hairy, octagonal, and longitudinally grooved, becoming tough and woody as the plant matures into a hardy bush. The leaves are simple, alternate, and pinnately or bipinnately dissected, measuring 20–30 × 12–25 cm, and they become smaller towards the branch tips. Both the stem and leaf surfaces are covered with four types of glandular and non-glandular, multicellular white trichomes. The flowers are creamy white, approximately 4 mm across, and emerge from the leaf forks. The plant produces an enormous number of pollen grains, about 624 million per plant, which are anemophilous (wind-pollinated). Each flower produces four to five black, wedge-shaped seeds and that are about 2 mm long, with thin white scales, making them difficult to see with the naked eye. The plant is a

prolific seed producer, capable of producing up to 25,000 seeds per plant, contributing to a large seed bank in the soil [10].

**Habitat:**

Parthenium hysterophorus thrives in various environments, including wastelands, public lawns, orchards, forestlands, flood plains, agricultural areas, urban areas, overgrazed pastures, industrial zones, playgrounds, roadsides, railway tracks, and residential plots. Drought conditions and reduced pasture cover create ideal conditions for the establishment of parthenium weed. Although the weed can grow in most soil types, it is particularly dominant in alkaline, clay loam soils.

**Harmful Effects:**

Parthenium hysterophorus is considered the most dangerous terrestrial weed due to its harmful impacts on both human health and biodiversity, as detailed below.

**Effects on Ecosystem:**

Parthenium has been reported to cause significant habitat changes in native Australian grasslands, open woodlands, riverbanks, and flood plains [9]. It aggressively colonizes wastelands, roadsides, railway sides, watercourses, cultivated fields, and overgrazed pastures. Between 2001 and 2007, the weed invaded 14.25 million hectares of farmland, a dramatic increase from the 2 million hectares invaded between 1991 and 2000 [10].

**Effects on Crops:**

Parthenium contains chemicals such as parthenin, hysterin, hymenin, and ambrosin, which exert strong allelopathic effects on various crops. Parthenin, in particular, has been identified as an inhibitor of germination and radicle growth in both dicot and monocot plants [13]. The weed also affects nodulation in legumes by inhibiting the activity of nitrogen-fixing and nitrifying bacteria, including Rhizobium, Actinomycetes, Azotobacter, and Azospirillum. The plant produces an enormous number of pollen grains (approximately 624 million per plant), which are dispersed in clusters of 600–800 grains and can settle on vegetative and floral parts, including the stigmatic surface, inhibiting fruit set in crops such as tomato, brinjal, beans,

capsicum, and maize. In India, P. hysterophorus has been reported to cause up to a 40% yield decline in agricultural crops [14]. In Ethiopia, grain yield losses in sorghum (Sorghum bicolor L. Moench) of between 40% and 97% have been reported when Parthenium is left uncontrolled throughout the season [7, 15]. In Australia, P. hysterophorus infests approximately 170,000 km² of prime grazing land in Queensland, resulting in economic losses of around $16.8 million per year to the pasture industry [16]. On cracking clay soils with annual rainfall between 600 and 800 mm, P. hysterophorus has been estimated to reduce the carrying capacity of affected farms by about 40% [17, 18]. Additionally, the weed serves as a collateral host for many crop diseases caused by viruses.

**Effects on Animals:**

Parthenium is toxic to animals, causing dermatitis with pronounced skin lesions in various species, including horses and cattle. When ingested, it can cause mouth ulcers and excessive salivation, and a diet containing 10–50% of this weed can be fatal to cattle [19]. In dogs, it causes anorexia, pruritus, alopecia, diarrhea, and eye irritation. The consumption of buttermilk and tainted meat from buffaloes, cows, and goats that have grazed on grass mixed with Parthenium can lead to acute illness in humans. Additionally, extracts from the weed have been shown to significantly reduce the white blood cell count in rats, indicating its potential to weaken the immune system [20].

**Effects on Human Beings:**

The pollen grains, airborne dried plant parts, and roots of Parthenium cause various allergic reactions in humans, including contact dermatitis, hay fever, asthma, and bronchitis. Common allergens found in this weed include parthenin, coronopilin, tetraneuris, and ambrosin. The pollen of Parthenium is particularly associated with asthma (allergic bronchitis), especially in children playing outdoors and in adults and the elderly. Skin contact with the plant can cause dermatitis, and the condition can spread across the body, leading to significant discomfort [21].

**Clinically, Parthenium dermatitis can present in five distinct patterns:**

**1. Classical Pattern (Airborne Contact Dermatitis, ABCD):** Affects the face, especially the eyelids, neck, V of the chest, and cubital and popliteal fossae.

**2. Chronic Actinic Dermatitis (CAD) Pattern:** Involves exposed areas such as the forehead, ears, cheeks, neck, and forearms, with relative sparing of non-sun-exposed areas like the eyelids, retroauricular areas, and undersurface of the chin.

**3. Mixed Pattern:** A combination of the classical and CAD patterns, manifesting as scattered, infiltrated, scaly papules on exposed parts and dermatitis on the eyelids, flexures of extremities, and neck.

**4. Photosensitive Lichenoid Eruption Pattern:** Presents with pruritic, discrete, flat, violaceous papules, and plaques on sun-exposed parts such as the forehead, ears, cheeks, upper chest, back, and forearms, resembling photosensitive lichenoid eruptions.

**5. Prurigo Nodularis-like Pattern:** Characterized by multiple hyperkeratotic papules and nodules on the extremities, with histopathologic features similar to prurigo nodularis [12, 22].

**Control of Parthenium:**

Singh (1997) identified the use of bio-control agents (insects and fungal pathogens) and the exploitation of competitive plants (allelopathy) as the most economical and practical methods for managing Parthenium. However, despite these efforts, the weed has not been reduced below the threshold level and continues to threaten biodiversity and pose significant health risks to humans and animals. Various control methods, including physical, chemical, bio-herbicidal, and integrated approaches, are being practiced worldwide and are discussed below.

**Physical Control:**

Manual uprooting of Parthenium before it flowers and sets seed is the most effective method for controlling this weed. Uprooting after seed setting can actually increase the infestation area. Some landholders have successfully ploughed the weed during its rosette stage before it seeds, but this must be followed by planting a crop or direct seeding of perennial pasture. Physical control, which involves hand weeding, is time-consuming and unpleasant, compounded by the health hazards associated with handling Parthenium. Burning has been employed as a strategy to manage the weed, but it is not considered effective for Parthenium control. Research indicates that burning for other purposes (e.g., woody weed control) does not result in increased Parthenium infestation, provided the pasture is allowed to recover before livestock are

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reintroduced. However, burning requires large amounts of fuel and destroys other economically important plants growing nearby, making it an inadequate control method [23, 24].

**Fig. No-1 Manual uprooting of Parthenium at Career Point University, Kota**

**Chemical Control:**

Chemical control is effective in areas where Parthenium natural enemies are absent. Herbicides such as chlorimuron ethyl, glyphosate, atrazine, ametryn, bromoxynil, and metsulfuron are known to be highly effective in controlling this weed. Studies [25–27] have shown that applying 2,4-D EE (0.2%) and metribuzin (0.25% and 0.50%) is particularly effective for controlling Parthenium 15 days after spraying (DAS), resulting in the complete eradication of the weed population without allowing further emergence. Khan et al. [28] reported that the timing of herbicidal application is crucial, with the rosette stage being the most effective time for control in wastelands, non-cropped areas, along railway tracks, water channels, and roadsides. Among various herbicides, glyphosate and metribuzin have shown the highest mortality rates 4 weeks after treatment (WAT) at both rosette and bolted stages, outperforming 2,4-D, triasulfuron + terbutryn, bromoxynil + MCPA, and atrazine + s-metolachlor. Pendimethalin was found to be the least effective treatment for both growth stages. Overall, herbicides are more effective on rosette-stage Parthenium plants than on bolted plants. In open wastelands, non-cropped areas, and along railway tracks and roadsides, spraying a solution of common salt (sodium chloride) at a 15–20% concentration has also been effective.

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**Mechanical Management:**

In many crop fields, Parthenium germinates profusely when left fallow for one season. In such cases, deep ploughing before the weed flowers is both economical and effective, as the weed can be turned into green manure. Care should be taken to spot-treat any remaining plants with chemicals, as those not fully buried may regenerate.

**Cultural Management:**

Farmers should be advised to plant fast-growing crops like sorghum and Sesbania (daincha) to suppress Parthenium growth, particularly in fields that are left fallow.

**Legal Management:**

State and central governments should declare Parthenium a noxious weed and implement laws holding landowners responsible for controlling it on vacant plots. Municipalities, the transport ministry (for roadsides), the railway ministry (for railway tracks), and irrigation departments (for canal bunds) should take appropriate steps to control the weed using available methods.

**Chemical Management:**

In areas where manual uprooting is not feasible due to labor shortages or high costs, Parthenium can be controlled using glyphosate (1–1.5%) for total vegetation control or metribuzin (0.3–0.5%) or 2,4-D (2–2.5 kg a.i.) where grasses need to be preserved. In different crops, herbicide use should be guided by weed scientists, as different crops require different herbicides. For example, alachlor (2.0 kg a.i.) can be used as a pre-emergence treatment to control Parthenium in soybean, rajmaha, banana, and tomato crops, while metribuzin (0.50–0.75 kg) can be used as a pre-emergence treatment just after sowing in potato, tomato, and soybean crops. Atrazine is recommended for use in maize.

**Biological Control:**

Biological control involves the intentional use of natural enemies to manage harmful weeds. It is cost-effective, environmentally safe, and poses no threat to non-target organisms, biodiversity, or the environment. Biological control agents include insects, fungi, nematodes, snails, slugs, and competitive plants, with insects receiving the most attention in Parthenium

control. Biological control is self-perpetuating and can spread on its own, making it easier to integrate with other control methods. Among the biological control methods, using *Zygogramma bicolorata* has emerged as one of the most promising. Under biological control programs, host-specific bioagents from the weed's native range are imported into other countries where the weed has become invasive.

**Public Awareness and Capacity Building Programs:**

For successful Parthenium management at the national level, public participation and awareness are crucial. Each participating unit should organize Parthenium Awareness Days, weeks, fortnights, or months. These programs should include live demonstrations, uprooting activities involving the public, students, and employees, photo exhibitions, video presentations, and rallies. Media should be invited to cover these activities to raise awareness about the weed. Training for various stakeholders is also essential for the successful implementation of Parthenium management. Master trainers from different states may be trained by the Directorate of Weed Research, Jabalpur, who can then disseminate this knowledge to other stakeholders. Emphasis should be placed on spreading the message through electronic and print media. The initial culture of the bioagent Z. bicolorata may also be provided by the Directorate of Weed Research for further mass multiplication and dissemination, along with training for stakeholders.


**Fig. No-2 Public Awareness and Capacity Building Programs at Kasar Village**

**Disadvantages of Herbicides:**

The use of chemical herbicides comes with several disadvantages, including environmental hazards and the development of resistance among many weeds. Resistance has been documented against herbicides like atrazine, 2, 4-D, metribuzin, paraquat (Gramoxone), trifluralin, diphenamid, and glyphosate [29–31]. Glyphosate, in particular, is one of the most toxic herbicides, with many wild plant species being damaged or killed by applications as low as 10 micrograms per plant. Moreover, glyphosate can be more harmful to wild flora than many other herbicides. Atrazine is highly persistent in soil and has been classified as a restricted-use pesticide (RUP) in the USA due to its potential for groundwater contamination [32].

**Allelopathic Control:**

The term "allelopathy" was introduced by Molisch (1937) and generally refers to the harmful effect of one plant species on the seed germination, growth, and reproduction of another. Numerous plants have been reported to possess allelopathic potential, and efforts have been made to utilize this property for weed control [33]. Parthenium can be competitively suppressed by planting species such as Cassia sericea, C. tora, C. auriculata, Croton bonplandianum, Amaranthus spinosus, Tephrosia purpurea, Hyptis suaveolens, Sida spinosa, and Mirabilis jalapa, which are effective in natural habitats [34]. In India, a study revealed that Cassia sericea reduced Parthenium biomass by 70% and population density by 52.5% [35]. Another study found that aqueous extracts from Imperata cylindrica, Desmostachya bipinnata, Otcantium annulatum, and Sorghum halepense significantly suppressed seedling growth and germination of Parthenium [36]. Additionally, crop rotation using Marigold (Tagetes spp.) during the rainy season has been 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, have been shown to reduce germination and suppress early seedling growth of the exotic weed P. hysterophorus. Aqueous foliar extracts of Azadirachta indica, Aegle marmelos, and Eucalyptus tereticornis have been found to completely inhibit the seed germination of Parthenium and may be used for its control.

**Biological Control:**

Biological control is an environmentally sound and effective method of reducing or mitigating pests and their effects through the use of natural enemies. Over the past three to four decades, significant emphasis has been placed on controlling Parthenium through various bio-control

agents, including microbial pathogens, insects, and botanicals [24, 37]. Among the different bio-control strategies, the use of plant pathogens for weed control has gained acceptance as a practical, safe, and environmentally beneficial method applicable to agro-ecosystems [38].

There are two basic strategies for implementing biological weed control: the introduction of foreign pathogenic organisms, known as the "classical approach," and the "augmentative" or "bio-herbicidal approach," where the population of existing pathogenic organisms (either native or introduced) is increased through mass rearing. In epidemiological terms, these strategies are referred to as the "inoculative" and "inundative" strategies, respectively [39].

**Integrated Weed Management:**

Neither the classical nor the bio-herbicidal strategies, when applied alone, are sufficient to suppress Parthenium effectively. However, Integrated Pest Management (IPM) has gained attention in recent years as a means of reducing pest-related losses while minimizing reliance on chemical controls, thereby promoting the long-term sustainability of agricultural systems. In Australia, to complement the classical biological control approach with other management tactics, two selected suppressive plants native Mitchell grass (*Astrebella squrossa*) and the introduced legume butterfly pea (*Clitoria ternatea*) along with two biological control agents a leaf- and seed-feeding beetle (*Zygogramma bicolorata*) and a stem-galling moth (*Epiblema strenuana*) have been used to control Parthenium under an integrated weed management program. The suppressive plants significantly inhibited weed growth even in the absence of the biological control agents. This suppressive ability was further enhanced when one of the biological agents was present. Research conducted in Australia has demonstrated that Parthenium weed can be more effectively managed by integrating existing biological control strategies with the use of suppressive plants.

This approach reduced the growth of Parthenium by 60–80% in the first year and 47–91% in the second year. The biomass of suppressive plants was 6–23% greater when biological control agents were present, demonstrating that Parthenium weed can be more effectively managed by combining the current biological control strategies with selected suppressive plant species.

**Conclusion:**

*Parthenium hysterophorus* is a highly invasive and harmful weed that poses significant threats to agriculture, biodiversity, and human and animal health across many regions, particularly in India. Its rapid spread is facilitated by its prolific seed production and allelopathic properties, which inhibit the growth of other plants and make it difficult to manage. Despite various control methods, including mechanical, chemical, and biological strategies, the weed continues to thrive and spread, underscoring the need for integrated management approaches. Biological control, which leverages natural enemies such as insects and pathogens, has shown promise as an environmentally friendly alternative to traditional methods. However, no single strategy has proven entirely effective on its own. Integrated Weed Management (IWM), which combines biological control with other methods like the use of suppressive plants, offers a more sustainable and comprehensive approach to controlling *Parthenium*. Continued research, public awareness, and coordinated efforts at national and international levels are crucial to mitigate the impact of this weed and protect ecosystems, agriculture, and public health from its adverse effects.

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