Partheniumhysterophorus L.: An Overview of Management and Beneficial Aspects

Abstract

The poisonous and invasive weed *Partheniumhysterophorus* L., also referred to as "famine weed" or "congress grass," is highly dangerous for human health, agriculture, and biodiversity. This plant is well known for its aggressive growth and allelopathic qualities, which prevent natural vegetation and good crops from growing. An overview of the benefits and treatment of *Partheniumhysterophorus* is given in this abstract. Many techniques, including mechanical removal, chemical herbicides, biological control agents, and cultural practices, are used to combat this weed. To successfully control its spread, integrated techniques are frequently advised. *Partheniumhysterophorus* has drawbacks, yet it also has some positive qualities. It has therapeutic qualities, and research indicates that it may be used in phytoremediation and the synthesis of biofuel. The main goal is to draw attention to how critical it is to manage *Partheniumhysterophorus* properly while investigating its possible benefits, underscoring the necessity of long-term, all-encompassing solutions to deal with this environmental threat.

Keywords: Parthenium, Ecology and human health Allelopathy, Herbicides, Bioethanol, vermicompost

Introduction

Parthenium is an Asteraceae herbaceous annual or short-lived perennial weed. It is a problem in many countries' agricultural and natural environments, which can have negative effects on ecosystem health, crop output, human health, and livestock. *Parthenium* comes from the Latin parthenice, meaning medicinal [1]. The annual herbaceous plant *Partheniumhysterophorus*, known as "*parthenium* weed" or "ragweed," is very invasive and toxic. Congress grass (*Partheniumhysterophorus* L.), a tall, much-branched annual or ephermeral plant in the family Asteraceae (Tribe: Heliantheae), is a renowned environmental, medicinal, and agricultural problem. [2] Weeds are plants that are generally considered unwanted because of their harmful, hazardous, or economically ruinous characteristics. As such, they constitute a serious threat to primary production and biodiversity.

A herbaceous plant with a deep taproot, *Partheniumhysterophorus* is tall, branching, scented, and annual (or short-lived perennial). The species grows quickly and reproduces via seeds. [3] The wild populations they've created may reproduce on their own and have changed adjacent manmade and biological systems. This prolific seed producer allelopathically affects surrounding plants and competes with commercially important items. Partial *hysterophorus*' history is one of unforeseen effects. American *Partheniumhysterophorus* is an invasive plant. [4] Currently, it inhabits more than 40 nations on five continents, encroaching on croplands and uncultivated regions with varying climatic, edaphic, and geographic characteristics [5]. It has drawn attention worldwide because of its unrelenting invasion of ecosystems, detrimental effects on agriculture, and health risks. It is general knowledge that invasive species are ones that have spread to new areas outside of their original ecosystems. Due to its geographic expansion over the last few decades, this plant now poses a threat to future invasions of far larger areas of the world. [6 & 7] The *parthenium* weed is native to Mexico, Central America, and South America. This short-lived, upright plant blossoms in hot climates and grows quickly. It is known as carrot weed, star weed, congress grass, wild feverfew, ragweed, caustic weed, white top, and the "Scourge of India" throughout Asia, Africa, Australia, and the Pacific.

This weed is thought to have arrived in India with US PL 480 grains, popularly known as "Food for Peace," a US government food assistance project. The weed initially appeared in India in

the 1950s. They become a naturalised weed in practically every Indian state like a fire. [8] *Parthenium* reduced crop yields by 40% in India. [131] In India, the cultivation and consumption of cannabis have experienced a rapid and widespread increase. It occupies almost 5 million acres of the country's territory. [9] Most Indian states are now under threat from *parthenium*. It has now spread over the whole country, affecting some 35 million hectares of crop and non-crop areas, including roadsides, wastelands, gardens, and railway lines. [10] In addition to invading wasteland, communal property, the sides of roads and railway tracks, and woods, it is currently one of the most common weeds in practically all types of agricultural fields. All of the states in India have reportedly seen varying degrees of *partheniumhysterophorus* spread. This weed is a significant issue in almost all of India's states, including Karnataka, Andhra Pradesh, Haryana, Bihar, Madhya Pradesh, and Uttar Pradesh. [11]. The states with the highest density and dispersion of *parthenium* are typically Andhra Pradesh, Maharashtra, Bihar, Punjab, Chhattisgarh, Delhi, Haryana, Karnataka, Madhya Pradesh, Tamil Nadu, and Uttar Pradesh; Jharkhand, Assam, Gujarat, Rajasthan, Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Orissa, and West Bengal have medium levels; and the Andaman Islands have low levels. On the other hand, the degree of its infestation differed across and between states.

Table 1: Status of *Partheniumhysterophorus* in different states of India.

Name of states	Over all spread and infestation level
Andaman & Nicobar Islands, Arunachal Pradesh, Goa, Gujarat, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim	Low
Assam, Chandigarh, Chattishgarh, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Orissa, Pondicherry, Rajasthan, Uttarakhand	Medium
Andhra Pradesh, Bihar, Delhi, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh	High

Originally, this plant species was relatively benign, coexisting harmoniously with other flora in its native habitat. However, it was the process of globalization, facilitated by the movement of people, goods, and agricultural products, that allowed this unassuming weed to traverse continents and establish itself as a formidable invasive species. *Parthenium* spreads rapidly through wind-dispersed seeds and poses significant challenges for control. Management strategies include manual removal, herbicides, and biological controls using insects. Farming greatly benefits from understanding *Partheniumhysterophorus* effects, habitat, and biology and it will only be feasible to control and manage this hazardous weed in various ways through knowledge of it. The current review investigates this possibility using knowledge of *Partheniumhysterophorus*' habitat, distribution, biology, and chemical makeup. The aim is to comprehensively explore the multifaceted issues surrounding *Partheniumhysterophorus*. It aspires to shed light on the weed's taxonomy and morphology, distribution and spread, ecological implications, agricultural impact, and the health hazards it poses to both humans and livestock. Furthermore, this paper will delve into the various control and management strategies employed to combat *Parthenium*'s proliferation, alongside the challenges and future prospects for control. Ultimately, the paper underscores the importance of ecological restoration efforts and evaluates the legislative and regulatory measures in place to mitigate the global spread of this invasive weed. By addressing these issues, this review seeks to raise awareness about the severity of the *Parthenium* issue, emphasizing the necessity of continued research and coordinated action to curb its adverse effects on the environment, agriculture, and public health.

1. Taxonomy and Morphology

Partheniumhysterophorus, commonly known as "famine weed" or "congress grass," belongs to the plant family Asteraceae. The genus *Parthenium* includes several species, but P. *hysterophorus* is the most widely recognized and problematic. Taxonomically, it is classified as follow: [12]

- **Kingdom:** Plantae
- **Phylum:** Angiosperms
- **Class:**Dicotyledonous plants
- **Order:** Asterales
- **Family:** Asteraceae
- **Genus:***Parthenium*
- **Species:***P. hysterophorus*

The genus *Parthenium* includes 17 species, all native to tropical America; one species, *Parthenium*argentatumGray (Guayule), has potential economic value. Other weedy genera in the same subtribe Ambrosiinae are Xanthium, Ambrosia, Iva, Hymenoclea, Dicoria, Parthenice and Euphrosyne, allnative to the Americas. [13] Crop plants of economic importance within the tribe Heliantheae include sunflower (Helianthus annus L.), Jerusalem artichoke (Helianthustuberosus L.) and niger seed (Guizotiaabyssinica Cass.). This classification places *Partheniumhysterophorus* within the larger group of asters, daisies, and sunflowers, making it a distant relative of some well-known garden flowers.

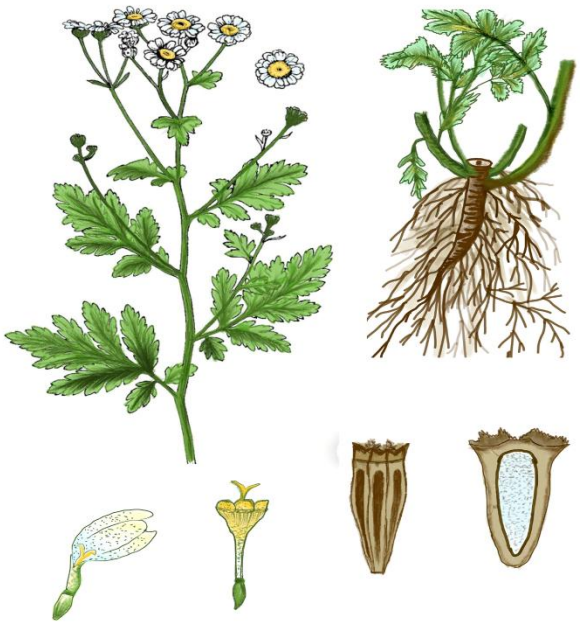

Fig.1 Different parts of Partheniumhysterophorus

Partheniumhysterophorus is a densely branched, annual, upright herbaceous plant that forms rosettes early on. Sometimes grows to 2.5 m or more in maturity. (14) Every flower-head contains seeds, or achenes as they are more commonly known. Two straw-coloured papery structures (really dead tubular florets) and a flat bract make up the seeds, which are obovate to ellipsoid, light brown when young and dark brown when mature. [129]. *Parthenium* flowers 24-48 days after germination. This can happen year-round. Weed seed germination is optimal at 21/16 ◦C (day/night) alternating temperatures. Its seeds can survive 4-6 years in the soil as seed bank. Studies suggest their submerged seeds live longer than soil-surface seeds [7]. Stem is cylindrical, solid, fluted, and has longitudinal lines that match leaf midribs. Greenish stems with tiny soft hairs are mature. Leaves are alternately

arranged and stalked (petioles) up to 2 cm long in two types. Early on, it produces rosette habitat. Alternate, simple, deeply pinnatifid leaves are present. Lower leaves have broad, sharply split blades 10–20 cm long and 6–10 cm wide. [16] Leaf abaxial surfaces have short, stiff hairs near the surface. Terminal panicles have clusters of capitulum, little flower heads. A stalk supports each flower-head (capitulum). Capitulums (3-5 mm broad) are off-white or white with 0.3-1 mm ray florets. They likewise have 15-60 tubular florets in the centre encircled by two rows of tiny green bracts. Flowers can appear year-round, but most often during rainy season.

2. Seed dispersal:

It spreads mostly by seed. The weed can produce 154,000 seeds/m2 and 15000–25,000 seeds per plant. The seeds are lightweight and can be carried by wind, water, machinery, stock, feral and native animals, and through feed and seeds. Due to increased stock fodder and travel, drought helps seed dispersion. [17]*Parthenium* may regrow shattered portions. Its allelopathic effects and lack of natural enemies like insects and illnesses contributed to its rapid growth in India. *Parthenium* seeds can germinate at temperatures ranging from 8º to 30º C, with 22º to 25º C being the ideal range. According to persistence studies, *parthenium* seeds buried 5 cm below the soil's surface had a survival rate of over 70% for at least two years, although seeds on the soil's surface only lasted for six months. [18] Additionally, 20-year seed viability has been documented.

3. Causes of rapid spread of *parthenium*

3.1. High reproductive potential:*Parthenium* weed is a prolific seed producer, producing up to 25,000 seeds per plant [19] and possessing a massive seed bank estimated at 2,00,000 seeds/ m2 in abandoned fields [130]. *Parthenium* seeds can grow at any time of year, assuming enough moisture levels, and can thrive in extremely adverse environmental circumstances.

3.2. Fast growth rate: The annual weed grows quite quickly. In general, plants start flowering between 4 and 8 weeks after they are born, and they may continue to bloom for several months. [20] The weed can sprout, grow, mature, and set seeds in four weeks when under unfavourable circumstances, such as drought stress.

3.3. Allelopathic potential: Allelopathy is the process by which *parthenium* stops other plants from germinating and growing. It is found that water-based extracts of the leaves and flowers stopped barely, wheat, and peas from sprouting and growing. When *Parthenium* extracts were sprayed directly on food plants. [21] it was found that cell survival and chlorophyll content dropped by a lot.

3.4. Unpalatable to animals: Studies have shown that goats can ingest *parthenium* while buffalos, cows, and sheep cannot. There are significant health risks to cattle in *Parthenium*-invaded areas, according to earlier findings in India. [22] In artificial feeding studies, cattle, bulls, and buffalo all accepted the weed either by itself or in combination with green feed, with disastrous results. The majority of individuals experienced severe dermatitis and toxic symptoms and passed away within 8 to 30 days

4. Infestation of *Partheniumhysterophorus*

4.1. Agriculture: Before 1980, this weed was rarely found in croplands, but now it invades practically all agriculture crops, woods, and plantation habitats. *Parthenium* is a damaging agricultural weed in Uttar-pradesh, Uttarakhand, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, etc. It thrives in fallow periods after modest rainfall in agriculture areas with one crop. It's heavily infested in irrigation canal fields. *Partheniumhysterophorus* weed thrives in narrow, human-made waterway systems (ditch or canal) due to moisture and irrigation water canal seeds.

4.2. Forest: It was formerly unknown in gardens and woodlands, but it has spread rapidly. Due to poor weeding, this plant thrives in orchards. *Parthenium* weed invades Uttar Pradesh, Madhya Pradesh, and Maharashtra mango orchards, giving producers problems. Most lower-elevation apple orchards in Himachal Pradesh have this weed. Growers in Maharashtra are also plagued by *Parthenium* weed in orange plantations. *Parthenium* thrives on bare land/wastelands and woodlands, inhibiting other plant development and threatening local biodiversity. *Parthenium* weed has invaded Indian National Parks including Pench, Rajaji, Kanha, and Bandhavgarh.

4.3. Bare lands: *Partheniumhysterophorus* thrives on bare soil. It grows on roadsides, surrounding industries and mills, platforms, and even places that are unsuitable for agricultural cultivation due to metal toxicity or mineral nutrient shortages. Key trait of *Parthenium* weed is its vast variety of habitat and ability to tolerate hard circumstances that other plants cannot. It contributes to *Parthenium*'s fast spread as an alien weed in India and other nations.

5. Harmful Effects of *Parthenium*

5.1. Consequence on Human Health: Approximately 73% of people living with *parthenium* weed are sensitive to its parts. Compared to males, females are twice as sensitive. [23]*Parthenium* weed can harm agricultural labourers. Long-term plant exposure during agriculture can cause allergic responses, skin and respiratory concerns. *P.hysterophorus* causes several cutaneous and respiratory diseases in humans. [24] Air-borne contact dermatitis (ABCD) affects the face, eyelids, neck, chest and popliteal fossae [25]. Chronic actinic dermatitis (CAD) affects the forehead, cheeks, nape of neck, rim of ears, forearm, hands, under chin, and skin folds [26]. Other skin abnormalities include mixed ABCD and CAD patterns with dispersed infiltrating scaly papules over exposed areas, eyelid dermatitis, and neck extremity flexures. Fourth, photosensitive lichenoid eruption pattern causes violaceous papules and plaques on sun-exposed cheeks, forehead, ears, upper chest, back, and hand dorsae[27]. Multiple hyperkeratotic papules and nodules with prurigo nodularis-like histopathology are seen [27 & 28]. At first,fever and respiratory issues grow, then asthma and allergic bronchitis develop after 3–5 years of incremental exposure [29].

5.2. Consequence on Animal Health: Plants like *partheniumhysterophorus* can damage animals. In livestock, it causes "*parthenium* poisoning." Skin, respiratory, and digestive related symptoms appear. A substantial decrease in rat WBC count indicates that *parthenium* extract weakens the immune system [30]. *Parthenium*contaminated pasture can cause weight loss and death. This herb can kill cattle (10–50%) in the diet [31]. Forage quality and quantity can be reduced by this invasive plant in pastures and rangelands, affecting grazing animals' health and production. P. *hysterophorus* can produce dermatitis and anorexia in mature livestock when fed continuously for up to 12 weeks (Osmanabadi). [32] It produces acute disease when bittermilk and infected buffalo, cow, and goat meat are fed *parthenium*-laced grass [33]. Protecting domestic and wild animals in the impacted areas requires *parthenium* weed eradication.

5.3. Effects on Ecosystem:*Partheniumhysterophorus*, or *parthenium* weed, exerts detrimental effects on ecosystem. As an aggressive invasive species, it displaces native plants, leading to reduced biodiversity. In Mehari Sub-Watershed of Rajouri Forest Range, India, *Parthenium* weed invades new areas and replaces native plants, causing biodiversity loss. [34] This disrupts ecological balance and can impact various organisms that are dependent on native flora for habitat and food. The introduction of *Parthenium* weed in Awash National Park, Ethiopia, led to a 69% decrease in herbaceous species stand density within a few years. [35] Aggressively colonising wastes, roads, railways, water courses, cultivated fields, and overgrazed pastures, it invaded 14.25 million hectares of farm land during 2001-2007, up

from 2 million hectares in 1991-2000. [36]*Parthenium* weed alters soil chemistry and depletes water resources. It reduces crop production by competing with nutrients and space. *Parthenium* weed removal is crucial to ecosystem health and limiting its negative effects on native plant and animal species, soil quality, and water systems.

5.4. Impact of *Parthenium* on crop production:*Partheniumhysterophorus*, commonly known as *parthenium* weed or Congress grass, negatively impacts crop production. This invasive plant competes with crops for essential resources like water, nutrients, and sunlight, reducing crop yield. *Parthenium* weed leaf litter can reduce seedling emergence and affect the early growth of a wide range of pasture and crop species.[37]*Parthenium* weeds pollute soils because their leaves produce p-coumaric acid and caffeic acid, reducing the germination, growth, and yield of Indian traditional crops. These hinder growth. [38] Its rapid growth and allelopathic properties can hinder the germination and growth of crops. *Parthenium*, however, allelopathically affected crop sprouting and development. [39] Research indicates that *parthenium* weed plants are more prevalent in corners of wheat fields, resulting in a 2 to 3% drop in production. [40]*Parthenium*'s allelopathy makes it hard for wheat, rice, maize, pigeon pea, sorghum, tomatoes, brinjal, beans, and ceraels and black gramme to germinate and grow, reducing yields by 40%. [41 & 42) *Parthenium* weed's prolific pollen can also affect crops by causing allergic reactions in field workers, disrupting agricultural activities. Additionally, the presence of *parthenium* weed in harvested crops can contaminate the produce and make it less desirable for sale or consumption. Effective management and control measures are necessary to mitigate its adverse effects on crop production.

5.5. Effects on Soil:*Partheniumhysterophorus*, also known as *parthenium* weed, has detrimental effects on soil. This invasive plant can alter soil chemistry by releasing allelopathic compounds, which inhibit the germination and growth of native plants. It competes with other vegetation for essential nutrients and water, depleting soil resources and reducing soil fertility. *Partheniumhysterophorus* L. inhibited Rhizobium phaseoli and Azotobactervinelandii. Important weed inhibitors parthenin, caffeic acid, and anisic acid were inhibited similarly. [43] The invaded plots had the highest pH, phosphate, and potassium, while the non-invaded plots had low to moderate values. [44]*Parthenium* weed can absorb nutrients from impoverished soils, resulting in high nitrogen (3%), phosphorus (2%), potassium (4%), and other nutrients, making it a green manure for field crops. [45] Additionally, the decomposition of *parthenium* weed can lead to soil acidification, which further hinders the growth of desirable crops and plants. In soil with *parthenium* weed leaf litter, all test plant species had 20–40% lower seedling emergence. The leaf litter from one to two *parthenium* weed plants may inhibit seedling emergence from other plant species in the seed bank. [46] The accumulation of *parthenium* biomass can also impede water infiltration and exacerbate soil erosion. These soil impacts highlight the importance of controlling and managing *parthenium* weed to maintain healthy, productive soils. Most of the soil parameters considered in this study were found to be better for the infested quadrats than non-infested quadrats, suggesting that *parthenium* weed does not impose adverse impact on soil nutrients. [47]*Parthenium* residue extracts were phytotoxic to both test crops and high in phenolics. Radish and chickpea growth may be reduced by *Parthenium* residue phenolics and affects the associated soil chemistry. (48)

6. Management of *Partheniumhysterophorus*

Due to the rapid rate at which it reproduces, the weed known as *parthenium* presents a formidable obstacle to be overcome while attempting to eradicate it. Because the plant has a greater detrimental impact not only on the environment but also on public health, it is imperative that measures be taken

right away in order to remove it. Because India faces a significant threat of a rapid invasion of the weed throughout its agricultural fields, [49] the nation should pay the appropriate amount of attention to the treatment that will prevent *Parthenium* from spreading. Numerous studies are currently being conducted in an effort to determine the most effective and economical method of preventing it. To identify a practical and affordable strategy to eradicate this weed, active research is being conducted. [50] The following are examples of some of the control mechanisms that could be used in India:

6.1. Mechanical: The best technique is to manually remove *parthenium* prior to blooming and seed setting. [51]When the soil is moist, doing this is simple. The extent of the infestation will grow if the weed is pulled out after the seeds have set. It has been successful for some landholders to plough *parthenium* weed when it is in the rosette stage, but this has to be followed by direct seeding the perennial grassland or planting a crop.[52]Pollen grains are dispersed when a flowering plant is pulled, which can cause allergy responses. It could be useful to sow pastures or other plants and to plough up weeds before the plants blossom.[53]Even in these situations, precautions such donning hand gloves and nasal masks are essential; however, this solution is only short-term and must be repeated.[55]The early indications of bolting or blossoming should be followed by hand weeding. Removing weeds later on might not stop seed production, especially if the removed plants are left in the field. In large regions with high infestation, the manual technique is not inexpensive nor feasible.[52]

6.2. Cultural: Plant canopies that are competitive can inhibit the growth and reproduction of *partheniums*. Certain cropping techniques can also be utilised to prevent weed development during the cropping season by promoting rapid crop growth and establishment. [56]If farmers want to stop *Parthenium* from developing in their fields, they could plant fast-growing crops like sorghum, berseem, and dhaincha/sesbania.[57]Furthermore, in order to decrease *Parthenium*, some researchers have suggested cultivating crops that are competitors, such as Digitariamilanjiana, Clitoreaterneata, and Cenchrusciliaris.[58] Planting plants that will compete with the weed and lower its population, such as Cassia sericea, Croton bonplandianus and C. sparsiflorus, Amaranthusspinosus, Sidaacuta, Tephrosiapurpurea, Stylosanthesscabra, and Cassia auriculata, is another way to replace *Parthenium* in a competitive manner.[59]In a similar vein, *parthenium* growth will be covered and inhibited by planting Cassia tora. Vehicles, animals, and agricultural products all have a significant risk of transmitting *parthenium* when they go through an area that is heavily infected. Reducing the spread of seeds can be achieved by cleaning vehicles and equipment before entering an area that is not affected. [60]The most economical course of action is to stop *parthenium* from spreading.

6.3. Control by burning: Burning*parthenium* weed is the method most often used to manage it. In this way, large amounts of this weed's vegetation can be efficiently eradicated. However, because soil water, fertility, and biodiversity are greatly threatened, this is not a safe management approach. *Parthenium* ash has allelopathic effects on some plants, however yield loss is minimal when compared to the dry mass of this weed.[49] Burning is not a *parthenium* control method that works well. However, if the burned area is given time to recover before further actions are undertaken, burning for other reasons (such as controlling woody weeds) could not lead to a worsening of the infestation.[53]Stocking recently burned areas where *parthenium* is known or believed to be present reduces pasture competition and favours *parthenium*, which can lead to a more severe infestation.[61]

6.4. Overgrazing control: The most effective way to manage large-scale *parthenium* infestations is through grazing management. Keep pastures well-maintained with high ground and grass crown cover levels.[61]On the other hand, *parthenium* has a relative rise in some areas due to overgrazing. Because of the significant rise in livestock, overgrazing reduces the vitality and variety of grasslands, which encourages the weed to spread even more widely. Therefore, maintaining the proper amount of cattle might stop *Parthenium* from spreading.[62] Cattle movement during rainy season helps disseminate seeds on muddy soil. To allow seeds fall off cow bodies and tails before releasing them into bigger regions, hold them in yards or small paddocks if necessary. Check for *Parthenium* contamination while buying livestock feed and agricultural seeds. Spring-summer is ideal for pasture sapling, especially the first 6-8 weeks. Winter grazing is safe since *Parthenium* spreads less. This is also when *Parthenium* may develop and germinate.[31]

6.5. Allelopathic control: The ecological strategy of allelopathy and the biological herbicide of allelochemicals have posed a challenge to existing methods [63].Regarding the use of allelopathic plants in *Parthenium* control, recent investigations conducted by our study have produced extremely favourable results.[64& 65) Allelopathic plants help control *parthenium* biologically. Growing competitive crops (fodder sorghum, sunflower, and maize) or self-perpetuating competitive plant species like Abutilon indicum in non-crop regions helps control *parthenium*. A recent botanical survey in India found that Cassia sericea, Cassia tora, Cassia auriculata, Croton bonplandianum, Amaranthusspinosus, Tephrosiapurpurea, Hyptissuaveolens, Sidaspinosa, and Mirabilis jalapa can suppress *parthenium* in natural habitats.[66]. Another Indian research found that Cassia sericea decreases *parthenium* accumulation by 70% and population by 52.5%50[67].In some regions of India, crop rotation with marigold (Tagetes spp.) during rainy season reduces *parthenium* infection in farmed areas[68].

A) Chemical Control: Chemical*parthenium* weed control is growing in India.[68]In regions devoid of natural adversaries, *parthenium* can be effectively managed by chemical management.[52]Herbicides are the most effective and extensively used *Parthenium* weed management [133] [135] The timing of chemical treatment is crucial for this weed management strategy to eliminate the plant in time. Treat plants before blooming and seed setting, when grass and other plants can recolonize the affected region. Post-emergent herbicides should be used in wasteland, non-cropped areas, railway lines, water canals, and roadsides during the rosette stage. [69]However, modest quantities of natural and biological herbicides, such as oils derived from medicinal plants, can be useful in controlling *Parthenium*. [70] But as of right now, conventional herbicides continue to be more successful than bioherbicides

B) Non-Crop Area: Prior to seeding, herbicides should eliminate *parthenium*. Treatment is immediate for small infestations. To avoid seeding, spray repeatedly. Before blossoming, spray tiny plants. Active development of other grasses may help suppress the weed. Glycerophosphate, bromoxynil, NaCl, amine, esters, fluometuron, hexazinone, metribuzin, atrazine, norflurazon, metasulfuron methyl, and paraquat are among the chemical herbicide Above herbicides control *Parthenium*. [71& 72] Chemical pesticides can manage this weed in agricultural and non-cropping regions. These herbicides injure main crops, making cropping regions dangerous. Different herbicide dosages work for spot spray, boom spray, or both.

6.6. Cropping areas: Chemical herbicides are safe in non-farming regions but can damage crop plants in cropping areas. Use of chemical fertilisers in agriculture needs careful herbicide selection to avoid crop damage. In such regions, low-concentration biological or natural pesticides such volatile oils from aromatic plants assist abort *Parthenium*seeds[73]. The effect of these oils on modern crops is negligible or nonexistent compared to *Parthenium*. [74] These essential oils don't affect the current vegetation or crops in any way. [74]. Numerous observations have shown that *parthenium* may be controlled by using essential oils from various plants, including Ageratum, Lantana camara, and Eucalyptus sp.

6.7. Biological Control: By the employment of natural enemies, biological management is a safe, efficient, and ecologically friendly way to reduce or mitigate pests and their impacts. Much attention has been focused on controlling *Parthenium* using different biocontrol agents, such as insects, microbial diseases, and botanicals, throughout the previous three to four decades. [75 & 76]There are two main approaches to implementing biological control of weeds: the "classical approach," which involves introducing foreign pathogenic organisms, and the "augmentative" or "bioherbicidal approach," which involves introducing or native pathogenic organisms already present and mass-raising them to increase their population. Both of these strategies are referred to as "inoculative" and "inundative strategy" in epidemiological terminology.[77]The use of plant pathogens to biologically manage weeds has become commonplace in agroecosystems as a safe, effective, and ecologically friendly approach of managing weeds[78].

A) Classical approach: Many nations have used insects to manage *parthenium* weed. Mexican-imported leaf-feeding beetles (Zygogrammabicolorata) and stem galling moths (Epiblemastrenuana) can suppress this plant. The leaf-eating Z. bicolorata beetle was brought from Mexico in 1980 to control *parthenium* in Australia. [79]Zygogrammabicolorata was originally brought to India in 1984, and three years after its introduction, it had spread widely over the country, significantly reducing the densities of *Parthenium* weed in certain locations.[80& 81].This insect's larvae and adults eat leaves. The early-stage larvae eat terminal and auxiliary buds before moving to leaf blades. Adult larvae pupate on dirt. The weed has strong generative capacity and the insect is not species-specific, attacking sunflower in India. An insect density of one adult per plant produced leaf skeletonization after 4–8 weeks [82]. Few trials on biological control agents like Zygogrammabicolorata against this invasion exist. The Tropical Pesticides Research Institute in Arusha, Tanzania, released Z. bicolorata beetles as bio-agent to inhibit P. *hysterophorus* from February to July 2019 (wet) and August 2019 to January 2020 (dry). Z. bicolorata feeding reduced P. *hysterophorus* leaves, flowers, height, and biomass in dry and rainy seasons[80].Thus, Zygogrammabicolorata is a useful biocontrol agent that may considerably slow down *Parthenium* weed's vegetative and reproductive development[83].The stem galling moth Epiblemastrenuana has also been attempted to be introduced, however because it grows on niger crops and deposits its eggs there, its cultures were destroyed [84].

B) Bioherbicidal approach: Plant pathogenic fungi are used as "living products that control specific weeds in agriculture as effectively as chemicals" or inundatively to control weeds. [85]. Bioherbicides are given by regularly distributing varying quantities of pathogenic inoculum. [86 & 87]. The notion of mycoherbicides was first presented by Daniel and colleagues. [88], who demonstrated how an endemic illness may be eradicated in its weedy host by administering a high dose of inoculum during a critical developmental stage. The pathogen needs to be culturable in artificial media, the inoculum needs to produce in large

quantities using traditional techniques like liquid fermentation, the finished product needs to be genetically stable and specific to the target weed, handling, application, and storage needs to be in line with modern agricultural practises, and the pathogen needs to be effective in a variety of environmental conditions in order to allow for reproduction. [88]. Weeds have been controlled with fungal products or mycoherbicides [89]

6.8. Integrated Weed Management: This plant defies classical and bioherbicidal treatments. To decrease insect losses, chemical pest control, and protect agricultural systems, integrated pest management (IPM) has grown in popularity. Mitchell grass (Astrebellasqurossa) and butterfly pea (Clitoriaternatea) and two biological control agents, a leaf and seed feeding beetle (Zygogrammabicolorata) and a stem galling moth (Epiblemastrenuana), have been used to control *parthenium* weed in Australia under integrated weed management. Suppressive plants drastically decreased weed growth without biological control. Biological substances may increase suppressive power. Research in Australia demonstrates that suppressive plants help control *parthenium* weeds [52].Shabbir [59] controlled *parthenium* weed in Australia for two years. Epiblemastrenuana Walker, ZygogrammabicolorataPallister, ListronotussetosipennisHustache, and Pucciniaabrupta var. partheniicola decreased *parthenium* weed growth by 60–80% and 47–91% in years 1 and 2. Biocontrol agents increased suppressive plant biomass by 6%–23%. Combining biological control with planted suppressive plant species can help control *parthenium* weed. Rice straw also show effective approach towards control of parthenium weed in standing wheat crop. [134]

7. Utilization of *Parthenium*

Despite being a weed, *Partheniumhysterophorus* offers a lot of advantages. The plant has several industrial, pharmacological, and therapeutic uses in addition to a wide range of other uses. As a result, the plant may be utilised directly for a variety of uses, and it can be widely employed in a variety of ways to manage this weed. Utilising this weed on a wide scale is one of the best ways to handle *partheniums*. The weed's insecticidal [90], nematicidal [91], and herbicidal [92] qualities have all been well studied.Here, we've covered *Partheniumhysterophorus's* documented uses, which can be applied to manage it through utilisation. Additionally, this weed is used to produce biogas and oxalic acid [93 & 94].One way to handle *parthenium* is to use it as green manure. Even in soils with low nutrient levels, it may extract nutrients. Because of the insecticidal, nematicidal, and herbicidal qualities of this unpleasant weed extract, numerous scientists and academics have begun to use it[95]. Below is a quick description of a few of this weed's significant uses:

7.1. Biochar Preparation. Bypyrolyzing*Partheniumhysterophorus*, biochar has been successfully created to store carbon for zero carbon dioxide emissions [96]. Increased Zea mays growth, increased basal respiration and microbial biomass carbon, increased catalase and dehydrogenase activities, decreased soil stress, and increased hydrolytic enzyme activity were all signs that the addition of this biochar to the soil improved the quality of the soil. Ambrosin, a molecule found in *parthenium* that has a phototoxic impact, was destroyed by degradation at high temperatures during charring [97]. Large additions of biochar did not appear to have any detrimental effects on the soil. According to the study's findings, adding biochar will help barley under drought stress with its antioxidant defence mechanisms, productivity, and soil fertility. Consequently, to increase the output of barley crops in regions lacking water, BC from the invasive plant P. *hysterophorus* can be used [98].

7.2. Biogas Production. A weed called *Partheniumhysterophorus* grows wild throughout much of India. In 3-liter batch digesters, *parthenium* was combined with cattle faeces at a 10%

concentration and allowed to process anaerobically at room temperature (30±1°C). The gas's methane percentage ranged from 60% to 70% [99]. Degradation of phytotoxic allelochemicals has been observed during the formation of biogas [100]. An further set of experimental data indicates that the mixture of 75% goat manure and 25% *parthenium* weed produces the highest gas output of 572.5 millilitres, indicating that this combination is ideal for producing the most amount of biogas. Overall, the results show that co-digesting goat manure and *parthenium* weed can greatly increase the biogas generation as well as the reduction of VS and TS. (101]

7.3. Composting. Composting *Parthenium* can turn this weed into a soil conditioner. [102] Waste from *Partheniumhysterophorus* was composted quickly. Two times richer than farmyard manure, *Parthenium* compost contains micronutrients like Fe, Zn, Mn, and Cu and macronutrients like NPK [103]. Organic acids from composting liberate insoluble K and improve P and K absorption [104]. Farm yard manure contains 3 times less nitrogen than *parthenium* compost. [105] Composter contains enzymes, vitamins, antibiotics, plant growth regulators, Azotobacter, and phosphate solubilizers [106]. An experiment compared *Parthenium's* composting and manurial usefulness to other organic wastes. *Parthenium* adds nutrients to crops after composting. Other than burning or eliminating *Parthenium*, exploiting it for crop production is a better strategy to eliminate it [107]. Composting was done using NADEP AC and Bangalore pit BC. Compost nitrogen, potassium, phosphorus, and Ca rise but C/N ratio decreases. In this experiment, the deadly plant *Parthenium* is turned into compost with increased nutrient concentrations that can be used to cultivate crops [108].

7.4. Vermicomposting. Vermicompost, generated solely by the epigeic earthworm Eiseniafoetida on *parthenium* (*Partheniumhysterophorus*), was tested for its effects on green gramme (Vigna radiata), ladies finger (Abelmoschus esculentus), and cucumber (Cucumis sativus) germination and early growth. [109] All treatments tested fertility-related physicochemical parameters. In all experimental pits, pH, conductivity, and total organic carbon decreased during 90 days. Nitrogen, potassium, sodium, and phosphorus concentrations rose. *Parthenium* and cow faeces were found to be vermicompostable. [110] Pit and worm bin vermicomposting were used. N, P, K, Ca, and C:N ratio were measured every 20 days up to 100 days in vermicomposts. Vermicompost has a high nitrogen, potassium, phosphorus, and Ca content but a low C/N ratio. Worm bin vermicompost (BVC) has more nutrients than PVC, AC, and BC composts. This technique turns the deadly plant *Parthenium* into vermicompost with better nutritional content that can be utilised to cultivate crops. [131] In an experiment, *Parthenium*vermicomposts improved soybean vegetative growth in different seasons. All studied vermicomposts had significantly higher vegetative growth metrics than controls. [111]

7.5. Green Manure.*Partheniumhysterophorus*, or "wild carrot weed," is a notorious invasive plant. Even while it may produce biomass for green manure, its quick growth and environmental damage render it unsuitable. Use non-invasive plant species to make green manure to avoid ecological damage. This pernicious weed can be managed by using it as compost, green manure, or mulch to improve soil health and crop productivity. Adding *Parthenium* biomass to crops in sequence may increase crop productivity due to better plant nutrient availability, soil health, and plant health. [112] In an experiment in Aurangabad, *Parthenium* foliage as green manure (GM) increased maize output and nutrient content, which may biologically reduce the negative consequences of this weed on agriculture and society. [113] In maize, 3% green manure produced the maximum root and shoot biomass, much

higher than the control and comparable to NPK fertiliser. Insignificant effects of NPK fertilisers and *parthenium* green manure on mung bean growth and yield. [114]

7.6. Synthesis of Nanoparticles. Traditional silver nanoparticle manufacture uses toxic chemicals that endanger individuals and the environment. Green chemistry nanoparticle synthesis is faster, safer, and greener than existing approaches. In this study, we synthesised silver nanoparticles from *Partheniumhysterophorus* leaf extract using green chemistry. [115] The present study synthesised silver nanoparticles (AgNPs) from *Partheniumhysterophorus* leaf extract and tested their antibacterial and anticancer properties. [116] Compared to fungus species, copper nanoparticles (CuNPs) showed high inhibitory activity against Staphylococcus aureus, Bacillus subtilis, Proteus vulgaris, and Pseudomonas aeruginosa at different doses. This *Partheniumhysterophorus* leaf extract CuNP production process is efficient and eco-friendly. [117]

7.7. Bioethanol Production. The waste land weed *Partheniumhysterophorus* L. has a high capacity for regeneration, is highly seed germination friendly, and can adapt to a wide range of ecosystems. As a result, it reduces biodiversity and crop productivity. The biomass of this plant can be used to produce bio-ethanol as a fossil fuel supplement. This has the potential to meet global energy demand and tackle greenhouse gas emissions. [118] Research on biofuel technology is concentrated on unconventional feedstocks for the synthesis of bioethanol. Ultrasound is used to ferment the biomass of *Partheniumhysterophorus* to produce bioethanol. Ultrasound (35 kHz, 10% duty cycle) is used in sonication. [119]. The first report on the pretreatment of *Partheniumhysterophorus* biomass with surfactant (Tween-20) assisted ionic liquid IL, (1-ethyl-3-methylimidazolium methane sulphonate [Emim][MeSO3]), saccharification by an in-house enzyme cocktail from Aspergillus aculeatus PN14, and consolidated bioprocess fermentation of sugars to bioethanol [120].Second-generation bioethanol synthesis utilising *parthenium* biomass from non-agricultural feedstock [121].

7.8. Heavy metal and dye removal. Metals and dyes pollute streams. Our eco-system is threatened by these toxins, threatening public health, ecological balance, and the environment. Plantextraction and heavy metal removal with *Partheniumhysterophorus*. Batch reactors removed methylene blue from aqueous solutions using *Partheniumhysterophorus* adsorbents, an unwelcome weed. SWC and PWC were the adsorbents [122]. Weed potential for heavy metals and dyes was investigated in this article. Weed can adsorb up to 90% of some heavy metals and dyes, according to research. Extracting *Parthenium* uses powdered cannabis, activated carbon, ash, etc. [123] A wild grass, *Partheniumhysterophorus* L., Asteraceae, grown on barren land along the National highways for Cd, Cr, Cu, Ni, and Pb was tested for bio-accumulation in its soil, roots, and shoot. In the study, *Partheniumhysterophorus* L was found to be able to translocate metals to its above-ground sections and remove them from polluted soil. [124]

7.9. Medicinal uses. *Partheniumhysterophorus* treats skin irritation, rheumatic pain, diarrhoea, UTIs, dysentery, malaria, and neuralgia. This plant may be used as an insecticide, herbicide, fungicide, wood preservative, anti-amoebic, and medicine [125]. Some nanomedicine experiments have been successful [7]. *P. hysterophorus* extracts are antioxidants and lipoprotective against membrane damage [126]. This study demonstrated that *P. hysterophorus* leaf extract phytochemicals, notably ET fraction, destroy human cancer cells. Iron binding, hydroxyl radical scavenging, lipo-protective, and moderate anti-HIV activities help *P. hysterophorus* leaf extracts battle oxidative damage. [127 & 49]

7.10. Mulching: By inhibiting the weeds' ability to produce oxygen through photosynthesis, mulching exerts a suffocating effect. Additionally, it protects against the rainy season while enhancing the quality of the soil, reduces surface temperatures, conserves moisture, and fertilises the soil. Because of the allelopathic actions of the *Partheniumhysterophorus* herbage mulching, it is possible to boost the production of soybeans under subhumid agroclimatic conditions while simultaneously reducing the number of weed infestations. [128]

8. People awareness on *Parthenium*

Parthenium management at the national level requires public engagement and knowledge. Each participating unit should organise *Parthenium* Awareness Day, Week, Fortnight, or Month. Awareness initiatives should include live demonstrations, uprooting, engaging people, students, and employees, picture exhibitions, film showings, marches, etc. The media should constantly be invited to raise awareness about marijuana.[17]. Like ragweeds in the US and chrysanthemums in Europe, it causes dermatitis. Despite the plant's widespread presence, the public is unaware of its harmful consequences. This cross-sectional study examined rural *P.hysterophorus* awareness.[132] From August 16th to August 22nd, 2021, 2022, and 2023, ICAR institutes across India held "*Parthenium* Awareness Week" to educate farmers about its negative consequences and control.[10]

Conclusion

The review study we are doing now comes to the fact that *Partheniumhysterophorus* is allelopathic and hurts animals and plants.This weed, in compared to others of its kind, propagates much more rapidly. It features a huge number of arid regions in addition to a significant amount of fertile land. When taking into account the present rate of population growth in India, land usage for agricultural and forestry purposes needs to be carefully studied.It is necessary for progress to make use of all of the resources that nature provides. We will be able to control this weed if we have a comprehensive understanding of the benefits and drawbacks associated with parthenium. Having access to the appropriate information enables us to utilise it in a variety of ways, as we have discussed previously.This is not a discussion about partheniums, even if it should also apply to other types of weeds.

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